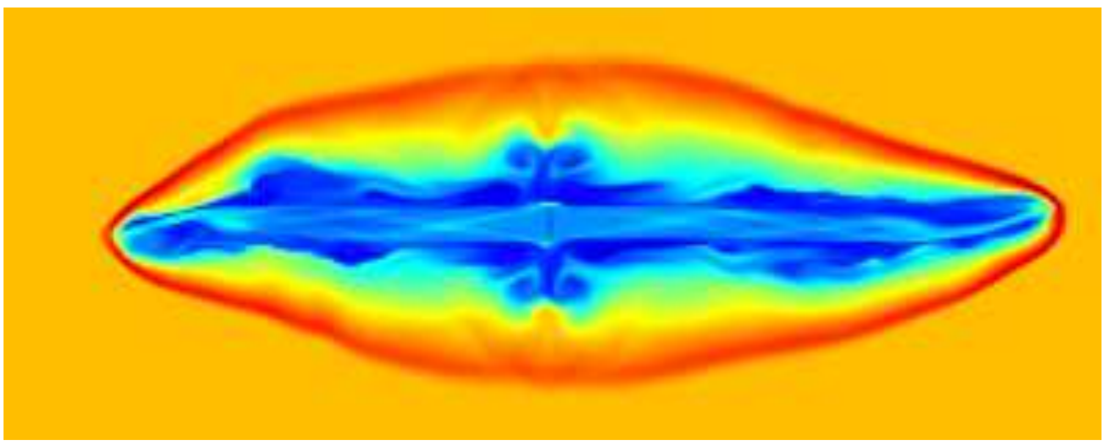
Tenth Annual Undergraduate Mini-Symposium

Department of Astronomy and Physics
Saint Mary's University
Friday September 6, 2013, Sobey 160



A *ZEUS-3D* simulation of a 3-D asymmetric twin jet, showing a 2-D slice of density along the jets' common axis (S. Campbell).

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The Department of Astronomy and Physics

The Office of the Dean of Science

Tenth Annual Undergraduate Mini-Symposium
Friday September 6, 2013, 10:00 am – 2:00 pm
Atrium 101

Programme

Opening remarks (Clarke)			10:00 – 10:10
1	J. Purcell (Kanungo)	*Looking for excited states in ^{11}Li and ^{22}Ne through inelastic scattering with a solid hydrogen target*	10:10 – 10:30
2	M. Keefe (Kanungo)	*Determining a Shift in a Beam by Differential Cross Section and Properties of Resonance in ^{10}Li*	10:30 – 10:50
3	K. MacLeod (Guenther & Deupree)	*Asteroseismology*	10:50 – 11:10
4	C. MacMackin (Thacker)	*Constraining Models of Galaxy Evolution Using Observational Data*	11:10 – 11:30
5	N. Murtha (Sarty)	*In-Situ Gamma-Ray Energy Calibration of the Crystal Ball Detector at the Mainz Microtron*	11:30 – 11:50
Lunch, Atrium 305 (courtesy of the dean of science)			12:00 – 12:30
6	M.C. Suteanu (Sarty)	*Extraction of Cross Section Values for Pion Production*	12:40 – 1:00
7	L. Francis (Clarke)	*Simulation of Gravitationally Driven Fragmentation of a Collapsing Gas Cloud with ZEUS-3D*	1:00 – 1:20
8	S. Campbell (Clarke)	*Ruminations and Simulations; Modelling Twin Jets with ZEUS-3D*	1:20 – 1:40
Award presentations (Golob, Young)			2:00 – 2:30

Abstracts

1. *Looking for excited states in ^{11}Li and ^{22}Ne through inelastic scattering with a solid hydrogen target*

Julia Purcell (Kanungo)

The IRIS project is focused on investigating unstable isotopes that are neutron-rich or proton-rich. The first radioactive beam experiment at IRIS started this summer, investigating the two-neutron halo nucleus ^{11}Li. Because of its unique structure, ^{11}Li is a Borromean system, where if one piece is disturbed, the whole system falls apart. One of the interests is to understand if the strong force, which governs the existence of elements, is capable of keeping ^{11}Li momentarily in an excited state. To study this phenomenon, we will search for soft-dipole resonance(s) in ^{11}Li. The prediction of a soft dipole resonance postulates that the halo neutrons oscillate against the core ^{9}Li giving rise to excited state(s) of ^{11}Li. This will be done by inelastic scattering using the newly developed solid hydrogen target. In order to extract the excitation spectrum from the data we need to define the energy calibration of our detectors accurately.

