2023 Conference for Undergraduate Women in Physics at Brown University Poster Session

January 21, 2023

4:00 PM EST

Table of Contents

The Signature of Planet Nine in Earth's Orbital Elements

Hanna Adamski, *Yale University,* Poster #1

The outer solar system's orbital architecture has been characterized by the unexpected clustering of Trans-Neptunian objects with semi-major axes in excess of 250 AU. One proposed hypothesis for this alignment is the presence of a distant body, Planet Nine. In this work, we quantify the influence of the ninth planet on Earth's orbital elements by using N-body simulations to compare models of the solar system with and without a ninth planet. Our possession of observations detailing the evolution of Earth's own semi-major axis, eccentricity, and inclination, makes it possible to match which characteristic Planet Nine parameters produce the same magnitude of deviations when synthetically generated within numerical simulations. The scale of influence a particular size Planet Nine has on Earth is understood when we compare the magnitude of its gravitational effect to those expected from general relativity, stellar flybys, and uncertainties in Earth's ephemeris. As a result of this comparison, certain sizes of Planet Nine are found to either have comparable or surpassable effects to those of previously stated phenomenon, implying that if Planet Nine exists in the outer solar system, its influence on Earth's orbital elements must be discernible, yet not overpowering that of other solar system bodies. Identifying which characteristic Planet Nine parameters give rise to detectable changes in Earth's semi-major axis, eccentricity, and inclination has allowed us to narrow the parameter space of a possible Planet Nine and determine its most probable influence on bodies within the solar system over ~Gyr timescales.

Quantifying Debris Production during Terrestrial Planet Formation

Sanskruti Admane, *Ohio State University,* Poster #2

For successful terrestrial planet formation, a given scenario must match the following observable constraints: the small eccentricities of planetary orbits, the masses of the terrestrial planets, specifically Mars' small mass, the structure of the asteroid belt, Earth's large water content, and the formation timescales of Earth and Mars. Different terrestrial planet formation scenarios invoke different mechanisms to satisfy all of these constraints such as an early instability, a Grand Tack, a truncated disk, or an excited giant planet system. However, prior exploration of these scenarios have not considered imperfect accretion. Here, we are investigating whether the debris created by giant impacts during terrestrial planet formation significantly changes the results compared to already published work that assumes perfect merging. We are using an astrophysical N-body integrator to model the dynamics of bodies in the protoplanetary disk and we model the outcomes of debris-producing collisions using an algorithm that is a function of their mass ratio, impact angle and velocity (Leinhardt & Stewart, 2009). These simulations will describe the change in mass, eccentricity and semimajor axes of the created debris particles. We will compare the constructed solar systems with published perfect merging simulations (e.g. Clement et al. 2018) and reality.

Probing the X-ray emission from ejecta-circumstellar medium interaction using 3D simulations of RS Ophiuchi

Danya Alboslani, *University of Connecticut,* Poster #3

Recurrent novae occur in mass transferring binary systems that contain a degenerate white dwarf and a non-degenerate companion. Outbursts occur when the accreted outer envelope on the surface of the white dwarf reaches ignition temperature, and a thermonuclear runaway ensues. In this work we focus on RS Ophiuchi, a system with a massive white dwarf that undergoes nova explosions every ~20 years. Utilizing a modified version of the Smoothed Particle Hydrodynamics (SPH) code, GADGET-2, we model the interaction of the nova ejecta with the circumstellar medium for two mass transfer - explosion cycles and trace its evolution for 20 years after each eruption. Additionally, the hydrodynamic simulations are post-processed to produce synthetic X-ray observations with PyXSim to study the early and late time ejecta evolution. In agreement with previous studies, the spherical ejecta interacting with the aspherical circumstellar medium from the quiescent mass-transfer phase produces a bipolar structure. We present the emission measure and X-ray emission produced for different assumed ejecta masses, velocities, and energies, and compare this to observational data from Chandra. Our study will provide insight into the physics of blast waves for RS Ophiuchi and other eruptive systems by constraining their ejecta characteristics and radiative cooling processes. Given that RS Ophuichi and many other recurrent novae have massive white dwarfs, these systems are also informative for studies of Type Ia supernova progenitors. This project was supported in part by the NSF REU grant AST-2149985 and by the Nantucket Maria Mitchell Association.

