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HI Content in the SIMBA Simulation at 0.74 < z < 1.45

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Neutral atomic hydrogen (HI) is an essential fuel for star formation, yet direct detections of HI emission beyond redshift about 0.4 remain extremely challenging. Recent observational studies, particularly Chowdhury et al. (2022), used HI 21 cm stacking of more than 11,000 DEEP2 galaxies to obtain statistical measurements of HI masses and star formation rates at z ~ 1. The goal of this project is to replicate these observational results using the SIMBA cosmological simulation to test how well SIMBA reproduces the gas and star-formation properties of galaxies at intermediate redshifts. Using CAESAR galaxy catalogues from SIMBA, we select simulated galaxies that match the DEEP2 criteria: blue, star-forming systems with stellar masses above 109 solar masses and excluding radio-bright AGN. We compute stellar masses, HI masses, and star-formation rates using both CAESAR outputs and observationally motivated scaling relations, then compare SIMBA scaling relations with those obtained by Chowdhury et al. (2022). Preliminary results show that the z ~ 1 SIMBA HI depletion timescale–stellar mass relation matches the observed scaling well, whereas the HI mass-stellar mass relation is noticeably shallower, partly due to the removal of radio-bright AGN at high stellar masses. These comparisons help evaluate how accurately simulations capture the gas physics regulating star formation and will be extended to additional simulations in future work.

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Inverse Kinematics Measurements of Key Resonances in $^{15}N(a,g)^{19}F$ with DRAGON

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On behalf of the DRAGON collaboration

The origin of the only stable fluorine isotope, ^{19}F, is a longstanding question in nuclear astrophysics due to persistent discrepancies between observations and model-predicted abundances constrained by measured reaction rates. Recent work highlighted that the reaction rate of $^{15}N(a,g)^{19}F$ – one of the key production channels – may carry significantly larger uncertainties than previously assumed. By exploring reaction-rate variations beyond the standard error estimates, they demonstrated improved agreement between predicted and observed ^{19}F abundances. This result has motivated new experimental efforts to measure the rate-determining resonances of the $^{15}N(a,g)^{19}F$ reaction, aiming to refine fluorine nucleosynthesis models and resolve the ^{19}F abundance puzzle. The $^{15}N(a,g)^{19}F$ reaction rate at relevant temperatures is determined by a number of narrow resonances, together with the direct-capture component and the tails of the two broad resonances at E_{cm} = 1323 and 1487 keV. Discrepancies in the results of recent measurements regarding the exact energies and strengths of the resonances at E_{cm} = 1323 and 1487 keV have triggered a new measurement at the DRAGON recoil separator at TRIUMF. The former is of particular note because of its use as a reference resonance for measurements of other rate-determining resonances. Using the inverse kinematics method at the DRAGON facility, we directly measured the resonance energies and strengths of the two broad resonances. In my presentation, I will outline the scientific motivation for studying this reaction rate, the analysis method used, and I will discuss the results in relation to the literature.

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Exploring Correlations Between the Dispersion Measures of Fast Radio Bursts and the Sunyaev-Zeldovich Effect

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On behalf of the CHIME/FRB collaboration

Fast Radio Bursts (FRBs) are micro-millisecond duration bursts of extragalactic radio light that carry information about the matter they've passed through in the form of dispersion measure (DM), an integral of electron density along the line of sight. The thermal Sunyaev-Zeldovich (tSZ) effect is a distortion produced by the scattering of cosmic microwave background photons due to hot electrons. In particular, it can be used to identify locations of galaxy clusters due to the gas in the intra-cluster medium (ICM) reaching high temperatures, thus ionizing this gas so there are many free electrons. While FRB host galaxies are assumed to be uniform across the sky, the increased density of galaxies along cluster lines of sight, as well as the prospect of lensing due to large dark matter halos, could indicate otherwise. Also, since both DM and the tSZ effect depend on electron density, there is reason to believe they may be correlated. Using the Canadian Hydrogen Intensity Mapping Experiment (CHIME) radio telescope's large dataset of FRBs, we looked for correlations between the DMs of FRBs and the tSZ effect at their locations. We found six FRBs with host galaxies either in or behind clusters, two of which were correlated with the same cluster, and further explored both the FRB properties, such as DM and scattering, and cluster properties like redshift, mass, and radial size. This work contributes to a better understanding of FRB populations, especially those with high DMs, and better constraints on models of the ICM electron density profile.

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Observing Differences in Cellulose Samples Hydrated with Different States of Water using THz-TDS

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Terahertz (THz) radiation is a sensitive probe for detecting water in organic networks, as organic materials tend to be transparent at these frequencies, while water is heavily absorbent. Thz time-domain spectroscopy (THz-TDS) provides a nondestructive probe to measure physical parameters in organic material systems. The interaction between cellulose and water of different molecular phases was considered by applying THz-TDS to samples hydrated to 3.81% and 6.81% moisture content (MC) using two different methods. The salt solution method of sample preparation exploits the hygroscopic nature of cellulose to condition samples to a set MC with water vapour, and is currently the standard technique used in material science; however, the method is time consuming and susceptible to error through fluctuations in MC over calibration times. Another method of sample preparation involves the direct addition of liquid water to samples followed by a wait time sufficient to achieve spatial equilibration by diffusion. THz-TDS revealed that while the complex refractive index of the liquid-hydrated samples generally approached that of the vapour-conditioned samples, the absorption coefficient was found to be greater in the liquid-hydrated samples for 3.81% MC and not when conditioned at 6.81% MC. The difference may result from the presence of water clustering effects as proposed in water cluster theory, and demonstrates the potential for THz to detect water behaviour at a microscopic level. The results suggest that the liquid-conditioning technique is a suitable replacement for the vapour-conditioning technique when microscopic property behaviour is not the principal interest.

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Comparing the Swimming Speed of Magnetospirillum magneticum AMB-1 Cells in Viscous Newtonian and non-Newtonian Mixtures

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Magnetotactic bacteria (MTB) are prokaryotes capable of using geomagnetic fields for navigation. This is made possible through the biomineralization of nano-magnetic crystals, which form inside magnetosome organelles. Chains of magnetosomes create an array of magnetic dipoles which enable the passive alignment of bacteria with external magnetic fields. The ability to align these cells along magnetic field lines allows for opportunities to study their swimming motion, which has important applications to understanding host-pathogen interactions. Magnetospirillum magneticum strain AMB-1 is an amphitrichous MTB with two flagella. Previous studies have indicated that these bacteria demonstrate different motility depending on the characteristics of the medium to which they are exposed. This project aimed to better understand these distinctions by tracking bacteria speed in various concentrations of a Newtonian glycerol and non-Newtonian polyacrylamide (PAM) mixtures. The speed of AMB-1 cells in 0-10% glycerol concentrations and 0-4.5 mg/mL PAM concentrations were tracked to visualize the impact of media viscosity on bacterial motility. AMB-1 cells were grown in culture and those demonstrating the best ability to follow external magnetic fields were isolated through capillary racetrack methods. Imaging was accomplished using phase-contrast microscopy, where cells were exposed to a 5-milli-Tesla magnetic field. Results showed a negative linear relationship between increasing glycerol concentrations and AMB-1 speed, but counter-intuitively showed a positive relationship between increased viscosity and speed in PAM solutions up to 1.5 mg/mL. This work can be used to inform pathogen mobility in viscous media such as human mucus.

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Modelling Hot Jupiter Atmospheres Using Shallow-Water Magnetohydrodynamics

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Hot Jupiters are a class of gas giant planets orbiting very close to their host stars, where they are subjected to intense stellar irradiation and tidal forces. Their proximity leads to extreme atmospheric conditions, where the coupling between their strong internal magnetic fields and atmospheric currents induces complex dynamical effects such as magnetic drag and Ohmic heating. Despite two decades of study, the physics that governs their atmospheric circulation remains incompletely understood, particularly the role of magnetic fields in shaping large-scale flow. To address these challenges, we construct an atmospheric model using the shallow-water approximation to the magnetohydrodynamics (MHD) equations in spherical geometry, pushing the work of Hindle et al. into new territory. Such a model allows us to gather further insight into observational results, such as westward hotspot displacement. We implement and solve the set of equations using the Dedalus spectral partial differential equation framework. Our setup builds on the hydrodynamic formulation used by Perez-Becker and Showman, providing a direct basis for comparison and validation of the magnetised system. Future work, motivated by Hardy et al., involves implementing temperature dependence of the magnetic diffusivity into the MHD equations via the electric conductivity. Additionally, this work is a potential motivator for new observations, as this temperature dependence can drive instability that excites large-scale oscillations in the atmosphere, requiring that multiple phase curves be retrieved from a given source to confirm this.

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Unveiling the Origin of a Historical Supernova

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The nature of historical supernovae are often not well-known, but supernova remnants and their environments can serve as powerful tools for probing their progenitor systems. RCW 86 is an interesting supernova remnant, thought to be associated with the historical supernova SN 185 as recorded by ancient Chinese astronomers. If so, that would make RCW 86 the oldest supernova remnant with surviving records. To reconcile its age with its large size, astronomers have determined it likely exploded into a low-density cavity. This theory allows for the rapid expansion necessary for RCW 86 to have gotten as large as we see it today. However, this leads to questions about the nature of the progenitor system, including its temperature and luminosity. To answer these questions, longslit spectroscopic data were gathered in 2025 using the 8.1-meter Gemini South telescope, both slightly ahead of the expanding shock front as well as on the shock itself. The data spanned 400-750 nm across two different observations, allowing for measurement of He I lines, He II lines, and the Balmer series. The data were reduced via the Gemini DRAGONS pipeline, with the goal of measuring or constraining the ionized H and He fluxes. From He/H flux ratios, estimates of the temperature and luminosity of the progenitor object will be determined.

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Contact Drawing of Recombinant Spider Silk Fibers

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Spider silks are renowned for their high strength and toughness, qualities that are desired for potential applications ranging from textiles to biomedical materials and devices. The mechanical properties of spider silks come from their constituent proteins called spidroins. It is difficult to harvest natural spider silk due to challenges both in housing spiders and in collecting their silks. Recombinant spider silk production is a promising alternative, at scales from laboratory research through to commercialization. Fibers can be produced by resuspending recombinant silk proteins in a concentrated "spin dope" state followed by spinning fibers in a variety of ways. This work has explored the properties of a ~57 kDa recombinant spider wrapping silk protein (the "W3" protein) produced in Escherichia coli formed into fibers using the technique of contact drawing. Fibers were analyzed using wide-angle X-ray diffraction (WAXD) and Fourier transform infrared (FTIR) spectromicroscopy to study structural elements such as beta sheet composition. A home-built mechanical testing apparatus was used to measure stress-strain curves, enabling determination of Young's modulus, ultimate tensile strength, extensibility, and toughness. These mechanical properties were compared for fibers of different compositions and correlated to differences in structural features observable by WAXD and FTIR.

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Review of Performance of the Digital Hadron Calorimeter Prototype

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The Digital Hadron Calorimeter (DHCAL) is a highly granular prototype developed by the CALICE collaboration to meet the precision needs of future lepton colliders. Its digital readout records only whether a pad is hit, which gives excellent spatial resolution but introduces challenges such as hit saturation and variations in chamber response. This project evaluates how two post-processing methods, saturation correction and Resistive Plate Chamber calibration, affect the detector's performance across beam energies from 2 to 120 GeV using reconstructed test-beam data from several Fermilab periods. Events were separated into muons, positrons, and pions using Cherenkov tagging and shower-based variables. For each particle type, the mean number of hits, linearity fits, and resolution were extracted before and after applying each method. The saturation correction, which statistically estimates unrecorded hits in dense regions, significantly improved the linearity of hadronic pion showers, increasing the power-law exponent from about 0.88 to 0.97. Calibration, based on efficiency and pad-multiplicity measurements from muon tracks, reduced run-to-run variations and stabilized the response. When combined, the two methods produced an energy dependence that was consistent with near-linear behavior across usable beam periods, with only a modest increase in resolution at low energies. These results show that digital calorimetry can achieve reliable and consistent performance when supported by suitable reconstruction algorithms, and that compensating for saturation and chamber-level effects is essential for improving the detector's ability to measure hadronic energy deposits.

