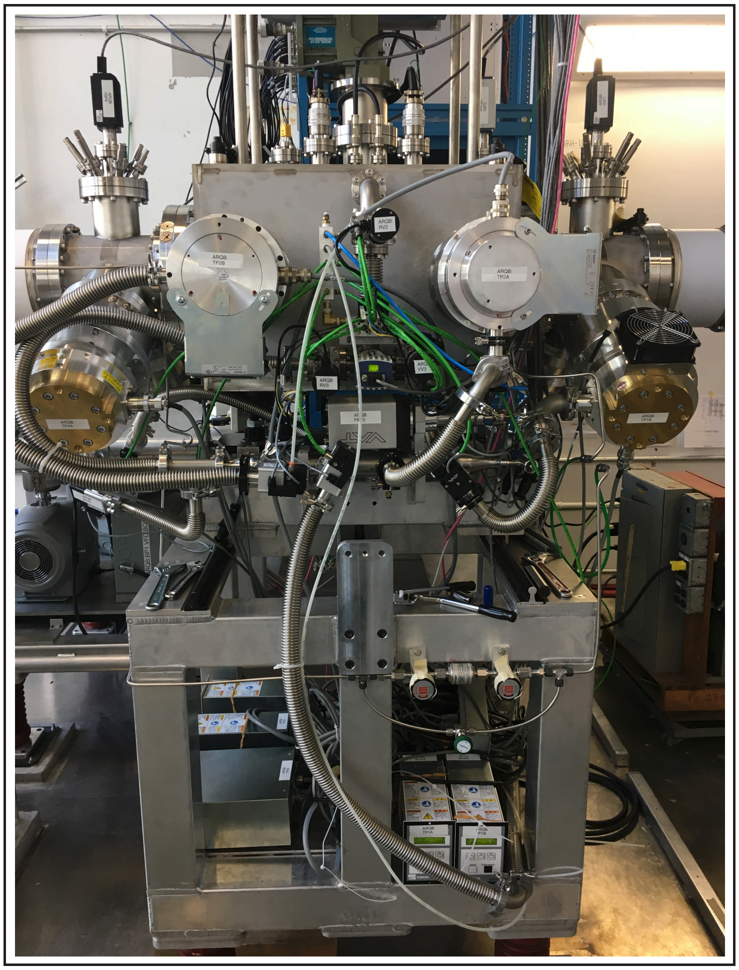
Fifteenth Annual Undergraduate Mini-Symposium

Department of Astronomy and Physics
Saint Mary's University
10:00 am – 3:00 pm, Friday September 7, 2018
Sobey 160 (presentations); Loyola 274 (lunch)



A Radio-Frequency Quadrupole beam cooler and buncher from the charge breeding component of CANREB located at TRIUMF (see abstract by S. Roy-Garand)

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The Department of Astronomy and Physics

The Office of the Dean of Science

Fifteenth Annual Undergraduate Mini-Symposium

Friday September 7, 2018, 10:00 am – 3:00 pm

Presentations in SB 160; Lunch in L 274

Programme

Opening remarks, SB 160 (Clarke)			10:00 – 10:10
1	M. Hellmich (Sawicki)	*Simulating Hubble XDF observations for the next generation of space telescopes*	10:10 – 10:30
2	H. Souchereau (Damjanov/Sawicki)	*Examining factors in galactic evolution using surface brightness profiles*	10:30 – 10:50
3	J. Laroche (Kanungo)	*Measuring the magnetic field flatness of TRIUMF's high resolution spectrometer*	10:50 – 11:10
4	S. Roy-Garand (Kanungo)	*RF integration and testing for a radio frequency quadrupole beam cooler and buncher*	11:10 – 11:30
5	M. McGrath (Gallo)	*Variability of the broadband SED of Mrk 335*	11:30 – 11:50
6	A. Hollett (Gallo)	*Calculating the statistical significance of features in the spectra of AGN*	11:50 – 12:10
Lunch, L 274 (Dean of Science)			12:10 – 12:50
7	C. Waterfield (Kanungo)	*Investigating the* ^{11}C(p,γ)^{12}N *cross-section using* ab initio *theory for measurement …*	12:50 – 1:10
8	I. Mackendrick (Kanungo)	*Time-projected chamber impurity measurements using electron drift velocity and …*	1:10 – 1:30
9	S. Waddell (Gallo)	*Spallation in active galactic nuclei*	1:30 – 1:50
10	J. Bayer (Short)	*Stellar structure and spectral line development for ChromaStarPy*	1:50 – 2:10
11	C. Power (Wiacek)	*How well are sea breezes captured in atmospheric dynamics models?*	2:10 – 2:30
Award deliberations/presentations (L. Chen and TBA)			2:30 – 3:00

