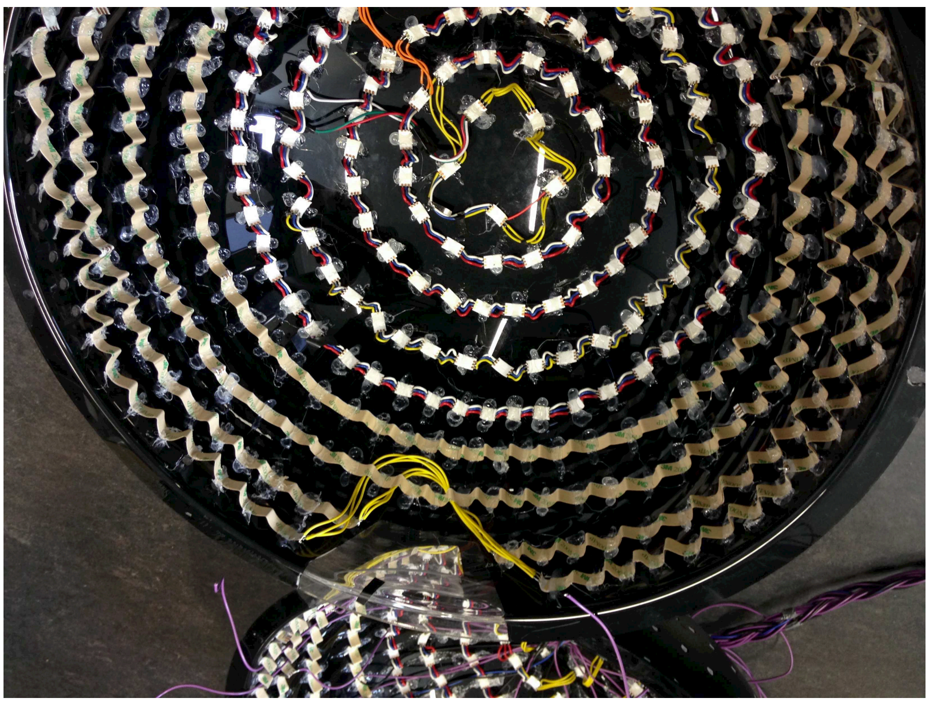
Fourteenth Annual Undergraduate Mini-Symposium

Department of Astronomy and Physics
Saint Mary's University
10:00 am – 3:00 pm, Friday September 8, 2017
Sobey 160 (presentations); Private Dining Room (L 298; lunch)



Deconstructed model of the Crystal Ball detector at MaMi (see abstract by A. Benson)

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The Department of Astronomy and Physics

The Office of the Dean of Science

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Presentations in SB 160; Lunch in the Private Dining Room (L 298)

