Capstone Research:
The Black Hole Information Paradox
By Austin Karwowski

The black hole information paradox is a fascinating topic because it provides an example of the types of contradictions that arise in physics, creating a need for a theory of quantum gravity. This topic is called a paradox because it is a contradiction between two fundamental theories in physics: general relativity and quantum mechanics. These two theories disagree when it comes to information and whether or not it is conserved in black holes. By analyzing Quantum Field Theory in curved spacetime, the information that makes up a black hole is lost through Hawking radiation. Quantum mechanics, however, has a fundamental axiom that states information is always conserved. It is this contradiction where the black hole information paradox is created.

This project has been a tremendous journey and I feel honored to be able to research something so modern and new. In pursuing this project I was able to learn general relativity, which was really interesting because I have only studied a little bit of special relativity. Since I was young, black holes have always fascinated me, so being able to take a deeper dive into general relativity has been incredible. This project has ignited a fire within me to continue past an undergraduate degree and work my way all the way to a Ph.D. After I graduate, I will attend San Jose State University for my master's in physics and then continue to get my Ph.D. in theoretical physics.

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THE PHYSICS MAJOR
Department of Physics and Astronomy
SONOMA STATE UNIVERSITY

New Degree in Physical Science
By Prof. Alexandra Miller

The Department of Physics & Astronomy has an exciting new degree offering: a Bachelor of Arts in Physical Science. This is an interdisciplinary STEM degree with a strong Liberal Arts basis that allows students to follow their individual interests via intentional pathways. Students in the major will be required to choose one of the following: a concentration in Teaching, a concentration in Foundational Health, or have no listed concentration. The concentration in Teaching will satisfy the requirements for a Foundational Science CSET waiver, which is required for those who are hoping to become K-9 science teachers. The Foundational Health concentration is intended for students with a broad interest in science, but want an emphasis in Health. This concentration can only be declared by students who have already completed BIOL 115 or 110, BIOL 220, and BIOL 224. Finally, the Physical Science degree with no listed concentration is an incredibly flexible STEM degree, allowing students to take a wide variety of courses in different fields that will help them meet their individual goals. Interested students are encouraged to reach out to Dr. Alexandra Miller (*millerale@sonoma.edu*) with general questions about the degree or to the Physics & Astronomy Department Administrative Coordinator to declare, Marissa Reichenberg (*padept@sonoma.edu*).

Four SSU Juniors are awarded Cal-Bridge Scholarship
By Prof. Alexandra Miller

www.cpp.edu/calbridge

Cal-Bridge is a bridge program supported by the National Science Foundation to connect undergraduate California State University (CSU) students with Ph.D. programs within the University of California (UC) system and other partner institutions. The mission of the program is to advance undergraduate physics and astronomy research and education among traditionally underrepresented groups and to increase the number who earn doctorates in those, and related, fields.

Students who are awarded the Cal-Bridge scholarship participate in the program for the final two years of their undergraduate studies. They are required to have bi-weekly meetings with a local SSU mentor and a UC mentor, attend a variety of workshops on topics ranging from how to write your graduate school application to imposter syndrome, and ultimately apply to Ph.D. programs in Physics, Astronomy, or related fields.

Pedro Jesus Quiñonez

Katie Toman

Juan Garcia Vega

Andrew Evans

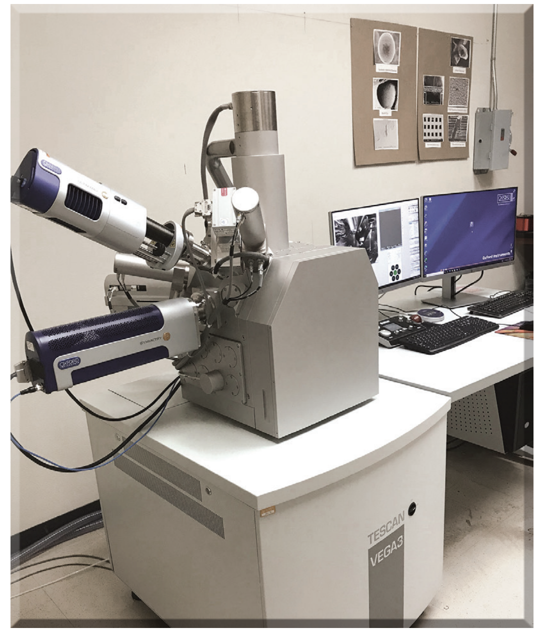
Sonoma State's very first Cal-Bridge Scholar, Alex Vasquez, graduated in Spring 2021 and is now attending UC Irvine for his Ph.D. Our second scholar, Natalie Sanborn, is currently in her final year at SSU and has been admitted to UC Irvine's Physics Ph.D. program with a concentration in Astronomy and Astrophysics. We are excited to announce that SSU's newest cohort of scholars is our biggest yet! Last Fall, four SSU students entered the program: Andrew Evans, Juan Garcia Vega, Pedro Jesus Quiñonez, and Katie Toman.

The department is very excited to see what the future holds for these bright young scholars!

Brand New Scanning Electron Microscope in the Keck Microanalysis Laboratory

By Prof. Hongtao Shi

A scanning electron microscope (SEM) uses an extremely small and well-focused electron beam to generate a variety of signals, resulting from the strong interactions between the electron beam and the sample surface. These signals can reveal information such as the sample morphology, chemical composition, crystalline structure and orientation of materials making up the sample. A modern SEM is also capable of producing high-resolution digital cathodoluminescent (CL) images of luminescent materials. Thanks to the interdisciplinary cooperation and collaboration among Geology, Chemistry and Physics and Astronomy faculty at Sonoma State, a grant proposal was funded in 2020 by the National Science Foundation (NSF), which allowed us to purchase and install a brand new SEM last summer in the Keck Microanalysis Laboratory. As director of the Lab, I am very excited to see students already taking advantage of this 21st century technology to get their education going at SSU. This new microscope will also continue to strengthen collaboration between SSU and local high tech industry.