Abstracts

1. *Simulating Hubble XDF observations for the next generation of space telescopes*

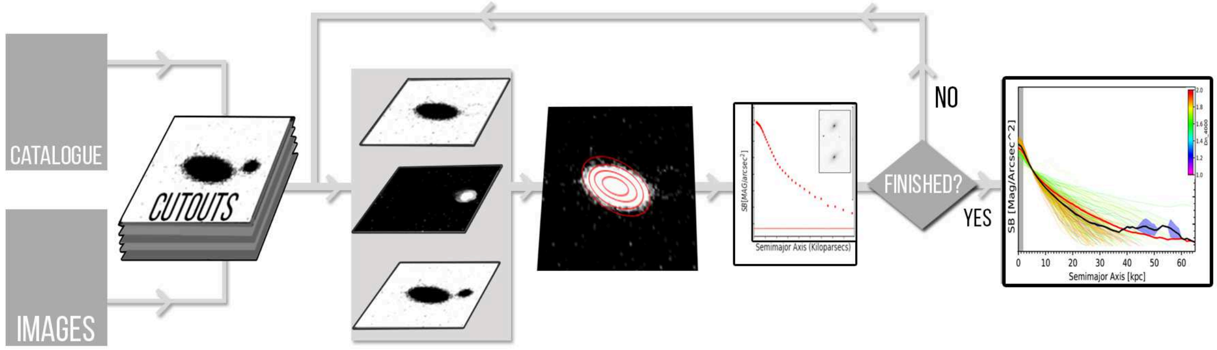
Martin Helmich (Sawicki)

From unprecedented depth and clarity of images to unleashing exploration into bandwidths invisible from earth, HST and its space-based contemporaries have set the path for further innovation to reach ever deeper into the universe. The next space telescope designs must balance resources to make sure they are properly equipped to answer our new questions in the post-Hubble era. Whether we want to probe the dark universe or understand galaxy evolution, the telescope has to fit the job. Factors such as the sensitivity of the instrument in different bandwidths, the size of the observable field, and the signal to noise ratio need to be estimated. This presentation outlines a method for creating simulated images of galaxies in the Hubble XDF given a proposed telescopes specifications. The method uses spectra models created from real Hubble observations for every pixel in the Extreme Deep Field. The method was used to simulate images for two space telescopes currently in development. The Cosmological Advanced Survey Telescope for Optical and ultraviolet Research (CASTOR) is a CSA mission rivalling Hubbles resolution in UV and optical bands, although it will cover a much larger field. CASTOR observations will be complimentary to NASAs Wide-Field Infrared Survey Telescope (WFIRST). Simulating images from both telescopes tests how the observations will work together. The simulation will help inform the design process and is the foundation for an observation planning tool for CASTOR as well as other instruments in the future.

2. *Surface Brightness Profiles*

Harrison Suchereau (Damjanov/Sawicki)

Surface brightness profile, the measure of a galaxy's surface brightness outward from its core, is an important tool in investigating the factors influencing the evolution of galaxies over cosmic time. Using images from the Hyper-Suprime Cam, a spectroscopic catalog of 16000 galaxies, and a custom processing pipeline, we build a catalog of surface brightness profiles for galaxies over redshift range $0.1 < z < 0.6$. We combine these profiles in bins of stellar mass and redshift to compute median surface brightness profile for galaxies in each bin (see flowchart, top of next page). For galaxies that ceased to form stars (quiescent systems) we find a trend with redshift: quiescent galaxies at lower redshift have progressively shallower profiles. All quiescent galaxies exhibit this trend in shape of their surface brightness profiles with redshift. However, less massive galaxies in our sample change their surface brightness profiles more rapidly than the most massive ones. For quiescent systems within individual stellar mass and redshift bins we find that galaxies harbouring older stars have steeper light profiles than their younger counterparts. Our results are consistent with an evolutionary scenario in which the average appearance of galaxies after they stop forming stars continuously changes over time through galaxy interactions and the evolution of star-forming galaxies that are becoming quiescent at later times in cosmic history.



