Message from the Chair

It gives me great pleasure to welcome you to the 2018 McMaster Physics & Astronomy newsletter. We’ve had an eventful year in the department and are looking forward to more great changes in the coming year.

After a number of difficult years financially in the Faculty of Science, the past year has seen a near miraculous turnaround. As a result there is now a possibility of faculty renewal in the faculty and our department. In the coming year we will try to recruit a new faculty member in theoretical particle physics for a joint position with the Perimeter Institute. We hope to be able to recruit more new faculty members in the coming years.

On the undergraduate side, our new program in Medical and Biological Physics has proven very attractive; we are entering our second year of this program with almost 30 students in our second cohort. Our other programs (Honours Physics, Astronomy, Integrated Science and Physics, Math and Physics and others) are also proving very attractive to students. In total 89 students are entering one of our undergraduate programs in the coming fall. Our students are doing research in our department and elsewhere and have had another banner year at the Canadian Undergraduate Physics Conference and the Canadian Association of Physics Congress, garnering many awards for their work.

Our graduate program remains very high quality, with many students winning prestigious fellowships (Vanier, NSERC, OGS) and our graduates winning NSERC postdoctoral fellowships and going on to top institutions for postdocs and into industry. They are presenting their research at the CAP Congress and numerous international meetings such as the APS March meeting.

Emeritus Professor Bill Harris has just been awarded an honorary Doctor of Science degree from McMaster University in recognition of his tremendous contributions to research and teaching. You can read more about Bill’s career in the coming pages of the newsletter.

In the department, Maikel Rheinstadter is taking over as Associate Chair (Graduate) from Alison Sills who has led our graduate efforts for many years, while Cecile Fradin will be our new Associate Chair (Undergraduate), taking over from Erik Sorenson who has also served for many years. Thank you to both Alison and Erik for their tremendous leadership and thanks as well to Maikel and Cecile for agreeing to serve in these important roles.

We were sorry to lose long-time member of the office staff Cheryl Johnston who retired this year but are happy to know she’s very much enjoying her much deserved retirement. We are pleased to welcome Hope Gianicos to the department; you can find her in the middle desk of the office. A big welcome to Dan FitzGreen who joins us in the 3H03 and 2H04 labs, replacing Ryszard Dabkowski. Ryszard has moved to NRC in Ottawa; he will be missed in the department, but we are happy for him with this exciting position as his career develops.

A most exciting development is that a team of students and researchers led by our own Dr. Soo Hyun Byun has received funding from the Canadian Space Agency to launch their radiation-detecting satellite to the International Space Station in 2021 (see page 8). The team will spend the coming years perfecting their satellite and preparing for launch. Congratulations to the NEUDOSE team!

The past year has been very rewarding with tremendous accomplishments by everybody in the department, from our undergraduates to emeritus faculty. Going forward, I am extremely excited about possible developments in the coming year and am looking forward to sharing them with you in a year’s time.

Contact Information:
Department of Physics and Astronomy, McMaster University
1280 Main Street West, Hamilton, Ontario L8S 4M1
Phone: 905-525-9140, ext. 24559 Fax: 905-546-1252
email: physics@mcmaster.ca http://www.physics.mcmaster.ca/
On Thursday, June 14 Dr. William Edgar Harris, Professor Emeritus in the Department of Physics and Astronomy at McMaster University, received an Honorary Degree, Doctor of Science from McMaster at the Spring convocation of the Faculty of Science. He addressed the graduating students that day. The degree is awarded for outstanding achievement in the pure and applied sciences, usually through research. His record checks all three categories for people upon whom the university confers honorary degrees: distinguished scholarship, distinguished reputation at the national and international level, and a person who has made noteworthy contributions to McMaster University.

Bill is one of Canada’s most distinguished astronomers, whose name and outstanding scientific achievements in observational extragalactic astronomy are well known throughout Canada and the international astronomical community. He has dominated the field of globular cluster (compact stellar systems less then 10 light years across, with millions of stars) research for decades. Globular clusters are among the oldest stellar systems in the in the universe and are found in all galaxies. Understanding their formation and evolution impacts our understanding of the earliest conditions of star formation in the universe, going back to less than a billion years after the Big Bang, to times when galaxies were first being assembled. Bill and his collaborators exploited a variety of new telescopes and instruments – such as the Canada-France-Hawaii Telescope (CFHT) and the Hubble Space Telescope – to open up new directions of research in studying these stellar systems. One of the important scientific drivers for the Hubble Space Telescope was to study globular clusters in order to glean constraints on the age of the Universe. Bill was the PI of no less than 10 Hubble observational programs, more than any other Canadian.

