# XXXIX

Annual

Rochester Symposium for Physics
(Astronomy & Optics) Students
SPS Zone 2 Regional Meeting

## March 20, 2021

**Department of Physics and Astronomy**
**University of Rochester**
**Rochester, NY 14627**

**Cosponsored by:**
**National Office of the Society of Physics Students; Department of Physics and Astronomy, University of Rochester; National Science Foundation (REU Program); Department of Energy**

University of Rochester, March 20, 2021

Dear Participants:

Welcome to the 39th annual Rochester Symposium for Physics Students (RSPS). The RSPS was instituted to provide an opportunity for undergraduates to present an account of their own personal research at a meeting whose format was chosen to closely resemble those of professional scientific societies.

At these symposia, research projects are presented in talks or poster sessions by undergraduates representing many regional institutions. Topics include condensed-matter physics, atomic physics and optics, computational physics, astronomy, particle and nuclear physics, instrumentation and techniques, environmental physics, biological physics, medical physics, and educational physics. The abstracts of all the participants' papers are published annually in the RSPS proceedings and distributed to the participants. The information is also available online at: http://www.pas.rochester.edu/news-events/rsps/2021/index.html

Students who present these talks can list their RSPS presentation(s) on their resumes and show the above web page in their list of publications as an "On-line Published Abstract". We encourage students to follow up on their research with the aim of giving a presentation at a regular American Physical Society (APS) meeting (which now also has a special session on undergraduate research), and eventually follow up with a publication in a regular journal, or in the APS Journal of Undergraduate Research.

At Rochester, the Department of Physics and Astronomy and the Institute of Optics are jointly running two National Science Foundation (NSF) funded Research Experience for Undergraduates (REU) sites. We encourage you to apply to one of these summer programs. Examples of research projects, talks, publications and awards won by our REU participants can be found on our REU Web page: https://www.pas.rochester.edu/undergraduate/reu/index.html

Your audience will include both students and faculty members and will provide you with the opportunity to address a knowledgeable and appreciative assembly of fellow researchers. Scientific research is an extraordinary activity. We certainly hope that many of you will decide to pursue careers that involve you intimately in mankind's greatest intellectual adventure, to comprehend nature. To quote Albert Einstein, “The eternal mystery of the world is its comprehensibility.”

**Frank Wolfs (Chair, RSPS)**
**Department of Physics and Astronomy**
**University of Rochester**

**LIST OF SPEAKERS**

| PRESENTER | TIME | ROOM |
|---|---|---|
| IAN BANIA | 09:00 | ROOM 1 |
| LUCAS BERENS | 09:00 | ROOM2 |
| GRANT BLOCK | 10:00 | ROOM2 |
| CHARLES CHIMERA | 14:15 | ROOM 1 |
| DAVID CLYMER | 11:30 | ROOM 2 |
| REBECCA COGLIANESE | 09:30 | ROOM 1 |
| COLIN DIXON | 11:45 | ROOM 2 |
| FREDRICK GENIER | 10:40 | POSTER 1 |
| ANDRES GONZALEZ | 10:40 | POSTER 2 |
| VANESSA HAVENS | 09:45 | ROOM 1 |
| KEONTRÉ HUGHES | 13:15 | ROOM 1 |
| DYSON KENNEDY | 10:40 | POSTER 3 |
| CALEB LEVY | 09:15 | ROOM 1 |
| RISHI LOHAR | 14:00 | ROOM 1 |
| ABBY LUPI | 12:00 | ROOM 2 |
| JUSTIN MAROTTA | 11:30 | ROOM 1 |
| ASHLEY MARTSEN | 10:00 | ROOM 1 |
| BLYDEN NARTEY | 12:15 | ROOM 2 |
| BENJAMIN NUSSBAUM | 12:00 | ROOM 1 |
| BRANDON PARKS | 09:15 | ROOM2 |
| JILLIAN PAULIN | 10:15 | ROOM 1 |
| CHAD POPIK | 13:15 | ROOM 2 |
| AROON PRESSRAM | 14:30 | ROOM 1 |
| JOSHUA RATAJCZAK | 13:30 | ROOM 2 |
| VASHISTH TIWARI | 10:40 | POSTER 6 |
| JACK TREGIDGA | 13:30 | ROOM 1 |
| NAVYA UBEROI | 10:15 | ROOM2 |
| STELLA VAN NESS | 14:00 | ROOM 2 |
| YUE WANG | 09:30 | ROOM2 |
| DANIEL WHINNERY | 12:30 | ROOM 2 |
| JACOB WILLIS | 10:40 | POSTER 7 |
| KAGAN YANIK | 12:15 | ROOM 1 |
| XI YEK | 14:15 | ROOM 2 |
| JOHN YEVOLI | 14:30 | ROOM 2 |

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|---|---|---|
| CHANJU (ZOE) YOU | 13:45 | ROOM 1 |
| GEORGE ZHANG | 09:45 | ROOM2 |
| GEORGE ZHANG | 10:40 | POSTER 8 |
| GEORGE ZHANG | 11:45 | ROOM 1 |
| YIFAN ZHANG | 13:45 | ROOM 2 |

# XXXIX – ROCHESTER SYMPOSIUM FOR PHYSICS (ASTRONOMY AND OPTICS) STUDENTS
# SPS ZONE 2 REGIONAL MEETING

## PROGRAM

**8:45 AM: WELCOME: PROF. FRANK WOLFS, UNIVERSITY OF ROCHESTER**

**9:00 AM–10:30 AM: SESSION IA. ASTRONOMY AND ASTROPHYSICS (*Zoom Rm #1*)**

**SESSION CHAIR: PROF. MARK ROSENBERRY, SIENA COLLEGE**

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|---|---|
| 9:00 AM | **The Effects of Multiscatter Dark Matter Capture and Evaporation on the Evolution of Population III Stars**<br>Ian K. Bania, Colgate University |
| 9:15 AM | **Constraining Dark Matter Properties with Population III Stars**<br>Cosmin Ilie, Caleb Levy, Jacob Pilawa, and Saiyang Zhang, Colgate University |
| 9:30 AM | **Neutron Stars in the Braneworld: The Role of the Nuclear Equation of State and the Brane Tension**<br>Rebecca Coglianese, Manhattan College |
| 9:45 AM | **Photometry and Imaging of Asteroid**<br>Vanessa Havens, Siena College |
| 10:00 AM | **Deblending Merging Galaxies using SCARLET**<br>Ashley Martsen, Jeyhan Kartaltepe, Michael Lam, Fred Moolekamp, RIT, RIT, RIT, Princeton |
| 10:15 AM | **The Effect of Stellar Velocity on Dark Matter Capture Rates of Population III Stars**<br>Jillian Paulin, Cosmin Ilie, Colgate University |

