Abstracts of Posters

presented at the Joint 2024 Fall Meeting of the Chesapeake and North Carolina Sections of the AAPT October 19, 2024 at Jefferson Lab

1. **Julianna Levanti** (Elon University)
2. **Aubrey Spicola** (Elon University)
3. **Jake Raugh** (Randolph-Macon College)
4. **Aubrie Thoms** (Randolph-Macon College)
5. **Keagan Bell** (Virginia Tech)
6. **Yihang Ma** (Virginia Tech)
7. **Hampton Smith** (Virginia Tech)
8. **Agastyya Kala** (Appomattox Regional Governor's School)
9. **Jeremy Adam** (North Carolina School of Science and Mathematics)
10. **Charlotte Goebel** (North Carolina School of Science and Mathematics)
11. **Arianna Lee** (North Carolina School of Science and Mathematics)
12. **Brandon Lofton** (North Carolina School of Science and Mathematics)
13. **Johnathan Strickland** (North Carolina School of Science and Mathematics)
14. **Ian Suh** (North Carolina School of Science and Mathematics)
15. **Adrian Tejada** (North Carolina School of Science and Mathematics)
16. **Jason Tran** (Georgetown University)

1. **Distinguishing between Active Galactic Nuclei and Ultra Luminous X-Ray Sources in Dwarf Galaxies**

Julianna Levanti (Elon University)

Intermediate mass black holes (IMBHs) remain elusive, in comparison to their supermassive or stellar-mass counterparts, but are essential for understanding galaxy – black hole co-evolution. The small size and distance to IMBHs make dynamic detections difficult, so active galactic nuclei (AGN) signatures provide an easier way to locate IMBHs in dwarf galaxies. Dwarf galaxies also contain other X-ray emitters, such as ultra-luminous X-ray sources (ULXs), that can mimic the signatures expected from dwarf AGN, so distinguishing between the spectral signatures of dwarf AGN and ULXs is notoriously difficult, especially at low metallicities. We present model spectral energy distributions (SEDs) covering 0.01-1.0 Z_solar that include fully self-consistent contributions of IMBHs as a function of metallicity and ULXs as a function of both metallicity and stellar age. Our preliminary analysis shows that at solar metallicity, an AGN contribution of 4% is enough to completely erase any ULX signature at energies ¿54 eV. Conversely, at low metallicities, ULXs continue to contribute to the ionizing spectrum at ¿54 eV until the AGN contribution reaches 16%, however, this result is also weakly dependent on stellar age. These results have implications for using emission line diagnostics sensitive to high energy photons, like He II and O I, for separating IMBH and ULX contributions at various metallicities in dwarf galaxies.

2. **Probing the Interstellar Medium through Pulsar Scattering Analysis using the MeerKAT Thousand-Pulsar-Array Program**

Aubrey Spicola (Elon University)

Pulsars provide a unique and reliable probe of the interstellar medium (ISM) through their timing and scattering properties. This project aimed to understand the small-scale structure of the ISM, particularly how electron density fluctuations influence the propagation of radio signals across different lines of sight. Utilizing the MeerKAT Thousand-Pulsar-Array program, which collects the time-averaged properties of pulsars, we measured scattering timescales (τ) and explored their frequency dependence. The scattering is shaped by the turbulent nature of the ISM, following a Kolmogorov turbulence spectrum, which broadens pulse profiles due to multipath propagation. Understanding these effects provides insights into the ISM's electron density distribution and its turbulent behavior. By leveraging MeerKAT's broad frequency range, we determined scattering levels for each pulsar, contributing to a more detailed map of the ISM's turbulent properties and electron distribution. We developed a Python-based pipeline to process pulsar profiles, calculate signal-to-noise ratios (SNR), and fit exponential models to estimate scattering timescales. The analysis involved loading pulsar profile data from FITS files, normalizing the data for consistency, and applying exponential, parabolic, and power-law fits, alongside automated Fourier Transforms for data smoothing. These fit pulsar parameters contributed to understanding how angular scattering affects pulse broadening functions (PBFs) at MeerKAT's operational frequencies. We compared these fits to theoretical power-law models to evaluate how well the scattering conforms to Kolmogorov turbulence, where scattering timescales are expected to scale with frequency as $\tau \propto \nu - 4$. We found a strong correlation between pulsar scattering properties and the ISM's turbulent structure, with regional variations in scattering reflecting differences in ISM characteristics.