The Influence of HCDs on Lyman-alpha Forest Correlation

Kaia Atzberger, *Ohio State University,* Poster #4

The Lyman-alpha forest is a region of absorption in the spectra of distant galaxies and quasars. My research question asks “what is the impact of HCDs on the linear bias factors of the Lyman-alpha forest?” High-column density absorbers, or HCDs, are key contaminants produced by light traveling close to high-density regions like galaxies. They are rare and characterized by very broad absorption lines that include damping. These broad wings cause localized HCDs to have a widespread impact. Their effect is a result of HCD’s correlation with the underlying mass distribution and therefore with Lyman-alpha forest intergalactic absorption. We want to use synthetic data sets to understand HCD contamination. Under which conditions can we best measure the expansion of the Universe? This is determined by finding parameters that best agree with observed values. Measuring the Alcock Paczynski effect to constrain cosmology, the corresponding parameters constrain further researched BAO parameters. BAO, or baryon acoustic oscillations, are fluctuations in the density of normal matter caused by acoustic waves in the plasma of the early Universe. I’ve worked on analyzing these parameters for different variations of cosmological mock data sets to identify the best model in terms of simulating realistic universal conditions. We can vary HCD abundance, noise, and continuum fitting to see how HCD modeling affects the constraining power and bias of our parameters.

Analyses of the cores of AlphaFold2 protein structure predictions

Jillian Belluck, *Brown University,* Poster #5

Developing computational methods to accurately predict the three-dimensional structure of a protein from its primary sequence of amino acids is an important and unsolved problem. AlphaFold2, a deep learning methodology developed by DeepMind to generate computational models of proteins, has been successful in recent Critical Assessment of protein Structure Prediction competitions. In the present work, we assess AlphaFold2 computational models using the number of residues in the core, a feature that is strongly correlated with protein stability. We find that while AlphaFold2's predictions for the E. coli proteome resemble X-ray crystal structures, the eukaryotic protein predictions contain too few core residues. Our analysis considers the influence of intrinsically disordered sequences on the fraction of core residues, using both AlphaFold2's per-residue confidence levels and the average charge and hydrophobicity of each protein. The variability in the core size of AlphaFold2's predictions across organisms demonstrates that while machine learning methods have increased the accuracy of computational models for protein structure, significant improvements must be made to achieve results comparable to those in experiments.

Early Cancer Detection with Magnetic and Fluoresced Mechanics

Charlotte Bimsom, *Bowdoin College,* Poster #6

Cancer research is the contemporary hallmark of biomedical work. While most studies focus on treating tumors throughout different stages of development, our principal objective is to create an early detection system to increase an individual's probability of early tumor detection and treatment. The improved detection system will locate and trap cancer cells from a small blood sample; the system is quick, portable, and easily and inexpensively manufactured. The processes that lead to the product's development and analysis method are examined with insect cells. Insect cells are tested with the common procedure of coating human cells with fluorescent functionalize groups and then detecting the cells under a new fluorescent microscope. The insect cells are also attached to micron-sized magnetic particles, so each cell can be guided to a tiny pocket of a sample cuvette under the effect of a gradient magnetic field. The combination of magnetic and fluoresced cells will allow for quick and simple detection of diseased cells.

Optical Study on the Topological Semimetal Bi 4 Se 3

Margaret Brown, *University of Dayton,* Poster #7

Quantum confinement of the topological semimetal Bi 4 Se 3 was observed as a giant enhancement of the optical bandgap in two characteristic length-reducing regimes: ultra-thin films and nanoplatelets. The films were prepared via DC magnetron sputtering and characterized using atomic force microscopy and ultraviolet-visible spectroscopy. Current work investigates correlations of reduced dimensionality to enhancements of the bandgap. By characterizing the dimensionality through microscopy, spectroscopy results can be mapped to changes in the band edge as determined through Tauc plots.

Using virus-like particles for controlled release of cargo

Camila Cersosimo, *University of Rhode Island,* Poster #8

A common conflict arises when designing drug delivery systems: the therapeutic must be encapsulated in a nanoscale container to provide protection from the elements, but the container must also readily disassemble for on-demand release at the target site. Viral protein capsids could play this role because viruses perform these two conflicting tasks in nature: a virus must protect its genome but release it once it encounters its host. Viral disassembly, or uncoating, can be triggered by chemical changes in the environment to achieve a targeted release of the viral genome. Past experiments using bacteriophage MS2 coat protein have shown that virus-like particles (VLPs) containing short oligonucleotides can serve as vectors to deliver a therapeutic RNA cargo to human cells, with the pH drop during endocytosis triggering cargo release inside the cells. However, little is known about the fundamental mechanisms behind viral capsid disassembly, nor the degree to which these VLPs disassemble under different conditions. We investigated the effect of different buffer conditions with varying pH, ionic strength, and temperature on the stability of MS2 VLPs containing RNA oligonucleotides to understand their effects on capsid disassembly. We probed the structure and dynamics of disassembly using gel electrophoresis and real-time fluorescence measurements of capsid permeability. A better understanding of VLP disassembly could lead to improvements in targeted drug delivery.