**9:00 AM–10:30 AM: SESSION IB. INSTRUMENTATION/EXPERIMENTAL TECHNIQUES, NUCLEAR AND PARTICLE PHYSICS (*Zoom Rm #2*)**

**SESSION CHAIR: PROF. ZACHARY ROBINSON, THE COLLEGE AT BROCKPORT**

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|---|---|
| 9:00 AM | **LCLS-II Photoinjector Optimization Using Measured Transverse Laser Profiles**<br>Lucas Berens (1,2), Nicole Neveu (1), Lipi Gupta (1,3), 1: SLAC National Accelerator Laboratory, 2: Rochester Institute of Technology, 3: University of Chicago |
| 9:15 AM | **Autonomous Arduino-Based Wetlands Sensor**<br>Brandon Parks, Rachel Schultz, SUNY Brockport |
| 9:30 AM | **Gaussian Process for Anomaly Detection in Particle Accelerators**<br>Yue Wang, University of Rochester, SLAC National Accelerator Laboratory |
| 9:45 AM | **Local Positioning System using Chip Scale Atomic Clocks (CSACs)**<br>Aaron Flowers, George Zhang, Saleem Ali, Dr. Paula Fekete, United States Military Academy |
| 10:00 AM | **Modeling Gamma Calibration Sources and Designing a Single Phase Time Projection Chamber in the Noble Element Simulation Technique**<br>Grant Block, Rensselaer Polytechnic Institute |
| 10:15 AM | **Detecting Neutrino Signals from Supernovae in the IceCube Neutrino Observatory**<br>Navya Uberoi, University of Rochester |

**10:30 AM–10:40 AM: BREAK**

**10:40AM–11:25 AM: SESSION II. POSTER SESSION (*Zoom Rms: Poster #1-#8*)**

**Using REBOUND to simulate the orbit of asteroid 2010 TK7**
Fred Genier, Mark Rosenberry, Graziano Vernizzi, Siena College
**(*Zoom Rm: Poster #1*)**

**Unexpected Effects of Polymer Flow on the Permeability of Porous Media**
Andres Orio Gonzalez, Rochester Institute of Technology
**(*Zoom Rm: Poster #2*)**

**Heavy Neutral Particle Search in MINERvA**
Dyson Kennedy, Jacob Smith, University of Rochester, on Behalf of the MINERvA Collaboration
**(*Zoom Rm: Poster Rm #3*)**

~~**Creating a Cost-Efficient Ionization Chamber**~~
~~Aroon Pressram, Siena College~~
~~**(*Zoom Rm: Poster #4*)**~~

~~**Searching for Milli-charged Particles in the MINERvA Experiment**~~
~~Jacob Smith, Dyson Kennedy, University of Rochester~~
~~**(*Zoom Rm: Poster #5*)**~~

**Using Machine Learning to Develop a Transient Identification Pipeline for DESI**
Amanda Wasserman, Vashisth Tiwari, Segev BenZvi, University of Rochester, for the Dark Energy Spectroscopic Instrument (DESI)
**(*Zoom Rm: Poster #6*)**

**Lightcurve Analysis of Minor Planet**
CDT Jacob Willis, United States Military Academy
**(*Zoom Rm: Poster #7*)**

**Field-controlled transport of Dirac particles with elliptical dispersion**
George Zhang, Dr. Paula Fekete, Dr. Andrii Iurov, Dr. Godfrey Gumbs, United States Military Academy
**(*Zoom Rm: Poster #8*)**

**11:25 AM–11:30 AM: BREAK**

**11:30 AM–12:45 PM: SESSION IIIA. EDUCATIONAL PHYSICS, QUANTUM OPTICS (*Zoom Rm #1*)**

**SESSION CHAIR: PROF. ERIC MONIER, THE COLLEGE AT BROCKPORT**

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|---|---|
| 11:30 AM | **Develop Augmented Reality Tools for Teaching Physics & Chemistry Concepts**<br>Justin Marotta, Natalie Stagnitti, Siena College |
| 11:45 AM | **Effects of Gravitational Time Dilation during Balloon Satellite Flights with Chip Scale Atomic Clocks**<br>George Zhang, Aaron Flowers, Saleem Ali, Dr. Paula Fekete, United States Military Academy |
| 12:00 PM | **A Photonic Electro-Optic Circuit for On-Chip Quantum Frequency Processing**<br>Benjamin Nussbaum, University of Rochester |
| 12:15 PM | **A Quantum Measurement Driven Engine and the Demon's Arrow of Time**<br>Andrew N. Jordan, Sreenath K. Manikandan, Kagan Yanik, University of Rochester |

**11:30-12:45 PM: SESSION IIIB. OTHER TOPICS (*Zoom Rm #2*)**

**SESSION CHAIR: PROF. CANDICE FAZAR, ROBERTS WESLEYAN COLLEGE**

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|---|---|
| 11:30 AM | **Free-Standing Membrane Formed of Nanoplatelet Translocation in MoS2 for Nanopore Sensing**<br>Vincent Meunier, David Clymer, Rensselaer Polytechnic Institute, Northeastern University |
| 11:45 AM | **Modeling Heat Flow Through Insulation**<br>Colin Dixon, Colgate University |
| 12:00 PM | **Deciphering Hidden Text in Historical Manuscripts: Multispectral vs. Hyperspectral Imaging**<br>Abby Lupi, Tania Kleynhans, David Messinger, Rochester Institute of Technology |
| 12:15 PM | **The A.R.M:A Customizable Myoelectric Prosthesis**<br>Blyden Nartey, Siena College |
| 12:30PM | **Boltzmann entropy for decision tree algorithms**<br>Daniel Whinnery, Siena College |

