PAGE Conference 2024

Tuesday, June 25, 2024

Life Sciences Building Rm. 103, York University

PAGE
PHYSICS AND ASTRONOMY GRADUATE EXECUTIVE

Schedule

9:00AM – 9:45AM	**Registration and Breakfast**	Main Lobby
9:45AM – 10:00AM	**Opening Remarks** Coral Hillel, PAGE President	LSB 103
Invited Talk I 10:00AM – 10:30AM	**Prof. Jennifer Chen** Nanocrystals for plasmonic-based sensing and hot electron-enhanced photocatalysis	LSB 103
Student Session I	**Chair: Jaskaran Randhawa**	
10:30AM – 10:45AM	**Vithurshan Suthakar** Image processing for space situational awareness from stratospheric imaging	
10:45AM – 11:00AM	**Bennett Wilson** Using meteorites to better resolve the composition of the protoplanetary disc	
11:00AM – 11:15AM	**Maheen Hemani** Galaxy quenching at high redshifts	Main Lobby LSB 103
11:15AM – 11:30AM	**Coffee Break**	
11:30AM – 11:45AM	**Foysal Arian** Biophysics on wings	
11:45AM – 12:00PM	**Coral Hillel** Controlling the photophysics of azo photoswitches with protonation: a tool and a danger	
12:00PM – 12:15PM	**Elizabeth Allison** Delayed fluorescence in bioluminescent phytoplankton	
12:15PM – 1:00PM	**Lunch**	Main Lobby LSB 103
Keynote Address 1:00PM – 2:00PM	**Dr. Androu Abdalmalak** *(Western University; NIRx Medical Technologies, LLC)* A novel functional NIRS approach for detecting consciousness after severe brain injury	LSB 103

Student Session II	**Chair: Anirudh Krishnadas**	Main Lobby LSB 103
2:00PM – 2:15PM	**Esther Sule** Picometer displacements of the eardrum: insights from the active ear	
2:15PM – 2:30PM	**Eduardo Chomen Ramos** Measurements of diffusion coefficients for rubidium–inert gas mixtures using coherent scattering from optically pumped population gratings	
2:30PM – 2:45PM	**Farshad Heydarizadmotlagh** Precision measurement of the *n*=2 triplet *P J*=1-to-*J*=0 fine structure of atomic helium using frequency-offset separated oscillatory fields	
2:45PM – 3:00PM	**Coffee Break**	
3:00PM – 3:15PM	**Adam Smith-Orlik** Squashed Jeans model for self-interacting dark matter	
3:15PM – 3:30PM	**Ali Kavaki** Lattice gauge theory on the Triamond lattice	
3:30PM – 3:45PM	**Ethan Brooks** Searching for magnetic monopoles at the Large Hadron Collider	
3:45PM – 4:00PM	**Esther Wang** Probing chemistry in ultra-hot Jupiter atmospheres - a case study of WASP-178b	
Invited Talk II 4:00PM – 4:30PM	**Prof. Matthew Johnson** Watching the vacuum decay	LSB 103
4:30PM – 4:45PM	**Closing Remarks and Winners** Coral Hillel, PAGE President	LSB 103

Abstracts

Keynote

A novel functional NIRS approach for detecting consciousness after severe brain injury

Dr. Androu Abdalmalak
1:00PM – 2:00PM
Western University; NIRx Medical Technologies, LLC

Over the last 20 years, neuroimaging techniques such as fMRI have transformed our understanding of the brain and the impact of diseases on brain health. More recently, there has been a growing interest in using fMRI in acute settings to aid in diagnosis and prognosis of comatose patients by providing objective markers of consciousness and recovery. Although promising, a major drawback with fMRI is its cost and accessibility, limiting its use for frequent examinations. An alternative is functional near-infrared spectroscopy (fNIRS), which is an emerging optical modality that is safe, inexpensive and can assess brain function at the bedside. However, the reliability of fNIRS for detecting the neural correlates of consciousness remains to be established. In a series of studies, we evaluated if fNIRS can record sensory, perceptual, and command drive neural processing in healthy participants and in behaviourally non-responsive patients. At the individual level, we demonstrate that fNIRS can detect sensorimotor processing, speech-specific auditory perception and volitional command driven brain activity. We then tested fNIRS with three acutely unresponsive patients and found that one could willfully modulate their brain activity– providing evidence of preserved consciousness despite no observable behavioural signs of awareness. The successful application of fNIRS for detecting preserved awareness among behaviorally non-responsive patients highlights its potential as a valuable tool for uncovering hidden cognitive states in critical care settings.

