The 7th Annual PHAS Symposium

February 22nd, 2022

With Support From:

Organizing Committee

The Physics and Astronomy (PHAS) Departmental Graduate Association (DGA) is comprised of graduate students to represent students' interests for the Graduate Student Association (GSA). One of our goals is to foster an inclusive and welcoming environment for the diverse group of graduate students within the department. The PHAS DGA organizes social and academic activities throughout the year, the PHAS Symposium being one of many. Additionally, the PHAS DGA works to recognize students' accomplishments within the department.

Please visit the PHAS DGA website for more information concerning the upcoming events and/or the PHAS DGA in general.

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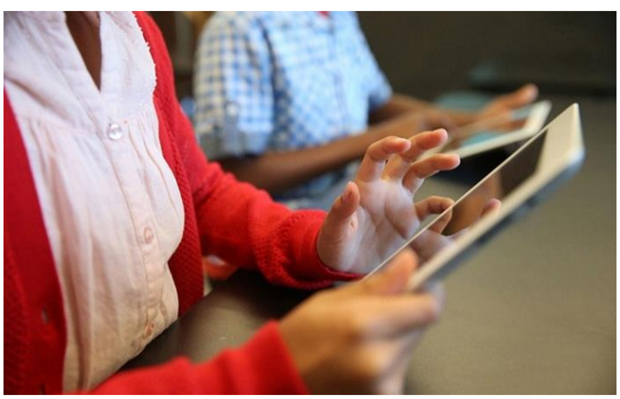
(GRC Rep)

Mahsa Faryadras
(Member at Large)

Schedule at a Glance

TIME	EVENT
9:30-9:45	Opening Remarks
9:45-10:30	Keynote Speaker - Dr. Ania Harlick
10:30-10:45	Coffee Break
10:45-12:00	Speaker Session 1
12:00-1:00	Lunch
1:00-2:00	Speaker Session 2
2:00-3:00	Panel Discussion – After Academia: A Conversation with Former Grad Students
3:00-3:15	Coffee Break
3:15-4:30	Speaker Session 3
4:30-4:45	Coffee Break
4:45-5:00	Closing Remarks and Prizes
6:30-8:00	Social Event



Zoom link for symposium:
https://ucalgary.zoom.us/j/95065818200

Meeting ID: 950 6581 8200
Passcode: 7_PHAS

Keynote Speaker

Dr. Ania Harlick

About the speaker: Ania Harlick is an Assistant Professor, Teaching Stream at the University of Toronto, and an Adjunct Senior Instructor at the University of Calgary. Originally from Poland, she holds a master's degree from Adam Mickiewicz University as well as a master's degree and a doctorate from Memorial University of Newfoundland and Labrador. She considers herself an accidental physicist with a passion for education. As her primary responsibilities are teaching university courses, most of her research focuses on implementing modern pedagogy into the design of course and laboratory components. As far as she is concerned, she has her dream job.

Abstract: Designing diverse and innovative techniques that can be used in the classroom requires creativity and considerations for accessibility, inclusivity, and student well-being. Assessing whether the new tools are helping students learn in the way they intended to do so calls for collection of both qualitative and quantitative data in real time. As both types of data are sensitive in nature and require the consent of the learners to be analyzed, there are ethical and behavioural considerations that need to be carefully examined in the process. The presentation will focus on the general design of a (small) research project in science education and show some examples of how one can use data from their own classroom as feedback and inspiration that could be applied in their teaching.

Panelists

After Academia: A Discussion with Former Grad Students

Dr. Behzad Khanaliloo

About the speaker: My PhD focus was on creating optomechanical structures in diamonds. This was a unique opportunity to learn about photonic devices' design, fabrication, and testing. I graduated from Dr. Paul Barclay's group in 2016 and joined Lumerical as an application engineer. I helped customers with their questions and developed application examples. This enabled me to expand my physics knowledge and learn more about silicon photonics. After that, I joined Rockley, focusing on building health care wearables to track biomarkers. We are working towards the commercialization of the product. Fun fact, I played soccer in div II Burnaby league and looking for a new team in California.

