Statement of Interest/Intent

Research Experience

Throughout my undergraduate career, I have had the opportunity to be involved in four separate astrophysics research projects, all of which have been invaluable experiences on my path towards a graduate research career.

My first experience in research was during the summer of 2015, after I had completed the second year of studies of my astrophysics degree. As part of the University of Toronto's Summer Undergraduate Research Project (SURP), I worked with Drs. Marten van Kerkwijk and Ue-Li Pen on a project investigating "giant pulses" emitted from pulsars—rapidly rotating neutron stars that are the remains of high-mass stars—and the "Crab pulsar" in particular. The Crab pulsar has long been known to be one of the strongest emitters of radio wavelengths that has been discovered to date, and its characteristic "pulse profile" (i.e. the typical pattern in which radio pulses are emitted) has been observed to consist of both a "main pulse" and an "interpulse" that occur at regular points in the pulsar's rotational period. Unknown, however, is why these pulses occasionally manifest themselves as giant pulses: short, extremely bright bursts of electromagnetic radiation with flux densities that can be thousands of times greater than those from average pulses (for further information on this topic see for e.g. Mickaliger et al. 2012, Pen et al. 2014, or Pen et al. 2015).

As a scientific endeavour, the study of pulsars is of great importance: they are environments of extreme physical phenomena relating to gravity, electromagnetic fields/waves, and density, and present physicists with a laboratory in which to study these fundamental physical properties unmatched by any laboratory on Earth. As a member of this research project, I had two main roles. Firstly, I was responsible for testing, debugging, and writing code with which to study the data collected from the Crab pulsar. As a relatively large research collaboration involving teams from the University of Toronto, the University of British Columbia, and Curtin University in Australia, among others, it was of the utmost importance that I create clear, understandable code that could be used by researchers across the project. Several key pieces of code that I wrote—including a program used for studying the polarization properties of individual pulses—continue to be used by researchers involved in this collaboration.

In addition to this, I was responsible for collaborating with other researchers during data collection excursions at the Algonquin Radio Observatory (ARO). During this time I took the initiative to create an archival system for the large amounts of data collected, in order to allow collaborators in the project to easily access all relevant data. I also identified a need for a centralized system of instructions for various tasks related to the research collaboration (e.g. accessing data, using relevant programs, etc.), and took it upon myself to create detailed project guidelines which continue to be used by students in the research group to this day.

During the 2015-2016 academic term (my third year in U of T's astrophysics program), I worked with Dr. John Percy on a project investigating an unexplored phenomenon known as "long secondary periods" (LSPs) exhibited by roughly a third of all pulsating red giant stars. These LSPs are about ten times longer than the star's pulsation period, and while the phenomenon has been known of for many decades, no suitable explanation has been put forth. In fact, this is said to be one of the most significant unsolved problems in stellar pulsation theory (Percy & Deibert 2016).

Prior to my research on this topic, several studies on LSPs had previously been completed, including one in particular which, although unable to determine a suitable explanation for the phenomenon, ended with a list of all currently known properties of LSPs (Nicholls et al. 2009). The purpose of my research was to make use of sustained visual observations from the American Association of Variable Star Observers (AAVSO) International Database in order to study LSPs and contribute further known properties to the current list.

As this was not part of a larger research collaboration, a great deal of my research for this project was undertaken independently. I was responsible for carrying out time series analyses on many decades worth of data, and wrote several programs that could be used in conjunction with the AAVSO's VStar analysis package to produce clear, informative plots that were used to study key properties of the stars' LSPs. In particular, I carried our Fourier and wavelet analysis of relevant data, and used this to characterize previously-unknown properties of LSPs. During my time working on this project I also took the initiative to create detailed weekly progress reports to share with my supervisor, as well as participate in several research conferences across Canada where I presented our work to fellow astronomers in the field.

