Abstract Book

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1 *Rowan Duim*

Augmenting the brightness and maximum photon energy of ultrafast X-ray free electron lasers is central to enabling science that is currently inaccessible. The fundamental limiting factor of any free electron laser is the photoinjector, which generates the electron bunches that are accelerated and undulated to produce X-ray light. The photoinjector produces free electrons by striking a photocathode with a UV laser pulse. The shape of this photoionizing pulse determines the shape and density distribution of the resulting electron bunch, thereby impacting the electron beam quality and brightness of resulting X-rays. A spatially and temporally flat-top pulse is desirable for minimizing emittance growth due to space charge effects. The nonlinear optics phenomenon of sum-frequency generation, in which the mixing of two waves with frequencies ω_1 and ω_2 results in the production of a new beam at frequency $\omega_1 + \omega_2$, provides a method for pulse shaping: Inducing opposite second- and third-order dispersion in the input pulses results in a summed-frequency pulse with a narrow wavelength band and side peaks in time, approaching a flat-top shape. A pre-existing code models this process in the longitudinal dimension. In order to treat focused Gaussian beams, a two-dimensional code was written which introduces a transverse component such that mixing of focused Gaussian beams may be simulated, including the interaction of beams with optical elements and propagation to the crystal entrance.

2 *Dixin Chen*

Secondary neutrons, generated as an unwanted byproduct in high-energy radiotherapy using photon beams, pose an iatrogenic risk for carcinogenesis. As the relative biological effectiveness of neutrons is energy-dependent, a Nested Neutron Spectrometer (NNS) can be used in radiotherapy bunkers to measure the secondary neutron fluence spectra that are necessary for the energy-dependent risk assessment. The NNS, when operated in its pulse-mode, has some operational limitations such as pulse pile-up and increased deadtime in high-flux radiotherapy environments. Therefore, to overcome these limitations, a passive NNS was developed in which the active thermal neutron detector (He-3 counter) of the standard NNS was replaced with passive gold activation foils. Response functions describing the input-output relationship of the passive NNS were generated by performing Monte Carlo simulations in GEANT4. This study aims to improve the sensitivity of the passive NNS by investigating how the response of the system varies with the activation foil parameters.

3 *Dia Martinez Gracey*

The Antarctic is only recently beginning to show changes associated with global warming, however these changes are accelerating. As the largest ice sheet in the world, loss of it will have significant impacts on global climate and sea levels. It is not currently known how thick the Antarctic ice sheet is, since altimetry data cannot distinguish between where the ice stops and the snow begins. Further, snowfall on sea ice has complex and contrasting impacts on sea ice growth. Thus, in order to determine how much ice is in the Antarctic and accurately predict and prepare for changes to it, snowfall data must be examined, and snow-on-sea ice interactions understood. It is logistically difficult to get in-situ precipitation data over the Antarctic, and thus satellite observations from CloudSat are used. This satellite uses a 94 GHz cloud-profiling radar, which is best suited to determine light snowfall events such as those seen in the Antarctic, and covers latitudes as low as 82 S. This work uses CloudSat observations to determine a snowfall climatology over the Southern Ocean (55 – 82 S) from 2006-2011, calibrates reanalysis snowfall products from ERA5, ERA-I, and MERRA2 to these CloudSat climatologies, and presents the foundation for a snow-on-sea ice model in the Southern Hemisphere.

4 *Michael Imseis*

A three-dimensional light-like foliation of a spacetime geometry is one particular way of studying its light cone structure and has important applications in numerical relativity. In this paper, we execute such a foliation for the Kerr-Newman-AdS black hole geometry and compare it with the lightlike foliations of the Kerr-AdS and Kerr-Newman black holes. We derive the equations that govern this slicing and study their properties. In particular, we find that these null hypersurfaces develop caustics inside the inner horizon of the Kerr-Newman-AdS black hole, in strong contrast to the Kerr-AdS case. We then take the ultra-spinning limit of the Kerr-Newman-AdS spacetime, leading to what is known as a Super-Entropic black hole, and show that the null hypersurfaces develop caustics at a finite distance outside the event horizon of this black hole. As an application, we construct Kruskal coordinates for both the Kerr-Newman-AdS black hole and its ultra-spinning counterpart.

5 *Angelo Hollett*

The centers of galaxies are home to some of the most amazing objects in the universe; Supermassive Black Holes (SMBHs). SMBHs consume gas, dust, and stars, through a process known as accretion. The centers of the host galaxies are said to be 'active' during this process, and are denoted as Active Galactic Nuclei (AGN). IRAS 13224-3809 is a particular AGN which has been observed and studied extensively over the past two decades. This AGN regularly shows strong absorption features in high-energy X-ray regimes. Similar features are often attributed to highly ionized winds being expelled from the accretion disk, known as Ultra-Fast Outflows (UFOs). However, another explanation for the appearance of such features is the presence of absorption lines originating from warm material in the accretion disk. A method is presented to explore a specific correlation expected during the presence of a disk-originating absorption line. Developing tools to distinguish the presence of a UFO from disk-originating absorption lines is vital to our understanding of the life cycles of galaxies. UFOs are of significant importance as they will influence host galaxy evolution. It is important to determine the origin of these X-ray spectral features and consider all alternative models.

6 *William Rettie*

The death of a star, known as a supernova, is a process which is well understood theoretically, but lacks concrete data. Supernovae are scarce phenomena that occur quickly. Consequently, there are no recordings of them in detail from start to finish. The Helium And Lead Observatory (HALO) aims to solve this issue by detecting neutrinos produced by supernovae. These neutrinos arrive on earth before the photons from the event. This allows HALO to alert astronomers of incoming supernova photons, increasing the likelihood of the process being captured in full. Neutron detectors are a key piece of technology within HALO. Analyzing their health, along with improved data analysis techniques, allows for more accurate predictions, ultimately helping in the capturing of supernovae.

7 *Ruhi Shah*

I introduce a formalism known as a quantum cellular automata (QCA) which evolves a sequence of qubits using a universal unitary operator. We then subsequently explore properties of this formalism to analyze and validate conjectures that relate quantum computational complexity to classical thermodynamics, in the context of blackhole physics. Then, I extend this formalism to allow evolution of mixed states. The Von-Neumann entanglement entropy of the entire system is then explored over time, and there is discussion on whether or not this QCA can be used to model a blackhole. This discussion includes questions related to the blackhole information paradox such as the Page curve and a potential connection with the recent conjecture ER=EPR. Finally, I discuss QCAs in the context of the new Wolfram Physics model, from which ER=EPR is a natural and obvious deduction.

8 *Desiree A. Rehel*

This study, which is motivated by some recent experiments on confined DNA, investigates systems of two identical, linear polymers confined to a box-like cavity with a square cross-section and strong confinement in one dimension. Both Brownian dynamics and Monte Carlo computer simulations, modelling the polymers as bead-spring chains, were used to study the system. Results for quantities such as a time constant characterizing the decay of the mean-square displacement of the centres of mass of the polymers and position probability distributions were analyzed. The behaviour of the system is dependant on box size, and four behavioural regimes were found: (1) The box is large enough that the polymers rarely interact with each other, and the behaviour of the system is unaltered. (2) The box is still large, but the polymers interact more frequently and have a slight preference for the box corners. (3) The box is small enough that the polymers frequently interact but still prefer to be segregated and behave like a Brownian rotor. (4) The box is too small to allow Brownian rotor behaviour, and the polymers start to overlap. In recent experiments on two DNA molecules confined to a box with a 10:1 width to height ratio, the molecules exhibited the dynamics of a Brownian rotor, consistent with the third behavioural regime observed in the present study.

