The 6th Annual PHAS Symposium

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phαs 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 many 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 PHAS DGA in general.

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Becky Booth
(Member at Large)

Pooja Woosaree
(Member at Large)

Omid Aligholamioskooee
(Member at Large)

Schedule at a Glance

TIME	Session
9:30-9:45	Opening Remarks
9:45-10:30	Keynote Speaker (Jennifer Howse)
10:30-10:45	Break
10:45-11:45	Speaker Session 1
11:45-1:15	Lunch
1:15-2:05	Speaker Session 2
2:05-2:50	Keynote Speaker (Dr. Mark Freeman)
2:50-3:05	Break
3:05-4:05	Speaker Session 3
4:05-4:15	Break
4:15	Closing Remarks and Prizes + Social Event

Zoom link for the symposium:

https://ucalgary.zoom.us/j/92116069923

Meeting ID: 921 1606 9923
Passcode: 1420

Keynote Speakers

Jennifer Howse

About the speaker: Jennifer Howse is the Education Specialist at the University of Calgary's Rothney Astrophysical Observatory. She has offered public programming at the RAO for the past fourteen years. Jennifer is proud to be a member of Metis Nation Region III and her main focus of research and personal interest is learning more about Indigenous Ways of Knowing and scientific knowledge and discovery. The priority is to learn from diverse perspectives of the natural world and the night sky to expand our knowledge of the universe.

Abstract: Astronomy is the world's oldest science and it is fundamental to the traditional conscious of the Indigenous peoples of Canada. Time and space are cultural as well as astronomical. Sky Science concepts are a appropriate and engaging way to introduce Indigenous Ways of Knowing to your students. The RAO's current project Wayfinding Under Blackfoot Skies design and new approach attempts to progress methodologies in how public science spaces embrace diverse world views. The Rothney Astrophysical Observatory is located within the foothills of the Rocky Mountains. Our facility is surrounded by Indigenous communities including Tsuu T'ina, Stoney-Nakota and Blackfoot territories. As a focal point of the surrounding communities as a focal point and connection to the universe. We are seeking to create connections to the land and sky though traditional Indigenous Ways of Knowing and current RAO research initiatives. Creating relevant Indigenous content for all of our spaces, programs, and engaging Indigenous students, is a priority for the Rothney Astrophysical Observatory and is part of the University of Calgary's strategy ii' taa'poh'to'p.

Dr. Mark Freeman

About the speaker: Born and raised in Edmonton, Mark Freeman obtained a BSc in physics from the University of Alberta in 1981, and a PhD in low temperature physics with Bob Richardson at Cornell University in 1988. He worked for six years at the IBM TJ Watson Research Center, before joining the faculty at the University of Alberta in 1994. The Freeman group's research concentrates on nonequilibrium physics in small structures, with an emphasis on magnetic systems. They have developed measurement techniques including stroboscopic magneto-optical microscopy, and nanomechanical detection of spin resonance. He has enjoyed opportunities to be involved in the development of the UofA nanofabrication facility (nanoFAB), and The Shack (a science hardware makerspace).

Abstract: This presentation is, in part, an homage to past professors, teaching staff, and the departments that enabled them to offer wonderful advanced teaching labs. Experiences in those labs sealed the deal and made me want to be a career physicist, and specifically an experimentalist. I'll describe one of the experiments that made a big impression (starting in the afternoon on January 25, 1982!), a study of strongly frequency- and temperature-dependent mechanical damping caused by impurity atoms diffusing inside a metal. Lessons learned in that experiment later echoed in my PhD thesis and still factor importantly in my group's research decades later. Upper-level undergrad and grad labs can provide a glimpse into the wide world of experimental physics, and be a life-changing opportunity for some students to hear the siren call of experiment and find out if it is one of their muses.