Capstone Research:
Particle Detector Safeguard for a Solar CubeSat

By Alexander Vasquez

In a collaboration between Sonoma State University, Howard University, and The University of New Hampshire, 3U³ intends to construct a 3U³ Cube Satellite for observing behavior in the Earth's atmosphere. As part of my senior capstone project, I was able to create a sensor capable of detecting high-energy particles that integrates with the onboard computer. This particle detector is essential for the health and safety of the satellite, due to the large amount of highly charged particles in the Southern Atlantic Anomaly.

The Sun produces a steady stream of solar wind, an outflow of high-energy, ionized particles radiating out into the solar system. As these particles approach the Earth, they reach its magnetic field and begin to travel along its magnetic field lines. They then are either deflected around the earth and sent further out into the solar system, or spend some time between the multiple bands of the magnetic field.

Symmetrical about the Earth's magnetic axis are the Van Allen radiation belts, regions representing where the magnetic field around the Earth facing the Sun are weakest. The Earth's magnetic axis is offset from the center of the Earth, resulting in one of the Van Allen belts ending 120 miles above the Atlantic Ocean, a phenomenon named the South Atlantic Anomaly.

Another phenomenon we wish to observe is the cusp, the region between where the bands of the magnetosphere split or meet. This split is where electrons and ions running down the bands of the Earth's magnetic field eventually meet, resulting in an aurora event in the ionosphere, about 60 miles up. Other atmospheric phenomena may be observed as well, such as why the cusp exists in both day and night time, and the electron temperature in the cusp as solar winds heat particles in the gas.

In order to detect high-energy particles in the Van Allen belts, and within the cusp and the South Atlantic Anomaly, I have constructed a particle detection board which will warn the satellite of particles which may harm other instruments on the satellite. The board works by the use of the SI PIN Photodiode Sensor, capable of detecting thermal electrons and short wavelength waves.

Testing is still underway to detect a cosmic ray using our setup. We have confirmed using the test circuit, as well as manual testing of each component of the circuit, that we should be able to detect a cosmic ray when the time comes. Future projects include high-altitude flat-sat testing in a balloon, as well as integration with OBC for 3U³, since this is part of the health and safety system as designed by SSU.

Thank You for Your Support!

We thank our ongoing student research assistantships contributors.

Research is thriving within the Department, and funded research experiences have provided our students with incredible opportunities. Other scholarship funds also support and provide students with opportunities they would not have if not for the generosity of donors.

Our public programs remain vital, including the "What Physicists Do" lecture series and the Public Viewing Nights at the SSU Observatory. These are partially supported through donations and grants from SSU's Instructional Related Activities Fund. WPD remains the longest-lived public lecture series on campus. To subscribe to the Public Email List, contact the Department at PAdept@sonoma.edu. If you would like to support our program and students, please see:

phys-astro.sonoma.edu/giving

or contact the SSU Development Office at

(707) 664-2712 or contact the Department at (707) 664-2119 or *PAdept@sonoma.edu*.

Current Funds:

#C0141 Public Programs
Robert A. Fisher

#C0142 Physics & Astronomy Equipment and Supplies
Charles A. Bullen ('75) & JoAnne Etheridge, Jon Seidel and Carol Haskell, David K. Hawk ('77)

#C0144 Student Development Program
Dr. Bryant P. and Diane Hichwa, Lauren Novatne ('89)

Endowment Funds:

#E0185 Charles and Norma McKinney Fund
The Charles and Norma McKinney fund supports public programs.

#E0208 Horace L. Newkirk Memorial Student Assistantship
Established by Nadenia Newkirk in memory of her father to support student research.

#E0231 Duncan E. Poland Physics & Astronomy Scholarship
Lynn Cominsky and Garrett Jernigan, Paul Shaffer

#E0269 Science at Work Fund
Established by John Max to support What Physicists Do.

#E0304 Sol and Edith Tenn Scholarship
Established by Joe Tenn to honor his parents.

#E0305 Joseph S. Tenn Scholarship
Dr. Richard De Freez ('80) and Ms. Toni Kristensen

Whatever happened to …?

Joseph S. Tenn, Professor Emeritus

In June it will be 13 years since I retired from SSU, where I was a member of the Physics & Astronomy faculty from 1970 to 2009. When Dr. Shi asked me to write something for The Physics Major, my first thought was that no reader would be interested. Then I remembered that I founded this newsletter in 1974 to communicate with the Department's graduates as well as current and prospective students. While there were only 22 graduates when I prepared the first newsletter, there are more than 500 now. Perhaps some of the older grads will remember me and wonder what I have been doing lately.

Starting when I was half-retired, I served eight years each as an associate editor of the *Journal of Astronomical History and Heritage* and as secretary-treasurer of the Historical Astronomy Division of the American Astronomical Society. Since 2013, my main academic pursuit has been the development of the Astronomy Genealogy Project (AstroGen), which I founded and continue to direct. Academic genealogy is a lot like ordinary genealogy, except that your thesis advisor is your academic "parent". With a small group of volunteers (including Ken Ritley, '88), I am attempting to compile a database of the world's Ph.D. astronomers. If you go to https://astrogen.aas.org, you will see that we provide much information about each astronomer, as well as his or her doctoral thesis (dissertation), academic advisor(s), and the institution that awarded the degree. We include links to all of these when possible.

There are currently close to 40,000 people listed in AstroGen, each having earned an astronomy-related doctorate* or supervised one. We provide the title of the doctoral thesis for more than 33,000, and links to the full thesis for some 2/3 of these. Brazil just became the 33rd country that we claim is "nearly complete", going back to the first award of the modern research-based Ph.D. in the late 18th century. You might be surprised to learn that half the doctorates in AstroGen have been awarded since 2003.

This year the American Astronomical Society meeting scheduled for January was canceled on short notice because of a covid surge. Most of the sessions planned, including those of the Historical Astronomy Division, will be held at the June meeting, which is usually much smaller. This year's June meeting will be in Pasadena, where I will present a talk titled "Astronomy's Lingua Franca". I will discuss the evolution of the language used in astronomical theses from Latin before about 1870 to the language of the country for much of the 20th century to nearly all English now in a number of countries. The majority of dissertations have been in English for many years in Sweden, the Netherlands, Finland, Denmark, Israel, Switzerland, Austria, and Germany. Since 2010, Spain Chile, and Greece have joined them. I am also coauthor of an iPoster to be presented by the chief archive specialist of the Chandra X-ray Center. She will describe how observatory archivists use AstroGen to compile lists of theses based on data from their telescopes.