In a study of citation rates of Canadian astronomers carried out in 2005, he was listed as one of Canada’s 10 most highly cited astronomers. Bill has won many honours for his research contributions including a FRSC (2004), a prestigious Killam Research Fellowship (2008-09), and the lifetime career achievement award of the Canadian Astronomical Society - the C.S. Beals Award (2010). He has served as the President of the Canadian Astronomical Society (1994-1996), chair of the NSERC Grant Selection committee (1992-93), and was Chair of the Board of Directors for Canada’s premier ground based telescope – Canada France Hawaii Telescope (CFHT) in 2004-2005. He was also one of 7 members of the NSERC/NRC/CASCA Long Range Planning Panel for astronomy in Canada (1998-2000) that was Canada’s first 10-15 year plan for astronomy and astrophysics.

Bill’s recent generous gift of the endowment that funds the Caroline and Wilhelm Herschel Postdoctoral Fellowship has added a critical new capacity to the astronomy and astrophysics group. The Herschel enables McMaster to attract the world’s top young talent in the field - especially important at a time when federal support for basic research has fallen substantially.

Here is the link to Bill Harris’ speech from convocation:

Congratulations to Dr. Cliff Burgess and his PhD student Peter Hayman who were awarded 3rd place in the 2017 Buchalter Cosmology Prize competition for their paper entitled “Magnon Inflation: Slow Roll with Steep Potentials”. Their paper was published in the Journal of Cosmology and Astroparticle Physics. The Buchalter Cosmology Prize is an annual prize that seeks to stimulate ground-breaking theoretical, observational, or experimental work in cosmology that has the potential to produce a breakthrough advance in our understanding.

Congratulations to Dr. Ralph Pudritz and his PhD student Ben Pearce who were awarded the PNAS (Proceedings of the National Academy of Sciences) best paper award in the Division of Physical and Mathematical Sciences – the Cozzarelli Prize - for their paper entitled “Origin of the RNA World: the Fate of Nucleobases in Warm Little Ponds”. One of the world’s leading scientific publications recognized their ground-breaking paper exploring meteorites and their role in delivering the essential biomolecules and the subsequent steps leading to the emergence of the first genetic molecules on Earth. This incredible prestigious award is given to the best paper in each of the 6 divisions of the NAS each year that are deemed to be of outstanding scientific excellence and originality.

Congratulations to Dr. Bruce Gaulin who was awarded the President’s Award for Excellence in Graduate Supervision. This prestigious award is administered by the School of Graduate Studies and the Graduate Students Association and is awarded to those who demonstrate excellent supervisory and mentoring skills.

Congratulations to Dr. Alannah Hallas who has been awarded the Neutron Scattering Society of America (NSSA) 2018 Prize for Outstanding Student Research. Dr. Hallas won the prize “for her exploration of new families of quantum pyrochlore magnets and elucidating their phase behaviour and excitations using forefront neutron scattering techniques”. Dr. Hallas was jointly supervised by Dr. Graeme Luke, Dr. Bruce Gaulin and Dr. Chris Wiebe during her PhD at McMaster University. She is currently a postdoctoral fellow at Rice University.

Congratulations to Dr. Gwendolyn Eadie as the 2018 recipient of the J.S. Plaskett Medal of the Canadian Astronomical Society (CASCA) and the Royal Astronomical Society of Canada. Dr. Eadie completed her doctoral studies at McMaster University under the supervision of Dr. William Harris. In her thesis entitled “Lights in Dark Places: Inferring the Milky Way Mass Profile using Galactic Satellites and Hierarchical Bayes”, she developed a high-level statistical method based on a Bayesian approach to derive the mass and mass distribution within astrophysical systems.

Congratulations to Governor General’s Academic Medal recipient Alex Dhaliwal. Alex just graduated from the Integrated Sciences (iSci) program with a triple minor in Biochemistry, Math and Physics. He’s the only student in the Faculty of Science this spring to achieve a perfect 12 grade point average – the highest GPA a student can receive. It’s a rare accomplishment, and one that has earned him this prestigious award. He completed his senior thesis in our Department with Dr. Maikel Rheinstadter and will now be pursuing a MD/PhD program at the University of Toronto where he will earn a PhD in Medical Biophysics. She is currently a postdoc at the University of Washington in Seattle.
McMaster’s Sidewalk Astronomy (SWA) brings astronomical observing opportunities to the public in and around Hamilton and is run by graduate students in the Physics and Astronomy (P&A) Department. We set up telescopes on campus weekly, at the beginning of Fall terms and end of Winter terms for students and other passersby to view astronomical objects and ask questions about astronomy. These include the transit of Mercury in May 2016, the solar eclipse in August 2017, and the annual International Observe the Moon Night. SWA has also participated in the Westfield Heritage Village Star Party, Hamilton Researchers’ Night, Graduate Women In Physics and Astronomy (GWIPA) Girls in Science days, and Supercrawl.

