2026 Undergraduate Physics Research Symposium

Thursday-Friday, September 24-25, 8:30 AM - 4:00 PM + Social Hour on Friday, 4:00 - 5:30 PM
Dynamic 10-minute talks by 62 Undergraduate Researchers from 43 Research Groups
Event organized by Brishti Chakraborty, Derek Lee, and Professor Mark Srednicki

THURSDAY

8:30 AM Opening Remarks
Brishti Chakraborty, Derek Lee, Mark Srednicki

8:38 AM Uryk Milian
Mentors: Deborah Fygenson, Connor Chatfield

Steric Domains Disrupt Nanostar Liquid Liquid Phase Separation by Stabilizing Clusters

DNA nanostars (NSs) are programmable, non-covalently interacting macromolecules that can undergo liquid-liquid phase separation (LLPS). We investigate the effect of structural asymmetry on LLPS of six-armed NSs, particularly on the relative concentration of the dense and dilute phases (a.k.a. the partition coefficient), when one of the arms is incapable of NS-NS binding. We find that, when the length of the inert arm is >3x that of the other arms, the partition coefficient decreases with NS concentration. Using dynamic light scattering, we show that the changing partition coefficient is caused by the formation of clusters comprised of a large number of NSs (>100) that depends on the binding arm length. The cluster phase emerges as the NS concentration increases, eventually replacing the condensate phase altogether.

8:51 AM Roxana Faridjoo
Mentors: Deborah Fygenson

Achieving Aster-like Organization of Filaments Nucleated by Condensate

Centrosomes are biomolecular condensates that nucleate and anchor microtubules by concentrating tubulin. This project seeks to replicate centrosome-like behavior using DNA nanotechnology to test how condensate-induced concentration drives filament nucleation and organization. We created a centrosome-like system from DNA nanostar condensates and tiled DNA nanotubes. In the first iteration, nanotubes formed outside the condensate, anchored to condensate surfaces, and extended tangentially. I aim to achieve a more centrosome-like radial organization of nanotubes by redesigning the nanostar-nanotube interaction. First, I am reducing the condensate diameter, D, to be less than the persistence length of nanotubes, Lp. Although it is not possible to achieve as small a D:Lp ratio as that of a biological centrosome, any D<Lp may suffice to reduce the tendency of nanotubes to curve along the condensate surface. Second, I am introducing a unique nanotube-binding domain on the nanostars, making the nanotubes guests in the condensates rather than participants.

9:04 AM Matthew Li
Mentors: Deborah Fygenson, Ruiyao Liu

Effect of Temperature Changes in the Bending Behavior of DNA Nunchucks

Understanding the dynamics of double-stranded DNA (dsDNA) is important for engineering with dsDNA structures. To study dsDNA bending behavior, we use a novel, single-molecule technique based on DNA nunchucks. DNA nunchucks consist of a pair of tiled DNA nanotubes on either side of a short dsDNA linker. Nunchucks are formed by self-assembling the linker between a pair of DNA origami nanotube “seeds” that then nucleate tile growth. The DNA nanotube “arms” mechanically magnify the bending motion of the dsDNA linker, allowing for real-time observation under a light microscope. The angle formed by the arms and how it changes over time provide information about the properties of the linker such as its flexibility. Here I report on how temperature affects dsDNA stiffness based on how the nunchuck bend angle distribution changes between 14°C, 25°C (room temperature), and 45°C.

9:17 AM Neha Desigar
Mentors: Omar Saleh, Michio Tateno (Materials)

Simulating Phase Geometries of DNA Nanostar Droplets With Particle-Size Asymmetry

Droplets comprising synthetic DNA nanostars have recently emerged as model systems for liquid-liquid phase separation, due to their programmable physical properties. Previous experiments have produced droplet-in-droplet or side-by-side phase geometries, which are particularly interesting for understanding complex membraneless cellular structures like the nucleolus. Experimentally testing all the relevant microscopic design parameters is unfeasible, so a simulation that systematically explores this parameter space would be helpful to identify geometries of interest. Prior simulations have focused on symmetric nanostars, but we expand this to systems of asymmetric particles by scaling the excluded volume while accounting for nanostar species, arm-length asymmetry within particles, and sticky end binding strengths. We have implemented 1D, 2D, and preliminary 3D simulations using the Cahn-Hilliard equation and Wertheim free energy theory. These produced droplet-in-droplet systems when binodal dense-phase densities differed sufficiently between components, and qualitatively replicated experimental results for a two-component asymmetric system with 16-20 base pair arms.

9:30 AM Eloi Prat Padró
Mentors: Isabel Pastor Del Campo (Universitat de Barcelona), Lukas Kühnemann (Universitat de Barcelona)

Measuring the Free Energy of a Single Molecule with Optical Tweezers

Most of what we know about molecules comes out of averages of over 10^23 of them, smoothing out the complications, individual jumps, pauses and failures that make molecular behavior unpredictable in specifics. Single-molecule force spectroscopy lets us do thermodynamics one object at a time, pulling apart a DNA hairpin while force and distance are recorded. With this talk I'll follow a measurement from the bench to the number. How optical tweezers operate, how they are built, and how an irreversible pull's force-distance curve becomes a free energy measurement through fluctuation theorems. Based on a six-week research stay in the group of Fèlix Ritort, Universitat de Barcelona, where I learned the instrument, built the chambers these experiments run in, and got to operate the optical tweezers.

9:43 AM Kira Collins
Mentors: Zvonimir Dogic, Christopher Ramirez

Examining Crosslinked Colloidal Membranes Under Varying Environmental Salinity

Colloidal membranes, self-assembling monolayer sheets of 200nm long rod-like colloids, provide an analogous system to study the dynamics of membrane folding. They are biocompatible, porous, and have future applications in drug delivery and cell morphogenesis. However, the formation and stability of these colloidal membranes is dependent on specific salinity and depletant concentrations in the surrounding solution. To stabilize colloidal membrane properties over a wider range of solution conditions, we develop a method to photocrosslink the colloids using UV-mediated thiol-norbornene click chemistry. Upon UV exposure, the colloids are locked in place, allowing the membranes to retain their shape amidst changes in the salt concentration of the solution. We then observe an immediate contraction of the membrane area due to forces exerted by the crosslinking polymer chain. Later, upon decreasing salt concentration, we can then tune the electrostatic forces between the colloids to expand the membrane area again.

9:56 AM Seamus Kenna
Mentors: Zvonimir Dogic, Nicholas Cuccia

Accordion Flagella: Exploring the Tunable Pitch of Coiled Flagella

Flagella derived from salmonella are unique, spiral shaped, biological filaments whose shape (pitch and radius) comes in eleven conformations. The properties of most of these conformations are well understood in the literature, however the coiled conformation, that with the smallest pitch, has values for pitch that vary widely between papers. Over the summer I have explored what might be causing this variability. I found that the pitch of coiled flagella depends on temperature, varying continuously from approximately 1um at 4C to below the diffraction limit of optical microscopy (~250nm) at 50C. In addition to temperature, I have observed that the density of the fluorescent dye (NHS-Rhodamine) on a flagellum affects pitch. The continuous nature of this shape change, as opposed to the discrete shape changes previously studied between conformations, unlocks the opportunity to create and explore smoothly expanding and contracting networks of entangled flagella.