9 *Alexander Wainwright*

Increased interest in fiber optic systems and smart windows has resulted in demand for glass produced with specific impurities that affect the material's utility. The ability for quick and relatively simple spectroscopic methods to determine sodium, magnesium and calcium concentration inside a glass sample allows industry professionals to improve glass quality. In this study, a 10.6 μm CO2 laser was used to produce a spectral diagram for six different glass types. It was first demonstrated that short laser bursts on the order of 0.1 s, at high intensity produced the same spectral lines as longer bursts on the order of 1 s, with a lower thermal curve and almost no damage to the sample. The short-burst method was used to produce three-dimensional spectral plots that show the development of spectral lines and the material's thermodynamic curve over the burst duration. Spectral analysis was performed to determine the relationship between relative intensity and the density of sodium, magnesium, and calcium in the glass samples. In trials, high relative intensity was recorded at the sodium doublet of 589 nm and 589.6 nm, 610-645 nm representing calcium's presence and 765-769 nm representing magnesium's presence. It is theorized that peak size is not related to impurities concentration; instead, the correlation will be between the time to reach maximum relative intensity. This study demonstrates an effective way to determine impurities in glass without compromising the integrity of a sample.

10 *Kaihim Wong*

The brain executes many tasks per day and when something goes wrong, the results can be devastating. It is hard to fix neurological disorders because it is difficult to trace the cause of the problem. Axons are the part of brain cells that allow message conduction. Autopsy studies suggest schizophrenia could be related to brain's axon distribution. This needs to be confirmed in living brains. Currently we are working on reducing imaging time for live animals' studies with non-invasive diffusion weighted MRI techniques which can determine the distribution of axons in the brain and provide more insights into diseases such as schizophrenia.

11 *Wucheng Zhang*

We consider the time evolution of a charged test particle of mass m in a constant temperature heat bath of a second charged particle of mass M. The time dependence of the distribution function of the test particles is given by a Fokker-Planck equation with a diffusion coefficient for Coulomb collisions as well as a diffusion coefficient for wave-particle interactions. For the mass ratio $m/M \to 0$, the steady distribution is a Kappa distribution which has been employed in space physics to fit observed particle energy spectra. The time dependence of the distribution functions with some initial value is expressed in terms of the eigenvalues and eigenfunctions of the linear Fokker-Planck operator and also interpreted with the transformation to a Schrodinger equation. We also consider the explicit time dependence of the distribution function with a discretization of the Fokker-Planck equation. We study the stability of the Kappa distribution to Coulomb collisions.

12 *Ophélie Karishma Leste*

Galaxy interactions are one of the key mechanisms driving their evolution. These interactions leave imprints on galaxy structure visible in deep images. We study galaxy merging features (shells and streams) based on Kado-Fong et al. (2018) classification of a sample of 21 000 galaxies with spectroscopic observations from the Sloan Digital Sky Survey (SDSS) and available deep images from Hyper Supreme-Cam Subaru Strategic Program. We first improve the classification of merging features by visually inspecting original galaxy images and the ones filtered to accentuate tidal features. For the sample of 1500 galaxies harbouring either shells or streams, we further analyse spectroscopic measurements obtained from the SDSS database. We find that galaxies classified as having shells are more massive and have older stellar population than both featureless and galaxies with streams. From emission lines measurements, we calculate the star formation rates and build diagnostic diagrams that classify emission-line galaxies based on the dominant ionisation mechanism. Our results show that shell galaxies are on average forming stars at lower rates than galaxies with streams, which correlates with their older age. About half of galaxies hosting shells show some levels of active galactic nucleus (AGN) activity. We will explore this connection between galaxies with merging features and their AGN by analysing their X-ray properties. Furthermore, we will investigate the environments of post-merging galaxies by creating maps of galaxy densities around them.

13 *Faheem Mosam*

Complex systems exhibit critical behaviour ubiquitously while still being out-of-equilibrium; however, the broad spectrum of relaxation timescales that such systems exhibit is often linked to critical behaviour in analogy with equilibrium statistical mechanics. This leads to a crossroads, either the equilibrium analogy must be challenged, or there exists some generic mechanism for self-tuning to a critical point. Many dynamical systems, such as Hidden Markov Models (HMM) are Markovian, meaning that they are governed by a transition matrix. Generic transition matrices follow random matrix theory, so how can there be a plethora of interesting macroscopic behaviour in complex systems? One simple mechanism is proposed: if the individual elements of the transition matrix have a sufficiently broad distribution, then the asymptotic limit of large matrices is avoided. This phenomenon is shown in the ensemble of HMM, allowing the identification of a transition point which corresponds to the emergence of structure in the output (as measured by entropy). Initially, a system may behave noisily but as it cools down into an ordered phase it will take on a nontrivial Shannon entropy. Additionally, biological systems are poised at criticality, so brain network dynamics will be tested with respect to the breakdown of random matrix universality in HMM in order to understand where human data lies in the space of random HMM. This work allows for future studies regarding the learning process for a task, as it could be identified through the emergence of order in HMM brain network dynamics.

14 *Utkarsh Mali*

As quantum computer become more complex and scaleable, the need for creating platforms to automate the design quantum processors also increases. SCILLA is a software for automating the discovery of superconducting qubits. The software, written in python, used parallelized closed-loop optimisation to design circuit parameters. We test the codes usability in different systems of the transmon regime such as c-shunted flux qubit and 2-junction symmetric/anti-symmetric transmon. The results highlighted the promising potential for automation. Circuit parameters were optimized to the desired range in simple circuit QED systems. It also demonstrated its drawbacks if the program was to be scaled to larger circuit QED systems with the software optimizations failing during circuit quantization. Further tests also highlighted its current computational limitations. SCILLA ultimately shows promising potential. It works as a proof of concept as we work to develop more robust circuit design systems.

15 *Yasmeen El-Rayyes*

The M13 bacteriophage is unconventional due to its rod-like shape and ability to self-assemble. There is potential for its use as an antibacterial additive in materials, however the physical properties of this bacteriophage must first be understood. These properties include diffusivity and flexibility and their measurement requires that the bacteriophage is chemically tagged with fluorescent molecules. In this project, the procedure for tagging the bacteriophage was created and adapted, allowing for measurements of the diffusion coefficient. These values were compared to diffusion coefficients of M13 found in literature to confirm that the tagging procedure was successful. The values were consistent, which means that this protocol can be used for future experiments and the tagged phage can be utilized in other applications, such as the examination of the phage's self-alignment.