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The $^{20}Ne(\alpha, \gamma)^{24}Mg$ Reaction in Stellar Nucleosynthesis

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Stellar nucleosynthesis is the process by which stars create new, heavier chemical elements from lighter ones through nuclear fusion reactions. It is a fundamental process that explains the origin of nearly all elements in the universe. One fusion reaction of particular interest is the $^{20}Ne(\alpha, \gamma)^{24}Mg$ reaction, which is important in understanding nucleosynthesis during the advanced burning stages of massive stars and in explosive events like X-ray bursts and supernovae. Despite its importance, current evaluations of this reaction rate rely on resonance strengths taken from only a single direct measurement by Schmalbrock et al. To verify and supplement this existing work, we plan to eventually perform a direct measurement of the $^{20}Ne(\alpha, \gamma)\ ^{24}Mg$ reaction using DRAGON, a recoil mass separator at TRIUMF designed to separate nuclear reaction products from the incoming reactant beam. In preparation for this experiment, Monte Carlo simulations were run to model how reaction products travel through the separator and how efficiently they are detected. This work will be essential for planning and interpreting the future experiment. Additionally, the astrophysical impact of the $^{20}Ne(\alpha, \gamma)^{24}Mg$ reaction rate in X-ray bursts was explored using NuGRID nuclear astrophysics simulation tools. By varying the accepted reaction rate by multiple factors and examining the effects on predicted element abundances, we were able to gain a better understanding of how the reaction influences element production in this stellar environment.

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Understanding 3I/ATLAS through Thunderbird South: Is it Aliens?

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3I/ATLAS (or simply, 3I) was discovered by Asteroid Terrestrial-impact Last Alert System station in July of 2025, making it the third observed astronomical object traversing the Solar System with confirmed interstellar origins. Thunderbird South is the University of British Columbia's telescope, located in La Serena, Chile. Operated remotely, the telescope has been able to image BVRI band images of 3I over multiple nights. Through these images, we are able to calculate certain features of the comet, such as photometry and astrometry. To determine the photometry of 3I, we employ a shift-and-stack technique. This method aligns a sequence of frames along the expected path of the moving object, amplifying the comet's photometric signal to interpolate a distinguishable image of the comet and its tail. By implementing this algorithm, we enhance the signal-to-noise ratio sufficiently to obtain reliable brightness measurements that would be difficult to extract from individual exposures. These values support ongoing attempts to characterize 3I and to compare it with previously observed interstellar objects. Such characterization is especially relevant given the substantial speculation surrounding 3I in popular media. In this presentation, we will discuss both the scientific results obtained from Thunderbird South and the broader implications of this work for public perception of astronomy. In particular, we will analyze the argument that 3I is an indicator of extraterrestrial life and why such claims are unlikely.

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Development of Alpha Spectroscopy as a Diagnostic Tool for Targeted Alpha Therapy on Cancer Cells

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Targeted alpha therapy (TAT) is an emerging treatment for metastatic cancers. This radiotherapy technique uses alpha-emitting radiopharmaceuticals to deliver precise, localized alpha radiation to tumour tissue. Alpha particles have high linear energy transfer (LET) and cause double-strand DNA breakage in tumour cells, leading to cell death even in resistant cancers, while minimizing harm to healthy tissue. Actinium-225 (225Ac) is a promising radionuclide for TAT due to the four successive alpha emissions produced in its decay chain. We developed the Bio-Sample Alpha Detector (BAD), a silicon-based alpha particle detector operating under ambient conditions, that enables the collection of direct, real-time alpha spectroscopy data of live cells. The BAD setup allows radiolabeled cancer cell samples to be placed within 100 µm of the detector, accounting for the positional dependence of alpha particle detection and thus obtaining statistical uncertainties of <1 % in alpha count rates.Differences in alpha spectra of cells and control samples confirm the uptake of 225Ac radiopharmaceuticals by A673 human tissue cancer cells. Geant4 Monte Carlo simulations confirmed that experimental data aligns with theoretical predictions. Uptake efficiencies measured by alpha spectroscopy align with that measured by gamma spectroscopy, confirming alpha-emission spectra results in anticipation of studies comparing other parameters of various cell lines. The BAD alpha spectroscopy technique is a novel tool for examining the behaviour of 225Ac radionuclides in live cancer cells in vitro. The possibility of accurately and quantitatively measuring alpha radiation deposited in biological samples is promising for furthering development of radiopharmaceuticals for TAT.

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Escape from a Fluctuating Barrier

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This study investigates the diffusive dynamics of particles in one-dimensional systems, progressing from free Brownian motion to barrier-crossing processes. We numerically model particles undergoing stochastic motion. The dynamics are influenced by thermal noise and viscous drag, confined within reflecting and absorbing boundaries. Our symmetric system is subject to a static, sinusoidal potential barrier that opposes particle motion toward the absorbing boundary. As predicted by Kramers' theory, the mean first passage time (MFPT) exhibits an exponential dependence on barrier height. Introducing a periodic modulation of the barrier height affords us the ability to study stochastic resonance and its influence on MFPT behaviour of the system.

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Straining of Transition Metal Dichalcogenide Monolayers Using an Atomic Force Microscope

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Transition-metal dichalcogenide (TMDC) monolayers have been recognized as a candidate material for quantum technologies due to their unique optical and electronic properties. TMDC monolayers are two-dimensional semiconductor materials consisting of a transition metal atom covalently bonded with two chalcogen atoms. While bulk samples of TMDCs are indirect bandgap semiconductors, their monolayers possess a direct bandgap. Direct bandgaps allow for efficient absorption and emission of light, which is necessary for optoelectronic devices. Strain fields can be applied to TMDC monolayers to create quantum emitters, which are nanoscale devices that confine excitons, enabling the controlled emission of single photons. An atomic force microscope (AFM) can be used to indent the monolayers, inducing the localized strain necessary to decrease the bandgap of the monolayers and form quantum emitters. We have fabricated tungsten diselenide (WSe2) monolayers by mechanical exfoliation, employing a similar method as that which is used to create graphene. Atomic force microscopy will be used to confirm regions of monolayers before they are deposited onto PMMA-coated silicon dioxide substrates. These samples will then be indented by the sharp tip of the AFM probe to create strain-localized single-photon emission centers in the WSe2 monolayers. TMDC monolayers are one of the solid-state quantum emitter systems which are studied at Dalhousie's lab in an effort to optimize quantum light sources, which lay the foundation for many areas of quantum information such as distributed quantum networks and quantum key distribution.

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Outflow Acceleration and Variability in SDSS J024221.87+004912.6

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Quasars are supermassive black holes at the centers of galaxies that accrete matter through an accretion disk and simultaneously produce powerful outflows by ejecting matter from the disk's surface. Some outflows are observed in quasar spectra as broad absorption line (BAL) troughs. BALs are variable across quasar rest-frame timescales ranging from days to years. Most variability results from changes in strength and profile shape, but can also result from acceleration/deceleration of BAL outflow material. Quasar SDSS J024221.87+004912.6 (hereafter J0242) exhibits an accelerating BAL outflow seen in 13 spectra over 6.9 years in the quasar rest-frame, from the Sloan Digital Sky Survey and the Dark Energy Spectroscopic Instrument. We extend the research of J0242 by measuring the stability of the acceleration and studying a remarkable feature in the latest spectra: a re-strengthening of a component of the outflow at close to its original velocity. The small shift in that component's velocity may indicate a new episode of acceleration beginning in this quasar. We investigate this outflow variability and compare our measurements with predictions of various models to determine which best describes the observed behaviour. We also analyze J0242's optical variability on timescales of decades using photometric data obtained from several different surveys.

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Ghost Nebulae of the Triangulum Galaxy: Studying He II, O III and Hα Emission from Nebulae without Detected Ionizing Sources

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Ionized nebulae are a key laboratory for understanding stellar evolution and the properties of the interstellar medium. A new class of nebulae, however, have been found to exhibit extended ionized emission line regions, yet do not appear to be associated with any known source of ionizing radiation. Two of these objects, HBW673 and BCLMP651 in the nearby Triangulum galaxy (M33), exhibit particularly strong He II 4686Å emission, associated with ionization by very hot and luminous objects. This may point to a rare phenomenon of photoionization caused by supersoft X-ray sources (SSS) or a long-gone fossil x-ray nebula. Using the University of Manitoba's Glenlea Observatory, our goal is to record the surface brightness of both targets using a He II 4686Å filter. Therefore, we will be able to compare the surface brightnesses with CAL83, the only known nebula that indicates ionization by SSS. Additionally, we plan to apply an upper x-ray constraint from different x-ray catalogues, such as XMM-Newton, of HBW673 and BCLMP651 to pick up low-emitting x-ray sources to further confirm that the emission is caused by SSS. Lastly, we aim to use the line flux ratios derived using the photoionization code Cloudy, to determine the best fitting model for the photoionization source. Time permitting, we will also be able to identify the elapsed time since the photoionized source has shut off to reveal if the mystery behind these "ghost" nebulae may actually indicate a fossil x-ray nebula.

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Development of Colorimetric Analysis Software for 2.2.2-Kryptofix Compliance Testing in [^{18}F]FDG Production

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[^{18}F]fluorodeoxyglucose ([^{18}F]FDG) is a glucose analog where the hydroxyl group in the C-2 position is substituted by the [^{18}F] radionuclide. This radiopharmaceutical is used in medical imaging, particularly in positron emission tomography (PET) scans for cancer diagnoses and monitoring. ^{18}F-FDG synthesis involves a nucleophilic substitution with 2.2.2-Kryptofix as a phase-transfer catalyst. Kryptofix residue quantities must be strictly regulated due to their toxicity. Current quality control processes employ spot testing where sample colours are compared to that of a standard, which is prepared at maximal Kryptofix concentration of 0.5mg/V. This comparison provides a rapid qualitative measure to determine if residues fall within regulatory parameters. To limit the subjectivity of human analysis, a user-friendly Python interface was built using the Tkinter library. The interface employs colorimetric analysis by quantifying pixel intensity and performing statistical comparisons on user-defined sections of the image. The software determines whether samples fall within safety limits for Kryptofix concentration. The system generates analytical reports required for regulatory compliance and quality assurance to be used in cases of test deviations. Software validation was performed using images of known sample concentrations and objective intensity differences. In a pilot study of 6 images with 45 distinct segmentations, the software successfully identified compliant and non-compliant samples in 41 instances. 7 segmentations yielded inconclusive results when pixel intensity differences were within 5 units, highlighting the necessity of standardized lighting and image acquisition conditions. Despite these limitations, the software generates necessary documentation for regulatory compliance and quality assurance.

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Radiation Effects on Qubits at the CUTE Facility

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Qubits with long coherence times are essential for quantum technologies and superconducting qubits. Over the past two decades, their coherence times improved, from less than 1 ns to over 100 µs, through constant improvements in design, materials, and fabrication. However, a key limitation could come from high-energy ionizing radiation, especially cosmic rays, which generate quasiparticle bursts in the superconducting aluminium resonators, degrading coherence. Previous experiments showed that cosmic rays produce excess quasiparticles, but these were done at ground level with only partial shielding using lead. To further investigate this, the Institute of Quantum Computing at Waterloo, SNOLAB, and Chalmer's University in Sweden extend this work to a deep-underground environment where cosmic-rays are suppressed by six orders of magnitude. The experiment is conducted 2 km underground at SNOLAB's Cryogenic Underground TEsting (CUTE) facility, where superconducting qubits are housed in a dilution refrigerator. At such depths, the dominant radiation source arises from neutrons produced by spontaneous fission of Uranium and (alpha,n) reactions, and gamma radiation in the surrounding underground rock and shotcrete from walls. Although the CUTE's fridge is protected by layers of lead and ultra-pure water, which effectively attenuate gamma rays and neutrons, a small fraction of these particles can still penetrate the shielding. To estimate the remaining background radiation at SNOLAB and inside the CUTE setup, simulations of neutron production and transport are performed using GEANT4 and Sources4C. This talk will introduce the CUTE design, previous work, current status, and plans for the QUBIT project.

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Kids are Alright: Investigating Star Formation Drivers via Age and Velocity Gradients in Young Stellar Populations

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Stars form within molecular clouds. Once born, they inject energy and momentum into their environment through winds, ionizing radiation, and eventually supernovae. This stellar feedback disrupts the parent cloud and can trigger further episodes of star formation in nearby gas. This process is known as sequential star formation. Several mechanisms have been proposed to drive star formation within a molecular cloud, including feedback from massive stars or cloud collisions. Previous analyses have shown that age and velocity gradients within a single association can indicate the history of star formation and feedback in that region. Yet, it remains unclear whether the observed patterns are unique to individual environments or reflect universal processes. We aim to fill that gap. In this project, we use the SPYGLASS survey, a sample of 116 young stellar populations within ≈ 1kpc of the Sun, to search for systematic age gradient patterns across many associations. Using Gaia-based distances and photometry, we derive consistent age estimates for each population and compare them to their spatial and kinematic structure. In my talk, I will introduce sequential star formation and explain why age and velocity gradients are powerful tools for studying it. I will then describe our method for measuring ages in SPYGLASS populations and show early results on where gradients appear. Finally, I will discuss how this work can help distinguish between proposed drivers of star formation and outline next steps.