10:09 AM Aliza Lam
Mentors: Zvonimir Dogic, Isabel Ruffin

Measuring multiscale forces in the global collapse of an active network

Biological cells are made up of complex, out-of-equilibrium systems, often driven by internal forces. Studying internally driven forces is difficult so most models only study the effect of external forces on a network. We investigate a transition between two non-equilibrium states where microscopic active stresses lead to global network collapse. In cells, kinesin motor proteins walk on stiff microtubule rods. A motor fixed in place can propel a microtubule. We bind kinesin motor proteins to a viscoelastic actin network. When the motor proteins push microtubules, the motors exert forces on the network. Increasing the microtubule concentration increases the force on the network, triggering a collapse. We can characterize the actin network’s transition from stable to collapsed at multiple scales, using fluorescence microscopy to visualize dynamics on the single microtubule scale to the bulk deformations. A better understanding of these transitions will help us build fundamental models of complicated cellular environments.

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10:33 AM Yutong Hu
Mentors: Zvonimir Dogic, Qi Zhang

Rotating Microtubule Networks Confined Inside Active Vesicles

Preliminary experiments have shown that droplet-like confinement can induce a transition from disordered, chaotic flows to coherent circular motion when the activity and interfacial properties are appropriately tuned. In this regime, the internal active stresses self-organize into a persistent rotational flow, giving rise to a "rolling"-like motion of the entire droplet, where internal circulation is tightly coupled to global translation and deformation of the interface. This behavior is a clear signature of spontaneous symmetry breaking, in which an initially isotropic system selects a preferred direction of motion without external bias. Such emergent coherence highlights the potential of confinement and interface mechanics as powerful control parameters for directing active matter dynamics.

10:46 AM Lillian Raesler
Mentors: Zvonimir Dogic

Quantifying Contraction: Amazingly Active Actomyosin Gels

The mechanism of contraction is essential for diverse life-sustaining functions, not only in whole muscle tissue but also within the cell. Contraction is driven by interactions between two key proteins: semi-flexible actin filaments and myosin motors. In skeletal muscle, actin filaments form organized sarcomeres to generate contraction, while inside cells, actin filaments form jumbled networks. These cytoskeletal networks drive essential processes like cell division, but their mechanisms are less understood. Our project reproduces simplified, quasi-2D actomyosin gels to map the local stresses and strains generated by myosin motors. We observe that network structure and force generation depend on energy availability, mirroring behaviors of living cells. Understanding this system will help us build accurate physical models of biology and answer questions in active matter about how biological components coordinate to produce large-scale motion. Studying these active systems could also help develop materials that mirror the amazing functionality of protein networks!

10:59 AM Calder Orrell
Mentors: Dirk Bouwmeester

Towards Biophoton Detection in Neuronal Mice Primary Cultures

Consciousness encompasses our entire perception of reality, and for that very reason it remains elusive, lacking concrete evidence of its physical origins and a rigorous theoretical framework. Quantum mechanics may offer a solution to this conundrum, despite being seemingly irreconcilable with the warm, wet environment of the brain. If quantum processes play a role in neural computation, any kind of transition of a quantum state to a lower energy level can emit this energy as electromagnetic radiation. We develop a sensitive imaging set-up to detect possible ultraweak photon emissions (UPE) from biological samples. Imaging neuronal cultures from dissociated mice brains plated on Micro-Electrode Arrays (MEAs) capable of measuring neurons firing provides the possibility of correlating neural activity with photon emission. Our system may enable us to detect UPE from a variety of biological sources and provide a platform for non-invasive measurement of cellular metabolic stress.

11:12 AM Nicholas Renner
Mentors: Taro Matsuo (University of Osaka)

A Potential Biosignature for Exoplanets: Examining the Visible Spectrum Characteristics of Coccolithophores

Recent remote sensing data has highlighted a coccolithophore bloom in the Black Sea. We are investigating the bloom as a possible new biosignature for exoplanetary study and its potential use on the future NASA Habitable Worlds Observatory. Coccolithophores are oxygenic phototrophs that thrive in oceans limited in nutrients. On Earth during the mid-Cretaceous greenhouse climate, coccolithophores rose to global ecological prominence due to substantially warmer surface oceans reducing upward nutrient supply from deeper waters. Coccolithophore blooms dramatically enhance the reflectance of oceans because they produce coccoliths (roughly $CaCO_3$). Compared to other ocean-dwelling micro-organisms, coccoliths can be dispersed by ocean currents quite rapidly, as they are non-living particles much smaller than their "mother cells". We are designing and running experiments targeting the optical properties and settling velocities of coccoliths, so that we may model and assess the viability of coccolithophore blooms as a detectable surface biosignature.

11:25 AM Chenhao Wang
Mentors: Ousmane Kodio (Mechanical Engineering)

From Circular Spreading to Star-Shaped Fracture in an Aging Protein Film

When an oil drop spreads on water coated by a whey-protein film, the interface can remain circular or develop a star-shaped fracture. We investigate how aging and viscoelastic relaxation determine these phenomena. Experiments indicate that aging transforms the interface from fluid-like to mechanically coherent, motivating a 2D viscoelastic model with elastic area response and Maxwell shear relaxation. The model yields a double-exponential loading history that, together with local Griffith initiation and global energy-capacity criteria, predicts fracture phases and crack number. GPU material point method (MPM) simulations provide a numerical test. Although phase classification and crack-number predictions retain quantitative bias, the model reproduces the overall topology and characteristic boundary trends, as well as how crack number N varies with the control parameters.

11:38 AM Romer Rosales-Hasek
Mentors: Demian Riccardi (National Institute of Standards and Technology)

Using Replica Exchange Molecular Dynamics to Sample Inhibitor-Bound ERK2

In cellular biology, the RAS-RAF-MEK-ERK pathway is an important signaling cascade that mediates cell growth. Dysregulation of this pathway can lead to uncontrolled cell proliferation, a hallmark of many cancers. Being the final effector in this cascade, ERK is a crucial target for therapeutic drugs, yet its activation mechanism remains poorly understood. From our 2023 long conventional molecular dynamics study, we identified that ERK's activation loop repeatedly settles into 3 distinct metastable contacts with the enzyme core for several microseconds before unsettling and forming new contacts. Separately, NMR experiments of inhibitor-bound ERK have identified two states labeled L and R; whether these states correspond to the computed settled states is unclear. To understand the relationship between the states observed in experiment and simulation, I created a workflow for conducting inhibitor-bound ERK simulations. I discuss the process behind parametrizing force-fields for co-crystals, a crucial task for ensuring reliability of simulation results.

11:51 AM Daniel Fischel
Mentors: Cristina Marchetti, Divyoj Singh

Emergence of Order in Microridge Development

A central question in biophysics is how living systems generate ordered patterns from disordered initial conditions. Microridges are maze-like actin-based protrusions on the apical surface of mucosal epithelial cells that provide a striking and experimentally tractable example of this problem. Despite the wealth of experimental data, a quantitative physical description of microridge pattern formation remains elusive. Here, we analyze the transition of microridges from stochastically distributed puncta into regularly spaced, ordered arrangements. We quantitatively characterize their emergence by measuring characteristic ridge spacing, spatial correlation functions, and the dynamics of topological defects. Our measurements reveal a progressive maturation towards a smectic state. By quantifying these defect dynamics and the remodeling forces associated with acto-myosin activity, this work lays the foundation for understanding the precise relationship between mechanical stress and the emergence of long-range order.