At the culmination of this research project, we had discovered several properties of LSPs in pulsating red giant stars that had previously been unknown to experts in the field. In particular, we showed that there do not appear to be any differences in the LSPs of carbon (C) and oxygen (M) stars, and that the phase curves of the LSPs tend to be sinusoidal. We also put forth a theory suggesting that the similarity between the LSP and the rotational period of the star points to the explanation that the LSP is caused by rotational variability modulated by a convective cell. These results are presented in a published, referred journal article (Percy & Deibert 2016).

During the summer of 2016, I was once again accepted into the University of Toronto's Summer Undergraduate Research Program, where I completed a research project focused on the architectures of *Kepler* planetary systems. I had initially been approached separately by two post-doctoral researchers, Drs. Chelsea Huang and Cristobal Petrovich, who both expressed interest in working with me on projects relating to planetary dynamics and planetary system architectures. I noticed that Dr. Huang's observational work would be well-complemented by Dr. Petrovich's theoretical research, and suggested that the three of us collaborate on a project, the purpose of which would be to explore possible resolutions of the so-called "Kepler dichotomy": a "problem" within planetary astrophysics in which the number of single-transit planetary systems discovered by NASA's *Kepler* mission is too high to be consistent with a single model for the observed multi-transit planetary systems (Lissauer et al. 2011). My research for this project focused on this and other unanswered questions relating to *Kepler* planetary system architectures.

For this project, I was responsible for creating and running N-body simulations which were used to study the evolution of *Kepler*-like systems over millions of years. I wrote complex yet clear codes which worked in conjunction with a number of other programs (e.g. `REBOUND` (Rein & Liu 2011), an N-body Python code developed at the University of Toronto, and `CORBITS` (Brakensiek & Ragozzine 2016), a code used to determine transit probabilities for planetary systems) to simulate and evolve *Kepler*-like multi-planet systems over time. Our simulations tested the hypothesis that unstable outer ($\gtrsim 1$ AU) giant planets may have an effect on the system architectures of inner ($\lesssim 0.5$ AU) Super-Earths. I performed a statistical analysis of simulation results and showed that the simulated outer giant planets (which had orbital elements drawn from observed Radial Velocity populations) greatly reduced the multiplicity of the inner Super-Earths. Our model predicted a population of dynamically hot single-transit planetary systems that was consistent with observations, and was able to explain several previously-discovered systems of eccentric Super-Earths. This project also resulted in a research paper which has been refereed and is currently being reviewed by astronomy and astrophysics journals for publication (Huang, Petrovich, & Deibert 2016). Furthermore, I will be presenting this research at a physics conference at McMaster University in January.

Finally, I am currently completing a research project with Dr. Chris Matzner on star formation in the Dragonfish Nebula. This project began as an independent reading course that I completed with a final grade of 97% during the 2015-2016 school year. After noticing that the undergraduate curriculum did not cover star formation in as much detail as I would have liked, I approached Dr. Matzner about doing an independent study with him on this topic. I spent the year gaining extensive background knowledge on star formation, and then together with Dr. Matzner identified an unanswered problem in the field of stellar formation—namely, can we find evidence of star formation in the Dragonfish nebula?—and have been working on this project since September of this year.

As a follow-up to a project which identified a candidate for the most luminous OB association in the Milky Way (known as the "Dragonfish Association", described in Rahman et al. 2011), the goal of my current project is to search for protostars and young stellar objects (YSOs) in this region and determine the association's star formation rate. To accomplish this, I have been working with data from existing IR surveys (e.g. *Herschel*, *Spitzer GLIMPSE*, and others). We are creating spectral energy distribution (SED) plots (i.e. plots of a star's flux density against the frequency or wavelength of its light) and comparing these to model SEDs in order to find evidence of protostars/YSOs in the region, therefore providing further proof that it is indeed an area of intense star formation. This project is ongoing but is expected to result in a research paper by the end of the semester.

I have a strong, diverse background in research, and have successfully followed several research projects through from their inception to the publication of results in astrophysical journals. My experience with these projects has not only taught me the importance of collaboration and research in the sciences, but has also made me realize that I have a strong passion for astrophysical research—a passion which I hope to pursue at the graduate level, and to eventually turn into a career.