SWA was started in September 2012 by former Ph.D. students in astronomy, Kazimierz Sliwa, Rachel Ward, Tara Parkin, and Aaron Maxwell. While running an undergraduate observing lab, Kaz and company realized people walking by were as interested in what the telescopes were being used for as the students so they decided to start using it for regular public outreach. In 2013 and 2014 we were granted funding through the Student Proposal for Intellectual Community and Engaged Scholarship (SPICES) offered by the School of Graduate studies to purchase a 10” diameter Newtonian telescope along with the majority of our observing equipment. Later, Dr. Laura Parker and undergrad Cissy Suen acquired funding through the McMaster Science Society and their Academic Science Fund to purchase a 12” Schmidt-Cassegrain telescope in February 2015. Equipment for running a CCD camera on this telescope was funded through Dr. Parker’s Petro-Canada Young Innovator Award and SWA has been using the equipment for outreach and lending a hand with observing for the Astrophysics Data Analysis Project course.

Both the 10” Newtonian and 12” Schmidt-Cassegrain are equipped with GPS and tracking motors so they can find objects in the sky by name and automatically follow them through the night. Our CCD cameras and slew of filters are used for taking science-quality still images and videos of objects imaged with the telescope. We also bring out our cell phone mount to allow people to take their own pictures of the objects they were observing by eye.

Our latest big event took place August 21, 2017 on campus during a solar eclipse. With the help of a few newspaper and radio interviews (organized with the help of McMaster’s communications office) about 500 people from the general public turned out to watch the eclipse.

When I was thirteen, my sister and I cofounded Books With No Bounds, a non profit which has empowered indigenous children worldwide through literacy by sending over 250,000 books and 100,000s school supplies and computers to schools, orphanages, and community centres in impoverished communities. My journey to solve a global problem of education accessibility lead me to biomedical engineering when, through BWNB I met a local teacher Beth and her husband Tim, who had ALS.

ALS, aka Amyotrophic Lateral Sclerosis, is a disease in which gradual deterioration of motor neurons causes loss of the ability to move, speak, eat, swallow, and eventually breathe. After researching pre-existing assistive technology, I came across ingenious devices which utilize movement of the eyes, breath, and electrical brain signals to facilitate communication through a computer. However, the complexity of development and invasiveness of surgical procedures resulted in high costs. I felt there was a gap in the market for inexpensive devices for those facing ALS in low income areas and decided I would create a new device, which would be be safe, simple to use, affordable, and able control a computer whilst improving the quality of life of a person with ALS, Multiple Sclerosis, spinal cord injury, or any other physical and communicative limitations.

In high school, I devoted months to self-teaching basics of hardware and software engineering. I called my invention TiC, Tongue Interface Communication. TiC is comprised of an inexpensive sports mouth guard, to which five tactile switches are glued and soldered to an ethernet cable, which connects to a circuit board and via usb to one’s computer. With the appropriate program, tongue to button presses inside the mouth are translated to computer mouse keys. Hence the user can move a computer mouse up, down, left, right, and enter, all using their tongue, since for many in the latter stages of ALS, one still has functionality of the tongue! At a less than ten dollar manufacturing cost, TiC opens the door to applications using electronics capable of synthesized speech, or wheelchair control.

In 2016 I was honoured with the Weston Youth Innovation Award by the Ontario Science Centre (OSC). Accompanying this award was a large public media outreach that resulted in the Tonight Show starring Jimmy Fallon hearing about my invention. A producer contacted me through the OSC to invite me to demonstrate my invention alongside Jimmy Fallon at the NBC Studio in New York City, where the show is filmed live. On the show, I was introduced by Jimmy, explained my inspiration foTiC, how it worked, etc. and then Jimmy tried it by moving the cursor along his webpage. It was a great opportunity to showcase my invention in an educational, yet comedic way!
Stephen Hawking died on March 14, 2018, after a long struggle with amyotrophic lateral sclerosis (ALS). His life story in general, and in particular his ability to roam intellectually and achieve so much despite his body’s cruel shackles, is an inspiration. His were the most expressive eyes in physics.

His many accomplishments along the way — such as helping bring science to the wider world — are well-known, and many of us can trace part of their initial attraction to physics to one of his books.

I first met Hawking when I was a graduate student attending the Les Houches summer school in 1984. He gave lectures, and at that time still spoke with his own voice (though he was hard to understand so one of his graduate students would translate what he said for the rest of us). He was at the time selling his ‘no-boundary’ proposal for the quantum state of the universe.

After this first exposure he (with his young family) and I would cross paths at conferences, such as meetings at the physics centres in Aspen and in Santa Barbara. Sometime during this period he started speaking through his automated voice-box (what he came to call his ‘American accent’).

