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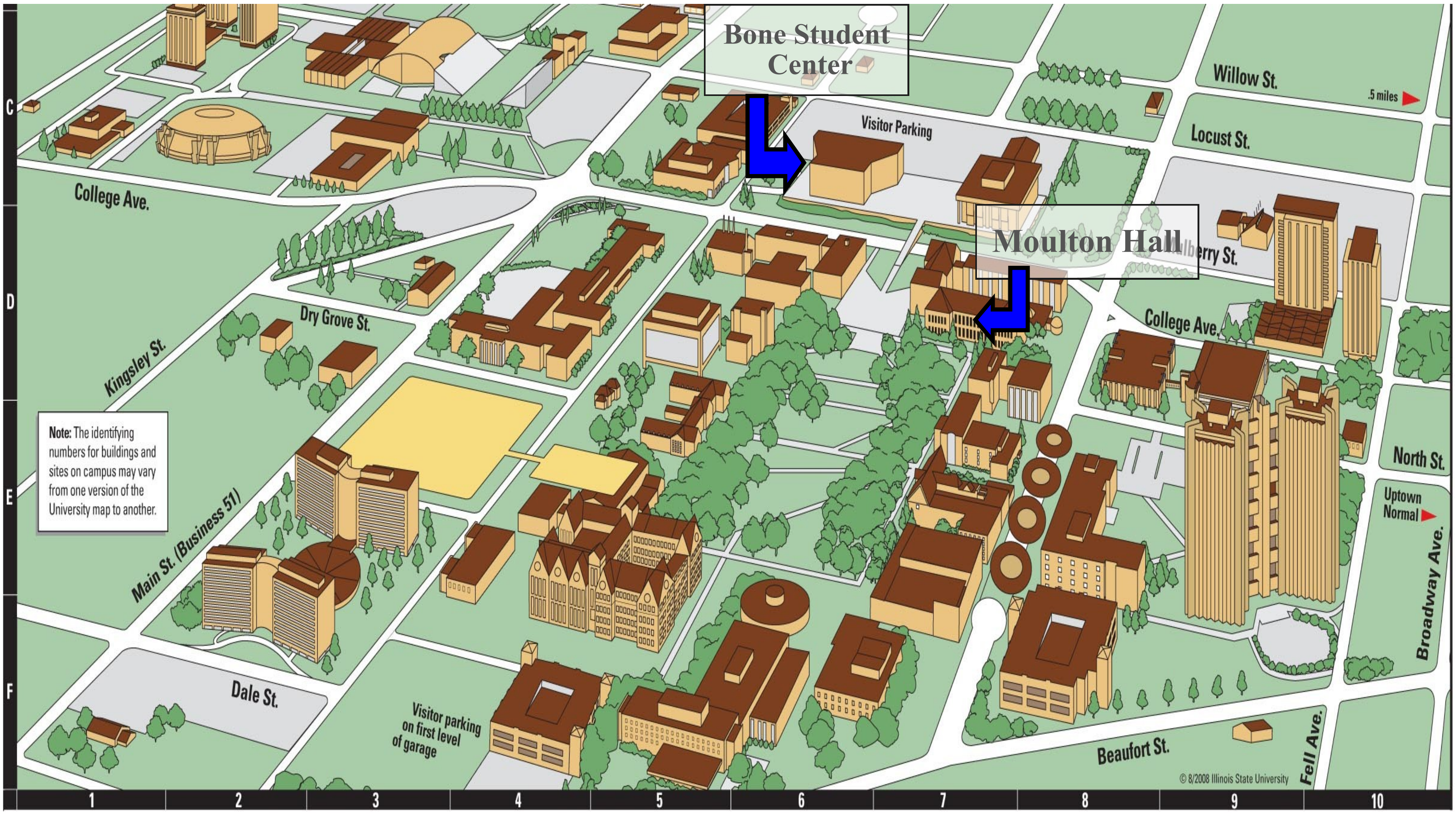
2026 UNIVERSITY RESEARCH SYMPOSIUM
Saturday, April 11, 2026
DEPARTMENT OF PHYSICS ORAL PRESENTATIONS



Moulton Hall: Department of Physics Oral Presentations 8:00 a.m. - 1:15 a.m. Room 309

The oral presentations for the Department of Physics will take place on Saturday, April 11, 2026.

