Department of Physics Colloquium

Speaker: Dr. Dariusz Seweryniak

Argonne National Laboratory, Argonne, IL

"Spectroscopy of Super-Heavy Nuclei"

Open to the public, free of charge

Monday, October 10, 2022 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: The search for new super-heavy elements is one of the most exciting frontiers of nuclear physics. Super-heavy nuclei have been an aim of intense experimental and theoretical research in recent years. This effort has culminated in the discovery of 4 new elements. The super-heavy nuclei pose a magnificent challenge to nuclear models. For example, theoretical calculations predict existence of the so called super-heavy island stability associated with spherical magic numbers beyond ^{208}Pb. However, predicted location of this island varies depending on a model used. Super-heavy elements also offer a unique laboratory for chemistry since relativistic effects are expected to be very strong in these atoms and can even change their chemical properties.

However, the nuclear structure of super-heavy nuclei is not known very well. Because of miniscule production cross sections, information about super-heavy nuclei is limited to their basic decay properties. On the other hand, trans-fermium nuclei near the deformed magic numbers Z=100 and N=152, which can be produced in quantities sufficient to perform nuclear structure experiments, can serve as a testing ground for nuclear models which are used to describe super-heavy nuclei. Trans-fermium nuclei have been extensively studied at the ATLAS facility at the Physics Division at the Argonne National Laboratory. In recent years, these studies have been performed using the newly constructed Argonne Gas-Filled Analyzer (AGFA) in stand-alone mode and together with the Gammasphere array of ⍰-ray detectors. In this talk, I will review the current status and the prospects of the super-heavy element research and illustrate it with recent results obtained with AGFA on nuclear rotation, K-isomers, ⍰-decay and spontaneous fission in trans-fermium nuclei. Among others, the observation of the rotational bands feeding the K-isomers in ^{254}No, the characterization of the ground-state rotational band in the fissile nucleus ^{254}Rf and the discovery of the new isotope ^{251}Lr will be discussed.

This material is based upon work supported by the U.S Department of Energy, Office of Science, Office of Nuclear Physics, under contract number DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Philip Ugorowski, Ph.D.

NASA Glenn Research Center

"Electric Propulsion and the Lunar Gateway"

Open to the public, free of charge

Monday, October 24, 2022 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Reaching the moon with a large spacecraft, like the combined first two sections of the Artemis program Lunar Gateway, is beyond the capability of even the largest available conventional rocket. What was called 'Ion Drive' in science fiction is now being developed and used by NASA and others to send large payloads long distances. It is 10x more efficient in integrated thrust delivered per pound of fuel, although the instantaneous thrust is much lower. It is now called 'Electric Propulsion' and relies on Hall-Effect thrusters powered by solar panels. This talk will focus on the application of electric propulsion to get the Lunar Gateway to a NRHO orbit around the moon and some of the expected uses of this space station during its' 15-year life.

Artemis Program
nasa.gov/artemisprogram
Lunar Gateway
nasa.gov/gateway
Near-Rectilinear Halo Orbit (NHRO)
en.wikipedia.org/wiki/Near-rectilinear_halo_orbit
youtube.com/watch?v=jfCaac1ijRg
Hall Effect thrusters
en.wikipedia.org/wiki/Hall-effect_thruster
en.wikipedia.org/wiki/Ion_thruster
en.wikipedia.org/wiki/Advanced_Electric_Propulsion_System
youtube.com/watch?v=Isn7FoJvtRY
Electric Propulsion NASA missions
solarsystem.nasa.gov/missions/deep-space-1/in-depth
solarsystem.nasa.gov/missions/dawn/overview/
solarsystem.nasa.gov/missions/dawn/technology/ion-propulsion/
NASA Research on Hall Effect Thrusters
jpl.nasa.gov/news/nasa-works-to-improve-solar-electric-propulsion-for-deep-space-exploration
NASA Glenn Research Center (GRC) vacuum chamber to test Hall thrusters
jpl.nasa.gov/news/nasa-glenn-tests-thruster-bound-for-metal-world
NASA GRC Neil Armstrong Test Center (formerly Plum Brook Station) vacuum chamber – world's largest
youtube.com/watch?v=E43-CfukEgs