What I remember most about these early encounters was his impish sense of humour (his very expressive eyes often conveyed more than a hint of a twinkle) and his immense patience with people. Patience with the frequent intrusions into his personal space (from which his immobility made it hard for him to withdraw) and with his painfully slow process of communicating by choosing letters and words to a computer which monitored his eye movements as he looked at a screen.

This patience was particularly on show on his recent visit to Perimeter Institute, where we spoke about the physics of de Sitter space (see photo). Several camera crews were present on this occasion and at several times they seemed to press themselves way too close to his face, though he did not so much as bat an eye about it.

At seminars he would often park his wheelchair front and centre. On my first occasion giving one with him in the audience I was fresh out of grad school and found his presence a bit intimidating. Imagine my horror when his wheelchair began to emit random words (often just the disconcerting word ‘No’, spoken with a strong but slightly ambiguous machine-like emphasis). I later found that these spontaneous emissions were just artefacts of his eye-recognition software and not editorial comments.

But what is Stephen’s scientific legacy? What is interesting in Hawking’s case is that his final legacy remains uncertain; as large as it presently appears in future it might be larger still.

Three of his scientific achievements stand out above the rest: the Hawking-Penrose singularity theorems (which remove any doubt that black holes really are predictions of General Relativity); his part in explaining primordial fluctuations (which attribute the initial density fluctuations measured in cosmology to quantum fluctuations during an earlier ‘inflationary’ epoch); and his discovery of Hawking radiation.

Of these, it is Hawking radiation that continues to surprise and may yet lead in new and unexpected directions. His many other accomplishments — such as his contributions to the field of quantum cosmology — are also important, but these two have had enormous impact.

Hawking’s discovery that quantum effects make black holes radiate came about once fields (like electromagnetic fields) were quantized in the presence of a gravitational background (such as the Schwarzschild geometry). A radiated particle comes out when a quantum fluctuation drops its antiparticle into the black hole. The magic of black-hole geometry extracts the energy required for the escaping particle from the initial black hole’s mass. The particles that emerge turn out to do so with a thermal distribution.

Acting over enough time the pair-production process eventually makes an isolated black hole evaporate, which means that in principle a pure quantum state (describing the initial material that collapsed to form the black hole in the first place) turns into a mixed, thermal, state. But evolution from pure to mixed states is usually impossible according to the rules of quantum mechanics.

Even weirder, Hawking radiation suggests gravity and quantum mechanics somehow know something about thermodynamics. Besides having a temperature, Hawking radiation also somehow conspires to satisfy thermodynamics’ second law, provided the black hole itself carries an entropy proportional to the area of its event horizon.

How can gravity and quantum mechanics give thermodynamics without the benefit of multiple collisions and thermal equilibrium? In statistical mechanics entropy counts the number of available states, so what states does a black hole’s entropy count? We do not know.

Related to this puzzle are paradoxes about information. When a black hole evaporates its information comes out mostly through Hawking radiation, which only knows about the hole’s mass, angular momentum and electric charge. So the information that comes out in radiation is the same regardless of whether the initial black hole was built from rocks or encyclopedias. Where does the rest of the information go?

Hawking radiation seems to be a small piece of 21st century physics that accidentally fell into the 20th century. Large as Hawking’s contributions to physics have been, it is Hawking radiation that is the gift that keeps on giving. His ultimate legacy depends on how puzzles about Hawking radiation finally get unraveled. Picking away at these puzzles has led to many of our best insights about the quantum nature of gravity. It may yet suggest how to construct a full theory of quantum gravity. If so, Hawking’s legacy could become even bigger, impressive though it now appears to be.

Cliff Burgess
One of the frontiers pursued at TRIUMF is the role of rare isotopes in stellar nucleosynthesis and stellar energy generation. The ISAC (Isotope Separator and ACcelerator) facility can produce and deliver unique beams of these isotopes with sufficient intensities for high-precision studies. Using such beams, the DRAGON (Detector of Recoils and Gammas of Nuclear reactions) facility is also unique worldwide in its ability to measure the rates of nuclear reactions important in supernova and classical nova events. The DRAGON facility is an electromagnetic recoil separator that can identify true reaction events from background at the level of one part in a trillion. DRAGON was commissioned in 2002 and since then it has accounted for most of these reaction measurements performed worldwide.

Alan Chen has had a long involvement with TRIUMF, first as a NSERC USRA back in 1992 and later as a postdoctoral fellow from 2000-2002. During the latter, he built and tested one of the DRAGON detectors – which still works! Since then, he and his McMaster students have maintained close connections with TRIUMF, the DRAGON facility, and other ISAC-based collaborations.

