Growing up, I had an intense passion for astronomy. Unfortunately, in a rural area like my home of mid-coast Maine, most educators through high school believe in a more classically practical application of knowledge. This meant that my dreams of unraveling the mysteries of the Cosmos were abandoned amongst rhetoric that there was no future in being an astronomer, and instead to apply my skill with mathematics to a more marketable career like engineering. With this in mind, my core studies while pursuing my Bachelors degree at Bowdoin College did not include physics or astronomy, but instead mathematics, computer science, economics, and German. In the eleventh hour of my senior year at Bowdoin, I made a simple, yet life-altering decision: I took an internship as a geospatial analyst in the Earth science division at NASA Langley Research Center and abandoned what was shaping up to be a career as a consultant. Being an effective NSF Fellow means stepping boldly into the unknown regions of your chosen field, where you will have by definition little to no prior knowledge to work with, and nevertheless making significant contributions and becoming a world expert. **This ability to start from scratch and quickly become accomplished in a research topic is one that I demonstrate repeatedly throughout the career I detail below, and one that I will apply relentlessly if honored with an NSF Fellowship.**

Relevant Experience: My research topic as part of a team in the NASA National DEVELOP Program was analyzing air quality in Houston, TX and correlating MODIS satellite data with new NASA High Spectral Resolution Lidar (HSRL-2) measurements to determine the effectiveness of HSRL-2 at assessing small ($<2.5\mu m$) particulate matter levels at the ground. Despite having no knowledge of remote sensing and only my math and computer science skills, I quickly became proficient with Matlab and was invaluable as the data and statistical analyst on the team. At the end of the project, the team and center leads requested that I travel to NASA Headquarters due to my deep understanding of the research, and present the results of the analysis in both a talk and a poster, which gave me valuable presentation experience.

After completing my research project at NASA Langley, speaking to numerous scientists, and gaining the experience of working at a NASA center, I finally understood that a career in space science research was plausible and exactly what I wanted with my future. With this in mind, I moved to NASA's Goddard Space Flight Center and became the research team lead for a programming intensive Earth science research project. Once again, despite my lack of experience with the programming language Python, I learned quickly and became the head developer for a remote-sensing powered, automated landslide detection software package for Nepal written entirely in Python. During this project, in addition to gaining additional experience presenting the results of my research at NASA headquarters for a second time, I learned to both lead and work effectively within a group of researchers. Furthermore, the automated landslide detection product was handed off directly to end-users in Nepal, and as the research team lead I was the main contact tasked with ensuring the product satisfied the needs of the International Center for Integrated Mountain Development (ICIMOD). The culmination of this position at NASA Goddard included making the product open-source in hopes that it could be adjusted to other regions of the world, and a publication that is currently under review in *Earth Interactions*.

During the same time period, I also worked for NASA's Applied Remote Sensing Education and Training (ARSET) program, where I wrote research-oriented python programs and gained experience training NGOs and government organizations in the use of NASA software and remote sensing data. Meanwhile, I attended every planetary science, astronomy, astrophysics, and heliophysics talk I could and spoke to as many scientists as possible in an attempt to pinpoint my interests, and possibly attain a research assistant position in one of those divisions. Eventually I met a planetary scientist, Dr. Conor Nixon, who was working on the Cassini CIRS instrument team at Goddard. Despite my complete inexperience with planetary science and atmospheric modeling, Dr. Nixon recognized my passion, motivation, and intelligence and hired me as a planetary science research assistant for the CIRS team.