Dr. Elizabeth Watt

About the speaker: I got my PhD from the UofC in Medical Physics in 2018. During my degree, I worked in collaborative and multidisciplinary research, clinical work, teaching, and co-curricular activities in PHAS. After my PhD, I worked at a medical device start-up in Calgary for two years; this was an exciting opportunity to explore beyond R&D. After a recent move to California, I started working in Commercial Insights at Amgen, a global biotechnology company. In this role, I support several of our marketed products through analyzing opportunities by assessing clinical, regulatory, and commercial developments. It is a cross-functional role, with many problem-solving, scientific communication, and data presentations. I volunteer with the Healthcare Businesswomen's Association and love exploring everything California offers outside of work.

Dr. Taylor Cameron

About the speaker: I'm a research scientist at Natural Resources Canada currently studying space weather effects on high-frequency radio wave propagation. I spent many years on the 6th floor of Science B before finally completing my PhD on large-scale structuring in the solar wind in 2019. I enjoy long-distance running and reading science fiction when I'm not messing around with space weather data.

Speaker Session 1

Joseph Madamesila

Can Diffusion-based Radiomics & Machine Learning Detect Metastases?

Purpose: To develop a machine learning (ML) model for early detection of brain metastases based on diffusion imaging radiomics.

Materials/Methods: Diffusion weighted MRI from 40 patients previously treated at our institution were retrospectively analyzed. Clinical target volume contours from 193 metastases were extracted from radiosurgery planning CTs and rigidly registered to corresponding Gd-T1 MRI and Apparent Diffusion Coefficient (ADC) maps. Control volumes were generated using contralateral contours located in healthy brain tissue to enable ML binary classification.

The ML input dataset consisted of: 1) ADC-based radiomic features calculated within target volumes using Pyradiomics, 2) linear slopes and intercepts of each radiomic feature calculated using timepoints before the metastasis manifested on conventional Gd-T1, 3) primary cancer site, 4) age and gender, and 5) anatomical target volume location data (frontal lobe, parietal lobe, temporal lobe, occipital lobe, and cerebellum), identified by registering images to the MNI152 T1 dataset and applying standard cortical atlases.

Correlation analysis was performed and any features with >95% Pearson correlation were excluded. The dataset was divided into training and validation sets using an 80/20 split with stratification and scaled using Scikit-Learn's StandardScaler. Five classification algorithms (SVM: Support Vector Machine, RF: Random Forest, MLP: Multi-layer Perceptron, ADA: AdaBoost, XGB: XGBoost) performed supervised learning using a 10-fold cross validation (CV) training set, with data labeled as either 'control' or 'metastasis'. Grid search was used to tune hyperparameters for each algorithm (CV = 10), optimizing towards classifier balanced accuracy score. Receiver-operator curve area (AUC) scores were calculated along with accuracy, recall, and precision.

Results: Gradient boosting-based algorithms XGBoost and AdaBoost showed superior AUC using both the training set (XGB: 0.883 ± 0.024, ADA: 0.887 ± 0.023) and validation set (XGB: 0.888 ± 0.046, ADA: 0.880 ± 0.051). Random forest also performed similarly (training: 0.873 ± 0.025, testing: 0.860 ± 0.055). Gradient-boosting algorithms displayed greater recall (XGB: 0.802 ± 0.056, ADA: 0.818 ± 0.054) when compared to Random Forest (0.775 ± 0.06). SVM and MLP algorithms performed lower in all calculated metrics using both training and validation sets. Twenty of the 25 most important ADA features involved the change in radiomic feature values within clinical target volumes. Twenty-three of the 25 features were radiomic calculated using wavelet filtered or edge enhanced ADC images.

Conclusion: Gradient-boosting based ML algorithms showed encouraging results in differentiating healthy brain tissue from metastases when using diffusion images prior to lesion detection on conventional T1 MRI. ADA and XGB performed better than RF and SVM-based models when detecting malignant tissue based on changes in diffusion weighted imaging radiomic features. Future work will use these findings to further refine the model by adding more patients and test cases, improving classification accuracy, and increasing the model's overall clinical applicability.