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Erno Sajo

Professor and Director, Medical Physics, Department of Physics and Applied Physics
Coordinator, Biomedical Engineering & Biotechnology, University of Massachusetts Lowell

“Non-Equilibrium Nanoscale Direct Energy Conversion”

From Nanoparticle-Aided Radiation Therapy to Self-Powered Nanofilm Radiation Detectors

Open to the public, free of charge

Monday, November 7, 2022 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Gold nanoparticle (GNP) enhanced radiotherapy has recently emerged as a promising modality in cancer treatment. The use of high atomic number nanoparticles can lead to enhanced radiation dose in tumors due to leakage electrons depositing in the vicinity of the GNP. The dose enhancement is often up to a factor of 100 or greater, depending on the particle size, material, and incident radiation characteristics. If translated to clinical practice, it could reduce normal tissue complications. While theoretical and computational studies abound, experimental characterization is a challenge. Although survival studies in the mouse model have been successful, clinical translation remains elusive.

The radiation transport phenomenon responsible for this dose enhancement is the interfacial disequilibrium in energy deposition. Theory and computations show that it is possible to devise a sensor that takes advantage of nanoscale interfacial phenomena to harvest energy. We have recently developed and demonstrated a thin-film X-ray detector that does not require external power and signal amplification. The device is flexible, scalable, and low-cost. Originally envisioned for medical dosimetry and beam monitoring, it has attractive properties for a wider variety of applications, including X-ray astrophysics: (1) Self-powered, converting the energy of incident X-rays directly into signal current, (2) Extremely lightweight, (3) Short event duration – promising high timing resolution (4) Customizable energy response and stopping power (5) Potentially can be used as a large-area timing array.

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Steve Southworth

AMO Physics Group
Argonne National Laboratory

"X-Ray and Inner-Shell Interactions and Applications"

Open to the public, free of charge

Monday, December 5, 2022 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Electron correlation is a topic of enduring interest and importance in basic and applied research on atoms, molecules, and materials. The Advanced Photon Source at Argonne and other synchrotron radiation facilities provide intense, tunable, narrow bandwidth x-ray beams that are ideal for experiments on inner-shell electrons using electron, ion, x-ray emission and coincidence measurements. Experiments and theoretical simulations on atomic inner-shell resonance, threshold, and multiple photoionization processes will be discussed. In related experiments and theory on molecules, *K*-shell vacancy cascades and charge redistribution lead to dissociation into energetic fragment ions. As an application of inner-shell vacancy decays, an instrument is being developed to measure Auger electron multiplicities from radionuclides in support of using radiopharmaceuticals injected into cancerous tissue to destroy tumorous cells and DNA while minimizing damage to healthy tissue.

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Rinkle Juneja

Materials Science and Technology Division
Oak Ridge National Laboratory, Oak Ridge, TN

"Exploring new frontiers of thermal transport: A combined first-principles and machine learning approach"

Open to the public, free of charge

Monday, January 30, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: The behavior of collective atomic vibrations, i.e., phonons, is crucial for understanding thermal transport of materials, which is tantamount to shaping thermal management technologies. Given the computational challenges in thermal transport estimation of complex materials, in this talk, I will introduce how machine learning (ML) can be used for accelerated prediction of transport properties. I will demonstrate the power of ML in discovering new material behaviors and in revealing unusual connections among transport properties using physics-aware descriptors and symmetry-based arguments. I will further showcase deeper fundamental symmetry insights dictating selection rules for thermal transport and unique scattering observables, validated by inelastic neutron scattering measurements, thereby providing new avenues and novel surprises in thermal transport behaviors of materials.

R.J. acknowledges support from the U. S. Department of Energy, Office of Science, Basic Energy Sciences, Materials Sciences and Engineering Division.

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Satya Kushwaha

William H. Miller III Department of Physics & Astronomy, Department of Chemistry
The Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials
The Johns Hopkins University, Baltimore, MD

"Development and Study of the Topological Quantum Materials"

Open to the public, free of charge

Wednesday, February 8, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Topological materials are the class of quantum materials that will probably be crucial for the next generation of quantum technologies. Since the advent of topological phases, the discovery and study of novel materials have been a central theme of research. Topological phases of matter display unusual electronic properties and phase transitions, such as the quantum spin-Hall effect, linear magnetoresistance, chiral anomaly, etc. [1]. In this talk, I will present the development and study of a high-quality topological insulator crystal [2]. I will then discuss the recent efforts to understand the ground state of a candidate topological Kondo-insulator and its consequence in strong magnetic fields [3].