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Helmholtz Cage for CubeSat Magnetic Testing

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Satellites rely on magnetic fields to perform detumbling, attitude determination, and pointing so they can achieve mission requirements. These tasks use devices such as magnetometers and magnetorquers, which measure and produce magnetic fields. Magnetic testing is crucial to ensure these devices meet performance requirements despite external disturbances such as the satellite's intrinsic dipole moment. Simulating the magnetic field a CubeSat would experience in orbit will enable the verification and validation of our CubeSat requirements and ensure spaceflight readiness. Our team is designing and building a 3-axis Helmholtz cage to simulate orbital magnetic field conditions. This process involved deriving apparatus design requirements from satellite performance requirements, simulating magnetic field behaviour, and optimizing design parameters. Several challenges were considered, particularly the impact of mutual inductance between coils and the variability of environmental conditions. Considerations of ambient magnetic fields from the environment and the device under test show that open-loop control cannot ensure field accuracy. As a result, magnetometer-based closed-loop feedback is necessary to achieve reliable field regulation. The Helmholtz cage will operate within an anechoic chamber which will shield half the Earth's magnetic field strength, resulting in a target maximum field strength of 1 Gauss. To optimize spatial efficiency while accounting for manufacturing constraints, the Helmholtz coils are square-shaped. The successful completion of this project will enable UBC Orbit to perform magnetic testing and ensure our CubeSat, ALEASAT, is spaceflight ready. Beyond ALEASAT, our Helmholtz cage will provide a versatile magnetic testing platform that can support future CubeSat missions.

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Probing Chiral Photochemistry of Amino Acids under Cryogenic Conditions

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The origin of biomolecular homochirality remains an open question in astrochemistry. One proposed mechanism is asymmetric photolysis driven by circularly polarized ultraviolet light (CPL) in star-forming regions, where scattering from aligned dust grains can generate strong CPL fields. To test this mechanism experimentally, we use matrix isolation spectroscopy, a powerful method for trapping molecules in cold, inert parahydrogen crystals, allowing us to investigate their behavior under cryogenic, astrochemically relevant conditions. Our group previously demonstrated asymmetric photolysis of leucine isolated in a parahydrogen matrix, observing a ~10% difference in their photolysis rate under left(L)- or right(R)-CPL. In this project, we extend this approach to valine to explore whether such asymmetry is molecule-specific or common across proteinogenic amino acids. Valine is co-deposited with parahydrogen gas at 4K to form a crystal analogous to cold interstellar ices. The samples are irradiated with 213 nm L- and R-CPL, and time-resolved infrared spectra are collected to monitor the decay of characteristic vibrational bands. From these measurements, we determined the asymmetric photolysis rate of valine. These results help assess whether CPL-drived photochemistry could serve as a plausible universal mechanism for generating the initial chiral imbalance found in meteoritic amino acids and, ultimately, in terrestrial biology.

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From the Margins to Momentum: A Story of Physics and Persistence

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As a young woman, I was interested in physics, however I was told by the science teachers in my high school: “You’re more suited for the arts.” And so I went to university as a theatre major in 2008. This began a journey of ups and downs, struggling with undiagnosed autism, burnout, and abuse that led to me dropping out and experiencing homelessness. Then I rediscovered my love of science which brought me to Carleton University, where I am in my third year of undergraduate studies at the age of 35 in Experimental Physics, as well as in their Science Communication Certificate program. In an effort to motivate and inspire other people with unusual pathways into science, I have created a website from which I share my story and my struggles (https://fromthemargins.ca/). I also use it as a science communication and education platform in which I endeavour to communicate complex scientific concepts in simple, creative metaphors, such as coffee to describe neutrino mass states and ice cream to describe quantum mechanics. I have also created an in-class card game that is currently being beta tested to teach students about interdisciplinary science problem-solving (such as colonizing Mars or building a space elevator) with a culminating science communication activity that I plan to host on my site once complete. I strive to make science fun and accessible for anyone and everyone.

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Laser Induced Fluorescence Helium Nanodroplet Spectroscopy of Tryptophan and its Water Complex

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Superfluid helium nanodroplets provide an ultracold, frictionless environment ideal for high-resolution spectroscopy of cold molecules and their complexes. This technique enables precise control over the number of dopants, making it particularly powerful for creating and probing small molecular complexes that are otherwise difficult to investigate. The rapid cooling inside the droplets can also stabilize unstable complex forms. In recent years, our group has employed this technique to investigate intermolecular interactions involving chiral molecules. Building on previous studies by Lindinger et al. (1999), our group investigates the laser-induced fluorescence (LIF) spectra of tryptophan molecules embedded in helium droplets. The droplet beam is produced via supersonic expansion of high-pressure, low temperature helium gas through a pinhole nozzle and subsequently doped target molecules by passing through sample cells containing vapors of the molecules. By adjusting the sample cell pressures and nozzle temperature, we can precisely control the cluster size. Fluorescence from the doped droplets is detected using a photomultiplier tube (PMT). Unlike most amino acids, tryptophan (Trp) possesses an unusually high fluorescence quantum yield, making it readily detectable by LIF. This property allows us to detect not only the previously reported fluorescence features, but also new lower-energy features at 34950-34970 cm^{-1} in He droplets. The comparison between isolated Trp and the Trp–water complex further demonstrates how water perturbs the electronic structure of Trp, giving rise to additional peaks. These results indicate the usefulness of helium nanodroplet spectroscopy for probing isolated biomolecular chromophores and their water complexes.

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Silicon Nitride Ring Resonator Biosensors for Detection of Human Immunoglobulin

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Silicon photonic biosensors offer high sensitivity, low detection limits, multiplexing capability, and CMOS compatibility, enabling precise, low-cost device fabrication. These features make them well suited for applications in healthcare, environmental monitoring, and food safety. Among waveguide configurations, microring resonators are advantageous because circulating light enhances light–matter interactions. Silicon nitride (Si_3N_4) waveguides further improve performance due to their ultra-low optical losses and wide transparency window. In this work, a 200 nm-thick Si_3N_4 microring resonator was used to detect human IgG. Gold nanoparticles (AuNPs) were spin-coated onto the microring to enable IgG capture at the sensor surface. After AuNP deposition (8% coverage), the quality factor decreased from 3.0(5)×104 to 1.5(5)×104 due to increased scattering loss. Despite this reduction, the sensor maintained acceptable performance, with a sensitivity of 0.37 nm/wt% NaCl. Sensor response was measured over time for varying human IgG concentrations. The lowest detectable concentration was 4.5 µg/mL. Equilibrium wavelength shifts were fitted using a Langmuir model, yielding a dissociation constant of Kd = 196 nM. Future work will focus on improving IgG binding affinity and surface functionalization to enable selective sensing.

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Hartree-Fock Study of Mixed-Stacking Graphene Multilayers

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Since superconducting phases have been discovered in rhombohedral trilayer graphene, crystalline graphene multilayers have been an emerging research topic. While there are many studies on rhombohedral (ABCABC...) and Bernal stacking (ABABAB...), mixed-stacking is a less-studied platform. In this work, we study mixed-stacking graphene using a self-consistent Hartree-Fock algorithm that incorporates both long-range and short-range interactions. After a quick introduction on the subject and the hopping terms used, I will be going over the different broken symmetries obtained in the phase diagram of ABCB, ABCAC and ABCBA stacking with varying electric field and doping level and their respective Fermi surfaces. Among those broken symmetries, we can observe half metals and quarter metals with intervalley coherent states or with spin and valley polarization. We can also observe that the addition of a Hund's coupling (capturing the effects of short-range interactions) favors spin polarization over valley polarization. Those results will be important to analyze future experimental work on these stackings.

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Encoding Memory in Crumpled Sheets

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When a thin Mylar sheet is repeatedly crumpled, it forms a disordered network of folds. In such disordered systems, the microstructure retains a memory of how it was shaped. To explore how memory is encoded in crumpled Mylar sheets, we use a strain cycling approach. The sheets are mounted in a two-dimensional rubber support and deformed using motorized translation stages, allowing us to apply controlled and repeatable strains. Using image subtraction, the changes in the fold structure can be tracked with each cycle. We find that the amount of change decreases over time, eventually reaching a stable fold configuration. Sheets exposed to larger deformations require more cycles to stabilize, suggesting that greater perturbations are more difficult for the sheet to remember. Additionally, using more complex strain patterns—such as alternating directions in a loop or in a uniaxial direction—significantly slows down the relaxation process. These results provide insight into the dynamics of structural relaxation in disordered media and offer a pathway for programming mechanical memory.

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Physics-Based Background Rejection for Pixelated X-Ray Measurements of Electron Precipitation

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Space weather is the time-varying state of the near-Earth space environment produced by solar-driven plasma and magnetic field interactions with Earth's magnetosphere, ionosphere, and thermosphere. An interesting aspect of space weather is how energetic electron precipitation from Earth's magnetosphere modifies atmospheric chemistry, potentially influencing atmospheric dynamics which impact weather and climate. Therefore, accurate quantification of electron precipitation is not only important for predicting space radiation, which is hazardous to satellites, but also for long-term climatological predictions. These precipitating electrons are commonly measured using particle detectors onboard satellites and high-altitude balloons. New-generation detectors measuring precipitating electrons are often contaminated by background galactic cosmic rays, which biases electron precipitation estimates. In this study, we use an X-Ray grading method applied in astrophysics to identify and discard background radiation events measured by pixelated particle detectors. In particular, the CHANDRA X-Ray telescope employs a 3x3 grid-based Advance Satellite for Cosmology and Astrophysics X-Ray grading method, which assigns detector measurements with a number from 0 to 7 based on hit shape. It separates tracks into grades characteristic of photon events, typical particle tracks, and cosmic rays based on the shape and energy deposited, additionally accounting for pixel charge leakage. This method was applied to measurements taken during the May 2024 geomagnetic superstorm, limiting contamination from background radiation in the electron X-Ray signals. Further development of the method can result in better design of physics-based particle identification for pixelated particle detectors being developed at the University of Alberta for flight on stratospheric balloons and Canadian CubeSats.

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Effective Field Theory Interpretation of Same-Sign WW Vector Boson Scattering with the ATLAS Experiment

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While the Standard Model (SM) of particle physics has been successful in describing known fundamental particles and interactions, it is incomplete. The amount of charge-parity (CP) violation predicted within the SM is insufficient to explain the observed matter-antimatter asymmetry in the Universe. Additionally, possible deviations in the self-interactions of electroweak bosons motivate the exploration of theoretical frameworks that extend the SM. Effective Field Theories (EFTs) provide model-independent approaches to capture effects of new physics by adding higher-dimensional operators to the SM Lagrangian. This talk will explore using data collected at Run 3 of the Large Hadron Collider at a centre-of-mass energy of 13.6 TeV to explore observables sensitive to effects of CP-odd EFT operators and study potential deviations from SM predictions using same-sign WW vector boson scattering.

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A Multi-Instrument Analysis of Stratospheric Water Vapour Mass after the Hunga Eruption

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The Hunga Tonga-Hunga Ha'apai (HTHH) underwater volcanic eruption in January 2022 injected 150 Tg of water vapour (H_2O) into the stratosphere. The stratosphere typically contains small amounts of H_2O, so this injection increased the total stratospheric H_2O mass by 10%, a value that is unprecedented since the beginning of the satellite record. Stratospheric H_2O is important to study as it is a greenhouse gas, with H_2O increases resulting in stratospheric cooling and tropospheric warming, and as it contributes to ozone depletion chemistry. Initial values of the H_2O mass increase are from observations made by the Microwave Limb Sounder (MLS) on Aura. The MLS stratospheric H_2O mass for the 3 years following the eruption is validated through comparison with observations from the Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III/ISS) and the Atmospheric Chemistry Experiment-Fourier Transform Spectrometer (ACE-FTS). The stratospheric H_2O masses observed by MLS and by ACE-FTS are in very good agreement, while SAGE III/ISS slightly underestimates the H_2O mass in the first year following the HTHH eruption. All three sets of observations show a relatively constant stratospheric H_2O mass anomaly of ~90 Tg throughout 2023, and a decreasing trend in the H_2O mass through 2024 and 2025. The stratospheric H_2O mass remains elevated by ~70 Tg in Jan 2025, 3 years after the eruption.