**12:45 PM – 1:15 PM: LUNCH BREAK**

**1:15 PM–2:30 PM: SESSION IVA. BIOLOGICAL PHYSICS, CONDENSED MATTER PHYSICS (*Zoom Rm #1*)**

**SESSION CHAIR: PROF. FEKETE, UNITED STATES MILITARY ACADEMY**

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|---|---|
| 1:15 PM | **Analysis of Electron Density Modifications During Vitamin D Absorption.**<br>Keontré I. Hughes, Colgate University |
| 1:30 PM | **Learning in Spiking Josephson Junction Neural Networks**<br>Jack Tregidga, Colgate University |
| 1:45 PM | **Studying Spin Noise in 1D Nanowires Using Quantum State Diffusion**<br>ChanJu (Zoe) You, Colgate University |
| 2:00 PM | **Terahertz Spectroscopy of Carbon Nanotubes**<br>Rishi Lohar, Colgate University |
| 2:15 PM | **Femtosecond Carrier Relaxation and Coherent Acoustic Phonon Generation in Bi2Se3 Nanolayers**<br>Charles Chimera, Jing Cheng, Peter Francis, University of Rochester |
| 2:30 PM | **Creating a Cost-Efficient Ionization Chamber**<br>Aroon Pressram, Siena College |

**1:15 PM–2:45 PM: SESSION IVB. ASTRONOMY AND ASTROPHYSICS (*Zoom Rm #2*)**

**SESSION CHAIR: PROF. MICHAEL DUNHAM, SUNY FREDONIA**

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|---|---|
| 1:15 PM | **Evaluating the BAO signal through CenterFinder**<br>Chad Popik, University of Rochester |
| 1:30 PM | **Exploring the Distribution of the Intergalactic Medium Gas 11 billion Years Ago**<br>Joshua Ratajczak, Satya Gontcho A Gontcho, Regina Demina, Zachery Brown, Gebri Mishtaku, University of Rochester |
| 1:45 PM | **Decomposition of Galaxy Rotation Curves**<br>Yifan Zhang, University of Rochester |
| 2:00 PM | **CaII Absorption in Quasar Fields**<br>Stella Van Ness, SUNY Brockport |
| 2:15 PM | **Detection of a Disk Surrounding the Variably Accreting Young Star HBC722**<br>Xi Yek (Zach), SUNY at Fredonia |
| 2:30 PM | **The Effects of Decaying Dark Matter at Early Times on The Hubble Constant**<br>John Yevoli, Manhattan College |

**SESSION IA. ASTRONOMY AND ASTROPHYSICS**

**The Effects of Multiscatter Dark Matter Capture and Evaporation on the Evolution of Population III Stars**

Ian K. Bania, Colgate University

After scattering off nucleons, dark matter (DM) particles may lose enough energy to become gravitationally bound to an astrophysical object. In order to become captured in this manner, heavy DM may need to experience a number of successive scattering events. This mechanism is in contrast to the other main method of transporting DM into an object, adiabatic contraction (AC). In the case of captured self-annihilating DM, in regions of sufficiently high DM density (such as ~$10^6$ $M_{sun}$ minihalos at redshifts z ~ 15) it then becomes possible for heating from DM annihilations to be a significant source of energy production. By implementing recently developed formalism of multiscatter capture in the stellar evolution package MESA, I model how the first generation of stars (Population III) react to heating from captured DM. I then explore how DM heating from capture alone may be able to drive the "dark star" phase of stellar evolution. Dark stars have been shown in previous work to emerge when there is significant DM heating due to adiabatic capture. Furthermore, for lower DM masses where it is relevant ($m_\chi < 10^4$ GeV) I calculate the DM evaporation rates in Pop. III stars at zero age main sequence (ZAMS) using radial profile data generated in MESA.

**Constraining Dark Matter Properties with Population III Stars**

Cosmin Ilie, Caleb Levy, Jacob Pilawa, and Saiyang Zhang, Colgate University

Dark Matter (DM) particles incident on a star can become gravitationally bound and trapped inside the star after colliding with stellar nuclei through a process known as capture. Captured dark matter can then do one of two things: self-annihilate or evaporate from the star, depending on the particle's mass. Thus, the number of dark matter particles inside a star is governed by these competing processes. Population III stars, the first stars formed in the universe between redshifts of z ~ 10-50, are an ideal candidate for the study of these processes as they are theorized to have been formed in dense DM mini-halos, implying a high DM capture rate. After some time, an equilibrium between capture, annihilation, and evaporation ensues and DM particles provide a stable source of luminosity through self-annihilation. Like any other star, population III stars in hydrostatic equilibrium have a maximum luminosity known as the Eddington

limit. This upper bound on luminosity provides a way to place projected bounds on the DM-proton scattering cross-section well below current direct detection experiments in the sub-GeV region. Thus, the mere observation of population III stars, a promising prospect with the new James Webb Space Telescope, can be used to constrain this key dark matter property in previously unexplored regions of parameter space.

**Neutron Stars in the Braneworld: The Role of the Nuclear Equation of State and the Brane Tension**

Rebecca Coglianese, Manhattan College

We studied the properties of neutron stars using a model of extra-dimension, known as braneworld theory, and utilized a state-of-the-art nuclear equation of state. This is an important research area as it advances our understanding of the fundamental laws of nature and explores the possibility of a warped geometry and a higher-dimensional universe, using compact objects as astrophysical laboratories. In particular, we found that the brane tension can enhance the observed mass of the compact object. Given the nuclear physics constraints on the equation of state and the astrophysical limit of the maximum mass of the neutron star, we set a lower limit on the brane tension.

**Photometry and Imaging of Asteroid**

Vanessa Havens, Siena College

Asteroids of all sizes orbit within our solar system, some come close to Earth and some far away. While the collision threat from asteroids is well known, we can learn about the formation of the Solar System by studying the orbital properties and composition of asteroids. Using the Siena College Breyo observatory, I have been and plan to continue tracking asteroids, focusing on the asteroid Danae. With the data processed, I will then analyze the images taken using the programs DS9 and AstroImageJ to measure a light curve of the asteroid. By looking at light curves you are able to see the variations in the light reflected from the asteroid which helps to determine the shape of the asteroid and its rotation period. We plan to obtain spectra to analyze the asteroid's chemical characteristics. The chemical composition and any absorption lines can help us to determine the region where the body came from in space, and determine what kind of asteroid it is.

