ROCHESTER SYMPOSIUM
FOR PHYSICS (ASTRONOMY & OPTICS) STUDENTS
SPS Zone 2 Regional Meeting being held at
HOUGHTON COLLEGE

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ABSTRACTS

Nuclear and Particle Physics, Session I

Examining Pion Electroproduction at the CLAS Detector

Ian Kleckner, University of Rochester
Advisor: Prof. Kevin McFarland, University of Rochester

Hydrogen and carbon targets are bombarded by relativistic electrons at the CLAS detector at Jefferson Laboratory in Virginia. The large number of data points taken in these types of scattering experiments minimizes statistical effects and experimental uncertainties. General trends in the data are used to extract the physics from millions of recorded collisions. The incident electrons collide with target nucleons and yield events in the elastic region, resonance region and the deep inelastic region. These regions qualify the different energies and particles that appear in the final state; most notably are pions produced in the resonance region. The behavior of pions produced under these conditions is of interest in the field of Neutrino Physics.

Connecting the 3-d O(4) Heisenberg Spin Model to the 4-d SU(2) Lattice Gauge Theory

David Starling, State University of New York at Fredonia
Advisor: Prof. Michael Grady, State University of New York at Fredonia

It is of great importance to particle physicists to understand the deconfining phase transition seen in SU(2) lattice gauge theory (LGT). Although generally interpreted as a finite temperature phase transition, recent evidence suggests it may continue to exist on the zero-temperature infinite 4-d lattice. Through partial gauge fixing, a partially-global residual gauge symmetry is exposed which appears to break spontaneously at the transition. A new spin-like magnetization allows this transition to be studied in detail, which has some unusual features, similar to a Berezinskii-Kosterlitz-Thouless (BKT) transition. To study it further, we have continuously connected the SU(2) lattice gauge theory to the well-known O(4) spin model via an external field term in the Lagrangian, which does not break the symmetry. At infinite field, the Lagrangian describes layered three-dimensional O(4) spin systems. For zero field, the Lagrangian describes four-dimensional SU(2) LGT. Using Monte Carlo simulations and finite size scaling, we have found evidence for the evolution of the bulk finite order magnetic phase transition (for large external field values) to an infinite order BKT like phase transition (at small but non-zero external field values).

Spin Correlation Functions in the Search for New Top Quark Physics I

Jeffrey J. Berger, Binghamton University
Advisor: Prof. Charles A. Nelson, Binghamton University

The first of two talks on work done in theoretical high-energy particle physics on probing new physics using the top quark. Spin correlation functions were computed for cases where the top quark was produced by gluon collisions as well as by quark annihilation. These functions utilize an interference effect between the $W^{\pm}$ boson in top decay. If the phase is measured and disagrees with the expected value calculated from the Standard Model, an extra coupling may be present in top quark decay. This extra coupling in the top quark may have interesting ramifications. Most of this talk is devoted to a brief background of the research including an overview of the Standard Model and why the top quark might deserve special attention. Tools used to calculate the spin correlation functions such as Feynman diagrams, helicity formalism, and the Dirac equation will be briefly mentioned.

Spin Correlation Functions in the Search for New Top Quark Physics II

Joshua Wickman, Binghamton University
Advisor: Prof. Charles A. Nelson, Binghamton University

The second of two talks concerning theoretical top-quark decay analysis using spin-correlation functions. These spin correlation functions were computed for cases where the top quark was produced by gluon collisions as well as by quark annihilation. An overview will be given of the steps taken in our calculations, from their starting point using Feynman diagrams to the final spin-correlation functions. The numerous angles appearing in the formulae will be shown and described, as well as the angular dependence of the final functions. Differences between the functions derived for quark production and for gluon production will be discussed, as well as differences between the original and CP-conjugate modes. If the phase is measured and disagrees with the expected value calculated from the Standard Model, an extra coupling may be present in top quark decay. Such a coupling would fall outside the Standard Model.

