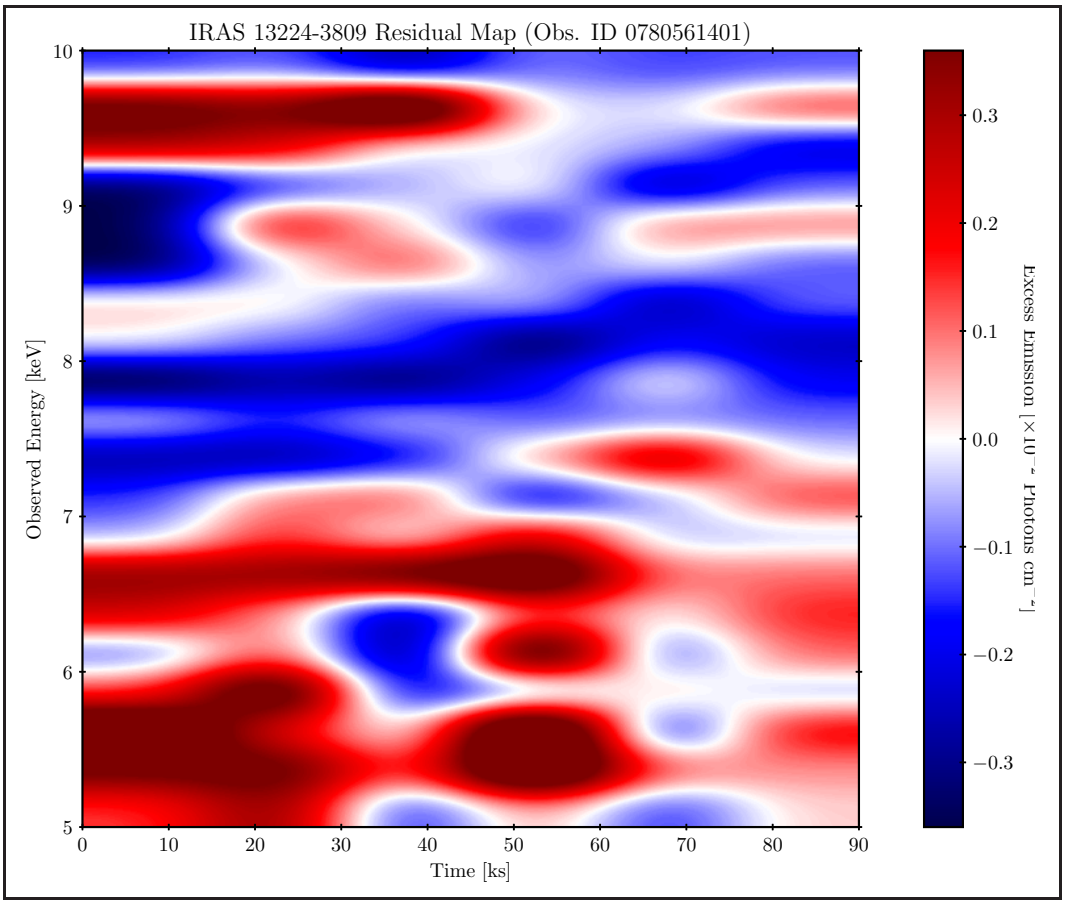
Seventeenth Annual Undergraduate Mini-Symposium

Department of Astronomy and Physics
Saint Mary's University
10:00 am – 3:00 pm, Friday September 11, 2020
On-line version; to be held on *Zoom* (passcode 171717)



Residuals for a continuum fit to the source spectrum. Red regions indicate positive residuals (emission), blue regions indicate negative residuals (absorption). (see abstract by A. Hollett).

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The Department of Astronomy and Physics

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All events happening on *Zoom* (passcode 171717)