**This includes eight SSU physics graduates: Lance Erickson ('80), David Lamb ('94), Ben Owen ('93), Ryan Quitzow-James ('05), Katherine Rhode ('89), Mallory Roberts ('94), Stephanie Snedden ('83), and Tyana Stiegler ('03).*

Cal-Bridge Scholar Admitted to Ph.D. Program at UC Irvine

By Natalie Sanborn

Beginning in Fall 2020, I had the pleasure of becoming a Cal-Bridge Scholar. Cal-Bridge is a program funded by the National Science Foundation designed to create opportunities for traditionally underrepresented groups and increase their numbers in Ph.D. programs in fields such as physics and astronomy. Being a Cal-Bridge scholar means I am provided with financial support, mentoring from both CSU and UC faculty, professional development workshops, and exposure to research opportunities.

Cal-Bridge has given me a greater sense of direction as a physics major and the opportunities I have for the future. With the encouragement and support of my Cal-Bridge mentors and the program as a whole, I participated in a summer research internship last year and I applied to graduate school last fall—two things I may not have even considered before becoming a Cal-Bridge scholar. My summer REU was part of CAMPARE, Cal-Bridge's summer research program. I worked with Dr. Jonathan Pober at Brown University on the Hydrogen Epoch of Reionization Array (HERA) project. This semester, I was accepted to UC Irvine's Ph.D. program in Astronomy! I will be starting there in the coming fall semester. In addition to these opportunities, Cal-Bridge has allowed me to connect and make friends with Physics and Astronomy students at other CSU schools, many of whom will also be attending Ph.D. programs. These connections provide me with a sense of community and a cohort of other students to talk with about our challenges and successes as physics students. I am thankful for the opportunities and community provided to me through Cal-Bridge.

Capstone Research: Simulating Data for James Webb Space Telescope

By Natalie Sanborn

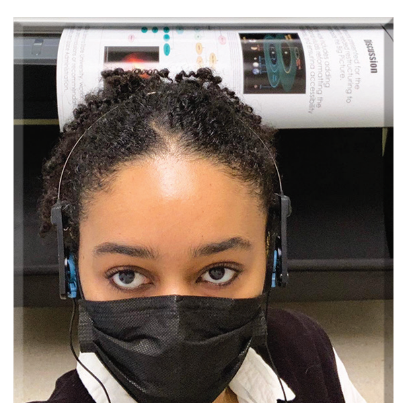
For my capstone research in the Spring of 2022, I worked with Dr. Thomas Targett on using simulations to prepare for the analysis of data from the James Webb Space Telescope (JWST). JWST is a successor to the Hubble Space Telescope (HST). HST allowed researchers to observe the universe with optical light to a redshift of z ~ 7-8, viewing as far as 13.4 billion light-years away. JWST will use infrared light for observations at higher redshifts of z ~ 9-10. The data from HST was extrapolated to create luminosity functions that predict the universe at redshift z ~ 9-10, and this extrapolation was used to create the JADES mock catalog. In my project, I analyzed simulated images created from the JADES catalog and compared them to the raw catalog data. This can ensure that the simulated images are created properly and will assist in the analysis of real data from JWST in Summer 2022. Throughout working on this research, I have continued to strengthen my skills in using Python for data analysis and have learned more about the James Webb telescope. I am excited to hear about the work done with data from JWST in the coming years. The opportunity to collaborate with Dr. Targett on an exciting new project has been a great way to round out my undergraduate experience before moving on to graduate school. In the fall, I will be attending the University of California, Irvine in their Physics Ph.D. program with a concentration in Astronomy and Astrophysics. I look forward to continuing my education with a Ph.D. program and whatever the future holds for me after graduation.

Capstone Research: Accessibility in STEM

By Zoie Bean

NASA's Neurodiversity Network (N3) is a program led by Dr. Lynn Cominsky, Director of SSU' EdEon STEM learning. N3 covers making high school STEM classes accessible to a neurodiverse audience with autistic students, which will shed light on how to make classes more accessible in general. More specifically I have conceptualized various dense topics taken from a sample set of lectures, and created a digestible concept map that ties big ideas together. I have also created other tangible resources for students to follow along with during each of these lectures.

The central question for sustaining interest is: Are we alone in the Universe? Through an exploration of exoplanets and using technology to collect astronomical data, the students will be better equipped to understand the complexities behind looking for life elsewhere in the Universe.



Ultimately, working together with Dr. Cominsky on making STEM more accessible to autistic students has helped me understand some of my own needs as an autistic student, and as an autistic individual. After graduation I will work to discover what truly makes me happy, while being able to give back to underrepresented communities and the broader environment. After all, in studying the Universe we learn the complexities of ourselves, and of our planet's own fragility.

Science by Diverse Scientists

By Prof. Alexandra Miller

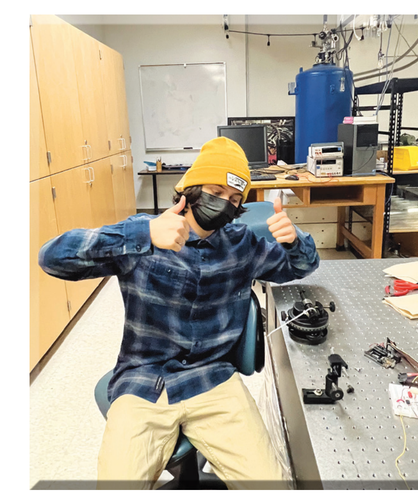
On Wednesday, June 10th, 2020, the STEM community came together to Strike for Black Lives (see, for instance, *Particles for Justice* and *Shut Down STEM*). The strike was not intended to be simply a day-off for non-Black scientists, but instead a day to put aside research, teaching, and committee responsibilities in order to take the time to work toward building a better society for everyone. The Cal-Bridge Program hosted a virtual event to bring together affiliated faculty and scholars to reflect on what we could do as a community to combat anti-black racism in academia and then commit to doing something about it. One result of this event was a new seminar series: *"Science by Diverse Scientists: A Cal-Bridge Physics & Astronomy Seminar Series".*