The Art of Ion Trapping

Renee Depencier, *Williams College,* Poster #9

I engage in experimental atomic physics research. My research, advised by Professor Charlie Doret, a specialist in ion trapping, relies on complex electronic components, vacuum chambers, and lasers. During my first year in the lab, I designed and constructed a laser that drives a key atomic transition in our upcoming experiment with Strontium ions. This construction involved creating a printed circuit board via ExpressPCB, soldering the components, machining parts, developing the optical assembly and troubleshooting wiring problems. In my senior thesis project I hold a lead role in the design and construction of an upgraded vacuum chamber for our newest ion trap. My poster will be about the design and creation of this chamber.

Modeling Cool Gas Kinematics of the Fermi Bubbles

Annie Giman, *Yale University,* Poster #10

In 2010, the Fermi Gamma-ray Space Telescope detected large gamma-ray emitting lobes on either side of our galactic center (GC). These lobes, named Fermi Bubbles (FBs), are the result of high-energy particle interactions corresponding to hot plasma, and eject gas in high-velocity outflows. Imaging surveys are not enough to constrain gas kinematics. However, using background quasar sightlines allows the detection of cool entrained gas in the bubbles. Because these observations are in projection, a model is needed to constrain the gas kinematics further. In this work, we develop a kinematic model of the Milky Way nuclear outflow to constrain the FB observed velocity profiles, which are used to constrain the age and velocity of the Milky Way's nuclear outflow.

Reentrant delocalization transition in one-dimensional photonic quasicrystals

Megan Goh, *Amherst College,* Poster #11

Waves propagating in certain one-dimensional quasiperiodic lattices are known to exhibit a sharp localization transition. We theoretically predict and experimentally observe that the localization of light in one-dimensional photonic quasicrystals may be followed by a second delocalization transition for some states on increasing quasiperiodic modulation strength - an example of a reentrant transition. We further propose that this phenomenon can be qualitatively captured by a dimerized tight-binding model with long-range couplings.

CMB-S4's Observatory Control System: Development and Documentation

Hannah Green, *Ohio Wesleyan University,* Poster #12

Simons Observatory's Observatory Control System (SOCS) is being used as the framework for CMB- S4's data acquisition system (DAQ). In this project, we focused mainly on documenting and researching OCS, as prior to this point, it was used as a part of a small-scale DAQ. CMB-S4 is a seven-year survey aimed at answering questions on the earliest stages of the universe through the study of gravitational waves. It consists of 18 small aperture telescopes and 6 large aperture telescopes spread throughout two sites located in Chile and the south pole, compared to Simons' total of four telescopes. Due to the difference of these project's scale, SOCS has documentation currently directed solely at the researchers who work at Simons'. In CMB-S4, researchers must be able to install and run SOCS on the fly, and this will require much more thorough documentation than what's currently available. This summer, we documented the installation of SOCS on a clean computer running windows, and began to understand what building a software agent to interact with telescope hardware would entail. Future plans involve continuing this process, as well as beginning to simulate certain hardware in order to aid the creation of other necessary agents down the line.

Constructing a Fizeau Interferometer

Lillia Hammond, *Amherst College,* Poster #13

Fizeau interferometry is a precise measurement tool for laser wavelengths and can be highly useful in experiments requiring laser pulses of specific wavelengths. When conducting AMO experiments, having an efficient and precise method of measuring laser wavelengths is essential. We have constructed a Fizeau interferometer and coded an algorithm to do just that. We built the Fizeau interferometer by collimating a laser beam and passing it through two nearly parallel and highly reflective mirrors. The slight angle offset will induce an optical path difference for each ray that passes through the mirrors. The path differences will create an interference pattern due to light's wave properties. We captured the interference pattern with a camera sensor. With the collected data, we wrote an algorithm that took this pixel data and found the average distance between peaks in the interference pattern. The distance between peaks is directly proportional to the laser wavelength, so with this data, we can determine the wavelength of a laser. We published this to ImageJ, so other physicists can use our work to efficiently and precisely determine laser wavelengths.

The Influence of the Small-Scale Environment on Dwarf Galaxy Evolution

Casey Ann Horvath, *Ohio University,* Poster #14

We study the impact of the proximity of a neighboring galaxy on dwarf galaxy evolution by analyzing the relationship between dwarf galaxy properties and the distance to their nearest neighbors. Previous results indicate that galaxies in void regions are bluer, fainter, less massive, and have higher star formation rates. By comparing how these properties depend on the distance to the nearest neighbor for dwarf galaxies in voids and in denser regions, we can better understand how the void environment affects galaxy evolution. We find that the proximity of another galaxy does not affect the specific star formation rate in star-forming dwarf galaxies, concluding that the higher star formation rates observed in void galaxies are from the environment itself. We also find that quiescent dwarf galaxies with close neighbors have lower specific star formation rates than those with more distant neighbors. This indicates that the nearby neighbor accelerates the quenching of star formation in those galaxies.

