BU CUWiP 2023

Posters

1e: Coulomb Repulsion of Quantum Dot Arrays and the Finite Element Method

Presenter: Jessica Jiang
Field: Solid State Materials and Applied Physics
Abstract: Silicon devices that incorporate a few impurities forming arrays are ideal materials for the solid-state implementation of quantum technologies. The nearly-atomic precision on the impurity distribution provides remarkable tunability of the device properties, resulting in their potential application in quantum simulations. A model Hamiltonian of interest is the extended Hubbard model, and a crucial part of it is the Coulomb electron-to-electron repulsion term, U. Coulomb interactions can be efficiently computed from the wavefunction of the bound electrons and by solving the Poisson Equation using the Finite Element Method (FEM). An investigation into FEM's numerical properties is necessary to understand its limitations in studying the dopant array system. We present results on two-dimensional FEM calculations of U as a function of impurity separation distance, $2 \leq D \leq 10$ au, for an impurity model where the molecular hydrogen wavefunctions describe the electron ground and excited states. We also present results on the numerical stability of one-dimensional FEM, finding that while linear elements are sufficient to compute the electric potential for the Gaussian electron density, they are insufficient to compute the correct electric potential with a hydrogen $1S$ orbital wavefunction electron density, even with an adaptive mesh. Consequently, we conclude that to obtain the true potential due to hydrogen-like electron charge distributions nonlinear elements are required.

2w: Laser Saturated Absorption Spectroscopy of Ytterbium Atoms in a Hollow Cathode Lamp

Presenter: Danelle Akanova
Field: Optical, Atomic, and Molecular Physics
Abstract: Ion trapping research has led the charge in expanding the field of quantum states, quantum computing, and mass spectroscopy. In this experiment, we studied the spectrum of neutral ytterbium (Yb) atoms in a hollow cathode lamp (HCL) to measure the transition that is necessary for photoionization loading of Yb atoms into an ion trap quantum computer. Employing saturated absorption spectroscopy, we eliminated Doppler-broadening effects by aligning two counterpropagating, overlapping laser beams from the same source at the same frequency, through a low-density vapor of atoms in the HCL. In our research,

we explored multiple hyperfine isotope lines in the 398.8-nm line in Yb, corresponding to $1S0 \rightarrow 1P1$, using this Doppler-free saturated absorption technique.

3w: HaloTag Hybrid Proteins for Multicolor Labeling of Synapses

Presenter: Ariana-Dalia Vlad
Field: Biophysics
Abstract: The study of brain functions is limited by the in vivo scientific tools available to provide information about the location, strength, and time span of neural contacts. Two hybrid proteins, VGlut1-HT and Synapto-HT, have been created using molecular cloning methods, and inserted into a plasmid that can be used for lentiviral transduction of neurons. To test the constructs' ability to label synapses while not interfering with the brain's function, the proteins have been expressed in cultured neurons. After checking correct localization, comparing excited samples to controls proved the efficiency of the constructs as synaptic integrators.

4w: Modeling the Mass Distribution of Binary Black Hole Mergers with GWTC-3

Presenter: Jingyi Zhang
Field: Astrophysics and Cosmology
Abstract: With ∼70 binary black hole merger (BBHs) events detected by the LIGO -Virgo Collaboration, it is possible to infer the overall character of the black hole population in the universe. Specifically, the mass distribution of BBHs provides us with valuable information on stellar evolution and binary formation channel. The project aim to test the current estimation of BBHs population mass distribution based on the third Gravitational-wave Transient Catalog (GWTC-3). The project involves: (1) Identifying outliers and examining the impact of non-conventional events with leave-one-out tests on population parameter estimation; (2) explore possible ways to adjust the model to better characterize astrophysical phenomena;(3) examine agreement between the observed data and the fitted mode by conducting goodness-of-fit tests. We did not found any statistically significant outlier event, though some events can help direct us with future observations. Our goodness-of-fit test shows agreement between current observations and fitted model.

5w: Directional Tensile Strength of Carbon Fiber Reinforced PLA as a Function of Fiber Orientation and Bead Geometry in Extrusion-Based Large Format Additive Manufacturing

Presenter: Lucinda Slattery
Field: Solid State Materials and Applied Physics
Abstract: Inherently, additive manufacturing printed parts have faults between layers perpendicular to the direction of printing, both in the plane parallel to the build plate and in the z direction (out of the build plate). For most parts, these "built-in" faults from the manufacturing process act as limiting conditions because of mechanical load the part can endure

before failure. While perpendicular to the direction of printing is typically the weakest orientation due to layer adhesion faults, parallel to the direction of printing is typically the strongest orientation due to cohesive material and fiber orientation. This research looks to create predictive printing methods for high directional strength due to fiber alignment and low directional strength perpendicular to the direction of printing for parts designed to fail within the performance context of a 1-dimensional load.