12:04 PM Lauren Lapajne
Mentors: Matthieu Louis (MCDB), Mihai Bibireata (Biomolecular Science and Engineering)

Testing The Robustness Of Network Computations on the Larval Drosophila Brain

In recent years, a synaptic-level mapping (connectome) of the Drosophila larval brain has been developed. However, the connectome was created only once, leaving opportunities for error. The goal of this research is to quantify the extent to which perturbations in synapse counts alter network computations. We tested this by creating 200 samples of perturbed networks under Gaussian noise and rerunning computations to compare results from the original network and perturbed networks. We focused on PageRank, Closeness, and Betweenness centrality measures in our analysis and computed p-values and IoU scores to assess the robustness of each measure. We found that all three centrality measures were robust to Gaussian noise; however, PageRank appeared most robust, followed by Closeness, and lastly Betweenness. This is valuable information as we can now more confidently use these centralities to better understand the Drosophila brain.

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12:28 PM Harry Kroft
Mentors: Boris Shraiman, Henrik Weyer

How Gene Networks Pattern Cell Fate

Each time an embryo develops, cells must reliably differentiate into distinct, spatially prescribed cell types in accordance with the organism's eventual body plan. Global positional information provided by chemical morphogen gradients is inherited locally by gene regulatory networks (GRNs) within each cell, wherein dozens of molecular regulators interact to control gene expression levels that determine the function of the cell. As physicists, we treat these networks as high-dimensional dynamical systems and investigate what dynamics allow them to translate position into robust fate patterns. By training in-silico GRNs to generate target patterns, we can probe the resulting networks and ask what dynamical principles they rely on, in the hope of learning something about what components are required to encode patterns of increasing complexity, and perhaps what "complexity" should even mean in this context.

12:41 PM Wesley Rullman
Mentors: Paul Atzberger (Mathematics)

Training as Thermal Escape: Rare-Event Theory for Learning Dynamics

Training a neural network means letting a noisy optimizer wander a rugged landscape of parameter settings in search of a good one. That is the same picture physics uses for a particle trapped in a well, occasionally kicked over a barrier by random noise, and the analogy turns out to be quantifiable. I'll introduce the theory of these rare escape events and the statistics of how long they take, then show that on small learning problems the predictions hold closely, with the barrier height read directly off the loss landscape. The second half will go into depth on how a model's architecture enters that escape time. Different features of the design turn out to enter at different orders: some merely rescale the time by a constant, others sit in the exponent and cost exponentially, and at the extreme some make escape not slow but impossible.

12:54 PM Qia Wang
Mentors: Matthew Fisher, Jake Hauser

Nonlinear Probes of Phases and Criticality in 1D Open Quantum Dynamics

Monitored open quantum systems can exhibit distinct steady-state phases characterized by different patterns of symmetry breaking and information flow. I study a one-dimensional Z2-symmetric open quantum system with weak Pauli-X and Pauli-ZZ measurements and dephasing using tensor-network simulations of the doubled density matrix. To characterize its phase transitions, I compare several nonlinear observables, including Edwards–Anderson and Rényi-2 correlation functions and their associated Binder parameters, together with the reference entropy as an information-theoretic diagnostic. These probes capture complementary aspects of weak- and strong-symmetry breaking and the fate of initially encoded quantum information. By analyzing their finite-size crossings and scaling behavior, I investigate whether different nonlinear observables identify the same bulk critical points and how their finite-size behavior may differ near the same underlying transition.

1:07 PM Brishti Chakraborty
Mentors: Leon Balents

Adding a Flux Quantum to the Hofstadter Butterfly

A lot of novel physics is found in 2-dimensional materials. The spectrum of an electron in a 2D lattice in a perpendicular magnetic field is known for $2\pi/n$ flux: the Hofstadter butterfly. Last summer, I rederived this spectrum, investigating different lattices and solving systems analytically and computationally. In recent work, I have investigated the effect of adding a single flux quantum (2π flux) to a square lattice with π flux through each square plaquette. This has created a new zero energy state for even lattice sizes. I have investigated this zero energy state by plotting the wavefunction for various sizes of lattice and values of added flux, also investigating the degeneracy of these zero energy states. I then introduced an interaction term, perturbatively exploring bosonic Hubbard interactions. These methods are used to build wavefunctions for quantum magnets using the Gutzwiller projection, or to investigate Moire patterns in 2D materials.

1:20 PM Parsa Pourghasem
Mentors: Cenke Xu

From Quantum to Classical: SW-SSB in dephased Fermi gases

The building blocks of all matter obey the strange laws of quantum mechanics, yet the world we observe every day is boringly classical due to thermal fluctuations and probabilistic effects. Exposing a system to noise and heat ruins its quantum nature, but is there a sharp point we can call the "quantum-classical phase transition"? Recent results show that strong-to-weak spontaneous symmetry breaking (SW-SSB) marks a clear shift from quantum to classical. My research this summer focused on exploring this novel transition under a few particular conditions; I calculated the scaling behavior of quantities used to diagnose SW-SSB in a free-fermion system exposed to the environment for a long time (dephased). I found a connection to a previously solved model, enabling me to compute a hierarchy of values using a method called the doubled-space representation. I am working to formalize this result and explore other connections.

1:33 PM Noah Brody
Mentors: Yasuhiro Niimi (University of Osaka), Tomoki Kobayashi (University of Osaka)

Large upper critical field in thin flake superconducting quasicrystal Ta1.6Te

Superconductivity in quasicrystals was first reported in an Al-Zn-Mg quasicrystal but the very low critical temperature of 0.05 K impeded further study of the superconducting state of qausicrystals. Then superconductivity was reported in Ta1.6Te at a much higher critical temperature of 1 K. Ta1.6Te is a unique transition-metal chalcogenide, van der Waals layered quasicrystal with a 12 fold symmetry. We prepared thin flake samples with manual exfoliation and performed magnetotransport measurements in a cryogen-free dilution refrigerator. We found that the out-of-plane upper critical field follows a collective flux creep model consistent with other thin flake superconducting crystals and the in-plane upper critical field exceeds the Pauli limit by a factor of 2.7. We propose that the enhancement of the in-plane upper critical is caused by spin orbit interactions like spin orbit coupling and spin orbit scattering.

1:46 PM Ruiyi Xiang
Mentors: Chenhao Jin, Chen Huang

Using a WSe2 Exciton to Probe Propagating Modes in Graphene

Collective electronic modes in graphene can carry spin and valley information with little net charge motion, making their propagation difficult to detect using conventional electrical transport. In this project, we aim to develop an optical approach using excitons in monolayer WSe2 as a local sensor of the electronic response in nearby bilayer graphene. Current work focuses on heterostructure assembly, device design, and fabrication. Future optical measurements will investigate whether the WSe2 exciton response can be used to resolve propagating collective modes in BLG.