Simultaneous Multi-Frequency Observations of Periodic Repeating FRB

Zhaoyu (Gemma) Huai, *Case Western Reserve University,* Poster #15

Fast radio bursts (FRB) are energetic millisecond-long radio pulses with large dispersion measure. Their origin has been suggested, but not fully confirmed to be magnetars, neutron stars with strong magnetic fields. To study such bursts over a wide frequency range, FRB180916, a repeating source with a period of 16.35 days, was observed simultaneously at400MHz and 1400MHz for 50 hours with the Giant Meter-wave Radio Telescope (GMRT) in India. We report the detection of 32 single pulse bursts at 400 MHz and zero bursts at 1400 MHz from these simultaneous observations. We also analyzed the frequency-dependent activity window exhibited by FRB180916 by combining these data with that from previous work and found some pulses occurring outside the optimal activity window established by earlier studies. Two bursts drift upward in frequency, with the highest drift-rate (+11(3) MHz/ms) yet detected, in contrast to the well-known downward drifting "sad trombone" effect seen in close to 100 FRBs. We compared the drift rate vs. frequency relation for the six drifting bursts we found, combined with the 30 bursts reported in previous studies. We fit different trends of drift-rate vs frequency, and found a linear fit with a negative slope to be a good fit, suggesting that FRBs exhibit shallower drifting patterns at lower frequencies, which has implications for the progenitor model.

Digital control of kilohertz acoustic oscillators

Ivy Huang, *Wesleyan University,* Poster #16

We demonstrate the use of inexpensive, software-based methods to control acoustic oscillations. The Ellis lab investigates a variety of non-Hermitian systems where active manipulation of the equations of motion can be used to engineer novel behavior. The instrumentation behind such manipulation and study of high-frequency oscillators is the focus of this research; we assess the efficacy of using a Raspberry Pi with external audio card connected to piezoelectric transducers to serve as a low-cost, easily reproducible, and versatile feedback loop. By developing our own software to interface with the Advanced Linux Sound Architecture, we apply our inexpensive hardware to sustain an effectively undamped and chiral 7 kHz gyration of an aluminum bar, correcting for asymmetry in x and y equations of motion. Features of our implementation include a matrix of finely adjustable gain parameters, recursive linear filtering to provide sub-sample control over phase shift and potential band-pass filtering, and concurrent data acquisition from two channels without interrupting the feedback loop.

Examination of the Membership and Variability of the Young Stellar Population in the Mon R2 Cluster

Sally Jiang, *Yale University,* Poster #17

The Monoceros R2 (Mon R2) star cluster is one of the closest large active star-forming regions. As an embedded cluster, it provides an excellent laboratory for studying star formation and early-stage stellar evolution of young stellar objects (YSO). One defining property of YSOs is their spectroscopic and photometric variability, caused by the object's environment and erratic properties. We determined the Mon R2 cluster's astrometric parameters using a list of previously associated stars in the YSOC catalog. We find the cluster's median and standard deviation values as follows: proper motion (R.A.) = -3.08±0.86 mas/yr and proper motion (Dec.) = 0.71±1.08 mas/yr and distance = 909±267/168 parsecs. We then assembled a new set of highly probable candidate members from Gaia DR3 based on the astrometric and photometric properties of YSOC-associated stars. With our new candidate list, we extracted optical light curves from the Zwicky Transient Facility, and we classified the stars using Q-M classification. We find that the Mon R2 star cluster is dominated by quasi-periodic symmetric variables, and lacking in aperiodic dippers compared to other similar stellar populations.

Manufacturing nanoscale structures with Nanoscribe

Yangheng Jizhe, *Case Western Reserve University,* Poster #18

Our group is dedicated to fabricating optical metamaterials using the technique of Two-Photon-Polimerization (TPP) with Nanoscribe, with the long-term goal of fabricating metalens with the same technique. We have tested the limits of Nanoscribe to produce nanopillar structures, reported aspect ratios up to 10, with a minimum lateral resolution of 300 nm. And we have done FDTD simulations to design the meta-atoms of a metalens functioning as a half-wave plate. In the poster, we will present our printed structures and simulation results. We would like to particularly acknowledge Dr. Joel K.W.Yang, Dr. Hao Wang, and their groups for providing us with guidance for gwl scripting.

