The 5th Annual PHAS Symposium

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phas dga

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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.

PHAS DGA Members

Pamela Freeman
(Co-Chair)

Svetlana Kuznetsova
(Co-Chair)

Davor Curic
(VP Events & GRC Rep)

Omid Khajehdehi
(VP Finance)

Carlton Osakwe
(GRC Rep)

Ayush Madwal
(Member at Large)

Mahsa Faryadras
(Member at Large)

Kyle Reiter
(Member at Large)

Schedule at a Glance

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<tr><td>9:15-9:30</td><td>Opening Remarks</td></tr>
<tr><td>9:30-10:15</td><td>Keynote Speaker (Lohrasp Seify)</td></tr>
<tr><td>10:15-10:45</td><td>Coffee Break + ePosters</td><td>TI Learning Studio E</td></tr>
<tr><td>10:45-12:00</td><td>Speaker Session 1</td><td>TI Learning Studio D</td></tr>
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<tr><td>1:00-1:45</td><td>Keynote Speaker (Dr Ann-Lise Norman)</td><td rowspan="2">TI Learning Studio D</td></tr>
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<tr><td>4:15-4:30</td><td>Closing Remarks and Prizes</td></tr>
<tr><td>5:00-7:30</td><td>Social Event</td><td>Last Defence Lounge</td></tr>
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Feel free to refer to the schedule throughout the Symposium.

You can also use the Room Finder to help find the Symposium facilities.

Key-Note Speakers

Dr. Ann-Lise Norman

About the speaker: I grew up in Calgary and am fortunate to have had the opportunity to pursue my research and career, and to teach wonderfully gifted University of Calgary students, at a quality university. I became fascinated with isotopes while working as an undergraduate in the laboratory of researcher, Dr. Roy Krouse. I was thrilled to be able to pursue my interests and passions right through to my PhD at the UofC. During my graduate studies I spent time in Bermuda getting acquainted with aerosol studies. I also travelled to the Institute for Ecotoxicology in Germany, for my PhD, and spent a year studying sulfur cycling in the Black Forest. After graduation, I set up and directed the isotope measurement laboratory at Environment Canada. A fortuitous interdisciplinary joint professorship between Physics and Astronomy and the Undergraduate Environmental Science Program opened at the UofC just as I was transitioning to a “next level” within the federal government research ranks. The freedom of the academic environment, the engagement teaching students, and the opportunity to explore non-siloed research attracted me back to Calgary.

Abstract: The ocean gives off a sulfurous gas that signals the presence of food to mammals and birds in the ocean. You might relate to this gas, dimethylsulfide (DMS), as the “smell of the ocean”. Although it exists in parts per trillion levels, its impact on climate is significant. It’s thought to be the climate “brake” in comparison to the climate greenhouse gas “accelerator” throughout geological time. DMS contributes to the creation of aerosols over oceans as it oxidizes. The sulfate it forms alters cloud properties that in turn scatter incoming solar radiation back to space. It also may play an important role in manipulating precipitation formation and ice nucleation in the Arctic. Field campaigns over the remote ocean and the Northwest Passage to explore the role of DMS in forming nanometer to micrometer size airborne particles, and DMS’s role in aerosol formation and growth as well as precipitation formation over the remote oceans, is the subject of several student theses. I will speak about how we use S and O isotopes to quantify how important DMS and its oxidation products are in comparison to the atmospheric sulphur compounds we generate from human activities. This talk will explore the revelations and new avenues for research in this exciting, interdisciplinary field of study.

Lohrasp Seify

About the speaker: Ever since graduating with a Master's in Physics, Lohrasp has switched between careers until he settled in with Blackline Safety. His academic experience in analyzing data obtained from particle accelerators and computer simulations, set him up to transition into any career that deals with data - or in today's world, almost any professional job out there. He now manages the data science, analytics, and data divisions of Blackline Safety.

Abstract: A physics degree does not necessarily give you relevant experience when it comes to a specific technology platform, a specific field of industry, or even how to communicate with everyday people - that believe it or not, might not be physicists. In this presentation, I'm going to tell the story of how I transitioned from a purely academic path into careers in different industries. I will discuss the pitfalls I experienced and the tangible qualities - which my physics degree taught me - that I used to excel in the industry.