These talks aim to highlight the scientific contributions of minoritized members of the physics and astronomy community, showcase future career paths for undergraduate students, and discuss anti-racism and the experiences of scientists of color. The discussions are aimed at undergraduate physics and astronomy majors, but are often also of interest to students and faculty in other STEM departments. The speakers in the series showcase the large variety of careers achievable to those with degrees in physics, astronomy, and related fields. Many of the speakers spend time discussing their own personal paths through physics and astronomy as minoritized scientists and share advice that would benefit most students in general, but especially those from underrepresented groups. Speakers have included faculty from California and beyond, as well as postdocs and Cal-Bridge alumni in Ph.D. programs.

The talks are posted on the *Cal-Bridge YouTube channel* for anyone interested. While the series was founded as part of the Cal-Bridge program, everyone is welcome. The founding committee members organizing this series include Dr. Alexandra Miller of Sonoma State, Dr. David Strubbe of UC Merced, Dr. Sara Callori of CSU San Bernardino, Dr. Carol Hood of CSU San Bernardino, and Dr. Aaron Romanowsky of San José State.

Capstone Research: Studying Aerosols in the Air

By Angel Corletto



The capstone project I was working on this semester was something I didn't expect to end up doing in my last year of college. I have been working using Dynamic Light Scattering (DLS) in order to see what aerosols are in the air that we breathe. This is used in order to see if the air in certain places is harmful to inhale. DLS tells us what the particle size is and its distribution. In order to find the particle size distribution the scattering of light and the intensity correlation function are used. Humans are susceptible to particles that are smaller than 2.5 microns. I have been working on a mobile DLS with already accessible particles that were in the lab. The mobile set up which is made up of a power source, resistors, capacitors, a photodiode, and a preamplifier will have the following: a raspberry pi, a circuit board that was built with help from Dr. Koh, and the DLS. The mobile set up is a cart that has all the stated components on top and can be installed anywhere so long as a power source is near.

This project has prepared me for a world I wasn't expecting to enjoy. It was rewarding to learn how to put a circuit board together and some minor programming in the sense of how to connect the DLS to the Raspberry Pi in order to read what's in the air. Was this project easy, the short answer is not even close to it. Not knowing how to use any programming language and having never really seen an unbuilt circuit board before really showed me there is a lot I needed to learn before even attempting to have the full set up built. Through the struggles I found success and confidence in myself which has allowed me to be able to now know something I want to do and that's go into industry right after college to gain experience and then to eventually go to grad school because Dr. and Corletto are two things that have never been said in that order. No idea where my future will actually be but I'm excited to use what I learned here in the real world.

Capstone Research & Hichwa / McQuillen Award:
Modeling supernova as a fireball
By Jacob Marshall

For my Capstone I developed a method of interacting with the Open Supernova Catalog in order to collect data and derive properties of supernovae. My sample included Type Ia and Type II supernovae. I modeled the supernova as an optically thick fireball, allowing me to use photometry from the catalog to approximate the surface temperature, radius, luminosity, and expansion velocity of the explosion. These approximations are plotted and their maximum values are placed in a histogram to highlight similarities and differences across these two different types of supernovae.

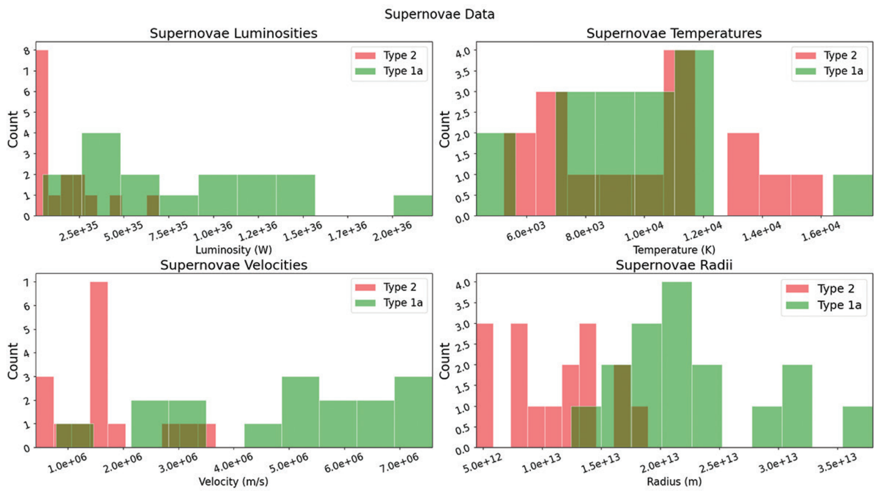


Fig.1

This scholarship allowed me to pursue my desire to further develop the work I did on my Capstone project. I learned a lot about coding in Python including data processing and visualization. Over the course of the summer I was able to fully automate my program in order to pull massive amounts of data from the Open Supernova Catalog. This allowed me to increase the size of my sample tenfold, including Types II P and IIb, leading to more meaningful results (fig. below) This scholarship also led to the creation of a draft paper based on this research, to be submitted to SPS upon completion .

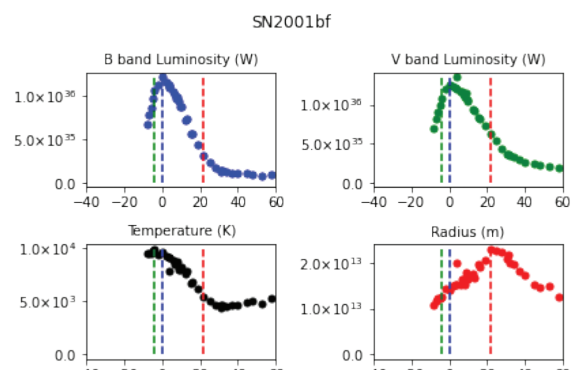


Fig.2

Fig.1 shows the rise in B band and V band luminosities as well as the modeled temperature and radius of a Supernova explosion.