Detecting Precipitation Bands Observed by SAMPEX using Power Spectral Density and a Self-Organizing-Map

Joann Jones, *Case Western Reserve University,* Poster #19

Precipitation bands are a form of relativistic electron precipitation in the outer Van Allen radiation belt. They contribute significantly to the rapid loss of electrons from the outer belt, yet their origin is still unclear. In this study, we develop an algorithm to automatically detect precipitation bands observed by the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) satellite (1992-2012) using an unsupervised machine learning technique called a Self-Organizing-Map (SOM). While traveling in a polar low-Earth orbit, SAMPEX measured counts of electrons with energies greater than 1 MeV. As opposed to much faster fluctuations in counts, such as microbursts, precipitation bands can easily be visually identified within the data. However, a visual survey of data is often impractical, biased, and hard to replicate. Instead, we separate the data and take the power spectral density (PSD) in order to detect these precipitation bands more efficiently. In a PSD produced from data containing a precipitation band, there is a clear peak within the low frequencies. This differs from the PSDs produced from data containing background events, which do not display such peaks. All of the PSDs from the count data are then fed into a SOM to be classified. The resulting data product is a catalog of precipitation band events that can be associated with L-shell, geomagnetic activity indices, and more recently available electromagnetic wave data from the outer radiation belt. The results from this study will be followed by a statistical analysis of precipitation bands to better understand the radiation belt dynamics.

Investigating jet charge for heavy and light quark jets in LHCb kinematics

MJ Khan, *Mount Holyoke College,* Poster #20

What are jets? In high-energy proton-proton collisions, quarks and gluons can escape the strong force bond & produce conical sprays of new hadrons called jets. What is a jet charge observable? Jet charge is an observable which is calculated as a momentum-weighted sum of the electric charges of the hadrons in the jet Why jet charge observable? It can help determine the flavor of quarks initiating a jet, in particular for light quark jets, based on Monte Carlo simulations of how light quarks hadronize. What is our goal? In this project, we study how well the jet charge observable performs to successfully identify the specific electric charge and flavor of the quark for heavy quark jets in LHCb kinematics, where we have both Monte Carlo and high-purity flavor-tagged real data samples available. In this way, we try to verify the accuracy and range of applicability of the jet charge observable.

Wave Packet Dynamics in Proximity to a Stationary Inflection Point

Serena Landers, *Wesleyan University,* Poster #21

Stationary inflection points (SIPs) are spectral singularities in the Bloch dispersion relations of periodic metamaterials. They emerge due to the formation of exceptional point degeneracies of the Bloch modes of the system. At the SIP, the group velocity and the second derivative of the dispersion relation with respect to the wavenumber k are equal to zero, signifying the formation of slow light which is robust against losses and structural imperfections. While previous studies have focused on monochromatic wave propagation in photonic structures with SIPs, here, we analyze pulse propagation. Using asymptotic series analysis and detailed numerical simulations, we quantify the spreading of such pulses. Our analysis allows us to design photonic circuits that maintain the shape of the wave packet via SIP dispersion engineering. Ultimately, the goal in these design schemes is to consider the interplay of the SIP slow light with the unavoidable nonlinear mechanisms and other experimental realities appearing in photonic arrangements.

Analysis of Black Hole Accretion and Feedback in CAMELS Simulations Using Artificial Intelligence

Sofya Levitina, *University of Connecticut,* Poster #22

In this project I expanded my analysis of black hole accretion and feedback, by employing the CAMELS simulations and neural networks. To achieve this I used Python to write code that extracted data from CAMELS. The written code was trained on the extracted data of set quantities such as when black hole is born, where it is born, the models of its transition into feedback, the models of its initial mass and speed. The algorithm analyzed the known results of the set data such as final black hole mass, final black hole speed, final black hole energy ejection, and the influence of black hole growth on galaxy evolution. Finally, I applied these trained algorithms to take set data and give predicted results. My initial training set was the Simba simulations due to their detailed data on black hole lives, and then I applied it to the IllustrisTNG simulations to test the robustness of my code. Robustness is defined by the ability of created neural networks to make accurate predictions regardless of the simulations they are applied to, their initial conditions, and their attention to black holes.

Marchantia Polymorpha Gemmae Interact as Capillary Multipoles on Fluid Interfaces

Katie Nath, *Williams College,* Poster #23

Marchantia polymorpha, or common liverworts, reproduce asexually by growing cup-like structures on their leafy thalli which contain multicellular propagules called gemmae. When rain fills the gemmae cups, mature gemmae are released, adsorb to the air-water interface, and subsequently are splashed out to grow into new plants. Gemmae have long been assumed to be passive agents, but their capillary interactions while attached to the air-water interface suggest they play a much more active role in liverwort reproduction. To investigate this, we directly measure capillary interactions of gemmae on both flat and curved fluid interfaces using brightfield and phase contrast microscopy as well as optical profilometry, and find that gemmae adsorbed to the water surface interact as capillary multipoles with a dominant quadrupolar character. Intriguingly, we observe different self-assembly behavior of multiple gemmae on flat fluid interfaces versus in their natural environment. This suggests that the gemmae cups may have evolved to shape the water surface to arrange the gemmae for better splash dispersal.