Abstracts

Invited Speakers

Nanocrystals for plasmonic-based sensing and hot electron-enhanced photocatalysis
Professor Jennifer Chen
10:00AM – 10:30AM

The interaction of light with matter underpins many biological functions and technological applications. From photosynthesis and photovoltaic cells to colorimetric biodiagnostics, light is both valuable as a source of energy and a spectroscopic probe. In this talk, I will f5irst present our work on developing discrete plasmonic nanoparticle assemblies for sensing biomarkers. Detection is achieved via the disassembly of DNA-linked nanoparticles, which yields a dramatic decrease in light scattering intensity as analyzed from darkfield microscopy images. The rapid and simple methodology for the biomolecular analysis of single cells and microenvironments may enable new opportunities in clinical care such as on-site molecular pathology. In the second part of the talk, I highlight our work on exploring Mn^{2+}-doped quantum dots (QDs) for photocatalyzed organic reactions. The incorporation of Mn^{2+} ions into CdS nanocrystals as a dopant promotes Auger cross-relaxation, a phenomenon that yields hot electrons with high reducing power. We examined several model reductive organic reactions to establish the versatility and superior performance of doped QDs over undoped CdS QDs, including the photoreduction of nitrobenzene that saw a 190-fold enhancement. Different from previous studies, we employ the QDs as films and coatings to facilitate the rapid separation of catalysts from solution and significantly reduce post-reaction workups. Our work demonstrates a drastic improvement in the efficiency of CdS QD-based photocatalysis that may have broad implications in photoredox reactions.

Watching the vacuum decay
Professor Matthew Johnson
4:00PM – 4:30PM

In quantum field theory, particles can be thought of as irreducible fluctuations on top of the state of no particles – the vacuum. In many theories, the vacuum state is not unique, and in some cases, one vacuum can ‘decay’ into another via a first-order phase transition. Such a process could be related to how our Universe began, or how it will end. However, vacuum decay is poorly understood from a theoretical perspective because traditional computational techniques in quantum field theory cannot be used. In this talk, I’ll explain vacuum decay at a heuristic level and describe efforts to perform quantum simulation of vacuum decay in laboratory systems.

Abstracts

Student Session I

Image processing for space situational awareness from stratospheric imaging
Vithurshan Suthakar
10:30AM – 10:45AM

The rise of mega-constellations has significantly increased the risk of collisions in near-Earth orbits, highlighting the need for improved Space Situational Awareness (SSA). SSA involves the accurate acquisition, analysis, and tracking of Resident Space Objects (RSOs) to enact preventative measures against potential collisions. Traditional SSA approaches are often hindered by the limited availability of public datasets and the constraints of ground-based and space-based observations. Addressing these challenges, our study leveraged a dataset obtained from a stratosphere-based camera, akin to a star tracker, which captured high-altitude optical images of RSOs at 36 km above sea level. This alternative approach facilitated enhanced imaging quality assessments of RSOs and stars, employing tools like Astrometry.net to analyze astrometric and photometric elements. The evaluation identified imaging residuals and verified the performance limits of the optical system, confirming the star tracker's utility in attitude determination. We implemented detection algorithms such as Adjacent Frame Differencing, Median Frame Differencing, and Proximity Filtering and Tracking, which identified 18,566, 9,194, and 22,036 RSOs respectively, and an additional 387 RSO streaks through image stacking. The resulting dataset, featuring over 500 unique RSOs characterized by distinct angular velocities, Signal to Noise Ratios, Full Width Half Maximum values, and imaging backgrounds, underscores the effectiveness of stratospheric imaging for SSA purposes. Our study demonstrates that stratospheric observation represents a viable alternative to space-based or ground-based SSA, stemming from the enriched nature of this dataset and the need for further exploration.

Using meteorites to better resolve the composition of the protoplanetary disc
Bennett Wilson
10:45AM – 11:00AM

The composition of the early protoplanetary disc was heterogeneous and produced compositionally diverse asteroids that depended on formation location and early asteroid conditions. Owing to our relatively small meteorite collection, the diversity of early asteroids is poorly understood and limits our understanding on components contributing to the forming Earth. The Tarda meteorite, however, samples a chemically unique parent asteroid implying a different formation history in comparison to the rest of the meteorite inventory on the Earth. This differing formation location and history (involving different temperatures, chemistry, and time scales) may have produced unique compositions and organics on the Tarda parent body. The process required to form the unique Tarda parent body is likely shared by other material that contributed to the early Earth, influencing early processes like biosynthesis.