Speaker Session 1

Archismita Dalal ***Quantum computing using neutral atoms***

Gate-based quantum computing (QC), which could make classically intractable problems easy to solve with important ramifications to cryptanalysis and quantum simulation, relies on high-fidelity entangling two-qubit gates. Of all the practical platforms for realizing gate-based QC, neutral atom (NA) is promising because of the ability to coherently control several qubits in different geometries; but the two-qubit gate fidelity is far behind competing QC platforms such as superconducting systems and ion-traps. My aim is to devise quantum control methods that would improve two-qubit gates in NA QC to the required scalability threshold, i.e. a fidelity value of 0.9999.

A quantum bit or qubit is a superposition of two logical states 0 and 1, with no classical counterpart. An entangled state is a multi-qubit state with a purely quantum-mechanical correlation between the qubits. Quantum information is stored in a string of qubits, and logical operation is performed on them using quantum gates, which is a unitary map from one quantum state to another. It has been proved that two single-qubit gates and one two-qubit gate are sufficient to design a universal quantum computer, i.e. to realize every quantum algorithm efficiently. In this talk, I will provide a brief introduction of these various QC components pertaining to a NA system.

In the later part of my talk, I will describe the quantum control technique I use to realize robust and high-performance two-qubit gates. We develop gate procedures based on simultaneous driving of the two atoms using adiabatic and shortcut-to-adiabatic pulses in the regime of a strong ,Rydberg blockade. Subsequently, the quantum control technique of laser pulse shaping is used to design the time-dependent shapes of these pulses. Our results show that this technique has the potential for achieving scalable two-qubit gates in NA systems.

Ryan Johnston ***Polarization of Faint Extragalactic Radio Sources***

Understanding the universe is impossible without understanding magnetism. However, the evolution, structure and origin of magnetic fields are all still open problems in astrophysics. The accretion of matter on a super-massive black hole in the centre of a galaxy creates two jets that travel through the galaxy and out into intergalactic space to form synchrotron emitting radio lobes. These lobes have high pressure, which results from the relativistic particles and magnetic fields, both of which roughly contributes to the pressure equally. The degree of polarization from synchrotron emission is of interest because it measures the regularity of magnetic fields on a galactic scale. My senior thesis aimed to further understand the role of magnetism‚Äôs in AGN outflows and feedback, where ejected plasma from a black hole interacts with the surrounding intergalactic and intracluster medium. I investigated the polarization of faint extragalactic radio sources in relation to their physical structure. I found that sources with structure on scales of 5, are more strongly polarized than more compact sources. Therefore, the correlation between fractional polarization and compactness is related to the projected physical size of the radio source and changes depending on structure. These findings also predict fewer compact sources contributing to the rotation measure grid in future surveys such as VLASS or the SKA.

Colleen Henschel ***Ice Nuclei Concentration in the Arctic Summer***

Climate models struggle to reproduce observed cloud formations in the Arctic. Opposite to what is found at mid-latitudes, low stratus clouds in the Arctic tend to warm the surface ocean, acting as a blanket to trap outgoing infrared radiation. As ocean ice retreats, a higher flux of particles and gases that contribute to stratus formation, and to precipitation, form. Regional models incorporating clouds and precipitation must be improved in order to couple them with global scale models and forecast the resulting global impacts of Arctic climate change. By improving our understanding of the effects of aerosols on Arctic clouds and climate, my research may provide information needed to improve these regional climate models.

Aerosol particles play a crucial role in the formation of clouds by acting as catalysts for water droplet formation (cloud condensation nuclei) and ice crystal formation (ice nucleating particles). In order to improve cloud modelling, we must develop a better understanding of the effects of aerosols on cloud formation and properties. Ice nucleating particle concentrations have been measured from size segregated aerosol samples collected at ten different Arctic locations during the summer of 2016. This will provide information on both the size and spatial distribution of ice nucleating particles in the Arctic summer.

Eduardo Paez *Optical atomic clocks based on trapped-ions*

The use of optical atomic clocks to measure time and frequency represents state-of-the-art in modern-precision measurement science thanks to the progress in atomic, optical and quantum science. In this regard, optical clocks have advanced the frontiers of science, having a strong impact on many fundamental research areas, providing improved quantum state control for quantum information/computing, insight in quantum science, tighter limits on fundamental constant variation and enhanced sensitivity for tests of relativity. Techniques developed for optical atomic clocks, such as advanced laser stabilization, coherent manipulation of atoms and novel atom trapping schemes, have given rise to new research opportunities in quantum physics.