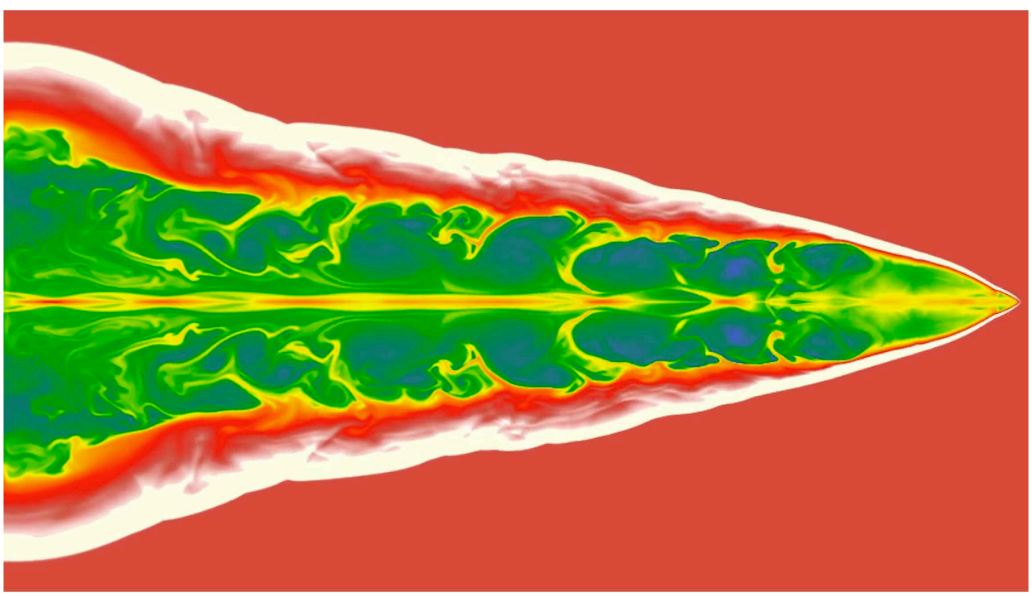
Programme

Opening remarks, SB 160 (Clarke)			10:00 – 10:10
1	M. Power (Clarke)	*The theory of ambipolar diffusion (AD), with applications to protostellar jets*	11:10 – 11:30
2	A. Benson (Sarty)	*Rebuilding the Crystal Ball model and detector-related hardware projects at the Mainzer Microtron*	10:10 – 10:30
3	J. Bayer (Short)	*Interface and hydrogen line development for ChromaStar: a stellar atmosphere and spectrum modelling code*	10:30 – 10:50
4	L. Burns (Short)	*ChromaStar: new exoplanets and atmospheric improved modeling*	10:50 – 11:10
5	T. Gray (Wiacek)	*Sensitivity analysis of spectroscopic retrievals of atmospheric composition*	11:30 – 11:50
6	M. Al-Saegh (Sawicki)	*Simulation of cosmic colonization*	11:50 – 12:10
Lunch, Private Dining Room (L 298) (Dean of Science)			12:10 – 12:40
7	M. Hellmich (Kanungo)	*Reaction spectroscopy with neutron-rich* ^{6}*He isotope*	12:40 – 1:00
8	S. Waddell (Gallo)	*A spectral analysis of active galactic nuclei III Zw 2 and Zw 229.015*	1:00 – 1:20
9	D. Gallant (Gallo)	*Principal component analysis of the X-ray spectra of blazars*	1:20 – 1:40
10	D. Blue (Gallo)	*Ten years monitoring Mrk 335*	1:40 – 2:00
11	J. LaRoche (Sarty)	*Quality testing and production of Pb glass pieces to be used in Super Bigbite Spectrometer's electron calorimeter (ECAL)*	2:00 – 2:20
Award deliberations/presentations (T. Fields and I. Damjanov)			2:20 – 3:00

1. *The theory of ambipolar diffusion (AD), with applications to protostellar jets*

Michael Power (Clarke)

The problem of star formation is fundamental to our understanding of the universe. Often, before stars can fully collapse and begin their fusion process, they must "bleed off" a large amount of their angular momentum to overcome the "centrifugal barrier" preventing their collapse. To expel this angular momentum, protostars launch an outflow from their accretion disks in the form of a jet. Morphologically, both hydrodynamical (HD) and magnetohydrodynamical (MHD) simulations of protostellar jets differ significantly from astrophysical observations, which may indicate a gap in the theory. Ambipolar diffusion (AD) seeks to close this gap by operating in a realm between HD and MHD, allowing for partial ionization of the fluid. Research conducted this summer focused on developing and subsequently understanding the mathematics behind non-isothermal AD using the so-called one-fluid model, which was then applied to a protostellar jet using the *ZEUS-3D* MHD code. These preliminary 2-D axisymmetric simulations seem to suggest that AD allows some jet material to slip past magnetic field lines, which may help bridge the morphological gap between the simulations and observations. Future work will focus on developing the so-called two-fluid model of AD, implementing that into *ZEUS-3D*, and performing fully 3-D simulations.



A 2-D axisymmetric simulation of a magnetohydrodynamical jet (M. Power).