16 *Ryan Ripsman*

The epigenetic changes that occur during cellular differentiation are traditionally compared to a ball rolling down a hill filled with peaks and valleys – a model called Waddington's Epigenetic Landscape. The flat top of the hill corresponds to the undifferentiated progenitor cell state and the valleys on the hill correspond to stable and semi-stable differentiated cell states. Understanding how the transcription levels of different genes create this landscape is an active area of research. This process has been characterized for simple differentiation processes involving few genes. However, for technical reasons, it has been difficult to characterize this process when many genes are involved. With the advent of single-cell RNA sequencing, these more complex systems can be re-examined. We examined the differentiation of cardiac tissue in zebrafish – a process that depends on the dynamics of many different genes. We looked at single cell-RNA sequencing data from two different zebrafish, one that can develop cardiac tissue, and one that cannot. Using biophysical techniques, we constructed different potential trajectories, describing the differentiation of cardiac tissue from its progenitors. We further examined the dynamics of the gene expression levels, as the cells differentiated and found several different patterns of gene expression levels. We intend to use these gene expression levels to quantify the interaction between different genes during the differentiation of zebrafish cardiac tissue. Our study will provide a clearer picture of how Waddington's Epigenetic Landscape arises in complex systems.

17 *Erika Kember*

Glioblastoma multiforme is a common and deadly form of brain cancer that usually kills patients within 18 months. Due to its aggressive nature, it must be treated swiftly and monitored closely using imaging to ensure as early as possible that an effective treatment has been selected. However, if unique features of medical images of a tumour could be analyzed to determine long term outcome shortly after treatment has begun, then it would allow physicians to quickly modify treatment plans to the benefit of the patients. As the traditional method of visually interpreting medical images is limited, we instead use a process called radiomics to quantitatively assess large amounts of data and pull out quantitative features. Radiomics features must be assessed to ensure that they are reproducible. Once we know that features are reproducible, we can perform statistical analysis and use machine learning algorithms to correlate patterns with clinical outcomes.

18 *Long Quachs*

Low energy (kinetic energy < 50 MeV) atmospheric muons were detected at ground level over a span of 920 days (Aug 28, 2017 to March 3, 2020). Local ground-level atmospheric conditions (pressure, temperature and humidity), and atmospheric height (at 10kPa) for the same period of time were obtained from archived local weather station data, and radiosonde data, respectively. Multi-linear regression was applied to the first 730 days of data to create a model which reproduces both the seasonal and daily fractional variations in the muon detection rate in terms of the fractional variations in the atmospheric parameters. Specifically, the fractional variations in the muon detection rate were found to be anti-correlated with the atmospheric height (αHeight = -2.218(72)), pressure (αPressure = -2.703(134)), and humidity (αHumidity = -0.0481(73)) fractional variations. The model successfully predicts both the seasonal and daily fractional variations in the muon detection rate over the final 190 days of the data set. It is proposed that the model can be repurposed to accurately determine the fractional variations in the atmospheric height, thus avoiding the need for radiosonde data from weather balloons.

19 *Caroline Deluce*

SNO+ is a neutrino experiment located at SNOLAB, which is 2km underground at Vale's Creighton Mine, in Sudbury, ON. The detector itself is composed of a spherical acrylic vessel (AV) that has a radius of 6m, which is currently undergoing a transitional period from being filled with ultrapure water (UPW) to scintillator - linear alkylbenzene (LAB) and PPO (wavelength shifter). The AV is centered and held in position within a geodesic shell of photomultiplier tubes, which are all submerged within a cavity containing UPW. The experimental set-up allows for the detection of scintillation light produced by particle interactions with LAB. Around 47% of the AV is already filled with scintillator - allowing for preliminary background studies. The experiment's primary physics goal is conducting the search for neutrinoless double beta decay. Additional physics goals include: invisible nucleon decay in UPW, solar neutrino studies (proton-electron-proton (pep) and carbon-nitrogen-oxygen (CNO)), geo- and reactor- antineutrino studies, and potential observation of neutrinos from a nearby supernova. In this presentation, I will introduce SNO+ and its physics program, and then discuss one specific example of a background study involving pulse shape discrimination for the partial fill phase.

20 *Matthew Coon*

Organic Photovoltaic (OPV) devices have attracted attention from researchers over the past several decades. This stems from the variety benefits they provide for large scale applications. Including the ability to deposit them on flexible substrates as well as the low cost of fabrication among other things. The proper testing of OPVs is an integral part of optimizing their performance. By tracking the performance over time, information can be gained that can determine the methods of degradation taking place within the devices to help prevent them. Testing can be done both indoors and outdoors however outdoor testing is limited to long time frames. However, indoor testing can be done much more efficiently. By holding devices at higher temperatures, accelerated testing can be done and information for outdoor temperatures can be extracted. For this reason, indoor testing is the more common and effective method. These indoor tests when done under the right protocol, adhere to industry standard. For this project we aim to first build a automated lifetime testing system for OPVs. Secondly, we can use this system to test up to 160 devices continuously. By making small alterations to the device properties such as materials, structures, and fabrication we can study the impact these alterations have on resulting lifetimes and electrical properties. This can be applied both to our current devices as well as new materials to optimize their performance. By testing many devices simultaneously big leaps in progress can be made in our devices with drastically less labour.

21 *Harmohit Singh Bindra*

To build quantum networks where waveguides act as information channels and quantum systems process the information, a fundamental understanding of single photon–qubit interactions inside waveguides is important. We consider a linear chain of N qubits coupled to a one–dimensional waveguide. The system is modelled using the real space approach[1]. A transfer matrix method is then used to analytically determine the excitation coefficients of the qubits. Born rule is applied to find the expression for the excitation probability when a Gaussian light pulse is incident on the system. The expression for the excitation probabilities thus obtained is an integral which has been computed numerically[2]. Here, we develop a fully analytical solution by applying partial fraction decomposition to the integrand followed using Voigt functions for integration. The fully analytical solution is used to solve for systems with small N and the results are verified by comparing them to the published semi–analytical results. The new results make it easy to predict the effect of changes in certain variables of the system on the excitation probabilities. Therefore, the analytical approach aids in understanding the fundamental physics behind the excitation of qubits.

22 *Nicholas Swidinsky & Braden Gail*

The European Space Agency (ESA) Herschel space observatory (May 2009-April 2013) came equipped with three focal plane instruments, one of which is the Spectral and Photometric Imaging REceiver (SPIRE) which consisted of a photometric camera as well as a Fourier Transform Spectrometer (FTS). The SPIRE FTS spectral Feature Finder (FF) is an automated procedure that identifies and creates spectral line catalogue entries from all of the SPIRE FTS observations, with results available in the ESA Herschel Science Archive (HSA). We present a Jupyter notebook tool, based on the Python programming language, to assist FF users in exploring and exploiting the FF data freely available within the HSA. The notebook provides sample code for accessing the data as well as providing details explaining the data shown. The notebook also contains other features that aid in the analysis of the data which includes a custom made Graphical User Interface (GUI) designed to allow quick analysis of the data without the need to access the code, and an export tool providing publication quality figures. This work also included testing and expanding the notebook for public release. The notebook is functional for all of the Herschel SPIRE FTS observations and includes new functions for graphical applications and data acquisition from the HSA. This work was done in collaboration with L. Spencer, J. Scott, C. Benson, and I. Valtchanov (See Hopwood et al., 2020 MNRAS).

23 *Cole Coughlin*

All the ordinary matter we see consists of mesons (two quarks) and baryons (three quarks), but states of four or more quarks are not forbidden by the standard model and detecting such particles could help further our understanding of the elemental particles and the laws that govern them. By using data collected with the ATLAS detector at the Large Hadron Collider, this study develops methods to search for states of Tetraquarks, Pentaquarks, and Hexaquarks through their corresponding possible decays into combinations of neutral Kaons and Lambdas.