Monitoring Missing-Et Resolution at the CMS Detector at the LHC Collider

Dylan Prendergast, University of Rochester
Advisor: Prof. Paul Tipton, University of Rochester

The turn-on of the Large Hadron Collider (LHC), scheduled for 2007, will mean a huge increase in discovery potential into a mass range predicted to be rich in new states by many beyond-the-Standard-Model theories. Many new signatures involve charged leptons and missing-Et from escaping neutral particles (dark matter candidates). Key to a discovery will be the ability to quickly measure our missing-Et resolution in data and to compare that to Monte Carlo simulations. We show results from a Monte Carlo simulation study of inclusive Z->l+l- decays, a sample with essentially no true missing-Et. We use the width of the Missing-Et distribution to measure the missing-Et resolution. We expect this data sample from early LHC running will provide a useful missing-Et resolution calibration point.

Astronomy and Astrophysics

Mid-Infrared Spitzer Spectroscopy and Models of Class I Protostars in Taurus

Melissa McClure, University of Rochester
Advisor: Prof. William Forrest, University of Rochester

Photometry and spectra are essential for the study of star formation. Using spectra taken with the Infrared Spectrograph (IRS) aboard the Spitzer Space Telescope, in conjunction with near infrared, far infrared, and sub millimeter photometry from ground based observations, we construct model spectral energy distributions (SEDs) for 6 Class I young stellar objects in Taurus. The SEDs are used to infer the parameters that describe the structure of the system, such as the inclination angle to the line of sight and the size and shape of the envelope. We use our modeling code to create SEDs from ~ 2 microns to 3 mm and match these models to our original spectrum and ancillary data, giving an interesting glimpse of the structural evolution of Class I protostars.

The Warped Nuclear Disk of Radio Galaxy 3C 449

Grant R. Tremblay, University of Rochester
Advisor: Prof. Alice Quillen, University of Rochester

Among radio galaxies containing nuclear dust disks, the bipolar jet axis is generally observed to be perpendicular to the disk major axis. The FR I radio source 3C 449 is an outlier to this statistical majority, as it possesses a nearly parallel jet/disk orientation on the sky. We examine the 600 pc dusty disk in this galaxy with images from the Hubble Space Telescope. We find that a colormap of the disk exhibits a twist in its isocolor contours (isochromes). We model the colormap by integrating galactic starlight through an absorptive disk, and find that the anomalous twist in the isochromes can be reproduced in the model with a vertically thin, warped disk. The model predicts that the disk is nearly perpendicular to the jet axis within 100 pc of the nucleus. We discuss physical mechanisms capable of causing such a warp. We show that precessional models or a torque on the disk arising from a possible binary black hole in the AGN causes precession on a timescale that is too long to account for the predicted disk morphology. However, we estimate that the pressure in the X-ray emitting interstellar medium is large enough to perturb the disk, and argue that jet-driven anisotropy in the excited ISM may be the cause of the warp. In this way, the warped disk in 3C 449 may be a new manifestation of feedback from an active galactic nucleus.

Optical Variability in Massive Black Hole Mergers

Bob Penna, University of Rochester, Milos Milosavljevic, California Institute of Technology
Advisor: Prof. E. Sterl Phinney, California Institute of Technology

Binary supermassive black holes are expected to form in galactic mergers. The black holes in the binary may ultimately coalesce, emitting gravitational waves. Any cold gas attempting to accrete onto the black holes forms a circumbinary accretion disk. Coalescence of black holes in general relativity is accompanied by radiation recoil and the loss of a few percent of the total black hole mass to gravitational waves. We study the response of the accretion disk to these processes. The reduction in total black hole mass due to gravitational wave losses excites an axisymmetric wave in the disk. Radiation recoil drives asymmetric waves and warps in the outer disk. These distortions to the disk cause the spectrum of thermal continuum radiation observed from the disk to vary. Detection of the optical counterpart to coalescence will help pinpoint the sources and redshifts of these massive black hole binary coalescence events. This information can be used to map the distance-redshift relation over a large span of redshift and observationally probe the dark energy equation of state.