Galaxy quenching at high redshifts
Maheen Hemani
11:00AM – 11:15AM

One of the significant mysteries in the field of extragalactic astrophysics is the observed existence of quenched galaxies at high redshifts. These galaxies present signs of halted star formation in the earlier epochs. We need to know how abundant these galaxies are and the possible causes of their quenching to better understand galaxy formation. In this talk, I will present results from the research I had undertaken over the past academic year to study galaxy quenching using a cosmological simulation called Thesan, based on the Lambda-CDM model of cosmology. Based on our research results, we observe quenching at high redshifts. However, the percentage and masses of quenched galaxies differ at the different redshifts. The star formation histories of several of these galaxies show signs of temporary quenching over a period, which has also been referred to in the literature as "mini-quenching". There still lies a gap in our theoretical understanding of quenching under Lambda-CDM and our observations. I will go over the phenomenon that, when considered, could potentially fill the explanatory gap between the Lambda-CDM predictions and observations of halted star formation within galaxies at high redshifts, proving which is one of the future goals of this research.

Biophysics on wings
Foysal Arian
11:30AM – 11:45AM

Not available.

Controlling the photophysics of azo photoswitches with protonation: a tool and a danger
Coral Hillel
11:45AM – 12:00PM

Molecular azopyridine photoswitches can undergo reversible light-triggered photoisomerization about the azo bond (N=N) between distinct *trans* and *cis* configurations, leading to great advancements in the design and photocontrol of liquid crystals, pharmacological agents, photodriven oscillators, and molecular spin switches. Yet detailed studies on the isomerization kinetics of azopyridines, a vital element in their materials design, are lacking, with inconsistent, inconclusive, and even contradictory results reported in the literature. This high propensity for error is likely the cause of adventitious protonation, which itself is not well understood. In this work, irradiation of 4-phenylazopyridine (AzPy) in chlorinated solvent with UV light acted not as a trigger for photoisomerization, but instead protonation of the photoswitch due to photodecomposition of the solvent. In addition, protonation markedly accelerated the isomerization rate. Density functional theory calculations demonstrated that protonation withdraws electron density from the azo bond by an inductive effect, thus enabling more facile isomerization. Furthermore, the singlet-triplet rotation mechanism assumed for many azo photoswitches was abolished. This work demonstrates protonation as a tool to precisely engineer azo photoswitches and provides a cautionary warning for using chlorinated solvents with UV irradiation in isomerization experiments.

Delayed fluorescence in bioluminescent phytoplankton
Elizabeth Allison
12:00PM – 12:15PM

Plant and phytoplankton species exhibit weak delayed fluorescence (DF) related to chlorophyll in their photosystems. As there can only be DF from photosynthetically active cells, the lifetime of these emissions can be used as a quick and non-invasive indicator of health. DF emissions have been studied previously only in phytoplankton species that don't exhibit bioluminescence. The Dinoflagellate species *Pyrocystis fusiformis* is a marine alga that bioluminesces in response to mechanical shear stress. We use a silicon photo-multiplier photon-counting device to measure and analyze time-resolved DF behaviour in *Pyrocystis fusiformis*. Future goals are to explore the impact varying environmental conditions have upon DF emissions of *Pyrocystis fusiformis*.

Abstracts

Student Session II

Picometer displacements of the eardrum: insights from the active ear
Esther Sule
2:00PM – 2:15PM

The ear is a remarkable detector: It is both highly sensitive and selective, and operates over a large dynamic range spanning more than 12 orders of magnitude of sound pressure. Not only does it respond to sound, but emits it as well. These sounds, known as otoacoustic emissions (OAEs), provide a means to probe the fundamental biophysics underlying transduction and amplification in the ear. It is well-established that spontaneous OAE (SOAE), readily measurable in the absence of any external stimuli presented to the ear, is evidence of an active process at work in the ear. However, precisely what is vibrating in the inner ear is unknown. Using laser Doppler vibrometry (LDV), we measured the spontaneous oscillations of the lizard eardrum. We observed that the eardrum motion matched SOAE activity, and that vibration peaks with displacements at little as 5 pm could be observed. For reference, the diameter of a hydrogen atom is 100 pm. These data serve as an entry point to elucidating how the inner ear generates force to improve detection, while incidentally turning the eardrum into a speaker that reveals the active processes of the ear.

Measurements of diffusion coefficients for rubidium–inert gas mixtures using coherent scattering from optically pumped population gratings
Eduardo Chomen Ramos
2:15PM – 2:30PM

We present determinations of diffusion coefficients D at T = 24ºC for trace amounts of naturally abundant Rb atoms in inert, naturally abundant He, Ne, N2, Ar, Kr and Xe buffer gases using a single measurement technique. The diffusion coefficients have been measured by establishing a spatially periodic population grating in the Rb sample using two laser beams intersecting at a small angle θ of order of a few milliradians. The atomic population grating decays exponentially in time due to diffusive motion induced by momentum-changing elastic collisions between Rb and buffer gas atoms or molecules. We distinguish the contribution of diffusion from other collisional processes by measuring the characteristic θ^2 dependence of the decay rate. Experimental results display a 6% to 20% discrepancy with our theoretical model but present a consistent systematic variation as a function of buffer gas mass. We are in the process of characterizing the discrepancies using different models to describe a systematic effect due to the transit time. If the discrepancies with theory can be resolved, it will be possible to develop a quantum pressure sensor based on these measurements.