Programme

Opening remarks (Clarke)			10:00 – 10:10
1	M. McGrath (Gallo)	*The connection between the x-ray and radio emission in jets*	10:10 – 10:30
2	A. Hollett (Gallo)	*IRAS 13224-3809: windy or warm?*	10:30 – 10:50
3	C. Power (Wiacek)	*Temperature and pressure dependence in spectral retrievals of carbon monoxide*	10:50 – 11:10
4	O. Leste (Damjanov)	*Spectroscopic analysis of galaxies with tidal tidal features*	11:10 – 11:30
5	P. Smith (Henault-Brunet)	*Using pulsar accelerations to probe the black hole content of 47 Tuc*	11:30 – 11:50
Zoom photo, stay put!			11:50 – 12:00
Brown bag lunch; *Zoom* will remain open			12:00 – 12:30
6	C. Waterfield (Kanungo)	*Searching for the signature of a tetraneutron resonance*	12:30 – 12:50
7	R. Arseneault (Henault-Brunet)	*Simulating the effects of binary systems on radial velocity surveys of . . . NGC 3201*	12:50 – 1:10
8	J. Hollett (Kanungo)	*Investigating the structure of neutron-rich calcium isotopes*	1:10 – 1:30
9	M. Harvey (Cisek)	*Construction of a wide-field second harmonic generation microscope*	1:30 – 1:50
10	A. Battson (Henault-Brunet)	*The mass-to-light ratio discrepancy of metal-rich globular clusters*	1:50 – 2:10
Award deliberations/presentations (G. Christian and TBA)			2:10 – 2:30

Abstracts

1. *The connection between the x-ray and radio emission in jets*

Maiti McGrath (Gallo)

A precursory investigation into analysis techniques to be used in a sample study focused on the connection between the radio and x-ray emitting regions in the jets of active galaxies. The source used for the testing was the blazar 3C 279. Techniques were examined to analyze the correlation between light curves, the variation of the light curves, and the power spectrum of the light curves. Given these techniques, a sample study will follow and these results will be compared against intrinsic black hole properties such as mass, accretion rate, and jet power.

2. *IRAS 13224-3809: windy or warm?*

Angelo Hollett (Gallo)

The centres 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 centres 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 ionised 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.

See figure on cover page.

3. *Temperature and pressure dependence in spectral retrievals of carbon monoxide*

Cameron Power (Wiacek)

Open-Path Fourier Transform InfraRed (OP-FTIR) spectroscopy is an established technique used to measure boundary layer trace gas concentrations, *e.g.*, in "fenceline monitoring" of industrial emissions. The measurement is made by sending an infrared beam to a distant retroreflector and recording the returned signal spectrum, which contains signatures of multiple trace gas absorptions in the beam path. "Retrievals", i.e., inversions, can be performed

on these IR absorption spectra to determine the underlying gas concentrations., although these inversions must be constrained with additional input parameters. The parameters include:

1. initial concentrations of expected target trace gases;
2. spectral continuum variables;
3. instrumental values determined by the hardware configuration; and
4. environmental variables of pressure and temperature.

This talk will describe numerical experiments exploring the sensitivity of carbon monoxide (CO) concentration retrievals to different sources of temperature and pressure data. CO is an important atmospheric pollutant, which leads to urban ground level ozone production.

4. *Spectroscopic analysis of galaxies with tidal features*

Ophélie Leste (Damjanov)

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 $\sim$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 $\sim$1,500 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.

5. *Using pulsar accelerations to probe the black hole content of 47 Tuc*

Peter Smith (Henault-Brunet)

Globular clusters (GCs) have long been thought to be ideal candidates to host Intermediate Mass Black Holes (IMBHs). Recently, the GC 47 Tuc has been subject to claims that it may host a central IMBH, with accelerations derived from pulsar timing being used to support this model. To investigate these claims, we fit multi-mass models with varying amounts of dark

mass to the available observational constraints. Our best fitting models accurately reproduce the kinematics of the cluster and incorporate pulsar accelerations into the fitting pipeline. When we compare the results of the fitting which incorporate pulsar accelerations and those that don't, we find a good agreement in the model parameters as well as in the black hole content. For both sets of models, the mean of the posterior probability distribution of the mass in black holes is roughly 450 $M_{\odot}$ although the models fitted on the pulsar accelerations allow for a slightly greater mass. Given that the proposed mass of the IMBH in 47 Tuc is $\sim$2,300 $M_{\odot}$ we conclude that with the current pulsar acceleration data there is no need to introduce a central IMBH in 47 Tuc. We finally discuss possible issues with previous results as well as future directions.

6. *Searching for the signature of a tetraneutron resonance*

Conor Waterfield (Kanungo)

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 understand better 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 under debate, and it is an open question whether they can be held together briefly in a short-lived resonant state. The existence of the tetraneutron 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 launching 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.

7. *Simulating the effects of binary systems on radial velocity surveys of globular clusters: the case of NGC 3201*

Rémy Arsenault (Henault-Brunet)

The velocity dispersion of stars within a globular cluster can be used to probe its internal mass distribution. In the cluster NGC 3201, the observed radial velocity dispersion in the outer regions is significantly higher than what is expected from N-body simulations of a cluster made of single stars. This discrepancy could in principle be explained by the presence of dark matter surrounding the cluster, but escaping and tidally stripped stars and/or the presence of undetected binary systems could also inflate the observed velocity dispersion. This research project focuses on the possibility that undetected binaries are the cause of this discrepancy.