2026 University Research Symposium Oral Presentations

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Department of Physics

Date: Saturday, April 11, 2026
Location: Moulton Hall, Room 309

SCHEDULE-AT-A-GLANCE

Session 1

8:00-8:15 Eyan James
8:15-8:30 Zachary Gunther
8:30-8:45 Moab Croft
8:45-9:00 Charles Stevenson Brown II
9:00-9:15 Eren Erdogan
9:15-9:30 Joshua Klein

Break: 9:30-9:45

Session 2:

9:45-10:00 Helen Jilek
10:00-10:15 Levi Webb
10:15-10:30 Elias Taira
10:30-10:45 Roberto Serrano
10:45-11:00 Nevin Smith
11:00-11:15 Claire Campbell

Break: 11:15-11:30

Session 3:

11:30-11:45 James Aygun
11:45-12:00 Samantha Sims
12:00-12:15 Helen Parker
12:15-12:30 Nicholas Majestic
12:30-12:45 Austin Alexander
12:45-13:00 Trent Butterfield
13:00-13:15 Carter West

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SCHEDULE and ABSTRACTS

Session 1

(8:00-8:15) BIRTH PROCESS OF ELEMENTARY PARTICLES INSIDE SUPERCRITICAL FIELDS BASED ON DEGENERACY-BREAKING PERIODIC BOUNDARIES
Presenter: Eyan James (Undergraduate)
Mentor(s): Dr. Rainer Grobe, Dr. Q. Charles Su

Abstract: We examine the dynamics of the electron–positron pair creation process triggered by a static, spatially inhomogeneous electric field of supercritical strength. Special focus is placed on the spatial distribution of positrons within the interaction zone before they are ejected. By exploiting periodic boundary conditions, the usual degeneracy of the Dirac energy eigenstates in the Klein tunneling region can be lifted, allowing us to remove unwanted contributions from the computationally obtained density using a combination of energy- and spatially based filters.

(8:15-8:30) A GEOMETRIC PATH TO LORENTZ SPINORS
Presenter: Zachary Gunther (Undergraduate)
Mentor(s): Dr. Neil Christensen

Abstract: Geometric algebra provides a natural extension of vector geometry that unifies rotations, boosts, and spinors within a single geometric framework. Starting from rotations in physical space, rotors emerge as the fundamental objects encoding orientation and transformation. This structure extends seamlessly to spacetime, where Lorentz boosts appear on equal geometric footing with spatial rotations. Within this language, spinors arise as concrete geometric entities associated with mass and motion rather than abstract algebraic constructs. The Lorentz spinor is introduced to establish the geometric foundation for a constructive formulation of relativistic quantum theory and, ultimately, particle physics.

(8:30-8:45) GEOMETRIC INSIGHTS TO CONSTRUCTIVE PARTICLE PHYSICS
Presenter: Moab Croft (Graduate)
Mentor(s): Dr. Neil Christensen

Abstract: The Constructive Standard Model (CSM) of Particle Physics has recently been analyzed using the geometric Algebra of Physical Space (APS), thereby affording new geometric insights. The language of the APS' geometry is simpler and visualizable: Many objects of the traditional CSM now have straightforward geometric interpretations that can be drawn by hand and explained to someone with no background. This vastly improves the accessibility of the subject and simplifies the surrounding concepts.

(8:45-9:00) ALGEBRAIC OBSTRUCTIONS TO OFF-SHELL CLOSURE IN 4D N=1 SUPERSYMMETRY
Presenter: Charles Stevenson Brown II (Undergraduate)
Mentor(s): Dr. Neil Christensen

Abstract: The component-level closure of the four-dimensional N=1 superalgebra for chiral, vector, and tensor supermultiplets is a standard result in the supersymmetry literature. In many cases, however, closure of the algebra is achieved only upon imposing equations of motion, obscuring the structural distinction between on-shell and off-shell representations. In this work, we analyze this distinction directly at the component level and show that failures of off-shell closure arise from well-defined algebraic obstruction terms proportional to equations of motion. Using explicit closure computations for the chiral, vector, and tensor supermultiplets, we demonstrate how auxiliary fields eliminate these obstructions by completing representations of the superalgebra without introducing additional dynamics.