1:59 PM Alex Russano
Mentors: Andrea Young, Ben Foutty

Development of a Feedback Mechanism for NanoSQUID Series Array Amplifiers

NanoSQUID (Scanning Quantum Interferometric Devices) are widely used to measure the magnetic and thermal properties of two-dimensional systems like graphene. Due to the low critical temperatures and high sensitivity of the NanoSQUIDs themselves, SQUID systems often use a SQUID Series Array Amplifier (SSAA) circuit as an ultracold low-noise amplifier of current through the SQUID. However, the electronics that maintain the sensitive position of the SSAA on its I-V curve limit the ability of SQUIDs to measure changes caused by high-frequency AC modulations in sample gates, which reduce noise as 1/f. Therefore, we utilize DAC/ADC system that emulates closed-loop feedback and adds an open-loop mode of operation for SQUID measurements to occur in, effectively reducing noise.

SHORT BREAK

2:23 PM June Kim
Mentors: Michel Devoret, Zhixin Wang

Fluctuations in Microwave Dispersive nSOT Magnetometer

NanoSQUID-on-tip magnetometers (nSOTs) are among the most sensitive devices for measuring magnetic fields. It is composed of a superconducting quantum interference device (SQUID), a superconducting loop interrupted by two Josephson junctions, which is located on the apex of a sharp tip and enables magnetic flux sensing with nanoscale spatial resolution. When operated in a dispersive microwave readout scheme, the nonlinearity due to the Josephson junctions increase device sensitivity, but can also introduce bistability and enhanced fluctuations leading to measurement instability. We model the nonlinear dynamics of the system as a driven Kerr resonator and investigate its behavior near the bistable regime. Using both classical and quantum descriptions, the latter implemented via QuTip, we characterize the resonator's response and analyze field fluctuations near and within the bistable region. Through this analysis, we aim to explore the tradeoff between increased device sensitivity and measurement stability.

2:36 PM Tom De Quercy
Mentors: Michel Devoret, Max Schäefer

Fabrication of Multimode Resonator and Loss Factor Investigation

It is worthwhile to find better-behaved materials for superconducting circuits for building qubits besides currently popular materials, e.g. aluminum and niobium. To examine if one material is good for cQED, it is important to understand its loss channel. Therefore, having a portable device that can be applied to any material and characterise different loss channels and their contributions is imperative. A resonator is an appropriate device for achieving the goals and inferring the optimal material with treatment. For this summer, we want to fabricate a combination of a 2D coplanar waveguide (CPW) resonator, which can investigate the surface loss factor and bulk loss factor. This design can be applied to predict the intrinsic quality factor of a new qubit design and to suggest how to enhance performance by identifying the dominance of different loss channels.

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2:49 PM Rajas Apte
Mentors: Jennifer Dionne (Stanford University), Remi Dado (Stanford University)

Tuning VINPix Nanophotonic Cavities for Optically Addressable Spin-Quibit Interfaces

I studied a high quality factor photonic resonator design, abbreviated VINPix, developed at the Dionne lab at Stanford University. Published in Nature Nanotechnology and Nano Letters, VINPix features a cavity section composed of a free-space coupled waveguide and adjoining photonic crystal mirror elements. The Q-factor and effective mode volume are highly tunable through geometric and refractive index perturbation, composing an agile platform for coupling to optically-addressable spin-qubits. I used finite-difference time-domain simulations, adapting a Si-on-sapphire cavity resonant near 1600 nm to a visible-range SiN-on-fused-silica platform, with a longitudinal slot. Simulations showed strong electric-field enhancement within the cavity slot. I also shadowed key fabrication and characterization processes supporting nanophotonic device development, including dry etching, plasma-enhanced chemical vapor deposition, surface functionalization by silanization, transmission spectroscopy, and two-photon confocal microscopy on a Leica Stellaris system, connecting the design of tunable metasurfaces with practical workflows to fabricate and evaluate photonic structures for spin-qubit interfaces.

3:02 PM Neil Munot
Mentors: Ania Jayich, Viraj Dharod

Engineering Diamond Mechanical Interfaces for Quantum Sensing

Diamond color centers, particularly nitrogen-vacancy (NV) centers, are promising platforms for quantum sensing, motivating the development of interfaces that can couple their spin states to mechanical systems. Mechanical resonators provide high-Q modes that can serve as intermediaries between spin, optical, and microwave degrees of freedom. Optical and electromechanical couplers provide two complementary approaches to interfacing with these mechanical modes. I previously designed and built an optical filter cavity for a diamond optomechanical crystal (OMC) experiment, where it formed part of the optical measurement and filtering chain. I am now working on the design and simulation of a diamond electromechanical coupler (EMC), which uses a microwave interface to drive and read out mechanical modes while avoiding optical absorption and the associated heating that can limit operation near the mechanical ground state. Using finite-element simulations, I am investigating how EMC geometry affects electromechanical coupling, mechanical quality factor, and fabrication feasibility. Future work will incorporate radiation-loss modeling, expanded geometric optimization, and fabrication-disorder simulations to develop realistic diamond EMC designs for future spin–phonon interface applications.

3:15 PM Phillip Davis
Mentors: Mark Sherwin, Alex Giovannone

How to Cut Light: Nanosecond Resolution Terahertz Pulse Slicing

By exposing spin systems to high magnetic fields, we can create a splitting in the spin's energy levels, known as the Zeeman effect. We can then drive this material with THz light, and this allows us to investigate the lifetimes of quasiparticles that emerge in these systems. This combination is known as Electron Spin Resonance (ESR). However, the primary method of producing THz light at high enough power for these experiments, a Free Electron Laser, produces pulses at microsecond windows, with uncontrolled phase. To investigate the quasiparticles of interest, however, we need nanosecond-length pulses with controllable relative phase. To remedy this, we have built a quasi-optical pulse slicer capable of reaching single nanosecond length pulses. We explore the science behind the quasiparticles we plan to study, the optical setup of the pulse slicer, and the electronic components and networking necessary to make the system work.

3:28 PM Wei-Hsu Lin
Mentors: Mark Sherwin, Alex Giovannone

Towards Probing the Quantum Zeno Effect in Cu(L-Met)2 with a Nanosecond-Resolution, FEL-Powered Pulsed ESR Spectrometer

A qubit coupled to its environment usually decoheres, yet under specific conditions, the Quantum Zeno Effect (QZE) occurs where strong environmental coupling can instead protect coherence, extending T1 and T2 in spin qubit systems. Cu(L-Met)2, a crystalline metal-amino acid complex with two inequivalent copper sites, provides a clean testbed for this phenomenon: environmental coupling produces an effective 2x2 non-Hermitian Hamiltonian, which predicts a bifurcation in ESR resonance energies and a revival in T2. On a low-power setup, we observed the predicted CW bifurcation but only a faint pulsed echo, demonstrating that further investigation requires nanosecond-scale resolution of spin dynamics. This need, shared by several other planned experiments, drove the construction of a frequency-agile, FEL-powered pulsed ESR spectrometer with nanosecond pulse slicing and a two-axis rotating sample holder for sample angle control. Calibration on diamond P1 centers and measurements on Cu(L-Met)2 pellet samples are imminent as the spectrometer comes online.