24 *Padraic Odesse*

In a binary star system, two stars orbit a common center of mass. Depending on its orientation, we may observe a periodic decrease in the brightness of a binary system corresponding to an eclipse of the two stars. Eclipsing binaries are of particular interest in stellar astrophysics because we can constrain the physical characteristics of the stars involved through analysis of the light curve of that system. The aim of this research is to constrain several physical parameters of three binary systems from the Kepler catalogue. To achieve this task, I used the stellar modeling package PHOEBE (Physics Of Eclipsing BinariEs) to generate potential models for a given set of parameters, and sampled the parameter space using the Markov Chain Monte Carlo (MCMC) methods implemented in the emcee package. By sampling different parameter sets for our simulated binary systems, I was able to fit synthetic models to the light curve data of the three eclipsing binaries, and derive a set of well-fitted binary parameters for each system. The issue of degenerate solutions is a well-known problem in binary analysis, so some degree of human interaction is required to identify if our MCMC method has converged on a set of parameter values in the global minimum or a local minimum of the parameter space. Currently, further analysis is required to determine if the parameters for each star are reasonable, and adjustments will be made to the fitting process as necessary to avoid degeneracies.

25 *Anastasia Afanassieva*

TRINAT (TRIUMF's Neutral Atom Trap) uses spin-polarized 37K nuclei to make precision measurements of nuclear beta-decay asymmetry with respect to spin. This poster outlines techniques in improving the circular polarization of the optical pumping light used to polarize the spin of trapped nuclei. Commercially available Twisted Nematic Liquid Crystals (TNLC) are able to quickly flip light polarization between two states. The characterization of these liquid crystal devices show their benefits over previously used liquid crystal variable retarders. The TNLC yielded a circular light polarization S3 = 0.99996(3) as defined by Stokes Parameters. This is a significant improvement from the previous liquid crystal device used which gave a circular polarization between S3 = 0.9931 and 0.9997. The poster will also look at the use of Quarter Wave Plates for light circular polarization. There is also a discussion on how the quality of polarization can be improved by an additional mechanically rotating linear polarizer. When combined with a demonstrated 3 times increase in laser power, the improved circular polarization of the light resulted in a predicted improvement in the nuclear spin polarization from 0.9913(9) to 0.9970. The circular light polarization is no longer a limiting effect the nuclear spin polarization. Supported by NSERC, NRC through TRIUMF and BioTalent Canada.

26 *Nelly Madani*

This research concerns x-ray fluorescence (XRF) data taken at the Canadian synchrotron facility also known as the Canadian Light Source (CLS) as a means of calculating the 2D distribution of the concentration values of the trace, minor, and major elements using the fundamental parameter method on a biological sample. The fundamental parameter (FP) method is considered the most general approach to quantification in x-ray fluorescence (XRF) analysis. In this method, the sample elemental composition is determined by comparing the experimental data with tabulated x-ray atomic cross-sections and XRF parameters. The first part of the data analysis was finding the areas and their uncertainties by fitting all the observed x-ray peaks. This was done using the graphing software PyMca by my research group and for more accurate results has been compared to another group's results from California.

27 *Sara Evans*

Quasicrystalline structures are ordered but not periodic, unlike crystalline structures which are both ordered and periodic. They have rotational, but not translational symmetry. Soft quasicrystals have been observed in many polymeric and colloidal systems. They have also been found in molecular dynamics simulations using artificial input. This project aims to find quasicrystalline phases in phase field crystal theory without the artificial input. To accomplish this, the location of the particles in a two-dimensional quasicrystal must be described mathematically. Then, the Matlab code written by Archer et. al. must be modified to incorporate quasicrystalline phases. Phase diagrams can then be constructed by exploring different parameters.

28 *Brett MacNeil*

The manganese germanides have a rich phase diagram and form many different structures. One such compoound, MnGe forms a B20 structure which is particularly interesting because of its chiral magnetic structure. This phase does not exist in equilibrium and must be stabilized artificially. However, CrGe forms a B20 structure that is reportedly easy to stabilize. Furthermore, CrGe is very closely lattice matched to MnGe, suggesting it can provide a non-equilibrium environment to stabilize the MnGe B20 structure. This talk reports on the use of molecular beam epitaxy (MBE) to grow thin films of B20 CrGe and an attempt to stabilize MnGe on top of these structures. Structural analysis using diffraction and atomic force microscopy are provided.

MnCoGe is a hexagonal ferromagnet, with the majority of the magnetic moment coming from Mn atoms in the unit cell. However, density functional theory (DFT) calculations show that when Mn atoms occupy the Co sites, their moments antiferromagnetically couple to the other Mn, creating a ferrimagnet. A model was constructed to determine the magnetic moments on each site as a function of disorder based on experimental data from sputtered MnCoGe thin films. Fits to the magnetization data using a Neel model show support for the conclusion that these films are ferrimagnetic due to the disorder between the Mn and Co sites.

29 *Virginia Rufina Marquez-Pacheco & Antoine Dagenais-Lalande*

Research on binary star systems has led to a series of discoveries that have lent good insight into the life of stars within such systems. One particularly interesting class of binary star systems are low-accretion rate polar cataclysmic variable stars. This research aimed to discover such a star system, determine its parameters, and map out its behaviour over one of its cycles. Using the Observatoire du Mont Mégantic's (OMM) 1.6m diameter telescope, multiple targets were observed over two separate weeks. Those targets were observed using photometry with the ultra-fast and sensitive PESTO camera. Using AstroImageJ, a photometry analysis tool, their light curves, which compared the relative flux of the target to that of surrounding non-variable stars, were created. The data was then transferred and plotted with Excel. To date, it appears that the target EPIC228682495 (an identified object of interest), has a period of 85.545348 minutes, and is exhibiting cyclotron radiation. This white dwarf does not appear to have an accretion disk, suggesting it is AM Her star. The accurate approximation for its orbital period resulted in the final folded light curve showing a sinusoidal form with minimal flattening of the curve. These characteristics place EPIC228682495 at the lower end of the period range for its class of star, thus making it an interesting target for future research.

30 *Katherine Herperger*

Ethylene is a frequently occurring model system with established photo-induced excited-state dynamics. By adding chemical substituents, such as pi-acceptor and pi-donor groups, to the central C=C bond, the properties of these dynamics may be controlled. During this talk, I will explain how the ultrafast quantum molecular dynamics of singly- and di-substituted ethylenes can be simulated. In particular, these calculations employ ab initio multiple spawning to propagate the electronic-nuclear wavefunction along the molecule's potential energy surface, as well as through regions where the Born-Oppenheimer Approximation breaks down: conical intersections. The generated data is used to visualize a molecule's energy levels, adiabatic populations, wavepacket expectation values, and transient charge localization. Together, these results provide a roadmap for directing photochemical reactions and influencing chemical properties.