(9:00-9:15) QUANTUM INTERFERENCE AND DEPHASING IN MOLECULAR-SCALE ELECTRONIC TRANSPORT
Presenter: Eren Erdogan (Graduate)
Coauthor name(s): Justin Bergfield
Mentor(s): Dr. Justin Bergfield

Abstract: Understanding how decoherence influences heat and information flow is essential for realizing the promise of quantum technologies. Two widely used models for incorporating decoherence in quantum transport are the voltage probe (VP), which imposes local charge current conservation, and the voltage–temperature probe (VTP), which also conserves heat current. Although these models are often treated as functionally equivalent, we demonstrate that this equivalence exists only under highly symmetric conditions, which may be challenging to achieve experimentally. Under asymmetric coupling or thermal bias, the VTP respects thermodynamic constraints and enforces decoherence in both charge and heat channels, while the VP instead acts as a source or sink of heat. Strikingly, the VP can fail to model decoherence in heat transport entirely, even with large probe coupling strengths. Using a benzene-based molecular junction as a realistic example, we show that these effects significantly impact predicted heat transport. These results establish that the VP and VTP models are not interchangeable; only the VTP provides a thermodynamically consistent framework for modeling decoherence in quantum transport.

(9:15-9:30) QUANTUM TRANSPORT SIGNATURES OF POLARITONIC STATES IN MOLECULAR CAVITY QED
Presenter: Joshua Klein (Graduate)
Coauthor name(s): Justin Bergfield
Mentor(s): Dr. Justin Bergfield

Abstract: When a molecule is strongly coupled to a confined electromagnetic field, its electronic excitations hybridize with photons to form polaritonic states, a central concept in cavity quantum electrodynamics (cQED). While such hybrid light–matter states are well described by the Jaynes-Cummings model for simple two-level systems, molecular junctions introduce additional complexity due to their many-body electronic structure and the presence of multiple transport pathways. In this work, we investigate how strong light–matter coupling modifies electronic transport through a molecular-scale junction coupled to metallic leads. By treating the molecule and a quantized cavity mode together as an interacting central system, we analyze how polaritonic eigenstates emerge and how their structure influences charge transport under nonequilibrium conditions. We find that the electronic current can act as a sensitive probe of polaritonic structure, revealing features that are not present in purely electronic or purely optical descriptions. This work highlights how combining concepts from quantum transport and cavity QED provides new insight into light–matter interactions at the nanoscale.

Session 2

(9:45-10:00) IMAGING QUANTUM INTERFERENCE WITH SPATIALLY RESOLVED THERMOPOWER

Presenter: Helen Jilek (Undergraduate)
Coauthor name(s): Justin Bergfield
Mentor(s): Dr. Justin Bergfield

Abstract: A temperature gradient drives charge carriers from hot to cold, producing a thermoelectric voltage in linear response, quantified by the Seebeck coefficient S. Beyond its technological relevance, S provides a uniquely sensitive probe of quantum interference and symmetry breaking in nanoscale conductors. Here we investigate the spatially resolved thermoelectric response of molecules adsorbed on metallic substrates using chemically accurate many-body quantum transport theory to simulate realistic scanning thermopower microscopy experiments. Within a fully interacting many-body formalism, we find the thermopower maps the coherent combinations of Dyson orbitals—the amplitudes connecting N- and (N−1)-electron states—thereby functioning as a phase-sensitive quantum “transport interferogram.” As representative examples, we show for ethylene and benzene junctions that while conductance maps may fail to distinguish distinct bonding configurations, spatial maps of the thermopower S(r) display pronounced, geometry-specific contrast that encodes bonding configuration, substrate symmetry, and molecular orientation.

(10:00-10:15) MD-INFORMED MICROFIELDS OF HED PLASMAS FOR LINE SHAPE CALCULATIONS

Presenter: Levi Webb (Graduate)
Coauthor name(s): Paul Grabowski, Jim Glosli, Thomas Gomez, Matt Caplan
Mentor(s): Dr. Matt Caplan

Abstract: Many properties used to study and classify astronomical objects depend upon the opacities of their constituent plasmas. Spectral line shapes are essential for determining the temperature and density of observed stellar and compact objects; understanding and accurately modeling plasma opacities from these parameters is crucial for computational stellar astrophysics. However, there are discrepancies between observed and calculated line shapes in the high energy density (HED) regime. We explore various plasma line shape models to ascertain potential sources of these discrepancies.

Current opacity models use semi-empirical molecular dynamics (MD) to simulate local particle electric fields (microfields), possibly contributing to the observed discrepancies in line shape calculations. Employing physically motivated MD models at these conditions may rectify this by improving microfield calculations. We demonstrate the microfield capabilities of LLNL's MD code ddcMD in preparation for a future merge with the pre-existing line broadening program Xenomorph to enable more accurate line shape simulations.