6e: Transition-edge Sensors in Bolometric Detectors of the Ricochet Experiment

Presenter: Jiatong Yang
Field: High Energy and Particle Physics
Abstract: A transition-edge sensor (TES) is a superconducting thin film operating close to its transition temperature. Designed to have a sharp transition, the TES is sensitive to small changes in temperature. Thus, it has been widely used in sensitive cryogenic calorimeters for particle physics experiments. Ricochet is an experiment that measures the neutrino spectrum of Coherent Elastic Neutrino-Nuclear Scattering at low energies. In the experiment, recoil energy deposited in a superconducting absorber is transferred to a TES that converts temperature changes into changes in current, which then gets amplified and read out. We modelled and characterized the TES's designed by Northwestern University and fabricated at Argonne National Laboratory. We measured the IV curves and impedance curves of the TES and observed pulses originating from events within the TES and the absorber. From those measurements, we obtained important parameters of the TES, including its transition temperature, its sensitivity to temperature and current, and its thermal time constant. These parameters enable us to model and understand the current and temperature response of the devices.

7e: Experimental detection of skull-based ultrasonic Lamb waves as an intracranial pressure monitoring method

Presenter: Dan Nguyen
Field: Biomedical Acoustics
Abstract: Pressure within the cranial vault, which consists of cerebrospinal fluid (CSF), the central nervous system (CNS), and blood, is referred to as intracranial pressure (ICP). Severely high ICP can damage the CNS so its monitoring is crucial for patients deemed to be at high risk of elevated ICP, such as those with traumatic brain injuries or undergoing neurosurgery. The standard approach requires the insertion of a pressure probe into the ventricles through a burr hole on the skull. A noninvasive alternative to ICP monitoring using guided acoustic waves on the skull was investigated. Different modes of Lamb waves were generated in a submerged acrylic flat plate with thickness comparable to the skull bone and their corresponding leaky components were detected. Dispersion curves, including the anti-symmetrical and symmetrical modes of Lamb waves propagation in thin, isotropic acrylic plate comparable to thickness of skull bone were computed using the Rayleigh-Lamb equation and the Bisection method. Physical parameters such as critical angle, frequency-dependence phase velocity, and time-of-arrival were analyzed. The behavior of Lamb waves

upon asymmetrical pressure loading of the plate will be examined to reveal metrics that were sensitive to pressure changes underneath the skull.

8e: Optimizing the Physical and Mechanical Properties of 3D Printed Silk

Presenter: Trisha Musall

Field: Biophysics

Abstract: My project focuses on the physical and mechanical properties of 3D printed silk protein, fibroin, from the B. mori silkworm. Printed silk contains bound water, which lowers the glass transition temperature and makes it mechanically weaker. The presence of beta sheet crystals strengthens the material. I will examine the relationships among bound water content, beta sheet crystallinity, and printing conditions that optimize the physical and mechanical properties of the silk, with the goal of improving upon these properties. Building more resilient and stronger silk means creating better 3D printed parts, beneficial in biomedical applications.

9e: Superconducting Lithium-Intercalated ITO

Presenter: Rain (Kimberly) Wang

Field: Solid State Materials and Applied Physics

Abstract: Indium tin oxide (ITO) is the most widely used transparent conductor (TC) for optoelectronics, liquid crystal displays, photovoltaic cells, and touch screens. Generally, optical transparency and high electrical conductivity are mutually exclusive, but the carrier density in a conductor can be optimized to a low enough level to allow for optical transmission in the visible region—this optimization is a central factor of transparent conductivity and has even allowed the creation of transparent superconductors. Previously, ITO thin films grown on glass have been electrochemically doped with Na, Li, K, Rb, Cs, Mg, or Ca ions to create optically transparent superconductors. In this work, we use n-butyllithium to intercalate Li ions into ITO thin films sputtered on technologically relevant substrates. Using x-ray diffraction, atomic force microscopy, and resistance–temperature measurements, we refine ITO sputtering growth parameters and n-butyllithium intercalation parameters to optimally adjust optical transparency and electrical conductivity in lithium-doped ITO thin films for transparent superconductivity.