31 *Shubham Kukreja*

This research project was motivated by the need to solve the time-dependent Schrodinger equation (TDSE) of a particle in a 1D periodic potential. In this study, I investigated numerical methods for solving the 1D time-dependent Schrodinger equation of a particle in a double-well potential, as well as determining its ground state. I used the Crank-Nicolson method [1], which is a finite difference method that can be used for numerically solving second-order partial differential equations. Using this method, I calculated the time evolution of an electronic wave function in a harmonic potential. My code was bench-marked against analytic solutions of the harmonic oscillator wave functions. I extended the use of this code by implementing the imaginary time method [2] to determine the ground state of an electron in a double well potential.

32 *Josephine Brewster & Cooper Wendland*

We conducted this experiment to help a larger research project. For that experiment, we needed to find a tube shape that would fit better in a pelican case than a straight tube. However, we also wanted to be able to easily calculate the frequencies at which that tube resonates (its resonant frequencies) using the same equations used to predict those of a straight tube. The two configurations we looked at specifically were a U-shape (three straight tubes connected with two 90^o elbow joints) and a T-shape (three straight tubes connected with one 90^o elbow joint and one T joint). To measure the resonant frequencies, we took those three configurations, their total lengths being equal, and placed a speaker at one opening and a microphone at the other. We then ran a sweep of frequencies from 0 to 5000 Hz and collected the amplitude of the sound being picked up on the microphone. We did this for each shape of tube, graphed the data for all, and then compared the results graphically. On the graphs of amplitude versus frequency, resonant frequencies show up as local maximums. We found that the U-shape tubes had resonant frequencies that appeared in the same spots as the straight tubes. The T-shape tubes, however, produced very different graphs, and therefore had different resonant frequencies. These differences come as a result of extra inference caused by the waves having multiple paths to take.

33 *Emily Huxter*

Many butterflies have ears on their forewings but our understanding of how they function is poorly understood. In a recent study, it was shown that when the enlarged subcostal vein of Cercyonis pegala was ablated, there was an observed dampening effect, decreasing the sensitivity of sounds on the lower frequency range of the butterfly's hearing (between 0.75 – 5 kHz). The long-term goal is to develop a model to explain how these 'hearing-aids' function in butterflies. This research focused on developing a preliminary model. The first step was to characterize the ear chamber, inflated veins and connecting openings. By treating the system as a bifurcated horn, the dimensions could be used to test sound amplification in the acoustic system. The model was refined by obtaining preliminary estimates of the first harmonics in each vein and estimating the frequency sensitivity range of the ear. The harmonic frequencies in the veins were found to be above the hearing range of C. pegala and the ear was found to be most sensitive to frequencies between 2 - 9kHz. Further calculations included a shell vibration analysis and finding the natural frequencies of the whole wing by treating the wing as a flat plate. Thin, intricate internal structures were observed throughout the inflation in the subcostal vein. These structures should be taken into consideration in future models as they may play a role in sound damping. The acoustic system of C. pegala represented as a simplified bifurcated horn, provides a novel model of sound amplification which if expanded upon in the future, could provide further insight into the function of 'hearing aids' in butterflies.

34 *Huba Khan*

The SNO+ experiment is a liquid scintillator experiment located 2km underground at SNOLAB, Sudbury, Canada, and resembles its predecessor, Sudbury Neutrino Observatory (SNO) experiment. The detector is a 6m diameter acrylic vessel (AV) and will be filled with 800 tonnes of scintillator composed of linear alkylbenzene (LAB), an organic liquid that will give off light as charged particles pass through it. These neutrino interactions are detected by 9800 photomultiplier tubes (PMTs). The primary goal of SNO+ is to detect neutrinoless double beta decay ($0\nu\beta\beta$) of tellurium (130Te), along with studying low energy solar neutrinos, geoneutrinos, and reactor neutrinos as well as supernova neutrinos. The optical and energy responses of the detector are to be measured with calibration sources deployed throughout the AV. The calibration of the detector will be executed using both optical and radioactive sources. One of such sources is the Cherenkov source, it uses 8Li decay to produce a tagged beta decay in an acrylic volume. This source will be attached to an umbilical as well as a high purity rope system, which can be controlled from the observatory deck above the acrylic vessel. A specially designed submersible umbilical cable is used to lower the source into the volume of the detector. The design and fabrication of 5/8" diameter umbilical needed for the Cherenkov source will be presented.

35 *Michael Astwood*

Microfluidics involves the transport of microscopic cargo in a low Reynolds number environment. In this setting the Navier-Stokes equations are linearized and reduce to the Stokes equations. We examine the possibility of using small particles in a microfluid to transport cargo from a distance. We show that an unconstrained active particle can steer a passive particle from any initial point to any final point using geometric control theory arguments. The controllability of various constrained systems is considered by examining a regular perturbation expansion of the dynamics. From this expansion, numerical results suggest that it is possible to steer cargo from a distance by introducing a second controllable particle.

36 *Zach Manson*

Trapped-ion quantum states are well-known to be good candidates for qubits in quantum computing. We study the application of an adiabatic method known as STIRAP to achieve qubit switching. Stimulated Raman Adiabatic Passage (STIRAP) is a method of quantum control that utilizes a specific atomic structure known as a 3-Level Lambda System (3LLS). The system consists of two ground states that are coupled to an intermediate excited state via two counter-intuitively ordered pulses known as the Stokes and pump pulses. STIRAP is a notable method of population transfer because not only is it robust against small experimental variations, but it also has the unique property to allow the complete transfer of population between the two ground states without loss of population due to spontaneous emission from the excited state. STIRAP can be extended to other chain-wise connected multi-level systems such as those that are present in the trapped-ion. In this study, we numerically determine the optimal pump and Stokes pulses that will maximize qubit switching in 3, 5, and 7-quantum states of the trapped-ion. We find that the overlap between the two pulses increases as the number of chainwise-connected states increases. We discuss the potential applicability of this method in quantum computing.

37 *Alex Wen*

Nuclear fusion is a physical process that combines light nuclei into heavier ones and releases energy. Harnessing fusion for commercial energy production would be desirable because it produces almost no pollution, is immune to meltdown, and uses plentiful hydrogen as fuel, making it the ideal candidate for future clean energy. To induce fusion reactions in an energetically-efficient system, reactors must confine nuclei at sufficient temperatures and densities for a sufficient time. In these conditions, reactants will exist in a plasma state. Therefore, fusion research is devoted to understanding how a plasma behaves, and finding ways in which it can be confined. General Fusion is aiming to develop the fasted and most cost-effective way to acheive efficient fusion. Its unique approach to implementing magnetized target fusion is to use pistons to mechanically compress the walls of the reactor to increase a magnetically-confined plasma's density. The successful design of such a reactor requires a comprehensive understanding of how plasma behaves under this complex and dynamic process. Computational simulations of plasma are used extensively to gain understanding. I will give an overview of General Fusion's practical approach to nuclear fusion, and discuss the computational techniques we use to understand the behavior of plasma in a reactor. I will end with prospects for fusion, and why it will be an exciting field of interest in the near future.