Probiotics delivery with nanofibers

Norah Nguyen, *Mount Holyoke College,* Poster #2

Past studies have linked human gut microbiota to a number of diseases where they can seemingly provide benefits, such as allergies, diabetes, obesity, and cancer. The delivery of live probiotic bacteria to the human gut can help to provide these effects. In this project, we explored the possibility of using alginate-based nanofibers as a biocompatible encapsulation technology for probiotic delivery. We used an optimized solution of sodium alginate (SA), poly(ethylene oxide) (PEO), and polysorbate 80 (PS80) of a 2.5/1.5/3 weight percent ratio as a shell solution. For the core, we used a 5 weight percent solution of SA with E. coli nissle. Nanofibers were developed using coaxial electrospinning with adjusted flow rates for core and shell solutions. Afterwards, the nanofibers were crosslinked in a calcium chloride solution of pH = 10 and rinsed in sterile deionized water. Then, we released the bacteria in LB EDTA (15 minute time point) and PBS (5, 15, 25, 35, 45 minute time points) solutions.

Categorizing ASAS-SN Rotational Variables

Anya Phillips, *Ohio State University,* Poster #25

Understanding the properties of binary star systems is a crucial problem in astronomy, as we find a majority of stars in to be in binaries. Rotating spotted stars (rotational variables) are key probes of these systems because many are expected to reside in close binaries where tidal interactions cause fast rotation and starspots. Here, we survey the properties of ~50,000 ASAS-SN rotational variables based on their ASAS-SN, Gaia, and APOGEE properties. We find that they divide into 8 distinct classes; three of main sequence and five of giants. The main sequence groups are MS1, MS2s, both groups of active single stars where MS2s have faster rotation rates, and MS2b, main sequence synchronized binaries. The giant groups are G1, fast-rotating synchronized binaries with aliased periods due to starspot placement, G2, sub-subgiants, an under-luminous and short-period subclass of RS CVn, G3, RS CVn themselves, G4s, recent merger products rotating rapidly enough to be flagged as variable, and G4b, sub-synchronous binaries beginning to tidally interact and not yet spun up to synchronicity. Several of the groups provide unique opportunities to better understand binary stellar evolution, and so given the large volume of our sample, the future expansion of the ancillary data from Gaia, APOGEE, LAMOST, and DESI on the stellar properties, rotation velocities, and binary properties of these rotational variables will be revolutionary.

Quantum Geometry of the Chirality Induced Spin Selectivity Effect

Smita Rajan, *Brown University,* Poster #26

Chirality underpins a vast array of physical systems, providing a degree of freedom that may often be hidden in plain sight but can give rise to exotic phenomena. One such effect which has garnered growing interest is the chirality-induced spin selectivity (CISS) in which ordered films of chiral molecules act as filters for electron spin, with substantial spin-dependent charge separation being realized. The CISS effect in molecules exhibits several hallmarks of topological insulators—spin-dependent transport, spin-locked states, and a nontrivial spin-orbit coupling. This reasoning is enhanced by the discovery of an orbital texture in the band structure of DNA-like molecules. As such, it seems critical to understand whether the spin-polarization from the CISS effect is due to a topologically nontrivial quantum geometry. Our approach involves examining the quantum mechanics of an electron constrained to a helical surface via thin-layer quantization. Additionally, we relate the geometric spin-orbit coupling derived from this approach to the spin-orbit coupling induced by supersymmetry in three dimensions, allowing us to analyze the quantum geometry due to the emergence of an SU(2) gauge connection. We then compute the non-abelian Berry phase and Chern number for the eigenstates of the Hamiltonian. Topological classification of chiral molecules potentially gives rise to novel exploitation of the CISS effect, expanding the field of spintronics into molecular materials.

Current Developments in the Application of Magnetocaloric Materials in Hyperthermia

Ekin Secilmis, *Brown University*, Poster #27

The conventional hyperthermia method relies on heating the parts of the body that contain the tumor, sometimes this denoting the whole body. With its co-therapies radiotherapy and chemotherapy, it is currently used to treat various types of cancer. Currently, hyperthermia presents hazards that can go up to impairment of bodily functions, tissue loss and even death, as the destruction of healthy cells remains inevitable with this method. In our previous work, a new approach to the Hyperthermia Method, making use of the magnetocaloric effect to reduce the risks was presented [1]. We had shown that magnetocaloric materials would provide precise, accurate and local temperature control and increase the comfort of the patient with their size. The suitable magnetocaloric materials are determined with their magnetic entropy change, the adiabatic temperature change, the Curie temperature, the Full Width at Half Maximum, and their bio-adoptability for the core-shell structure. Further on the applicability of the method, a core-shell structure may be used. Another option is to implant the MCM inside the leucocyte membranes. Althoughurther investigation on the subject remains needed, various materials complying with the required MC and core-shell characteristics are found in the literature, as well as alternative ways to produce new MCM are listed.