(10:15-10:30) DIFFUSION COEFFICIENTS OF PLASMA MIXTURES WITH LARGE CHARGE RATIOS
Presenter: Elias Taira (Graduate)
Coauthor name(s): Elias Taira, Dany Yacoub, Matt Caplan
Mentor(s): Dr. Matt Caplan

Abstract: Diffusion coefficients within crystalizing white dwarves (WDs) are vital to understanding their evolution as they impact how phase separation and sedimentary heat sources behave during this phase in the WD's lifecycle. Previous work has found an empirical law that relates the diffusion coefficient of a single ion to its coefficient in a mixture more analogous to a WD interior. This law works well for species with low charge ratios with respect to the average charge of the plasma but is much less accurate for higher charge ratios. In this work, we aim to use a symbolic regression algorithm to improve the accuracy of the model using the data from previous molecular dynamics simulations of charge ratios of up to $z_i/(\langle z \rangle) = 4.5$. Additionally, we seek to perform a new suite of simulations that will extend the range of available charge ratios to $z_i/(\langle z \rangle) = 6.0$.

(10:30-10:45) DIFFUSION IN YUKAWA CRYSTALS: THE EFFECTS OF GRAIN BOUNDARIES & SHEAR STRAIN
Presenter: Roberto Serrano (Graduate)
Mentor(s): Dr. Matthew Caplan

Abstract: Molecular modeling of the neutron star crust has shown that the diffision of nucleons in the crystal lattice composing the crust is well described by an Eyring model. We show that adding the effects of grain boundaries and shear strain enhance diffusion relative to the fiducial monocrystal case. We show that these effects can be effectively modeled as a correction term to the exponential term in the Eyring model.

(10:45-11:00) MAGNETIC FAULTS AND PLASTIC FLOWS IN NEUTRON STARS
Presenter: Nevin Smith (Graduate)
Coauthor name(s): Matt Caplan, Ashley Bransgrove
Mentor(s): Dr. Matt Caplan

Abstract: The motion of magnetic field lines in the crusts of neutron stars (NS) can cause large shear forces to accumulate in the rigid ionic lattice, with stresses that exceed breaking causing crust quakes. This mechanism is believed to be the source of the spectacular bursts and flares of NS. From first principles, we perform molecular dynamics simulations of a screened Yukawa plasma coupled with one-dimensional magnetic field lines to study magnetized faults within the crusts of a neutron star. We find that the crust yields by a formation of grain boundary networks that have a strong dependence on fault width. Additionally, we strain several polycrystalline lattices to agnostically study the viscoelastic properties of the crust and how energy is dissipated in the grain boundaries. We show the stress strain dependence on the grain density and box size, with robust convergence on our MD scales. We demonstrate hysteresis of a polycrystalline lattice strained at large deformations.

(11:00-11:15) MODELING THE FORMATION OF QUASI-STARS FROM SUPERMASSIVE STARS
Presenter: Claire Campbell (Undergraduate)
Coauthor name(s): Claire Campbell, Andy Santarelli, Matt Caplan
Mentor(s): Dr. Matt Caplan

Abstract: Recent James Webb Space Telescope observations of early-universe supermassive black holes (SMBHs), such as the ∼4 × 10^7 stellar mass quasar in UHZ1 and little red dots (LRDs), motivate work studying their early-time formation pathways. Known formation mechanisms do not explain SMBH mass and abundance: typical stellar core collapse is limited, and subsequent accretion onto even the largest of collapsed stars is not sufficient to form an SMBH within a Hubble time. An alternative method of SMBH formation is direct collapse, wherein a disk of pre-galactic gas rapidly infalls to its center. Direct collapse occurs in a quasi-star, a theoretical star-like gaseous envelope supported by BH accretion rather than nuclear reactions. In this work, we trace the evolution of supermassive stars to quasi-stars using the stellar evolution code MESA to place realistic constraints on the SMBH seeds formed via direct collapse.