Koorosh Esteki

Thermo-Electro-Optical Properties of Seamless Nanowire Networks

Transparent conductors (TCs) appear in various state-of-the-art thermoelectronic and optoelectronic devices. In particular, nanowire networks composed of metal nanowires have received considerable attention in this field because of their high electrical and optical responses as well as mechanical durability. Recently, continuous metal networks which are known as nano-based crack template with seamless (and less resistive) connections have been proposed as potential alternatives over conventional nanowire networks. In this work, a multiscale computational approach is being developed to study the thermal, electrical and optical properties of seamless nanowire networks made of different materials including sliver, gold, copper, and aluminum. The thermo-electro-optical simulations are carried out using a finite element method algorithm implemented in COMSOL® Multiphysics software. To illustrate the contribution of each thermal, electrical, and optical properties on overall network performance, we have constructed computational custom-made approach that obtains the electrical resistance and optical transmission calculations independently and these are compared with results and insights predicted with COMSOL simulations. We investigated various seamless nanowire network structures and estimated their respective figures of merit (optical transmittance versus sheet resistance/ thermal conductance versus sheet resistance) to provide a strong platform for examining the local heat /current density distributions and electrical sheet resistance of various nanomaterials fabricated in a seamless fashion.

David Amaro Alcala

An Introduction to Ternary Quantum Computation

In this talk I will introduce the notion of ternary quantum computation, define the qutrit as the basic unit of computation for quantum systems and describe some of the advantages that qutrits offer over the most common unit of quantum computation: the qubit. Finally, I will new results on a method to characterize operation on qutrits.

Maryam Abarashi

Electronic Transport Properties of Tailored 2D Materials for Ultrasensitive Chemical Sensors

Nanoscale sensors are widely used for different industrial, environmental, and healthcare applications. The performance of chemical sensors depends on the host materials properties; low dimensional materials, e.g. graphene or carbon nanotubes, can be used as host materials to detect chemicals in the environment. These materials provide wide surface area per unit of volume capable of hosting concentrations of impurities, and they exhibit conductivity that is sensitive to chemical perturbations. In this work, we obtain the electronic transport properties of low dimensional materials to improve sensitivity and selectivity features of nanoscale chemical sensors. Volatile organic compounds, in the vicinity of the host, can cause alterations in their electronic properties. These alterations, such as variances in the energy-dependent conductance, can be investigated and categorized for each chemical component. We aim at solving the inverse-problem in which the hitherto unknown chemical impurities and their concentrations are determined by analyzing the conductance variance they impart onto the host. Our goal is to quantify the conductance fingerprint that some organic compounds induce on the host and to propose ways of improving the device sensitivity based on these findings.

Armin Tabesh

Optomechanical Quantum Transduction

Establishing quantum networks will push the boundaries of quantum computation and quantum sensing. Quantum networks are generally hybrid quantum systems; They consist of various components that typically work in different frequency regimes. To make different parts with different frequencies communicate, the system should be able to convert quantum information between frequencies. Therefore, we need devices that convert quantum states (and consequently, quantum information encoded on them) from one frequency to another to use them as media between different components. Converting quantum states coherently between frequencies is named quantum transduction, and the devices are quantum transducers.

Optomechanics is the field of studying the interaction of electromagnetic fields and mechanical motions. Optomechanical interaction emerges from the momenta of electromagnetic fields and the fact that they can push objects mechanically. We can use optomechanics to make electromagnetic fields and mechanical oscillators interact. This interaction can cause an electromagnetic field state to be transferred to a mechanical oscillator and vice versa. Since the electromagnetic field and the mechanical oscillator have different frequencies, the transference is actually transduction. Therefore, optomechanical interaction can be exploited to perform quantum transduction. We are designing and fabricating quantum transducers based on optomechanics.

Abby Swadling

Distinguishing Signal from Background for a Direct Measurement of Antihydrogen's Lamb Shift

