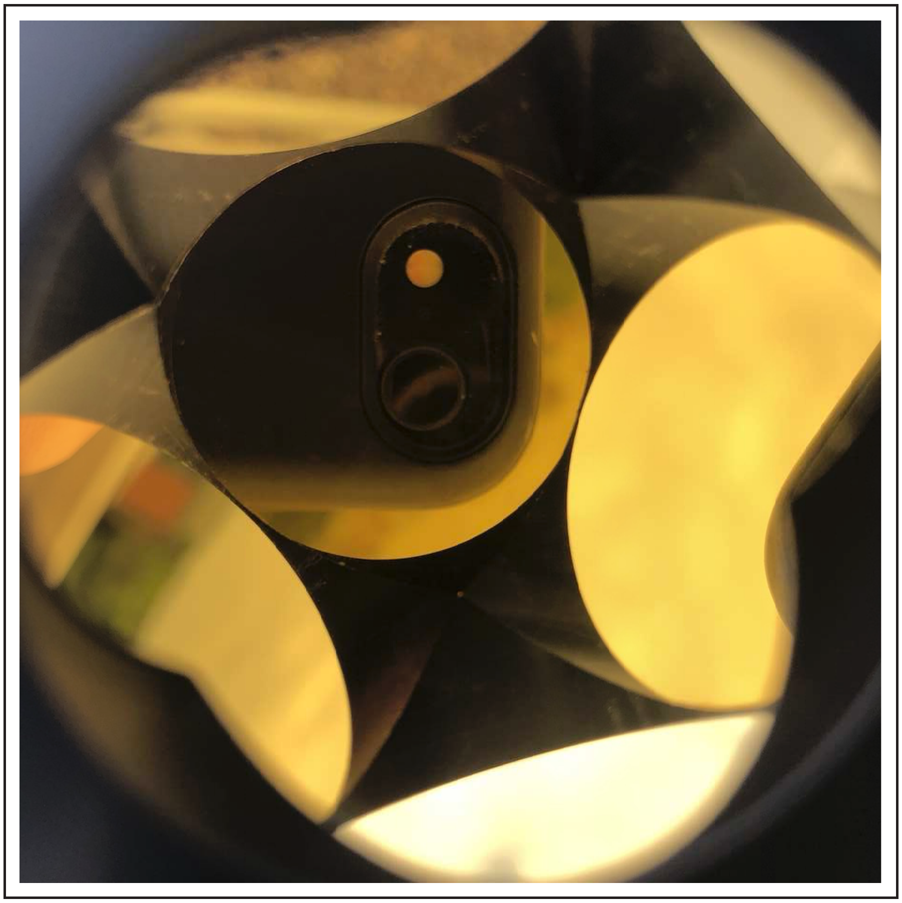
Sixteenth Annual Undergraduate Mini-Symposium

Department of Astronomy and Physics
Saint Mary's University
10:00 am – 3:00 pm, Friday September 6, 2019
Sobey 260 (presentations); Private Dining Room, LA 298 (lunch)



The internal retroreflector of the spectrometer (see abstract by C. Power).

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The Department of Astronomy and Physics

The Office of the Dean of Science

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Presentations in SB 260; Lunch in the Private Dining Room, LA 298

Programme

Opening remarks, SB 260 (Clarke)			10:00 – 10:10
1	R. Arsenault (Sarty)	*Construction of lead glass modules for an EM calorimeter*	10:10 – 10:30
2	C. Waterfield (Kanungo)	*Simulating beam transmission through the IRIS facility*	10:30 – 10:50
3	J. Hollett (Kanungo)	*Investigating the structure of neutron-rich calcium isotopes*	10:50 – 11:10
4	C. Power (Wiacek)	*Commissioning of the SMU atmospheric observatory*	11:10 – 11:30
5	S. Roy-Garand (Kanungo)	*Search for* 0^+ *excited states in neutron-rich krypton isotopes*	11:30 – 11:50
Department photo, front steps Main McNally			11:50 – 12:10
Lunch, PDR, LA 298 (Dean of Science)			12:10 – 12:50
6	M. McGrath (Gallo)	*What's got Mrk 335 so low?*	12:50 – 1:10
7	S. Waddell (Gallo)	*The identity crisis in Mrk 478: distinguishing AGN reflection models*	1:10 – 1:30
8	A. Hollett (Gallo)	*Detecting ultra-fast outflows in active galactic nuclei*	1:30 – 1:50
9	R. Tobin (Sarty)	*A look at Compton scattering events performed by the A2 collaboration: . . .*	1:50 – 2:10
10	H. Souchereau (Damjanov/Sawicki)	*Surface brightness profile extraction and analysis for big data*	2:10 – 2:30
Award deliberations/presentations (V. Hénault-Brunet and A. George)			2:30 – 3:00

Abstracts

1. *Construction of lead glass modules for an EM calorimeter*

Rémy Arsenault (Sarty)

The EM calorimeter is a useful instrument when studying the physical properties of electron-nucleon elastic scattering. High energy electrons will interact with the dense material within the calorimeter which will produce Bremsstrahlung radiation and pair-production. These effects will create a particle shower of photons inside of the calorimeter's modules and will be detected by photo-multiplier tubes. In this way, it is possible to measure the energy of the electrons (to within an uncertainty of 5%) and also their direction after they have been scattered elastically (region hit on the calorimeter can be measured to within 5 mm). The dimensions of the calorimeter's full frame are $1.5\,\mathrm{m} \times 4\,\mathrm{m}$. It needs to be ready by 2022 for installation in Hall A of Jefferson Lab.