Statement of Academic Goals

Since the first confirmed detection of a planet outside our solar system in the year 1992 (Lissauer et al. 2011), the study of extrasolar planets and planetary systems has been an exciting and rewarding area of study within the astrophysics community. In the roughly two-and-a-half decades since this first detection, the field has grown exponentially, with thousands of exoplanets discovered to date and nearly half of these discovered in the past year alone (Lissauer et al. 2011). Yet despite the popularity and astounding progress in this field, many fundamental questions about the nature of exoplanets and planetary systems remain unanswered. Are the properties characteristic of our Solar System essential to all other planetary systems, or are they unique? What determines the architecture and occurrence rate of planets around their host stars? How does star formation affect the formation of planets? These are just a few of the many unanswered questions surrounding planetary systems that I hope to explore and potentially answer during my graduate career.

The study of exoplanets is important not just to astronomers within the subfield, but also to astrophysics as a whole—and indeed, to the general population. Studying exoplanets can shed light not only on our own solar system and how it will evolve, but also on other planetary systems throughout the galaxy. Planet formation is tied to star formation and is thus of interest to stellar formation theorists, and can also serve as a laboratory in which to study astrophysical dynamics. Furthermore, the study of exoplanets is closely linked to the study of extraterrestrial life, and can provide a vast amount of knowledge that will be key in humanity's exploration of the rest of the universe. I strongly believe that planetary astrophysics is currently one of the most important and promising areas of study within the field, and for this reason hope to pursue this topic at the graduate level.

My unique research and academic backgrounds position me as one of the strongest candidates to pursue research on exoplanets and planetary systems. During the summer of 2016, I was awarded a Natural Sciences and Engineering Research Council of Canada (NSERC) Undergraduate Student Research Award (USRA) in order to carry out a research project on the architectures of *Kepler* planetary systems. During my time spent working on this project I delved into the subject material and background literature, learning a great deal about exoplanets and planetary systems. I also carried out a number of large-scale simulations and tested several hypotheses which led to the completion of a research paper (Huang, Petrovich, & Deibert 2016) which has been refereed and is currently being reviewed for publication. In addition to having a strong background in planetary astrophysics, I also have a great deal of experience with stellar formation—a field which is closely tied to planetary astrophysics. I have previously completed an independent reading course on star formation, and am currently working on a research project focused on identifying evidence of star formation in the Milky Way. My extensive experience with both planetary astrophysics and stellar formation make me uniquely qualified to study planets and planetary formation at the graduate level.

My previous experience researching planetary astrophysics has taught me the importance and utility of programming and large-scale simulations within the field. I am interested in using N-body simulations to answer questions about the formation and long-term dynamics of planetary systems. With the large number of observational results being released from missions such as *Kepler*, *TESS*, and other programs, there are increasingly more questions about the histories and evolutions of observed planetary systems that can be addressed and potentially resolved through computer simulations. For example, can highly eccentric orbits of *Kepler* Super-Earths be explained by gravitational interactions with outer giant planets? What conditions led to the formation of *Kepler* systems made up of ultra-short period planets? I am interested in using N-body simulations to explore chaotic orbital dynamics of planetary systems in order to better understand the processes that led to observed systems to form. In addition to this, I am interested in exploring methods of improving current astrophysical simulations in order to further refine results in future research. I have a strong programming background and have completed several courses in computational physics/astrophysics, and feel that I am well-suited to theoretical, computational research.

In addition to planetary astrophysics, I have also completed extensive research on topics in star formation and would be interested in pursuing this further at the graduate level as well. Like with planetary astrophysics, I feel that theoretical computer simulations can be extremely effective in answering open questions about star formation. For example, although we have a general view of how protostars form—namely, from the gravitational collapse of clumps of dust and gas—there are numerous physical processes involved that simply haven't been modelled with a sufficient level of detail to produce a complete picture of the stellar formation process (McKee & Ostriker 2007). I am interested in using numerical modelling to study and help understand the role that processes such as turbulence, magnetic fields, and hydrodynamics play in the formation of protostellar objects.

