APS CUWiP @ UC Merced Poster Abstract Book

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1. ***Periodicities of Sunspots Recurring for Two or More Rotations***
by Aislinn McCann, Sharveny Parthibhan, Ana C. Cadavid, Debi P. Choudhary

The goal of this investigation is to explore properties of the solar rotation period using sunspots which make multiple disk transits. Sunspots are dark regions in the solar photosphere which are formed from very strong localized magnetic structures. These magnetic structures are formed in the solar convection zone–the outermost layer of the Sun's interior–as a result of the turbulent motions of the non-viscous plasma. Traditionally sunspots have been used as tracers to determine the solar surface rotation of the Sun which in turn reflects the properties of the underlying dynamo for sunspot generation. Using data from the Debrecen Photoheliographic Data Sunspot Catalog (1977-2017), we have identified recurrent sunspot groups which have remained in their H or J Zurich classification for two or more solar rotations. We have applied a least square fit method to calculate the angular rotation synodic velocities and a seasonal dependent method to convert them to sidereal velocities. These are then used to obtain the solar rotation parameters via a least-square fit to the solar differential rotation law. The solar rotation rates determined using the sunspots recurring for two successive disk passages are used to calibrate our methods with respect to previous results. Comparison of these periodicities with the ones corresponding to sunspots recurring for more than two rotations can provide information on the anchoring depth of the magnetic structures.

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2. ***Chemical gradients coupled to self-generated activity exhibit largescale structure formation in active materials***
by Alana Hartsell-White, Isabel Ruffin, John Berezney, Zvonimir Dogic

Active materials are composed of microscopic constituents which consume energy to drive material reorganization. For example, the molecular motor, kinesin, can drive spontaneously self-organized flows in networks of microtubules through the hydrolysis of a fuel source, adenosine triphosphate (ATP). In our work, we introduce colloidal beads, which locally inject ATP, into active microtubule networks to investigate how fuel concentration gradients impact material dynamics and structure. At low bead concentrations, microtubules locally evacuate from each bead, leaving the network largely undisturbed. At high bead concentrations, the network is entirely fluidized, similar to those composed with uniform ATP concentration. Between these extremes, there is a steady-state regime consisting of large-scale, persistent density fluctuations that disassemble and reassemble over time.

3. ***Widely Tunable Femtosecond Pump Pulses for the Compact X-Ray Light Source***
by Anastasia Martinez, Sudeep Banerjee, Marc Messerschmidt, Jade Stanton, Sean Tilton, Samuel W. Teitelbaum,Petra Fromme, and Robert A. Kaindl

A state-of-the-art high power, ultrafast laser system has been commissioned as a pump source to trigger dynamic processes in natural, engineered and quantum materials, as probed with the Compact X-ray Light Source (CXLS). Parametric and frequency mixing stages render the pulses widely tunable across the UV, visible, near-IR and mid-IR. This will enable researchers to conduct cutting-edge experiments, including biochemical dynamics during photosynthesis and human vision, molecular dynamics of synthetic catalysts, or light-driven phases in quantum materials. Additional characterization and integration with the CXLS is underway.

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4. ***Observing the Momentum Density of Waves in Black Hole Mergers***
by Andrea Ceja, Noah M. Ring, Aryan V. Saju and David G. Wu

SpECTRE is a next-generation numerical relativity code aiming to model gravitational waves emitted by black holes and neutron stars with much higher accuracy, by using novel techniques that scale well, to make effective use of exascale computing facilities. One physical quantity of interest that SpECTRE aims to compute is the recoil ("kick") of the remnant. After a binary black hole merger, the momentum released through gravitational waves causes the merged black hole to experience a recoil velocity. As a first step toward computing the recoil of a binary-black-hole merger, I enabled SpECTRE to compute the momentum density for a scalar wave, a simple test case.