3:41 PM Peter Scherer
Mentors: Everett Lipman

Prototyping a Microwave Interferometer for Precision Seismology

Modern creepmeters can measure the relative motion of tectonic plates along a transform fault boundary with micrometer-scale precision over minutes. While sufficient for quantifying gradual fault slip, this resolution pales in comparison to that of interferometers, which measure changes in optical path length by exploiting the interference effects of overlapping electromagnetic signals. We are currently developing a microwave interferometer prototype for ranged detection of seismic fault slip. The latest iteration of our system uses recently developed phase-locked loop frequency synthesizers, granting us highly stable digital control of frequency and phase at 2.4 GHz. Initial benchmark testing yielded millimeter precision at target ranges of several meters, with both precision and range expected to improve substantially as the system is refined.

3:54 PM Sanjit Masanam
Mentors: Nadir Jeevanjee (Geophysical Fluid Dynamics Laboratory)

Understanding Diversity in Deep Ocean Heat Uptake

Solar radiation warms the Earth's surface and drives global warming. Meanwhile, various processes such as outgoing LW radiation, albedo, and deep ocean heat uptake (DOHU) tend to cool the surface by transporting heat away from the surface. Due to the deep ocean's large heat capacity and subsequent slow warming, the DOHU process plays a significant role in this heat export from the surface. However, the specific processes and mechanisms that drive DOHU, and how those mechanisms will evolve in a changing climate, are not well understood. To further investigate the drivers of DOHU, this talk presents various simple ocean models (2-box EBMs and diffusive models) calibrated to climate models and their DOHU evolution in time. The simplicity of these models, and their ability to reproduce the behavior of complex climate models, gives insight into the main mechanisms that drive DOHU.

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8:38 AM Junda Chen
Mentors: Christopher Palmstrom (Materials & ECE), Shirshendu Chatterjee (ECE)

Shadow Masks for Fabricating BiSb Hall Bars

BiSb alloys are topological insulators, which means they exhibit quantum hall effects under strong magnetic fields. To study them, Hall bars are fabricated on thin films of BiSb grown epitaxially on InSb. To combat the lack of efficiency with direct fabrication methods, we make shadow masks from doped silicon wafers using techniques including lithography, deposition, dry & wet etching. Shadow mask cells are then loaded into the high-vacuum condition of the Palmstrom Group Molecular Beam Epitaxy (MBE), with the epitaxial growth of BiSb through the cells. Hall measurements can be taken from samples loaded in a cryogenic environment, where the Shubnikov-de Haas (SdH) oscillations can be analyzed to reveal characteristics regarding the band structure of the material.

8:51 AM Julian Choi
Mentors: Christopher Palmstrom (Materials & ECE), Teun Van Schijndel (ECE)

Towards Single-Crystalline Tunnel Barriers in Epitaxial CoSi2/Si for Low Loss Superconducting Circuits

Josephson junctions are superconductor/tunneling barrier/superconductor structures that are crucial for superconducting quantum circuits due to their non-linear inductance creating an anharmonic oscillator when coupled to a capacitor. However, challenges in the development of these systems arise from the usage of polycrystalline and amorphous materials, theorized to host two level energy loss systems. Thus, one method of making progress in this field is to carefully select materials that best minimize this loss. Cobalt disilicide (CoSi2) is investigated due to its close lattice match with silicon (Si), which enables epitaxial growth on Si substrates. More importantly, Si can be grown as a single-crystalline tunneling barrier on CoSi2, potentially eliminating the usage of polycrystalline and amorphous materials. Molecular beam epitaxy is utilized to optimize a process that synthesizes high quality CoSi2 films by changing growth conditions, duration, etc. The films are analyzed using X-ray diffraction, atomic force microscopy, and superconductivity measurements.

9:04 AM Kasey Wang
Mentors: Elaheh Ahmadi (ECE), Navid Kafi (ECE)

Developing NbN/AIN/NbN trilateral films for superconducting devices

Superconducting quantum devices commonly rely on aluminum-based Josephson junctions, which require millikelvin operation and can be sensitive to thermal noise. Niobium nitride (NbN) based devices offer a promising alternative due to higher Tc, a larger superconducting gap, and greater tolerance to magnetic fields / thermal fluctuations when compared to aluminum. In this talk, I will investigate sputtered NbN/AIN thin-film heterostructures as a materials platform for nitride-based superconductor-insulator-superconductor junctions. NbN and AIN films are grown by reactive sputtering, with growth parameters varied to evaluate their effects on film continuity, surface roughness, crystallinity, and superconducting transition behavior. Atomic force microscopy is used to assess morphology and thickness uniformity, and X-ray diffraction is used to identify crystalline texture and phase quality. Low-temperature transport measurements are also used to determine superconducting transition temperature and film resistivity. These results are used to identify deposition conditions that produce uniform, crystalline films with favorable superconducting properties.

9:17 AM Orhun Ciftcioglu
Mentors: Sriram Krishnamoorthy (Materials), Akhila Mattapalli (Materials), Rachel Kahler (Materials)

Characterization of planar MOS Capacitors on Etched β-Ga2O3 Surfaces for Quality Evaluation

Understanding the influence of surface preparation and etching on electrical properties of Beta-Gallium Oxide (β-Ga2O3) metal-oxide-semiconductor (MOS) structures is essential in developing high-quality and high-performance power electronics. In this work, we investigated the electrical characteristics of planar MOS capacitors fabricated on β-Ga2O3 subject to four distinct chemical treatment conditions. The samples were prepared using two etching techniques: low etch damage MOCVD Ga etch; and the dry etch samples was followed by three chemical treatments: HF, HF & HCl, and HF & heated H3PO4. A Keithley probe station was used in order to obtain current-voltage (IV) and capacitance-voltage (CV) characteristics of these samples in order to evaluate leakage and dielectric characteristics of the device. The results provide further information about the effects of differing surface treatment techniques on device performance and contribute to the optimization of β-Ga2O3-based MOS devices for future power electronics applications.

9:30 AM Jose Gutierrez
Mentors: Jim Speck (Materials), Kent Nitta (Materials)

Reducing Leakage Current and Non-Radiative Recombination in III-N Optoelectronic Devices

MicroLED technologies have promising applications towards AR, VR, and smart-device displays however the sidewall effect serves to be a major barrier towards the commercialization of microLEDs. The sidewall effect is a phenomena which occurs during the fabrication process where the ions damage the sidewall of our LED resulting in high non-radiative recombination at the sidewall, drastically reducing the efficiency and light emission of our LEDs as size decreases. Commonly, wet chemical treatments are used for removing the sidewall damage. However we could alternatively confine the current from reaching the sidewall altogether which may reduce non-radiative recombination and leakage current. Additionally, stacked microLEDs offer the advantage of having various LED colors on one pixel allowing for a much higher pixel density.

9:43 AM Derek Lee
Mentors: Steven DenBaars (Materials & ECE)

Sidewall Passivation and Size-Dependent Efficiency in Long-Wavelength GaN MicroLEDs

MicroLEDs offer several advantages over conventional LEDs, including improved light extraction and more uniform current spreading, making them promising for efficient high-resolution displays. Their superior heat dissipation and higher modulation bandwidth also make them strong candidates for visible light communication, with the potential to reduce the energy footprint of data centers. Some reports suggest that long-wavelength III-nitride microLEDs even exhibit an inverse relationship between device size and external quantum efficiency (EQE). This is notable because smaller devices have a proportionally larger fraction of their active area near the etch-damaged sidewall, where dangling bonds and surface states promote carrier leakage and non-radiative recombination. Using the facilities of SSLEEC and the UCSB Nanofab, we fabricated long-wavelength GaN microLEDs to independently quantify the relationship between device size and EQE. This talk presents those results along with our efforts to suppress sidewall leakage through passivation schemes combining dry etching, wet etching, and dielectric deposition.