Presently, Ph.D. student Athanasios (“Thanassis”) Psaltis, seen in the picture explaining DRAGON ins and outs to a TRIUMF visitor, is the principal investigator on an experiment to measure the cross section for alpha-particle capture on a (unstable) Beryllium-7 nucleus. Surprisingly, computer simulations of supernovae show that this reaction, although involving low-mass isotopes, strongly influences the synthesis of elements in much higher mass regions, including some whose stellar origin is currently unknown. On the technical side, his experiment is pushing the DRAGON performance well beyond its design limits for the first time; thus, Thanassis is also working on Monte Carlo simulations of the entire DRAGON facility to identify required modifications to the DRAGON setup and operations. Also, the project requires Beryllium-7 beams of unprecedented intensity and purity, and so the ISAC Beams Group is very busy developing new techniques to meet these challenges.

Looking forward, the Advanced Rare IsotopE Laboratory (ARIEL) is currently being built at TRIUMF, in partnership with 19 Canadian universities including McMaster. Alan Chen’s group is excited about ARIEL because it will significantly increase the variety of accelerated rare isotopes and their intensities. In particular, the discovery of gravitational waves from a collision between neutron stars (see page 7) surprisingly revealed that these events may be "the* “cosmic laboratory” responsible for the synthesis of about half

of all elements heavier than iron, including gold, silver and platinum. From a nuclear physics perspective, this synthesis (the “r-process”) depends sensitively on the properties of nuclei that are both far from stability and neutron-rich. Improving our understanding of the r-process will be one of ARIEL’s major research areas. McMaster Ph.D. student Johnson Liang has been a co-principal investigator, in collaboration with Dr. Balraj Singh (McMaster) and researchers from TRIUMF and elsewhere, on a project that compiled and evaluated all previous measurements, over a wide range of atomic masses, of an important nuclear property for r-process calculations. Their results will illuminate areas where more experiments are required, thus shaping ARIEL’s future research program in stellar nucleosynthesis.

2017 CUPC

Another successful Canadian Undergraduate Physics Conference has come and gone. This annual conference brings together about 150 of the top undergraduate physics students from across Canada to present summer research, meet peers, network, and much more. The 2017 version took place at Carleton University in Ottawa. McMaster was well represented at the conference. As usual, all McMaster attendees gave incredible presentations and made our school proud. 6 students in particular were able to come away with medals for top talks in their respective presentation categories:

Christian DiMaria - 1st Place, Applied & Engineering Physics
Cissy Suen - 1st Place, Quantum & Solid State Physics
Karan Chowdhry - 2nd Place, Quantum & Solid State Physics
Adree Khondker - 2nd Place, Biological & Medical Physics
Leanne Dias - 3rd Place, Applied & Engineering Physics
Dana Murdoch - 3rd Place, Astrophysics & Cosmology

We are extremely proud of all winners and students who attended for representing McMaster and our department with professionalism. It is not a coincidence that McMaster students perform well at every CUPC. Each student participates in practice sessions prior to attending the conference and each student puts in considerable effort into producing the best talk or poster possible. Congratulations to all participants, winners and their supervisors!
Postdoc Profile - Chelsea Sharon

I joined the department in the fall of 2016 as the inaugural William & Caroline Herschel Postdoctoral Fellow. As a native Californian, I’ve had plenty of time to adjust to the Canadian winters as I worked my way up the east coast from Rutgers, the State University of New Jersey for my Ph.D., to Cornell University for my first postdoc, before landing here in Hamilton. The Herschel Fellowship has been a tremendous opportunity to develop an independent research program while benefiting from close contact with Christine Wilson’s group and others.

My research focuses on the gas content and star formation of galaxies in the early Universe, nearly 10 billion years ago. I use synchronized arrays of radio telescopes, like the Karl G. Jansky Very Large Array in New Mexico and the Atacama Large Millimeter/submillimeter Array in Chile, to characterize the molecular gas clouds from which stars form. In particular, I have been searching for observational evidence that the rapid growth of galaxies’ central supermassive black holes prevent molecular gas clouds from overproducing stars within the most massive galaxies.

I’ve greatly enjoyed McMaster and Hamilton. In addition to my time in the Physics & Astronomy Department, I’ve also gotten to take advantage of the MacPherson Institute on campus to hone my teaching skills in preparation for future faculty positions. I’ve also had fun taking frequent trips into Toronto to play for a wonderful club water polo team, the Toronto Triggerfish.

Graduate Student Profile - Sarah Dawson

When I was a kid I loved to read science fiction and mystery novels, and studying science in school always gave me the same sense of wonder and discovery that I love in a good book. In high-school I took all of the math and science courses I could, but I had an especially excellent physics teacher and so that was always my favourite.