2. *Rebuilding the Crystal Ball model and detector-related hardware projects at the Mainzer Microtron*

Annika Benson (Sarty)

This talk presents an overview of the two main detectors used in the A2 hall of the Mainzer Microtron, and aims to outline the related hardware projects undertaken during the summer of 2017. It will focus on the "Tagger" and the "Crystal Ball", which are responsible for inferring photon energy, and providing energy and timing information about scattered particles, respectively. During the summer of 2017, the Tagger was being upgraded, requiring the assembly of a housing unit for the individual scintillator and light guide pairs, and the design of a mounting device for the scintillator towers. The Crystal Ball also underwent renovation, during which broken Photomultiplier tubes were identified, and replacement parts were tested. In 2016, a model of the Crystal Ball was constructed by summer students which, by 2017, had greatly deteriorated. In order to return the model to its original purpose, it was deconstructed, a new wiring schematic was designed, and the model was rebuilt such that it would be safer and more durable than its original version.

3. *Interface and hydrogen line development for ChromaStar: a stellar atmosphere and spectrum modelling code*

Jason Bayer (Short)

ChromaStar is a stellar atmosphere and spectrum modelling code designed to give approximations of stellar observables. We report on several projects to create a more interactive interface, and more realistic spectra. The output was converted to Scalable Vector Graphics (SVG), allowing interactivity to be added to all plots. Special pedagogical markers were added to show how the observable spectral line profile of a user-defined two-level atom and the atmospheric structure are related. The treatment of the hydrogen Balmer spectral line profiles was made more precise to relate more closely with observables of A stars. Through this research it can be seen that it is possible to create fast, interactive, and precise tools that can be useful for small research projects and in a classroom setting.

4. *ChromaStar: new exoplanets and atmospheric improved modelling*

Lindsey Burns (Short)

ChromaStar is a responsive, approximate stellar atmosphere and spectrum modelling code written entirely in JavaScript and HTML that runs in a Web browser, and that also models the habitable zone around the star for planetary surface conditions adjustable by the user. I have supplemented the built-in library of stars by adding the important exoplanet hosts Proxima Centauri and Fomalhaut. I have made the atmospheric modelling more general by adding the ability to set the chemical abundance values to non-solar distributions accounting for three types of chemical peculiarity: He-rich A and B stars, C-enriched AGB stars, and alpha-enriched metal poor RGB stars. I have improved the physical realism of the stellar atmospheric modelling by replacing the approximation of partition function values based on crude interpolation among two temperature values with a more realistic one based on more recent data and interpolation among five temperature values. This yields ionization equilibrium results that vary more smoothly as a function of depth.

5. *Sensitivity analysis of spectroscopic retrievals of atmospheric composition*

Taylor Gray (Wiacek)

The Tropospheric Remote Sensing Laboratory (TRSL) uses a Fourier transform infrared (FTIR) spectrometer to record atmospheric trace gas absorption spectra in a horizontal segment of the troposphere at the Earth's surface, so called open-path FTIR spectroscopy. Spectra acquired in this way are analyzed using a nonlinear least squares (NLLS) fitting routine. A forward model of atmospheric absorption is iteratively adjusted to determine the concentration of trace gases and instrumental parameters which lead to a best fit between measured and modelled spectra. In atmospheric physics, this process is called a retrieval. This summer, a sensitivity analysis of the NLLS routine "MALT" was performed to characterize the behaviour of retrievals of NO_2, which is an important atmospheric trace gas involved in tropospheric O_3 production. Retrieval parameters such as NO_2 spectral band, spectral window width, water vapour concentration, and atmospheric path length impact the information content of the spectra with respect to the target gas (NO_2) and the stability of the computational retrieval process itself. This talk will give an overview of these effects in the search for an optimal NO_2 retrieval.

6. *Simulation of cosmic colonization*

Mahassen Al-Saegh (Sawicki)