Session 3
(11:30-11:45) TWO-DIMENSIONAL MODELING OF MOLECULAR PHOTOIONIZATION TIME DELAYS
Presenter: James Aygun (Undergraduate)
Mentor(s): Dr. Allison Harris

Abstract: The recent development of attosecond laser pulses has allowed for the ability to probe the dynamics of electrons inside atoms and molecules. Attosecond lasers allow us to study photoionization, during which a short, high intensity laser pulse causes the emission of an electron from an atomic or molecular target. One long-standing question is whether photoionization is instantaneous. It has been recently demonstrated that the photoionization process does not occur instantaneously and that it requires a finite time (called the ionization time delay). Our previous study in one dimension showed that using a type of sculpted ionizing XUV pulse, an Airy XUV pulse, can change the ionization time with dependence on the third-order and fifth-order spectral phase in atomic and molecular targets. Now we present a two-dimensional model to study the effect of pulse sculpting with airy pulses on the ionization time delay on a diatomic molecule. In two dimensions we can study angular implications on ionization delay time as well as the effects of symmetry and rotation of a diatomic molecule together with the effects of pulse shaping with the

(11:45-12:00) PREDICTING CROSS SECTIONS FOR COMPLEX MOLECULES USING MACHINE LEARNING
Presenter: Samantha L. Sims (Graduate)
Mentor(s): Dr. Allison Harris

Abstract: Atomic and molecular cross sections are essential for modeling complex system dynamics in many fields. Cross sections are a measure of the probability of a process occurring during a collision, and they provide key information about how charged particles interact with atoms and molecules. While there are several online databases where atomic and molecular cross sections can be found, such as LxCat or the NIST electron elastic-scattering cross section database, there is still a need for additional data, particularly for molecular targets. Existing methods for generating cross sections include solving the classical equations of motion, solving the quantum mechanical Schrödinger equation, extracting them from swarm data, or measuring them experimentally. While these methods work well, they are often computationally and technically challenging, as well as financially expensive. Machine learning techniques offer new avenues to overcome these challenges and are becoming effective tools for accurately and efficiently predicting cross sections here data is not currently available. I will review existing machine learning techniques used to predict atomic and molecular collision cross sections and provide an outlook for future applications to complex molecular targets.

(12:00-12:15) ENHANCED PRODUCTION OF CIRCULAR RYDBERG STATES USING TWISTED VORTEX ELECTRON COLLISIONS
Presenter: Helen Parker (Undergraduate)
Coauthor name(s): Samantha L. Sims, Daniel J. Lamphere II
Mentor(s): Dr. Allison Harris

Abstract: Circular Rydberg states have important applications in quantum information and quantum simulation, as they have long lifetimes and strong dipole-dipole interactions. However, producing these circular Rydberg states is technically challenging. In this work, we examine the ability of twisted electron collisions to produce these states. Twisted electrons carry orbital angular momentum, which may increase the efficiency of production of circular Rydberg states. Here, we use Bessel electron beams to excite hydrogen, rubidium, and cesium atoms to circular Rydberg states. Using a fully quantum mechanical framework, we calculate the total excitation cross sections for excitation to circular Rydberg states from the ground state. We find that twisted electrons with large opening angles increase the probability of excitation compared to their non-twisted counterparts, pointing to the possible utility of these techniques for efficiently generating circular Rydberg states. We also show that electrons with large orbital angular momentum contribute significantly to this increase in excitation probability. Lastly, we examine the effect of projectile-target alignment and find that a non-zero impact parameter increases the maximum intensity of total excitation cross sections in hydrogen and shifts that maximum to lower energies. Overall, our findings demonstrate that twisted-electron excitation may provide a feasible and potentially advantageous pathway for generating circular Rydberg states.

(12:15-12:30) EXTENSIONS BEYOND 4-POINT AMPLITUDES IN CONSTRUCTIVE QED
Presenter: Nicholas Majestic (Graduate)
Coauthor name(s): Dr. Neil Christensen, Gabriel Minney
Mentor(s): Dr. Neil Christensen

Abstract: The field of particle physics constitutes the theoretical and experimental methods that we implement to study the universe at the smallest fundamental scales. The current primary theoretical framework that for electrons, positrons, and photons is Quantum Electrodynamics (QED). To compare QED with experiment, it is necessary to calculate scattering amplitudes. The traditional method of calculating amplitudes involves Feynman diagrams. Although sufficient in principle to calculate any possible amplitude, it has been found that as the number of particles within a process increases, both the number of Feynman diagrams as well as the complexity of calculating the diagrams grow to become too computationally expensive even for the most powerful supercomputers. New techniques for calculating scattering amplitudes are needed. Constructive amplitudes are a potential candidate with their own set of strengths and challenges. It has already been used to calculate scattering amplitudes in QED for up to 4 particles. In this work, we extend these calculations to diagrams beyond 4 particles.