At the heart of any clock there is a regular oscillatory phenomenon, whether it be the swinging of a pendulum, the spring-driven oscillations of a watch or the voltage-driven oscillations of a quartz crystal. The basic principles of atomic clocks are rather straightforward. An oscillating electromagnetic field, either microwave or optical, serves as a local oscillator (LO) and is referenced to the resonant frequency of a carefully chosen atomic Transition. Cycles of this local oscillator (LO) serve as a time-base on which to divide up and quantify a particular time period.

Arguably, single trapped ions benefit from having relatively few systematic shifts that can be extremely well characterized and controlled. Thus, single ion clocks can more easily reach the stability limits imposed by quantum projection noise. Nevertheless, the relatively low stability offered by a single atom is a current bottleneck to any possible improvement in clock accuracy.

In this presentation, the basis ideas related to atomic clocks, their importance in fundamental science and a summary of the state of the art in time and frequency measurements are provided.

Becky Booth *Investigating students, seriousness during selected conceptual inventory surveys*

Conceptual surveys are routinely used in post-secondary physics education to identify student learning needs and assess instructional practices. There is concern that students might not fully engage with these instruments because of the low stakes attached to them. The presentation will describe three seriousness tests that were developed to estimate the percentage of students who might not have taken such surveys seriously. Serious students were defined as those who thoughtfully participated in the conceptual survey, choosing their responses with consideration. These tests were applied to large data sets of students from across North America to conclude that there is a low incidence of nonseriousness in the undergraduate student population participating in conceptual surveys.

Speaker Session 2

Russell Shanahan ***A Magnetic Fingerprint In The Sagittarius Arm Of The Milky Way***

I will present the first result for Faraday rotation of compact polarized sources in The HI/OH Recombination line (THOR) survey of the inner Galaxy. In the Galactic longitude range from 39deg to 52deg, we find rotation measures (RMs) in the range of -310 to 4219 rad/m^2, with the highest values concentrated within a degree of Galactic longitude 48deg at the Sagittarius arm tangent. Most of the highest RMs arise in diffuse plasma, along lines of sight that do not intersect massive star forming HII regions. For Galactic longitudes greater than 49deg the RMs drop off rapidly but longitudes less than 47deg the mean RM is higher with a larger standard deviation than for larger longitudes. We attribute the RM structure to the compressed diffuse Warm Ionized Medium in the spiral arm upstream of the major star formation regions. With the detection of Faraday rotation from extragalactic polarized sources, as well as polarized emission from supernova remnants within the Milky Way, we can investigate the Galactic magnetic structure.

Anustup Das ***Demonstration of hexagonal boron nitride optical microcavities with Q&gt > 200,000***

Hexagonal boron nitride is a unique opto-electrical 2D material that hosts ultra bright quantum emitters and is an emerging candidate for integrated quantum-optical system. Here we demonstrate hBN integrated microdisk optical resonators with optical quality factor > 280,000.

Aran McDowell ***A Mathematical Morphology of Leaves***

In the last couple of years a body of work has been built up around developing a dynamical model of leaf growth. Of particular note is the work of J. Pulwicki, whose model was used to predict growth in the plant species Acetabularia. However, the boundary of Acatebularia has a very simple circular shape. For a fully formed dynamical model of leaf growth, one needs a means of generating general boundaries for leaves in 2D polar coordinates. My senior's research thesis is thus focused on trying to develop a general algorithm for generating these boundaries using methods drawn from fourier analysis. As of me wrtiting, I have been able to generate the boundaries of maple, ivy and cannabis leaves using fourier series.

Bishnupada Behera ***High-Frequency Torsional Optomechanics***

In nanoscale devices, the strong interaction between light and mechanical vibrations allows optomechanical measurement or sensing of force and displacement with ultra-high precision. To date, most applications of optomechanical sensors are based on measuring an applied force. Recent studies have demonstrated the ability of optomechanical systems for torque sensing; however, most of these systems possess mechanical frequencies in the MHz range or below. In this talk, I will present a cavity optomechanical system for high-frequency torque sensing, which has the potential to advance fundamental experiments and applications such as torque magnetometry of the magnetic dynamics of nanoscale materials, and detection of spin and orbital angular momentum of photons.