After deciding at the end of my first NASA internship that I would like to pursue a future in space science, **it had taken me less than a year to go from an Earth science intern with little research experience to a fully-fledged research assistant in the planetary science division at NASA Goddard.** Again I found myself in a position requiring programming languages that I had no experience with, and knowledge of atmospheric modeling and infrared spectroscopy that I lacked. Nevertheless, I committed myself to becoming an expert in my research topic: using the Cassini CIRS far-infrared interferometer to determine the D/H abundance on Saturn and Jupiter. By asking endless questions of my advisor, reading a litany of papers for background information, and immersing myself in the atmospheric modeling software, I swiftly was up to speed and contributing to the CIRS research team at Goddard. Over the next year, I worked and problem solved primarily on my own, but with overall guidance from my advisor and other members of the CIRS team. I gained invaluable experience working through issues in my research independently, as well as added Fortran and IDL to my list of proficient programming languages. **As the lead author on a publication in the Astronomical Journal with 9 other co-authors** that resulted from this work[1], I became skilled at technical writing, compromising with co-authors around the world, and the publication process as a whole. This measurement of D/H had never been made with the high spectral resolution CIRS data, and the results showed definitively for the first time that the deuterium abundance on Saturn is lower than that of Jupiter. This is contrary to current model predictions, which suggests that our understanding of planetary formation and evolution is incomplete, a result that will spur much research in the future to discover the cause of this discrepancy.

I knew once I had decided that I wanted to pursue a career in astronomy that I would need to obtain a PhD if I wanted to conduct my own research and return to NASA as a fully qualified research scientist. During my year as a research assistant for the CIRS team at Goddard, I was accepted to the Physics PhD program in the Department of Physics & Astronomy under advisor Dr. Steven Rodney at the University of South Carolina, where I would finally get a chance to explore extragalactic astrophysics. With no previous physics education, I was accepted with the understanding that I would need to quickly prove that this would not hinder me academically in any way. I completed my first year of graduate education with a 3.9 GPA and passed my qualification exams on the first of three attempts, solidifying my position as a PhD candidate. **As a PI I was awarded a $\sim$ \$50,000 NASA HST Archival Research Grant titled "Turning Gravitational Lenses into Cosmological Probes", and as a Co-I I was awarded a \$25,000 NASA EPSCoR grant titled "Rare and Peculiar Stellar Explosions with the Next Generation of Space Telescopes".** Under the second grant, I already have a publication in preparation as lead author in which I have extrapolated supernova (SN) spectral energy distribution (SED) templates into the IR and UV, to be used with next generation space telescopes JWST and WFIRST. Under the first grant, I will be developing a standardized software package capable of measuring time delays and lensing properties of strongly gravitationally lensed and multiply imaged SNe.

Future Goals: My first goal, which I am already well on my way toward accomplishing, is to obtain my PhD from the Department of Physics & Astronomy at the University of South Carolina, which will make me the **first member of my family to obtain a doctorate.** I will tailor my research and the software I develop during this time to be relevant for the next generation of space telescopes, namely JWST and WFIRST. After completing my PhD, I hope to return to NASA and become a research scientist analyzing data from one of these telescopes, where the expertise and global connections gained through an NSF Fellowship would make me a valuable and effective researcher.

Summary of Intellectual Merit: Time and time again I've proven my ability to master a subject effectively and efficiently. I have continually challenged myself by stepping into an area of research I have no experience with, and nevertheless have been extremely successful. After starting my quest to become an astronomer in 2014 with no experience, I have already gained a complex understanding of remote sensing, statistical analysis, atmospheric modeling, technical writing, STEM outreach, SN classification, gravitational lensing, and much more. I am proficient with Matlab and R, I can program in seven languages, and I have shown through my success thus far in my Physics degree that the obstacle of stepping into the unkown is no obstacle at all. In short, I have a plethora of research experiences and technical skills that, in addition to my aptitude for mastering new subjects quickly, set me up to become a world expert in analyzing multiply-imaged SNe and a successful NSF Fellow.