(12:30-12:45) TOKAMAK PLASMA SIMULATION
Presenter: Austin Alexander (Undergraduate)
Mentor(s): Dr. Jay Ansher

Abstract: Nuclear fusion has long been viewed as a promising solution to global energy needs due to its potential to provide abundant, clean, and sustainable power. Since its early development in the mid–20th century, fusion research has advanced through significant experimental achievements, particularly in the area of magnetic confinement. Tokamak reactors, which use powerful toroidal magnetic fields to confine high-temperature plasma, remain one of the most extensively studied designs. Modern projects such as ITER represent the latest efforts to overcome remaining challenges, such as plasma instability, confinement, and sustaining fusion conditions for long durations. This research project examines both the historical progression of nuclear fusion technology and the computational modeling of plasma dynamics within a tokamak reactor. A central component of the work is the development of a Python-based plasma simulation program that models the trajectories of charged particles under the influence of electromagnetic fields. To achieve accurate and stable numerical integration, the simulation utilizes the Boris integrator, a widely used algorithm in plasma physics due to its energy-conserving properties and effectiveness in resolving cyclotron motion in strong magnetic fields. The program applies the Lorentz force equation to simulate particle motion in a simplified tokamak geometry, allowing us to look at things such as confinement behavior, drift effects, and the influence of electric and magnetic field configurations. By using the Boris integrator, the simulation provides improved long-term stability compared to standard integration techniques, making it particularly suitable for studying plasma behavior over many time steps. Through this combined historical and computational approach, the project connects foundational fusion research with modern numerical techniques used in contemporary plasma physics. The results demonstrate how simulation tools can

contribute to understanding the complex physical processes that govern plasma confinement and stability, supporting ongoing efforts toward achieving practical nuclear fusion energy.

(12:45-13:00) MAGNETIC RECONNECTION IN EARTH'S MAGNETOTAIL

Presenter: Trent Butterfield (Undergraduate)
Mentor(s): Dr. Jay Ansher
Year in School: Senior

Abstract: Magnetic reconnection in Earth's magnetotail plays a critical role in converting magnetic energy into particle motion and plasma flows. The Earth's magnetic field traps plasma (electrically charged gas) from the Sun. The Sun's magnetic field can interact with the Earth's magnetic field, through magnetic reconnection on the day side of the Earth and on the night side of Earth in the magnetotail. Magnetic reconnection is the process where magnetic field lines break and reconnect releasing magnetic energy which can then inject the trapped plasma into the polar regions, or eject the plasma down the magnetotail away from the Earth. In this study, we present a preliminary analysis of magnetotail reconnection signatures using magnetic field and particle flux measurements from the Geotail spacecraft that was launched in 1992. Electron and ion observations spanning distinct energy ranges are examined to identify reconnection related features, including changes in particle flux, timing differences between species, and associated magnetic field variations. Ongoing work will explore further data to identify additional reconnection events, to better understand particle dynamics in the magnetotail.

(13:00-13:15) THERMAL DECOMPOSITION-ASSISTED THZ SPECTROSCOPY FOR AEROSOL DETECTION

Presenter: Carter West (Graduate)
Coauthor name(s): Eden Winters, Daniel Tyree, Michael Brothers, Ivan Medvedev
Mentor(s): Dr. Ivan Medvedev

Abstract: THz (Terahertz) spectroscopic sensing of volatile gases provides a rapid, accurate, and sensitive method for assessing the contents of a gas mixture. However, it is limited to detection of lighter volatiles. Thus, to extend the sensing to aerosols in ambient air, the aerosols must be modified to form molecules detectable by THz absorption spectroscopy. This project focuses on thermal decomposition of acetaminophen, the active ingredient in many common fever and pain relief medications. We are studying this molecule as it is safe, accessible and it is easy to decompose upon heating. By controlling the temperature of the sample, we can analyze the measured THz spectra using molecular spectroscopic facility at the ISU Physics Department. The system can record the THz spectrum of a sample in gas-phase between 0.207 and 0.320 THz. Analysis of the spectral changes as a function of temperature enables identification of molecular fragments produced during thermal Breakdown. By identifying characteristic decomposition products, this work establishes a framework for indirect THz detection of heavier aerosol species in ambient air.

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