Visual depiction of a surface brightness profile generation program, starting with a catalogue of objects and a set of images to individual surface brightness profiles and further analysis (H. Souchereau)

3. *Measuring the magnetic field flatness of TRIUMF's high resolution spectrometer*

Joseph Laroche (Kanungo)

The nuclei having either many more or less neutrons than stable isotopes, called rare isotopes, are bringing unexpected new information on nuclear structure and the role of these nuclei in element synthesis in our Universe. At TRIUMF, 500 MeV protons accelerated by the cyclotron are used to produce radioactive isotope beams which contain many unstable isotopes. For most experiments, all but one of these isotopes will be considered contaminants and will thus need to be filtered out. This is accomplished by using a magnetic spectrometer consisting of dipole magnet(s) in which a stream of particles passing through is separated by the particles' charge-mass ratio. Isobars, however, cannot be easily resolved with current mass spectrometers since their masses are so similar, with the need for higher resolving power increasing with mass [1]. The resolving power of the spectrometer required to resolve two specimens is m/dm where dm is the difference in mass between them and m is the specimen of interest [1]. A high resolution mass spectrometer (HRS), with two dipoles, was therefore constructed for the Canadian Rare Isotope Beam Facility with Electron Beam Ion Source (CANREB), with the goal of having a resolving power of 20,000 which would be able to resolve $> 50\%$ of any two combinations of isobars up to atomic mass 210 [1]. This technical milestone requires the magnetic field within the dipole to be constant in space or "flat" [1]. The rate at which current is passed through the coils of the magnet affects the flatness of the field with our goal of having a change in field dB/B no greater than 2.5×10^{-5}. In this presentation I will report on the field mapping study of the CANREB HRS in which I will describe the optimal procedure determined for achieving the best field flatness by systematic measurements of the magnetic fields at different locations within the dipole magnet with gradual increase and decrease of the current.

[1] Marchetto, M, 2003, *Magnetic field study for a new generation high resolution mass separator* , Laurea in Fisica, Università Degli Studi di Padova.

4. *RF integration and testing for a radio-frequency quadrupole beam cooler and buncher*

Sebastien Roy-Garand (Kanungo)

The CANadian Rare-isotope facility with Electron Beam ion source (CANREB) is a new expansion at TRIUMF, Canada's national particle accelerator centre. It is a partnership of Saint Mary's University and TRIUMF. With the addition of CANREB, high purity heavy ion beams of rare isotopes with high charge state can be delivered for post-acceleration for masses up to Uranium. This re-acceleration is needed to investigate the properties and nuclear reactions of rare isotopes in experiments such as TIGRESS, EMMA and IRIS. CANREB has a Radio-Frequency (RF) Quadrupole cooler and buncher (RFQ) that transforms the continuous beam of rare isotopes from the target-ion source into pulsed beams since that is most efficient for injection into the Electron Beam Ion Source (EBIS) which then charge breeds the beam to match the requirements for post-acceleration by the superconducting linear accelerator. The RFQ is composed of the quadrupole as well as trapping electrodes. The tuning of both the direct current (DC) used on the trapping electrodes and the RF quadrupole is vital to the yield of the EBIS. An issue when operating at frequencies on the order of MHz is RF feedback through DC inputs. To counter the issue, multiple filters had been tested such as a knotch filter, low-pass filter, and an inductive filter. Although their main use was to dissipate the RF which made it into the DC, it was essential that the incoming square DC pulse remain unaffected. Each of the filter configurations will be presented as well as their tested results. When properly tuned the incoming beam will be confined transversely and discretely trapped in the direction of motion, all with minimal losses.