2. *Simulating beam transmission through the IRIS facility*

Conor Waterfield (Kanungo)

Stars burn by fusing lighter elements into heavier elements, the majority of which involve neutron-rich or proton-rich nuclei. We can study the properties of these reactions through scattering experiments wherein beams of nuclei are accelerated onto a target, with the subsequent product angles and energies measured by detectors. At the IRIS facility at TRIUMF in Vancouver, nuclei interact with solid hydrogen or deuterium to probe the unknown characteristics of these nuclei with excess neutrons. Aside from the reactions themselves, there are many other effects which lead to loss of beam transmission through the entire setup. These must be understood in order to establish the beam tune on the target so as to correctly determine the cross section of the reaction. To assess these effects, one must first look at the conditions without the solid H_2 or D_2. I developed a Monte Carlo simulation by generating the beam particles and their interactions randomly. The calculation takes into account the effects of beam width, multiple scattering and Rutherford scattering. The percentage of hits at the end scintillator gives the transmission. This presentation will detail the method for creating this simulation and the results compared to the measured values.

3. *Investigating the structure of neutron-rich calcium isotopes*

Jacob Hollett (Kanungo)

The behaviour of neutron and proton rich nuclei that lie far from the region of stability is a matter of great scientific interest. This is because not only do these nuclei play important roles in stellar nucleosynthesis events such as the r-process, they also allow us to observe changes in the nuclear shell structure, which helps shape our understanding of the nuclear interaction. Such behaviour is often attributable to the existence of shell closures that occur at a few specific numbers of protons and neutrons. Forming a complete understanding of such shell closures requires knowledge of the orbital occupancies of these nuclei. Over the course of the summer of 2019, an experiment was conducted at TRIUMF—Canada's particle accelerator centre—to investigate such orbital occupancies in neutron rich calcium nuclei. These nuclei, with a conventional closed proton shell of $Z = 20$, draw interest with new neutron shells signalled at $N = 32$ and 34. An overview of the process will be discussed in this presentation.

4. *Commissioning of the SMU atmospheric observatory*

Cameron Power (Wiacek)

The SMU Atmospheric (not Astronomical!) Observatory became operational in May of 2019 after 5 years of fundraising, design, planning, and construction. This rooftop research space is currently dedicated to remote sensing of atmospheric composition, primarily using Fourier Transform Infrared (FTIR) spectroscopy. The gaseous composition of the atmosphere is probed using infrared absorption over a 224 m path between the Student Centre roof and the roof of the Rice Residence tower. To interpret these measurements, accurate knowledge of winds is necessary. However, Halifax is found in a complex flow environment, i.e., subject to coastal circulation systems, and the observatory is on top of an obstacle to flow. This talk will describe efforts to evaluate the newly installed wind measurements at the Observatory. The Observatory was also designed to support other atmospheric composition measurements with its easily accessible (tiled and railed) rooftop space. As such, in May and June of 2019 we hosted the Halifax Fog and Air Quality Study (HaliFAQS), which involved scientists from York and Dalhousie Universities operating their complementary instruments alongside ours. This talk will also describe efforts to characterize the suitability of the Observatory for *in situ* atmospheric measurements given the design compromises that had to be made.

5. *Search for* 0^+ *excited states in neutron-rich krypton isotopes*

Sebastien Roy-Garand (Kanungo)

Similar to electron models, in nuclear physics neutrons and protons arrange themselves in discrete energy orbitals forming the nuclear shell structure. Once all orbitals of a nuclear shell are occupied, this state is known as *shell closure*. Besides their fundamental importance, these particular nucleon arrangements are of interest because they impact nucleosynthesis processes such as the r-process. For the isotopes of Krypton, one of the shell closures occurs at $N = 50$ which, for the Krypton isotopes, is in ^{86}Kr. Further, certain theoretical models suggest there may be a subshell closure at $N = 56$ in ^{92}Kr. An interesting feature of coexistence of nuclear shapes is exhibited through 0^+ excited states near and beyond closed shells. Krypton isotopes in the region of $N = 50$–60 are of particular interest as evolution of the first 0^+ excited state in ^{92}Kr does not exhibit the behaviour of its atomic neighbours ^{88}Sr and ^{90}Zr. Located at TRIUMF, the ISAC Rare Isotope Reaction Spectroscopy station (IRIS)—a Saint Mary's led facility—was employed to study neutron-rich isotopes using nucleon transfer reactions. IRIS utilizes a solid deuterium target to perform the reactions ^{93}Kr(d,p)^{94}Kr and ^{93}Kr(d,t)^{92}Kr using a re-accelerated beam of ^{93}Kr. The presentation will describe the experiment and discuss some preliminary data analysis.