38 *Caleb Lammers*

Galaxies are massive, distant systems comprised mostly of stars, gas, and dust with many competing physical processes. The multi-wavelength distribution of light ("spectral energy distribution") emitted from galaxies is one of the primary pieces of information used to study galaxy evolution. Spectral energy distribution fitting ("SED fitting") aims to reconstruct the physical properties of galaxies (especially star-formation histories) from their spectral energy distributions. This is a difficult task and traditional SED fitting methods are quite computationally expensive. However, with the increasing popularity of detailed astronomical data (e.g. spatially-resolved surveys), fast and accurate SED fitting codes are needed. I will present a new SED fitting technique that extends the dense basis method (Iyer et al. 2019) with machine learning. We use a neural network, trained on a sample of artificially generated noisy galaxies to calculate physical parameters with uncertainties from input SEDs. Our method reproduces the results of other SED fitting codes, such as the dense basis method, much faster. In fact, the neural network fits SEDs to physical parameters 10 - 10^3 times faster than the relatively quick dense basis method. This allows for efficient SED fitting which is important for a range of applications where more traditional SED fitting would be too computationally taxing.

39 *Rebecca Tobin*

Aging is a complex process and very little is known about it. One approach to researching aging is to model aging using networks, where the nodes represent health indicators and the edges represent the interactions between those health indicators. The Generic Network Model, developed by Spencer Farrell (2016), simulated damage propagation in a scale-free network over time and was able to achieve a mortality vs age curve characteristic of human populations (know as Gompertz law). The model is notable for being able to incorporate both mortality and health. My project was to incorporate disease into this model and to categorize different disease type based on their impact on short-term mortality, long-term mortality, and long-term health. The goal was to create a phase space of mortality and health and identify different classes of diseases. In this talk, I will discuss the Generic Network Model and the results I obtained from comparing different diseases.

40 *Anthony Allega*

SNO+ is the successor to the SNO (Sudbury Neutrino Observatory) experiment with the primary goal of searching for neutrinoless double beta decay in tellurium–130. The experiment aims to reveal the Majorana nature of the neutrino, confirming the theoretical prediction that the neutrino is its own antiparticle. Other research areas of interest include low energy solar neutrinos, geoneutrinos and reactor neutrinos. Currently, SNO+ is in the stage of loading liquid organic scintillator (a mixture of LAB and PPO) into the detector volume; however, due to the 2020 COVID–19 pandemic, scintillator fill needed to be put on hold for an extended period of time. As a result, the top half of the detector is full of roughly 364 tonnes of scintillator, while the bottom half contains ultra–pure water from the previous phase. In turn that provided the opportunity to study backgrounds and the response to external calibration sources in this partial fill mode. While internal calibration source deployments are not possible in partial fill, it is useful to utilize backgrounds naturally present in the scintillator volume as calibration sources. The backgrounds stem primarily from the U and Th decay series emitted from the surrounding rock in the mine. This talk presents a Gaussian model for the high energy shoulder of the bismuth–210 background emission spectrum.

41 *Luke Fraser-Leach*

The rotation curves of galaxies tell us that 85% of the mass in the universe cannot be described within the Standard Model of particle physics. Most of the effort to detect this "dark matter" (DM) has been through direct detection: the use of large detectors in low backgrounds to observe elastic scattering between DM particles and target nuclei. However, stars are $10^{2}7$ more massive than any direct detector we have constructed on earth: DM might have significant effects on them. In this talk, I will outline the effects of one DM model, Asymmetric DM, on stellar evolution. I will show how this ADM would act as a heat conductor and discuss the effects this would have on the star. I will also compare two limits for heat conduction by DM in stars: the limit in which they have long mean free path, and the limit in which they have a short mean free path. The assumption of each of these limits in stellar simulations has consequences on stellar evolution.

42 *Rebecca Tobin*

Breast microwave sensing has emerged as a potential alternative to current breast cancer screening methods. Based on the dielectric contrast between healthy and cancerous tissue, breast microwave sensing uses a microwave signal to illuminate the breast and utilizes the backscattered signal to determine if a tumor is present through either image reconstruction or machine learning. One of the current issues in the field is known as the skin response. The skin response causes reflections at the air-skin interface due to the high contrast in permittivity. This response is large and obscures the tumor making it difficult to determine if a tumor is present. Current methods to minimize this problem either use a skin coupling media which increases the complexity of the system or use signal processing methods, but these methods have been found to be inconsistent across the field. The work presented here provides preliminary results using a machine learning algorithm to suppress the skin response, that was trained and tested using an experimental dataset. The machine learning algorithm shows potential in removing the skin response and allowing for reconstruction which highlights the presence of a tumor.

43 *Ryan Curtis*

The Light only Liquid Xenon (LoLX) experiment aims to investigate the Scintillation and Cherenkov light emissions in liquid xenon. Light emission is measured using 24 Hamamatsu VUV4 Silicon Photomultipliers (SiPM), which are able to measure single-photons. The SiPMs are arranged in an octagonal cylinder with different optical filters added to separate Cherenkov and Scintillation light: 22 with 225nm longpass filters, 1 with a bandpass filter centered at 175nm and 1 without filter. A Strontium 90 Beta source is placed in the center of the SiPM arrangement. Once filled with liquid xenon, which is expected in November 2020, the radioactive source will produce Cerenkov and scintillation light, which is detected by the SiPMs. First LoLX data were taken in cold nitrogen gas, with the goal of characterizing cross-talk between SiPMs, as the process can lead to false photon counts. Future plans exist for a Light only Liquid Argon (LoLA) experiment, to precisely determine scintillation time constants in Argon. This talk will give an overview of the LoLX experiment, and highlight the current status and future planning.

44 *Johnny, Donavin, & Adam*

The Thompson Rivers University Physics Club has been successfully selected to participate in the Canadian Reduced Gravity Experiment and Design Challenge sponsored by SEDS(Students for the Exploration and Development of Space). The proposed experiment's goal is to measure the Van der Waals force in a microgravity environment. The experiment builds off works on acoustic agglomeration, acoustic resonance, and Van Der Waals forces. Having a better understanding of the magnitude of the Van der Waals forces can lead to a minimum power needed for advanced filtration systems used in industries and in space. Our presentation is about the experiment design and scientific methods to be used to achieve our expected results. We would like to acknowledge SEDS, the Canadian Space Agency, the National Research Association, and GKSound for sponsoring this project.

45 *Julia Azzi, Carmen Lee, Kari & Dalnoki-Veress*

The liquid rope coiling instability causes a falling thin stream of viscous fluid to buckle when it hits a surface, creating a coil. This effect can be observed when squirting honey on your toast or shampoo into your hand. If the viscous stream falls onto a surface that is moving, unexpected patterns form. Here, we investigate the liquid coiling effect on a rotating surface. We observed the same coiling patterns found in experiments using a translating surface as well as other more complex patterns. Furthermore, coils prefer to form in the direction opposite the rotation of the surface and will spontaneously switch directions if the direction of rotation is changed. We explore the coil switch by varying the height of the source and the speed of rotation.

46 *Jordan Ducatel*

The proposal to use gate defined quantum dots as a platform for spin qubits has led to extensive research in fundamental properties of quasiparticles isolated in semiconductors. The ultimate objective of such research is to build robust and reliable qubits, the core component of quantum computers. We study the tunneling barriers of a gate defined lateral GaAs/AlGaAs double quantum dot device populated by hole quasiparticles cooled to sub-Kelvin temperatures in a dilution refrigerator. We report characterization of the main tunneling barriers of our device in the single hole regime by comparing various measurement techniques, specifically charge sensing, transport current, time-resolved pulsing, and EDSR spectroscopy. Good agreement was observed between different techniques measured under the same conditions. We further report dependencies of the strength of these tunneling barriers as a function of relevant gate voltages as well as an external magnetic field. These dependencies allow us to control the strength of each barrier in the hole quantum dot device over a range of four orders of magnitude. Careful control of these barriers is a critical requirement for quantum information applications as well as fundamental studies.