3. **Investigation and Limited Experimental Validation of a New Model for Characterizing Aircraft Lift Generated Wake Vortices**

   Jake Raugh (Randolph-Macon College)

   All lift generating aircrafts produce a pair of counter-rotating vortices in their wake, making it extremely dangerous for any aircraft to follow. This project explored and mathematically modelled the characteristics of these vortices, and compared them to experimental wind tunnel data measured by NASA. The vertical velocity of these vortices was modelled, and the model's five parameters were optimized, producing an R2 value of 0.972. The normalized induced lift and rolling moment on three downstream test wings were also mathematically calculated and compared to this data, resulting in R2 values of 0.94, 0.96, and 0.985 for the three wings considered in the experiment.

4. **Multi-messenger Astronomy: Optical Follow-up of a Short Gamma-ray Burst**

   Aubrie Thoms (Randolph-Macon College)

   We used the 0.4318 m ground-based telescope at the University of Texas Rio Grande Valley's Dr. Cristina V. Torres Memorial Astronomical Observatory (CTMO) located in Resaca de la Palma State Park in Brownsville, Texas. The CTMO telescope is an f/6.8 CDK17 astrograph manufactured by PlaneWave. We used an FLI ProLine CCD with no filter. On the night of 2024 June 16, CTMO pursued a short gamma-ray burst GRB240615a via optical observational methods. All observations were 60 second exposures set at 10°C and binned in 1×1 mode. Information regarding the transient, such as its coordinates, was provided through the NASA GCN alert system. A GCN circular for GRB240615a was released when the Fermi Gamma-ray Burst Monitor (GBM) was triggered on 2024 June 15 at 17:51:45 UT. We followed-up the alert provided by Swift-BAT GUANO. Data reduction and photometry was performed by Python scripts and catalog cross-matching by ds9. We did not observe GRB240615 in the optical spectrum using the CTMO telescope.

5. **Probing the Internal Structure of Protons**

   Keagan Bell (Virginia Tech)

   General Parton Distributions (GPDs) are statistical "functions" used in quantum chromodynamics (QCD) to describe the internal structure of hadrons, such as protons and neutrons, in terms of their constituents, known as partons (quarks and gluons). Physicists have been studying GPDs for about 30 years, and are now approaching the ability to create tomographic images (i.e., 3D images) of the nucleon. To reach this point, we need to study various interactions to access certain information from the GPDs. Such reactions include "Compton Scattering off quarks" for instance: Timelike Compton Scattering (TCS), Deeply Virtual Compton Scattering (DVCS), and Double Deeply Virtual Compton Scattering (DDVCS). DVCS has been studied intensively. TCS has recently been observed at Jefferson Lab, but DDVCS has never been measured. This study focuses on the implementation of a muon detector at Jefferson Lab for the study of DDVCS. It uses a simulation framework developed at CERN called Geant4. The purpose of our simulations is to provide an understanding of the experiment and its challenges. One challenge that needs to be addressed is the detection of muons in a large background of pions, since the pions and muons have similar mass.

6. **Preparation of a new electromagnetic calorimeter to measure the nucleon Form Factors at Jefferson Lab**

   Yihang Ma (Virginia Tech)

   We are working on the preparation of a detector for a new experiment at Jefferson Lab, in the Hall A. This detector will ensure the reconstruction of scattered photons and electrons in high energy beam electron and target proton collisions. The CEBAF accelerator is providing the electrons, and this detector will be placed within the SBS (super big bite) spectrometer, for a new generation experiment aiming at measuring the elastic Form Factors (FFs) of the nucleon (protons and neutrons). The FFs are parametrizing the "position" of quarks inside of the nucleon. We started working on this project in the spring of 2024 with the preparation and assembly of photomultipliers, and we are now contributing to the installation of the detector at JLab.