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Signed Graphs Exhibiting Perfect State Transfer Through Quantum Walk

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In a quantum system, information transmission can occur through a quantum walk, where a “walker” (the quantum state of a particle) transitions probabilistically between vertices in a graph. The transition probability depends on the likelihood of the quantum state’s wavefunction tunnelling from one potential well to the next, represented by signed numbers called edge weights. Superposition empowers the walker to occupy multiple vertices simultaneously, and interference from the wavefunction contributes to a given walk’s intricacies. Information can be transmitted between two vertices of a graph accurately in finite time through Perfect State Transfer (PST), or with high probability through Pretty Good State Transfer (PGST). In this project, we conduct a survey of structurally distinct and uniquely signed graphs that exhibit PST. The methodology involves generating all non-isomorphic graphs with a fixed number of nodes, applying all sign combinations to the edge weights, and analysing their impact. This survey returns graphs of both PST and PGST results, ranging in size from five to eight nodes. Findings with strong potential for future development in signed graph research include patterns of bipartite, tripartite, and complete graph structures. Interestingly, while many of these graphs share structural patterns, properties such as eigenvalue symmetry and time of state transfer do not unanimously characterize the results. Calculations in this process scale rapidly, hence a maximum of eight nodes were examined. This research provides the framework for the discovery of signed graph families, as well as providing insight into the conceptual understanding of signed graphs as a whole.

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How to Measure the Shortest Events Ever Created: Building a Frequency-Resolved Optical Gating Setup

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Superfluid helium-4 is a dense system of strongly interacting phonons, maxons and rotons. An area of active research in coherent control is the ultrafast cooling of hot roton pairs. This experimentation is extremely dependent on the temporal and spectral quality of the exciting and probing femtosecond pulses. Even modest levels of TOD, satellite pulses from imperfect compression, or residual spectral phase ripple can alter excitation pathways. Hence, being able to detect these imperfections before experimentation is crucial. This work details the design, alignment, and optimization of a second-harmonic generation Frequency Resolved Optical Gating (SHG FROG) setup to precisely characterize double and single kick femtosecond pulses. The system employs a Type-I nonlinear crystal operated under angular and spectral phase-matching conditions chosen to maximize bandwidth and minimize spatiotemporal coupling. By gating a pulse with a delayed replica of itself in the tuned crystal, a second-harmonic signal whose spectrum depends on the temporal overlap of the two pulses is created. Scanning across relative delays and recording the corresponding spectra, a two-dimensional spectrogram encoding the pulse intensity and phase is constructed. We also report the usage of the iterative reconstruction FROG retrieval algorithm to retrieve full field information. This diagnostic capability provides a critical foundation for future roton-control experiments, enabling precise verification of pulse-shape and improved understanding of pulse–roton interactions.

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Toward Chirp Modulation Stimulated Raman Scattering Microscopy of Stained Samples

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Fluorescence microscopy is a common imaging tool used to characterize a variety of samples; however, it is reliant on the contrast provided by added fluorophores. In some biological samples, such labels can not be added without the risk of tissue modification or are not able to be applied at all. In these cases, one can exploit the inherent chemical contrast within a sample. Coherent Raman Microscopy, including Coherent Raman Scattering (CARS) and Stimulated Raman Scattering (SRS) microscopies, provide label-free and chemical specific imaging modalities that use the Raman vibration of a target molecule for contrast. SRS microscopy is a powerful tool but is limited by non-Raman background signals due to other nonlinear photophysical processes such as cross-phase modulation and two-photon absorption that can dominate the signals of interest. These background signals are especially significant in stained samples that strongly absorb and fluoresce. We propose Chirp Modulation Stimulated Raman Scattering Microscopy (CM-SRS), a novel scheme, as a potential method to address this problem. Unlike previously used modalities, CM-SRS eliminates non-Raman background signals by modulating the sign of the relative chirp between Pump and Stokes laser pulses in a spectral focussing configuration. Here, we show preliminary results for the use of this promising new technique, showing that CM-SRS is a highly sensitive, chemical-specific, and background-free imaging modality. This lays the foundation for using this technique to extract new chemical-specific information from stained tissue samples.

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Time-Resolved THz Spectroscopy of Ultrafast Carrier Dynamics in Nanomaterials

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As the demand for smaller and faster technology increases, the need for a precise understanding of ultrafast (sub nanosecond) charge carrier dynamics in nanomaterials arises. Time-resolved terahertz spectroscopy (TRTS) is an experimental technique used to study ultrafast charge carrier dynamics in materials. By measuring the transient electric field of a terahertz (THz) pulse following optical excitation, this method provides a non-contact approach to probing conductivity, carrier scattering, and relaxation processes in semiconductors. Using a 1030 nm ytterbium-based ultrafast laser, we study transient conductivity dynamics of photoexcited carriers in SI-GaAs, and we observe a carrier mobility of 4000 cm^2/Vs. We are currently using TRTS to explore photoconductivity dynamics in nanostructured silicon-on-sapphire films made of two-dimensional silicon nanowire random fractal arrays.

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Slowing a Pulse of Light with Coupled RLC Circuits

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The idea of manipulating the speed of an electromagnetic pulse via wave interference was first proposed in the late 19th century. Since then, it has maintained widespread attention due to its potential for optimization of electromagnetic communications systems and enhanced calibration of laser systems. In the past few decades, many exotic materials and solid-state systems that can delay an electromagnetic pulse have been investigated, but classical systems have remained relatively unexplored despite their potential both in implementation and as simpler teaching tools. The fundamental underlying physics of most of these slow light systems involve a pulse delay caused by phase shifts applied to each constituent frequency component of a pulse which, when sharply varied, interfere in such a way that the peak of the pulse is shifted backward. This interference can be achieved with electromagnetically induced transparency (EIT), an originally quantum optical phenomenon. EIT arises when a driven damped oscillator is coherently coupled with a damped oscillator, meaning it can be observed within a classical circuit. Unfortunately, circuits contain unavoidable impedances which dissipate energy and diminish the slow light effect. These dissipations can be counteracted by adding a source of energy into the circuit in the form of gain. In this work, the theory behind classical gain-assisted EIT and its generation of slow light is presented. EIT behaviour is experimentally demonstrated with two coupled resistor, inductor, capacitor (RLC) circuits driven by microwave frequencies and a microwave pulse is sent across the circuit to demonstrate slow light.

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Background Magnetic Field Fluctuations Disrupting Ultracold Quantum Gas Experiments

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The purpose of this project is to measure background magnetic field fluctuation that is potentially disruptive to ultracold quantum gas experiments. The LeBlanc lab uses lasers to induce atomic transitions in Rubidium-87. However, the resonance frequency of Rubidium-87 changes with exposure to magnetic fields, making it challenging to induce intended transitions when unexpected background magnetic fields are present and fluctuating. The magnetic field survey project uses the Sparkfun Micro Magnetometer MMC5983MA and RedBoard Qwicc components to produce a setup that measures magnetic field for a predetermined run time without requiring wifi up to a frequency of 15Hz. After calibration the magnetometers can detect fluctuations with an error of 0.5-0.7 milligauss along three axes. Measurements have shown noise, drift, and jumps in the background magnetic field, with an average change per second of 1 milligauss, which is enough to disrupt experiments in the LeBlanc lab. Data collection is ongoing with plans to expand to other lab spaces and attempt to determine potential sources of background fluctuation.

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Dust on the Move: Changing-Reddening Quasar Candidates in the AWTQ Survey

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Quasars are extremely luminous active galactic nuclei powered by accretion onto supermassive black holes. Their light is often reddened by interstellar dust, small grains containing carbon, silicon, and other elements in their host galaxies, but we usually treat that reddening as fixed in time. The Again With The Quasars (AWTQ) survey revisits thousands of Sloan Digital Sky Survey quasars with new spectra from SDSS-V and Dark Energy Spectroscopic Instrument, together with long-term optical light curves. While searching the AWTQ sample for especially interesting objects, we identified a small set of changing-reddening quasars whose colours and brightness evolve together over only a few years in the quasar rest frame; which if proven to be changing-reddening quasars could be the first of their kind observed. The poster highlights several of these dramatic candidates. J1347 and J1504 show decreasing reddening and increasing flux, evolving from red, faint states to bluer, brighter ones. J1440, J1330, and J1556 instead show increasing reddening and decreasing flux, becoming redder and dimmer, with J1556 also potentially developing new broad absorption features from outflowing gas along our line of sight. Across the main candidates the broad emission lines remain similar while the continuum shape and optical colours shift, and the mid-infrared varies much less than the optical. Together, these objects provide vivid evidence that dust in quasars is not static, rearranging our view of active galactic nuclei on human timescales.

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The Role of Dark Matter in Galactic and Cosmological Structures

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Dark matter comprises approximately 85% of the matter in the universe, yet its nature remains unknown. Its existence is inferred through gravitational effects observed in large-scale structure formation, stellar motion, gravitational lensing, and galaxy distribution. It has been demonstrated by previous experiments that non-baryonic matter provides the additional gravitational influence required to account for observed stellar motion and galaxy clustering. This is far beyond what baryonic matter alone can explain. In this independent research study, I examined observational evidence for dark matter, and explored a theoretical approach to its detection in the solar system. In this proposed model, detection is done using CubeSats and quantum sensors which travel to space with solar sail technology instead of more orthodox methods where detection happens using large instruments on Earth. Although just a theoretical model, such approaches illustrate how emerging instrumentation could contribute to future experimental efforts. Advancing our understanding of dark matter has the potential to address key limitations of current physical theories, including the Standard Model. This knowledge can drive technological innovations in medicine, sensors, imaging, and related fields.

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DOROTHY: Stellar Catalogue for 12 Million DESI Milky Way Stars Derived Using a Machine

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We present the DESI Observations Revealing Origins of the Halo via Spectroscopy (DOROTHY) catalogue, which provides stellar parameters and nine chemical abundances for stars in DESI Data Release 2. Stellar labels are inferred using a fully connected deep neural network trained on high-resolution APOGEE DR17 measurements, enabling the transfer of precise spectroscopic information to the lower-resolution DESI spectra. The training sample consists of approximately 38,000 stars observed by both surveys with blue-arm signal-to-noise ratios greater than 20. The model takes as input robustly normalised DESI spectra and inverse variances, and outputs predictions and uncertainties for eleven parameters, including effective temperature, surface gravity, metallicity, and detailed chemical abundances. In the test set, we achieve mean absolute residuals below 0.05 dex for several elemental abundances, approximately 59 K for effective temperature, and 0.086 dex for surface gravity. The catalogue includes five quality flags to identify unreliable predictions; applying all flags yields a high-quality sample of approximately 6.4 million stars spanning metallicities from −2.2 to +0.4. In total, DOROTHY provides measurements and uncertainties for more than 12 million Milky Way stars, offering a powerful new resource for studies of Galactic chemical evolution, stellar populations, and the assembly history of the Galaxy.

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Single Crystal Synthesis of Magnetoplumbite-Type Lanthanide Aluminates: $CeMgAl_{11}O_{19}$ and $NdZnAl_{11}O_{19}$

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Geometrically frustrated magnets (GFMs) are of significant interest because their lattice geometry and competing interactions can prevent conventional magnetic order and potentially stabilize exotic magnetic ground states such as quantum spin liquids. Rare earth triangular lattice compounds are especially promising due to the presence of strong spin orbit coupling, which generates anisotropic interactions that may support these unconventional phases. $CeMgAl_{11}O_{19}$ and $NdZnAl_{11}O_{19}$ belong to a family of magnetoplumbite like materials where the rare earth ions occupy well defined two dimensional triangular sublattices, making them strong candidates for exploring frustrated magnetism. Both compounds were synthesized using solid state reaction methods starting from rare earth oxides and polyvinyl alcohol as a binder. Repeated grinding and high temperature sintering were carried out, and phase purity was tracked using powder X-ray diffraction (XRD). Following phase optimization, single crystal growth of $NdZnAl_{11}O_{19}$ was attempted using a floating zone furnace. Characterization revealed that the resulting crystal was zinc deficient, due to evaporation during growth, and powder XRD indicated that the majority of the crystal core was aluminum oxide, producing two simultaneous structural phases. Powder neutron diffraction measurements were performed to determine the structure of the zinc deficient material and to understand how cation loss influences the crystal lattice. Future work will focus on refining the growth conditions by incorporating a cold trap and reducing furnace power to improve stoichiometric control and mitigate zinc loss.