It is predicted that following the Big Bang equal amounts of matter and antimatter should have been created, however the universe is dominated by matter and there is much less of its counterpart. Antihydrogen is created and analyzed by the ALPHA (Antihydrogen Laser Physics Apparatus) collaboration at CERN to look for asymmetries by comparing its spectra with hydrogen's. The Lamb shift is an important transition in hydrogen, it is traditionally defined as the splitting of the $2S_{1/2}$ and $2P_{1/2}$ states at zero magnetic field. Presently it has been only indirectly measured in antihydrogen using data from two separate laser spectroscopy experiments. ALPHA's goal is to make a more precise direct measurement of this transition, where contrasting measurements of the Lamb shift in hydrogen and antihydrogen will provide insight as to the differences between the two. To measure this, a trapped antihydrogen atom must be excited from 1S (ground state) to 2S with a laser. Next, microwave radiation will be applied to cause a transition to 2P. The 2P state has a high probability of undergoing a positron spin flip transition to an untrapped state, resulting in the anti-atom annihilating on the surrounding apparatus walls. There are two types of annihilations occurring, those from a 2S-2P transition followed by a spin flip decay, the desired signal, and those from the ionization of the 2S state by the excitation laser, an undesired background. It is critical to distinguish between the two to complete a Lamb shift measurement. This is done by examining existing laser spectroscopy datasets categorized into those with and without ionizations. Those without ionizations are from experiments where the excitation was directly from 1S to 2P, followed by a spin flip decay down and detected annihilation. Contrasting these datasets allows ionization and spin flip annihilation position distribution variations to be determined. A statistical analysis of position distribution variations gives the information necessary to distinguish between the desired and undesired background signal. It also provides insight as to how various experimental modifications impact the location of annihilations. Knowing this is critical in determining the viability of a direct lamb shift measurement and the appropriate laser and microwave parameters. From here ALPHA can design an experiment to make the first direct measurement of this important transition in antihydrogen which could lead to a discovery in the matter/antimatter asymmetry problem.

Speaker Session 2

Eli Sollid
Using Biology and Chemistry to Excite Students About Physics

Over the course of most introductory physics classes, student attitudes about physics tend to decrease. We hope to change this by introducing interdisciplinary examples into the preexisting course material. We examine the impact of a 5 week intervention of introducing interdisciplinary examples in an introductory electromagnetism course composed primarily of life science majors. These introduced examples relate biological and chemical applications to current course material and range from explaining molecule polarity to how an electrocardiogram works. We use examples in these fields where the fundamental understanding of the physics plays a crucial role in the understanding of these systems to make explicit the value of physics across scientific disciplines.

Snehasis Addy
Error Correction in Quantum Communication

Error correction is the method of data recovery, that might get corrupted during transmission. More than ever, our society relies on the exchange of data and the ability to have long-distance communication between people in different locations. With the advancement in long-distance communication systems including quantum communication the risk of introduction of errors into the transmitted sequence increases. The errors are introduced into the data either due to fluctuations in the conditions of the channel in which the signals are transmitted or due to an eavesdropper trying to tap into the ongoing communication or both. With the errors present in the received sequence, the transmitted message will never be recovered successfully by the receiver resulting in communication failing miserably. Therefore the inclusion of an error correction in any communication protocol is very important. In this talk, I will introduce the basic idea behind the process of error correction and how does the implementation of error correction differs in classical communication from quantum communication.

Owen Paetkau
Targeting Dysphagia in Head and Neck Cancer Patients with Adaptive Radiotherapy

Head and neck cancer radiation therapy treatment may cause side effects due to radiation damage to healthy tissue. Dysphagia, or difficulty swallowing, is one such side effect and has been attributed to excess dose to the pharyngeal constrictors muscles. Reducing these side effects will improve patient quality of life after radiation therapy treatment. The goal of my work is to reduce the side effect by developing appropriate interventions on the patient treatment plan or through the course of treatment with adaptive radiotherapy. The first step is to determine the dosimetric and anatomical changes to the pharyngeal constrictors over the course of a treatment and characterize the dose-response of the organs at risk. Machine learning algorithms and other statistical methods will be employed to analyze the large data set available for the studies.

Paula Brandt
K114 Staining as a Prospective Gold Standard in the Diagnosis of Renal Amyloidosis

Renal amyloidosis is a rare condition characterized by the deposition of protein fibrils organized in β-pleated sheets within vascular compartments of the kidney. There are currently 40 known precursor proteins, with each causing a different type of disease. The most common forms that affect the kidney are AL and AA amyloidosis, which are caused by the misfolding of immunoglobulin light chains and serum amyloid A respectively. Without treatment, patients tend to progress to organ failure and ultimately death.

A diagnosis of renal amyloidosis requires a kidney biopsy followed by demonstration of fluorescence when stained with Congo Red. As Congo Red cannot differentiate between disease types, renal biopsies must undergo a variety of additional tests to accurately identify the type of amyloid present and therefore determine an effective treatment plan. This makes the current diagnostic method arduous and complicated, and results in disease progression while a patient is awaiting treatment.