In this talk, I will describe the experimental setup that was used to measure the excitation energy and how we identify the reaction channel of interest. I will discuss the importance of elastic scattering of ^{22}Ne, a stable nucleus, in the experiment and how I used it to calibrate the silicon and CsI detectors. The analysis results will show how the experiment exhibits excitation of ^{22}Ne. The success of explaining ^{22}Ne is necessary to demonstrate for understanding all features of the more challenging ^{11}Li spectrum accurately.

2. *Determining a Shift in a Beam by Differential Cross Section and Properties of Resonance in ^{10}Li*

Matthew Keefe (Kanungo)

This presentation will talk about the bound system of ^{11}Li and the importance of its unbound subsystem ^{10}Li. This was done at the Iris facility through the ^{11}Li(p,d)^{10}Li reaction. To do this, the excitation energy was found using scattering angle and energy upon passing through the detector. The scattering angle can only be used when the center of the detectors is aligned with the center of the beam line but this is the ideal case and will never happen in reality. If there is a shift, the hit pattern of the scattering particles will be off and must be accounted for. This shift was calculated each time the experiment was run for the ^{11}Li(p,d)^{10}Li reaction using Rutherford's equations for scattering and differential solid angle.

3. *Astroseismology*

Kieran MacLeod (Guenther, Deupree)

Asteroseismology uses the oscillations of stars to study their structure and evolution by comparing the observed oscillation frequencies to the modes calculated from theoretical models. I worked on two asteroseismology projects this past summer. The goal of the project with Dr. Deupree is to determine if there are scaling relations similar to the period-mean density relation for rotating stars and under what conditions they may apply. Thus I computed about 180 frequencies for each of a number of models. For the relatively slow rotation thus far examined and examining the scaling between two models with the same rotational shape but different masses, we find that the p modes scale as one would expect from the period-mean density relation, while the g mode scaling is determined by the interior structural differences between the two models.

My second project involved analyzing observed frequencies using a Bayesian method to perform asteroseismic inference (Gruberbauer *et al.*, 2012), I investigated four stars observed by the Kepler satellite. The Bayesian approach allows one to take into account the systematic errors due to the model. Using a grid containing approximately 10 million models, each containing 50 to 100 oscillation modes, I determined the fundamental parameters for these stars.

4. *Constraining Models of Galaxy Evolution Using Observational Data*

Chris MacMackin (Thacker)

Previous work by Wurster and Thacker has compared various models of feedback from AGN (active galactic nuclei) during galactic mergers. Here, feedback refers to energy from matter accreted by the SMBH (super-massive black hole) which is returned to nearby galactic gas. Observational research has tried to determine how BHAR (black hole accretion rates) varies over the course of galactic evolution and has also looked for correlations between SFR (star formation rate) and BHAR. The focus of this summer's research was to compare the simulated SFRs and BHARs with this observational data. Due in part to differences in luminosities of the simulated and observed galaxies, the results of this comparison were, unsurprisingly, mixed. General trends were reproduced but some variances in behaviour were found, due in part to the difficulty of obtaining data for systems similar to the one simulated. However, it has become clear that plots of SFR against BHAR may be useful to track and compare the evolution of different models and simulations. Further research should include attempts to populate such a plot with simulations of many different galaxies.

5. *In-Situ Gamma-Ray Energy Calibration of the Crystal Ball Detector at the Mainz Microtron*

Nathan Murtha (Sarty)

The Mainz Microtron (MAMI) accelerator facility based in Mainz, Germany, is being used by an international team of physicists to study properties of the proton. The detectors must be properly calibrated in order to ensure accurate data from which results can be drawn. However the calibrations cannot be done prior to the experiment, and thus must be done "in-situ" after the data have been acquired. The facility and beam production will be briefly overviewed before discussing the detectors being used in the experiments. Reasons for calibrating and the calibration process will then be addressed in more detail.

