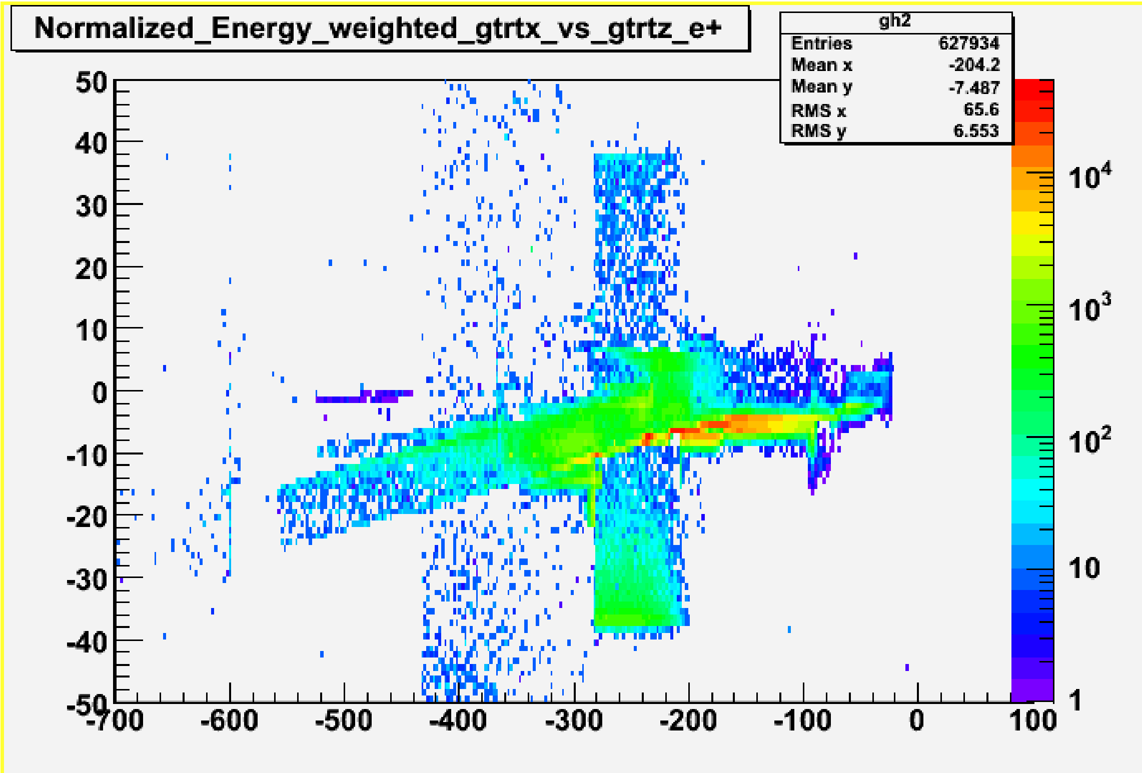
ASTRONOMY & PHYSICS
SUMMER UNDERGRADUATE RESEARCH CONFERENCE
SEPTEMBER 16, 2005



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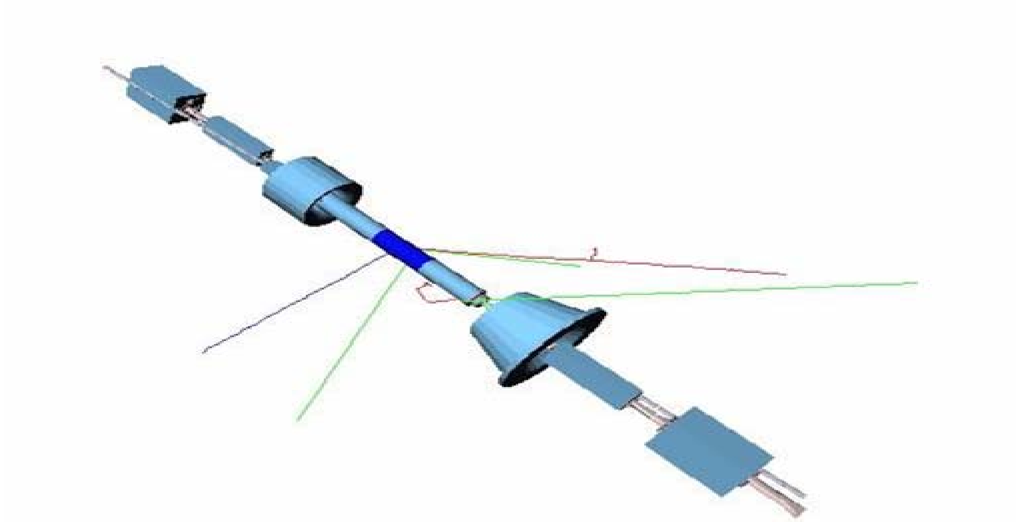