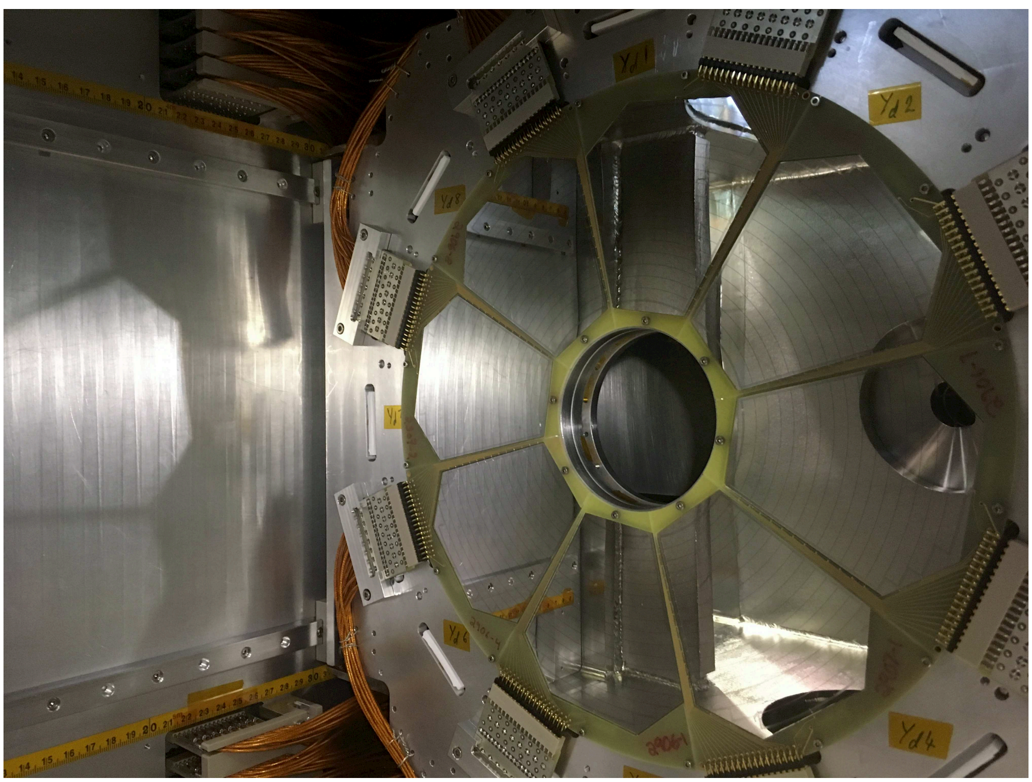
The goal of this research is to study the colonization process on the cosmic scale. Here we consider the colonizers to be a very advanced civilization which can travel between clusters of galaxies rather than colonizing single planets within a single galaxy. We investigated how colonization proceeds in both static and expanding universes. Our universes also contain galaxy clusters and filaments distributed along the "Cosmic Web" which we model using Voronoi tessellations.

As expected, we found that a static universe can be colonized more quickly than an expanding one. Our new result is that colonization proceeds more slowly in universes that contain a Cosmic Web as compared to homogenous universes.

7. *Reaction spectroscopy with neutron rich* ^{6}*He isotope*

Martin Hellmich (Kanungo)

New structures found in neutron-rich nuclei show potential to further our knowledge of the strong nuclear force and the synthesis of elements in the universe. Accelerated beams of neutron-rich nuclei are produced at specialized accelerator facilities, such as TRIUMF, Canadas national laboratory in Vancouver. Nuclear reactions with these neutron-rich nuclei are then investigated using the IRIS reaction spectroscopy facility, an infrastructure led by Saint Marys University at TRIUMF. In this presentation, I will describe a recent experiment at IRIS using an exotic isotope ^{6}He interacting with a ^{116}Sn target. One of the interests was to search for the Giant Pairing Vibration (GPV) state, which is a collective resonance mode predicted in 1977 by Broglia and Bes [1]. In a previous experiment performed at the INFN-LNS laboratory in Catania, Cappuzzello et al. [2] reported resonances in ^{14}C and ^{15}C consistent with GPV. A collective GPV mode is however expected to be more prominent in heavier nuclei with many nucleons, so its non-observance thus far remains an unsolved mystery. In our experiment, the GPV resonance in ^{118}Sn was searched for through two-neutron transfer from ^{6}He onto ^{116}Sn. In order to interpret the cross sections of such transfer processes, one needs knowledge on the interaction potential between ^{6}He and ^{116}Sn. Therefore, a second aim is to investigate the elastic scattering cross section of this neutron-rich nucleus in order to derive the interaction potential of ^{6}He and ^{116}Sn from it. Unlike ^{4}He that is abundantly found on earth, ^{6}He has an unusual structure of a two-neutron halo. Because of the relatively weak binding of the two-halo neutrons in ^{6}He, the two-neutron



An array of detectors are used in the IRIS experiment to identify and analyze reaction products. This photo of a silicon detector downstream of the target was taken during setup time when the main chamber is briefly vented from vacuum and opened for detector positioning (M. Hellmich).

transfer reaction has a large Q value thereby increasing the probability of populating the GPV state at high excitation energy. The properties of these neutron-rich nuclei then guide our understanding of how nuclear structure evolves from stable to unstable nuclei and their role in element synthesis in the universe.