7. **Galois Field Quantum Mechanics**

   Hampton Smith (Virginia Tech)

   Canonical Quantum Mechanics (CQM) is performed on a vector space over either the Field of Real or Complex numbers, and is equipped with an inner product, particularly a Hermitian form. This allows for a rich and experimentally verified model of non-relativistic physics on the smallest physically relevant scale. Questions have been raised however about whether the theory is obscuring a deep more fundamental problem. One way to refer to this problem is “too complete.” This presentation will demonstrate how replacing the Real and Complex numbers with extensions of Finite Fields leads to a similar but simpler mathematical object on which quantum calculations can be performed. This model is called “Galois Field Quantum Mechanics” or GFQM. Important operations within CQM are shown to have analogous objects within GFQM and what role they serve in the model is elaborated on. Applications of the theory are discussed. For example, a special case appears within the case of Mutually Unbiased Bases. Potential avenues for further research are suggested.

8. **Detection of Exoplanets and Their Properties Using Python**

   Agastyya Kala (Appomattox Regional Governor’s School)

   The transit method is used to detect exoplanets and their properties by analyzing the intensity and duration of a dip in a host star’s brightness. By determining the dip in brightness of stars in regions of space through the analysis of FITS files, areas with exoplanets detectable through the transit method can be identified. Using Python packages such as MatPlotLib, DAOStarFinder, and Astropy, these detections can be visualized in a browser application. Furthermore, given ample data, exoplanet characteristics such as orbital period and size can also be determined via the transit depth formula and Kepler’s Third Law. In this project, I use these concepts to create a web application that enables the visualization of exoplanet-hosting regions and determines the size and orbital period of available planets.

9. **Analytically Modeling the Gravitational Radiation Generated from a Quasistar System**

Jeremy Adam (North Carolina School of Science and Mathematics)

We study Quasistars, which consist of a stellar to intermediate mass black hole embedded inside a massive star-like envelope. The accretion rate onto the black hole matches the Eddington rate for the entire Quasistar, easily placing it in the hyper-Eddington accretion region. The quick growth of the black hole leads to the outwards transport of angular momentum and energy, causing the envelope to expand following $n = 3$ polytropic relationships. We allow the black hole to have some small initial offset from the center of mass of the Quasistar and have some initial tangential velocity, which makes the black hole orbit inside of the Quasistar. This orbit generates gravitational radiation as a result of a sinusoidal Quadrupole moment tensor that can be modeled through the use of the Quadrupole formula. We use analytical models to derive formulas for the separation between the black hole and the envelope's center as a function of time and the characteristic gravitational wave amplitude as a function of radiation frequency. We then numerically model these formulas for various initial mass and separation conditions. The numerical model for characteristic gravitational wave amplitude can be compared to the sensitivity curves of active and upcoming gravitational wave observatories, such as LIGO, LISA, and μAres, in order to determine the detectability of the system. We find that the separation between the black hole and the envelope's center increases over time, which is an unconventional result that stems from the nature of sub-Keplerian orbits and the mass transfer between the black hole and the envelope. Additionally, we find that our model produces gravitational waves with peak strain amplitudes between 10^{-20} and 10^{-24} at frequencies between 10^{-5} Hz and 10^{-9} Hz, which is 2 to 6 magnitudes below the sensitivity curve of μAres.