Speaker Session 1

Omid Aligholamioskooee

Quantum repeater platform using carbon timer defect in hexagonal boron nitride

A quantum network has important applications including distributed quantum computing and secure communications. Since long-distance quantum networks need quantum repeaters, there are many attempts to make practical, more efficient, and cheaper repeaters. We are studying carbon trimer defect in hexagonal boron nitride which seems promising as a quantum repeater at room temperature. We plan to use nuclear spins as the quantum memory needed for repeaters because the nuclear spins have higher coherence time. There are two main things that we have to figure out. First, we will study the hyperfine coupling of the defect. Then, we will determine optical selection rules to find out the allowed optical transitions. These will pave the way to build a repeater that will be much cheaper, simpler, and widely usable compared to other repeaters since they all need temperature close to zero kelvins to operate but this repeater can operate at room temperature. Ultimately, the repeaters will let us have secure quantum communications and distributed quantum computation over long distances.

Kenneth Sharman

Repeaters based on individual electron spins and nuclear-spin-ensemble memories in quantum dots

Inspired by recent developments in the control and manipulation of quantum dot nuclear spins, which allow for the possibility of transferring entanglement to the nuclear ensemble for storage, we propose a quantum repeater scheme that combines individual quantum dot electron spins and nuclear-spin ensembles, which serve as spin-photon interfaces and long-term memories respectively. Distant quantum dot electron spins are entangled by heralding single photon emission after which-path information is erased using a beam splitter. The excellent light out-coupling efficiencies offered by quantum dots allow us to generate entanglement efficiently. We consider the use of quantum dots embedded in high-cooperativity optical microcavities to perform heralded entanglement swapping using cavity-assisted gates. Entangled states are transferred to the surrounding quantum dot nuclear-spin ensembles for storage. Our scheme promises the establishment of high-fidelity entanglement over long distances with a distribution rate exceeding that of the direct transmission of photons.

Jade Fischer

Impact of post-stereotactic body radiation therapy imaging time point on liver function estimation

Stereotactic Body Radiation Therapy (SBRT) is a radiotherapy technique that focuses a high dose of radiation to a small tumor volume while sparing as much healthy tissue as possible. Conventional radiotherapy is delivered over several weeks in a relatively small dose of radiation (about 2 Gy per treatment) while SBRT is delivered with higher dosage per fraction (10 Gy or more), over 5 treatments or less. The highly focused radiation in small number of treatments has proven to be very effective and particularly advantageous over conventional radiation therapy. Unfortunately, not all of the patients qualify for this procedure. In the case of Liver SBRT, this is due in part to some patients not having an adequate overall liver function. The current method for determining liver function utilizes numerous clinical factors and results in an overall liver grade that does not carry any regional information. By assuming that liver function is uniform, specific patients may be prevented from receiving SBRT treatment. To identify the most optimal approach to quantifying regional functionality of the liver, PrimovistTM contrast enhanced MRI scans were taken pre-SBRT and in 4 week increments post-SBRT. A PrimovistTM MRI scan uses a highly specific contrast agent which is taken up by the functional liver tissues and increases signal intensity in areas of strong hepatic function, providing regional liver function information. The equivalence of two known enhancement metrics were compared, Relative Enhancement (RE) and Liver-to-Spleen coefficient

(LSC). The metrics are calculated at the voxel level to gather regional liver function information rather than a singular grade encompassing the overall liver function. Relative Enhancement is evaluated by comparing the pre-contrast signal intensity against the contrast-enhanced signal intensity. Liver-to-Spleen Coefficients are quantified by normalizing the signal intensity of each voxel of the liver to the average signal intensity of the spleen. By calculating a Pearson‚Äôs correlation coefficient between the RE and LSC values, it was found that the highest correlation for all patients occurred at 8-12 weeks post-SBRT. Furthermore, the liver parenchyma enhancement was qualitatively observed to increase post-SBRT. Determining the best metric for regional liver function quantification will help shift liver SBRT techniques towards a patient-specific treatment where highly functioning regions can be spared. Thus, allowing for liver SBRT to be a treatment option for patients who previously would not have qualified.