The observation of Congo Red's ability to bind to amyloid fibrils has inspired the creation of related dyes that aim to improve the process of amyloid detection. One Congo Red derivative, known as K114, can produce a characteristic emission spectrum depending on the type of amyloid it is bound to. This dye is also unique in that when exposed to high levels of laser power, amyloid-bound K114 increases in intensity (photoconverts) while unbound K114 becomes dimmer. This study aims to show that spectral analysis of K114-stained kidney biopsies can be used to readily detect and differentiate between AL and AA amyloid deposits, and that this method could be used as a quantitative and improved one-step method to diagnose renal amyloidosis.

Renal biopsies with AL amyloid, AA amyloid, and no evidence of disease were stained with both K114 and Congo Red. Samples were imaged using a spectral confocal microscope and data were imported to ImageTrak for analysis. As expected, Congo Red displayed very little spectral variance when bound to different tissues. In contrast, K114 could chromatically distinguish between the tissue types with normal kidney appearing blue, AL amyloid appearing blue-green, and AA amyloid appearing bright green. This was confirmed quantitatively, with spectral phasors successfully differentiating between all tissue types. Photoconversion analysis revealed expectedly that amyloid plaques increased in brightness while normal tissue decreased in brightness over time. Unexpectedly, areas with no evidence of disease behaved differently in AL and AA amyloid samples, raising the possibility of amyloid being present throughout the kidney and not just in visible plaque-like regions. In support of this, both amyloid plaques and background regions red-shifted while normal tissue blue-shifted in response to repeated imaging. Overall, the methodology presented here describes an objective technique that can detect and identify AL and AA amyloidosis using a single stain. Due to the fact that K114 staining may be faster and more accurate than the current Congo Red diagnostic protocol, this technique warrants further development for potential use in clinical settings.

Ayush Mandwal

Refining Metabolic Networks from Empirical Omic Data Constraints

The main aim of biology is to understand and determine how genes and the proteins they encode result in specific behavior characteristics in the intact organism. The process of relating genes to biological processes is called Genetic annotation. However, this process of annotation is very complex and has several limitations. This results in either missing or misannotation of the organism genome which can be addressed only by rigorous experimentations. Metabolic profiling provides necessary phenotype information that is essential for validating new genetic annotation to genes. There are various ways to perform quantitative metabolic profiling such as constraint-based metabolic profiling. However, such an approach is information-intensive and does not work for organisms whose metabolic networks have missing reactions. By determining boundary fluxes one can infer active reactions of the metabolic network of the organism. KEGG database has well-defined ortholog metabolic maps which can be used as templates for annotating any missing/mislabelling reactions for an organism. To exploit KEGG metabolic map for understanding cellular metabolism, I developed a web application based on JavaScript. This tool provides an easy way to combine the metabolic map with flux data or any data measured in the experiment such as metabolomics, proteomics, etc. to determine unknown reactions in the metabolic network of less studied disease organisms such as Borrelia pathogen which causes Lyme diseases. Understanding the metabolism of pathogen bacteria allows understanding of how the organism grows which can be targeted for the cure of the disease. Besides studying pathogens' metabolism for medical diagnosis, it offers enormous possibilities for cell biology to understand the cellular metabolism of any cell in general which can help discover fundamental laws in biology and application in both medicine and industries.

Speaker Session 3

Gaurav Saxena
Distilling Coherence from Noisy Quantum Operations

Quantum coherence is a crucial resource for a variety of practical tasks like quantum computing, quantum biology, etc. Since we are living in an era where quantum devices are noisy, extracting a near-perfect resource from an error-prone device to use it for practical purposes becomes a challenging task. Thus, it is important to consider resource extraction protocols succeeding with some probability. In this talk, I will show you how to find the maximum success probability of extracting coherence from a noisy quantum operation up to some allowed error.

Mayte Li Gomez
Quantum Optical Coherence Tomography

Quantum Optical Coherence Tomography is an imaging process that uses non-classical sources of light to reconstruct the internal structure of a multilayered material or sample. Compared to its predecessor, the classical Optical Coherence Tomography, QOCT provides enhanced resolution images and is unaffected by light dispersion. In my talk, I would introduce the basic principles of interferometry and how we use it in the quantum regime to perform tomography scans.

