During my undergraduate experience, I have participated in 4 research projects that are applicable to my graduate studies. The first was a course centered around completing a research project. The second, and is currently ongoing, is for the Lab for Atmospheric and Space Physics working with Professor Mark Rast applying machine learning to problems in helioseismology. The third was my successfully completed REU project. The fourth was a graduate course project modeling ice plumes on the surface of Europa.

In the spring of 2020, I worked on a project for a research methods course that involved characterizing the profile of occulting Trans-Neptunian Objects (TNOs). Research and Education Collaborative Occultation Network (RECON) is an organization that has trained and set up dozens of telescopes spanning from Canada to Mexico in an attempt to observe occulting TNOs. The occultation observations (or lack thereof) are important in characterizing the shapes of TNOs, and this was the main objective of this research project; I was part of a team characterizing the shape of a specific TNO. Using tools in Python and IDL, we looked at light curves of a target star that the TNO was to occult, and measure the length of time of the occultation (or no occultation). In Python, I built a normalization algorithm that took an input of a series of images, focused on a single star, then output a light curve for the images. RECON uses a similar IDL algorithm that we compared our built algorithms with, and in the end, we found the telescope sites that observed the occultation, and for how long the TNO occulted the star. These chords we obtained helped us characterize the shape of the object; however, the COVID-19 outbreak split the team up before we could publish the paper. While the specific project is still on hold, we expect to publish the shape of the TNO when RECON is able to return to the object.

At the University of Colorado at Boulder, I am currently working on an honors thesis project using machine learning to create synthetic images of the solar surface, and use these to train a neural network to perform a Fourier filter on a single image. The Fourier filter uses a time series of images to separate solar granulation from resonant spherical harmonics oscillating on the solar surface, but applying machine learning could allow us to perform the Fourier Filter without the need for an observationally expensive time-series.

Professor Mark Rast at the Lab for Atmospheric and Space Physics (LASP) came to me with a project he wanted to investigate, regarding the ability of neural networks to separate acoustic oscillations from solar surface granulation in images of the sun. Prof. Rast has had little to no experience with machine learning, so this project was essentially not developed, meaning I had the liberty to define the project on my own. I also had no machine learning experience at the time, so we contacted a graduate student in Prof. Rast's research group to point me in the correct direction for beginning the project. Upon consulting, we defined the scope of the project to involve using a neural network to separate acoustic modes, which has not come without obstacles. The data set we are looking at to apply the Fourier filter to has a limited number of images (about 100), which is not nearly enough to train a machine to perform the filter. We required a much larger set of images, prompting the use for machine learning again. Actually Fourier filtering the time series provided a set of granulation images and images of acoustic modes. The acoustic modes are defined by a relative phase shift in time according to their lifetimes, meaning we could shuffle up the acoustic mode phases and we could obtain many novel images of acoustic modes. If we could build granulation images, we could then combine them with acoustic modes and generate synthetic images of the sun to train a machine to separate. This is exactly what I am currently doing, and am using a variational autoencoder (VAE) with the current set of images to generate a possible parameter space that would assist in generating novel granulation images. I will also be applying a convolutional generative adversarial network (CGAN) to compare the performance of the VAE with the CGAN in generating novel granulation. After creating synthetic solar images, we will apply a filtering neural network that will separate the granulation from the acoustic modes. Finally, we will apply this network to the original images and analyze the performance of the neural network. This work will end up potentially publishable, and will be presented as an honors thesis in the spring.

The machine learning project led me to apply to REU programs related to simulations, and I completed my 2021 (delayed from 2020 due to COVID-19) REU at Montana State University simulating solar flares and loop-top ridge heating post-flare.

My REU experience at Montana State University helped mature my interest in modeling and gave me tangible experience – the results of which were presented in December at the annual **AGU conference.** There have been questions about the bright loop-top plasma ridge structures during solar flares, and my work at Montana State involved running simulations to test if compressive magnetosonic shocks could reproduce the observed structure, densities, and magnetic field retraction velocities. Professor Dana Longcope has spent significant time building IDL code called Post-Reconnection Evolution of a Flux Tube (PREFT), which uses the governing magnetohydrodynamic equations to model the heating caused by a retracting flux tube through plasma. Previous studies of magnetic reconnection have issues with reproducing retraction velocities consistent with observed downward moving features, which was the central motivation behind this project. I proposed introducing aerodynamic drag of the radially moving plasma to the governing MHD equation as a solution to the high retraction speeds of previous simulations. To test this, we compared simulations of the MHD equations to observed feature downflow speeds. While aerodynamic drag slowed retraction speeds within an order of magnitude to the observed downflows, the introduction of drag decreased the plasma loop-top density, which became inconsistent with observation. Though the 10-week program did not prove to be enough time to tackle any further inconsistencies, we suggest that the way PREFT handles magnetic pressure balance may not be accurate and would influence the simulated densities. Furthermore, a time-dependent drag could enhance densities while slowing retraction, but the physical interpretation of this is unreliable. This provides possible future work in understanding magnetic reconnection as a method of understanding loop-top flare properties. The results of this project were presented by Professor Longcope as a larger project at AGU and myself as a presentation of my own work at AGU. The work will contribute to a published paper (in draft) in the coming months that I will be an author on.

Finally, as part of the graduate course on planetary surfaces I took at CU Boulder, we were tasked with designing and our own project regarding some topic in planetary surfaces or interiors. Due to my interest in modeling, I conceived of a project that involved modeling the detectability of plume deposits on Europa to the thermal imager aboard the upcoming Europa Clipper mission, E-THEMIS. For E-THEMIS to detect a deposit, we require plumes to build a thermal skin-depth (approx. 10 cm) high deposit of very fine-grain material before sintering makes material indistinguishable from the background, fine-grain surface. This process occurs on the scale of multiple decades. Furthermore, the resolution of E-THEMIS is on the scale of tens of meters, so the deposit must be larger than a safe estimate of 100 meters to detect. After developing probability functions involving the particle velocity distributions upon exiting plume vents, as well as the particle size distributions, I determined that a constantly erupting plume would be able to deposit enough material in time before sintering would make the deposit undetectable. The particle size distribution is highly impactful for the timescale in which plumes deposits are created, and is thus one of the constraining factors. A sharp log-normal distribution and a wider Weibull distribution were both used to simulate particle sizes. With more rigorous modeling techniques and investigating particle size distributions further, this project could end up publishable in the spring.

These projects have developed my skills in modeling and statistics, preparing me for graduate study and research. LSU is an ideal place for me to continue my studies due to the variety of projects that faculty are researching, like Dr. Boyajian's work and Dr. Penny's work. My hope is to further my understanding of statistics in an astrophysical context, better my skills in machine learning, and take part in modeling projects to begin my career in the field.

Thank you for taking the time to read this research statement. I look forward to hearing back from LSU and exploring the cosmos!