Precision measurement of the *n*=2 triplet P *J*=1-to-*J*=0 fine structure of atomic helium using frequency-offset separated oscillatory fields
Farshad Heydarizadmotlagh
2:30PM – 2:45PM

Increasing accuracy of the theory and experiment of the n=2^3P fine structure of helium has allowed for increasingly precise tests of quantum electrodynamics (QED), determinations of the fine-structure constant α, and limitations on possible beyond-the-Standard-Model physics. Here we present a 2-part-per-billion (ppb) measurement of the *J*=1-to-*J*=0 interval. A helium beam is produced using a liquid-nitrogen-cooled dc-discharge source and is intensified using a two-dimensional magneto-optical trap. The microwave measurement is performed using frequency-offset separated oscillatory fields (FOSOF). Laser excitation to a Rydberg state, followed by Stark ionization allows for efficient detection. Our result of 29,616,955,018(60) Hz represents a landmark for helium fine-structure measurements, and, for the first time, will allow for a 1-ppb determination of the fine-structure constant when QED theory for the interval is improved.

Squashed Jeans model for self-interacting dark matter
Adam Smith-Orlik
3:00PM – 3:15PM

The isothermal Jeans model is a semi-analytical approach to modelling galaxies and galaxy clusters with self-interacting dark matter (SIDM) that has been shown to work remarkably well. However, the Jeans model has only been used to calculate the spherically-averaged density profiles. In this talk I will describe a two-dimensional extension to the Jeans model--the squashed model--that allows for the predication of the nonspherical density profiles and shape data in the presence of baryons. The squashed model has the potential to be a strong discriminator of SIDM and CDM cosmologies for Milky Way-sized galaxies where the density profiles are indistinguishable but where shapes can deviate significantly between SIDM and CDM, especially in the presence of strongly asymmetric baryon profiles, i.e., disk galaxies.

Lattice gauge theory on the Triamond lattice
Ali Kavaki
3:15PM – 3:30PM

The Triamond lattice is the only maximally isotropic lattice where three links meet at each vertex, and for technical reasons, that provides an elegant bookkeeping method for quantum field theories on a lattice. Considering that most researchers have not attempted to simulate Hamiltonians in three spatial dimensions until now, this work is an important step toward large-scale simulation on quantum computers. Specifically, we studied the geometry of the Triamond lattice, derived its Hamiltonian, and calculated the ground state of the unit cell of this lattice by imposing the periodic boundary condition on each face of the unit cell.

Searching for magnetic monopoles at the Large Hadron Collider
Ethan Brooks
3:30PM – 3:45PM

Magnetic monopoles have been a subject of interest to many physicists since they were first proposed by Paul Dirac in 1931. Many searches have been conducted using various approaches however, they remain elusive. The talk will outline the search for magnetic monopoles in the ATLAS detector at the Large Hadron Collider. An overview of the ATLAS detector will be given as well as outlining the analysis strategy. Machine learning and its application to identifying monopoles within the ATLAS detector will also be discussed. The future ambitions of the analysis group will be discussed briefly as well.

Probing chemistry in ultra-hot Jupiter atmospheres - a case study of WASP-178b
Esther Wang
3:45PM – 4:00PM

The study of atmospheric compositions in ultra-hot Jupiters (UHJs) provides critical insights into the chemistry and dynamics of these extreme environments. WASP-178b is unique among known exoplanets for its especially hot host star, offering an exceptional case for examining the presence of silicon monoxide (SiO), a potential indicator of silicate vapor processes at high temperatures. Our research utilizes spectroscopic data from the Hubble Space Telescope's Space Telescope Imaging Spectrograph (STIS) in the near-ultraviolet (NUV) to detect and analyze SiO features in the atmosphere of WASP-178b. By employing a rigorous data reduction process, we derived high-precision spectral data to identify the signatures of SiO. Our analysis involves a combination of differential spectroscopy and model comparisons to isolate the SiO absorption features from other atmospheric constituents. The detection will be further substantiated by comparing observed spectral lines with theoretical models predicting SiO presence at the temperatures and pressures typical of WASP-178b's upper atmosphere.