Drew Patton
What Controls the Characteristics of Compressive Failure and Accelerated Seismic Release?

When a brittle material is under a sufficiently high external stress it will eventually fail. As the stress approaches the point of failure, which coincides with peak stress, the material goes through a dynamic deformation where microcracks nucleate at sites with large stress, grow, and coalesce. The approach to this failure point is usually accompanied by an accelerated seismic release (ASR) in which there is a divergence of the total energy of acoustic emission (AE) events. However, other characteristics such as the presence or absence in a change of the AE size distribution and whether the failure point can be interpreted as a critical point varies across experiments. Here, we show that macroscopic stress heterogeneities induced by a notch fundamentally change the characteristics of the failure point in triaxial compression experiments under a constant displacement rate on Westerly granite samples. Specifically, we observe accelerated seismic release without critical failure and no change in power-law exponent or b-value of the AE sizes. This is in contrast to intact samples, which exhibit a significant decrease in b-value. Our findings imply that the presence or absence of macroscopic heterogeneities play a significant role in our ability to predict compressive failure in rock.

Devin Van Elburg
3D Transvaginal Ultrasound for Gynecologic Interstitial High-Dose-Rate Brachytherapy

Purpose: To improve implant quality of gynecologic interstitial brachytherapy implants using intra-operative 3D transvaginal ultrasound.

Methods: All gynecologic template-interstitial brachytherapy patients at the Tom Baker Cancer Centre qualify for this ethics-approved study. The radiation oncologist performing the interstitial needle implant uses real-time 3D ultrasound guidance to visualize and guide interstitial needles. Implant quality is assessed based on dosimetric quantities related to target coverage and organ-at-risk dose, and the rate of needles passing through the clinical tumour volume (CTV). Results are compared to a retrospective cohort of 32 patients who have undergone gynecologic template-interstitial brachytherapy implants at TBCC using conventional methods (2D ultrasound).

Results: Patient accrual began in November 2021. Two patients have undergone 3D ultrasound-guided interstitial implants. In total, six needles (five and one for Patient 1 and 2, respectively) were implanted under 3D ultrasound guidance out of a total 17 implanted needles (11 and 6, respectively). All six 3D ultrasound-guided needles hit the CTV. Dose coverage of the CTV met clinical standards for both patients. Rectal dose for Patient 1 exceeded tolerance for risk of toxicity, however this is attributed to close proximity of the CTV to the rectum and not an indicator of implant quality. More data is needed to show any dosimetric advantages between 3D ultrasound and 2D ultrasound cohorts.

Conclusion: Three-dimensional ultrasound improves visualization of interstitial needles during implant. Accrual for a patient study is underway which aims to demonstrate improvement of implant quality when using 3D ultrasound methods compared to conventional 2D ultrasound methods.

Rebecca Frederick

Automated Treatment Planning for Total Body Irradiation

The medical physics community has been focusing recent efforts on improving standardization in radiation therapy treatment planning, with the goal of reducing planning errors, improving efficiency, and increasing compliance with clinical trial protocols. Automated treatment planning has been proposed and implemented as a means of addressing this problem, particularly for more challenging treatment sites like total body irradiation (TBI). However, there is little quantitative evidence showing how automated treatment planning has impacted standardization for TBI. My presentation will introduce how we have implemented automated treatment planning for TBI at the Tom Baker Cancer Centre. In addition, I will show how we've used other automated tools to determine if automated treatment planning has changed the heterogeneity of our treatment plans.

Kyle Reiter

Space Weather and Geomagnetically Induced Currents

Impulsive changes in the Earth's magnetic field have been found to be associated with negative impacts on ground-based technological infrastructure, such as power transmission systems. Geoelectric fields associated with these impulsive events have been found to excite geomagnetically induced currents (GIC) and produce harmonic distortion of transformer voltages. We have developed an algorithm for the selection of impulsive geomagnetic events to select for large perturbations in geomagnetic components (>50 nT) over short time periods (< 10 minutes). Cataloguing events occurring Quebec from 2015-2020, we determine the local-time distribution of impulsive events at a variety of magnetometer stations ranging across a large range of latitudes. Comparisons between the local-time distributions of impulsive geomagnetic events in ground-based magnetometers and of proximal harmonic distortion events are also conducted.