Paula Brandt

Detection and Typing of Renal Amyloidosis by Spectroscopy Using the Micro-Environmentally Sensitive Fluorophore K114

Amyloidosis is the most common renal protein deposition disease and occurs when insoluble precursor proteins coagulate to form plaques which infiltrate the delicate structures of the kidney. If this condition is left untreated, the kidney becomes unable to filter blood properly, leading to failure of the organ and eventually death of the affected patient. There are 36 known proteins that cause different types of amyloidosis, with each requiring specialized treatment. The most common forms that affect the kidney are AL and AA amyloidosis.

As amyloidosis is a progressive disease, it is vital to make an accurate diagnosis as early as possible in the disease's progression. Currently, the two-step process used to diagnose renal amyloidosis consisting of detection using Congo Red staining and typing using immunofluorescence has many drawbacks that can negatively impact the outcomes of patients. Primarily, these detection methods are slow and prone to reporting false-negative results early in disease progression, meaning that many patients are diagnosed in the late stages of amyloidosis. These patients have a far worse prognosis compared to those who are diagnosed early in their disease progression. As a result, it is important to investigate methods which could provide a more reliable diagnosis faster and in earlier stages of amyloidosis compared to current methods.

The fluorophore K114 has the potential to improve upon the current diagnostic process, primarily due to its ability to produce a characteristic emission spectrum depending on the type of amyloid it is bound to. Our group has shown that the spectra produced by K114 stained AL and AA amyloid are distinctly different and can be differentiated quantitatively. Additionally, K114 has revealed the presence of amyloid in patients with diabetic nephropathy which is a poorly understood phenomenon. It is hoped that this study will not only allow for the development of a faster and more accurate method to diagnose amyloidosis, but will also contribute to the overall understanding of the disease.

Joshua Peltonen

Mapping Molecular Clouds using Gaia data and All-Sky Surveys to Find YSOs

Mapping a diffuse object in space is a difficult task. Molecular clouds are unique in that they form stars within them. Therefore, if the location of young stellar objects (YSOs) within the cloud is known, this can indicate the cloud's structure. Using inversion of Gaia parallax, distances to YSOs can be found. The significant difficulty is locating the positions of YSOs in the sky. Several molecular clouds have databases of known YSOs that include the position in the sky. We were able to correlate the positions of known YSOs with Gaia to find the position and distance to several clouds' YSOs. Thus, the 3Dimensional structure of the clouds is now known. We also created a method of finding YSOs using all-sky infrared surveys. These all-sky surveys record spectroscopic data on every star in their catalogues. YSOs were identified using their unique spectrographic properties. Once the YSOs are identified, 3Dimensional maps can be created for clouds that do not have databases of known YSOs.

Speaker Session 2

Braedyn Au

The search for criticality in biological neural networks

The human brain is a fascinating system from which our consciousness and thoughts emerge, yet its dynamics have yet to be fully understood. The critical brain hypothesis posits that information spreading in the brain operates near a self-organized critical point of a continuous phase transition, meaning brain activity is balanced between exponential growth and decay. Previous studies show that systems at criticality exhibit optimal stimuli encoding and response, suggesting that criticality provides an evolutionary advantage. Evidence of criticality has been observed on scales of cell cultures, brain slices, and full-scale brain functional MRI scans. To model neural activity, neurons are assumed to spread activity like a simple branching process and thus fall into the universality class of directed percolation. The branching process describes activity spreading from a single initiation site, an assumption that can be violated in real neurons where external drivers and spontaneous activity (e.g. minis) can initiate multiple cascades. By incorporating spontaneous activity into the branching process, criticality has been achieved on various random network types via analytical investigation and numerical simulation with the underlying universality class transitioning from directed to undirected percolation. Directed percolation describes only small-scale distributions of activity, whereas on larger scales cascades can merge and undirected percolation becomes the appropriate description. However, this behaviour has yet to be observed on real brain networks. Here, we apply the branching process with spontaneous activity on networks reconstructed from diffusion MRI with 1014 and 967 366 nodes corresponding to coarse-grained brain regions at different resolutions. We show that on the smaller network, the critical exponents of directed and undirected percolation can each be observed independently for cascade size distributions. However, a universality class transition cannot be observed due to finite-size effects. In the larger network, the universality class transition can be observed. However, both directed and undirected percolation critical exponents vary along the critical line and further work is required to investigate this phenomenon. This work provides a natural bridge for future work searching for criticality with spontaneous activity, both experimentally and computationally.