SAINT MARY'S UNIVERSITY

DEPARTMENT OF ASTRONOMY & PHYSICS

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Upper Figure
Simulation of positron energy-losses in the BABAR detector. As the incident 3.1 GeV positrons lose energy through collisions within the detector, the magnetic field bends these positrons into various components of the detector itself, creating even more energy-loss. This figure maps the energy-loss distribution.

Lower Figure
Simulation image of high-energy electron-positron collisions in the BABAR detector at the Stanford Linear Collider. The main structure depicts various magnets positioned close to the interaction point. This simulation is for final states of the collision containing only the scattered electrons (green lines) and positrons (blue lines), and created photons (red lines).

Figures contributed by Claire Cohalan

PROGRAM

Friday, September 16, 2005 in Sobey Room 260

Session 1. Subatomic Physics: Quarks, Cosmic Rays, and Exotic Nuclei

9:30am (1.01) Mapping the Luminosity Backgrounds of the BABAR Experiment
C. Cohalan (Saint Mary's University) and S.Robertson (McGill University)

9:50am (1.02) Magnetic Monopoles and Cosmic Rays
J. Maclean and M. Butler (Saint Mary's University)

10:10am (1.03) Simulations of Cosmic Ray Air Showers using Corsika 6.203
A. Misner, J. Maclean, I. McLeod, N. Ribeiro, and M. Butler (Saint Mary's University)

10:30am (1.04) Coulomb Excitation of Neutron Rich Neon (A > 28)
S. Seif El Nasr and R. Austin (Saint Mary's University)

10.50am (1.05) The Puzzle of Creating Level Schemes
E. McCullough and R. Austin (Saint Mary's University)

11:10am (1.06) A Picture is Worth a Thousand Theories: A Photographic Tale of Physics
J. Derrah, G. Welch, and J. Hahn (Saint Mary's University)

11:30am Lunch

Session 2. Stars & Disks

12:30pm (2.01) Triple Mode Oscillations and Convective Core Overshoot
C. Geroux and R. Deupree (Saint Mary's University)

12:50pm (2.02) Synthetic Photometry with Stellar Atmospheric Models
J. *Sherar and I. Short (Saint Mary's University)*

1:10pm (2.03) Gravity in Binary Star Models
P. Rogers and R. Deupree (Saint Mary's University)

1:30pm (2.04) On the Origin of the High Inclination Component of the Kuiper Belt
Y. Poirier (Université de Moncton) and J. Hahn (Saint Mary's University)

1:50pm (2.05) Modeling β Pictoris In Six Easy Steps
C. Capobianco and J. Hahn (Saint Mary's University)

2:10pm (2.06) Modeling Spiral Density Waves with ZEUS3D
N. Macdonald, D. Clarke, J. Hahn (Saint Mary's University)

30 minute Break

Session 3. Galaxies and Supernovae

3:00pm	**(3.01)**	**Point Ignition of Type Ia Supernova** ***D. Doucette (Saint Mary's University) and J. Dursi (CITA)***
3:20pm	**(3.02)**	**Delayed Detonation Ignition of Type Ia Supernova** ***C. Hiratsuka (Saint Mary's University) and J.Dursi (CITA)***
3:40pm	**(3.03)**	**Diffuse Dust in Elliptical Galaxies** ***J. Savoy and G. Welch (Saint Mary's University)***
4:00pm	**(3.04)**	**The Infrared Structure of S0 Galaxies** ***T. Byrne and G. Welch (Saint Mary's University)***