10e: Carbon Nanotubes as an Alternative to DNA Tethers for Improved Single-Molecule Force Spectroscopy

Presenter: Maitreya Rose

Field: Biophysics

Abstract: Optical tweezers have made important contributions to biophysics due to their ability to make force measurements on single nanoparticles. Utilizing a dual beam optical trap, we can manipulate and exert forces on single molecules bound between two trapped probe particles. DNA tethers are utilized to measure force exerted on a molecule of interest. However DNA is elastic and flexible, resulting in poor resolution of force measurements at low forces. Due to their longer persistence length, carbon nanotubes (CNTs) would make stiffer tethers and could improve force resolution. CNTs will also allow us to move into different solvent environments, as they are nonpolar and stable in organic solvents, where DNA condenses and precipitates. We have successfully functionalized CNTs such that they bind with gold nanoparticles. Utilizing optical tweezers ability to measure pN-scale forces we determine that the binding of CNTs to gold significantly reduces the diffusion of particles relative to plain gold. We hypothesize that the use of CNT coated gold particles as probes will allow the measurement of extremely fine forces due to increased stability of the trap and the stiff nature of CNTs.

11e: Using DNA Nanostars to Program the Crystallization of DNA-Coated Colloids

Presenter: Adrian Koretsky

Field: Condensed Matter, Renewable Energy

Abstract: DNA-coated colloids have been used as a model system to study self-assembly, and in particular, crystallization: the formation of ordered, repeating structures. Typically, attractive interactions between particles are due to direct hybridization between DNA strands grafted onto the particles' surfaces. I will describe a new approach in which DNA nanostars mediate the interactions of DNA-coated colloids. DNA nanostars are multi-armed, self-assembled structures made up of complementary single-stranded DNA molecules. At the end of each arm, there is a short sticky-end hand that is complementary to the DNA-coated colloids, allowing them to link the particles together. Changing the number of strands and their sequences alters the number of arms, arm length, and strength of interaction. We find that two-, four-, and eight-arm nanostars can direct the assembly of colloidal crystals with variable lattice spacing. Furthermore, whereas direct hybridization typically results in polycrystalline morphologies in a one-component mixture, we find that four-arm nanostars direct the assembly of single-domain, faceted crystals. These results suggest that DNA nanostars may be a useful tool to more easily control single crystal formation and program crystal properties, like the lattice spacing, without the need to synthesize many different particle types.

12w: Activity in the Jets of Blazars during Flares in Gamma-ray and Optical Light

Presenter: Hannah Willy

Field: Astrophysics and Cosmology

Abstract: Radio interferometry using the Earth-sized Very Long Baseline Array (VLBA) offers valuable insight into energetic activity in active galactic nuclei (AGNs), which are powered by accretion onto supermassive black holes. The BU blazar research group has been monitoring changes in the jets of a sample of the most extreme AGNs, blazars, by imaging their high-energy plasma jets monthly and following changes in their flux (light curves) at gamma-ray and optical wavelengths. I have modeled emission features ("knots") in the images in order to determine their motions, which I parameterize by one or more time periods of constant velocity. From this analysis, I calculate an "ejection" time of each individual knot and compare these times to those of gamma-ray and optical flares, defined as fluxes that are > 2 standard deviations above the mean. I determine the statistical significance of coincidences between flares and knot ejections to test the hypothesis that the two types of events are related. I find that gamma-ray activity is strongly related to ejections, whereas optical activity has a much higher chance of randomly coinciding with an ejection. These results infer that gamma-ray flares occur in the knots, while optical flares are more likely to occur elsewhere. In the future, I will continue to analyze more of these sources to determine whether my findings are confirmed. This project is funded by grants from the National Science Foundation and NASA.

13w: Application of Hamiltonian Truncation on 2d ϕ^4 Theory

Presenter: Zhengxian Mei
Field: High Energy and Particle Physics
Abstract: The goal of this project is to develop computational methods for such strongly interactive theories. We would like to compute the scattering amplitude of different particles, which will predict the cross-section of interactions that can be measured in experiments. The specific method that we consider is the Hamiltonian truncation, where instead of the infinite dimensional Hilbert space that the Hamiltonian acts on, we truncate it to a finite dimensional space and work on finite basis. This method has been widely used to calculate prediction for particle masses in QFT, but still lacks application on predictions for scattering experiments. We will work on a 2-dimensional scalar field model, which is a 'toy version' of the strong interaction theory in our 4-dimension space-time. We will probe into numerical solutions to the form factors, and then use these form factors to construct the scattering amplitude of different particles states.

14w: Muon Flux at Various Elevations

Presenter: Lindsay Yatsuhashi
Field: Astrophysics and Cosmology
Abstract: Cosmic rays are high energy particles that come the sun and other galaxies. They reach Earth's atmosphere and decay into muons, which are subatomic particles. Muons are created with an energy of approximately 6 GeV and they lose around 2 GeV of energy while traveling through Earth's atmosphere. Some muons start with less than 2 GeV of energy, and therefore lose most of their energy before reaching the surface of Earth. This means the muon flux will decrease as we move closer to sea level. We are able to detect muons on Earth using special telescopes. This summer, we were able to use our telescopes at different elevations to measure the muon flux at each location. We measured the muon flux at Holy Cross here in Worcester, in the town of Idaho Falls, Idaho, and at the summit of Grand Targhee Mountain in Alta, Wyoming. We were able to see a clear increase in muon flux as we increased our elevation. We thank the Weiss Summer Research Program for financial support.