6. *What's got Mrk 335 so low?*

Maiti McGrath (Gallo)

The current model describing Active Galactic Nuclei (AGN) include a supermassive black hole actively accreting material. The accreted material and surrounding areas emit approximately evenly across the electromagnetic spectrum. Mrk 335 has been observed dimming significantly in the X-ray region, but the UV and optical emission do not show the same dimming. Through use of the spectral energy distribution (SED), the X-ray dimming over time is shown to lower the bolometric luminosity. The yearly SEDs that we were able to create show the changes over long and short timescales. These SEDs were then modelled using multi-wavelength data, and using the parameters from the modelling process we are looking to find the driving force of the changes within the SED.

7. *The identity crisis in Mrk 478: distinguishing AGN reflection models*

Sophia Waddell (Gallo)

Active Galactic Nuclei (AGN) are supermassive black holes which are actively accreting material. These objects are responsible for some of the most extreme and energetic phenomena in the Universe. Observing AGN in the X-ray regime allows for the study of the innermost regions of the black hole in an attempt to understand the inner structure and geometry. In this work, data spanning 16 years from a nearby AGN, Markarian 478, are processed and modelled. To explain the spectral shape and variability, we consider a commonly adopted scenario in which X-rays are emitted isotropically from a hot cloud of electrons (*i.e.*, corona) located some height above the black hole. Some of these photons are observed directly, while others are reflected off the accretion disk which surrounds the black hole before being observed. This process is modelled using two separate reflection codes, and the results are compared. While some parameters are in agreement between models, the interpretations differ dramatically. In one model, both coronal and reflected emission are required, while in the other, the emission is dominated by the reflected component. To distinguish between these models, we measure the light travel time between the X-ray emitting corona and the accretion disk. Doing so strongly favours the model with equal contributions from both components.

8. *Detecting ultra-fast outflows in active galactic nuclei*

Angelo Hollett (Gallo)

A 2010 paper by Tombesi et al. reports evidence for blue-shifted absorption features in the X-ray spectra of 35% of the active galactic nuclei (AGN) in their sample. These blue-shifted features are interpreted as highly ionized winds expelled from the accretion disk around the black hole, and are known as Ultra-Fast Outflows (UFOs). The presence of a UFO can affect star formation in the host galaxy, and the occurrence rate is important for understanding the evolution of both the host galaxy and local galaxies in a cluster. Analyzing the significance of these spectral features is therefore paramount to our understanding of galaxies. A new methodology is presented for measuring the statistical significance of spectral features. We find that in many cases the detection of a significant UFO candidate feature may be model- and binning-dependant, and also influenced by other factors during the data simulation and analysis process.

9. *A Look at Compton scattering events performed by the A2 collaboration: motivation, methods and data analysis*

Rebecca Tobin (Sarty)

Quantum Chromodynamics (QCD) is a theory for the strong interaction in which the force between quarks is mediated by the exchange of particles called gluons. QCD by itself is difficult to test at the *long-range* (lower energy) regimes associated with particle structure, but QCD-derived models that make various kinds of simplifications are able to produce testable predictions. Some of these models can make predictions about the structural properties (*e.g.*, spatial distribution of charge, total spin) of hadrons, which are particles composed of quarks (*e.g.*, protons, neutrons, pions). Therefore, experimentally determining these structural properties is one important avenue for testing these models. Of these structural properties is the polarizability, which quantifies a particle's response to electric and magnetic fields. Compton scattering experiments in which high energy photons are scattered off of protons can be used to determine their polarizability.

In this talk, I will explain how Compton scattering can be used to determine polarizabilities and describe how Compton scattering experiments are performed by the A2 collaboration at the Mainz Microtron in Germany, my place of work this summer. I will finish by discussing some of the functions of the data analysis program I wrote, which isolates Compton events from background signals and other reactions.

10. *Surface brightness profile extraction and analysis for big data*

Harrison Souchereau (Damjanov/Sawicki)

The surface brightness profile—the measure of a galaxys surface brightness as a function of distance from its centre—is a powerful tool in exploring the morphologies of galaxies and galactic evolution. We have developed and extensively tested an improved pipeline to extract these profiles for large datasets. We use multi-band images from the CLAUDS-HSC survey and process these images using a computer cluster on Compute Canada. From one subset of our data we have extracted 1.105 million profiles for analysis. We test limitations on the extraction across all bands to understand which objects are being successfully processed. The effects of the background on profile extents are tested using simulated galaxies, and through this we can determine how far to extend our profiles into the environment.

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