10. **Investigating the Effects of Mechanical Deformation on a Flexible Polymer's Thermoelectric Efficiency**

Charlotte Goebel (North Carolina School of Science and Mathematics)

Thermoelectric materials, capable of harnessing waste heat in industrial applications, use a temperature difference to create a voltage difference. The most efficient thermoelectric materials are rigid inorganics, but hybrid organic-inorganic materials are flexible and more applicable to moving heated surfaces. To quantify a material's thermoelectric power factor, we develop an apparatus to determine how strain and temperature variances affect its Seebeck coefficient and electrical conductivity. The measurement setup consists of a sample holding platform, temperature and voltage data acquisition boxes, and an online environment in LabVIEW for data collection and analysis. LabVIEW controls the temperature on either side of the material through a temperature PID loop. We chart an I-V curve for the thermoelectric sample, allowing us to find the sample's Seebeck voltage and resistance. Initial testing on bismuth telluride ensures an accurate calibration of the setup. An adjustable mechanism on the measurement platform compresses the sample for data during strain. We report preliminary results for bismuth telluride's Seebeck voltage and electrical conductivity versus temperature. Our next step will be to fabricate PEDOT:PSS/CNT, a hybrid thermoelectric material, and measure its Seebeck voltage and electrical conductivity versus strain and temperature.

11. **Assessing the Mechanical Properties and Morphology of Biomimetic Electrospun-Nanofiber Hydrogel Composites for Articular Cartilage Engineering**

Arianna Lee (North Carolina School of Science and Mathematics)

Articular cartilage (AC) is an important connective tissue located at the ends of bones in joints. AC's unique mechanical and physical properties enable it to cushion and facilitate smooth movement. However, its limited regenerative abilities often lead to osteoarthritis, a degenerative joint disease affecting over 32.5 million adults in the United States. Cartilage tissue engineering aims to create porous and degradable scaffolds to serve as sites for cartilage cell regeneration in the human body. Current AC scaffolds have difficulty achieving equivalent mechanical properties to native AC. Our project synthesized biomimetic nanofiber hydrogel composites by electrospinning PLLA-PCL nanofibers, forming stacks of anisotropic nanofiber mats, and crosslinking the stacks with calcium alginate hydrogel. We performed uniaxial tests to assess the strength and viscoelastic properties of the PLLA-PCL-Alg composites. Finally, we determined their porosity and fiber alignment. We aim to determine the efficacy of PLLA-PCL-Alg composites as potential AC scaffold materials for tissue engineering.

12. **Measuring the Absorption of Microwaves Within a Metamaterial**

Brandon Lofton (North Carolina School of Science and Mathematics)

Electromagnetic metamaterials can interact and change light's properties. We fabricated a microwave metamaterial that has electronic ring resonators which impact the incoming microwaves's electromagnetic fields. Metamaterials are used in a variety of applications, in invisibility cloaks, perfect absorbers, solar cells, super lens, and more. We used a microwave 2.8cm wavelength Sargent Welch transmitter that emits coherent and polarized waves to emit microwaves at the back plates of the metamaterial and the metal plates at certain angles. We also used a microwave diode probe that was placed between the metamaterial's gap and the two metal plates' gap, which is how we were able to measure the power output. Our research found that resonance occurs at intervals of 1.4cm as the gap height for our metamaterial changes. Metamaterials are able to create resonance, but compared to a similar wave entering two reflective metal plates of the same distance and angle, the energy received is generally the same for the metamaterial than the two reflective plates as they change gap heights. We were also able to make a model equation that predicts the amplitude and wavelength of the resonance graph as a function of gap height.

13. **Investigating the Morphologies of Local-Scale Dust Storms in the Vicinity of Mars's North Polar Ice Cap**

Johnathan Strickland (North Carolina School of Science and Mathematics)