References:

[1] Jun Xiong, Satya Kushwaha, et al., *Science* **350**, 413 (2015).
[2] Satya Kushwaha, Ivo Pletikosić, et al., *Nature Commun.* **7**, 11456 (2016).
[3] Satya Kushwaha, Mun Chan, et al., *Nature Commun.* **10**, 5487 (2019).

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Hang Chi

Research Scientist, Massachusetts Institute of Technology, Cambridge, MA

“Magnetic Interface Engineering for New Paradigm of Memory and Logic”

Open to the public, free of charge

Monday, February 13, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Significant progress has been made in conceptualizing geometric aspects of condensed matter [1]. Intertwining topology and low-dimensional magnetism, particularly at intrinsic/hybrid interfaces leveraging disparate quantum features, offers an exciting arena for exploiting novel magnetic phenomena towards disruptive energy efficient memory, logic and information technologies. Here in this talk, we introduce MBE grown magnetic transition metal chalcogenide Cr_2Te_3 as an emerging platform for exploring spin-orbit driven Berry phenomena [2]. A unique temperature and strain modulated sign reversal of the anomalous Hall effect has been uncovered, resulting from nontrivial Berry physics. The versatile interface tunability of Cr_2Te_3, hybridized with topological insulator, offers new routes for topological devices. Furthermore, we observe nonreciprocity in supercurrent transport and demonstrate strong field-free superconducting diode effect in magnetic insulator/superconductor bilayers [3]. These heterostructures enable new computing regime with intrinsically low energy cost, mitigating Joule heating with dissipationless supercurrent, leading to a cold computing scheme well suited for high-performance supercomputing and data centers. The discovery-rich magnetic surface and interface are key in further advancing quantum materials in the exciting fields of topological and superconducting spintronics.

References

[1] *"Progress and prospects in the quantum anomalous Hall effect"*, H. Chi and J. S. Moodera, *APL Materials* **10**, 090903 (2022).
[2] *"Strain-tunable Berry curvature in quasi-two-dimensional chromium telluride"*, H. Chi, Y. Ou, T. B. Eldred, *et al.*, arXiv:2207.02318 (2022).
[3] *"Ubiquitous Superconducting Diode Effect in Superconductor Thin Films"*, Y. Hou, F. Nichele, H. Chi, *et al.*, arXiv:2205.09276 (2022).

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Gaurab Rimal

"Novel Phases Via Heterostructure and Material Engineering"

Open to the public, free of charge

Wednesday, February 15, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Modern material processing tools provide routes to obtain ultra-clean materials and has led to the discovery of unexpected phenomena that contradict traditional physical principles. Emergent phases such as quantum fluids, magnets and superconductors can arise at the interface of different materials. Furthermore, these systems have helped drive modern technological innovation through the development of numerous electronic devices. Thin film heterostructures, which are typically made using layers of different materials, provides avenues to understand the physics of electrons in reduced dimension. I will discuss how new materials and methods have helped develop and understand new phases in these "atomic sandwich" structures, and are creating new breakthroughs for future quantum technologies. Emphasis will be placed on oxide heterostructures which have allowed the coupling of many degrees of freedom and are well-suited to investigate how new phases arise in materials.

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Western Michigan University

Department of Physics Colloquium

Speaker: Dr. Benjamin Coughenour

Postdoctoral Associate, Space Sciences Library
University of California, Berkeley, CA

“Reflection in Neutron Star and Black Hole X-ray Binaries”