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Using the Terahertz Chemical Microscope to Study the High Sensitivity Detection of DNA

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The terahertz chemical microscope (TCM) provides a label-free approach for real-time monitoring of biochemical reactions through terahertz emission, particularly those with changes in electric potential. This study explores the application of the TCM for detecting DNA hybridization, a fundamental process in molecular biology. Using silicon-on-sapphire sensing plates, how variations in Tris, acetic acid, and magnesium (TAMg) buffer concentration, a buffer in which allows DNA hybridization to occur and variations in DNA concentration, influence terahertz signal response was investigated. Experiments were conducted across a range of buffer concentrations (0.1-1.5 times of 40mM Tris, 20mM acetic acid, and 12.5mM $MgCl_2$). Then, experiments continued with single-stranded DNA (ssDNA) concentrations from femtomolar to micromolar levels, followed by the introduction of complementary strands to initiate hybridization. Terahertz signals were recorded at each stage to establish calibration curves and assess system sensitivity. There is a strong dependence of terahertz signal on buffer composition, with increasing TAMg concentration correlating with enhanced signal amplitude and a saturation point. These observations confirm the role of ionic environments in modulating surface potentials on the sensing plate, a critical factor for optimizing detection conditions. However, within the tested range, the TCM system did not exhibit sufficient sensitivity to detect changes in DNA concentration or hybridization, likely due to the low molar range. Potential deterioration of the sensing plate was also possible. These findings suggest that higher DNA concentrations and optimized sensing plate conditions are required for effective calibration and kinetic analysis.

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Myelinated Axon Diameters in Mice Measured at Various Angle Orientations

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Neurons are specialized cells composed of axons. Axons propagate neuronal signals through the brain and are organized into fibre tracts. Postmortem studies suggest that changes in axon diameters and fibre tract densities change with various neurological conditions. Measuring axons diameters in vivo can provide insight into when and how axons change during disease development. A custom diffusion magnetic resonance imaging (MRI) model was developed to estimate axon diameters; overestimations occur in the model as measurements are taken in a single direction. The objective was to measure myelinated axon diameters at multiple angle orientations to determine if MRI measurement direction affects the axon diameters. The dataset consisted of ten 9.4 µmx5.5 µm electron microscopy (EM) images from three male and female mice. To estimate the diameters, a 0.77 µm, 20° and 90°, and a ± 45° grid was overlaid onto each EM image using ImageJ. If a grid line crossed a complete myelinated axon, a line was drawn overlaying the grid line to represent the diameter. This was repeated at each angle orientation of 0°, 90°, and ± 45°. The weighted mean diameters (AxD) were calculated for each angle. The male mice AxD ranged from 0.9 ± 0.1 µm to 1.3 ± 0.4 µm and the female mouse AxD ranged from 0.61 ± 0.03 µm to 0.9 ± 0.1 µm. Using a linear mixed model for statistical analysis showed no significant differences between the diameters at each angle, suggesting that MRI measurements can be made in any direction. Expanding the dataset to include a variety of mice is crucial for further development of the MRI model.

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The Hygroscopicity of Wildfire Smoke by Material

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The increase in wildfires in Canada has led to an abundance of smoke being released into the atmosphere. Smoke has negative effects on air quality and the climate via aerosol particles that can act as Cloud condensation nuclei (CCNs). CCNs are atmospheric aerosol particles that have the ability to turn into cloud droplets, and can play a significant role in the formation and properties of clouds. The formation of these particles and their full climate effects depend on size and hygroscopicity. This study examines the hygroscopicity of aerosol particles generated during the combustion of both inorganic and organic materials in a controlled laboratory setting. The data analyzed in this study are total particle concentration from a condensation particle counter (CPC), aerosol size distribution from a scanning mobility particle sizer (SMPS), and CCN concentration from a CCN Counter (CCNC). These were used to derive the hygroscopicity parameter (κ) by the κ-Köhler theory for each burn experiment, which indicates the ability of the smoke to turn into cloud droplets. By comparing κ values across material types, this analysis provides new insight into how differences in combustion influence CCN activity. This project contributes to a broader understanding of the role of wildfire emissions in cloud interactions and supports efforts to better represent the emissions in atmospheric processes and climate models.

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Radon Mitigation, Removal, and Testing at SNO+

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The SNO+ experiment, located two kilometers underground at SNOLAB, aims to study rare neutrino processes such as neutrinoless double beta decay. Achieving these physics goals requires ultra-low background conditions, making the control and removal of radon-222, a gaseous decay product in the uranium-238 chain, crucial. Radon and its progeny can introduce alpha and beta decays that mimic the signals expected from 0νββ events. This work presents ongoing efforts to quantify, mitigate, and remove radon backgrounds in the SNO+ detector environment through gas-phase radon assays and the development of zeolite-based trapping systems. A silver-exchanged ETS-10 zeolite was selected for its high adsorption efficiency and ability to trap noble gases at room temperature without cryogenic cooling. Experimental assays conducted with the SNO+ gas assay board demonstrated that baking the zeolite at 150 °C for 20 hours reduced emanation rates by 84%, significantly lowering radon release. Calibration and background assays further explored the trap's capacity under controlled conditions, with plans for higher-temperature calibration at 300 °C to refine performance evaluation. These results highlight the promise of zeolite traps as a practical, regenerable, and thermally stable method for radon mitigation within low-background neutrino experiments.

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Novel high-throughput method for the interpretation of LUNATIC FRINGE variants

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Spondylocostal Dysostosis Type III (SCD 3), the malformation of the vertebrae and ribs, is caused by the LFNG variants. However, these variants are of uncertain significance and make it difficult to treat each individual based on their genetic code. Can we use bacteria to screen for disease causing LFNG variants? If variants in LFNG are not selected against in bacteria then we should be able to screen for pathogenic LFNG variants in vitro. This is tested by plating WT LFNG and variants on plates with X-GAL alongside plates lacking X-GAL to observe colony growth and colour. We completed site-directed mutagenesis to produce our chosen variants which were then transformed into Mach 1 *E.coli* and cloned. A random colony from each plate was selected and its DNA was extracted following miniprep protocol. Extracted DNA was used for PCR and an Agarose gel was run to detect presence of LFNG. Based on growth observed on WT LFNG Agar plates containing X-GAL, we have concluded that X-GAL does not turn on the LFNG gene as hypothesized. The observation of blue colonies leaves room to further study TOPO-LFNG and its relation to the LacZ gene as the insertion of LFNG did not appear to interrupt the LacZ gene and its functionality as theorized. While this method could theoretically allow families to have greater informed consent during reproductive risk counseling if they harbour LFNG variants, more research is required to confirm the viability of this screening method for testing pathogenic LFNG variants.

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Enhancing Radiotherapy Response in Hypoxic Tumors Using a Combined Drug–Radiation Approach

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Hypoxia poses a fundamental problem in radiotherapy physics. When oxygen levels are low, the chemical fixation of radiation-induced DNA damage becomes less efficient, reducing the biological effect of a given physical dose. As a result, hypoxic tumour subregions behave as radioresistant “cold spots” that limit tumour control, even when overall dose delivery is adequate. This project examines a combined-modality strategy in which ionizing radiation is paired with a hypoxia-targeting drug tested by researchers at the BC Cancer Research Institute. The overarching goal is to determine whether altering microenvironmental oxygenation can enhance radiation effectiveness without escalating dose. Using both cell-culture systems and a mouse tumour model, we compare radiation-only versus drug-plus-radiation treatments. Quantitative markers of hypoxia, DNA damage, and survival fractions are measured in vitro to evaluate how the drug influences radiation response. In vivo experiments further assess how physical dose deposition interacts with dynamic changes in tumour oxygenation. Together, these data allow us to interpret treatment outcomes through a lens that links observed biological improvements to underlying physical interactions. Although still early-stage and not intended for clinical translation, our findings suggest that reducing hypoxic burden can meaningfully enhance the impact of ionizing radiation. This study demonstrates how modifying tumour microenvironmental conditions can complement traditional physics-based dose planning and highlights the growing role of combined-modality approaches within medical physics research.

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Using Deep Learning to Improve Low-dose CT Images

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Introduction. Photon-counting computed tomography (PCCT) detects individual X-ray photons which enables energy-specific images to be produced. This results in clearer images, improved tissue contrast, and better material identification than conventional CT. Conventional CT requires many X-ray views collectively delivering a substantial ionizing radiation dose to patients. In contrast, PCCT may produce clinically useful images using views, but this lowers spatial resolution and increases image noise. Objective. This project aims to improve the image quality of low-dose CT scans by using a machine learning model trained on PCCT images. Methods. Images of twelve different chicken drumsticks were acquired using a zinc telluride (CZT) photon counting detector (PCD) with 330 μm pixels, a 120kVp imaging beam, and a 1mA current. Images collected at six energy thresholds of 25keV, 33keV, 41keV, 50keV, 59keV, and 68keV were leveraged using a Denoising Convolution Autoencoder (DCAE). The model was trained using ground-truth images reconstructed from 360 projections and corresponding low-dose images reconstructed from 90 projections across all energy bins. Results. Preliminary results show that the average structural similarity index measure increased from 0.936 to 0.979 after processing with the model. Discussion. Image noise was reduced, but this improvement came at the expense of spatial resolution. This work shows that machine learning can be used to improve the image quality of low-dose PCCT. Future work will focus on refining the model to reduce resolution loss, exploring other models, and on comparing models trained on PCCT data with those trained on conventional CT data.

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Behaviour Of Sound Waves: Interference and Diffraction

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This project investigates the behavior of sound waves in cylindrical tubes through a series of controlled laboratory experiments designed to isolate and analyze acoustic phenomena. Initial work focused on characterizing resonance in both open-ended and closed-ended tubes. Using a speaker to generate sinusoidal signals and a microphone mounted on a probe rod, resonant frequencies were identified from amplitude–frequency graphs, and spatial mapping of the sound field allowed clear observation of displacement nodes, antinodes, and pressure distributions. These experiments established a baseline understanding of how boundary conditions and tube geometry govern standing wave formation. Building on these results, the next phase of the research will expand the experimental method beyond discrete resonant frequencies. The project will investigate sound wave behavior between resonant modes, focusing on gradual transitions, partial standing waves, and interference effects. Systematically varying tube length, diameter, and boundary configuration will allow for exploration of how waveforms evolve under constrained conditions. Additional experiments will introduce adjustable apertures, and varied experimental setups to study interference and diffraction patterns both inside the cylindrical tube and within alternative geometries such as cube shaped boxes. This methodical progression of experiments aims to provide a comprehensive picture of acoustic wave behavior in guided systems, with insights relevant to architectural acoustics, noise control engineering, musical instrument design, and the optimization of waveguides in communication systems.

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Exoplanet Transit Detection in TESS Derived Light Curves with Machine Learning

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The Transiting Exoplanet Survey Satellite (TESS) provides a vast collection of Full Frame Images (FFIs), offering a powerful resource for detecting new exoplanets through transit photometry. The idea behind this project is to take FFIs from Mikulski Archive for Space Telescopes (MAST) and transform them into light curves as input for a machine learning based pipeline to identify potential transit signals of exoplanets. After extracting flux values, each light curve is normalized to remove scale differences and highlight relative variations in brightness. Because normalization places all curves on a common amplitude range and time can be represented as a sequential index, the input data is essentially one dimensional and ideal for a convolutional neural network (CNN) as well as creating a much smaller amount of data to store. The 1D CNN utilized 30-minute cadence light curves, the training set including: confirmed TESS exoplanets (positives), confirmed eclipsing binaries (negatives), and confirmed false positives (negatives) such as instrumental noise for example. This combination allows the model not only to detect transit-like dips but also to distinguish them from common mimics. The goal of this work is to evaluate the effectiveness of 1D convolutional architectures for exoplanet detection directly from FFI derived light curves, and to assess whether a lightweight, normalized, time-indexed representation can reliably capture the signatures of planetary transits. This approach aims to support future large-scale, automated searches for exoplanets in TESS data and other upcoming survey missions as more and more data is released.