I started university at Western in ‘general sciences’ and, after taking the standard first-year science trifecta: biology, chemistry and physics, I decided that physics was the subject for me. During my summers I did research in medical physics (working with CT) with Dr. Eugene Wong. However, I also took several upper-year math courses throughout my undergrad, and I pictured myself going into high-energy physics. I think this was because the subject always felt so mysterious and exotic to me - it was exciting!

Working with Dr. Shi on a couple of different challenging and exciting problems in soft matter physics has been a wonderful experience for me, and I am looking forward to working more closely with his collaborators in Shanghai and hopefully going there myself for a couple months next year!

I have had an awesome time getting to know the other grad students here at McMaster! In particular, as a part of GWIPA (graduate women in physics and astronomy), who meet with female colloquium speakers and organize an annual outreach event called girls in science day. Being able to meet so many excellent role models, and also to mentor future scientists has really made me excited to call myself a physicist.

Undergraduate Student Profile - Mahmood Mohammad

After not knowing what physics was for most of my life, and not being too proficient in mathematics, I decided to take grade 11 and 12 physics. My teacher, Mr. Dallaire, made me realize that it was an amazing field of science worth studying. I entered McMaster University through Chemical and Physics Sciences wanting to pursue studies in astronomy, but never in my wildest dreams did I think I would end up doing a double major in Math and Physics.

After my second year in Hon. Math and Physics, I was hired as a research assistant in the biophysics lab of Dr. Cecile Fradin at McMaster. This research was presented at Dalhousie University for the Canadian Undergraduate Physics Conference (CUPC) and the Physics Conference at Western University (winning 3rd place). I was fortunate enough to continue work the following summer in the same lab. This research was presented at Carleton University for CUPC and the Physics Conference at Western University (winning 3rd place).

From third year onwards, I was hired as a teaching assistant in the Department of Physics and Astronomy for courses such as Physics 1D03, Physics 1E03, and Physics 1A03. This meant leading tutorials and labs and marking a lot of quizzes and midterms. This allowed me to hone my teaching skills and the ability to convey physics ideas.

After first year, I have been an executive member of the McMaster Undergraduate Physics Society (MUPS), holding the titles Second Year Representative, Vice President Social, and Vice President Academic. All these jobs meant different responsibilities, but they all encompassed the idea of creating a welcoming and fun environment for all.

All these opportunities would not have been possible if not for the support from the faculty and staff in the Department of Physics and Astronomy. The camaraderie among peers, the kindness and flexibility from faculty, and the endless help and guidance from staff make the Physics and Astronomy Department at McMaster truly incredible. The training received from such a well-rounded program has given me the skills such as programming, lab skills, and data analysis, to be successful in any field. I will use the skills gained from an undergraduate career in mathematics and physics to pursue a Masters in Physics at McMaster in biophysics.
Neutron Star Merger - Caught In The Act

On August 17, 2017 the first signals from a major cosmic cataclysm that took place in a far off galaxy 130 million years ago, swept through our solar system. Gravitational waves - ripples in space-time produced by major gravitational disturbances – were recorded by the LIGO gravitational wave detector. This observatory had discovered the merger of two massive black holes just a year earlier in 2016 (see last year’s newsletter). Unlike that event, this one also lit up the entire electromagnetic spectrum – starting 2 seconds after the LIGO detection with the detection of a burst of gamma rays by the Fermi Gamma-Ray Space Telescope and carrying on through X-rays, and radio waves. By the time of the announcement and scientific publication of this event on Oct. 16, a combined team of 3500 astronomers working at 70 telescopes would be involved. It was one of the most spectacular cosmic firework displays in astrophysics – a kilonova – the merger of two neutron stars. The paper was published in the Astrophysical Journal Letters.

Neutron stars have the mass of up to a couple of solar masses, packed into an object that would comfortably fit within Hamilton’s city limits. A spoonful of this material has the mass of Mount Everest, and the star itself is supported against its own enormous weight by an exotic form of quantum mechanical pressure arising from the tightly packed neutrons that make up its bulk.

Among the many important aspects of astrophysics that flow from such events, neutron star mergers have long been thought to produce many of the heavier elements in the universe, most notably – gold. Astronomers calculate that such an event creates a cloud of gold 40 – 100 times the mass of the Earth. Think of this exotic origin the next time you give or receive gold jewelry!

The intense distortion of space-time associated with the merger of two black holes is carried through the universe by a tsunami of gravitational waves – an event that is otherwise invisible. The neutron star merger signal was detected by the two LIGO antennae (in Washington and Louisiana) that detected the black hole merger.

Fortunately, over the ensuing year, a third European Virgo antenna joined this network. This made it possible to triangulate the position of the event on the sky – the source was in the Hydra constellation making the follow up observations possible.