Ayush Mandwal

A biochemical mechanism behind temporal learning in Purkinje cells for the precise movements

Purkinje cells (PCs) of the cerebellar cortex are necessary for controlling movement with precision, but a mechanistic explanation of how the activity of these inhibitory neurons regulates motor output is still lacking. PCs store kinematics information that corresponds to any precise movement but where exactly this information is stored and how it is encoded are still elusive. Classical eyeblink conditioning offers a superior example to understand the underlying mechanism behind the precision movements. In the eye-blink experiment, it was found that Purkinje cells can learn to suppress their firing rate for a specific duration which results in the closing of the eyelid at a specific time interval. Furthermore, a specific metabotropic glutamate-based receptor type 7 (mGluR7), which resides on the synapses of the Purkinje cell, was found responsible for the initiation of the response, suggesting an intrinsic mechanism within the Purkinje cell for the temporal learning. In an attempt to look for a mechanism behind memory formation associated with temporal learning within individual Purkinje cells, we propose a biochemical mechanism based on recent experimental findings. The proposed mechanism attempts to answer key aspects of the “Coding problem” of Neuroscience by focusing on the Purkinje cell’s ability to encode time intervals. The proposed mechanism augments new insights into the long-standing model of cerebellar function and provides a molecular mechanism behind precise control of movements.

Kim Owen

Measurement-device-independent quantum key distribution using quantum dots

It is only a matter of time until quantum computers will be capable of breaking all current encryption methods. In light of this cryptography crisis, it is vital to experimentally realize Quantum Key Distribution (QKD) protocols, which are information-theoretic secure. This form of security, which is not possible with classical cryptography protocols, states that the protocol will remain equally secure regardless of the computational power of eavesdroppers and hackers. Although one form of QKD is already commercially available, it is susceptible to side-channel attacks based on flaws in how it is physically implemented. The most common attacks are detector-based attacks, and photon-number splitting attacks. For my thesis, I am working on the first implementation of Measurement-Device-Independent Quantum Key Distribution (MDI QKD) using quantum dot single photon sources. This form of QKD is not only information-theoretic secure, but also inherently secure against all possible detector and photon-number-splitting side-channel attacks.

Prasoon Kumar Shandilya

Optomechanical control of qubits

Quantum networks enable a broad range of practical and fundamental applications. Experimental realization of such networks is hampered by many challenges, one of them being a lack of an efficient interface between stationary and flying qubits working at room temperature. We demonstrate an interface between ensembles of the nitrogen-vacancy centers in diamond and photons with wavelengths near 1550 nm. Photons are coupled to spins via local dynamical stress produced by optomechanical driving of a diamond microdisk. Our approach does not involve intrinsic optical transitions and can be easily adapted to many other colour centers.

Speaker Session 3

Elijah Adams

Modelling neuromorphic maze solving

Computation is a key ingredient behind the technological revolution experienced by modern society. However, computation using conventional architectures will inevitably reach a limit; as electronic components reach the nanoscale, dissipation effects become a bottleneck. Alternative computing architectures are being pursued within the scientific community to offer solutions for brain-inspired and in-memory computing applications. An example of such modern architectures are the emerging resistive-switching nanowire networks where each cross point operates as an electrical switch with memory attributes. In my research, circuit simulations, integrated with resistive-switching modelling, were conducted on square lattices to quantify their efficiency in performing maze-solving operations and memory hysteresis loops when exposed to bias voltage sources. The simulations account for the time-varying behaviour and history of resistance change of the system and hope to uncover how the switches at the cross points synchronize to solve intricate maze problems by means of finding the shortest resistance path between source and drain nodes in the circuit. The project is a proof-of-concept model demonstrating that nonlinear resistive switching materials can be used to solve complex problems such as maze-path-finding. Maze generation and solving algorithms are used to test the characteristics of the solution path of the device.