[1] Ali Osman Ayaşet al.;New application area for magnetocaloric materials: Hyperthermia method, Journal of Molecular Structure, doi.org/10.1016/j.molstruc.2021130010.

Construction of an Optical Microscope with Video Projector Illumination

Neha Sunil, *Miami University,* Poster #28

Due to the costs of using commercially available microscopes with individual filter sets for different methods of contrast-enhancement modalities, we created a design for a 3D printable microscope to make microscopy more accessible. Our design explores the utility of a video projector as the source of dynamic pattern illumination for a 3D printable microscope in conjunction with Raspberry Pi module and camera system. The video projector serves as both the source of illumination and projects a nonphysical filter focused on the back focal plane of the microscope's condenser lens in order to replace physical filters attachments required for commercial microscopes. With this two-fold use of the video projector, the setup provides a low cost solution in achieving difference contrast-enhancement modalities on top of traditional brightfield such as darkfield, Rheinberg, and oblique illumination as well as polarization microscopy. We quantified the imaging capabilities of our system by deriving the optical resolution from a Modulation Transfer Function using a modified version of the knife-edge method on an image of a 1951 USAF Resolution Chart. We present results confirming that the resolution of our imaging system is 8.55 μm in comparison to the ideal system's 6.33 μm and display images of radiolarian specimens with the various contrast-enhancement methods achievable with our design.

Simulating silo flow of soft particles in varying gravity

Abigail Tadlock, *Mount Holyoke College,* Poster #29

Common systems such as sand, soil, and even people on a crowded street can be examined through the lens of granular matter. Despite their ubiquity, there is no complete theory describing how granular systems flow, because the complex network of interparticle forces affects the bulk behavior in ways that are difficult to analytically describe. The commonly used Beverloo equation empirically models the flow of granular particles out of a silo geometry; however, it often fails for non-typical system configurations, such as those at non-normal gravity. We have conducted over 100 LAMMPS molecular dynamics simulations in a quasi-2D silo geometry, varying gravity, particle stiffness (Elastic Modulus), and outlet diameter. Using these simulations, we study the effect of gravity and particle stiffness on the flow rate and associated characteristics, such as velocity profiles and granular temperature. We introduce a dimensionless combination of particle diameter, density, stiffness, and the gravity of the system that collapses these measurements. We also observe and perform measurements on pressure waves present in the system.

Mass Loading Instability for Radiative Galactic Outflows

Ashley Tarrant, *Ohio State University,* Poster #30

The physics of launching multiphase galactic winds remains uncertain; cool (10^4 K) gas is observed moving out of nearby galaxies at high speeds, but the mechanism behind cool gas acceleration is still a mystery. One possibility is that the clouds are ram pressure accelerated, but in this case the clouds are typically destroyed and incorporated into the hot phase. This process mass-loads the flow which increases the flow density and decelerates it. Here, we describe the instability behind this process and quantify how much mass-loading is necessary to allow radiative cooling to occur. When mass-loading is sufficient so that the flow is decelerated through critical Mach numbers M=1 and $1/\sqrt{3}$, the process is overstable which results in filamentary structures that should be visible in X-ray observations. We use 3D time-dependent hydrodynamic simulations to confirm recent 1D steady-state results for both planar and spherical mass-loaded flows. Our results show that mass-loading of hot winds can produce cool material with high velocity without ram pressure acceleration.

Probing microtubule-kinesin active matter in a low activity regime

Sasha Toole, *Mount Holyoke College,* Poster #31

Countless living systems exhibit complex behaviors driven by the spontaneous self-organization of their constituents. The dynamics of these systems occur far from equilibrium and often rely on the localized consumption of biological energy sources. In this work, we leverage kinesin-driven microtubule networks as a simple experimental system to quantify non-equilibrium material behaviors. By limiting kinesin-motors' access to energy-rich ATP, we tune the activity of our reconstituted ensembles, allowing us to probe the transition between fluidized and elastically gelled protein suspensions. We observe that our system's dynamics depend non-trivially on ATP concentration and can be further tuned by varying an incorporated ATP regeneration backbone. Together, these observations lend a new perspective on the energy-consuming protein interactions that drive emergent non-equilibrium flow in active materials.

Traces and their relation to the density operator

Sarah Tucker, *Ohio Northern University,* Poster #32

We present a general overview of the important linear algebra concept of trace of an operator and we discuss, with computational examples, some of its applications to quantum mechanics, specially the density operator for pure and mixed states.