**Deblending Merging Galaxies using SCARLET**

Ashley Martsen, Jeyhan Kartaltepe, Michael Lam, Fred Moolekamp, RIT, RIT, RIT, Princeton

We discuss how to use the Python package SCARLET to deblend and model interacting, overlapping, or merging high redshift galaxies in the COSMOS Field.

**The Effect of Stellar Velocity on Dark Matter Capture Rates of Population III Stars**

Jillian Paulin, Cosmin Ilie, Colgate University

In recent years, much work has been done concerning the dark matter capture rates of Population III stars and the resulting observable effects. In these cases, it is customary to assume the star would form exactly at the center of a dark matter halo. In this paper, we break from this assumption. Instead, we explore the effects we can expect to observe if a Pop III star forms at some distance away from the center of the halo. The capture rate of dark matter in such a star is suppressed by a predictable amount. In this paper, we develop an analytical expression for the capture rate suppression factor and re-evaluate the bounds placed on the dark matter-nucleon cross section as a result of dark matter capture.

## SESSION IB. INSTRUMENTATION/EXPERIMENTAL TECHNIQUES, NUCLEAR AND PARTICLE PHYSICS

### LCLS-II Photoinjector Optimization Using Measured Transverse Laser Profiles

Lucas Berens (1,2), Nicole Neveu (1), Lipi Gupta (1,3), 1: SLAC National Accelerator Laboratory, 2: Rochester Institute of Technology, 3: University of Chicago

An upgrade to the Linac Coherent Light Source (LCLS) is currently under construction (LCLS-II). Simulations of the photoinjector are used to better understand and predict beam quality under different operating conditions. These simulations, however, do not currently account for the transverse laser profile at the photocathode. We present results on using transverse laser profiles from Virtual Cathode Camera (VCC) images to optimize LCLS-II photoinjector simulations. We have used these VCC images as initial transverse particle distributions for ASTRA photoinjector simulations, as opposed to ideal particle distributions. We also present preliminary hyperparameter settings for optimization of the emittance and bunch length using NSGA-II.

### Autonomous Arduino-Based Wetlands Sensor

Brandon Parks, Rachel Schultz, SUNY Brockport

Data loggers used to conduct field research by SUNY Brockport's Environmental Science Department are costly, and limited in their use. Thus, we were asked to create one that was more versatile and cost effective. Using an Arduino Uno, a solar panel, and a battery, we were able to create an autonomous long-term data logger that could run continuously with minimal interaction required. When placed in the field, the prototype system collected data for months at a time. It was only when the surrounded foliage blocked out the sun that the battery ran out, and intervention was required. Three soil oxygen and temperature sensors were attached to the logger, as well as three soil moisture sensors. Our system could interpret and record the digital input of the oxygen sensors, as well as the analog input from the moisture sensors.

**Gaussian Process for Anomaly Detection in Particle Accelerators**

Yue Wang, University of Rochester, SLAC National Accelerator Laboratory

Common anomalies in particle accelerators are point anomaly, shift anomaly, and drift anomaly. The current troubleshooting procedures for the accelerator at SLAC are resources and time consuming. A method that is able to detect anomalies in real-time and report a list of potential causes of the anomalies will be presented in this talk. Gaussian Process (GP) fits the signal functions from limited noisy observations. GP was used to calculate the functional values and the derivatives in real time. Furthermore, we classified and visualized points leading to an anomaly using the predicted values with a matrix. We demonstrated the method on a Toy Model and accelerator simulation data set.

**Local Positioning System using Chip Scale Atomic Clocks (CSACs)**

Aaron Flowers, George Zhang, Saleem Ali, Dr. Paula Fekete, United States Military Academy

The purpose of this research project is to utilize Chip Scale Atomic Clocks (CSACs) to create an accurate local positioning system that can operate as a contingency to the conventional Global Positioning System. GPS measures the time it takes for radio signals to travel to and from a receiver to calculate the pseudorange between the receiver and its corresponding satellites. We investigate this concept employing smaller, ground-based handheld devices that are rapidly deployable with ground-based receivers and receivers onboard low altitude balloon satellites. We show that our local positioning system can operate using hand portable CSACs that will accurately measure the time it takes for radio signals to travel to and from a receiver at closer distances, while accounting for time dilation due to altitude differences. Using the process of trilateration, we find an accurate distance and location between the receiver and three other CSACs. This local positioning system is expected to be useful for situations where GPS is unavailable such as in high pressure deployment situations for the military, as well as in places where GPS satellites cannot reach such as underground locations.

**Modeling Gamma Calibration Sources and Designing a Single Phase Time Projection Chamber in the Noble Element Simulation Technique**

Grant Block, Rensselaer Polytechnic Institute

The Noble Element Simulation Technique (NEST) is a computational framework which models the response of noble elements, specifically as target media in time projection chambers (TPCs) to various particle interactions. Modeling the responses of these elements is a critical component for TPC-based experiments such as dark matter searches and neutrinoless double beta decay. We motivate the ability of NEST to describe single, as well as dual-phase detectors by comparing the differences between these detectors, such as direct ionization measurement via induction wires versus an electroluminescence channel. The need to effectively compare data from single-phase TPCs such as EXO-200 and NEST also motivates the development of a comprehensive framework to model signals from gamma decays of sources commonly used to calibrate TPC experiments. We implement this on top of NEST's existing gamma yield model. As a further step to incorporate single-phase TPCs into NEST, we implement a noise term on the quanta yields, which single-phase experiments such as EXO-200 use to account for the noise on cathodes used to read electron yield. This noise term can also be applied to NEST's dual-phase detector models to more flexibly deal with statistical and experimental data fluctuations.

**Detecting Neutrino Signals from Supernovae in the IceCube Neutrino Observatory**

Navya Uberoi, University of Rochester

Estimates of star formation rates in the Milky Way predict about three supernovae per century in the galaxy. However, we have not observed a supernova in our galaxy since the invention of the telescope 400 years ago - a potential discrepancy that calls for novel methods of supernova observation. Neutrino signals from core-collapse supernovae could not only provide up to 24 hours advance warning of the explosion for optical astronomers, but also increase our understanding of the explosions of massive stars, nuclear physics under extreme conditions, and the properties of neutrinos. The IceCube Neutrino Observatory, currently the world's largest neutrino detector, is a part of the Supernova Early Warning System (SNEWS) and would be instrumental in alerting the world of an imminent supernova in our galaxy and the Magellanic Clouds. However, there is a gap between supernova simulations and the corresponding signals in detectors which will make any comparison between theory and observation very difficult. SNEWPY

is an open-source software package which bridges this gap. SNEWPY can interface with supernova simulation data to generate a time series of neutrino spectra at Earth which it can then use to calculate the neutrino event rates as seen in the detector.