More specifically, there are a number of unanswered questions relating to star formation that I am interested in exploring. What is the origin of the stellar initial mass function (IMF)? Answering this question is crucial in producing a complete theory of star formation, and furthermore, understanding the origin of the IMF will allow researchers to begin to understand why and how the IMF may vary in different environments (Bonnell, Larson, & Zinnecker 2006). Simulations can be used to investigate the role and effect of different physical processes on the IMF. Likewise, what is the role of feedback in the stellar formation process? Although we know that feedback from massive stars likely has an effect on the star-forming environment, the exact nature of this effect is unclear (Matzner & Jumper 2015). Deepening our understanding of stellar feedback during the star formation process will not only give researchers a more complete view of star formation, but will also allow for improved, more accurate results in future numerical simulations. These and other questions within the field require the collaboration between theorists and observers, with computational simulations being based on observational results and future observational endeavours being informed by computational outcomes. I am interested in this intersection between theory and observation, and feel that recent advances in both computational and observational technologies have positioned astrophysicists at the brink of answering many of these crucial questions within the field of star formation in the near future.

Finally, as a student of English as well as astrophysics, I am also very passionate about writing and communication and hope to apply these passions to my work as a graduate researcher. As evidenced by my numerous publications (including one that was awarded the Arthur Irwin prize for best writing in a campus publication, see Deibert 2014), I have very strong communication skills and know how to convey ideas through writing. I firmly believe that one of the most important aspects of scientific research is being able to communicate results in a clear, concise manner, and feel that as a student of both English and astrophysics, I am exceptionally well-suited to this task. I am confident in my ability to produce polished, professional research papers, and hope to continue doing so at the graduate level.

I have a wide range of research interests and a great deal of previous research experience, and feel that I am well-suited to continue pursuing astrophysics research at the graduate level. Furthermore, I am passionate and curious about the field, and believe that I have a great deal to contribute to the future of astrophysics. Throughout my undergraduate career I have demonstrated that I am a very strong student academically and I intend on continuing this through my graduate studies.

Leadership Experience

Throughout my time as a student at the University of Toronto, I have been involved in a wide range of both professional and extracurricular activities that have given me the opportunity to grow and develop as a leader within the community.

During my first several years as an undergraduate student, I played a key role in a number of on-campus publications. As early as the first week of university I was involved with *The Strand*, a Victoria College-based student-run newspaper produced and distributed on campus. I initially volunteered to cover the university's Orientation Week for the newspaper, and from there continued helping out as a writer and editor, eventually earning the title of Staff Writer. In my second year of university I was elected for the position of Section Editor for the newspaper's creative/humour section. During my three years in this position I spearheaded a number of new initiatives for the newspaper, including the creation of an increased online presence and a number of new policies for the section, and more than doubled the number of pieces being submitted to the section on a weekly basis.

My experience as a Section Editor for *The Strand* helped me to earn a role as an editorial board member for *Goose*, an annual student-run anthology of short fiction. In this position I was responsible for soliciting, selecting, and editing student-written works of fiction for publication in a journal. During my first year in this position I was a valuable asset to the team, helping out not just with my assigned duties but also with tasks outside of my role, including organizing events, distributing journals, and advertising for the club. My strong work ethic and leadership skills led to me being elected as the President and Editor-in-Chief of the journal the next year, where I was responsible for running all aspects of the club and ensuring the production of a professional, polished journal to be distributed around campus. During this time I was responsible for a number of new initiatives, including the creation of an online archive of past issues and the inclusion of interactive fiction through QR codes in the journal.