4:20pm Close of conference

ABSTRACTS

SESSION 1: SUBATOMIC PHYSICS: QUARKS, COSMIC RAYS AND EXOTIC NUCLEI

(1.01) Mapping the Luminosity Backgrounds of the BABAR Experiment

C. Cohalan (Saint Mary's University) and S. Robertson (McGill University)

Luminosity backgrounds in the BABAR detector result in reduced performance due to radiation damage and increased subdetector occupancies. The luminosity backgrounds arise from radiative bhabha events, e+e- -> e+e-gamma, in which outgoing particles are emmited at small angles relative to the beam direction. The particles strike accelerator components, producing electromagnetic shower fragments and nuclear particles which can enter the BABAR detector. In this work, simulations of radiative bhabha events are used to study fluxes and energies of particles which strike certain machine elements. Particular attention was given to the Calorimeter. Neutron sources, energies and interaction points were also studied.

(1.02) Magnetic Monopoles and Cosmic Rays

J. Maclean and M. Butler (Saint Mary's University)

Cosmic rays capable of producing the high energy air shower events are unable to travel with energies above 6*10^10 GeV. Events above this energy have been observed and the origin of these events is not confirmed. It has been proposed that magnetic monopoles may be capable of producing these events. The project included writing a computer simulation of a magnetic monopole interacting with the upper atmosphere and initiating an air shower. There are no conclusive results to date.

(1.03) Simulations of Cosmic Ray Air Showers using Corsika 6.203

A. Misner, J. Maclean, I. McLeod, N. Iberia and M. Butler
(Saint Mary's University)

The characteristics of cosmic ray air showers were further studied using the updated Corsika 6.203. New files made it possible to access compressed muon data at the observation level of 11000 cm above sea level. Various runs were made at 1x102, 1x103, 1x104, 1x105, 1x106, 1x107, and 1x1011 GeV. Semi-logarithmic graphs were produced calculating the slope, slope error, mean and standard deviations. The slopes have a direct correlation between energy and the number of muons reaching the ground surface. Moreover, multiply slopes of the same energy were plotted together, yielding a statistical upper and lower limit. In addition, to the research done within the realm of Corsika 6.203 the information gained will help to assist the networking project, The Imperial Oil Cosmic Rays In The Classroom Project.

(1.04) Coulomb Excitation of Neutron Rich Neon (A > 28)

S. Seif El Nasr and R. Austin (Saint Mary's University)

Coulomb excitation is the excitation of the nucleus by the electromagnetic field between colliding nuclei. It assumes that the interaction is purely electromagnetic, which makes it fairly easy to calculate the excitation cross sections using time dependent perturbation theory. COULEX, written by Aage Winther and Jorbhit de Boer and modified by Tom Drake, calculates the excitation cross sections by solving the coupled differential equations resulting from the time dependent perturbation using a combination of numerical integration techniques.

I will discuss the theory behind coulomb excitation, and how to solve for the excitation cross sections. I will also mention the motivation behind my work, and the results for the excitation of Ne28 and Ne30 using different beam energies and targets.

(1.05) The Puzzle of Creating Level Schemes

E. McCullough and R. Austin (Saint Mary's University)

If the nucleus of an atom is excited to an unstable energy state, the nuclide will emit gamma rays of different energies as it de-excites to lower and lower energy levels. Usually, there is more than one "path" through the possible energy levels that the de-excitation may take. By studying the gamma ray spectra of a de-exciting nuclide, our work was to create a Level Scheme, or map of the possible transition paths down to the ground state, for the nuclides 40K, 41K and 37Ar. Background, puzzle solving methods, difficulties encountered and our results will be discussed.

(1.06) A Picture is Worth a Thousand Theories: A Photographic Tale of Physics

J. Derrah, G. Welch, J. Hahn (Saint Mary's University)

The goal of this project was to create posters for the hallway covering a wide range of topics in physics and astrophysics. The topics covered thus far include planets in the solar system, galaxies, nuclear physics and images taken here with the Burke Gaffney Observatory. The posters were compiled using Adobe Photoshop and Corel Photo-paint. Each had their own difficulties and problems which will be discussed briefly.