How do such rare events occur in the universe? The story begins with the evolution of two massive stars in a binary star system. During their evolution, the more massive star of the pair begins to swell as it depletes its hydrogen fuel. This material is captured by its less massive companion. Ultimately, the first star explodes as a supernova. As the stars slowly spiral ever closer together, the second star eventually also undergoes expansion and its atmosphere envelopes the neutron star in a “common envelope”. Then it too goes supernova. The resulting neutron stars spiral ever closer together shedding their orbital energy by weak gravitational waves. Ultimately they orbit one another at near the speed of light. Tidal forces bulge their surfaces forming a stretched out doughnut like structure. At the moment of merger, the gravitational waves reach their highest frequency at 1000 cycles per second, corresponding to the number of orbits per second of the merging stars. At that moment, a shock wave is also produced and a highly energetic, ultra relativistic (very near the speed of light) jet is accelerated away by the intense magnetic fields in this confined region. The intense radiation from this jet produces the gamma ray burst. As the jet propagates away and pushes through the surrounding interstellar gaseous medium, it slows down. The resulting emission from the shocked gas accounts for its X-ray activity that fades down to radio wave lengths weeks later.

The merger also creates a big splash of neutrons which inundate some of the elements in the former crusts of the neutron stars transmuting them into heavy elements such as gold and platinum. Such processes can be studied by experiments in the laboratory such as at TRIUMF (see the companion piece by Alan Chen in this newsletter).

The ultimate fate of the merged object is still unknown. If massive enough to exceed the “Chandrasekhar mass”, the merger product would have collapsed into a black hole. The exact value of this critical mass depends on details of the physics of dense matter which are not well understood to predict if a black hole formed or not. However, with future kilonova detections now possible, the future looks bright for coming to understand even this most exotic aspect of astrophysics.

Other astrophysical research in our department is impacted by these results. One place that these mergers are likely to happen is in dense star clusters. Dr Alison Sills has modelled many kinds of stellar collisions in clusters to explain other unusual stars, and is currently working to understand the earliest stages of evolution in clusters. Her work will help understand how clusters form and why the conditions there could produce many exotic stellar interactions that give rise to gravitational wave sources. Also, massive stars form as members of a binary system in young star clusters in massive molecular clouds in the galaxy. Massive star formation is a research topic pursued in Dr. Pudritz’s group and involves radiative hydrodynamics simulations of the gravitational collapse and formation of massive disks which may fragment into massive star binaries.
Recent M.Sc.s. and Ph.Ds.