Mars is notable for its frequent and intense dust storms. These storms can be found at nearly every location on the planet, though they vary in frequency and intensity. Dust storms on Mars are seasonal, with most storms occurring during northern fall and winter, from $L_s \sim 135$ to $L_s \sim 360$. During this season, increased heating associated with perihelion causes intense westerly jets to form around the north polar ice cap with wind speeds frequently greater than 130 m/s. Recent studies have suggested a possible correlation between the curvature and orientation of storms in this region and whether they formed in an entrance or exit region of a jet streak. To evaluate the validity of these claims, we have developed the Mars Storm Orientation and Curvature Quantifier (MSOCQ), a novel computer program which determines the approximate average curvature of dust storms and their orientations based on satellite imagery from Mars Daily Global Maps (MDGMs) produced by the Mars Reconnaissance Orbiter (MRO) Mars Color Imager (MARCI). Our study focuses on storms that are considered to be "local-scale" ($< 1.6 \times 10^6\,\text{km}^2$) centered above ~45N from Mars Year (MY) 28 $L_s \sim 160$ to MY 28 $L_s \sim 195$ and MY 28 $L_s \sim 340$ to MY 28 $L_s \sim 360$. We manually classified storms into one of four categories based on their appearance: "puffy", "pebbled", "ruffled", or "plume-like." Because each of these storm types has different methods of formation and is associated with different convective environments, we expect to observe significant differences in the importance jet streaks play in their formation.

14. **Custom Manufacturing and Design of a Tube Furnace for Production of Superconducting YBCO**

Ian Suh (North Carolina School of Science and Mathematics)

Superconductors, while displaying phenomenal physical properties, are impractical for many applications due to their low operational temperatures. A developing solution to this problem is the usage of dopants, which may improve several qualities found in a superconducting material, such as its critical temperature and microstructural morphology, greatly improving their practicality. For the production of many ceramic superconductors, a sintering and calcination process must occur, for which we have designed and manufactured a tube furnace using commonly available resources. Using a PID loop, we control our tube furnace with a microcontroller in conjunction with a relay, taking inputs from a high-temperature thermocouple. With this setup, we managed to create a stable linear ramp and constant soak for our heating curves. For our next steps, using $YBa_2C_3O_{7-\delta}$(Y123) as a basis for our superconductor, we will synthesize the YBCO ceramic through a citrate pyrolysis process, in which external elements such as Ag and Mg will be added during the sintering process. Confirmation of the superconducting state will be visually determined by means of the Meissner effect using LN_2, and data on the physical properties of the doped YBCO will then be collected by thorough experimentation with devices such as a four-wire setup and an Atomic Force Microscope.

15. **Additive Manufacturing and Performance Measurement of an Electroplated Electrospray Propulsion System**

Adrian Tejada (North Carolina School of Science and Mathematics)

Driven by advancements in electronics and manufacturing, microsatellites have become increasingly capable and popular in recent years, driving down the cost to access space. However, propulsion systems have not evolved in tandem with these microsatellites, leading to many being launched without the necessary propulsion for orbital maintenance, interplanetary travel, and other critical operations. Our research details the development of an additively manufactured electrospray propulsion system that fits within the size and budget constraints of modern microsatellites. We fabricated electrospray thrusters using stereolithography 3D printers, a cost-effective alternative to the MEMS manufacturing methods typically used. These thrusters were found to have an average tip diameter—a marker of thruster efficiency—of approximately 25 μm, a fivefold improvement on additively manufactured electrospray thrusters previously reported in the literature. We also document the successful copper electroplating of additively manufactured electrospray thrusters, a possible gateway to improved thrust and efficiency. Preliminary results on the thrust generated by our additively manufactured electrospray thrusters compared to typical MEMS-manufactured ones will also be reported. These findings confirm both the feasibility and possible advantages of additively manufacturing an electrospray propulsion system.

16. **Efficient Solution for Kepler Orbits Yields Natural Relationship to Quantum Hamiltonians for Intermediate-Level Physics Courses**

Jason Tran (Georgetown University)

As a more student-friendly approach, decoupling the differential equations typically found in central force problems allows for a simpler, more efficient solution to the orbits of the Kepler problem by removing the need for complex integral analysis. As an additional bonus, the quantization of radial variables uncovers a deeper connection between the Keplerian orbits and quantum mechanical Hamiltonians of hydrogen states, perfect for junior and senior undergraduate physics students. The original idea for this comes from the 1930 textbook Elementare Quantenmechanik by Born and Jordan.