In addition to being involved in a number of publications, I have also spent a great deal of time volunteering with astronomy-related outreach initiatives. For the past several years I have been involved as a volunteer with the University of Toronto's monthly AstroTours event, which focuses on making astronomy accessible for the general public. During my capacity as an AstroTours volunteer I have led groups to planetarium shows, gathered feedback from event attendees, and led Xbox Kinect and Oculus Rift astronomy demonstrations. I have also taken the initiative to recruit and train new student volunteers for future events, and have helped out with organizing/restructuring the event in order to best meet the needs of attendees.

I have also spent the past two summers volunteering with the University of Toronto's Sidewalk Astronomy initiative. For this event I worked as a telescope operator and engaged with members of the public while observing the sun during lunchtime. This role required me to develop strong interpersonal skills, and allowed me to share my passion for astronomy with interested members of the general public.

In a similar vein, I have also spent the past several years volunteering with Astronomy on Tap: an outreach event held at a local pub with the purpose of educating the general public on current topics in astronomy. At Astronomy on Tap I volunteer as a "roaming astronomer" and answer any questions the public may have on a variety of astronomy-related topics. My experience with both AstroTours and Astronomy on Tap has not only allowed me to make astronomy more accessible to those without a science background, but has also given me the chance to develop strong leadership and interpersonal skills.

Last year I also helped to organize and volunteer with a new astronomy outreach initiative aimed at children and based out of the Royal Ontario Museum. I was responsible for organizing and setting up the event, which ran during March Break, and liaising with contacts at the Royal Ontario Museum in order to facilitate the event. I was also responsible for leading Xbox Kinect demonstrations that offered a "tour of the universe" through the World Wide Telescope software. In this position I engaged with elementary school-aged children and taught them facts about the solar system.

After becoming heavily involved in a wide range of astronomy outreach initiatives, I was approached by Dr. Dae-Sik Moon, the undergraduate astronomy chair at U of T, about becoming a teaching assistant for AST201: Stars and Galaxies, which is a large, introductory astronomy course aimed at students without a science background. Although these TA positions are typically reserved for graduate students, I had previously spoken with Dr. Moon about the possibility of helping out with the course, as I am very passionate about both outreach and teaching. My strong academic achievements and numerous contributions to outreach initiatives led to me being hired to lead two tutorial sections during the 2016 winter semester.

As a teaching assistant, I was responsible for leading in-class discussions and administering quizzes during tutorials. I was also responsible for marking midterms for a class of 1500+ students, and providing extra help and guidance as needed. Additionally, I helped out at optional evening outreach activities for students hoping to learn more about astronomy outside of classroom hours. This position taught me a great deal about leadership and professionalism, and made me realize my passion for teaching in addition to outreach.

Perhaps my most important contribution to the University of Toronto community is my involvement as the founder of an undergraduate students' union for the astronomy program. Historically, astronomy undergraduate students at U of T—despite having their own department separate from the physics department—have been represented by a students' union run out of the physics department and targeted mainly at physics students. Indeed, although the union was supposed to be a "Physics and Astronomy Students' Union", astronomy students were largely ignored by the union in favour of physics-exclusive events and initiatives. Although physics and astronomy are closely related, I felt that there were many issues specific to the astronomy program that could be addressed by an astronomy-specific students' union, and so I approached the University of Toronto administration, the Arts and Science Students' Union, and the Physics and Astronomy Students' Union about creating a union specifically tailored to students in the astronomy department. In particular, my goals were to increase the number of astronomy-related academic and social events on campus, create a space where issues with the astronomy program or astronomy courses could be addressed, and provide astronomy students with more information on outreach or professional opportunities. After recruiting several of my peers for this initiative and researching the process of creating a new students' union, I am proud to say that the Astronomy Undergraduates' Union (AU) will be active at the University of Toronto as of January 2017. With this project I noticed an area requiring improvement within the astronomy community, created a solution and researched the process of implementing it, and motivated the entire undergraduate astronomy program to come together and effect change within the university community.

I am passionate about astronomy outreach and have been fortunate to have been involved in a number of outreach initiatives throughout my undergraduate career. I believe myself to be a hardworking, dedicated leader within the astronomy community, and hope to continue this throughout my graduate studies.

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