Koorosh Esteki

Tuning the electro-optical properties of nanowire networks

Conductive and transparent metallic nanowire networks are regarded as promising alternatives to Indium-Tin-Oxides (ITOs) in emerging flexible next-generation technologies due to its prominent optoelectronic properties and low-cost fabrication. The performance of such systems closely relies on many geometrical, physical, and intrinsic properties of the nanowire materials as well as the device-layout. Adequate comprehensive computational study is essential to make any device fabrication cost-effective. Here, we present a computational toolkit that exploits the electro-optical specifications of distinct device-layouts, namely standard random nanowire network and transparent mesh pattern structures. The target materials for transparent conducting electrodes of this study are aluminium, gold and silver nanowires. We have examined a variety of tunable parameters including network area fraction (AF), length to diameter aspect ratio (AR) between, and nanowires angular orientations under different device designs. Moreover, the optical extinction efficiency factors of each material are estimated by Mie light scattering theory. We studied various nanowire network structures and calculated their respective figures of merit (optical transmittance versus sheet resistance) from which insights on the design of next-generation transparent conductor devices can be inferred.

Behnam Ashrafkhani Limoudehi

Design and evaluation of laser ion source in TITAN MR-TOF-MS in order to measure 222Rn daughter product abundances

Radon and its progeny pose a radiation risk for North Americans who are exposed to high levels of radon in the home and work environments. People inhale radon gas that emits alpha particles and therefore high levels of radon exposure might put people at risk for developing lung cancer. Radiation measurement in biological tissues provides long-term archive for radiation exposure and brings about the development of analytical measurement tools for biological dosimetry. Among all daughter products in the radon decay chain, 210Pb and 210Po are the longest-lived. Multi-Reflection Time-of-Flight Spectrometer (MR-TOF-MS) as an analytical technique is employed to measure isotope abundances and performing the measurement with high resolving power enables us to separate different isobaric masses in the spectrum. The goal of the study is to develop a laser ablation source (LAS) that utilizes the high-resolving power MR-TOF-MS. To integrate LAS, the laser beam, after passing through different optics, is focused in a high vacuum on a small point on the surface of the sample. Employing optical telescoping system and different polarizers, the pulse energy can be modulated. Transfer of laser pulse energy and absorption by sample lead to ionization and plasma production on the target which liberates different elements with varying isotopic compositions. Thereafter, the produced ions need to be steered towards the MR-TOF-MS. Using SIMION, ion optical simulations were performed to optimize the ion source. Ion optics extract and guide the ion beam to the match point of MR-TOF-MS to perform mass measurement experiments. When the LAS is installed, ion production and transport efficiency would be calibrated using standard reference materials. Measured isotope abundances is expected to match with the abundances predicted with decay equation simulation. In the simulation, the decay equation in the radon decay chain was solved with respect to the boundary conditions established for radon exposure level and absorption levels by different biological tissues. Human nails will be analyzed with predicted amounts of 210Pb and 210Po on the order of femtograms per gram and attograms per gram, respectively.

Salini Karuvade

Quantum internet

Quantum internet enhances information and communications technology through applications such as secure quantum computing in the cloud, quantum sensing and quantum-enhanced high precision clock networks. I discuss the structure and working of the quantum internet, its applications and how the quantum internet compares against its classical counterpart.

Maria Masoliver Vila

Control of coherence resonance in multiplex neural networks

We study the dynamics of two neuronal populations weakly and mutually coupled in a multiplexed ring configuration. We simulate the neuronal activity with the stochastic FitzHugh-Nagumo (FHN) model. The two neuronal populations perceive different levels of noise: one population exhibits spiking activity induced by supra-threshold noise (layer 1), while the other population is silent in the absence of inter-layer coupling because its own level of noise is sub-threshold (layer 2). We find that, for appropriate levels of noise in layer 1, weak inter-layer coupling can induce coherence resonance (CR), anti-coherence resonance (ACR) and inverse stochastic resonance (ISR) in layer 2. We also find that a small number of randomly distributed inter-layer links is sufficient to induce these phenomena in layer 2. Our results hold for small and large neuronal populations.