Personal Statement (NSF GRFP 2015): Rhondale Tso

As an active participant in scientific research, my educational and career goals are to continue my academics in astrophysics. I wish to promote the inception of my field of gravitational wave astronomy, act as an ambassador to underrepresented groups, and extend international collaboration to promote scientific value. Collectively, my intent and ambition is to excel in graduate school, where I will work towards post-doctoral fellowships and academic positions. Coming from a destitute family, I entered a degree program in physics amidst a recovery from heart surgery. After my second and final heart surgery in the fall of 2009, I was in a state of mental and emotional stress that carried over into my academic pursuits. My innate resilience and stubborn drive to succeed, however, insured that my research did not suffer as a result. To date my health has made tremendous progress and, despite a skiing accident that strained work this past spring, my health has been unyielding.

Intellectual Merit (Relevant Background)

Research has been an integral component of my undergraduate education: my main focus being gravitational physics and relativity. Funded through a NASA-sponsored grant, I began my research career under the guidance of Dr. Quentin Bailey, testing the symmetries of relativity through the phenomenon of light bending due to gravity. Here I performed analytic calculations in weak gravitational fields under a theoretical framework known as the Standard Model Extension (SME), which investigates fundamental physics under the condition that Lorentz symmetry is violated. Within the pure gravity sector of the SME, standard predictions of General Relativity are augmented through a set of Lorentz-violating coefficients, terms that can be constrained through experimental and observational tests. In the SME framework, I derived a modified deflection angle of light rays grazing massive bodies and presented a means of testing this. My work in this field led to a first-authored publication in *Physical Review D* in the fall of 2011 as well as my presentation at the 2011 American Physical Society April Meeting in Anaheim, California. As a result, I was also invited to attend the Fifth Meeting on CPT and Lorentz Symmetry at the Indiana University Center for Spacetime Symmetries (IUCSS). This largely one-on-one collaboration between Dr. Bailey and myself revealed to me what constitutes scientific research. I was required to direct my own approach and unveil consequences subject to peer review for assimilation into the forefronts of the scientific community. Today, experimental consequences of my predictions are testable through the European Space Agency's ongoing Gaia space mission.

Continuing down the path of relativity-violating effects in the SME, I was invited to the IUCSS to begin a project with Dr. Alan Kostelecký during the Summer of 2011. Working with Dr. Kostelecký, I was able to collaborate with a team of theorists for the first time. Here Dr. Kostelecký and I considered the classical limit of fermions in curved spacetimes subject to *explicit* violations of Lorentz symmetry. Explicit violations, as opposed to *spontaneous* violations considered in my light bending paper, provide a condition where key mathematical identities in Riemann geometry, the language of General Relativity, are not satisfied. In our investigation we relaxed certain conditions of this geometry to allow the particles to reside in an extended form of this limited mathematical descriptor. Such an extension produces the well-established Finsler geometry. Our work in the SME provided structures independent of other well-studied Finsler spaces. Ultimately, we uncovered new mathematical spaces:

opening up the possibility of physics predicting and promoting new mathematics, a rare occurrence. Our new structures, termed bipartite Finsler structures, opened a rich field of exploration. My activities involved calculating specifics in this more general bipartite space, what we termed *H-space* and *b-space*. The mathematical consequences we discovered that summer led to a coauthored publication in *Physics Letters B* in the fall of 2012.

Beyond my work in testing relativity, I also attended the University of Chicago Physics NSF REU[1] program during the summer of 2010, working with Dr. Robert Wald. My work entailed modeling charged particles near the surface of a rotating black hole submerged in a magnetic field. My approach and activities blended analytic and computational calculations in extremely relativistic regimes. An unpublished manuscript was produced that summer. Returning to Embry-Riddle, I then switched my focus to gravitational waves for my undergraduate thesis. In the next few years the Laser Interferometer Gravitational-wave Observatory (LIGO) and its European counterpart, termed Virgo, may, for the first time, directly detect a new type of radiation: gravitational radiation. A direct detection could open a new field of astronomy. With this knowledge I began a project with Dr. Michele Zanolin, a member of the LIGO Scientific Collaboration. Dr. Zanolin and myself sought to apply a new technique in determining error estimates. Our approach was to quantify the degree to which alternative theories of gravity could be constrained through gravitational waves. A first-authored publishable manuscript is currently in preparation.