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Strong Bars, Strong Inflow: The Effect of Bar Strength on Gas Inflow

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Stellar bars are elongated structures in disk galaxies that can torque and funnel gas inward, influencing galaxy evolution. While strong bars are known to induce rapid inflow, the impact of weaker bars remains less certain. We collected spectroscopic data using the Isaac Newton Telescope to analyze 18 nearby galaxies (strongly barred, weakly barred, and unbarred) drawn from Galaxy Zoo DESI ($0.01 < z < 0.05$, $Mr < -18.96$). We obtained spatial profiles of equivalent width (EW) and ionized gas velocity dispersion by fitting Gaussian profiles to the Hω emission lines. Strongly barred galaxies exhibit a distinctive three-peaked EW[Hω] structure, with a central maximum and two smaller peaks near the bar ends, consistent with inward funnelling of gas. Weakly barred systems lack this pattern, which suggests limited inflow. Velocity dispersion distributions further distinguish the bar types, with strongly barred galaxies showing significantly higher values than weakly barred and unbarred systems. These results suggest that strong bars drive gas inflow, while weak bars exert a limited dynamical influence and occupy an intermediate state. In this talk, I will introduce the physics of bar-driven gas inflow, outline our methods, present these results, and discuss how bar strength regulates gas inflow, central star formation, and the secular evolution of disk galaxies.

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Analysis of Central Diffraction with the CMS-TOTEM Precision Proton Spectrometer

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Central diffraction in proton–proton collisions arises when the incoming protons exchange colour-neutral objects, producing a centrally located hadronic system, while both protons remain intact in the final state. Several theoretical models have been proposed to describe this process, each predicting different central-exclusive and central-dissociative cross-sections. Despite its importance for understanding non-perturbative QCD dynamics, no measurement of central diffraction has previously been made at LHC energies. This project presents an analysis of central diffractive events using data from the CMS–TOTEM Precision Proton Spectrometer (PPS). By tagging forward protons and reconstructing their time-of-arrival in the PPS timing detectors, we determine the longitudinal vertex position with O(mm) precision and correlate it with the primary CMS vertex. This enables the isolation of exclusive and semi-exclusive diffractive topologies from pileup and non-diffractive backgrounds. The analysis studies kinematic distributions in both data and Monte Carlo simulation, and employs a series of data-driven background estimation techniques—including timing-vertex correlations, sideband subtraction in Δz, and an event-mixing framework to model uncorrelated backgrounds. We report one of the first measurements of the central-diffraction cross-section at LHC energies: $\sigma = 0.063 \pm 0.002$ (stat) $\pm$ 0.007 (syst) $\pm$ 0.008 (theory) mb. These results provide valuable constraints on poorly modelled pomeron-mediated interactions, offering new insight into diffractive dynamics in the non-perturbative regime and establishing a framework for future precision studies with improved timing detectors.

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Developing a Scalable Multi-Channel Readout System for Directional Sensitivity of the NEWS-G Dark Matter Experiment

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The New Experiments With Spheres-Gas (NEWS-G) uses spherical proportional counters filled with a light noble gas mixture to directly detect light dark matter particles. The detector consists of a large sphere equipped with a high-voltage 11-anode sensor, “ACHINOS”, which detects electrons from ionizing radiation. The current electronic setup limits the readout to two channels, grouping the five top anodes and six bottom anodes into north and south channels, respectively. Independent readout of the 11 anodes would enable directional sensitivity in the NEWS-G detector, a key capability for discriminating dark matter signals from solar neutrino backgrounds. To this end, a new scalable low-noise charge-sensitive preamplifier has been developed at the University of Alberta and tested with a small-scale NEWS-G detector in the Piro Lab. Preliminary results show an improved event selection and promise for future multi-anode scalability. These results also provide quantitative feedback for hardware refinement and establish analysis tools needed for scalable, multi-channel spherical proportional counter readout.

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Design and Implementation of a Shielded Cryogenic Enclosure and Circuit for SuperCDMS HVeV Detectors

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This project focuses on improving radiation shielding and circuit connections for SuperCDMS HVeV dark matter detectors, which use superconducting silicon crystals to measure phonons generated by potential dark matter interactions . In current experiments, these detectors are mounted in copper holders with readout cables connected to custom PCBs and placed inside helium dilution refrigerators, where they are cooled to several millikelvin. The resulting voltage pulses from the circuit are amplified by SQUIDs and used to extract particle threshold information and event data. Experiments at facilities such as NEXUS at Fermilab and the CUTE facility at SNOLAB have shown that further minimizing detector radiation exposure is essential for dark matter investigation, while also highlighting the challenges and costs of relying on specialized underground laboratories. Establishing a functional setup in a university laboratory would therefore support detector development efforts. The objective is to design, machine, and test a copper shielding and PCB system that encloses the SuperCDMS payload in the new helium fridge at the University of Toronto. The initial focus is adapting the shielding design used in the Low Energy Excess investigation at CUTE to this new environment, followed by improvements that enhance thermal noise reduction, increase detector capacity, and minimize resistance within the readout circuit.

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A Modulation-Free Laser Frequency Stabilization System using an Acousto-Optic Modulator for Atomic Physics Experiments

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The most common technique for laser frequency stabilization involves frequency modulation of the light source and a lock-in amplifier. We use a modulation-free technique that utilizes Acousto-Optic Modulators (AOMs) to stabilize the frequency of homebuilt diode laser operating at 780 nm, suitable for ongoing experiments, namely, atom interferometry, measurements of diffusion, and determination of excited state lifetimes. This feedback loop requires an AOM and a saturated absorption spectrometer with a rubidium vapor cell in a side-arm. The absorption of a weak, linearly polarized probe laser is monitored in the presence of a strong counterpropagating pump laser. The radiofrequency (RF) oscillator driving the AOM is modulated, resulting in a modulated saturated absorption spectrum recorded on a photodiode. By high passing the photodiode signal and mixing it down to DC with the modulation, we generate a dispersion-shaped error signal which stabilizes the laser frequency. Our system relies on homebuilt electronic circuits and avoids expensive commercial lock-in amplifiers. Laser frequency stability is ideally determined by beating two independent locked lasers at slightly different frequencies and measuring the Allan deviation (AD) of the beat note. Instead, we measure the Allan deviation of the AOM stabilized laser by recording the error signal voltage as a function of time. Our results, which are affected by noise on various timescales, indicate an AD floor of ~ 2x10-11 and lock durations of ~ 2 hours. We investigate improvements associated with the reduction of electronic noise.

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Evaluating and Automating Denoising Algorithms for Diffusion MRI Tractography in Depression Research

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Diffusion MRI tractography is a powerful tool for investigating white matter microstructure, with growing relevance in clinical studies of psychiatric disorders like depression. However, variability in image noise levels can distort connectivity estimates and downstream analyses. This project explores and compares the performance of several denoising algorithms (NLMeans, MPPCA, LPCA, and Patch2Self) on multi-shell diffusion MRI data from a large, multi-site depression cohort. Signal-to-noise ratios (SNR) are estimated within anatomically defined white matter regions derived from FreeSurfer's wmparc segmentation. To support reproducible, large-scale analyses, fully automated preprocessing workflows are being developed in Bash and Python. Aspects of this pipeline perform BIDS-compliant reorganization of raw data across sites, artifact correction, and data analysis. Automated logging tracks subject mapping and missing data, facilitating rapid quality control. Initial results suggest that NLMeans may offer greater SNR gains while preserving anatomical detail compared to other methods. Ongoing work will quantify these effects statistically and examine their impact on downstream connectivity measures. Early experience with the automation framework indicates a marked reduction in manual preprocessing steps, supporting reproducibility across hundreds of subjects. This work seeks to inform best practices for robust and reproducible denoising and tractography.

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Magnetic Restructuring of Ferrofluid Droplet Rafts

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We produce a 2D raft of ferrofluid droplets at a curved meniscus. These droplets have a short-range attraction to each other as well as a gravitational attraction to the centre of the meniscus. When a magnetic field is applied to the cluster, the dipoles in the ferrofluid align and the droplets experience a long-range repulsion. When the long-range magnetic force overcomes the short-range attractive force between the droplets, there is a rapid separation between droplets in the cluster. Such a rapid change does not happen as the magnetic field is ramped down. Here we exploit the asymmetry in the forces to study how clusters find more stable states. We start the droplets in an unstable state. We then cycle the magnetic field and track the droplet trajectories and find that the clusters relax to a stable configuration. This study illustrates how even simple cyclic forcing can steer complex, interacting systems toward states of higher symmetry and stability.

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Single Pulse RRAT Timing

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On behalf of the CHIME collaboration

Pulsars are a type of neutron star that have very short rotational periods and are highly magnetized, resulting in twin beams of electromagnetic radiation being emitted from the magnetic poles. There is usually a misalignment between the magnetic and spin axis that results in the emitted radiation rotating around the spin axis. Observatories on Earth can detect pulsars that are oriented such that the beam hits Earth at some point in its rotation around the spin axis. Rotating radio transients (RRATs) are a type of pulsar that do not regularly emit pulses with each rotation (a phenomenon called nulling), and can only be observed by single pulses. This is in contrast to the usual method of pulsar observation, called folding, where a pulsar observation is stacked upon itself at the period of the pulsar. RRATs can only be observed by single pulses because of their irregularity and the often long times between pulses. In 2018, seven galactic pulsars were discovered by the CHIME collaboration, of which four are likely RRATs. Updated timing solutions were found for three of the four RRATs. Furthermore, for the pulsar J0121+53, two methods of generating the times of arrival (TOAs) of pulses were used, and the resulting fit parameters were compared. Both methods produced similar timing solutions, but the updated approach provided more reasonable uncertainties. Further research is required to determine if the updated method is viable for timing other RRATs.

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Probing the Origins of Fast Radio Bursts Through Counterpart Cross-matching

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On behalf of the CHIME collaboration

Fast Radio Bursts (FRBs) are very energetic ~millisecond duration bursts of radio emission with extragalactic origins that were discovered nearly 19 years ago. While there is some evidence suggesting FRBs may originate from magnetars, their progenitors are still largely unknown. One potential method to find evidence for an FRB progenitor is to cross-match the localization and date of an FRB with a different transient with a known progenitor. In this work, I used the Canadian Hydrogen Intensity Mapping Experiment (CHIME) to automatically cross-match all FRB candidates with gamma-ray bursts (GRBs) and gravitational waves (GWs). In this talk I will first introduce FRBs and the CHIME experiment. I will then introduce other transients and their progenitors, specifically focusing on gamma-ray bursts (GRBs) and gravitational wave (GW) events. Next, I will introduce the purpose of conducting the cross-matching and the potential results of an astrophysical coincidence. After that I will discuss the cross-matching pipeline that I developed using GRBs and GW events detected by the Swift observatory, Fermi telescope, and Ligo-Virgo-Kagra (LVK) collaboration, reported to us through NASA's General Coordinates Network Kafka service (GCN). Finally, I will discuss how I developed the alert system that incorporates all of these aspects and is now running automatically through CHIME.

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Synthesis and Characterization of Quantum Spin Liquid Candidate $Ba_9Yb_2Si_6O_{24}$

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On behalf of the McMaster-CNL collaboration

The search for exotic magnetic states, such as the quantum spin liquid (QSL) state, is a key area of interest in the field of condensed matter physics. In a QSL, the spins of atoms are highly entangled and disordered, leading to spin fluctuations that persist even at absolute zero temperature. One promising route to a QSL involves geometrical frustration, where lattice geometry prevents spins from settling into a single-favoured orientation. Rare-earth-based honeycomb-lattice materials are promising candidates for QSLs, since their geometry helps avoid magnetic order. This project aimed to synthesize the honeycomb-lattice material $Ba_9Yb_2Si_6O_{24}$ in polycrystalline and single crystal form and determine if its properties are consistent with a QSL. To synthesize $Ba_9Yb_2Si_6O_{24}$ in polycrystalline form, we pressed starting materials into a rod for it to be reacted in a furnace. Powder X-ray diffraction confirmed the formation of the desired material. We took magnetic susceptibility measurements in a temperature range of 0.5 K to 350 K, and the lack of sharp features in the susceptibility data indicates the absence of magnetic ordering, which is consistent with QSL properties. We also conducted μSR measurements at TRIUMF, and the zero-field measurements indicate that fluctuations in the moment persist even at the lowest measured temperature of 0.03 K. This finding further supports $Ba_9Yb_2Si_6O_{24}$ as a QSL candidate. In order to synthesize single crystals, we employed the floating zone image furnace technique, however, phase-pure single crystals were not achieved. Future work will involve additional single crystal synthesis methods, such as flux growth.