Broader Impacts: Due to my academic experience at a young age, I am committed to ensuring that no child's love of astronomy will go unfostered in my community. It is crucial that childen who love STEM, and specifically astronomy, are reinforced that this is a valid future career and that a graduate degree is possible for them. Growing up in rural Maine, graduate degrees were few and far between, and even the percentage of high school graduates attending a 2-4 year college was only around 50%. In my current neighborhood, the Lyon Street Community within Columbia, SC, **only** 27% **of people graduated from high school,** 13% **have a bachelor's degree,** 3% **have a master's degree, and** 0% **have a PhD.** I will use my STEM outreach experiences with NASA's ARSET program, as well as the techniques I learned volunteering in elementary school math classrooms in college and tutoring high school students while at Goddard, to help foster excitement for STEM in my community. By way of the plan that I outline in my research statement, I hope to convince these students that **achieving higher degrees is possible and valuable**, and break the vicious cycle of suppressed academic opportunities forming in my community.

[1]Pierel J. D. R. et al. 2017, doi:10.3847/1538-3881/aa899d

It has been over half a century since astrophysicist Sjur Refsdal first developed the theory to enable the use of a gravitationally lensed supernova (SN) resolved into multiple images as a cosmological tool. The first multiply-imaged core-collapse (CC) and Type Ia SN, Refsdal[2] and iPTF16geu[3] respectively, have been discovered in just the past 3 years. As the light for each of the multiple images follows a different path through the expanding universe and through the lensing potential, the SN images appear delayed by hours (for galaxy-scale lenses) or years (for cluster-scale lenses). These gravitational lenses are also important tools for extending our SN sample into the early universe, beyond the limit of current detections at $z \simeq 2$. As PI on an ongoing HST Archival Research Grant, **I am developing the first open-source software for analysis of lensed SNe** (*Supernova Time Delays* [SNTD]). This Python package will be essential for precise measurements of lens properties and time delays from the hundreds of multiply-imaged SN observations expected over the next decade (Figure 1), and despite its design for SNe will be valuable for lensed quasar measurements as well. My research will have two major components: 1. Using SNTD and multiply-imaged SN as a cosmological probe. 2. Observing and understanding the rates and physical properties of very high-z SNe.

Intellectual Merit : After completing SNTD, I will use the software to make more precise time delay measurements for the two currently documented multiply-imaged SN, and any others discovered in the interim. Accurate measurements of the lensing magnification and time delays for strongly lensed CC SN Refsdal can be used to test models for the dark matter distribution in the lensing object[5;6] or as a probe to test cosmological models[7]. For a multiply-imaged Type Ia SN such as iPTF16geu, more accurate measurements will provide both an important milestone in breaking degeneracies in the lens model and a measurement of the Hubble constant H_0 that is completely independent of the local distance ladder[8;9]. The methodology and software I develop will be **be widely used by future SN surveys** for analyzing multiply-imaged SN and tightening the constraints found in the course of this work.

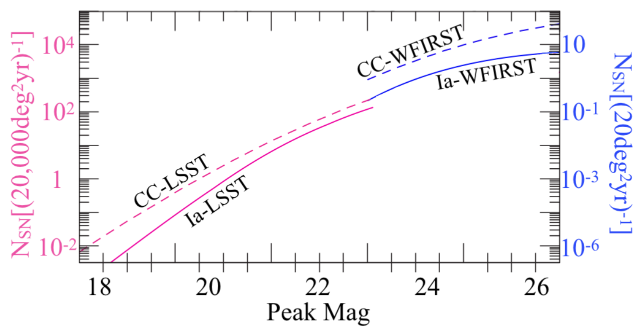

Figure 1: Expected numbers of lensed SN Ia and Core Collapse SN after one year of $20,000deg^2$ LSST (Pink, $i_{peak,lim}$) and $20deg^2$ WFIRST (Blue, $H_{peak,lim}$) surveys. With this huge volume of lensed CC and Ia SN observations expected in the next decade, the open-source SNTD package will be widely used and essential for analyzing this large WFIRST/LSST SN sample (adapted from Oguri & Marshall 2010[4]).