**SESSION II. POSTER SESSION**

**Using REBOUND to simulate the orbit of asteroid 2010 TK7**
Fred Genier, Mark Rosenberry, Graziano Vernizzi, Siena College

The asteroid 2010 TK7 is currently the only known Earth trojan object, oscillating about the Sun-Earth L4 point. The first goal of our project is to attempt to simulate 2010 TK7's orbit using the Python n-body integrator REBOUND. Additionally, we seek to test whether a passing near-Earth object could perturb 2010 TK7's orbit enough to free it.

**Unexpected Effects of Polymer Flow on the Permeability of Porous Media**
Andres Orio Gonzalez, Rochester Institute of Technology

Understanding the effects of polymers on the permeability of different porous media is vital to various industries. In enhanced oil recovery, hydrolyzed polyacrylamide is injected into oil reservoirs to decrease the water-oil mobility ratio and drastically increases oil recovery. After polymer flow, the permeability of a porous medium decreases due to retention. This decrease depends on multiple variables such as the concentration of the polymer, volume of polymer, flow rate, and the allotted time for polymer retention. However, porous media are complex networks and such effects are difficult to understand with simple mean field approximations. Utilizing bulk permeability measurements and Darcy's Law, we observe that the permeability of a glass square capillary tube decreases by an order of magnitude after polymer flow. The majority of reduction in permeability occurs in the first few volumes of polymer flow and additional polymer only decreases the permeability an extra 15%. Using confocal microscopy, we probe the changes in the local structure of the network and show that some pores are blocked due to polymer flow. This explains the unexpectedly large reduction in permeability which provides a deep understanding of the role of polymer flow in oil recovery.

**Heavy Neutral Particle Search in MINERvA**

Dyson Kennedy, Jacob Smith, University of Rochester, on Behalf of the MINERvA Collaboration

The MINERvA experiment observes neutrino interactions from the most intense neutrino beam in the world (NuMI). If a rarely interacting neutral particle with a mass on the order of 100 MeV were to be produced in the beam, it would arrive in the detector much later than the ultra-relativistic neutrinos and might deposit energy noticeably higher than other expected sources of late-in-time energy in the detector. We describe efforts to understand and eliminate the backgrounds in the MINERvA data outside the beam gate in order to search for signals that fit this description. Such a particle is not predicted by the Standard Model and thus this search could help direct the future extensions of the Standard Model.

**Creating a Cost-Efficient Ionization Chamber**

Aroon Pressram, Siena College

Creating a cost-efficient ionization chamber can serve as an effective learning tool for students interested in areas of applied physics that focus deeper on radiation (e.g. Medical Physics, Nuclear Physics, Linac engineering). Many simplified ionization chambers are made by building a Darlington pair circuit. For the purposes of delivering a more accurate and reliable ionization chamber, I used a 4-pair Darlington circuit following C. Wentzel's design as opposed to a single-paired Darlington circuit. This is due to the single pair circuit’s susceptibility to temperature and stray electrical fields, both of which cause imprecise fluctuations in the reading. Several prototypes were made on a Protoboard and soldered into mini-solder boards, which then went into the chamber. I decided to create and utilize a printed circuit board (PCB). This would show the placement of each component, preventing problems that others might run into when trying to solder components together. The circuit is a demonstrative model of an actual representation of ionization chambers that are found in clinics; it has a similar structure and functionality with a simpler design intended to provide a working knowledge of a more complex instrument.

**Using Machine Learning to Develop a Transient Identification Pipeline for DESI**
Amanda Wasserman, Vashisth Tiwari, Segev BenZvi, University of Rochester, for the Dark Energy Spectroscopic Instrument (DESI)

During the next five years, the Dark Energy Spectroscopic Instrument (DESI) will carry out a massive redshift survey of 35 million galaxies and quasars, mapping the large scale structure of the universe out to a redshift of 3. During the DESI survey we expect to find galaxies that host bright transients such as supernovae, tidal disruption events (TDEs), and compact binary mergers. The identification of transients is important not only to ensure correct estimates of the host redshifts, but also because it provides an opportunity to obtain serendipitous spectra of the transients themselves. Spectroscopic classification is the "gold standard" in the categorization of transients, making these discoveries invaluable when combined with data from large photometric surveys. We have developed machine learning tools to identify and classify transients in galaxy spectra. In this contribution we describe these tools, characterize their performance using simulated spectra, and estimate the sensitivity of DESI to transients important for both astrophysics and cosmology.

**Lightcurve Analysis of Minor Planet**
CDT Jacob Willis, United States Military Academy

In observational astronomy, there is a variety of data that needs to be collected on celestial objects. For minor planets, or asteroids, one such parameter is how fast the object is rotating. To collect rotational data, the light reflected from the minor planet is used as a proxy for the planet's period in a process called lightcurve analysis. This method uses sinusoidal patterns in the light reflected from a minor planet as an indicator for how often an asteroid completes a full rotation. In our research, we are outfitting West Point's observatory to take such measurements. Then, we will conduct lightcurve analysis on a minor planet with a known period to confirm our method is accurate.

**Field-controlled transport of Dirac particles with elliptical dispersion**

George Zhang, Dr. Paula Fekete, Dr. Andrii Iurov, Dr. Godfrey Gumbs, United States Military Academy

We investigate tunneling and transport properties of Dirac electrons dressed by a linearly-polarized, off-resonance, and high-frequency dressing field through graphene and dice lattice sheets. We employ Floquet-Magnus perturbation theory to obtain the quasiparticle energy dispersion relation and closed form analytic expressions for dressed electron wave functions. We illustrate how features of the anomalous Klein paradox, i.e., a complete, asymmetrical electron transmission, which is independent on the barrier height or width, is modified by the anisotropic energy dispersion caused by the applied dressing field. We investigate the current strength and its dependence on the asymmetry introduced by Klein tunneling. The relationship of transmission and tunneling conductivity current peaks to Klein tunneling maxima is examined. We predict a decrease in transmission current when the Klein transmission peak is located at a larger angle. We expect larger transmission current in the dice lattice than in graphene due to a much broader Klein tunneling peak in the former system. Predicted transport properties are expected to be useful in the design of novel electronic and optical graphene-based devices and electronic lenses in ballistic-electron optics.