Each topic has a wide range of interesting physics involved, from tidal forces between galaxies to the strong forces between fundamental particles. These phenomena and others can be explained much beyond the scope of the captions and the limited space the posters provide. Some of the images from the five posters will be discussed in greater detail, revealing the physics behind them and therefore why they are interesting enough to be found on a poster.

The discussion will also include information about the instruments used in these research areas that help scientists to learn a great deal more about the universe around us, from the largest galaxy to the smallest quark.

SESSION 2: Stars &Disks

(2.01) Triple Mode Oscillations and Convective Core Overshoot
C. Geroux and R. Deupree (Saint Mary's University)

In recent work of Moskalik and Dziembowski three observed radial oscillation periods were used to constrain stellar models of the stars LMC SC3-360128 and LMC SC5-338399. They concluded that, due to the constraints imposed on the masses of the models by the observed periods along with the observed luminosity, there was an upper limit on the amount of core hydrogen burning convective overshoot allowed. This limit is below the amount of overshoot deduced from some other lines of evidence. However, rotation modifies the mass luminosity relation in the opposite direction from that of convective core overshoot and I wish to explore how significantly rotation alters the overshoot limit.

My research consisted of first reproducing the results of Moskalik and Dziembowski using an envelope integrator and linear stability code based on two codes written by Paczynski and by Castor and then exploring the effects of rotation on the constrained models. The first task proved more difficult than initially thought and caused the second task to be delayed for the time being. In my talk the difficulties and techniques of constructing a grid of models with a parallelized code utilizing the envelope integrator and linear stability code in order to find models which satisfy the observed periods will be discussed.

(2.02) Synthetic Photometry with Stellar Atmospheric Models
J. Sherar and I. Short (Saint Mary's University)

We present a computational procedure for calculating synthetic photometric colors in the Strömgren uvby and Johnson UBVRI photometric systems with simulated stellar spectra as input. We study the dependence of colour indices on the use of local thermodynamic equilibrium (LTE) or non-LTE atmospheric models and synthetic spectra produced with the atmospheric synthesis code PHOENIX for standard stars Arcturus and the Sun. We exhibit photometric colours for LTE and non-LTE models of red giant stars with a range of metallicities from near solar to extremely metal poor (XMP) values. This is part of a larger, on-going study of the abundances of elements of astrophysical significance in XMP stars.

(2.03) Gravity in Binary Star Models

P. Rogers and R. Deupree (Saint Mary's University)

Deupree and Karakas (2005) modeled the evolution of members of a binary star system using the 2-D fully implicit code ROTORC, developed by Deupree. In order to model a given star, the gravitational potential on a boundary surface just exterior to the star is required. To evaluate the component of this potential due to the star being modeled, an integration was carried out; however, for the component due to the companion, the companion-gravity, a point-source approximation was used.

In order to test the validity of this approximation, Rogers wrote a code that performs an integration to calculate each star's component of the potential on each stars boundary. This code was then used to compare the integrated companion-potential to the point-source companion-potential for a number of different configurations and evolutionary stages of the system. It was found that the point-source approximation agrees to within a few tenths of a percent of the integrated value for the cases examined.

With the future prospect of modeling binary systems in a synchronous, parallel fashion, and examining the mass transfer that occurs when the primary star has reached Roche lobe overflow, a second code is being developed. This code uses the integration technique to solve the potential on a closed boundary region between the two stars and implicitly solves Poisson's equation within this boundary. In this fashion, the gravitational potential in the region between the stars can be computed.

(2.04) On the Origin of the High Inclination Component of the Kuiper Belt

Y. Poirier, (Université de Moncton) J. Hahn (Saint Mary's University)

The Kuiper Belt is a large group of large comet-like objects orbiting beyond Neptune. The Kuiper Belt has two dynamical components ; a low-inclination (i~3°) component and a high-inclination (i~15°) component (Brown 2001). This is curious since most models of the formation of the Kuiper Belt Objects (KBOs) require low relative velocities, hence low inclinations. One of the possible origins of the Kuiper belt is from the migration of the main planets through a primordial particle disk. Neptune, being the most outward planet, would then scatter KBOs into wide eccentric orbits.