<table>
<thead>
<tr>
<th>Name</th>
<th>Thesis Title</th>
<th>Degree</th>
<th>Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jesse Mumford</td>
<td>Singularities in a BEC in a double well potential</td>
<td>Ph.D.</td>
<td>O'Dell</td>
</tr>
<tr>
<td>Ben Pearce</td>
<td>The Emergence of the RNA World on the Early Earth</td>
<td>M.Sc.</td>
<td>Luke</td>
</tr>
<tr>
<td>Chi To Lai</td>
<td>Binary Mixtures of Diblock Copolymers: A new route to the bicontinuous</td>
<td>M.Sc.</td>
<td>Shi</td>
</tr>
<tr>
<td></td>
<td>double-diamond &amp; plumber's nightmare phases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angus Mok</td>
<td>The Effects of Environment on the Atomic and Molecular Gas Properties</td>
<td>Ph.D.</td>
<td>Wilson</td>
</tr>
<tr>
<td>Gwen Eadie</td>
<td>Lights in Dark Places: Inferring the Milky Way Mass Profile using Galactic</td>
<td>Ph.D.</td>
<td>Harris</td>
</tr>
<tr>
<td></td>
<td>Satellites and Hierarchical Bayes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alannah Hallas</td>
<td>Application of Chemical Pressure to Magnetically Frustrated Pyrochlores</td>
<td>Ph.D.</td>
<td>Luke</td>
</tr>
<tr>
<td>Corey Howard</td>
<td>The Effects of Radiative Feedback on Star Cluster Formation and the Galactic</td>
<td>Ph.D.</td>
<td>Pudritz/Harris</td>
</tr>
<tr>
<td></td>
<td>Interstellar Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alex Cridland</td>
<td>Connecting the Chemical Composition of Planetary Atmospheres with Planet</td>
<td>Ph.D.</td>
<td>Pudritz</td>
</tr>
<tr>
<td></td>
<td>Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sarah McKenzie-Picot</td>
<td>On Modelling the Atmospheres of Potentially Habitable Super-Earths</td>
<td>M.Sc.</td>
<td>Pudritz</td>
</tr>
<tr>
<td>Sean Takahashi</td>
<td>High Field NMR Investigation at Yb2Pb2O7</td>
<td>M.Sc.</td>
<td>Imai</td>
</tr>
<tr>
<td>Wyatt Kirkby</td>
<td>Singularities in Many-Body Quantum Dynamics</td>
<td>M.Sc.</td>
<td>O'Dell</td>
</tr>
<tr>
<td>Peter Lunts</td>
<td>Low Energy Behavior of the Antiferromagnetic Quantum Critical Metal</td>
<td>Ph.D.</td>
<td>Lee</td>
</tr>
<tr>
<td>Richard Alsop</td>
<td>Pharmaceuticals And Physics: Studies Of Drug-Membrane Interactions Using</td>
<td>Ph.D.</td>
<td>Rheinstadter</td>
</tr>
<tr>
<td></td>
<td>Advanced X-Ray And Neutron Scattering Techniques</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gandhali Joshi</td>
<td>Mass Loss and Preprocessing of Galaxies Traversing Group Environments</td>
<td>Ph.D.</td>
<td>Parker/Wadsley</td>
</tr>
<tr>
<td>Xin Wang</td>
<td>Spontaneous edge current in chiral superconductor with high chirality</td>
<td>M.Sc.</td>
<td>Kallin</td>
</tr>
<tr>
<td>Ben Davis-Purcell</td>
<td>Snakes and Labyrinths: Adhesion-induced Fingering Instabilities in Thin</td>
<td>M.Sc.</td>
<td>Dalnoki-Veress</td>
</tr>
<tr>
<td></td>
<td>Elastic Films</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Galaxies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jean-Christophe</td>
<td>Rearrangement of 2D clusters of droplets under compression from crystal to</td>
<td>M.Sc.</td>
<td>Dalnoki-Veress</td>
</tr>
<tr>
<td>Onodit-Biot</td>
<td>glass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nathan Brunetti</td>
<td>An ALMA Archival Study of the Clump Mass Function in the Large Magellanic</td>
<td>M.Sc.</td>
<td>Wilson</td>
</tr>
<tr>
<td>Qianli Ma</td>
<td>Crystal Growth and Neutron Scattering Study on High Tc Superconductors</td>
<td>M.Sc.</td>
<td>Gaulin</td>
</tr>
<tr>
<td></td>
<td>La1.6-xNd0.4SrxCuO4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murray Wilson</td>
<td>Muon Spin Rotation Studies of URU2SI2 and Dichalcogenide Superconductors</td>
<td>Ph.D.</td>
<td>Luke</td>
</tr>
<tr>
<td>Jonathan Gaudet</td>
<td>Fragile magnetism in XY rare earth pyrochlores</td>
<td>Ph.D.</td>
<td>Gaulin</td>
</tr>
</tbody>
</table>

Radiation Satellite to be Launched!

Congratulations to Drs. Soohyun Byun and Fionna McNeill and their team for their successful proposal to build a satellite at McMaster! On May 4, 2018, the Canadian Space Agency announced that as part of their Canadian CubeSat Program (CCP), the McMaster Interdisciplinary Satellite Team’s proposed NEUDOSE satellite will be launched from the International Space Station in 2021. The NEUDOSE satellite will be launched and deployed from the ISS by the Canadarm, after being (likely) delivered by a SpaceX Falcon 9 rocket.

The big question behind the project is what kind of radiation, and how much of it are astronauts exposed to in space. High exposure leads to much greater risks of cancer as well as cataracts. The atmosphere shields us from this dangerous radiation so it is particularly important to understand the risks faced by astronauts in long manned missions or future deep space missions to Mars.

The radiation in space is complex and consists of different kinds of components including high energy gamma rays, charged particles, and neutrons. McMaster’s unique approach is based on the detectors built by Dr. Soohyun Byun for the nuclear industry, that are capable of detecting all of these different types of radiation in real time.

The project was the brainchild of McMaster Radiation Sciences graduate Andrei Hanu and former researcher at NASA’s Goddard Space Flight Center. Hanu approached Soohyun Byun with the idea of building a radiation-monitoring satellite and together they assembled an elite student team. This is a completely student driven project consisting of about 40 graduate and undergraduate students who are involved in all aspects of designing, testing, and fabricating the entire satellite structure. The satellite itself is about the size of a loaf of bread.

Once in space, the satellite will begin a 9-month mission. Each time it passes over the university campus, it will beam down reams of data which will be collected and analyzed by researchers on the ground, including Erica Dao, project manager and a PhD student in Radiation Sciences. This fall, some members of the team will travel to Palestine, Texas – home of NASA’s Columbia Scientific Balloon Facility – to test a prototype of the satellite aboard a stratospheric balloon reaching altitudes of 120,000 feet.

Radiation Satellite to be Launched!