[1] Broglia, R. A. & Bes, D., *High-lying pairing resonances*, Phys. Lett. B 69, 129133 (1977)

[2] Cappuzzello, F. *et al.*, *Signatures of the Giant Pairing Vibration in the* ^{14}C *and* ^{15}C *atomic nuclei*, Nat. Commun. 6:6743 doi: 10.1038/ncomms7743 (2015).

8. *A spectral analysis of active galactic nuclei III Zw 2 and Zw 229.015*

Sophia Waddell (Gallo)

Active Galactic Nuclei (AGN) are thought to be powered by supermassive black holes which are actively accreting material. AGN demonstrate variability across all wavelengths including X-ray, the emission range studied in this work. This presentation will first introduce AGN and explain some classifications. It will be followed by examining the X-ray spectral data from XMM-Newton, Suzaku and Swift on two selected objects; the radio-intermediate AGN III Zw 2 and the radio-quiet Zw 229.015. Various models will be presented for these data in an attempt to explain the inner machinery of these objects. Multiepoch observations will be used to show the X-ray variability of these two objects over time. For III Zw 2, spectral differences between observations are critically examined, and it is hypothesized that the spectral variability arises from a precessing jet.

9. *Principal component analysis of the x-ray spectra of blazars*

Dennis Gallant (Gallo)

Principal component analysis (PCA) is a data reduction and analysis technique that can reveal underlying trends in a data set in a model-independent manner. It has seen use in many diverse fields, such as statistics, economics, and neuroscience. Only recently, however, have enough high quality data been gathered to begin applying this technique to x-ray astronomy. This talk introduces PCA and demonstrates its application on the x-ray spectra of a sample of blazars. With PCA, spectral features of these objects can be identified even in cases where those features are not apparent from the spectra alone.

10. *Ten years monitoring Mrk 335*

Derek Blue (Gallo)

The Seyfert 1 Active Galaxy Mrk 335 has been the subject of a ten-year long monitoring campaign, throughout which X-Ray, UV, and optical instruments on the satellite telescope Swift have taken periodic observations of the AGN. Unfortunately the resulting data are unevenly sampled with large gaps in some of the optical filter observations. To overcome this, a structure function and discreet correlation function were chosen for their ability to deal with uneven sampling and large gaps without suffering from windowing and aliasing. Here I present the results of these two methods.

11. *Quality testing and production of Pb glass pieces to be used in Super Bigbite Spectrometer's electron calorimeter (ECAL)*

Joseph LaRoche (Sarty)

The Super Bigbite Spectrometer (SBS) is an experimental facility under construction at Jefferson Lab in Virginia. ECAL is a Pb glass calorimeter in development, which will be used in SBS, that is designed to measure the energy deposited by deflected electrons with energy between 4–5 GeV. Through a process called thermal annealing, ECAL holds component glass blocks at 200°C in order to reverse the effect of exposure to very high levels of ionizing radiation, and ensure proper functioning for the experiments. In order not to overheat the photomultiplier tubes collecting the light from the detector, a cylindrical borosilicate piece of glass is fixed between the photomultiplier tube and the block, serving as a thermal gradient as well as a light guide. This presentation outlines the procedures for gluing the light guides to the glass blocks and quality testing the alignment and transparency of the resultant glass pieces. Additionally, this presentation discusses the thermal expansion of a Pb glass block, which was found by measuring its change in length as a function of its temperature, yielding a coefficient of thermal expansion of $(8.94 \pm 0.07) \times 10^{-6}\,\mathrm{K}^{-1}$. This result was found to be consistent with researched values of the thermal expansion of various types of glass.

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