Gomes (2003) showed a mechanism by which particles can orbit on low eccentricity orbits but still retain high inclination. This happens when KBOs are scattered by Neptune into high inclination orbits. A small fraction of these could then be trapped by a resonance and experience a decrease in eccentricity, thus decoupling from Neptune and entering a stable orbit. This 'Neptune-Evading' mechanism would account for the high inclination particles of the Kuiper belt.

Using the Mercury 6 N-Body integrator, I have reproduced the results of Gomez (2003). In this talk, I intend to show that the 'Neptune-evading' mechanism does in fact yield high inclination low eccentricity KBOs in comparable proportions to the observations made of the Kuiper Belt. I also intend to show the process by which the 'Neptune-Evading' mechanism takes place, it's efficiency as well as the limitations of the model.

(2.05) Modeling β Pictoris In Six Easy Steps
C. Capobianco and J. Hahn (Saint Mary's University)

Asymmetries are often observed in circumstellar dust-disks such as the beta Pictoris and epsilon Eridani systems. In the case of beta Pictoris, five different types of asymmetries are observed. The most intriguing is a small warp seen in the inner portion of the disk.

The aim of this work is to model these asymmetries using a more realistic multiple planet model. However, the number of parameters used to describe such a system can easily exceed two dozen. To alleviate some of the computational demands, we make use of Brouwer and Clemence's secular model to simulate the evolution of the dust grain's orbital elements. In this secular model, we tacitly ignore mean motion resonances and radiation forces (e.g. Radiation pressure and Poynting-Robertson drag).

To fit our model to an optical HST image of beta Pictoris, we employ a simplex algorithm. A simplex is a method of determining the set of best fitting model parameters, and is used primarily when an analytical form for the model does not exist.

Our preliminary results indicate that at least two planets are required to reproduce the warp seen in the inner portion of the disk. As well, the inclination distribution of the dust grains are quite complex. There are still some issues associated with uniquely determining the inclination distribution, but we expect to resolve this issue as well as place constraints on all the model parameters.

(2.06) Modeling Spiral Density Waves with ZEUS3D
N. MacDonald, D. Clarke, J. Hahn (Saint Mary's University)

The rings of Saturn are a very complex dynamical system. When the Voyager spacecraft flew by Saturn in 1979-80, it revealed a richness of structure in the rings that had previously been unobserved; namely spiral density and spiral bending waves. Much of this structure has been linked to the collective effects arising from the self-gravity of the ring material and the gravitational potentials of Saturn, and its many moons. These waves, therefore, carry with them massive amounts of information about the dynamics of the Saturnian system.

My talk will outline the work done by myself, David Clarke, and Joe Hahn, to construct a computational fluid model of the ring system using the ZEUS3D magnetohydrodynamics Code. Specifically, I will discuss the methods taken to set up the density profile of a ring in Keplarian orbit about a central point mass, and next to introduce self-gravity to that profile via a Poisson Solver. Finally I will outline the steps taken to introduce a moon into our computational model to potentially perturb the system and instigate the propagation of waves throughout the ring.

SESSION 3: Galaxies and Supernovae

(3.01) Point Ignition of Type Ia Supernova

D. Doucette (Saint Mary's University) and J. Dursi (CITA)

Type Ia Supernovae have been used extensively in recent cosmological research. However, their explosion mechanism is not completely known. Understanding the detailed physics of these complex events is important if we are to continue to use supernovae as distance indicators.

Observational constraints indicate that the progenitor is likely to be a highly-turbulent white dwarf. The turbulence will cause small temperature fluctuations that may ignite flames in the core of the star. These fireballs likely serve as the origin of the explosion. The present study serves to characterize the fluctuation and background parameters required to ignite flames in the core. 1D hydrodynamical simulations are used to model the evolution of a thermal fluctuation. This work should help to connect observational constraints with present-day models by providing starting-points for different ignition scenarios.