9:56 AM Tina Wu
Mentors: Daniel Blumenthal (ECE), Rahul Chawlani (ECE)

Simulation of Alumina Waveguides for Visible and Near-UV Photonic Integrated Circuits

Alumina (Al_2O_3) is a promising waveguide material for photonic integrated circuits due to its wide transparency window extending into the UV and its potential for low propagation loss. We present finite-difference time-domain simulations of alumina-on-silica waveguides at wavelengths spanning the near-UV to visible range (370–532 nm). Mode profile simulations characterize the effective index, group index, and mode area across two waveguide geometries for both TE and TM polarizations. We further simulate evanescent directional couplers to extract the coupling strength and 50/50 splitting length as a function of wavelength and waveguide width. These simulation results will inform the design of alumina-based photonic components, with future work extending to ring resonator structures.

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10:09 AM Hayden Borg
Mentors: Thomas Kruijer (Lawrence Livermore National Laboratory)

Evidence Against Giant Planet Migration Based on Statistical Analysis of Nucleosynthetic Isotopic Compositions of Bodies of the Inner Solar System

The isotopic composition of planetary materials are highly variable, reflecting the fact that they are mixtures of elements produced in stars, super novae, and by neutron star mergers. We have identified a correlation between heliocentric distance and the nucleosynthetic isotopic composition of materials from Earth, Mars, and the asteroid Vesta. Statistical analysis is consistent with a linear relationship between isotopic composition and heliocentric distance for 8 of 9 measured isotopic systems. This implies that Earth, Mars, and Vesta have remained in their current positions since they were accreted during the primordial stages of solar system evolution. Current models of giant planet migration, in which Jupiter and Saturn move inwards and then outwards after their formation, would disturb the orbits of Earth, Mars, and Vesta. Thus, these observations challenge such models of giant planet migration.

SHORT BREAK

10:33 AM Sarah Choi
Mentors: Maxwell A. Millar-Blanchaer, Ryan D. Hersey

Wavefront Metrology for an Exoplanet-Imaging Moderate-Contrast Coronagraphic Testbed

Finding habitable worlds has been the inspiration for generations of astrophysical research. Several methods are used to detect and characterize potential exoplanets, including radial velocity, transit photometry, and direct imaging. Of these, only direct imaging captures light from the planet itself, which requires suppressing the host star's infrared emission relative to the much fainter planet. Coronagraphs require a flat, collimated input wavefront, since deviations from flat limit achievable contrast; this is difficult to maintain due to several factors including misalignment and deformable mirror drift. We present a closed-loop wavefront metrology system that successfully corrects for deformable mirror drift, maintaining a stable wavefront over short timescales. In future work, we will perform closed-loop wavefront control for longer timescales and quantify the resulting improvement in coronagraphic testbed contrast.

10:46 AM Eric Shen
Mentors: Maxwell A. Millar-Blanchaer

Polarimetric Simulations of the Roman Space Telescope Coronagraph Instrument

The coronagraph instrument on the recently launched Nancy Grace Roman Space Telescope is currently the most powerful space-based coronagraph, with capabilities to directly image an extrasolar Jupiter analog in reflected light for the first time. The Roman Coronagraph consists of a series of diffractive masks and an adaptive optics system that can suppress the light of a host star to reveal orbiting companions up to 100 million times fainter than the star. In addition, imaging in polarized light provides an effective method to separate out the generally unpolarized starlight from the polarized reflected light of companions and circumstellar disks, enabling further starlight suppression in post processing. To aid in the development and testing of the Roman Coronagraph Data Reduction Pipeline (Corgidrp) ahead of launch, we implement simulations of polarized light observations with the coronagraph instrument as a part of Corgisim, a comprehensive simulation package for the Roman Coronagraph.

10:59 AM Krista Caballero
Mentors: Madeleine McKenzie (Carnegie Observatories)

Chromospheric Activity in Globular Clusters: Investigating the H-alpha Line

Chromospheric activity in red giant branch (RGB) stars provides important insight into stellar atmospheric heating, mass loss, and stellar evolution. However, the physical mechanisms driving chromospheric activity and its dependence on stellar properties remain poorly constrained, and previous investigations have been limited by smaller, non-homogenous datasets. This project uses high-resolution spectra from the Data Release 4 of the Galactic Archaeology with Hermes (GALAH) survey to examine chromospheric activity in RGB stars within globular clusters. Residuals of emission features between the synthesized and observed spectra are integrated and examined as functions of effective temperature, metallicity, and light-element abundances. We have found chromospheric activity to be prevalent in lower effective temperatures, specifically in M22 we see H-alpha emission features beginning to emerge at temperatures < 4400 K and see no correlation between H-alpha emissions and metallicity. Ultimately, this work aims to provide constraints on chromospheric activity to aid our understanding of mass loss in stellar evolution.

11:12 AM Tomas Forney
Mentors: Caitlin Casey

Quantifying Extragalactic Contamination for directly imaged planetary searches with JWST

Direct imaging with JWST offers new opportunities to identify exoplanets in the infrared, but its exceptional sensitivity also increases the risk of confusing planetary candidates with extragalactic background sources. We use empirical deep-field catalogs from COSMOS-Web and JADES to quantify potential contaminants. While unresolved point sources are the nominal contaminating population, PSF subtraction can distort extended galaxies so that they appear point-like, with the effect depending strongly on separation and host-star brightness. We develop a framework to estimate extragalactic contamination as a function of host-star magnitude and contrast curve in key JWST/NIRCam filters. We find that contamination is generally low, except for especially deep contrast curves or faint host stars. We also compare the color-magnitude distribution of extragalactic sources with ultracool-object models to assess photometric degeneracies. Finally, we provide the MIRAGE online tool to calculate cumulative extragalactic contamination probabilities for general use by the direct-imaging community.

11:25 AM Suraga Nallan
Mentors: Sandra Faber (Lick Observatory)

Radius Growth of Galaxies in TNG100

This paper examines the growth of half-mass radius in TNG100 galaxies and its connection to star formation morphology, merger history, and halo spin. We studied 100 TNG100 galaxies between 10^10.2 and 10^11 M⊙ from z = 2–0.5 and found that radius oscillates over time: it grows when star formation shifts to the outskirts (centrally red) and shrinks when star formation concentrates in the center (centrally blue). We then extended our sample to a broader range of stellar masses and redshifts and used TOPCAT to correlate the change in radius between timesteps against a wide set of TNG100 fields, finding age slope, ex-situ stellar mass fraction (f_exsitu), and halo spin as the strongest correlates. We further tested these relationships with a custom Python script searching for the best-fit linear combination of these fields, and separately with a random forest model to capture nonlinear effects. Both methods confirm that radius is strongly tied to where stars form, and is shaped by mergers and halo spin.