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5. ***Simulating Qubits Coupled to a Cavity***
by Arianna Meinking, Dr. Daniel Bowring

The goal of this research is to simulate different aspects of two qubit systems in order to better understand qubit arrays coupled to one cavity. Multiple qubits are coupled to one cavity in order to minimize external noise, since up-scaling the number of qubit arrays is necessary for computation. However, this cavity coupling system can be more prone to qubit cross-talk noise. We begin by considering a single qubit system coupled to one cavity. We determine how the single qubit simulation agrees with theory by comparing Rabi frequency calculations. We also simulate a Ramsey experiment to measure dephasing to ensure that all types of noise are incorporated in the simula- tion. This Ramsey experiment is compared to a chosen dephasing rate. Next, we build two-qubit simulations coupled to one cavity. The first considers Rabi oscillations, and compares oscillation frequency to theoretical frequency. The second simulation examines the effects of qubit cross-talk on the qubit readout fidelity, but is incomplete since noise has not been added to the system. The simulations are built using the QuTip python package.

6. ***Viability of a Novel Technique for Low-Mass Leptoquark Searches***
by Audrey Cole

In the standard model of particle physics, the two types of matter particles, leptons and quarks, can not directly decay into each other. A leptoquark would allow such decays, unifying the matter particles. Current searches for leptoquarks focus on masses above about 200 GeV, in order to comply with trigger requirements at LHC experiments. However, it is in principle possible to probe less explored lower mass regions via single leptoquark production, triggering on single lepton produced with the leptoquark and targeting leptoquarks with high momentum. In this phenomenological study, I have verified that the resulting lepton and quark of a decaying leptoquark are in a close geometrical region such that they would be reconstructed as a single object. I have also verified that processes relying on the high leptoquark momentum and its low mass, between 50 and 200 GeV, result in significant cross sections for leptoquark-lepton-quark couplings between 0.5 and 2.5, thus offering a proof of concept for a feasibility study for the search of such particles in an unexplored mass range.

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7. ***Further Characterisation of AstroPix Sensor***
by Autumn Bauman

Gamma ray astronomy currently has a gap in sensitivity from roughly 200keV to 1GeV, known as the “MeV gap”. A proposed instrument that would cover this gap is AMEGO-X (All-sky Medium Energy Gamma-ray Observatory eXplorer) which utilizes the AstroPix monolithic silicon pixelated tracker. This past summer was spent characterizing version 2 of the sensor with a focus on radiation hardness and depletion depth. Radiation hardness to cosmic rays was tested with a heavy ion beam. No latchup conditions occurred, although single event functional interrupts occurred at linear energy transfers over 20MeV˙cm2/mg indicating susceptibility to data degradation. Depletion depth was measured as a function of bias voltage and was found to range from 11μm to 33μm.

8. ***Developing Phages with a Versatile End-Label toward a Model System for Endocytosis***
by Changyuan Wang (graduate mentor: Raymond Adkins; Advisor: Zvonimir Dogic)

Endocytosis is an essential biological process responsible for transporting materials into and out of the cells. It involves the ability of membranes to curve and enclose materials. The energetics of how a membrane closes is a physics question. However, conventional lipid bilayers are nanometer-scale in thickness, making their shape transformations occur on too small time and length scales to be visualized by optical microscopes. Colloidal membranes developed by the Dogic lab overcome this obstacle. They are monolayer membranes self-assembled from rod-like phages that obey the same physics as lipid membranes. Colloidal monolayers are micron-scale in thickness, enabling high temporal and spatial resolution imaging. We employ colloidal membranes to investigate the dynamics of endocytosis. To imitate the interactions between encapsulated particles and membranes, we build the model with colloidal membranes labeled with single-stranded DNA and a polystyrene bead coated with complementary strands of DNA. When the bead is placed on a membrane, DNA hybridizes, wrapping the membrane around the bead. Thus, the first step is to attach DNA molecules at the end proteins of rod-like viruses (phages), the building blocks of colloidal membranes. We chose M13C7C phages and maleimide-DNA because it provides a robust covalent conjugation. Further analysis of dynamics is still in progress.