I will give a quick overview of current work in the field, introduce some concepts of astrophysical combustion, and present some of our results. A related study by Christine Hiratsuka considers related questions with the Pulsational Delayed Detonation model.

(3.02) Delayed Detonation Ignition of Type Ia Supernova

C. Hiratsuka (Saint Mary's University) and J. Dursi (CITA)

Owing to the use of Type Ia supernovae as distance indicators because of their property of being standard(izable) candles, they are of increasing importance to cosmological researchers. Although they are believed to result from the explosions of accreting carbon/oxygen white dwarfs which have reached Chandrasekhar mass, their detailed ignition mechanism is still not well understood. Is it a subsonic deflagration phase propagating through the star that becomes so turbulent and causes the star to explode? Or is it a deflagration phase turning into supersonic detonation?

In this project, the pulsational delayed detonation model is considered. In this model, a first turbulent deflagration phase fails to unbind the star, and a recollapse occurs, which in turn triggers an ignition, and possible detonation. Extending the work in Daniel Doucette's project, which considered point ignition in quiescent material, we examine what it takes to locally ignite material under conditions of rapid compression. First, a small region of spherically homogeneous collapse is studied to understand the required compression to trigger an ignition under various conditions. Then, the case is studied by adding a small temperature fluctuation to see how the hotspot can modify the non- hotspot conditions. In this talk I shall briefly explain the delayed detonation mechanism and present the results from the simulations.

(3.03) Diffuse Dust in Elliptical Galaxies

J. Savoy and G. Welch (Saint Mary's University)

It is well established that the broadband colors of elliptical galaxies become redder near their centers, which provides an important constraint on models of elliptical galaxy formation. The observed radial color gradients are usually explained by a gradient in stellar metallicity, but if a diffuse dust component is present, it would also contribute to the reddening. Dust is commonly observed near the centers of elliptical galaxies, but the dust mass implied from optical extinction is generally 5-10 times less than values derived from far infrared (FIR) emission measured by IRAS photometry at 60 and 100 microns. One explanation for this discrepancy is that the majority of the dust is diffusely distributed, and not concentrated in dense clouds, but previous FIR experiments have lacked the spatial resolution to determine the location of the existing dust. The SCUBA instrument on the JCMT, which operates at 450 and 850 microns, is the first detector capable of producing images and providing total flux measurements in the FIR/sub-mm region.

In an effort to determine the importance of a diffuse dust component, 18 elliptical and S0galaxies have been observed with SCUBA. These observations, combined with published fluxes through optical and FIR passbands, are modeled using a three dimensional Monte Carlo radiative transfer code which has been extended to include an oblate Jaffe model for the density distribution and modified to run in parallel. Reduced images of NGC 6524 will be presented along with an example of the modeling process.

(3.04) The Infrared Structure of S0 Galaxies

T. Byrne and G. Welch (Saint Mary's University)

S0 galaxies comprise a central elliptical bulge and a rotating disk devoid of spiral structure. They form a bridge between ellipticals and spirals; they lack extensive gas/dust and prefer densely populated regions, as do ellipticals, but they share the thin rotating stellar disks of spirals.

Currently accepted stellar evolutionary models allow astronomers to estimate the amount of gas returned to a galaxy's ISM by its aging stars. Mysteriously, Welch and Sage (2003) have shown that, in a sample of 27 nearby (within 20Mpc) S0 galaxies, there is much less gas found in the atomic and molecular phases together than models of stellar evolution predict. The main goal of this ongoing research is to provide clues to this mystery by answering questions such as: outside of class similarities, how closely related are the structures of the sample members and is there any correlation at all between the IR properties of these galaxies and the amount/phase/location of their cool gas?

Using the Image Reduction and Analysis Facility (IRAF), the structure of the galaxies in Welch and Sage's S0 sample is currently being examined through isophote fitting applied to images from the Two Micron All Sky Survey (2MASS). Due to the uniformity of this survey, we were not hampered with the task of having to compare images taken with separate telescopes in different passbands.

This talk will focus on the details of the structure profiling and how the above questions may be answered in the future.