6. *Extraction of Cross Section Values for Pion Production*

Maria Cristina Suteanu (Sarty)

The process of extracting a non-polarized cross section for pion production is presented. The data analyzed were obtained at the Mainz Microtron (MAMI) in the Nuclear Physics Institute, Johannes Gutenberg University, from experiments conducted in December, 2012, involving a linearly polarized photon beam incident on a liquid hydrogen target. The selection of pion production events is illustrated with one of the data files: invariant mass cuts, missing mass reconstructions, timing cuts, and weighted subtraction involving missing mass plots were applied to the studied data, to identify the number of pion production events involved. It is likewise shown how the total number of possible reactions can be determined at MAMI, and the correction factors that must be taken into account to accurately determine the cross section are discussed. The latter consist of tagging efficiency, target thickness, and detection efficiency, and their precise values will be determined in the near future.

7. *Simulation of Gravitationally Driven Fragmentation of a Collapsing Gas Cloud with ZEUS-3D*

Logan Francis (Clarke)

A Protostar is the earliest stage in stellar evolution, an object wherein nuclear reactions have yet to begin, formed from the collapse of a gas cloud composed of molecular hydrogen and dust. Observations show that groups of protostars are often formed in the collapse of the molecular cloud, creating multiple star systems. The process of fragmentation that divides a collapsing cloud requires modelling the physics of both gravitation and magnetohydrodynamics (MHD). The code *ZEUS-3D* models the equations of MHD required to simulate this process, while an algorithm developed for ZEUS-3D was used to model gravitation. An algorithm that directly solves for gravitational potential is of order N^2 while solving the equations of MHD is of order N, resulting in rapidly rising compute times for problems involving gravity. To mitigate this, a gravity solver for *ZEUS-3D* based on the Fast Fourier Transform (FFT) was created. This gravity solver was used to demonstrate fragmentation, with the goal of replicating the results of modelling fragmentation from a 1998 paper by J. Kelly Truelove *et al.*

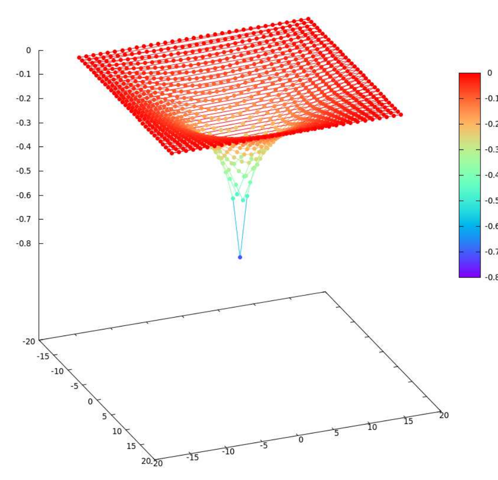

Figure 1: The gravitational potential of a straight "wire", as computed by the new FFT gravity solver written for *ZEUS-3D*.

8. *Ruminations and Simulations; Modelling Twin Jets with ZEUS-3D*

Stephen Campbell (Clarke)

Astrophysical jets are long outflows of fluid emanating from either protostellar objects (PSO) or active galactic nuclei (AGN). These jets are believed to be two-sided such that opposing jets are launched from the central engine. Typically, AGN jets are on the scale of 10^6 light years in length and the fluid can reach speeds $> 99\%$ the speed of light. In practice, the equations governing the physics of these jets need to be solved computationally. Using the magnetohydrodynamical (MHD) code *ZEUS-3D*, hydrodynamical calculations of twin jets were run in both 2-D and 3-D (see cover). By comparing these current simulations to previous examples it was found that the current working version of *ZEUS-3D* remains reliable for these types of calculations. This allows for simulations with additional physics (*e.g.*, $\vec{B}$) to be undertaken in the near future.

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