During my post-baccalaureate period I joined Columbia University as a research staff assistant. At Columbia, I've been working with Dr. Janna Levin on dynamics of compact binary systems, particularly the effects that rotational and orbital angular momenta have on gravitational waves generated. For a year we focused on the frequencies manifested in the periodicity of eccentric binary systems while their momenta precess. Our approach was exploratory, investigating new detection strategies to be implemented by LIGO for burst signals produced from eccentric binaries. Current work has shifted and involves rotating black holes in electromagnetic fields, combining my experience of gravitational waves with previous work at the University of Chicago. We are building the foundations of a rigorous understanding of black holes in strong magnetic fields. Efforts are necessary for the understanding of electromagnetic counterparts to compact binary inspirals, a blend of electromagnetic and gravitational radiation that is known as multi-messenger astronomy.

Broader Impacts (Relevant Background)

My background for broader impacts is divided into two categories: outreach and academics. As an undergraduate I participated in the Society of Physics Students (SPS) and the ΣΠΣ Physics Honors Society at my institution, both national organizations of the American Institute of Physics. In SPS I presided over our chapter as President, Vice-president, and Community Outreach Officer, while in ΣΠΣ I served as the President and Vice-president. During the 2010-11 academic year, I was also the principal proposer for the Marsh W. White Award. Awards granted to our chapter funded outreach efforts at the Kinlani Bordertown Dormitory (a native american dormitory in northern Arizona), which I orchestrated a year later. Here the SPS chapter I oversaw, in cooperation with the Northern Arizona University SPS chapter, conducted an outreach program targeting underrepresented minorities, mainly

[1]National Science Foundation Research Experiences for Undergraduates

those of the Navajo and Hopi tribes. Expanding upon these efforts I received a grant from my alma mater in the winter of 2012 to perform STEM[2] outreach presentations across the Navajo Indian reservation. I succeeded in visiting eight high schools scattered over twenty-five thousand square miles of high-elevation desert. Furthermore, I even acted as the National Associate Zone Councilor in SPS, where I was responsible for overseeing SPS activities in Arizona and New Mexico and represented our district at the SPS National Council Meeting in Washington DC. My service to my community hasn't ended: today I remain active with stargazing activities hosted by Columbia University and open to the New York City public.

Academically, outside my undergraduate institution, I was employed as a tutor in a local high school assisting underperforming students for six months. I also interned as an academic assistant at Arizona State University during the summer of 2009, where I was employed by the Joaquin Bustoz Math-Science Honors Program, a high school program targeting high achieving underrepresented minorities in mathematics and science. During the 2012-13 academic year I also acted as a scribe for a visually impaired undergraduate enrolled in mandatory calculus courses at Northern Arizona University. These experiences have allowed me to bring my knowledge and joy of science to a diverse range of students.

Future Goals

It is in my best interest to continue academic service to my community, collaborate with local native american residents, and expand my horizon to overseas. Studies done by the American Institute of Physics mark native americans as one of the lowest demographics in the sciences, especially in physics and astronomy[3]. By engaging with my network of educators, and expanding my connections, I hope to foster a team of collaborators for the promotion of STEM fields to a host of underrepresented demographics. My goal is to also work with a diverse group of young researchers, both graduate and undergraduate, in my research.

My conviction in the importance of gravitational wave astronomy is furthered by its social impact. A collaboration as vast as the international LIGO-Virgo partnership is expected to expand beyond the Western world in order to integrate interferometers in India and Japan. Targeting developing nations, expanding technological progress, and increasing international collaboration are benefits the LIGO-Virgo group will have on the world. In progressing through my career I hope to enhance this collaboration, improve on outreach efforts, and address the need for underrepresented groups in the sciences. Previous work in organizing outreach efforts and promoting scientific endeavors, demonstrates that I am capable of embarking on such an enterprise. Furthermore, my experience in working with students across a wide spectrum of abilities and demographics makes me well-qualified in receiving the NSF Graduate Research Fellowship.

The research experiences I have amassed during my time as a scientist have provided me with a sagacious perception of scientific endeavors. To this day, witnessing the never-ending ride of successes and failures that go hand in hand with academia, I still find the experience humbling and maturing. Attending a graduate institution will further my journey as a scientist and allow me to achieve the future I know I am meant to have: bringing the brilliance of scientific discovery to others around the world.

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[2]Science, Technology, Engineering, and Mathematics (STEM)

[3]R. Czujko, www.aip.org/sites/default/files/statistics/minorities/nativeamer-pg-08.pdf