15w: Using a Quantum Diamond Microscope (QDM) to Image Novel Magnetic Biomaterials

Presenter: Camille McDonnell
Field: Optical, Atomic, and Molecular Physics
Abstract: Numerous studies have explored the properties of silk fibroin gels doped in magnetic nanoparticles to understand their application to tissue regeneration. This study investigated the magnetic properties of silk fibroin gels doped in ferric chloride hexahydrate using a Quantum Diamond Microscope (QDM), which has yet to be accomplished. This study was conducted on silk fibroin gels doped in three different concentrations of ferric chloride hexahydrate: 0.015mM, 1.50mM, and 150.0 mM. The QDM was used to image each silk fibroin gel by placing the transparent sample on top of the Nitrogen-Vacancy (NV) center diamond quantum sensor. This research led to the creation of an imaging procedure consisting of sample and diamond preparation, experimental parameters, and data analysis necessary for producing an accurate 2D magnetic field map. It was found that the concentration of the silk fibroin gel and the laser power have an inverse relationship. Additionally, the concentration of the silk fibroin gel and the magnitude of the magnetic field have a direct relationship. Further research is needed to refine the data analysis procedure to produce more accurate magnetic field results to better understand how these silk fibroin gels can be applied to tissue regeneration.

16w: Towards Cryogenic Packaging for Grating Coupled Optical Devices

Presenter: Laurel Barnett
Field: Solid State Materials and Applied Physics
Abstract: We test multiple optical and cryogenically-rated adhesives in an effort to determine a packaging procedure for grating coupled optical devices that can withstand cycling between room- and cryogenic temperatures. This will be an important tool in order to more efficiently transport and test optical devices in the cryogenic environments necessary for systems that involve superconductors.

17w: Carbon Nanotubes as an Alternative to DNA Tethers for Improved Single-Molecule Force Spectroscopy

Presenter: Maitreya Rose
Field: Biophysics
Abstract: Optical tweezers have made important contributions to biophysics due to their ability to make force measurements on single nanoparticles. Utilizing a dual beam optical trap, we can manipulate and exert forces on single molecules bound between two trapped probe particles. DNA tethers are utilized to measure force exerted on a molecule of interest. However DNA is elastic and flexible, resulting in poor resolution of force measurements at low forces. Due to their longer persistence length, carbon nanotubes (CNTs) would make stiffer tethers and could improve force resolution. CNTs will also allow us to move into different solvent environments, as they are nonpolar and stable in organic solvents, where

DNA condenses and precipitates. We have successfully functionalized CNTs such that they bind with gold nanoparticles. Utilizing optical tweezers ability to measure pN-scale forces we determine that the binding of CNTs to gold significantly reduces the diffusion of particles relative to plain gold. We hypothesize that the use of CNT coated gold particles as probes will allow the measurement of extremely fine forces due to increased stability of the trap and the stiff nature of CNTs.

18w: Quantum Scattering States in a Nonlinear Coherent Medium

Presenter: Allison Brattley
Field: Optical, Atomic, and Molecular Physics
Abstract: We present a comprehensive study of stationary states in a coherent medium with a quadratic or Kerr nonlinearity in the presence of localized potentials in one dimension (1D) for both positive and negative signs of the nonlinear term, as well as for barriers and wells. The description is in terms of the nonlinear Schrodinger equation (NLSE) and hence applicable to a variety of systems, including interacting ultracold atoms in the mean eld regime and light propagation in optical fibers. We determine the full landscape of solutions, in terms of a potential step and build solutions for rectangular barriers and well potentials. It is shown that all the solutions can be expressed in terms of Jacobi elliptic functions with the inclusion of a complex-valued phase shift. Our solution method relies on the roots of a cubic polynomial associated with a hydrodynamic picture, which provides a simple classification of all the solutions, both bounded and unbounded, while the boundary conditions are intuitively visualized as intersections of phase space curves. We compare solutions for open boundary conditions with those for a barrier potential on a ring, and also show that numerically computed solutions for smooth barriers agree qualitatively with analytically solutions for rectangular barriers. A stability analysis of solutions based on the Bogoliubov equations for fluctuations show that persistent instabilities are localized at sharp boundaries, and are predicated by the relation of the mean density change across the boundary to the value of the derivative of the density at the edge. We examine the scattering of a wave packet by a barrier potential and show that at any instant the scattered states are well described by the stationary solutions we obtain, indicating applications of our results and methods to nonlinear scattering problems.