5. *Variability of the broadband SED of Mrk 335*

Maiti McGrath (Gallo)

Active galactic nuclei (AGN) are described by our current model of a supermassive black hole that is actively accreting material. AGN emit across all wavelengths and can vary in all wavelengths as well. We present analysis of the optical-to-X-ray spectral energy distributions (SED) shape and variability since Mrk 335 went into a low-flux state in the past eleven years. Previous works have investigated the average low-flux data, but this work will examine the variability from one year to the next. Our current hypothesis is that the changes are predominately isolated to the X-ray band and less important in the other bands. The changes are likely occurring in the X-ray corona.

6. *Calculating the statistical significance of features in the spectra of AGN*

Angelo Hollett (Gallo)

Studying the central region of a galaxy is essential in understanding the evolution and various other properties of the host galaxy. Probing the centres of galaxies reveals supermassive black holes (SMBHs) which, when actively accreting material, produce active galactic nuclei

(AGN). These AGN nurture complex and extreme environments. A 2010 paper by Tombesi *et al.* reports evidence for blue-shifted features in the spectra of many AGN. These blue-shifted features are proposed to be explained by the presence of a highly ionized wind leaving the accretion disk of the AGN. These winds are deemed ultra-fast outflows (UFOs). Given a specific orientation of the AGN, our line of sight may coincide with the UFO, thus allowing us to detect these spectral features. The presence of a UFO has major implications on various properties such as the evolution of the host galaxy. Thus, analysing the significance of these spectral features and therein the presence of a UFO is paramount to our understanding of galaxies. A new methodology is presented in testing for spectral features and measuring the statistical significance of these features. We conclude that in some cases, the detection of a strong UFO feature is model and binning dependant, and affected by other factors during the data simulation and analysis process.

7. *Investigating the* ^{11}C(p,γ)^{12}N *cross section using* ab initio *theory for measurement at TRIUMF*

Conor Waterfield (Kanungo)

Stars are powered by the fusion of elements in their cores, releasing energy by converting lighter elements into heavier elements. Over the course of its life, the star goes from burning hydrogen in the proton-proton chain to burning carbon in the Carbon-Nitrogen-Oxygen (CNO) cycle. In order to make this leap there must be some process which produces the necessary elements to begin the CNO cycle. It is thought this is achieved through the fusion of three alpha particles (^{4}He nuclei) resulting in ^{12}C. Finding alternatives to this process which may occur earlier during the stars life is important for better understanding the life cycle of stars [1,2]. One potential alternative is through ^{11}C(p,γ)^{12}N that may beta decay into ^{12}C and reach the CNO cycle [3]. This reaction's rate is not well known experimentally. In order to plan an experimental investigation of this reaction at TRIUMF, we studied the reaction kinematics and the theoretical prediction of the cross section. The cross section calculation was carried out using *ab initio* theoretical models at different centre of mass energies, which is useful to compare to other reactions and to determine the possibility of measuring the cross section experimentally at higher energies to test the theory at lower, astrophysically relevant energies. The results will be discussed in the presentation.

[1] Lee, D. W., Powell, J., Peräjärvi, K., Guo, F. Q., Moltz, D. M., & Cerny, J., (2011). *Study of the* ^{11}C(p,γ) *reaction via the indirect* d(^{11}C,^{12}N)n *transfer reaction* [Abstract]. Journal of Physics G: Nuclear and Particle Physics, 38(7), 075201. doi:10.1088/0954-3899/38/7/075201

[2] Tang, Xiaodong & Azhari, Ahmad & Gagliardi, CA & Mukhamedzhanov, Akram & Pirlepesov, Fakhriddin & Trache, Livius & Tribble, R & Burjan, V & Kroha, V8clav & Carstoiu, Florin, (2003). *Determination of the astrophysical S factor for* ^{11}C(p,γ)^{12}N *from the* ^{12}N$\rightarrow$^{11}C + p *asymptotic normalization coefficient* [Abstract]. Phys. Rev. C, 67. 10.1103/PhysRevC.67.015804.