Fig.2: the x axis measured in days, with the units of the y axis next to the subplot titles. The vertical grid lines represent the phases we discovered by analyzing all plots in our sample. These phases indicate key points over the course of the event. The first grid line occurs at maximum temperature, and marks the beginning of the fireball's cooling while it continues to grow and get brighter. The second grid line marks the time of peak luminosity. After this line we see the fireball dimming and cooling until the third grid line, marking the time of maximum measured fireball radius. This phase signifies the onset of the fireball becoming partially transparent.

Capstone Research:
Exoplanets: Transit Method and Characteristics
By Kathryn Allen

My project was about finding exoplanets by using the transit method and deriving its characteristics. The transit method is one of the methods used to find exoplanets. This method measures the brightness of the star over time, creating a light curve. When an exoplanet crosses in front of its star, the star's brightness will lower. The transit method does not work for all star systems, and is dependent on the inclination. This method cannot determine mass, other methods are needed to determine the mass and other characteristics. I used data gathered from the Doppler method, which measured the effect of the exoplanet's gravity on its star's motion.

I developed a technique for measuring light curves, and I used my analysis from the light curve and physics to determine characteristics of exoplanets. I was able to determine the exoplanet's radius, volume, mass, density, orbital period and orbital radius. I was also able to conclude what type of planet these exoplanets were, most were gas giants with one planet that could be terrestrial due to its density and size. I was able to produce similar values to the currently published ones.

I am planning on applying to graduate school in the fall. There are a few schools that I like within California, Arizona, and New Mexico. I plan on continuing studying exoplanets. I am also looking into jobs within the Bay Area.

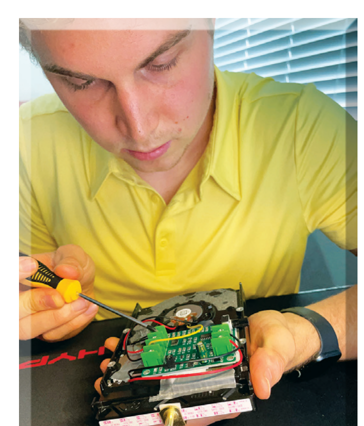
Capstone Research:
Coupled Oscillators and Waves: Creating a Way to Present Complicated Interactions Easily
By Jordan Braun

The world around us is filled with interactions that can be described with physics. These phenomena range from light rays to pendulums or even springs. While some of these situations may seem simple, they can be incredibly complex to model mathematically, especially in larger systems. As such, physicists model them as oscillators and waves in order to simplify them. However, the math for the systems is often still too complicated for most people to understand. Because of this, I aimed to find a way to better present the topic to the masses. In order to do so, I worked to model systems in a few different ways. First, I worked with my professors to solve the equations for systems of varying degrees of difficulty and then simulate them to get solutions using Mathematica. Finally, I used CAD software to design and then 3d print a physical model that used pendulums to represent the oscillators.

In completing the project I did learn a few things that I likely would not have in other courses. I learned how to use modeling software and work within the restrictions of a 3d printer to make sure that parts would be made accurately and in a timely manner. Second, I learned more about mathematical programming and how best to get the results that I wanted. Finally, I learned how to better present advanced physics concepts to the general public so that my work could be understood by not only classmates and professors, but parents and family members as well. With my work as an undergraduate completed, I am staying in Rohnert Park and looking to use my physics knowledge in a science career, which has currently led me to work in the wine industry doing analytical work.

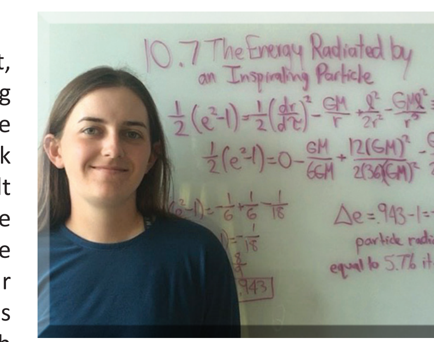
Capstone Research:
Physics of Gyroscopes and Their Applications
By Jacob Watkins

My project involves the physics of gyroscopes and their engineering applications. I had to explore physics concepts such as angular momentum, torque, force and inertia. A powered gyroscope was constructed using a hard disk drive motor, platters and a lithium battery pack. This project allowed me to gain experience in both mechanical and electrical engineering. I had to disassemble several hard disk drives to find the appropriate motor as well as to combine their platters for increased mass. I had to research and find the appropriate motor control and a battery pack to power the system.



After graduation I plan to move back to San Diego and join the work force as an engineer. I've always enjoyed creating things and I feel the physical side of physics is much more suited for me than the theoretical side.

Capstone Research:
General Relativity: Deriving the Kerr Metric for Black Holes
By Lindsey Batterton



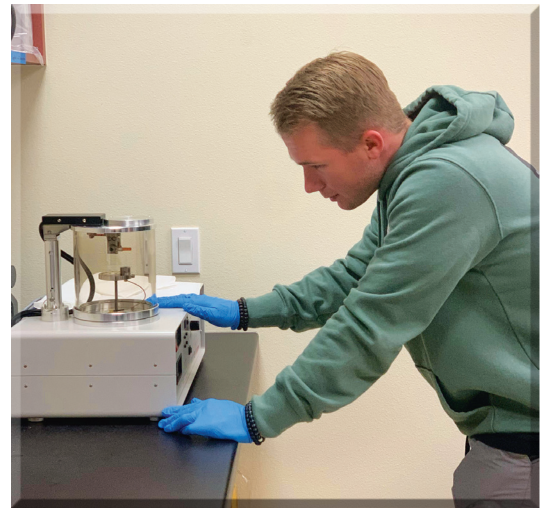
For my Capstone project, I have been researching general relativity and the physics of black holes. Black holes have been difficult to view in space because they require a telescope with a very large angular resolution. Only particles in the accretion disk with the correct trajectory and distance from the center of it are able to escape its gravitational pull to be seen from Earth. The Event Horizon Telescope was created to view black holes, and published the first image ever created of a black hole fairly recently, in 2019. With guidance from Dr. Alexandra Miller, my goal was to use what I have learned about general relativity to explain the different parts of the image and to understand what influences a black hole's appearance. I have also created a labeled diagram of the image to highlight the different regions that can be seen. Using equations from general relativity I have been able to derive the Kerr metric and calculate the trajectories of particles that orbit outside of the Schwarzchild radius.