Using a realistic binary population from a snapshot of a simulation of the globular cluster

NGC 3201 (from the MOCCA Database), we create mock radial velocity measurements with time sampling and observational uncertainties that mimic the radial velocity observations of the outer regions of this cluster. We apply a statistical method based on the χ^2 distribution to these simulated observations, allowing to estimate the probability of each star to be variable. The stars with a low probability of being variable include true single stars but also undetected binary systems. We conclude by discussing the possible effects of these undetected binaries on the velocity dispersion in the outer regions of NGC 3201.

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

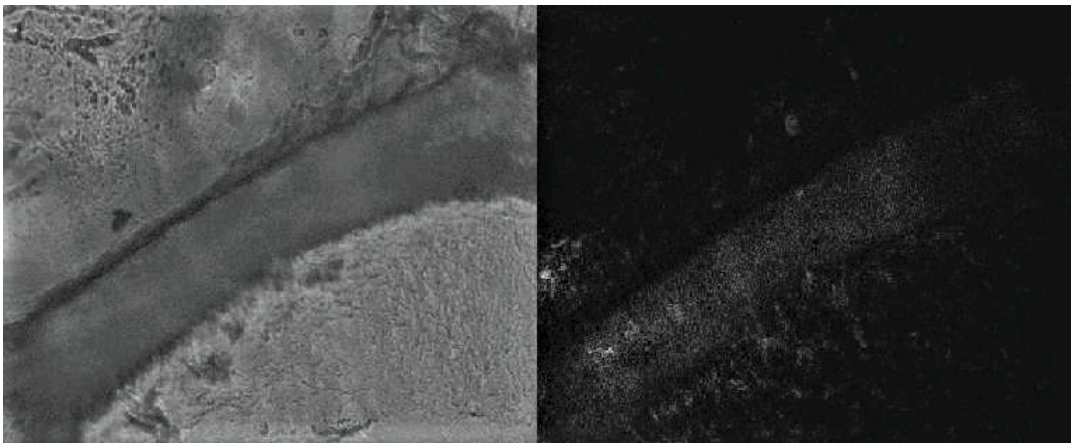
Jacob Hollett (Kanungo)

In stable nuclei, the seemingly regular patterns of a number of observables have long since been successfully described by a shell model framework that results in particularly stable nuclei having closed shells that occur at specific neutron and/or proton numbers. However, this picture is shown to change in short-lived, exotic nuclei that exhibit extremely asymmetric proton to neutron ratios. In observing these changes in shell structure, we are further improving our understanding of the nuclear interaction. Forming a complete understanding of shell structure and associated shell closures requires knowledge regarding the orbital occupancies of these exotic nuclei. 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 experiment and parts of analysis undertaken will be discussed in this presentation.

9. *Construction of a wide-field second harmonic generation microscope*

MacAulay Harvey (Cisek)

Second harmonic generation (SHG) microscopy is a form of optical microscopy which utilises 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 because of 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.



Bovine collagen imaged using white light microscopy (left) and second harmonic generation microscopy (right) (M. Harvey).

10. *The mass-to-light ratio discrepancy of metal-rich globular clusters*

Abigail Battson (Henault-Brunet)

The predicted mass-to-light ratios (M/L) of metal-rich globular clusters are considerably higher than their inferred dynamical M/L based on observations. This discrepancy could point towards an issue in the stellar population models on which these predictions are based, which would in turn have important consequences for the interpretation of more distant stellar populations. I investigate whether this discrepancy could be explained by incorporating the preferential loss of low-mass stars which occurs throughout the lifetime of a globular cluster. I used the Flexible Stellar Population Synthesis (FSPS) code to obtain updated M/L predictions for 50 clusters in the Milky Way. The updated predictions incorporate the loss of low-mass stars by using the present-day mass function of the sampled clusters. These new predictions reduce the discrepancy for the metal-rich clusters by half, also revealing that the models underestimate the M/L for the metal-poor clusters when correctly taking into account their present-day mass function. I conclude that incorporating the loss of low-mass stars in models of globular clusters explains much of the M/L discrepancy, although there are potentially other factors which can be updated or incorporated to improve and understand further residual discrepancies.

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