**SESSION IIIA. EDUCATIONAL PHYSICS, QUANTUM OPTICS**

**Develop Augmented Reality Tools for Teaching Physics & Chemistry Concepts**
Justin Marotta, Natalie Stagnitti, Siena College

Many undergraduate students find it difficult to visualize 3D concepts in physics, chemistry and engineering courses. There is a need for context-specific spatial visualization activities to help students connect 2D representations to 3D models. We have assembled an interdisciplinary team of undergraduate physics, chemistry, and computer science research students and faculty to create 3D, augmented reality (AR) models of physics concepts including centripetal force, torque, electric and magnetic fields and forces, and electromagnetic induction. Utilizing software including Unity, Vuforia, and Merge SDK, research students create the 3D physics models. Once developed, researchers upload the AR apps to Apple's TestFlight and export them as APKs for Android, making them available to students. To use, students download the apps to their smartphone or tablet and view the Merge Cube through their device, the 3D physics model appears on the Merge Cube. By rotating the Merge Cube, the students can view the 3D model from different perspectives. This provides an opportunity for students to envision many 2D representations of the same 3D concept. Students and Instructors can utilize these AR apps in a variety of situations including for use within lectures, problem solving sessions or labs either within in-person or remote instruction. Augmented reality 3D models have applications in many STEM disciplines where strong spatial visualization improves student performance in STEM. In this talk, we will present the AR app development process to create physics and chemistry apps and the lessons created to accompany the app.

**Effects of Gravitational Time Dilation during Balloon Satellite Flights with Chip Scale Atomic Clocks**
George Zhang, Aaron Flowers, Saleem Ali, Dr. Paula Fekete, United States Military Academy

We explore the theoretical principle of gravitational time dilation by collecting experimental data obtained by chip scale atomic clocks aboard balloon satellite flights. We illustrate how gravitational time dilation can be modeled given intermittent data throughout a low altitude balloon satellite flight. We compare experimental data against

theoretically modeled estimates of gravitational time dilation through a numerical integration process that incorporates multiple corrections to include latitude and crust density corrections. We expect that our model will significantly support our experimental data, and the corrections will improve accuracy. We predict that gravitational time dilation will be further verified and that our model will be accurate to within 5 nanoseconds. The model is expected to be useful in future balloon satellite operations, as well as for the design of time sensitive systems involving balloon satellites, or other similar low-earth orbiting devices.

**A Photonic Electro-Optic Circuit for On-Chip Quantum Frequency Processing**
Benjamin Nussbaum, University of Rochester

As classical computational power grows, some problems continue to remain impractical to solve at large scales, becoming intractable for any typical use case. By leveraging knowledge of quantum interactions, recent algorithms promise efficient alternatives to the limited classical solutions. Although quantum information processing and quantum computing have been well established as fields of significant research interest, efforts to make these technologies scalable still pose significant challenges. Rather than following this same path of atom or electron spin to build qubits, or even exploring other properties of light such as polarization or spatial modes, encoding information in the wavelength or frequency of light supports a swath of potential advantage. This research will explore the use of a frequency mode space for quantum information processing in the mature platform of silicon photonics, focusing on the fundamental operation of a Hadamard transformation.

**A Quantum Measurement Driven Engine and the Demon's Arrow of Time**
Andrew N. Jordan, Sreenath K. Manikandan, Kagan Yanik, University of Rochester

We discuss a quantum measurement engine, powered by dichotomous quantum weak measurements on a single qubit weakly coupled to a thermal reservoir, and feedback control by a quantum Maxwell's demon. We find that for a demon acquiring information via quantum weak measurements, the work extracted is completely determined by the demon's quantum measurement arrow of time. We also discuss a realistic time-continuous operation of the engine where the measurement and feedback

operations compete with the thermalization, and we show that the engine approaches a steady state where it operates with finite efficiency.

**SESSION IIIB. OTHER**

**Free-Standing Membrane Formed of Nanoplatelet Translocation in MoS2 for Nanopore Sensing**

Vincent Meunier, David Clymer, Rensselaer Polytechnic Institute, Northeastern University

We built an integrated computational scheme to construct a free-standing 2-dimensional MoS2 membrane for nanopore sensing. In this computational scheme, we model the 2-dimensional system by using a large-scale atomic simulator, and we study this model on Python. Our method is based upon the nature of Van der Waals force in thermal equilibrium in materials, MoS2 in particular. The major portion of this method relies on our use of a nanoplatelet syringe in addition to the existing MoS2 bulk model.

**Modeling Heat Flow Through Insulation**

Colin Dixon, Colgate University

Heating and cooling are some of the largest uses of energy in the United States and energy efficiency improvements, such as insulation, have been shown to be a cost effective way to significantly reduce this energy use. Dr. Park's lab is developing a faster, simpler and less expensive method of measuring the R-value of a wall, which is a common metric of how well a wall is insulated. The purpose of this project is to use a computational model of heat flow to analyze the accuracy of the measurement method. One focus of this project is studying the inherent measurement error that comes from a portion of the heat-flow going around our apparatus rather than through it. Second, we wanted to investigate the effects of changing outdoor temperatures on our measurements. We found our apparatus has an error below 10% for a range of normal values for the parameters of the wall. We also found that there is a constant delay between a change in temperature outside the wall and the corresponding change inside the wall. This makes it possible to accommodate for this delay by applying a time shift to temperature data taken inside the wall. Finally some of the ongoing work for this project includes expanding the capacity of the computational model to simulate more variations in the material of the wall, such as adding joists and pipes into the wall.

**Deciphering Hidden Text in Historical Manuscripts: Multispectral vs. Hyperspectral Imaging**

Abby Lupi, Tania Kleynhans, David Messinger, Rochester Institute of Technology

Whether by intentional erasure or weathering from the elements, some historical texts are damaged beyond recognition... or so we thought. The Rochester Cultural Heritage Imaging, Visualization, and Education (R-CHIVE) research group at RIT analyzes data from multispectral and hyperspectral images to reveal text that is otherwise invisible to the naked eye. This research compares hyperspectral (HSI) and multispectral imaging (MSI) using language that is accessible to non-scientists. In particular, we distinguish the merits of HSI vs MSI and the contexts in which each is useful.