Using Astrometric Jitter to Find Recoiling AGN Candidates in Optical Imaging Survey Data

Anavi Uppal, *Yale University,* Poster #33

When supermassive black holes (SMBHs) combine during a galaxy merger, special conditions can sometimes cause the newly merged SMBH to be kicked out of the center of the galaxy through gravitational wave recoil. If this SMBH retains its inner accretion disk, it can be visible as an off-nuclear recoiling active galactic nucleus (AGN). At present, only a handful of recoiling AGN candidates have been found, and none have been robustly confirmed. Creating a large sample of recoiling AGN would enable us to study the effect of displaced AGN feedback on galaxy mergers, and to constrain the mass and spin evolution of binary SMBHs. We present a new method that uses astrometric jitter to identify recoiling AGN candidates in optical imaging survey data. We apply this method to the Pan-STARRS1 3pi Survey which obtained ~10 epochs over a baseline of three years in grizy bands over 30,000 square degrees of sky, and present our best recoiling AGN candidates. Our method can be easily adapted to work with data from the future Vera C. Rubin Legacy Survey of Space and Time (LSST). Since LSST will have a higher cadence and a deeper magnitude limit than Pan-STARRS1, it should be possible to detect many more recoiling AGN candidates.

Simulating Antihydrogen Annihilation Trajectories in ASACUSA's Cusp Trap

Alison Weiss, *Amherst College,* Poster #34

The hyperfine structure of hydrogen is known very precisely, and if Charge, Parity and Time reversal (CPT) symmetry holds, antihydrogen will have the exact same spectrum. CPT violation may help explain the Baryon Asymmetry, the mysterious and presently unexplained fact that the universe contains much more matter than antimatter. The Atomic Spectroscopy And Collisions Using Slow Antiprotons (ASACUSA) Collaboration aims to measure the ground state hyperfine structure of antihydrogen in a magnetic field-free region with a precision of 1 ppm. Antiproton and positron plasmas which are produced further upstream are combined in the Cusp trap. The ASACUSA-Cusp collaboration is working to increase antihydrogen production within the Cusp trap in order to have enough antihydrogen to make a precision measurement. We simulate antihydrogen annihilation patterns in ASACUSA's Cusp trap using Simion. We then process the data output by Simion to account for plasma rotation and thermal velocity distribution. Understanding the annihilation patterns will permit the interpretation of experimentally detected antihydrogen annihilation data. This will help us to optimize plasma properties for producing more antihydrogen.

Subcellular Steering with Optogenetic Neutrophils

Chloe Widman, *Brown University,* Poster #35

Neutrophils are key immune cells in the inflammatory response: they circulate to locate pathogens, eliminate microbial invaders in multiple ways, and produce signals for other immune cells. These neutrophils are driven by reaction-diffusion waves that propagate signaling cues for migration, morphology changes, and phagocytosis. Ongoing research involving neutrophils and its model cells is concerned with understanding the behavior of these waves as they travel intracellularly. With optogenetics, a stimulation method that exploits light-activated proteins to control activity at the subcellular level, these questions can be tested. To create activation waves with light signals, one must use an optical system that directs spatially and temporally controlled laser light into a cell. In this project, I fabricated such a system using a spatial light modulator, a device that utilizes phase manipulation to alter the shape and position of an input beam. After building an appropriate beam path, I used the spatial light modulator to generate example stimulation patterns for testing wave propagation in neutrophils, including arcs of light that move to mimic naturally observed waves in model cells. Having shown the feasibility of this stimulation tool, I now propose methods of subcellular steering to test the spatiotemporal dynamics of these waves.

Searching for Heavy Neutrinos with Large Transition Magnetic Moment using MicroBooNE Data

Julia Woodward, *Amherst College,* Poster #36

Beyond Standard Model events are potential sources for the low-energy excess investigated by a neutrino detector such as MicroBooNE. One such source is heavy neutrino decay, during which a heavy neutrino with a nonzero transition magnetic moment decays into a single photon and a light neutrino. In this research, I investigated single-photon electromagnetic showers in the MicroBooNE detector produced via this neutrino interaction. I first generated heavy neutrino production and decays using the DarkNews generator to explore the kinematics and behavior of these interactions. I then used the generated data to simulate events in the MicroBooNE detector, using high statistics to build on previous analyses. I selected heavy neutrino signal in the detector and rejected backgrounds to the signal by using boosted decision trees that filter events. After signal reconstruction and optimization under one set of parameters, we observe a signal significance of 0.127σ for 1 signal event and 53 background events at 6.91e20 protons on target (POT). This research explores the contributions from neutrino interactions in the dirt surrounding the detector, as well as investigates MicroBooNE's sensitivity to this signal given different parameters such as mass and transition magnetic moment.