It has been exciting learning all about the structure and behavior of black holes. Working on this Capstone project has also helped me learn more about general relativity and the skills needed to conduct a research project, which I hope to use when joining the workforce after graduation.

Capstone Research: An Analysis of Carbon Deposition

By Jack Dobar

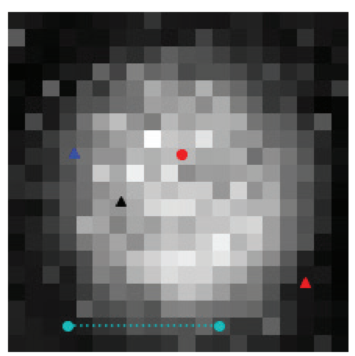
Carbon deposition is an important process to look at the morphology of materials that have little electrical conductivity. This process works by depositing a thin conductive carbon layer on top of otherwise insulating materials. This prevents a phenomena called the charging effect, which makes observing these materials nearly impossible. By providing a conduit for incoming electrons to flow, this carbon coating allows the sample material to be observed with clarity using a scanning electron microscope (SEM). This project, under the guidance of Dr. Hongtao Shi, used a new Cressington Carbon Coater in the Keck Microanalysis Laboratory in order to coat multiple sample materials with various thicknesses of carbon. We then scanned materials using an SEM to evaluate charging effects and to examine surface features.



This project exposed me to interesting scientific instruments and processes. I was able to learn about optical deposition, vacuum science, and the SEM. Most importantly, however, I was able to practice management of project outlines, deadlines, and tasks. I was also able to practice my communication of scientific concepts. I feel like these skills will translate to my future career. After graduation, I plan to start working in the Bay Area. Ideally, I'd like to work for a company that has a positive impact towards people, animals, or the environment. I hope that this kind of opportunity can act as a launchpad as I pursue leadership and management in either technology or sustainability

Capstone Research: Mapping Io with Cross Correlation

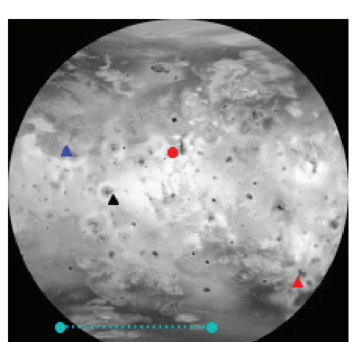
By Elizabeth Marshall



Io, the innermost of Jupiter's Galilean moons, has more volcanoes per square kilometer than anywhere else in the solar system. This volcanism was first confirmed with the Voyager missions, as scientists noticed differences in surface features between Voyager 1 and 2. However, Io is difficult to observe without the use of probe missions, making the use of cross correlation to determine the observed face of Io an important tool in studying the solar system's most volcanic object. Cross correlation is a mathematical method of finding where two functions or images best fit. I worked under Dr. Scott Severson on cross correlating an image of Io taken at the Table Mountain Observatory by Stephanie Church with a composite of Voyager images taken from "Geologic Map of Io" by Crown et al. (1992). I found that the result of the cross correlation agreed with the hemisphere based on ephemeris (the location of Io at the time the image was taken). This finding indicated that the variations in the brightness of the pixels in the image were due to surface features rather than noise, meaning that in the future, we can potentially use this method to observe changes in Io's surface due to volcanic activity from an Earth-based telescope. The cross-correlation peak was highest when Church's image was rotated 51 degrees counterclockwise, indicating that the image was taken at an angle.

The adaptive optics images of Io from the Table Mountain Observatory were taken in a 2016 capstone by Stephanie Church. Though I don't believe I've ever met Church, it's been an honor to be able to continue their work. This project has so much room to be continued, and I hope that some student in the future will find it as fascinating as I did and pick up where I left off. I feel this project has really driven home how collaborative the field of STEM is — we are all in the place that we are now thanks to the advancements of those who came before us.

Working with astronomical images has solidified some of the concepts from Astronomical Imaging, and working in Python and Astropy has made me much more confident in the language. I hope to use these skills in the workforce until the COVID 19 pandemic allows more flexibility. I want to be able to support myself financially when the time comes for grad school and gain a better idea of what field of astrophysics I'd like to focus on. My current long-term goal is to get a Ph.D. and/or study or work abroad.



Students in the SSU Theoretical Physics Group Earn Koret Scholarship

By Dr. Alexandra Miller

Lindsey Batterton, Andrew Evans, Austin Karwowski, and Pedro Jesus Quiñonez have been awarded a Koret Scholarship in order to help them complete research projects in General Relativity and Quantum Field Theory with Dr. Alexandra Miller. Lindsey is analyzing Kerr spacetimes, which describe rotating black holes. This will help her to better understand the very first image of a Black Hole, which was taken by the Event Horizon Telescope collaboration in 2019. Andrew is studying Quantum Field Theory so that he may compute the probability for different particle scatterings, such as those seen at the Large Hadron Collider, to occur. Austin is investigating the Black Hole Information Paradox, which is an open problem driving progress in the field of Quantum Gravity. Pedro Jesus is writing a program that will help to streamline lengthy calculations in General Relativity. All four students will be presenting their results at the SSU Science Symposium this April.

The Decay of Higgs-Like Particles

By Andrew M. Evans

Quantum mechanics (QM) deals with the small and slow, whereas special relativity (SR) deals with the large and fast. In particle physics, quantum objects move at close to the speed of light, and therefore both theories must be considered; however, these theories disagree. QM has no max speed particles can travel, whereas SR says the speed of light is the fastest anything can travel. SR is a deterministic theory, but QM is intrinsically probabilistic. Quantum field theory (QFT) is the theoretical framework that blends QM and SR. A notable discovery of QFT is the Higgs boson, a spin-zero particle that is fundamental to the modern understanding of mass. My project was to calculate the decay rate of a theoretical particle that was mathematically analogous to the Higgs boson.

