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$E=mc^2$ Journal Article

I've lived in the small town of Burnt Hills, New York for all of my life. Starting at a young age I developed a love for science. In my spare time I would polish rocks in my rock tumbler. I spent hours digging around my gravel driveway trying to pick out the quartz among the limestone. I also enjoyed analyzing fingerprints with my toy forensic kit. At one point I actually wanted to become a forensic anthropologist (the show Bones was a favorite of mine). My father had a part in helping to propel my scientific interests. He had an old chemistry set and we would do experiments on the weekends. He also would set up his old telescope so we could gaze at the stars. Perhaps that's where my love of astronomy began. My interest in nature also influenced my passion for science. As a little girl I would catch frogs, butterflies, crickets - really anything I could get my hands on. I loved, and still love, fishing at my grandparent's lake, only a couple hours from where I live. Bloody Pond, despite the gruesome name, is where I have had some of my best memories. I've especially enjoyed my time spent looking up at the sky on those clear nights.

As I got older I watched documentaries and read books on concepts like light speed and parallel universes, which immediately captured my imagination. I was in awe by how the world works and how we can learn about it through equations and experiments. What drew me to astronomy and physics is the idea that it is the basis of study for the entire universe; from the most elementary of particles, such as neutrinos, up to the largest and most distant galaxy structures studied. My passion for science was escalated the summer going into my sophomore year of high school. That summer I attended a career exploration program at Cornell University

where I took a workshop on astronomy. Immediately I fell in love with the field and the exciting research it was producing. I was fascinated by dark matter, exoplanets, and all of the mysteries in the farthest depths of our universe.

So, naturally when I was accepted into my school's science research program, that started my sophomore year, I decided to pursue an astronomy project. That fall I spent hours reading professional papers on various types of astronomy research. I also scoured through the internet searching for possible mentors at various college campuses. Incredibly, my science research teacher had arranged for me to meet with Professor Heidi Jo Newberg of Rensselaer Polytechnic Institute (RPI) that November. At first Professor Newberg was hesitant to work with high school students, protesting that they weren't really interested in science and just wanted to win Intel science fairs. However, once I told her I had read about thirty of her papers I soon joined the research team and delved into a project of my own.

Throughout my three years in the science research program in addition to the research I did at RPI I had incredible experiences that cemented my interest in physics and astronomy. In the spring of my sophomore year I became a Dudley Observatory Rising Star Intern. Through this program I was given my own telescope, a beautiful Dobsonian reflector. I attended star parties and taught local people in my community about astronomy. That next summer I was awarded a scholarship to attend the Advanced Astronomy Camp in Tucson, Arizona. While I was there I was able to work with various types of telescopes, from solar to radio. The sky was so clear that for the first time I was able to see the Milky Way with my own eyes - it was truly incredible. While I was there our group actually discovered several supernovas and the results were published! During my time there I was also able to participate in a mini research project

where two other students and I measured the amount of dark matter in galaxy NGC 4559. We did this by first measuring the total mass of the galaxy by looking at the galaxy's rotational curve. Then we measured the mass of the gas in the galaxy by using the radio telescope and found the mass of all the star light in the galaxy. When we subtracted the gas and stars from the total mass we found the mass of the dark matter! It was an extraordinary experience that I will never forget.

My love for astronomy and physics continued to grow. I branched out my junior year of high school by participating in an Astrobiology Short Story Contest funded by the New York Center for Astrobiology. I have always been fascinated by science fiction. I love TV shows such as The Twilight Zone, Star Trek, Firefly, etc. I thought it would be fun to see how far I could stretch the science in my own story. I wrote about what life would be like on an exomoon millions of light-years away. I won the contest that summer and was interviewed on National Public Radio about my story.

I was selected to be a part of the NASA WISH (Women in STEM in the High School) Scholars program in my junior year of high school. I participated in graded online assignments that consisted of essays, math problems, quizzes and design modules. After completing all my assignments I was chosen as one of eighty girls that were able to participate in an onsite experience at NASA's Johnson Space Center in Houston, Texas that summer. There, I was able to tour mission control, design a mission to Mars and even ask a question to an astronaut aboard the International Space Station!