[3] Guo, B., Li, Z. H., Liu, W. P., & Bai, X. X., (2006). *Determination of astrophysical* ^{11}C(p,γ)^{12}N *reaction rate from the asymptotic normalization coefficients of* ^{12}B$\rightarrow$^{11}B n [Abstract]. Journal of Physics G: Nuclear and Particle Physics, 34(1), 103-114. doi:10.1088/0954-3899/34/1/006

8. *Time-projected chamber impurity measurements using electron drift velocity and a MicroMEGas detector*

Ian Mackendrick (Kanungo)

An active target time projection chamber is a device that is used both as a target and detector for measuring reaction products using rare isotope beams. The device uses various types of gases as the target and detection material. It is particularly useful for measuring very low energy reaction products while using a thick target, as well as targets that can only be available as gases. Such a device is currently being used at the National Superconducting Cyclotron Laboratory at Michigan State University where our projects are on reactions with proton-drip line nuclei. To characterize the performance of this device, we need to understand various aspects one of which is the drift velocity in the gas.

After measurements of fission-fusion cross section of Pb nuclei, observations in drift velocity in the active target time projection chamber were not as expected from previous values. The drift velocity was a factor of two slower than previous experiments. The assumption is that it is gas impurities that is causing this unknown change. This work undertakes a study to analyze gas impurities using a down sized drift chamber and a MicroMEGas (micro-mesh gaseous) detector. Gases such as CH_4 and P10 (90% Ar, 10% CH^4) were tested thoroughly after performing adequate tests on the detector. Initially, air impurities were added slowly but did not receive the desired change in the drift velocity. It was not until trying water vapour that the drift velocity changed by the factor of two concluding that this is the cause of the discrepancy from previous experiments. The presentation will report on the results of this study.

9. *Spallation in active galactic nuclei*

Sophia Waddell (Gallo)

Spallation occurs when high energy particles (cosmic rays) are incident on an atomic nucleus. This causes nucleons to be ejected from the nucleus, effectively creating a lower Z element. This process creates over-abundances of some elements. We consider the effect that spallation of iron has on the spectra of active galactic nuclei (AGN), in particular, the spallation of iron creating higher than solar abundances of Mn, Cr, V and Ti and an under-abundance of Fe. This result has previously been reported in numerous AGN spectra. We expand upon previous work by using a new spallation model calculated by J. Randhawa, and by modelling the spallation of iron in neutral, ionized, and relativistically blurred sources. Simulations of the resulting spectra are presented. We will also consider the differences between the resolution of XMM-Newton and the Hitomi (and future XRISM) instruments. From the simulations, we can conclude that spallation from neutral sources may be detected with XMM with careful analysis, while XRISM will likely allow us to resolve clearly spallation in both neutral and ionized sources, and examine different spallation models.

10. *Stellar structure and spectral line development for ChromaStarPy*

Jason Bayer (Short)

ChromaStarPy is a stellar atmosphere and spectrum modeling code written in python designed to give good approximations of stellar spectra, whilst being easily accessible to students at a wide range of levels. We present several projects including:

1. Incorporating a more accurate interpolation of temperature-dependent partition functions;
2. Fitting more realistic limb darkening curves to surface intensity distributions; and
3. Using a new model atom treatment for spectral lines.

The new limb darkening curves are based on fitting a linear limb darkening law to the surface intensity distribution separately at each wavelength, and produce more accurate limb darkening coefficients (LDCs). The improved partition function treatment is based on fitting a cubic interpolation function to the variation with temperature and produces smooth variations of number densities of elements in each ionization stage with depth. The new model atom treatment allows us to improve the treatment of natural line broadening, producing line profiles that are closer to the observed line width.

11. *How well are sea breezes captured in atmospheric dynamics models?*

Cameron Power (Wiacek)

The Tropospheric Remote Sensing Laboratory (TRSL) uses a Fourier transform infrared (FTIR) spectrometer to record atmospheric trace gas absorption spectra near the surface. To interpret these measurements, accurate knowledge of winds is necessary. However, Halifax is found in a complex flow environment, *i.e.*, subject to sea breeze and other coastal circulation systems. Typically, wind information is obtained from atmospheric dynamics models implemented with a horizontal resolution of the order of tens of km. The first part of this presentation will review the sea breeze circulation. Next, the representation of sea breezes in both *in situ* measurements and model outputs will be compared. The second part of this presentation will introduce the field work conducted at the Canadian Forces Base Halifax Dockyards to measure atmospheric composition and quantify instrument bias between the FTIR spectrometer and co-located *in situ* instrumentation.

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