19w: Investigating Fuzzy Dark Matter through Stellar Streams

Presenter: Claire Recamier
Field: Astrophysics and Cosmology
Abstract: Fuzzy Dark Matter, an alternative to the Cold Dark Matter (CDM) model, is an axion-like particle with a mass of $m < 10^{-22}$ eV, or 10^{-31} times the mass of a proton, and therefore exhibits quantum behaviors. This dark matter candidate theoretically solves many of the small-scale structure problems where typical CDM fails, such as the core-cusp problem. Galaxies are orbited by gravitationally self-bound groups of stars called globular clusters. The potential of the galaxy periodically pulls stars out of the globular cluster system and into orbit with the galaxy. As a result, some globular clusters are accompanied by thin trails of stripped stars, called stellar streams, which have different orbits and energies

than their progenitors. We use stellar streams as an observational probe into the nature of the dark matter particle. Kinematically cold stellar streams in smooth potentials create thin, long strings of stars. However, existing stellar streams have some width and visible perturbations in density fluctuations and gaps, caused by gravitational interactions with dark matter. In fact, the thin structure of stellar streams results in a sensitivity to gravitational interactions with dark matter, which are recorded as perturbations in the streams' densities. In an overall effort to constrain the mass of the dark matter particle, we aim to simulate the path of stellar streams in different potentials. We want to generate streams in CDM and fuzzy dark matter potentials with identical density profiles, to isolate how the nature of the dark matter particles changes interactions with stellar streams. From these simulations, we hope to be able to characterize how perturbations from a cold dark matter halo differ from perturbations from a fuzzy dark matter halo. As for generating the stellar streams, we follow the streakline approach used by Bonaca et al. in "Milky Way Mass and Potential Recovery Using Tidal Streams in a Realistic Halo." The streakline approach evaluates at every timestep the force experienced by the globular cluster due to the galactic potential, and updates position and velocity of the globular cluster accordingly. It also ejects a star and updates the positions and velocity of stars in the streams at every timestep, allowing us to track the motion of a globular cluster and its accompanying stream as it orbits the galaxy.

20w: Sporulation Patterns in Wild Type Bacillus subtilis

Presenter: Angelina Serafini
Field: Biophysics
Abstract: Different Bacillus subtilis strains sporulate at different rates, these dynamics largely determining biofilm morphology. The goal of this project is to use time-lapse confocal microscopy data to determine the spatiotemporal distribution of sporulating cells within a biofilm. Genetically encoded fluorescent proteins allow us to differentiate sporulating cells from others with the help of Python image analysis libraries like SciPy. Preliminary data supports our hypothesis, showing consistent patterns for certain sporulation rates: early sporulation shows a ring of cells around the edge and spores in the middle of the biofilm, while delayed sporulation shows cells and spores evenly distributed throughout the biofilm. The Python code allows us to extract quantitative metrics from the imaging data. These include the center of mass of the biofilm, the velocity of radial growth, the density of spores, the density of cells, their position etc. Image analysis is still ongoing, aiming to obtain quantitative values for these observed growth patterns.

21w: Computational Prediction of the Structure of Coulomb-Exploded Molecules

Presenter: Julia Bellamy
Field: Optical, Atomic, and Molecular Physics
Abstract: Coulomb Explosion Imaging (CEI) is a method in which femtosecond X-ray free-electron (XFEL) and strong IR lasers can charge up molecules through sequential multiphoton ionization that then explode in charged fragments. The final momenta of these charged

fragments contain information about their initial geometry that are obscured in other imaging methods. Knowing the atomic structure provides invaluable information about physical, chemical, and biological properties. There are many methods to determine the initial geometry of molecules such as studying reaction pathways, analysis through molecular orbital theory, performing spectroscopy, and solving the molecular Schrodinger equation. These all have their advantages, but a common limitation is that no current method can directly determine the geometry from CEI experimental data. The goal of this research project is to predict atomic geometry utilizing Newtonian dynamics, standard integration methods, and computational simulation directly from CEI momentum data. Inversion and simulation code libraries were developed to consider the variety of molecules and initial conditions studied in CEI. Comparing the predicted atomic geometry to the error suggests the ability of this computational inversion method to accurately predict the initial geometries of Coulomb Explosion Imaging molecules. Further work is currently underway to incorporate additional AMO models, increased computational power, and comparison to experimental data into the developed code.

22w: Optical readout of Nitrogen-vacancy centers for quantum sensing

Presenter: Melody Ellen Tsutsumi Cruz & Katherine Lasonde

Field: Optical, Atomic, and Molecular Physics

Abstract: This project demonstrates the feasibility of room temperature coherent control experiments on the electronic spin state of a Nitrogen-vacancy (NV) center in diamond. The poster will introduce the theory of nitrogen vacancy centers as quantum sensors. Then, it will outline the process of designing an inexpensive tabletop set up to run such experiments. Finally, methodology and data collected through continuous wave (CW) optically detected magnetic resonance (ODMR) and T_1 decay experiments will be presented.