During the project, I got a formal look at Feynman diagrams. Feynman diagrams are often seen in pop science since they are interesting to look at, but the meaning behind the diagrams is usually simplified or ignored. I learned how the diagrams represent particle interactions. The diagrams have three components: propagators (straight or curved line sections), vertices (intersections of propagators), and sources. These components are terms in a Taylor series expansion. This implies any diagram that follows the rules is some valid particle interaction, but the more "pieces" inside the diagram the higher-order the terms in the Taylor series must be, and thus the interaction is less likely to be observed. Another part of my research I found captivating was the importance of symmetry in the Feynman diagrams. Symmetry is used to prevent overcounting inside the diagrams. The hardest part of my research problem was understanding the symmetry of the diagram I was studying.

After I graduate I plan on attending graduate school for theoretical particle physics. I have a passion for both physics and mathematics so theoretical work seems to be perfect for me. I hope to study QFT, the standard model, and even theories beyond the current models.

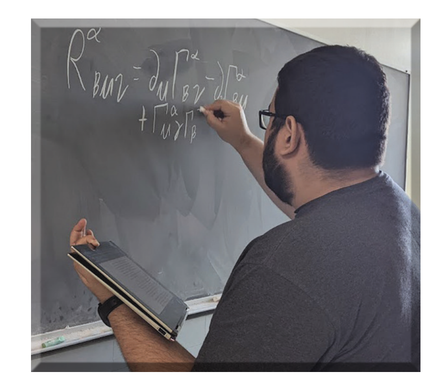
A Symbolic Python-Based Computational Tool for General Relativity

By Pedro Jesus Quiñonez

In my project, I created a python tool to derive general relativity equations. General relativity is all about how massive objects bend the fabric of spacetime. The problem is that these equations that describe how mass and energy bend spacetime are very, very large, and even more tedious to derive by hand. So, I wanted to make a computational tool that would derive these equations automatically.

Python is the standard in astrophysics, but it mainly deals with data, not equations. So, if I wanted my tool to give out symbolic equations, I had to use the Sympy library. From there, I was able to code the general relativity equations and then test them against my hand derived solutions, and found my tool to work perfectly. I then put my tool up on github for others to use and build upon. I hope in the future to expand the code's functionality and use.

I still have my senior year to look forward to, but once I graduate from Sonoma State University, I hope to apply to graduate schools in California to get my Ph.D. in Astrophysics and eventually become a professor of physics.



EdEon Spring Update 2022

By Hannah Hellman and Prof. Lynn Cominsky

EdEon staff have been busier than ever, with three major projects underway. Here are some of the highlights:

Learning by Making (Lbym)

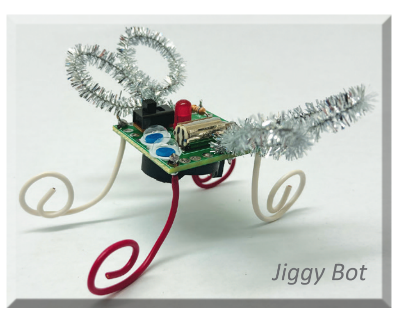
EdEon's Learning by Making program launched new WebApp software that can be used for both software and hardware based lessons. The Learning by Making curriculum requires technology that allows students to interact with computer software, computer hardware, and experimental lab setups. The first six years of curriculum development have required customized student laptops. Beginning in 2020, EdEon has moved this technology to a Web App, making it possible for students to use their own computers while in the LbyM course. The LbyM curriculum is now more accessible than ever, and the feedback from teachers has been very positive. With the launch of the new WebApp came a completely revamped Turtle Unit, complete with information about Sea Turtles and how we can help them thrive. The WebApp interface is available for use by students across the globe at: ***https://app.lbym.org.***

Interstellar Mapping and Accelerating Probe (IMAP)

EdEon's Associate Director Dr. Laura Peticolas is leading SSU's participation in $3U^3$, a student collaboration project associated with NASA's Interstellar Mapping and Acceleration Probe (IMAP). Six SSU students (Walter Foster, Erika Diaz Ramirez, Onasis Mora, Jack David Dawson-Trujillo, Christopher Gopar Carreno, and Alex Vasquez) researched designs and created and presented their research at the Preliminary Design Review to NASA officials and reviewers. Thanks to the hard work of everyone involved, the $3U^3$ satellite has passed its Preliminary Design Review! By participating in this CubeSat project, SSU students will support scientists' research of electron heating in the ionosphere and ion outflow from Earth's magnetic boundary between open and closed magnetic fields.

The next step for $3U^3$ is the Critical Design Review (CDR), in which all details of the design will be presented before the flight hardware is built.

NASA's Neurodiversity Network (N3)



Jiggy Bot

Along with the N3 partners, Education Design Center (EDC) and the New York Hall of Science (NYSCI), SSU has partnered with Orion Academy, Anova Center for Education (ACE), Oak Hill School, Stanbridge Academy and Autistry Studios to test previously developed STEM resources. SSU students, N3 team members and a few of last summer's N3 interns are also testing the resources. For example, EdEon SSU students Hannah Hellman, a graduate student in the English Department, and Amber Kaljumagi, an undergraduate in the Biology Department, tested and created a video demonstrating how to build the Jiggy Bots. Neither student had ever built a Jiggy Bot before, nor created a teaching video. The video shows Amber soldering the parts together as she explains the process for teens to follow. When asked about her experience building a Jiggy Bot and learning to solder, Hannah said, "I really enjoyed building the Jiggy Bot and learning to solder! Turning the switch on for the first time and feeling the board vibrate before I had even finished decorating it was such a good feeling. Learning how to solder is a very empowering experience, and I am so excited to see how much more we can empower our N3 learners."