**The A.R.M:A Customizable Myoelectric Prosthesis**

Blyden Nartey, Siena College

In the medical field, there is a need for prosthesis; however they are often ineffective, difficult to use, and so expensive that they are beyond the reach of most amputees.Most of these devices are body powered prostheses, but are inefficient and limited in their movements. Other types are powered electronically, but are costly to make. A large number of arm amputees in particular don't have their elbow so even a traditional electric arm will not suffice because there is no muscle there to bend. Each prosthetic is made custom, as different amputees have different needs. The Autonomous Reengaging Mechanism a.k.a the A.R.M provides  a controlled range of motion using myoelectric sensors. These sensors track the muscle conductivity in the active muscles in the shoulder and back, which trigger rotational motors in the prosthetic to activate. These motors provide a range of elbow and wrist flexion that other prosthesis cannot provide. The cost to make the A.R.M is significantly reduced compared to most prosthetic arms, since the A.R.M's parts are printed using a 3D printer and PLA filament. In this presentation, I will demonstrate the design and prototype testing of a generic A.R.M. I will be summarizing the range of motion of the myoelectric sensors and the motors I chose to provide enough force to move the A.R.M and simulate the movement of a real human arm as closely as possible.

**Boltzmann entropy for decision tree algorithms**

Daniel Whinnery, Siena College

Decision trees and random forests are generated by the recursive binary partition of a given dataset. The goal is to increase the diversity (or information content) of the data among different partitions. That task is usually achieved by minimizing information-theoretic functions such as the Shannon/Gibbs entropy, or the Gini index. This work explores the question whether the use of the classic Boltzmann entropy for optimizing decision trees/random forests presents differences or advantages over traditional functions. In addition, the Boltzmann entropy reveals a connection between the generation of branches in a decision tree, and the so-called Gibbs-paradox or mixing-paradox in classical statistical mechanics. Although this work is in progress still, preliminary hypotheses and results will be discussed, including a bibliographic search comparing previous work in the literature on this topic.

## SESSION IVA. BIOLOGICAL PHYSICS, CONDENSED MATTER PHYSICS

**Analysis of Electron Density Modifications During Vitamin D Absorption.**
Keontré I. Hughes, Colgate University

Chronic vitamin D deficiency is a relatively common condition worldwide. We studied a mix of vitamin D binding proteins and model membranes, with the goal of understanding structural changes that occur as cells absorb vitamin D. Data are gathered with synchrotron X-ray diffraction (XRD) in addition to NMR and spectroscopic techniques such as FTIR. From this data we extract and model the electron density of model membranes by relying on the Harper-Gruner approach [Biophysical J. 81, p 2693]. By analyzing the effects of proteins vs buffers for these electron density models, we saw that XRD shows peak splitting near 75 Angstroms, as well as peak shifts in the amount of approximately 5 Angstroms, depending on temperature [environmental and physiological] and cholesterol concentration. Accordingly, we found that changes in temperature and increase in cholesterol concentration contribute to changes in lamellar spacing, seen in XRD.

**Learning in Spiking Josephson Junction Neural Networks**
Jack Tregidga, Colgate University

Neuromorphic systems, which mimic the structure and behavior of biological neurons, are of considerable interest to several scientific fields, including physics, biology, mathematics and computer science. In this paper we explore the dynamics of Josephson junction-based neural networks. Through simulations we have shown non-trivial learning in a three-neuron, two-synapse network, where the output state depends on both the input variables and the current learning state variables. Output states are both discrete and self-reinforcing, meaning they are delineated and self-sustaining over long time periods. Consideration is also given to future implementation and characterization of Josephson junction neural networks in physical circuits.

**Studying Spin Noise in 1D Nanowires Using Quantum State Diffusion**
ChanJu (Zoe) You, Colgate University

Quantum state diffusion is a useful modeling technique when it comes to understanding the interaction between a quantum system and its surroundings, in other words - an open quantum system. Here, we examine its usefulness in studying spin noise phenomena in quasi-1D semiconducting nanowires. Motivated by the significance of understanding spin relaxation dynamics in semiconductor nanostructures, we studied how electric bias and contact geometry influences spin relaxation in quasi-1D nanowires. Spin relaxation times ranged from 50 ns to 400 ns for a variety of sample geometries and nanowire aspect ratio. Spin noise spectra of quasi-1D GaAs nanowires have shown an unusual feature of the appearance of a secondary peak in addition to the main peak. We propose that the appearance of the secondary peak is due to the two different modes of spin transport in nanowires - the drift-diffusion transport and ballistic transport. This is examined by correlating quantum state diffusive trajectories and experimental spin noise spectra.

**Terahertz Spectroscopy of Carbon Nanotubes**
Rishi Lohar, Colgate University

Carbon nanotubes (CNTs) are one dimensional, hexagonal lattices of carbon atoms with unique electromagnetic properties. The goal of this study is to develop a better understanding of the electronic properties of CNT sheets in the terahertz regime. In particular, we measure the electro- magnetic response of CNT sheets with the use of terahertz time-domain spectroscopy (THz-TDS). This study sets the stage for observations of plasmon resonance oscillations in charge density along the length of the nanotubes within aligned CNT sheets in the little explored terahertz regime.

**Femtosecond Carrier Relaxation and Coherent Acoustic Phonon Generation in Bi2Se3 Nanolayers**
Charles Chimera, Jing Cheng, Peter Francis, University of Rochester

We report the generation of excited carriers and coherent acoustic phonons (CAPs) in Bi2Se3, a topological insulator, 6-nm- to 32-nm-thick layer excited by femtosecond optical laser pulses. We use a time-resolved optical pump/probe spectroscopy technique,

where 100-fs-wide optical pump pulses with photon energy above the Bi2Se3 bandgap create hot electrons, while time-delayed probe pulses (100 fs) measure electron relaxation dynamics. The results are modeled based on the time evolution of nonequilibrium/hot carrier concentrations within the material. During this relaxation process excess energy is converted into lattice vibrations creating CAPs. Half of the Bi2Se3 samples were deposited directly on a silica substrate and the other half had a graphene nanolayer between the Bi2Se3 and silica. We measured both transmissivity (T) and reflectivity (R) transients simultaneously, since this way we can find the absorbance (A) changes, using the relationship T + R + A = 1. The simultaneous experiments in both the reflection and transmission mode, gave a holistic view of the electron lifetimes as well as CAP generation and their respective lifetimes.