23w: Towards laser cooling and trapping of SrOH to probe for dark matter and EDMs

Presenter: Hana Lampson

Field: Optical, Atomic, and Molecular Physics

Abstract: Laser cooled polyatomic molecules provide several advantages for precision measurement that arise from their complex structure and our ability to precisely control them and their environment. The linear triatomic molecule SrOH is an ideal candidate for probing ultralight dark matter because of its nearly degenerate vibrational states whose energies depend differently on the proton-to-electron mass ratio, μ. SrOH also serves as a testbed to measure the electron electric dipole moment. Based on high-resolution vibrational branching ratio measurements of four excited vibronic states in the linear triatomic molecule SrOH, we are able to design a laser-cooling scheme requiring only 8 lasers to scatter over 10,000 photons before loss to unaddressed vibrational states, allowing us to form a MOT and load an optical trap. We describe progress towards laser cooling of SrOH for high-sensitivity measurements of μ variation and the electron EDM.

24e: Progress Towards Low Energy Lithium-Proton Collision Experiments

Presenter: Elia Fisher
Field: Optical, Atomic, and Molecular Physics
Abstract: Quantifying charge transfer collisions between lithium atoms and protons is relevant to tokamak, nuclear fusion research. Previously, work done in the physics department at the College of the Holy Cross studied collisions between a continuous (DC) beam of protons and a quasi-DC beam of lithium atoms. Using an electric field to sweep Li+ ions produced in the collisions to a detector, the charge transfer collision cross section was measured at energies as low as 130 eV. To better mimic the collisions occurring in nuclear fusion reactors, collision energies as low as 10 eV are desirable, which requires a modified experimental method. Progress towards achieving this new method is described in this poster. The new method entails pulsing the proton beam and the electric field rapidly on and off. In order to achieve this, precisely coordinated voltage pulses must be applied to specific parts of the experiment. Two pulse generators are used to create the seven required pulses which are controlled using the LabView computer program. To ensure accurate pulse timings, internal equipment delays were considered, and the final output pulses from each piece of equipment were examined together. Aside from generating the correct pulses, the new method requires new experimental parts to be designed and machined. For the purpose of turning the proton beam on and off a pair of deflection plates were proposed to control when protons would be allowed to enter the collision site. Moreover, the inclusion of a metal ring with a constant positive voltage will be used to slow the Li+ ions thus optimizing the detection efficiency of Li+ while maximizing the proton-lithium interaction time. Using the computer program SIMION, we simulated both proton and Li+ trajectories to confirm the effectiveness of the new experimental parts and then created machine shop drawings using AutoCAD. We thank the Robert J. Stransky Foundation Research Fellowships in the Sciences at Holy Cross for their generous financial support and Dick Miller for machining expertise that made this research possible.

25e: Hunting for Distant Giants in the Outer Edges of Compact Multi-Planet Systems

Presenter: Nicole Sobski
Field: Astrophysics and Cosmology
Abstract: The compact multi-planet systems discovered through the Kepler Mission exhibit strikingly uniform characteristics such as regular orbital spacings, similar planetary masses/sizes, and coplanarity. While observations have been made on the inner regions of these systems, there remain many questions regarding the outer architectures and the potential giant perturbing planets that could impact inner planetary stability. Our research aims to address the peculiar truncation observed in the outer edges of the compact multis, determining whether interactions with distant planets could account for the shaping of these outer edges. To test this theory, we use computational modeling to vary an outer perturbing planet's physical and orbital properties over thousands of iterations and apply a machine learning algorithm (SPOCK) to provide a calculated stability of the system over long time-scales. We create

data visualizations to depict the related impact that increasing mass and semi-major axis measurements has on system stability, noticing an associated metastable region where an additional planet could exist and would not have been detected through Kepler. Through our analyses, we explore the limits of stability of distant giant planets in the compact multis. Ultimately, our research suggests that these outer giants are most likely not responsible for the architectures of the outer edges.

26e: Quantifying Errors Within Data-Assimilative Global Ocean Models Using Glider Data From The Mid-Atlantic Bight Slope Sea

Presenter: Grace Kirkpatrick
Field: Climate Science/Physical Oceanography
Abstract: We used the Julia programming language and observational data from several ocean gliders to evaluate the skill of the global data-assimilative models RTOFS and GOFS at recreating the temperature, salinity, and density structures of the Mid-Atlantic Bight slope sea. Comparisons between model and glider data reveal a model error that is within roughly 10-15% of the normal range of each of the variables (practical salinity, potential temperature, potential density anomaly, and spice). GOFS' skill at representing the MAB was generally higher than RTOFS, and RTOFS struggled to resolve the North Wall of the Gulf Stream in several glider missions.