Remembering Bryant Hichwa

By Prof. Lynn Cominsky

Just as this issue of the Physics Major was going to print, we were notified that Professor Emeritus Bryant Hichwa passed away peacefully at home on April 30, 2022. Prof. Hichwa's association with SSU began around 1990, when he taught part-time while working at Optical Coating Laboratory, Inc. (OCLI) as vice president of research. After retiring from OCLI, Hichwa joined SSU's tenure-track faculty in 2002. He was an amazing teacher and colleague who won the Excellence in Teaching Award in 2005. Students recognized him as a teacher, mentor and friend, and truly appreciated the efforts he expended both in the classroom and as their advisor. During the Darwin Hall remodel, Dr. Hichwa led the Physics & Astronomy Department's redesign efforts, including determining the arrangement of all our labs and offices, as well as choosing lab benches and equipment. A truly well-rounded individual, Hichwa was active in environmental causes and was also an expert photographer. Hichwa also analyzed antique baroque bassoons, giving lectures about this work at What Physicists Do and the American Physical Society's Far West Section. After retiring from SSU's faculty in 2009, Dr. Hichwa and his wife Diane established a Summer Student Research Assistantship program in 2011. To contribute to this program in his memory, please indicate fund #C0144.

Capstone Research: From Wheatstone Bridge to Planck's Constant

By Janelle Griswold

For my capstone, I did two projects with Dr. Hongtao Shi. The first one was modifying an existing Wheatstone bridge lab for Physics 216, second semester calculus based introductory physics laboratory. I replaced a multi-turn pot resistor used in this lab with a decade box resistor, which resulted in eliminating user errors and yielded much more consistent results. The second project I did was determining Planck's constant through the photoelectric effect. This project is to be a teaching demonstration for Physics 314, Introduction to Physics III: Relativity and Quantum Physics. By measuring the wavelength and the stopping voltage of multiple lasers we can fit the data linearly with the slope representing the Planck's constant, while the intercept is related to the work function of the material used in the evacuated tube. The most challenging part of this experiment was maximizing the photocurrent while controlling the same sizes of all three lasers. The red and the green laser diodes were especially difficult to work with because of their large beam size. After adding a lens into the beam path we were able to focus the beam and obtain better and more consistent results. I really enjoyed working on this project. It helped me better understand Planck's constant on a visual level, and I hope that this demo will also help future physics students better understand the photoelectric effect.

Capstone Research: Dome to Home Efficacy Survey

By Meghan Miller

For my Senior Capstone project I created a survey that the viewers of the Dome-to-Home shows would take after viewing one, or multiple of their episodes. Dome-to-Home is a virtual planetarium show hosted by the Fiske Planetarium at the University of Colorado, Boulder. They are 30-40min long YouTube videos that cover a wide range of astronomy topics including exoplanets, Mars exploration, and the search for life on other planets. The videos are geared towards 4th-8th grade students, but are interesting to viewers of all ages. The specific Dome-to-Home series I focused on was their March 2021 series on water in our Solar System, and how it is important for our search for other life. The series spanned 5 episodes that came out every Wednesday of the month. The survey typically takes 5-10 minutes to complete and consists of two open-ended content questions that change depending on which episode they watched, four ranking questions about the viewer's experience with the video, and four (optional) demographic questions, to get a better sense of who the audience for these videos is. It is a completely voluntary survey. Due to COVID-19, presentations that the Fiske Planetarium would typically show on a planetarium dome or Science on a Sphere were now being presented to a public audience remotely. Some of the same 2D images that were used on domed-planetarium screens are now being wrapped on a dome, shown on a flat laptop or computer screen. The purpose of this study is to determine the effectiveness of these virtual planetarium shows to see if this type of virtual learning is a viable platform for educational presentations. The feedback questions in the survey allow viewers to describe if the length of the video was good, if the information given was at a level even people with no prior knowledge could understand, etc... These responses will be given to the Fiske Planetarium staff so they can improve the quality of their future videos. NASA's MACH Center also plans to use the data from this survey to improve these types of online YouTube streaming presentations on their own content. I had the pleasure of working closely with Dr. Laura Peticolas, Dr. Lynn Cominsky, and the staff of the Fiske Planetarium. I also worked closely with SSU's IRB board to get it approved after a long IRB protocol process.

Capstone Research: Schottky Diode Current vs Voltage Curves Using Zinc Oxide (ZnO) and Gold

By Bradley Stobba

I wanted an opportunity to gain hands-on experience with a semiconductor material and get familiar with the equipment in the Keck Microanalysis Lab. My capstone research project granted me this opportunity. Under the guidance of Dr. Hongtao Shi, I was able to fabricate Schottky diodes using ZnO and gold thin films. Using a technique called electrochemical deposition (ECD), we were able to grow ZnO nanowires on a glass ITO substrate that was coated with gold nanoparticles to help with the uniformity of nanowire growth. Our ECD parameters were held constant while only the runtimes were varied to produce different samples. Using a scanning electron microscope we managed to verify that the shorter ECD run time created more uniform nanowires. Next, we were able to verify the bandgap of our semiconductor material using laser induced photoluminescence to be 3.23 eV, which confirmed the expected wide bandgap. Additionally, we thermally annealed half of one of the samples at 300 °C for 30 minutes to see the effect it would have on the photoluminescence. We determined that the intensity of the light emission was ten times greater for the annealed half, compared to the as-deposited one. After this we used a DC sputtering device coupled with a mask to deposit the gold onto our ZnO samples creating multiple Schottky diodes per sample. We used a LabVIEW program to control a power supply and Fluke meter to determine the current versus voltage curves (I-V curves) for an individual Schottky diode. One of the major themes we saw in our I-V curves was the appearance of a negative differential resistance during the first one or two runs (a run occurs when DC voltage is applied). After two to three runs this negative differential resistance would disappear and the curve would resemble a smooth exponential relationship between the current and the applied voltage, indicating that such a behavior is related to the interfacial states. This capstone project gave me a better understanding of semiconductor materials, the Keck Microanalysis Lab equipment, and how real world research is conducted. I am incredibly grateful for this opportunity Sonoma State University was able to create, and thankful for all lessons and guidance I received throughout the research process.