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Functional MRI Signal complexity in Temporal Lobe Epilepsy

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Temporal lobe epilepsy (TLE) is the most common form of epilepsy in adults, characterized by seizures originating in the temporal lobe. Accurate diagnosis is challenging, as many disorders mimic epileptic seizures, and routine magnetic resonance imaging (MRI) scans and electroencephalograms (EEG) often appear completely normal in TLE patients. Resting-state functional MRI (rs-fMRI) may offer a promising alternative. This technique measures low-frequency fluctuations in blood oxygenation associated with neutral neural activity. The complexity of rs-fMRI signals reflects local dynamics of brain activity, and analysis of this complexity, quantified by the Hurst exponent, has shown utility in identifying and classifying certain neurological disorders. This study evaluated whether a similar analytical approach would be of diagnostic value for TLE patients. High-resolution T1-weighted 3D structural images and rs-fMRI data from 38 individuals with TLE (24.6 ± 4.0 years old) and 38 age- and sex-matched healthy controls (24.6 ± 4.1 years old) were obtained from the Epilepsy Connectome Project. Rs-fMRI data were preprocessed in FSL, and Hurst exponent was computed voxel-wise in grey matter using rescaled range analysis. Group differences were assessed with voxel-wise and regional linear mixed-effects models. TLE patients exhibited significantly ($p < 0.05$) reduced rs-fMRI signal complexity in temporal lobe regions, including the fusiform gyrus, parahippocampal gyrus, and amygdala. These findings suggest that complexity analysis captures functionally relevant and spatially specific rs-fMRI signal alterations in TLE. This approach may represent a novel, noninvasive biomarker for TLE diagnosis, particularly when conventional imaging appears normal.

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Towards an Improved Monte Carlo Simulator for Increased Accuracy in Axon Diameter Measurements

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Diffusion magnetic resonance imaging (diffusion MRI) offers a non-invasive technique for studying axon microstructure in people with neurodegenerative diseases such as multiple sclerosis. Unlike post-mortem electron microscopy, diffusion MRI enables estimation of axon diameters and longitudinal assessment of axon integrity in living people. However, current models rely on accuracy limiting assumptions — such as membrane impermeability and idealized cell geometries — leading to uncertainty in signal interpretation. This study aims to develop a Monte Carlo diffusion MRI simulator capable of modelling water diffusion and spin dynamics under biologically realistic conditions. A GPU-enabled Python framework was built to support multiple cellular geometries with adjustable boundary permeabilities. Complex environments featuring latticed cylinders or spheres could be created, with the ability to introduce nested membranous structures and intracellular compartments. Water molecules within the simulation underwent 3D Brownian motion and were paired with evolving magnetization vectors. Multiple gradient waveforms were supported, including oscillating gradient spin echo (OGSE) sequences. Initial results demonstrated valid diffusion mechanics and support for geometrically complex simulations. This work demonstrates an extensible, GPU-accelerated Monte Carlo simulator for modeling diffusion MRI in complex biological environments. Future work includes fitting simulated signals to estimate axon diameters and validating outputs against diffusion MRI and electron microscopy data of mouse models. Planned extensions include mesh-based geometries for greater complexity and refinement of fit models based on novel diffusion metrics from experimental data. This work shows potential for validating diffusion encoding schemes and developing improved physiological models for diffusion MRI signal interpretation.

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Generation and Application of Structured Neutrons

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Neutrons are invaluable tools for non-destructive material analysis and experiments in fundamental physics. As charge-less, magnetically sensitive particles with nanometer wavelengths, they interact directly with atomic nuclei, providing high material penetrability and isotope sensitivity. To refine the neutron as a high-precision quantum probe, it is possible to endow the neutron with additional quantum degrees of freedom by structuring the neutron wavefunction. While it is straightforward to shape light and electrons, neutrons are challenging due to their refractive index being extremely close to unity, making conventional neutron lenses impractical. However, recent advances in nano-fabrication have opened new opportunities for a holographic approach to neutron shaping. By fabricating microscopic silicon diffraction gratings, we can imprint specific phase profiles onto the wavefunctions to map the spatial profiles in the far field. In this presentation, we demonstrate how we utilize the neutron's degrees of freedom using these holographic techniques. We demonstrate neutron Orbital Angular Momentum (OAM), which has potential applications in quantum information processing, and magnetic material characterization. Furthermore, we explore the generation of neutron Airy beams, which have properties of self-acceleration, non-diffraction, and self-healing. These beams have applications ranging from neutron imaging to defining quantum gravitational energy states in the search for dark energy and dark matter. Finally, we present the development of modified Fresnel Zone Plates (FZPs) as a pragmatic alternative to conventional lenses. The modified FZPs could enhance neutron shaping techniques by increasing efficiency and resolution, thus advancing neutron diffractive optics.

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Beyond the Standard Model: The Search for Vector-Like Leptons

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The Standard Model of particle physics (SM), despite its success in describing elementary particles and their interactions, fails to account for several observed phenomena, such as the universe's baryon asymmetry. Vector-like leptons (VLLs), whose left- and right-handed components transform identically under the gauge groups, constitute a possible extension of the Standard Model. They offer potential solutions to open problems, and arise in grand unified theories. Searches performed by the ATLAS experiment have already excluded vector-like muon singlets up to masses of about 400 GeV. To probe higher mass regions, more sensitive methods for identifying VLLs in the ATLAS detector data are necessary due to their low production cross-section. To search for high-mass vector-like muons in four-lepton final states, we developed a deep neural network (DNN) to classify events into signal and control regions, and extracted exclusion limits using a profile-likelihood fit. We observe little to no improvement so far compared to the latest ATLAS searches. The network mainly learned the bulk behavior of the Standard Model, while the true discriminating power lies in outlier events within the Standard Model, which partially overlap with the signal. Therefore, identifying these outliers and constructing physics-motivated variables is essential to improving sensitivity to VLLs using a DNN. Incorporating complex kinematic information related to the decay topology as input features is a promising approach, as it provides strong separation between signal and the outliers in our signal regions. These conclusions provide direct guidance for future ATLAS efforts in Run 3.

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Resistance Growth in Iron and Manganese Based Positive Electrode Materials for Lithium-Ion Batteries

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The need for environmentally friendly energy storage and electric vehicles is increasing and so is the need to develop lithium-ion battery materials with low cost and abundant materials. Electric vehicles typically use $LiNi_xMn_yCo1_{-x-y}O_2$ (NMC) batteries, or $LiFePO_4$ (LFP) batteries. NMC batteries use expensive and scarce transition metals while LFP is a lower cost option but with inferior energy density. Improved energy density can be achieved by using the material $LiMn_xFe_{1-x}PO_4$(LMFP) which includes lithium, manganese, and iron. In this work, we set to identify the causes of resistance growth in LMFP batteries. $LiMn_{0.8}Fe_{0.2}PO_4$ artificial graphite pouch cells were formed and cycled for 0, 100, 200, 300 cycles and to 80% capacity (~500 cycles). Pouch cells were disassembled and constructed into symmetric cells containing two positive or two negative electrodes to isolate the cause of impedance growth to the positive or negative electrode. Electrochemical impedance spectroscopy (EIS) was run on these cells from −10 °C to 10 °C. As cycles increased, we noticed that the charge transfer resistance increases for the positive electrode but does not for the negative electrode. Next, we charged pouch cells to four different states of charge (SOC): 10%, 30%, 50%, and 90%. This gave us a broad range of points to collect data along the voltage vs. capacity curve of LMFP. This allows us to examine how the Jahn Teller distortion of Mn^{3+} may influence polarization growth. The result might suggest that lithium content is affecting the magnitude of charge transfer resistance.

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Specific and Sensitive Hemoglobin Quantification with Photovoltaic Devices

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Hemoglobin (Hb) is an iron-containing protein known for its primary function, to bind and release oxygen from the lung tissues into the bloodstream. Standard Hb sensing is performed using automated cell counters, specifically haematology analysers. This project proposes an alternative for Hb quantification by measuring the short circuit current generated by photovoltaic devices (PVDs) which work under the Photoelectric Effect. Source photons excite the electrons of the semiconductor producing diffusion of electron-hole pairs within the interface of the semiconductors, called the p-n junction, where current is then created. A series of experiments were performed to determine the sensitivity of the setup by following the decrease in short circuit current with the increase in Hb concentration. The sample was positioned on the surface of the PVD, that is, in between the photon source (RGB LEDs in this case) and the PVD. The setup was isolated from external light sources. To ensure specificity of the sensor to Hb, we will functionalize the substrate to bind only with Hb via a ligand. Results show the inverse relationship between the short-circuit current and pigment concentration in all PVDs tested. This work on specificity and sensitivity will serve as a base for a Hb sensing point-of-care PVD-based device.

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The Independence of AC Susceptibility from Frequency for the Magnetic Pyrochlore Oxide $Gd_2Ti_2O_7$

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Advances in probing magnetic monopoles in pyrochlore oxide materials using flux-noise analysis have shown this technique to be effective. Previous studies on spin-ice pyrochlores $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ have successfully detected deconfined, emergent magnetic monopoles using flux-noise spectroscopy. Emergence in condensed matter systems refers to collective behaviours such as superconductivity, magnetism, or fractionalized excitations arising from strong electron interactions. Magnetic excitations in spin-ice materials have been identified as deconfined magnetic monopoles. However, the method for detecting these monopoles lacks a control case confirming that, in materials where no monopole-like excitations are expected, flux-noise detection indeed shows no frequency-dependent signatures. Establishing this absence is essential for validating monopole identification in spin-ice systems. In this study, we show that the AC frequency using SQUID magnetometry for a pyrochlore oxide $Gd_2Ti_2O_7$ crystal produces no frequency dependence in magnetic susceptibility, particularly in the 40–500 mK range. $Gd_2Ti_2O_7$ is an antiferromagnet with isotropic Heisenberg spins, providing no opportunity for long-range magnetic ordering; therefore, no magnetic-monopole-resembling excitations will emerge or be detected. Measurements between 1–500 Hz show that the AC magnetic susceptibility converges with initial DC susceptibility values, agreeing with known magnetic phase transition temperatures of 0.75 K and 1.045 K reported in earlier literature. Overall, this study verifies that if no deconfined, emergent monopoles exist in a material, they will not be detected by any noise-based method as a function of the input field, providing a more solidified framework for probing emergent magnetic monopoles in pyrochlore oxide materials.

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Satellite Galaxy Quenching Across Cosmic Time

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The galaxies we perceive now are the result of billions of years of evolution that consequently affect their internal and external environments. These evolutions directly impact star formation within the galaxy and lead to "quenched galaxies" — galaxies that see a significant decrease in star formation rates. The question arises, what is the relation between the mass and environment of the galaxy and the rate of star formation across cosmic time? How does this quenching fraction evolve and can this relation be described and modelled? This project aims to answer this by examining galaxies found in the COSMOS-Web 2025 Catalog and using various statistical analysis methods, such as exploiting the bimodality of the switch between active star-forming galaxies to quenched galaxies, to determine the quenched point and the quenched fractions in various redshifts in relation to the mass of the galaxy. Finally, we examine how environment plays a role by comparing the quenched fraction between field and group galaxies. What we discover is that quenching decreases when redshift increases as expected and that we can describe the relation between quenching and mass as linear. As well, galaxies found in fields are likely to be more star-forming than their counterparts found in groups.

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Charged Pion Polarizability Reconstruction

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On behalf of the Charged Pion Polarizability collaboration

The strong force, responsible for holding quarks together within a hadron, is governed by the theory of quantum chromodynamics (QCD), examining how quarks and gluons interact. The theory is well understood at high energies; however, at low energies the theory remains unsolved. The polarizability is a fundamental property that measures the "stretchiness" of a hadron, a bundle of quarks, in electric and magnetic fields. Since polarizability directly measures the quark interactions, it gives significant information on the strong force and quantum chromodynamics at low energies. The pion polarizability is exceptionally difficult to measure due to the pion's extremely short decay time. There are few measurements for charged pions and those that exist have large uncertainties, which result in contradictory results. In the summer of 2022, an experiment was run with the GlueX detector in Hall D at Jefferson Lab in Virginia, where data was taken on pion runs using a linearly polarized photon beam on a Pb-208 target with additional multiwire proportional chambers for pion-muon sorting. This data analysis requires reconstruction software to sort event types as well as the use of neural nets and machine learning to sift through different data channels and extract pions. These measurements of polarizability will help with understanding the strong force within simple systems, and this can then be extrapolated and integrated into the theory of QCD at low energies which will provide a better understanding of matter and our universe.