Cepheids in IC 1613, M31 and M33: an Investigation into the Metallicity Effects on the Cepheid PL Relation

Shashi M. Kanbur, Daniel Crain, State University of New York at Oswego
Advisor: Prof. Chow Choong Ngeow, University of Illinois

Hubble's constant governs the expansion rate of the Universe. Its value, accurate to 1%, is vital to constrain cosmological models. Crucial to this is the calibration of the extra-galactic distance scale and central to this is the metallicity dependence of the Cepheid period-luminosity (PL) relation. Cepheids are pulsating stars whose period of oscillation is thought to be related to their absolute brightness. Hence observations of their period and apparent brightness yield their absolute brightness and thus their distance. The existing paradigm has been that their absolute brightness is linearly related to their period. In recent years evidence has emerged that this relation is non-linear with a sharp break at a well defined period.

We present the results of analyzing Cepheid data in nearby galaxies IC 1613, M31 and M33 to test this assertion. We present preliminary analysis to "smooth" out the observed data using Fourier analysis. We will use this to construct Cepheid PL relations in these galaxies and then test these relations for linearity or non-linearity using rigorous statistical procedures.

Poster Session

Construction of a 200 keV Electrostatic Electron Accelerator

Alexander Lipnicki, and Joshua Troyer, Houghton College
Advisor: Mark Yuly, Houghton College

The 200 keV electrostatic electron accelerator at Houghton College is being upgraded. The previous design used a makeshift electron gun that did not allow the beam to be easily controlled and did not produce a well-defined beam spot. A new electron gun, taken from a RCA 3RP1 cathode ray tube, is being installed which will allow the beam intensity, focus and initial accelerating voltage to be remotely controlled. Using a 2000 V test system, a beam current of 0.1 μA was obtained into a beam spot of less than 1 mm diameter. The electron gun is to be remotely operated via an Ethernet-GPIB-RS232-fibre optic link to a BASIC Stamp-2 microcontroller inside the high voltage terminal of the accelerator. The microcontroller will set the voltages on the grids of the electron gun with a 12-Bit four channel DAC7624 digital-to-analog converter feeding four 4-transistor power amplification circuits which energize four EMCO G20 DC to HV DC converters.

Construction of a Small Cyclotron

Andrew Loucks, Houghton College
Advisor: Mark Yuly, Houghton College

A cyclotron is being constructed at Houghton College. The cyclotron consists of a 17.2 cm diameter, 3.9 cm thick evacuated chamber containing a hollow “dee” shaped electrode and a “dummy” electrode placed between the poles of a 1.1 T electromagnet. Low pressure gas will be released into the chamber where a filament will ionize the gas, and magnetic and electric fields will force the ions into an accelerating spiral. Ideally, the final kinetic energies should be about 280 keV, 140 keV and 70 keV for protons, deuterons and helium nuclei, respectively. Currently, the vacuum system, filament, gas handling system, and faraday cup are completed. The RF circuit is being built which should allow us to begin testing.

Volume-Limited Survey for Wide Substellar Companions to Nearby Stars

Amanda A. LaPage, University of Rochester; D. Labrier, P. Brammeier, J. Keller, and A. Case, Northern Arizona University
Advisor: Prof. David Koerner, Northern Arizona University

We report preliminary results from a search for substellar companions to all stars within the NStars Database: a catalogue of all stars known to be within 25 pc by virtue of having a well-established trigonometric parallax. Our survey uses the 2MASS, GSC, and USNOB point source catalogs to color- and magnitude-select a list of all candidate companions within a projected separation of 20,000 AU. Visual inspection is used to eliminate non-stellar sources whenever possible. Common proper motion, when available from multi-epoch survey data, is also used to test for multiple system membership. The end product of this survey will be upper limits for the presence of wide companions, together with a minimized candidate list for follow-up confirmation of possible substellar companions. This work is supported by NSF grant AST-0453611 and promises to yield a milestone in the comprehensive survey of wide binary companions below the hydrogen-burning mass limit.