11:38 AM Nathan Madsen
Mentors: Crystal Martin

From Local to Reionization-Era Lyα Emitters: HI Column Distributions and the IGM

The shape of a galaxy's Lyman alpha line encodes the neutral-hydrogen column density (N_HI) of the gas that scatters its photons and the distribution of N_HI is a direct probe of the structure of the scattering medium, yet whether that structure differs between local star-forming galaxies and their reionization-era counterparts is unknown. We test whether the N_HI distribution recovered from Lyman alpha profiles differs between low-redshift (CLASSY) and high-redshift (JWST) galaxies. We model each observed profile as a weighted sum of single-column expanding-shell (zELDA) profiles since a linear combination approximates a continuous N_HI distribution. Uncorrected, the high-z galaxies appear to reach higher columns (KS D ≈ 0.27). but we trace this to intergalactic-medium (IGM) absorption of the high-z blue wing, which the shell model does not include. Correcting for the bias in two independent ways shrinks the difference to D ≈ 0.18. Thus the six-galaxy sample suggests that certain populations of local galaxies provide low-z analogs to high-redshift Lyman alpha emitters.

11:51 AM Roman Gonzales
Mentors: Crystal Martin

Lyman Alpha Propagation: zELDA and The Expanding Shell Model

Lyman-alpha is the most prominent spectral line in the universe, serving as a key probe of star-forming galaxies in the early and local universe, and of cosmic reionization. This talk examines the expanding shell model, a well-constrained, physically intuitive framework for the resonant scattering physics that shapes the Lyman-alpha line. We fit observed profiles with the expanding shell model using zELDA, which employs a deep neural network to bypass costly radiative transfer simulations. A single homogeneous shell, however, is a strong simplification of a real galactic outflow. We extend the model with a covering-fraction treatment, approximating the shell's surface as a linear superposition of column densities or, separately, of outflow velocities. While not a full multiphase radiative transfer solution, this decomposition better captures the physical variety expected in galactic outflows, and produces fits and fit parameters that appear more consistent with expectations from other spectral lines.

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12:04 PM Vansh Agarwal
Mentors: Nathaniel Craig

Advancing Autonomous Hypothesis Generation in High Energy Physics with FERMIACC

The FERMIACC is a framework using scaffolded reasoning agents to read experimental papers and autonomously produce and validate quantum field theory hypotheses to explain features in these papers using the computational tools available to modern phenomenologists. Given a successful signal hypothesis, the natural next step is to determine limits on it from other experimental analyses. The "Librarian" module determines these limits by searching present literature and reinterpreting relevant analyses using the same deterministic simulation tools employed in hypothesis generation.

SHORT BREAK

12:28 PM Shosei Chiang
Mentors: Philip Lubin, Matthew Oaks

Computational Assessment of Neutron Activation in Structural and Environmental Materials

Determine which common materials produce relatively low or high residual activity and dose, identify the isotopes responsible, and explain how neutron-spectrum energy change the result.

12:41 PM Jacob Mucic
Mentors: Philip Lubin, Matthew Oaks

Computational Assessment of Neutron Activation in Structural and Environmental Materials

Determine which common materials produce relatively low or high residual activity and dose, identify the isotopes responsible, and explain how neutron-spectrum energy changes the result.

12:54 PM Rebecca Raymond
Mentors: David Caratelli

Identifying Michel electrons in the MicroBooNE neutrino detector

Neutrinos are fundamental particles with many open questions about their nature, including whether differences between neutrino and antineutrino oscillations contribute to the universe's matter-antimatter imbalance. This study identifies low-energy "Michel" electrons produced when neutrino-induced muons decay inside the MicroBooNE detector – a liquid argon time projection chamber (LArTPC) with three wire planes and 32 photomultiplier tubes (PMTs) for charge and light readout. Identifying Michel electrons enables measurement of muon decay-times in the TPC to statistically distinguish neutrinos and antineutrinos. Michel electrons produce an ionizing track that deflects from the original muon trajectory, creating a characteristic "kink". We identify this topology using NuGraph2, a graph neural network, and develop an algorithm tagging corresponding light in PMT waveforms. Distinguishing Michel signals from late light produced by the primary interaction on similar microsecond timescales additionally addresses a challenge relevant to the upcoming Deep Underground Neutrino Experiment, which will see O(100) interactions per event.

1:07 PM Aidan Shim
Mentors: David Caratelli, Alexander Antonakis

Anomaly Detection For Rare Standard Model Processes in LArTPC Neutrino Experiments

Liquid argon time projection chambers (LArTPCs) such as the Short-Baseline-Near-Detector (SBND) experiment will detect millions of neutrino interactions. Within these interactions exists a myriad of rare standard model events such as eta mesons, a particle that acts as a background for many searches for undiscovered particles.. However, isolating these particles is difficult due to their low rates and similar topologies to background events such as neutral pions. We present an unsupervised anomaly detection based autoencoder to isolate eta mesons from typical neutral pions. In our work we isolate particle interactions using a clustering algorithm to group segments of the event displays that contain charge. We then investigate the autoencoder's abilities to distinguish between various topologies during its training procedure such as distinguishing between showers and tracks.

1:20 PM Sofia Sodhi
Mentors: David Caratelli

Charge to Light Signal Matching for Astrophysical Neutrino Detection at DUNE

The Deep Underground Neutrino Experiment (DUNE) will observe neutrinos from galactic supernovae and from the core of the Sun, arriving at energies around tens of MeV. Locating where each of these faint events occurred inside the detector helps filter backgrounds and understand the astrophysical processes from which they came. DUNE records each interaction as ionization charge and as scintillation light. The charge signal fixes two spatial coordinates but leaves ambiguities on the third dimension. Scintillation light provides this information through the pattern of light seen across the 184 photodetectors lining the module. In this work, we combine information from scintillation light and ionization charge to correctly identify the timing of low energy neutrino interactions, a procedure referred to as "charge to light matching". On simulated supernova and solar neutrino events, this method recovers the drift coordinate with a resolution of tens of cm and an event mismatch rate of around 1%.

1:33 PM Oscar Lewis
Mentors: Joseph Incandela, Danyi Zhang

Classifying Electronuclear Events at Unexplored Energy Scales in LDMX

Long-baseline neutrino oscillation experiments rely on precise modeling of neutrino-nucleus interactions to reconstruct neutrino energies and oscillation parameters, for which electron scattering data has historically been essential. The Light Dark Matter eXperiment is well suited to make such measurements. We will develop dE/dx– and machine learning–based particle identification methods for final-state hadrons, study the kinematics of electronuclear final states, and estimate the electronuclear event yield at LDMX, delivering a comprehensive characterization of electronuclear interactions across multiple target materials and theoretical models for the sake of improving neutrino interaction models and reducing systematic uncertainty in future experiments.