27w: EXoplanet ConfIrmaTIoN throuGh transits (EXCITING): Determining False Positives

Presenter: Haedam Im
Field: Astrophysics and Cosmology
Abstract: EXoplanet ConfIrmaTIoN throuGh transits (EXCITING) is a research project that determines the validity of TESS Objects of Interest (TOI) exoplanet candidates. The project aims to identify false positives, mainly eclipsing binaries, using a 1m remotely controlled telescope. Among various exoplanet detection methods, EXCITING utilized the transit method to detect TOI target candidates over the course of a year. FITS images from the SOPHIA 2048B CCD camera were analyzed through aperture photometry to detect the change in flux of the target star compared to that of reference stars. The light curves were detrended with various parameters, including airmass, average sky counts, and sky/pixel. Based on the morphology of the resultant light curves and fitted parameters such as the estimated radius and transit depth, this paper reports that TOI 1638.01, TOI 2120.01, and TOI 1252.01 are likely to be exoplanets, while TOI 496.01 is most likely to be an eclipsing binary. TOI 2047.01 and TOI 1516.01 require further investigations using the radial velocity method: the results show a possibility of being either a large exoplanet or a small eclipsing binary star, likely a red or brown dwarf. This research will further contribute to the conclusive exoplanet confirmation process for TOI candidates, such as radial velocity verification and spectroscopic analysis.

28w: Developing an Image Visualization Pipeline for WHISPER's Polarization Sensitive Camera

Presenter: Celeste Berenbaum & Nina Christenson
Field: Astrophysics and Cosmology
Abstract: The outermost layer of the Sun's atmosphere, otherwise known as the solar corona, is difficult to observe and study due to its relative dimness compared to the photosphere. The corona is most visible during a total solar eclipse, which is the main motivation behind designing and building the Wheaton Imaging Solar Polarimeter (WHISPER). WHISPER will measure the polarization structure of the solar corona during total solar eclipses. Central to WHISPER is the Phoenix PHX050S-PC polarization camera, equipped with a Sony IMX250/264 CMOS sensor. We will present our studies to quantify the sensor's properties such as linearity, offset, and gain parameters. We will also present polarization imaging of various targets such as the International Space Station, the Ring Nebula, and the sunlit sky. Another application of the WHISPER project is to image protoplanetary nebulae, and eventually quasars, using the SONY IMX250 chip mounted in the QHY550P Polarized Camera. The QHY550 camera has a built-in cooling system, allowing for clearer signal and the ability to image fainter objects. Mounting this camera to the Wheaton Observatory's Meade LX600 12-inch telescope has allowed us to image the Egg Nebula and the Footprint Nebula for polarization analysis. Results from these imaging sessions will be presented, along with a discussion of potential next steps.

29w: Low-Energy Electron Beam Irradiation as a Possible Way of Nitrogen-Vacancy Formation in Diamonds

Presenter: Ekaterina Arutyunova
Field: Solid State Materials and Applied Physics
Abstract: Nitrogen-vacancy (NV) centers are point defects in the diamond crystal structure. A single NV center is a vacancy in the diamond lattice lying next to a nitrogen atom that now substitutes one of the carbon atoms. Nitrogen-vacancy centers show impressive performance at room temperature and have potential applications in nanoscale magnetometers, quantum sensing, quantum communication, and spintronics. A conventional technique for fabricating NV centers in diamonds is nitrogen ion beam implantation. The well-established method, however, produces a limited creation yield of desired diamond defects. This work investigates a novel way to form nitrogen-vacancy centers in diamonds with a higher defect creation yield via a low-energy electron beam irradiation technique. We show a possible way of nitrogen-vacancy formation using scanning electron microscopy (SEM) tool in two different diamond samples: (1) diamond with native low-concentration nitrogen impurity and (2) already nitrogen-implanted and annealed diamond. The efficiency of the proposed technique is analyzed based on optical characterization data of post-irradiated samples obtained with confocal microscopy. The results of this work give multiple directions for further method improvements.