Condensed Matter and Material Science

Vortex Motion in Superconductors: Interferometric Lithography

Krissy Williams, Colgate University
Advisor: Prof. Kiko Galvez, Colgate University

Superconducting physics research is an ever growing field with many areas still left to be discovered. Our research investigates the movement of vortices in superconducting thin films. In the presence of an applied magnetic current there is a voltage drop associated with vortex motion, which leads to heat dissipation. Vortex motion can be controlled by creating sites on the substrate where it is more energetically favorable for the vortices to remain, unless a great enough force is applied. Using interferometric lithography we have made organized pinning sites on the superconducting thin films to examine the motion of these vortices. A laser of ultraviolet wavelength was used to create an interference pattern, and generate the desired arrays on the thin film.

Production and Joining Techniques for Template Synthesized Nano-Components

Jordan S. Peck, Binghamton University; Andras E. Vladar, Daniel Josell, and Jonathan Mallett, National Institute of Standards and Technology
Advisors: Prof. Gordon A. Shaw and Prof. Jonathan R. Pratt, National Institute of Standards and Technology

Template synthesized nanocompontents of various Ni, Co and Pt alloys have been fabricated and characterized. These components are grown in the pores of an aluminum-oxide membrane which is then dissolved leaving free standing high aspect ratio nanowires 200 nm in diameter and up to 50 μm long. The morphology, composition, structure, and mechanical properties of these wires were studied using scanning electron microscopy, atomic force microscopy, x-ray diffraction, and instrumented indentation. Electrochemical deposition is utilized to pursue joining the nanowires to macroscopic wires as well as atomic force microscope tips. Once understood, this joining technique can then be used in the creation of functional nanodevices.

Study of Crater Formation in Granular Media

Michael Nitzberg, Colgate University
Advisor: Prof. Kiko Galvez, Colgate University

The impact of an object into a granular medium was studied using an embedded accelerometer to measure the force the granular medium exerts to stop the impacting object. With this method, we were able to obtain data showing the dependency of force on the velocity of the impacting object. In small glass beads, velocity and the stopping force were directly proportional for the latter part of the curve. Additionally, when the impacting object sank entirely below the glass beads, a small amount of negative acceleration (force downwards) was observed before the object came to a stop.

Biophysics

Theoretical Estimates of Polaron Energy and Wavefunctions in DNA

Steven Bloch, University of Rochester
Advisor: Prof. Esther Conwell, University of Rochester

The debate over whether radical cations, or holes, in DNA are localized on a single base pair, or spread out over several base pairs, was ended by recent experiments of Barton and colleagues that showed that the hole wavefunctions are delocalized. A Hamiltonian has been suet up to take into account the effect of the water and ions, and used to calculate the wavefuncitons and stationary energy values for a sequence of adenines [D.M. Basko and E. M. Conwell, Phys. Rev. Lett. 88, 098102 (2022)]. We did further calculations using this Hamiltonian to obtain theoretical polaron energies and wavefunctions for various DNA sequences. With a transfer integral value of 0.08 eV, obtained by a number of workers in the field, we were able to match experimental data for polaron energy difference between a single guanine, two guanines and three guanines, in all three cases surrounded by adenines. We were also able to conclude that the polaron on a triple guanine sequence surrounded by adenines is about 3 base pairs wide

Mathematical Modeling of Tumor Evolution I

Christian Volk, Canisius College
Advisor: Prof. Mitra S. Feizabadi

The activity of cancer cells can be illustrated in both the Gompertzian and Webb-Gyllenberg models of tumor growth. The two models have a different approach to evaluating tumor growth. The Gompertzian model investigates the behavior of the total cell population as a function of time. The focal point of the Webb-Gyllenberg model is subpopulations' cell kinetics. Combining these two approaches leads us to a hybrid model (Kozusko-Bajzer), which can express the evolution of subpopulations analytically. This talk explores the use of physical rules and mathematical models as tools for enhancing the understanding of the behavior of biological systems.