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9. ***Characterizing thin-film MgB2 transmission lines for the development of superconducting devices***
by Christina Bell, Daniel P. Cunnane, Chang Sub Kim, Ritoban Basu Thakur

We describe the characterization of magnesium diboride (MgB2) in the application of superconducting devices. MgB2 is a promising material due to its high transition temperature (39 K) and its level of nonlinear kinetic inductance needed to realize a large current-controlled phase shift for accessibility to frequencies in the terahertz gap (0.5 - 3 THz). An internal quality factor of 10,000 and a phase shift of 7 fs/square was found in MgB2, comparable to optimized results of Niobium Titanium Nitride (NbTiN). An understanding of the nonlinear kinetic inductance and total loss of MgB2 allows for the realization of a THz on-chip spectrometer. Research in the THz range is of interest for quantum sensors at large and paves the way for development of kinetic inductance devices.

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10. ***Full Field Simulation of the Compact X-ray Free Electron (CXFEL) Laser Optical Undulator***

by Elena L. Ros, William S. Graves, Samuel W. Teitelbaum

The goal of the Compact X-ray Free Electron Laser (CXFEL) at Arizona State University is to create coherent x-ray radiation at a university-scale facility. Unlike conventional X-ray free electron lasers (XFELs) the CXFEL will use an optical undulator instead of an undulator based on (static) electromagnets . Reducing the undulator from a mm-scale period to a micron scale period lowers the requirements on the electron beam energy, which in turn enables CXFEL to be a compact instrument relative to conventional XFELs which kilometer-scale instruments. Simulating the interaction between the electron beam and the optical undulator is a necessary step for designing the CXFEL. The goal is to understand what parameters (undulator strength, incoming beam energy, overtaking angle, and interaction length) the incoming optical undulator will require to be able to create a seeded X-ray laser. This can be approached with a particle-in cell full-field simulation. Here, MITHRA, a full-wave solver software package, is employed for the simulation of the electron/radiation interaction in free electron lasers (FELs). MITHRA includes physics and the appropriate code to account for inverse Compton scattering, which is the basis of optical undulators. We have begun to adapt this code to the CXFEL instrument design to simulate the radiation/electron beam interactions to determine the viability of our optical undulator design to produce 1.24 nm wavelength (1 keV photon energy) radiation.

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11. ***Ordering Dynamics of Self-Intercalated TaS2 Traced with Ultrafast Electron Diffraction***

by Jayanti M Higgins

Prior to the development of pump-probe experiments, condensed matter physics was limited to studying materials in equilibrium states at long time scales. Ultrafast electron diffraction resolves this issue by using laser pulses to excite samples out of equilibrium followed by timed electron pulses to capture snapshots of photoinduced structural changes on picosecond to femtosecond time scales. Layered materials with 2D order host a variety of interesting phase transitions and ordering dynamics that can readily be investigated using ultrafast electron diffraction. Intercalating atoms between layers provides a means to controllably alter the physics present in 2D materials and manipulate their electromagnetic properties. In this study, a laser-induced topotactic transition is discovered in the layered transition metal dichalcogenide TaS2. When excited with sufficient laser fluence, individual atomic layers of a thin section of 1T-TaS2 make the transition to the 2H phase. Intercalation and subsequent ordering of interlayer Ta atoms can occur during this transition. The ultrafast nonequilibrium dynamics of this new superstructure are investigated using a home-built ultrafast electron diffraction apparatus, with stoichiometric and electronic measurements done in conjunction to identify the emergent properties of this intercalated compound.

12. ***Improved Dynamical Masses of HD130948BC***
by Lanxuan Wang, Timothy Brandt, Trent Dupuy

Brown dwarfs are failed stars that have masses in between stars and planets. Researchers are interested in gaining insights into how stars form by examining the traits of brown dwarfs, and their masses are essential parameters to be determined. HD130948 is a main sequence star with binary brown dwarfs orbiting around it. While the mass of the primary star is well-known, the masses of the two orbiting companions are not well-measured. Thus, we are the first to determine the two brown dwarfs' individual masses precisely. Using images taken by Keck II and Hubble Space Telescope, we extract relative positions for the primary and companions taken on different dates. We fit the barycenter of the two companions around the primary as a Keplerian orbit and derived the companions' total mass. We then apply two approaches to calculate a mass ratio for the two brown dwarfs.