1:46 PM Yuze Li
Mentors: Joseph Incandela, Tamas Almos Vami

Searching for photophobic ALPs using BDT classification at LDMX

Photophobic ALPs are dark matter candidate pseudoscalar particles that couple primarily to electrons rather than photons. This study aims to understand the kinematics and improve sensitivity for photophobic ALPs in the Light Dark Matter eXperiment (LDMX). We studied key signal and background shower features, constructed shower-level observables using jet-clustering techniques to increase discriminative power, and developed a Boosted Decision Tree (BDT) classifier to optimize the ability to distinguish signals from high-energy photons undergoing electron-positron conversion and ECAL photonuclear interactions. The BDT output outperformed the signal efficiency of previous cut-based analysis methods under identical conditions, thereby expanding the maximum mass detection range and lowering the detectable coupling threshold. Ongoing work will measure BDT signal efficiency across multiple decay positions in the electromagnetic calorimeter and will involve the hit-level GNN ParticleNet algorithm.

1:59 PM Benjamin Payne
Mentors: Joseph Incandela, Talia Benioff-White

Thermal Characterization of a Light Dark Matter eXperiment (LDMX) Electromagnetic Calorimeter (ECal) Silicon Module

The Light Dark Matter eXperiment searches for dark matter in the MeV-to-GeV mass range via a "missing momentum" signature when electrons strike a thin target. The electromagnetic calorimeter, central to reconstructing particle showers, is built from silicon sensor modules, each composed of a carbon fiber baseplate, silicon sensor, and PCB with readout electronics. Since sensor noise depends on temperature and radiation dose, this project characterizes a representative module's thermal behavior to determine LDMX's operating temperature range and cooling requirements. Thermistors mounted directly on the silicon sensor, dispersed near the highest-heat electronics, measure the module in a cold box across multiple temperatures (approximately –20°C to 0°C), mapping thermal gradients across the silicon and validating finite element analysis (FEA) predictions for the first time. These measurements will be combined with prior simulations of radiation-induced dark current in the silicon to model how heat load and noise evolve over the detector's lifetime.

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2:23 PM Keaton Cross
Mentors: Dave Patterson, Samuel Kresch

Mass-Selective Loading and Trapping of 88Sr+ Ions

Ion traps are a cornerstone of AMO physics and a crucial component of our work with spectroscopy of single polyatomic ions. However, loading our trap with the strontium ions that are used to produce our data is a delicate and low-efficiency process which throttles the rate at which our data can be collected. Over the summer, I developed custom ion optics that promise to greatly increase the loading efficiency of strontium ions into our trap. The combination of a quadrupole shuttle and various focusing electrodes will allow us to more precisely control the energy and trajectory of our ions, which facilitates an upgraded loading scheme that eliminates the use of contaminating neon buffer gas. The subsequently increased loading efficiency will greatly improve the uptime of our trap, and therefore our ability to collect meaningful data.

2:36 PM Holden Archie
Mentors: Andrew Jayich, Robert Kwapisz, Spencer Kofford

225Ra+ Laser Cooling, Spectroscopy, and Atomic Source Development

Having diagnosed and repaired a nonfunctional ion trap, we have regained the ability to trap 225Ra+ ions. We have demonstrated control by performing preliminary micromotion compensation and spectroscopy of the 2S1/2↔2P1/2 cooling transition. This isotope's I=1/2 nucleus creates a clock transition that is magnetic-field-insensitive to first order. That insensitivity, combined with radium's low charge-to-mass ratio, suppresses leading systematic uncertainties limiting clock stability. We aim to operate an optical clock on the 2S1/2↔2D5/2 transition of a single 225Ra+ ion as a precursor to a multi-ion clock, for which we are developing a new vacuum chamber. Our experiments are impeded by the 3-hour heating time of the effusive oven, a major source of blackbody radiation and stray electric and magnetic fields. We have designed a lightweight titanium oven that reaches its 500 °C operating temperature in 3 minutes to expedite future experiments including the multi-ion clock.

2:49 PM Zhecheng Liao
Mentors: Andrew Jayich, Robert Kwapisz

88Sr+ optical clock with a fully integrated photonic laser

Atomic clocks utilizing optical transitions as a frequency reference offer extremely high stability and precision, allowing for better unit definition and tests of time variation of fundamental constants. As 88Sr+'s cooling and clock transitions lie in the visible or near infrared regime, they are compatible with integrated photonics lasers. This makes 88Sr+ a good candidate for transportable optical clocks. In this work, an integrated photonics laser at 1033 nm was used to operate a clock on the 2S1/2 to 2D5/2 transition, cool the the motional motion of the ion to the ground state, and perform spectroscopy of the 2D5/2 to 2P3/2 transition. We are now working on the 2D5/2 to 2P3/2 spectroscopy and running the clock with this integrated photonic laser. For future work, we will focus on improving the 88Sr+ clock stability and compare it with our radium-based clock.

3:02 PM Ori Khasin
Mentors: David Weld, Madeleine Bow Jun Leibovitch

Fiber Phase Noise Cancellation for Coherent Rydberg Dynamics in Ultracold Potassium

Rydberg atoms possess expanded electron orbitals and massive dipole moments that enable long-range interactions. In our experiment, we isolate ultracold Potassium-39 Bose-Einstein condensates in optical tweezers and drive them to Rydberg states via a 405 nm and 980 nm two-photon transition. This enables investigation of Rydberg excitations within degenerate quantum gases, as well as the generation of entanglement across engineered atomic arrays. Driving these transitions coherently requires sub-kilohertz laser stability. However, delivering light through 50 meters of optical fiber introduces environmental phase noise matching our atomic timescales, causing fluctuating detunings that degrade excitation fidelity. To eliminate this noise, a fraction of the transmitted beam is reflected back through the fiber to detect the accumulated phase error. Feeding this signal into an active negative-feedback loop pre-compensates the beam, delivering phase-stable, resonant light directly to the trapped atoms.

3:15 PM Siddharth Adiraju
Mentors: David Weld, Anna Dardia

SWAPping to Colder Atoms

The growing field of quantum simulation involves a medium to represent a quantum object. The medium we use is Bose-Einstein Condensates (BEC): a collection of ultracold atoms (specifically bosons) that can effectively represent a single coherent quantum state. A requirement to make a BEC is cooling atoms to subkelvin temperatures, achieved through laser cooling. A recent method of laser cooling known as the Sawtooth Adiabatic Passage (SWAP) can produce a colder and denser BEC, and therefore a more robust platform to study quantum phenomena. I will discuss the idea behind SWAP and our first implementation of it on Strontium-84 atoms.

3:28 PM Shravan Ramanand
Mentors: David Weld, Anna Dardia

Probing High Harmonic Generation using Ultracold Atoms

Direct experimental access of ultrafast phenomena on the scale of attoseconds is limited by existing technology. Using a Bose-Einstein Condensate (BEC), we are able to access the same phenomena by engineering an equivalent Hamiltonian. Because of the larger mass of the BEC relative to an electron, we are able to probe the same ultrafast dynamics on much larger timescales. Using this system, we were able to experimentally realize High Harmonic Generation, one of the pillars of ultrafast dynamics. Direct imaging of the condensate gives us access to the probability density of the electron which gives us insight to the microscopic dynamics of High Harmonic Generation in different regimes.

3:40 PM Closing Remarks
Brishti Chakraborty, Derek Lee, Mark Srednicki

PRESENTER/ADVISOR RECEPTION

4-5:30 PM Social Hour with Refreshments
KITP's Gurley Courtyard

Special Thanks to Mark Zakharyan for helping set up Typst formatting document!