Open to the public, free of charge

Monday, February 20, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: *Among the most extreme objects in the Milky Way are accreting stellar-mass black holes and neutron stars. Either compact object is most visible when actively accreting material from a companion star, and these systems are described as high-mass or low-mass X-ray binaries (LMXBs) depending on the mass of the companion. Both types of systems are naturally variable and will evolve between periods of active accretion and quiescence, changing in flux by a factor of a million or more in the X-ray band. The accreting, inflowing material forms a disk around the compact object, and heats up to millions of degrees, emitting thermally in low-energy X-rays. At the same time, non-thermal high-energy X-rays, either from the base of a relativistic jet or ‘corona’ surrounding the compact object, will illuminate the accretion disk. This results in a series of emission features, the most notable of which are Fe K-shell emission between 6 and 7 keV, and a broad Compton ‘hump’ above 10 keV. These features are shaped by the environment of the inner accretion disk, and in particular by relativistic effects near the neutron star or black hole. As a result, they provide an opportunity to measure the inner accretion disk radius, as well as other physical attributes of the accretion disk. In black hole systems, if the accretion disk falls to the innermost stable circular orbit, this provides a measure of the black hole’s spin. In neutron star systems, tracking the evolution of the accretion disk may explain the patterned behavior and variability of these systems, and has the potential to set upper limits on the neutron star radius, which may help constrain the neutron star equation of state. I will review my own work on reflection in LMXBs, as well as summarize ongoing work in the field and prospects for future research.*

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Andrew O'Hara

Research Assistant Professor, Department of Physics and Astronomy
Vanderbilt University, Nashville, TN

"Ferroelectricity in layered 2D materials: novel properties and applications"

Open to the public, free of charge

Wednesday, February 22, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: Ferroelectric materials are electrical analogs of ferromagnetic materials, possessing a spontaneous electric polarization that is switchable by an external electric field. Applications include sensors, tunable capacitors, and non-volatile memory elements. Recently, paralleling broader research trends in nanoscience and nanomaterials, significant research efforts have focused on discovering, characterizing, and utilizing ferroelectricity in layered two-dimensional (2D) materials. In this talk, following a brief introduction to ferroelectricity, I will review our recent research, combining quantum mechanical calculations with experimental data by collaborators, on the layered, ferroelectric thiophosphate $CuInP_2S_6$ (CIPS). After a brief description of our original discoveries that triggered a growing interest in CIPS, including the presence of a quadruple-well potential energy surface, I will focus on the most recent work, including ionic control of ferroelectricity, emergence of novel surface phases, and metallic interface effects. Lastly, I will discuss very recent work demonstrating alternative routes to ferroelectricity at the 2D limit and the use of ferroelectrics to control magnetic materials.

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WESTERN MICHIGAN UNIVERSITY

Department of Physics Colloquium

Speaker: Dr. Jan Tobochnik

Dow Distinguished Professor in the Natural Sciences
Department of Physics, Kalamazoo College

"Agent-based modeling of wealth distribution"

Open to the public, free of charge

Monday, April 10, 2023 - 4 p.m. – 1110 Rood Hall

Refreshments: 3:30-3:50 p.m., Bradley Commons, 2202 Everett Tower

Abstract: What drives wealth inequality? An agent-based approach developed by physicists and mathematicians suggests that extreme wealth inequality is a natural occurrence of economic transactions. We extended the original models by adding economic growth and wealth redistribution and found that depending on how the growth of the wealth is distributed, characterized by a parameter lambda, there is a phase transition at lambda = 1. For lambda < 1, there is economic mobility, no wealth condensation, and the model can be described using the tools of statistical mechanics. However, the wealth distribution is unrealistic. In contrast, for lambda > 1, there is wealth condensation and no economic mobility. I will discuss further extensions that generate the growth in wealth endogenously using an investment mechanism that distinguishes between wealth and income and generates a more realistic wealth distribution. These agent-based models are becoming realistic enough to provide insights into how economic systems work and how various policies might affect economies.

Brief Bio: Jan Tobochnik is the Dow Distinguished professor in the Natural Sciences at Kalamazoo College where he has taught since 1985. His primary research interests are in statistical mechanics, particularly focusing on phase transitions in a variety of systems using computer simulations. He has co-authored two undergraduate texts, *An Introduction to Computer Simulations Methods* now in its third edition with Harvey Gould and Wolfgang Christian, and *Statistical and Thermal Physics* now in its second edition with Harvey Gould. He was the editor of the *American Journal of Physics* (AJP) from 2001-2011, was a divisional Associate Editor for *Physical Review Letters*, and currently co-edits a column on computational physics in AJP. He received his PhD in physics from Cornell University, his B.A. from Amherst College, and was a postdoc with Joel Lebowitz at Rutgers University. He is currently working with Bill Klein's research group at Boston University on models of wealth distribution.

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