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13. ***Building a Dichroic Telescopic Camera to Detect Transients at a Quicker Rate***
by Lee Fowler

Current basic telescopic imaging doesn't allow for rapid detection of moving objects in space. Telescopes take in incoming light through an optical channel using a single charge-coupled device, but in order to get multiple optical channels at once in an image, the use of multiple CCDs and several filters for divided light to enter is required. This is where the multi-dichroic camera excels, as it takes a dichroic divider and splits the incoming light into several different colored filters –in this case two blue and green filters– producing several imaging bands. Our group is currently in the process of building the current model of our dichroic camera. Once ready, the angle of the filter will be tested using a laser to ensure it will be able to achieve quicker and more accurate imaging of transients. Our group's current dichroic camera model has been designed to accommodate a CDK20 telescope and is designed to produce more frames per second than standard imaging. The base parts currently being assembled were all created through 3D modeling using polyethylene while the imaging camera is an ASI290MM camera that, with its low read noise and high dynamic range, will pair with the dichroic filter to capture clearer images of transients at a quicker rate. Going forward, this model will be worked to accommodate smaller telescopes and utilize more dichroic filters to streamline the transient imaging process.

14. ***Neural Network Emulator for the Lyman-α Forest Flux Auto-Correlation Function***
by Linda Jin, Mentors: Joseph Hennawi, Molly Wolfson (UCSB Physics)

The auto-correlation function of Lyα forest flux characterizes the strength and scale of its transmission fluctuations, and hence is important in learning the thermal history of the universe. The scarcity and high expense of high-resolution data make a precise emulation process pivotal. Running a multi-layer perceptron emulator with the input of three thermal parameters--namely, average observed Lyα forest flux, temperature at the mean density, and temperature-density relation -- allows us to do an inference test with the HMC (Hamiltonian Monte Carlo algorithm) for parameter estimations.

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15. ***Investigating the Atmospheric Evolution of Exoplanets***
by Manasa Lakshmi

For the past school year, I have worked with graduate student researcher William Misener to find potential exoplanets that might contain a portion of its initial atmospheric envelope. I wanted to find exoplanets that have undergone atmospheric loss to a certain degree but have still retained a bit of their atmosphere. These planets are especially interesting because they are typically the size of Earth (called super-Earths) and their retaining atmosphere can tell us a lot about the composition of the planets, how they were formed, and why these planets in particular, as well as planets known as sub-Neptune, are the most common type of exoplanets we have discovered so far. Using code on Python developed and refined by me, we have modeled the lifespan of several planets, such as the TRAPPIST-1 system, and have successfully found that the recorded data on the planets align with our models! We will continue looking at more planets with our model and see how we can refine our code.

16. ***Modeling Spectra of Exoplanet Atmospheric Compositions from Stellar Elemental Abundances***

by Marina Beltran

Exoplanets are formed by accreting material in the protoplanetary disk that develops from a stellar nebula collapsing. It has been proposed that the same elemental components present in star formation are also present in the formation of planets in the protoplanetary disk. By looking at the abundance of certain elements of the host star one can predict the chemical composition of the exoplanet's atmosphere. In this study, we utilized stellar abundances measured from the Keck/HIRES optical spectrograph to develop models of the exoplanet's atmospheric composition by using the elemental abundances of the host stars. We calculated the mixing ratios of H2O, CO, CO2, CH4, NH3, HCN, and TiO to generate model exoplanet atmospheres and synthetic spectra. These models will later be compared to the spectra produced by the James Webb Space Telescope (JWST) to verify the validity of our method of computing the atmosphere of exoplanets and to properly interpret JWST's exoplanet measurements in the context of their host star.