All of these incredible opportunities could not have been possible if I had not started my research project. Over three years my research with Professor Newberg blossomed into more than I could have hoped for. Briefly, my research investigates the mistakes with spectral

classifications within the Sloan Digital Sky Survey database. Because of my research I have been able to present at two state level professional conferences, one at Skidmore College and one at Stony Brook University. I also presented my research at the American Astronomical Society Meeting in Long Beach, California this past January. In addition, I have participated in various local science fairs.

The experiences I have had and curiosity I possessed as a child had led up to my success in the Intel Science Talent Search (STS). This past year I was honored to have been named one of the forty Intel STS finalists for 2013. At Intel I meet the most fascinating people and learned about such great research, all done by high school kids like me! It also didn't hurt that I got a minor planet named after me and shook hands with the president.

I have learned so much from participating in a research project. Perhaps the most important thing I have learned is how to be independently motivated and driven. I have learned to be curious and question everything. During my research I had to learn mathematics and physics that, at the time, was above my level. I remember having to calculate the error bars on a proper motions diagram using logs when I wasn't even finished with geometry yet in school. I would spend hours reading books on advanced physics and properties of stellar spectra. I needed to be an expert in classifying stars so I immersed myself into the world of astrophysics.

Computer programming was another skill I needed to learn fast for my research project. I started out learning Java with the computer teacher at school just to get the basics. Then I soon had to learn to program languages such as Python and Iraf to do much of my actual research. What I loved about my research project was the fact that there were so many different aspects of it; from looking at the actual spectra and classifying stars to writing code to plot the stars.

Because of this I was able to learn so much about various research techniques. Most students in high school don't see the applications that math and science have in the real world. I think participating in a research project makes kids realize that mathematics and physics is the foundation for much of what goes on in the world we live in. I know I have seen the beauty of numbers and equations in my own research.

My advice to students who wish to pursue a science and math related project is this: in order to have the best possible experience you truly have to love what you are doing. Many students start a research project for all the wrong reasons. They think it will look great on a resume for college and will set them one step ahead everybody else. While this is all very true, if this is your only motivation for starting a research project I wouldn't recommend starting one. I know research projects, especially the really great projects, take a lot of time to complete. I know I spent over a hundred hours just looking at the over 12,000 spectra I had to analyze. In order to be successful you need to be passionate about your research. With that said if you are unsure about your feelings and are curious about science and math I encourage you begin a research project. I encourage you to get out there on the internet and read articles about topics that intrigue you. Ask questions and never give up looking for an answer. If you work hard and always try your best I guarantee there will be results.

The research I do with Professor Newberg involves classifying blue stars in the Sloan Digital Sky Survey (SDSS). Stars are classed based on their temperate and luminosity, with blue stars being of the very hot and luminous variety. They are unique to study because of their rarity. Blue stars burn their fuel faster compared to other cooler stars, therefore they die faster. An accurate classification of stars, specifically rare blue stars, is important when astronomers want to gain information about stellar populations and describe the structure of our galaxy.

The SDSS provides publically accessible data of objects in one-fourth of the entire sky. The SDSS has been a part of numerous discoveries, including the discovery of the most distant quasars and of various substructures in the outer Milky Way. Visually, errors within the computer generated spectral template classification system have been noticed. It's important to minimize these errors so future research can become more accurate.

My research involved looking by eye through the spectra of over 12,000 blue stars. I found that 10% of these stars were misclassified by the SDSS. I then placed these misclassified stars into eleven new classes. Some of these classes include binary stars, featureless stars, cataclysmic variable stars, DB white dwarfs, and unknown blue stars. I found that the spectral classification problems within the SDSS can be accounted for the lack of templates for stellar objects. There are 42 templates with only 8 templates for hot blue stars. I suggest that additional templates be added into the SDSS to account for rarer types of blue stars.

Much of the research done with SDSS is on extragalactic objects, such as galaxies and quasars. But as research on stellar spectra from the SDSS data becomes more common, errors with the classification should be minimized. The work I've done will hopefully draw attention to the classification problems and create accurate data results in the future so astronomers can learn about the structure of our galaxy and universe as a whole.

Working with Professor Newberg on this project has been an incredible experience. Being a part of this research and being able to collaborate with professional scientists has been life changing. Scientific research has given me the ability to learn beyond the confines of a classroom. I have had the opportunity to ask questions and find my own answers. I look forward to a long and prosperous future in research, and I hope I can inspire other young students

interested in math and science to follow in my footsteps. Good luck to all of you high school students, teachers, parents etc., it's never too late to achieve your dream. Keep reaching for the stars!