**Creating a Cost-Efficient Ionization Chamber**

Aroon Pressram, Siena College

Creating a cost-efficient ionization chamber can serve as an effective learning tool for students interested in areas of applied physics that focus deeper on radiation (e.g. Medical Physics, Nuclear Physics, Linac engineering). Many simplified ionization chambers are made by building a Darlington pair circuit. For the purposes of delivering a more accurate and reliable ionization chamber, I used a 4-pair Darlington circuit following C. Wentzel's design as opposed to a single-paired Darlington circuit. This is due to the single pair circuit’s susceptibility to temperature and stray electrical fields, both of which cause imprecise fluctuations in the reading. Several prototypes were made on a Protoboard and soldered into mini-solder boards, which then went into the chamber. I decided to create and utilize a printed circuit board (PCB). This would show the placement of each component, preventing problems that others might run into when trying to solder components together. The circuit is a demonstrative model of an actual representation of ionization chambers that are found in clinics; it has a similar structure and functionality with a simpler design intended to provide a working knowledge of a more complex instrument.

**SESSION IVB. ASTRONOMY AND ASTROPHYSICS**

**Evaluating the BAO signal through CenterFinder**
Chad Popik, University of Rochester

Around 10 billion years after the big bang, the expansion of the universe began to accelerate from what is referred to as dark energy. To understand dark energy, we must study the expansion of the universe at this epoch, which is done by observing astronomical structures of fixed size, known as standard rulers. One such structure is the imprint left on the galaxy distribution by Baryon Acoustic Oscillations (BAOs), which we observe through the survey of millions of galaxies. In our research, we have developed the algorithm CenterFinder to find probable centers of BAO's in the cosmic matter distribution. This algorithm presents a novel way to detect the BAO signal in galaxy surveys and therefore can be used to constrain the BAO length scale.

**Exploring the Distribution of the Intergalactic Medium Gas 11 billion Years Ago**
Joshua Ratajczak, Satya Gontcho A Gontcho, Regina Demina, Zachery Brown, Gebri Mishtaku, University of Rochester

The matter in our universe is not randomly distributed. Baryonic Acoustic Oscillations (BAO) are distinguishable features that have the shape of spherical shells with a measurable radius where matter is preferentially distributed. An algorithm developed by the DESI team at the University of Rochester, "CenterFinder," can be used to identify where these BAO and their centers are located. In this project, we use CenterFinder in combination with Stripe 82 quasar spectra, to analyze the correlation between overdense regions of cold intergalactic gas and baryonic acoustic oscillations.

**Decomposition of Galaxy Rotation Curves**
Yifan Zhang, University of Rochester

In this project, we decompose galactic rotation curves in order to better understand the dark matter content of the universe. Using the data from SDSS MaNGA DR16, we fit the rotation curves of spiral galaxies. We decompose the mass of spiral galaxies into three components: the central bulge, the stellar disk, and the dark matter halo. With the existing physical models and various statistical methods, we obtain the best fitting

parameters for these components that, when combined, best fit the overall rotation curve of these galaxies. We fit both the one dimensional rotation curve (rotational velocity as a function of galactocentric radius) and the two dimensional H$\alpha$ velocity map (observed gas velocity along the line of sight at each location on the galaxy). The two dimensional velocity map requires solving for both the inclination angle i and phase angle $\Phi$ with the respect to the semi-minor axis of the galaxy. Once the fitting is completed, we use these parameters to further study the distribution of dark matter within the galaxy.

**CaII Absorption in Quasar Fields**
Stella Van Ness, SUNY Brockport

Quasars, the most luminous objects in the Universe, are powered by accretion onto supermassive black holes. Since they can be seen to great distances, they can be used as beacons to study the intervening gas along the line of sight. Eleven quasar fields were identified with potential absorption due to singly ionized calcium (CaII), which can be used to identify galaxies in the low-redshift Universe. Imaging and higher-resolution multi-object spectroscopy of the quasars and galaxies in these fields were obtained from the Gemini North 8-m telescope. After data reduction and spectral extraction, we are using the higher resolution data to confirm that the CaII absorption in the quasar spectra is real, and to measure the strength of CaII absorption in these regions. The Gemini imaging and spectroscopy of the galaxies will then be used to identify the galaxies at the absorption redshifts.

**Detection of a Disk Surrounding the Variably Accreting Young Star HBC722**
Xi Yek (Zach), SUNY at Fredonia

We present new 233 GHz continuum observations collected using the Atacama Large Millimeter/Submillimeter Array (ALMA) on the newly discovered FU Orionis candidate HBC722. Previous millimeter continuum data from the Submillimeter Array (SMA) failed to detect this object, ruling out the possibility of the burst being triggered by gravitational instability in a massive disk. With these data we detect HBC722 at millimeter wavelengths for the first time with a 1.3 mm continuum detection at the expected position. We use this detection to calculate a circumstellar disk mass of 0.024 $M_{sun}$. With a known stellar mass of approximately 0.5 $M_{sun}$, our results imply that HBC722

has a disk-to-star mass ratio of approximately 5%, which is marginally too low for gravitational instabilities to serve as the burst triggering mechanism (such instabilities likely require disk-to-star mass ratios of 10% or higher). However, due to uncertainties in the ALMA continuum detection, future analysis using radiative transfer modeling is required to better determine the true mass of the HBC722 disk.

**The Effects of Decaying Dark Matter at Early Times on The Hubble Constant**
John Yevoli, Manhattan College

We analyze models of decaying dark matter, searching for shifts in $H_0$ and $\sigma_8$ to resolve the tensions between linear and astrophysical measurements. While previous searches have focused on dark matter with lifetimes on the order of the current Hubble time, we instead consider dark matter that decays between the time of last scattering and the era of large scale structure. We find that while decaying dark matter pushes parameter likelihoods in the right direction to resolve the Hubble Tension, the bounds $\Omega_{\mathrm{dcdm}} < 3.33 \times 10^{-2}$ for lifetimes a tenth of the Hubble Time) on decaying dark matter are too strong to resolve the tension completely, a conclusion unchanged even when spatial curvature is allowed to vary. These bounds can, however, be used to constrain theoretical models such as coupled axions from string compactifications.

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