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Of Dragons and Diffraction: A Defence of the Liberal Arts in a Physics Education

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The liberal arts are essential for a balanced and effective physics education at all levels of study. As physics curricula increasingly prioritize technical specialization, opportunities for engagement with philosophy, literature, and history are often overlooked, risking the cultivation of adept problem-solvers rather than reflective and innovative thinkers. This presentation argues that the integration of liberal arts into physics education is crucial for fostering critical thinking, scientific creativity, and a deeper understanding of the natural world. Through a literature review and comparative case studies of the educational backgrounds of Marie Curie, Grete Hermann, and Nicole Yunger Halpern, three extraordinary woman physicists, this presentation demonstrates how interdisciplinary learning and a broad education, contributed to their scientific insight, potential and field impact. These examples highlight how supporting a broad intellectual training has historically, and throughout modernity, empowered women to navigate and challenge scientific and access-based barriers in physics. The presentation argues that upholding space for the liberal arts in physics education is not only desirous but essential for empowering the next generation of innovative and creative thinkers. By introducing systematic and keyways that liberal arts can be reintroduced into education and offering suggestions on ways to support cross-disciplinary students, this presentation concludes with an outline for the pathway ahead and how a revolution in physics education can occur.

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Characterizing Rolling-Shutter Distortions in a 1U CubeSat Camera Using High-Speed LED Strobe Imaging

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This study characterizes the rolling shutter behaviour in the ArduCAM OV5642 sensor for the ALEASAT 1U (10cm x 10cm x 10cm) CubeSat, a student design team project with educational goals and a disaster monitoring-focused low-Earth orbit observation mission. Rolling shutter sensors acquire images by sequential row readout; therefore, relative motions between the spacecraft and target may introduce geometric distortion. This mission requires high spatial fidelity with affordable production costs; an assessment of this effect is therefore essential for establishing optimal exposure and sensor suitability. The characterization utilizes an LED strobe that produces periodic pulses across sensor rows, where images are captured over various exposure and pulse settings. A SciPy-based pipeline converts images to grayscale, meaning each pixel is stored as an intensity value rather than separate colour channels. It then computes row intensities to identify illuminated peak intervals, hence measures the rolling shutter progression. The results display well-defined bands with reproducible spacing across trials. We obtained identical linear relationships between pulse durations and peak intervals along various exposure settings, with an average of R^2 = 0. 999 135 ± 3. 18 ms . A readout time of was achieved. Collectively, these findings point to a stable, linear rolling shutter-readout behaviour. Future work will focus on simulating image acquisition under ALEASAT's expected orbital motion with obtained results. This predicts the viability of the OV5642, thereby motivating the development of potential deskewing algorithms. These results carry border implications for the fast-growing CubeSat sector, where accessible and reliable space instrumentation becomes increasingly important.

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Collagen Imaging Using Fluorescent Peptides

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Collagen is the major structural component of mammalian tissues and plays a critical role in cell proliferation, migration and differentiation. This unique triple-helical protein undergoes extensive remodeling during many life-threatening diseases including fibrosis, myocardial infarction, and cancer. Detection of excessive degradation of collagen is an important marker of tissue damage, which is essential to the diagnosis and treatment of disease. Conventional collagen detection and targeting tools are difficult to use; an alternative method of detection generating great interest is the use of Collagen Hybridizing Peptides (CHPs) which are fluorescently labelled peptides that detect damaged collagen. CHPs have a repeating Gly-X-Y sequence, the same motif found in natural collagen, which provides a strong affinity to hybridize with unfolded collagen chains. CHPs enable direct localization of collagen damage in tissues. However, much remains to be learned about the mechanisms by which these peptides interact with fibrillar collagen, as well as with gelatin networks. Here, our experiments with fluorescence microscopy demonstrate that CHPs have some affinity for collagen fibrils. They show the importance of the repeating Gly-X-Y sequence, through comparison with experiments using peptides with this sequence order scrambled. We are extending this work to quantify the binding of CHPs to gelatin networks, which contain much higher amounts of damaged collagen. These assays lay the groundwork for future experiments that provide additional insight into the binding mechanism of CHPs.

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Development of a Rubidium-Based Single-Photon Source for Quantum Networking

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The rapid development and potential commercialization of quantum computers poses a threat to modern cryptography, which relies heavily on the difficulty of prime factorization. As a consequence of this, quantum communication has been formulated as a 100% secure alternative, using photons to transmit information and atoms to store information. In particular, single photons serve as ideal carriers of information, since the no-cloning theorem ensures that any attempt to intercept them will be detectable. This project focuses on designing a tabletop experiment using a Rubidium vapour cell to generate single photons - the first of its kind at the University of Alberta - with the goal of eventually interfacing it with the Ultracold Lab quantum memory experiment. After reviewing previous literature, parameters were chosen for a configuration based on the DLCZ protocol, using a pair of optical transitions in the D1 and D2 lines of Rb-87 to create correlated photon states. The lasers were frequency-stabilized using saturated absorption spectroscopy. The experiment operates with counterpropagating “read” and “write” beams through the vapour cell, and emitted photons are filtered by polarization and frequency before entering a Hanbury-Twiss Interferometer and single photon detector. A cycle-control system was adapted to coordinate timing and data acquisition. Current work involves collecting photon statistics and calculating the autocorrelation function for the single photons. This will verify the production of true single-photon states and provide a baseline for how to improve the efficiency of the experiment for eventual integration with a quantum memory experiment.

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Lg-wave Crustal Attenuation and Its Tectonic Implications for the Craton-Cordillera

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Shear wave attenuation constrains crustal properties such as temperature, age, deformation, and fluid/melt content. A well-resolved attenuation model can resolve crust and upper mantle structures more sensitively than seismic velocities, commonly used as proxies for temperature and composition. We investigate crustal attenuation beneath the southern Rocky Mountain Trench (RMT), a crustal fault at the juncture between the North American craton (NAC) and the Cordillera using ~20 years of regional broadband recordings from western Canada and the northwestern U.S. Through attenuation (Q) inversions using Lg waves, we 1) map the craton–Cordillera transition boundary within the crust, and 2) infer the history and preservation of craton margins. Our attenuation model shows minimal correlation with sediment thickness or Moho depth, suggesting stronger influence from crustal heterogeneity. Our data reveals relatively low Q values along the RMT, which likely reflect the sensitivity of Lg waves to surface topography as well as localized crustal structure associated with deformation within the suture zone and adjacent foreland belt. The model reveals a sharp northwest-trending low-to-high Q boundary from the coastal belt to the central Cordillera that aligns with the volcanic arc. Low-Q regions to the west correspond to the coastal belt and Cascadia arc, consistent with melt, and active subduction. High-Q regions to the east highlight well-preserved crust within the central Cordillera, Hearne Province, and Medicine Hat Block. While foreland basin sediments locally reduce Q within the craton, the Medicine Hat Block remains well defined with consistently high and homogeneous Q values, indicating long-term preservation.

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Gravitational Waves from Neutron Stars Candidates in Pulsar Wind Nebula

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Continuous gravitational waves (CWs) are theorized to be emitted by rapidly rotating neutron stars and offer a unique perspective into extreme gravity and dense matter. Neutron stars, characterized by their rapid spin and potential non-axisymmetric deformations, are prime CW emitting candidates. The motivation to pursue these searches remains strong. Despite decades of dedicated effort, no continuous waves have yet been observed. Such a breakthrough would transform our understanding of neutron-star structure, the equation of state, and energy-dissipation mechanisms, offering direct access to internal physics that electromagnetic observations cannot probe, and opening a new era in neutron-star physics. Our search strategy emphasizes efficient data handling and targeted investigations. The Band-Sampled Data (BSD) framework provides a robust analysis pipeline for LIGO detector data, enabling focused searches for signals from neutron stars. BSD facilitates processing of large datasets while preserving sensitivity to CW signatures and reducing computational costs. Utilizing the BSD pipeline has yielded stringent upper limits on strain amplitude and neutron star properties, advancing our understanding of potential gravitational-wave sources. The BSD framework not only optimizes current searches but also serves as a foundation for future investigations into other types of gravitational-wave signals, significantly contributing to ongoing research efforts aimed at unlocking the mysteries of neutron-star behaviour. This work aims to utilize the BSD pipeline to search for neutron star candidates in pulsar wind nebulae and place stricter limits on their physical properties than previously achieved.

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Correction Algorithm Effectiveness for the AHCAL Particle Detecor

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Multiple particle detection calorimeters were developed by the CALICE (Calorimeter for Linear Collider Experiment) collaboration. The DHCAL (Digital Hadronic Calorimeter) is an array of digital cells put in 3 dimensions. When a particle passes through the digital cells, the “off” signal is switched to “on” and a “hit” is registered. The path of particles can be retraced by looking at the position of the cells that were hit. The disadvantage of the DHCAL is that, if a second particle passes through a cell that was already hit, the detector does not register a second hit because it is already “on”. To remedy this, an algorithm was already developed to correct the number of hits in a cell depending on how many neighbouring cells are hit. The objective of this research was to verify the algorithm. To do this, data from the AHCAL (Analog Hadronic Calorimeter) was observed. For the AHCAL, instead of having only binary “on” and “off” cells, the energy of the particle passing through it is also recorded. This advantage comes at the price of having larger cells than the DHCAL and thus being less precise about the path. Since the data from the AHCAL also contained the energy (which is proportional to the number of hits), the correction algorithm was tested on the AHCAL data and compared to the actual energy of the particles. The correction algorithm ended up not working as expected on the AHCAL since it did not correct in accordance with the measured values.

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Development of an Atomic Force Microscopy (AFM) Simulator via Poisson Equation Solvers

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Quantum dots (QDs) are promising solid-state spin qubits, with their discrete energy levels frequently probed via atomic force microscopy (AFM) electron tunneling. However, experimentally determining how QD energy structures depend on complex nanoscale device geometries remains challenging. To address this gap, we developed a custom numerical solver to model the electrostatic potential of AFM-based QD devices and systematically extract electrode-specific lever arms—the critical conversion factors between gate voltage variations and energy level shifts. Our simulator solves the generalized Poisson equation on 3D finite-difference grids. It accommodates realistic experimental configurations, including the hyperbolic AFM tip and buried arsenic gates defined via hydrogen resist lithography. Spatially varying permittivity is incorporated using harmonic averaging at material interfaces, with convergence accelerated by successive over-relaxation. From the computed 3D potential landscapes, we extract the lever arms and analyze their dependence on gate position, tip height, and device geometry. Ultimately, this work provides a robust computational tool to guide QD device design and interpret experimental AFM measurements from Prof. Peter Grütter's laboratory.

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Characterizing Charge Defects in a Double Quantum Dot Device using Machine Learning

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Spin qubits in Quantum Dot devices use the electron's spin as a quantum two-level system. By manipulating the device's electrostatic potential landscape (using metal electrodes known as "gates"), "potential wells" can be formed and electrons can be trapped and confined inside them. Such a potential well with electrons is referred to as a "Quantum dot" and the electrons inside function as qubits. Random charged defects present inside the device material however can distort the device's potential landscape, making stable operation more difficult. We use machine learning to infer properties of these defects from simulated measurements of qubits inside such a device. We frame defect characterization as an inverse problem: given a charge stability diagram of a double quantum dot, infer the location of the defects present in the device. We train a Convolutional Neural Network (CNN) on synthetic data to predict the location of a single localized charge defect from its imprint on the charge stability diagram. Furthermore, to extend this approach to devices containing multiple defects, we need large, realistic training sets while keeping simulations computationally feasible. We therefore compare several numerical solvers that model disordered electrostatic landscapes with different trade-offs between accuracy and cost and examine how well they reproduce defect-induced features in the charge stability diagrams.

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Impact of CCD Camera Responsivity on Light Spectrum

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Meteors provide vital insights into the composition of comets and asteroids, which are fundamental building blocks of our solar system. The study of meteor physics is not only important for understanding the origin of our world, but also practical as it provides assessment to the risk meteors posed to spacecrafts. One key challenge in meteor observation is accurately measuring their intensity, as it can vary depending on the camera used to capture the light spectra. Different Change-Coupled Device (CCD) cameras have different responsibilities which could lead to discrepancies when measuring brightness of the meteors. Moreover, correcting these variations can be difficult at times, as it involves intricate calibration and corrections. To address this issue, this study utilizes a unique spectral tracking system designed specifically to track meteors and capture their light spectra. By analyzing the spectra produced by this system, I aim to study how the sensitivity of various CCD cameras impacts the intensity of the meteor. The primary focus of this study is to understand how different wavelengths are affected by the unique responsivities of each camera, which can lead to over- or under-representation of certain color bands. This study helps quantify the effect of camera responsivity in the measurement of meteor brightness, which contributes to improving the accuracy of meteor detection networks, providing a clearer understanding of the uncertainties involved in measuring meteor intensity. Which will in turn help characterize the potential hazards posed by meteor to spacecraft, a critical step in protecting space missions and infrastructure.

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