Speaker Session 3

Pooja Woosaree ***Precision Measurements on Antihydrogen using the ALPHA-g Apparatus***

The ALPHA (Antihydrogen Laser PHysics Apparatus) experiment aims to provide a possible solution to the baryonic asymmetry problem by testing CPT (charge conjugation, parity reversal, time reversal) theory and observing whether antimatter follows Einstein's Weak Equivalence Principle (WEP), where the acceleration due to gravity that a body experiences is independent of its structure or composition. A measurement of this nature has never been done before, as previous experiments used charged particles which meant the experiments were dominated by electromagnetic forces. The ALPHA-g apparatus will use electrically neutral antihydrogen produced in a vertical Penning-Malmberg trap and hold the antihydrogen in a magnetic well. Once the antihydrogen is released, the position of the resulting annihilation can be reconstructed with a radial TPC (time projection chamber) surrounding the trapping volume. This data will be used to measure the gravitational mass of antihydrogen, making this a crucial step in testing the fundamental symmetry of matter and antimatter.

The ALPHA-g apparatus is currently being commissioned at CERN, and the first gravitational measurements of antihydrogen are expected to begin in April 2021. I will be presenting some key components of the ALPHA-g apparatus and their functions, then proceed to discuss the future of the ALPHA-g apparatus.

Koorosh Esteki ***Nonlinear Ion Drift-Diffusion Memristance Description of TiO2 RRAM Devices***

The nature and direction of the hysteresis in memristive devices is critical to device operation and performance and the ability to realise their potential as neuromorphic applications. TiO2 is a prototypical memristive device material and is known to show hysteresis loops with both clockwise switching and counter-clockwise switching and in many instances evidence of negative differential resistance (NDR) behaviour. Here we study the electrical response of a device composed of a single nanowire channel Au-Ti/TiO2/Ti-Au both in air and vacuum and simulate the I-V characteristics in each case using Schottky barrier and ohmic-like transport memristive model that capture nonlinear diffusion and migration of ions within the wire. The dynamics of this complex charge conduction phenomenon is obtained by fitting the nonlinear ion-drift equations with the experimental data. Our experimental results support a nonlinear drift of oxygen vacancies acting as shallow donors under vacuum conditions. Simulations show that dopant diffusion under bias creates a depletion region along the channel that results in an NDR behaviour, but which is overcome at higher applied bias due to oxygen vacancy generation at the anode. The model allows the motion of the charged dopants to be visualised during device operation in air and vacuum and predicts the elimination of the NDR under low bias operation, in agreement with experiment.

Sara Shafiei ***Quantum Memory***

Long distance quantum communication may utilize the quantum phenomenon of entanglement to realize secure quantum information exchange between distant parties.

The distribution of entanglement is critical for long-distance quantum networks and is likely to rely on quantum repeaters, which require quantum memories that can preserve entanglement between distant network nodes. Thus, proposing practical mechanisms for implementing a quantum memory is of high importance for future quantum communication applications.

Quantum memory requires a very isolated and controlled system to assure a high fidelity and high efficiency storage for long enough time and developing such devices is quite challenging. Cavity-based quantum memories and Media-based Quantum memories are two main approaches that have seen a lot of progress in recent years.

While many different systems are being studied, including individual neutral atoms and ions, cold and hot atomic vapors and quantum dots; our group is focused on the study of crystals doped with ensembles of rare-earth ions. They make promising candidates for optical quantum memories due to their long-lived optical transitions with long optical and spin-level coherence times achievable at cryogenic temperatures.

In our lab, we have demonstrated the setup for a quantum memory based on spectral shaping of an inhomogeneously broadened optical transition into an atomic frequency comb (AFC) enhanced by an impedance matched cavity. In the talk, I will summarize and explain the results.

Adam Powell ***In Situ Magnetometry for the ALPHA experiment at CERN***

The Antihydrogen Laser Physics Apparatus (ALPHA) at the CERN antiproton decelerator facility uses low energy antiprotons in a bound state with a positron to produce and trap antihydrogen. Given the long history of atomic physics experiments with hydrogen, spectroscopy experiments with antihydrogen offer some of the most precise tests of quantum electrodynamics and charge-parity-time symmetry. A test the weak-equivalence principle is also on the horizon with a major addition to the ALPHA experiment, ALPHA-g, aiming to measure the free fall of antihydrogen.