47 *Telmah Lluka*

The cytoplasmic membrane (CM) is central to the survival of all cells; it facilitates the action of important biological processes and insulates the cell from environmental stressors, among many of its other functions. As such, they are tightly regulated by the organism through lipid composition modifications and de novo synthesis. Alterations in membrane fluidity and lipid phase have been shown to influence cell growth and survival, membrane integrity, and antimicrobial efficacy and resistance mechanisms. Despite this, there is a paucity of studies that intertwine the impacts membrane properties have on bacterial proliferation and drug susceptibility. In this study, we will combine biophysical and molecular genetic techniques to measure CM fluidity and stability. Primarily, we will employ fluorescence polarization (FP) with 1,6-diphenyl-1,3,5-hexatriene (DPH), a fluorescent probe which allows for whole cell fluidity measurements. Using Escherichia coli as a model organism, the FP of DPH is explored using a single-gene knockout (Keio) collection, while coincident temperature ramps provide melting temperatures indicative of membrane stability. The primary goal of this study is to identify genes linked to fluidity regulatory processes and utilize these target genes for future chemical screening of novel antimicrobials.

48 *Braedyn Au*

A cascade of events occurs when a triggering event causes one or more subsequent events, which in turn may lead to a chain reaction of further events. Cascading dynamics are studied in systems across multiple disciplines including finance, where cascades of trading activity may occur due to overlapping portfolios. Overlap occurs when portfolios have investment similarities which creates correlated risks that traders are not aware of. When one trader rebalances their portfolio, the price impacts on the traded stocks will impact other portfolios which may cause their respective traders to rebalance as well. In this sense, every trade in the stock market results in a cascade of rebalancing. The impact of these cascades may be inconsequential or large enough to affect the entire market as a whole, even being cited as a possible contagion for a financial crash. In the New York Stock Exchange, traders can choose from more than 20,000 stocks to invest in. However, most traders will invest in familiar stocks such as those in the 30 Dow Jones Industrial Average, making overlapping portfolios and the resulting rebalancing cascades a prevalent issue. Here, we developed an artificial stock market from first principles to simulate trading activity. Based on the network structure of overlapping portfolios, we can identify and characterize these cascades using universal methods. Preliminary results suggest these rebalancing cascades follow power-law distributions similar to cascades in other complex systems. This work highlights the risks of overlapping portfolios and rebalancing cascades with the goal of real-world applications.

49 *Paul Deguire*

Galaxies formation and evolution are not yet well understood nowadays. In order to study the historic of a galaxy, its spectrum could be analysed. This spectrum gives information about a lot of the galaxy's characteristics: its metallicity, its weight, its star formation rate, etc. The development of a code that detects peaks of intensity in different filters of the galaxy's spectrum is then primordial in the study its evolution. Each filter gives information about different characteristics. For instance, peaks of a filter centered on Hα (656 nm) indicate HII regions while peaks of a mix of filters centered on [O II] (373 nm) and on [O III] (496 nm) indicate young star forming regions. During my experience of research, I have participated to the elaboration of a detection code. This code analyses maps from SITELLE, an interferometer installed on Canada-France-Hawaii Telescope (CFHT) and detects peaks of intensity in 3 different filters. Peaks identification is performed by 1) a threshold in the luminosity of the map or 2) the Laplacian. By modifying the code, I could compare different versions of the code on the galaxy NGC628 to choose the best parameters of the peaks and of their zone of influence.

50 *Zhi Gu Li*

Relativistic electrons trapped in the Van Allen belts can be transported through drift-resonant interactions with ultra-low frequency (ULF) plasma waves. Interactions with a single mode can produce signatures of a coherent resonant process, and which transitions towards the diffusive paradigm as the wave frequency spectra become increasingly broadband. Whilst the transport of electrons through interactions with ULF waves is often modeled using statistical approaches which assume diffusive dynamics caused by the perturbed electromagnetic fields, in the real system on the timescales of particle transport during a single storm a limited number of discrete mode interactions may be more realistic. Here we use a single particle-tracing approach to the dynamics of ensembles of relativistic electrons, and simulate their trajectories. We focus on interactions with Alfvenic disturbances which are assumed to be locally standing field line resonances, and examine how the ensemble responds to varying numbers of discrete modes. We will attempt to characterize the point of onset of diffusion as a transition from separate discrete interactions using the two-thirds resonance island overlap rule found in statistical theory which involves the comparison between the distance and widths of the electron's primary resonant islands in its phase space. We further derive a criterion in terms of wave frequency spectra and amplitude which predicts the transition to diffusive behavior and test it with our simulations. Finally, we compare the rates of diffusion produced in the ensemble particle dynamics with analytic predictions from a number of prior analyses and approaches.

51 *Heather Chaundy*

Supermassive black holes (SMBHs) that formed early in the universe oppose the way we believe black holes form, since they appear to be well-established by several hundred millions years after the Big Bang. Therefore, theories including direct-collapse black holes (DCBHs) and times of super-Eddington accretion are utilized to explain the phenomenon. Quasars can be studied to help explain the growth of these SMBHs using the quasar luminosity function (QLF). The function used here to model the QLF is a four parametered function, the tapered power law. With further calculations, this data shows that periods of super-Eddington accretion are likely happening, and that the seed mass for these SMBHs ranges from about 10^2 to 10^5 solar masses.

52 *Garrett Leverick*

Simulations play an important role in the design and performance of a subatomic physics experiment. One such experiment is MOLLER, a parity-violating electron scattering (PVES) experiment which will take place at Jefferson Lab. MOLLER aims to make an ultra-precise measurement of the weak mixing angle at relatively low energy. A simulation study which analysed the effect of varying the spectrometer magnet current on the yields in the main detector for MOLLER was performed. During this talk, I will describe the MOLLER experiment and the findings from this study.

53 *Yi Ming Chang*

The title of my research is, "Non-linear Bulk Electron Transport with the McKelvey-Shockley Flux Method". Basically what we are doing is simulating a voltage to a semi-conductors and to understand how much current flows inside the material. For our project, we are focusing on non-linear electron transport (there are stablish ways to solve linear regime). It is typically hard to solve non-linear regime, since you will need to solve Boltzmann Transport Equation by using Monte Carlo simulations. We believe there is a method called McKelvey-Shockley Method, which is more simple and phyiscally intuitive. Now we are having a working code of McK-S approach, and we are testing the accuracy of the method.

54 *Nadia Aiaseh*

The nudging method is a powerful data assimilation method that combines data and modelling to obtain more accurate predictions. We studied the implementation of this method for the Kawahara model, a nonlinear dispersive partial differential equation. We do this by adding the nudging term which requires previously attained data. The Kawahara models the wave profile of shallow water waves. Although it is possible to gather actual data for this equation, we have chosen to treat it as an idealized situation wherein we instead solve the equation using numerical methods. We then use this solution as artificial data. In order to mimic real world data, we delete the same spatial points for all times of our solution matrix to make it sparse. In this work, we show that the nudged equation converges to the given data, regardless of the initial conditions that we have tested for the nudged equation so far. We then explore how other factors such as adding a damped or forced term and changing the sparsity of the data can affect this convergence.