30w: Low-Resistance Ohmic Contacts for MoSe2

Presenter: Athalia Meron
Field: Solid State Materials and Applied Physics
Abstract: Transition metal dichalcogenides (TMDs) are a class of 2D materials, nanomaterials made of strongly covalently bonded atom-thick sheets. TMDs generally exhibit favorable properties such as enhanced light matter interactions and strong electron-electron interactions, which makes them promising platforms for novel physics. However, these phenomena cannot be observed without good electrical contacts. Synthesizing such contacts will help open up this material for further study, opening the doors for the investigation of phenomena such as Wigner crystallization and Bose-Einstein condensation. The main challenge here is synthesizing Ohmic contacts that will allow us to perform reliable transport measurements. When synthesizing metal-semiconductor contacts, there are two possible junctions that can be formed—Ohmic junctions and Schottky junctions. If the workfunction of the metal and the semiconductor material differ, charge transfer occurs until their Fermi levels reach equilibrium, causing the junction to behave as a rectifying diode. These junctions have strongly nonlinear voltage-current relation, making the interpretation of electrical measurements difficult. Recent experiments have demonstrated that palladium and bismuth are good candidates to produce Ohmic contacts to the semiconducting TMD MoSe2. We fabricate devices using various thicknesses of Pd and Bi to determine the optimal contact recipe. Controlling the thickness of the contacts allows us to better match the workfunctions of the two materials, creating an Ohmic junction, which has a linear current-voltage relationship. We will perform transfer length method measurements to determine the contact resistance on each of our devices.

31w: Quantum Chaotic Dynamics and Effective Random State Generation

Presenter: Srishti Nautiyal
Field: High Energy and Particle Physics
Abstract: As a many-body quantum system evolves in time, it explores an immense Hilbert space whose volume grows exponentially with the number of particles. In this study, we are interested in generating random quantum states that explore this gigantic space as efficiently as possible. Such random states have applications in modern quantum information processing, statistical sampling, and randomised benchmarking. One way to efficiently explore Hilbert space is to utilise scrambling dynamics, which randomises an initial state due to the buildup of global entanglement that delocalizes quantum information. Here we study this phenomenon in large $SU(2)$ angular momentum spin models, where we scramble the information using different unitary models of quantum chaos including Brownian spin dynamics and Kicked Top dynamics. To study how rapidly information spreads in these models, we calculate the Lyapunov Exponent using an out-of-time-order correlator (OTOC), which characterises the evolution of simple operators into complicated ones that span the entire Hilbert Space. We also calculate the Frame Potential to characterise the system's circuit complexity in time. This investigation has two possible applications: a. the Frame Potential can tell us how deep our circuit must be or the minimum amount of gates required to generate a sufficiently random state, with direct applications to testing

and benchmarking state of the art quantum simulators. b. As information gets delocalised over the Hilbert space, it becomes increasingly impervious to the destructive effects of local measurements. When non-unitary elements like measurements are added to the dynamics, we expect to encounter potential Quantum Error Correction Codes due to this competition between measurement and scrambling.

32w: Studying the Cone-Size Dependence of Jet Suppression in Heavy-ion Collisions with PYTHIA

Presenter: Zihui (Mary) Zhang
Field: High Energy and Particle Physics
Abstract: Quantum Chromodynamics (QCD) is the theory of strong force. At sufficiently high temperatures, quantum chromodynamics matter becomes a hot dense medium of deconfined quarks and gluons called the Quark-Gluon Plasma (QGP). The QGP can be experimentally reproduced through relativistic heavy-ion collisions. Jets, which are sprays of particles in a cone shape, are expected to lose energy in the QGP and can be used to probe its qualities. Specifically, the ratio of the jet yield in heavy-ion collisions to the expected unmodified yield in proton-proton collisions, the nuclear modification factor, is a useful parameter that gives access to energy loss information. This information, in turn, gives insight into the QGP medium. Particularly interesting is the cone-size (R) dependence of the RAA, as it can help separate out the different energy-loss mechanisms, such as out-of-cone radiation and the medium response. One open question is how the various energy loss mechanisms would contribute to the R-dependence of the nuclear modification factor separately. To answer this question, I will show the RAA calculated from modified PYTHIA simulations at 5.02 TeV in comparison to existing experimental results in order to investigate the relative contributions of different energy loss mechanisms at different cone-sizes.

33e: Effects of the Acoustic Temporal Window on Ultrasound Transmissions in Treatment for Mesial Temporal Lobe Epilepsy

Presenter: Abigail Rothstein
Field: Biophysics
Abstract: Studies have suggested a correlation between neuromodulation therapy in the hippocampus and decreased epileptic seizure activity for those with mesial temporal lobe epilepsy (MTLE). This particular type of epilepsy has proven itself a very promising area to focus on due to the characteristics of the skull adjacent to the target site and the disease itself. It is often difficult to pinpoint the origin of epileptic activity, but MTLE exhibits hippocampal sclerosis, making it an ideal indication. MTLE is commonly drug resistant, so that surgery remains the only available treatment for those who suffer from it. Due to the high risks associated with open brain surgery, other methods have been sought out. Ultrasound possesses neuromodulatory properties, and past work has involved examining the transmission of ultrasound through the skull's acoustic temporal window. We present our initial experimental results in measuring the distortion of ultrasound after transmission through ex vivo human skull bone. Future work will include comparative analysis with three dimensional simulations of the transmitted energy.