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17. ***Transient Detection with YOLO Darknet***

by Rachel Darlinger

With an increasing need for full sky surveys, the speed of data collection generally exceeds the ability of a traditional data processing pipeline to process and analyze the collected images. Thus, we present a principally accurate and fast first-look, real-time source extraction method for finding astronomical transients. This method uses YOLO Darknet, a pre-trained convolutional neural network that was optimized for transient source extraction with subtracted image residuals created from starfields simulated using Skymaker. With this algorithm, we obtain a source extraction method that, once trained, operates within a few tens of milliseconds per image and identifies transient sources ≤16th magnitude with ≥90% accuracy. Even dimmer sources (between 16-18 magnitude) were found with ~70% accuracy. This algorithm represents a promising start to a new method of fast transient detection and source extraction.

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18. ***Polaron Self-Energy using Density Functional Theory and Many-Body Perturbation Theory***

by Sophia Wolczko, Dr. Vojtech Vlcek

The development and construction of renewable energy sources is of ever-increasing importance. Current photovoltaic technologies increasingly rely on organic (semi)conducting materials due to their high versatility and tunability. The compound trans-polyacetylene exhibits all hallmarks of charge transport in typical organic conducting polymers (OCP): its conductivity can be tuned across eight orders of magnitude via oxidation reactions that highly charge the system, up to one charge per repeating unit. Charges added to OCPs form polarons, emergent quasiparticles due to strong electron-phonon coupling, that consist of a spontaneous localization of electronic states and a corresponding shift in surrounding nuclear coordinates. The formation of such additional excitations impacts the properties of the system. A theoretical description of the quasiparticle energies of polarons in OCPs would allow for calculation of electron and hole spectra and thus prediction of charge transport properties. We aim to model the polaronic states in highly charged conjugated polymer systems in the condensed phase, using trans-polyacetylene as a test case. We first optimize the geometry of charged systems using the Density Functional Theory (DFT) software Quantum Espresso. Then we use advanced stochastic many-body perturbation theory (MBPT) to compute quasiparticle self-energies and spectra. Specifically, we use the GW approximation to the self-energy, which downfolds all many-body effects into a non-local and dynamical effective potential constructed by diagrammatic field theory approaches. From this, quasiparticle stability, localization and trapping effects, and transport properties can be studied. In future work, the same methodology will be applied to more complex polymer systems.

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19. ***Analyzing the Efficiency of the Trigger System in the ICARUS Neutrino Detector***

by Tanvi Krishnan, Gianluca Petrillo

Neutrinos are elusive elementary particles with many interesting properties that warrant further study. To do this, we use neutrino detectors like ICARUS. The detector is target of a pulsed neutrino beam from an accelerator, and it employs a trigger system to filter the massive amounts of data collected daily, keeping only the desired events for further analysis, and my work centers around analyzing the efficiency of the trigger system. The trigger works by allowing the recording of events in which a minimum requirement of light is generated. We use a software emulation of the trigger hardware to analyze the efficiency of recording only our desired events using different light requirement levels. We focus on cathode-crossing tracks in this analysis, due to limitations in the reconstruction of detector data at the time of this analysis. This data was collected bypassing the hardware trigger system, to avoid bias in the data filtration. I have analyzed the efficiency of the trigger system as a function of different track characteristics and uncovered a drop in the efficiency of the trigger system when detecting 2-meter-long tracks.

20. ***A Brief Analysis of BRITE Constellation Nanosatellites data of Variable Supergiant Deneb***

by Teagan Laws

Deneb is the prototype of the supergiant stars called alpha Cygni variables. These stars are highly luminous OBA stars that exhibit low amplitude variations both in photometry and velocity. They exhibit non-radial pulsations when the surface of a star is contracting and expanding at the same time. The mechanism responsible for these variations eludes theory thus far but photometric and spectroscopic observations of the stars will aid in finding the source for stars such as Deneb. Photometric observation campaigns have been done with the BRITE-Constellation nanosatellites between 2014-2022, which will provide a clearer understanding of the photometric variability. Fourier transformations were done for each data set as part of the analysis process. We aim to compare these results to those from spectroscopic campaigns in the past as well as to interferometric results to understand the properties of Deneb.