55 *Katie Simzer*

Rayleigh-Bénard convection occurs between two horizontally infinite plates when the lower plate is heated with respect to the upper one. The temperature gradient between the two plates causes convective rolls to form as the warmer fluid below becomes more buoyant than the cooler fluid above it. The standard (classical) analysis uses the Boussinesq approximation, which assumes that the fluid is approximately incompressible with only small variations in density, but this is not accurate for some real-world applications. This project is inspired by the atmosphere, so we will assume a vertically stratified fluid. The standard analysis is presented in many text books and is used as a comparison to the solution for a stratified fluid presented here. For all the cases that are observed, the stratified solution follows the standard solution for plate separations d ¡ 1m. As in the standard case, by changing the value of the viscosity, it was seen that the more viscous the fluid, the more difficult it is to overcome its static state to produce convection. For larger d, it is observed that the stratification also inhibits the onset of convection. Thus, although the non-stratified case can be a good approximation of the stratified fluid at very small scales, stratified fluids behave very differently as the scale increases.

56 *Adam Czarnecki*

In this presentation I will talk about the physics of the Beirut harbour explosion. The aim of our research was to find the energy of the explosion through video analysis of the shock wave observed after the event. We were able to determine the yield of the explosion using a technique first demonstrated by G.I. Taylor after the 1945 Trinity test. We also found that the high pressure zone of the blast wave was visible in some of the footage. We were able to analyze this footage to verify Lev Landau's relation between the thickness of the shock wave's high pressure zone and its radius.

57 *MacAulay Harvey*

Second harmonic generation (SHG) microscopy is a form of optical microscopy which utilizes the natural frequency doubling properties of materials with non zero second order electric susceptibility as a contrast mechanism. This form of microscopy is of great scientific interest because it allows for the direct study of the structure and physical properties of certain biological samples without the need for potentially harmful dyes. Collagen is an ideal candidate for study using SHG microscopy due to its high second order electric susceptibility, and because the SHG signal from collagen can be used as an indicator for cancer diagnosis. This presentation will provide an overview of the theory of SHG, and of the process of constructing a wide field SHG microscope, including design aspects such as control and measurement of input power, selection of microscope objectives, the calibration of liquid crystal variable retarders used to control polarization, and efforts to reduce noise in images. An experiment to prove that the output signal of the microscope is generated by SHG and not some other optical effect will also be presented.

58 *Conor Waterfield*

Many environments in the universe give rise to conditions extreme enough to allow exotic forms of nuclear matter. Understanding how this matter interacts allows us to better understand the nuclear forces and astronomical phenomena such as neutron stars. A tetraneutron is an exotic nuclear form which is composed of four neutrons. Its existence is debated, with an open question of whether they can be held together briefly in a short-lived resonant state. The existence of the tetraneutron state would be observable in reactions with four neutrons as their end product. At the IRIS facility at TRIUMF, an experiment involving the reaction 8He(d, 4n)6Li was carried out by reacting a beam of Helium-8 with a deuterium target and measuring the kinematics of the resulting Lithium-6. The existence of the tetraneutron state could be determined from the missing mass spectrum. In order to be able to interpret the results of the experiment, the effect of the non-resonant four neutron final state must be determined. This is done by simulating the non-resonant reaction with five-body final state through the experimental setup. I will present part of my ongoing work of building this simulation using the properties of the reaction and the experimental setup.

59 *Keito Watanabe*

The computational complexity of 3-D trajectory calculations has been an emerging issue since the advent of cosmic ray physics, which rely on computationally expensive approaches such as Monte Carlo integration. As a step to construct an alternative approach for such computations, we developed a high-performance 3-D tracking simulation that traces the trajectories of cosmic rays that propagate within the terrestrial geomagnetic field. We utilized a 4th-order Runge-Kutta algorithm to numerically integrate equations of motion from the Lorentz force and used the International Geomagnetic Reference Field model for the geomagnetic field. This simulation additionally determines the geomagnetic rigidity cut-offs, a criterion to distinguish trajectories that may arise from background to those that originate from a cosmic ray source, at any geographical location on Earth. We compare different implementations of the algorithm written in Python and C++, which reveal that those written in C++ show a performance gain of 1000 compared to that in Python. We additionally compare between the scalarly and vectorially constructed Runge-Kutta algorithm, which yield an accuracy gain of 1e7 in the vectoral version. The geomagnetic rigidity cutoffs at Kamioka, Japan were evaluated, and the obtained results were accurate when compared to those obtained by Gaisser and Honda [Ann. Rev. Nucl. Part. Sci. 52 (2002) 153-199]. We plan to extend our simulation by integrating muon tracking and increasing the performance with multi-threading using Graphical Processing Units cores.

60 *Layla Haddad*

The gravitational properties of antimatter are currently being tested by the Antihydrogen Laser Physics Apparatus (ALPHA) experiment at CERN. ALPHA uses a magnetic trap to confine antihydrogen ($\bar{H}$) atoms. If the magnetic traps are disengaged, then the $\bar{H}$ atoms will annihilate with the trap wall. The ALPHA-g apparatus is part of the ALPHA experiment and aims to perform the first measurement of the $\bar{H}$ gravitational acceleration. At TRIUMF, I worked on the development of a Data Acquisition (DAQ) and control system for the laser multiplexer with the ALPHA-g radial Time Projection Chamber (rTPC). The goal of the control system is to control the laser multiplexer to generate electrons from the central cathode of the rTPC to confirm that the drift properties are uniform. The functionality of the laser multiplexer is currently being tested at TRIUMF.

61 *Karnav Raval & Xiyuan Li*

The most commonly used and cited epidemic spread models consider a population and divide it into individuals who are susceptible (S), infectious (I) and recovered (R) from an infection of interest. An exposed (E) class may also be added to account for individuals who have been exposed to the infection but are not yet infectious to others. This leads to a compartmental epidemic model, where the dynamics of infection spread are modelled by a set of coupled ordinary differential equations. Solutions correspond to the number of individuals in each compartment over time. To improve the resolution of classic compartmental models, spatial compartmental models consider interaction between communities within a population for modelling dynamics. Infection dynamics in each community are modelled by a classic model with 5 compartments and models are coupled with each other by the level of interaction between communities, resulting in 5N coupled differential equations for N communities. We study a spatial compartmental model and add functionality to implement real-world mobility/interaction data during the COVID-19 pandemic. We solve this model by numerical methods and produce infection-spread visualizations to compare model outputs with COVID-19 data.

62 *Mahima Siali*

Much of modern cryptography is based on the concept of "hard math problems" - problems that would take hundreds of years to solve on a classical computer. As a greater understanding of physics leads us to the inevitable advent of the functional quantum computer, with incredibly fast computational abilities, cryptographers are tasked with developing new ways to keep our data safe. This talk will discuss Shor's Algorithm — the quantum computer algorithm that breaks much of modern cryptography — as well as some of the tools that researchers are currently using in the study of post-quantum cryptography. These include the computation models, namely quantum Turing machines and reversible circuits with quantum gates, as well as cryptographic models, namely lattice-based cryptography, with brief mentions of code-based cryptography and others.