Over the next 2 years, I will measure the rates and properties for a sample of high-z and lensed SN discovered with the Hubble Space Telescope. This sample will draw from a series of HST programs (CLASH, FrontierSN, RELICS, and the new BUFFALO survey) that have targeted massive galaxy clusters. I am currently collaborating with the team of Dr. Rogier Windhorst on the JWST Guaranteed Time Observations (GTO) program 1176. Beginning in 2019, this program will apply 110 hours of cadenced imaging on massive galaxy clusters as well as a deep field at the North Ecliptic Pole. The GTO should deliver over 300 SN detections for $z < 5$, including a significant portion above the current detection limit of $z \simeq 2$, as well as a chance for observations of Type Ia and Pair Instability (PI) SNe at $z > 5$

(Figure 2). In addition to spurring return observations with HST and JWST, this new sample of high-z SNe alone will enable tests of star formation rates (SFR), the stellar initial mass function (IMF), SN progenitor pathways, and explosion models for SNe in the early Universe.

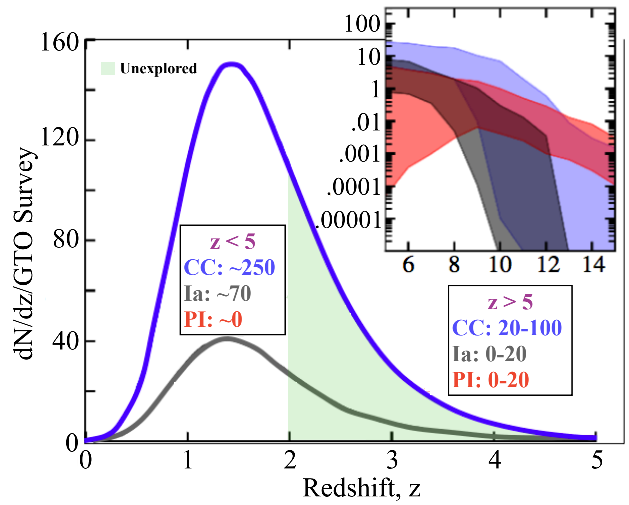

Figure 2: Projected SN yield from the JWST GTO 1176 program. We will detect *every* Type Ia SN that explodes in this field to z $\lesssim$ 5 and 90% of all Core Collapse (CC) SNe to z $\simeq$ 1.5, allowing the first high-z SN rate studies with an effectively complete sample. The green region represents redshifts above the most distant SN currently recorded, suggesting that observations from the GTO will create a significant catalog of the most distant SNe yet detected. The inset shows SN yield for $z > 5$, where observations of early universe Type Ia and PI SNe are possible.

Research Plan: 1)Complete the python software package SNTD and write a paper presenting its capabilities and validation. 2) Perform reanalysis of SN Refsdal and SN iPTF16geu using SNTD, writing a second paper presenting the more precise time delay measurements, detailing the methodology required for these analyses, and obtaining an initial constraint on H_0 from iPTF16geu. 3)Form a sample of high-z and lensed SNe from HST surveys and JWST GTO, and write a paper using this sample to constrain the physical properties of SN progenitors in the early universe.

Evidence for the success of this work will come from these **three publications**, as well as the vetting and extensive use of the open-source SNTD package by the entire community throughout future work with the next generation of space telescopes.

Broader Impacts: I will use my previous STEM outreach experiences (see personal statement) to **increase the participation of young students in astronomy and other STEM fields from my neighborhood in Columbia, SC, where 88% of the residents are underrepresented minorities in STEM.** My research is a terrific gateway into STEM because it is naturally exciting and interesting: space telescopes, exploding stars, and gravitational lensing are surefire topics to capture the attention and imagination of a young learner. I have already created a plan with the *Lyon Street Community After School Program* that will include taking the kids to our local University observatory, and leading them through a series of astronomical exercises over the course of the year. I will have each student choose and carry out an astronomy project within our neighborhood, such as monitoring sunspots to measure the rotation of the sun, and present their results to the community. By teaching the students and engaging their parents via the research projects and presentations, this outreach program will **encourage higher learning in STEM, and increase public scientific literacy and public engagement with STEM**.

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