For the spectroscopy and gravity experiments in ALPHA, precise measurements of the magnetic field inside the apparatus are essential. A technique developed in ALPHA determines the in situ magnetic field by measuring the cyclotron frequency of an electron plasma. Microwave pulses at resonance with the electron cyclotron frequency, which is magnetic field dependent, heat the plasma. A campaign to improve the precision and accuracy of this technique in a high magnetic field gradient is required before a successful measurement of the effect of Earth‚Äôs gravity on antimatter can be made.

This talk will introduce the ALPHA in situ magnetometry technique, discuss some of the technical challenges to be overcome and present the latest measurements.

ePoster Presentations

Anna Ordog ***Adventures in Faraday Space: a Polarisation Study of Galactic Magnetism***

The Galactic Magnetic Field (GMF) is a key feature of the interstellar medium, and mapping out its structure is crucial to understanding the physics governing our Galaxy as well as its interactions with both larger and smaller scale astronomical structures. Detecting the GMF is challenging, and its indirect observation relies on knowledge of the ways in which magnetism affects or causes radiation. Polarised radiation can be produced by relativistic electrons as they accelerate around magnetic field lines, a phenomenon known as synchrotron emission. The polarisation angle of this radiation can then be rotated in the presence of a magnetic field and an electron gas in the process known as Faraday Rotation. We use radio telescopes to study the polarisation properties of synchrotron emission in an attempt to gain insights into the GMF structure. When comparing results from different instruments, there are differences in the observational and data analysis techniques that can give rise to discrepancies or can highlight distinct features of Galactic structures. I give examples of some of the challenges associated with this through images made with the Canadian Galactic Plane Survey and the Global Magneto-Ionic Medium Survey. The aim of my work is to contribute to a better understanding of GMF structures by assessing the quantity and quality of information contained in different polarisation datasets.

Braedyn Au ***Fluorescent magnetic nanoparticles as a tool to find barriers in membrane diffusion***

Membrane diffusion barriers play a vital role in maintaining the identities of different compartments within a cell, and defective barriers are associated with ailments such as bipolar disease. Yet, the nanoscopic location and mechanisms of these barriers are mostly unknown. Fluorescent magnetic nanoparticles (fMNPs) are a promising tool for research in molecular and cell biology. When attached to proteins of interest in the plasma membrane, we can use single-particle tracking on a fluorescent microscope to follow its motion with nanometer and millisecond resolution. Furthermore, by applying an external magnetic field we can manipulate the protein motion such that when moved against a barrier, this motion will be affected. A possible cause of diffusion barriers is the actin cytoskeleton of cells. However, actin can be found in arrangements so dense that the novel techniques of super-resolution microscopy must be used for nanometer resolution imaging. Here, we established a workflow that combines single- particle tracking of directed fMNPs and super-resolution microscopy with stochastic optical reconstruction microscopy (STORM) methods to search for a link between protein diffusion and actin structures.

Jade Fischer and **Mahsa Faryadras** ***Structural and Functional Connectivity in the Brain***

Developmental topographical disorientation (DTD) is a condition in which individuals are not able to orient themselves in what are commonly thought to be familiar surroundings such as one neighbourhood. The condition is present from childhood and is not known to be associated with a neurological disorder or brain damage. Individuals affected by DTD get lost in familiar environments due to their inability to form cognitive maps, i.e., mental representations of the environment that are critical for navigating in order to reach a destination. The limited spatial orientation abilities of these individuals have been hypothesized to be a consequence of altered communication (i.e. functional connectivity) between brain regions that are known to be important for spatial orientation. The key objective of this project was to analyze the direct and indirect functional connectivity in the brain of both healthy and DTD-affected individuals to identify how exactly the communication is altered. A total of 20 right-handed females with DTD were included in the study, as well a group of 17 right-handed female control participants. None of the participants reported neurological or psychiatric disorders. Time series data was obtained from eyes-open resting-state functional magnetic resonance imaging scans of each participant. Calculation of Pearson correlation coefficients using the time series data allowed for the identification of indirect connections between regions of interest. Focus on the partial correlation coefficient values allowed for the identification of direct connections as partial correlation measures the linear relationship between regions while adjusting for the effect of the other regions of the brain. The current analysis shows promise in identifying links of interest associated with individuals with DTD, which could be helpful in further quantifying the structural and functional properties of the brain of individuals affected by DTD.