Mathematical Modeling of Tumor Evolution II

Sarah Hirschbeck, Canisius College
Advisor: Prof. Mitra S. Feizabadi, Canisius College

In this talk, a simple modification to one of the recent mathematical models in the presence on anti-tumor agents is introduced and supported qualitatively by computer simulations. In a tumor, cell cycle specific chemotherapeutic drugs only affect proliferating cells. This adds another considerable factor to the Webb-Gyllenberg model—a further death rate in addition to the natural death rate of the proliferating subpopulation. By introducing the action of the drug as a simple structure and including this in the Webb-Gyllenberg model while considering the evolution of total tumor cells during the course of therapy, the effects of the drug on the behavior of the proliferating subpopulation as a function of time can be illustrated.

Special Guest Speaker

Accelerated Galaxy Evolution in the Stressful Environment of a Cluster of Galaxies

Professor Rebecca Koopmann, Union College

Galaxies in the crowded, 'urban' environment of a cluster of galaxies differ from isolated 'rural' galaxies in morphology, star formation properties, and gas content. Evidence is mounting that at least some of the differences are caused by environmental effects within a cluster rather than an inherently different formation mechanism for cluster and isolated galaxies. I review the major environmental processes that might affect cluster galaxies and present results from multiwavelength surveys of the gas and star formation properties of galaxies in the nearby Virgo Cluster. The results suggest that environmental effects are responsible for the 'premature aging' of many cluster galaxies.

Quantum Optics

Remote Phase Shifting of Polarization-Entangled Photons in a Mach-Zehnder Interferometer

Mehul Malik, Colgate University
Advisor: Prof. Kiko Galvez, Colgate University

This experiment demonstrates the remote manipulation of the quantum state of a pair of photons in an entangled state. Polarization-entangled pairs of photons are sent in two directions, one through a Panchratnam-Berry Geometric-Phase Shifter, and the other through a Mach-Zehnder interferometer. Manipulating the phase of the photon going through the phase shifter allows us to control the phase and amplitude of the interference that the entangled partner undergoes in the Mach-Zehnder interferometer. Polarizers at the end of both paths collapse the quantum state of the photons. We show data that successfully displays the feasibility of this type of remote phase shifting.

Spatial and Temporal Profiling of a Pulsed Laser Beam

D. Odera and J. Magnes, United States Military Academy, West Point
Advisor: Lieutenant Colonel John Hartke, United States Military Academy, West Point

We compare the spatial beam profiles of a picosecond pulsed laser obtained through various techniques that included the knife-edge method, slit width method, and pinhole method. We found that the knife-edge method was unaffected by size of the beam or fine structures, therefore we used this method to investigate the overlap and relative size of three picosecond pulsed beams. We are investigating a method to determine the temporal profile of the pulse beam. The temporal beam profile will be determined using an optical autocorrelator. The set-up is an interferometric autocorrelator that resembles a Michelson interferometer. By mapping the intensity of the correlated beam versus time, we will be able to determine the temporal structure of the beam.

Composite Optical Vortices

Nikhil Fernandes, Colgate University
Advisor: Prof. Kiko Galvez, Colgate University

We study optical beams that are formed by superimposing two beams that contain phase vortices (Laguerre-Gaussian beams). The composite beams showed new arrays of vortices not seen before. We observed the formation and propagation of vortices as a function of the relative intensities of the combining beams. In all cases, our results confirm theoretical models.

Nuclear and Particle Physics, Session II

The Design and Construction of a Small Cyclotron

Mickael Cressman, Houghton College
Advisor: Prof. Mark Yuly. Houghton College,

A small cyclotron is under construction at Houghton College. It utilizes a water cooled GMW 3473-70 electromagnet with 15.2 cm pole faces that produces a maximum field of approximately 1.1 T with a 3.9 cm gap. The vacuum chamber consists of a brass ring sealed to two aluminum end discs by Viton o-rings. It has eight ports: one each for pumping, introducing gas, an ion gauge, and a Faraday collector, as well as two optical viewports and two electrical feed-throughs. It is evacuated using a rotary fore pump, a diffusion pump and a liquid nitrogen cold trap. The 'dee' electrodes are made of copper, and consist of a dummy dee at ground potential and a true dee supplied with a radiofrequency signal produced by a function generator and an rf power amplifier. The expected kinetic energies for protons, deuterons and helium nuclei are about 0.28 MeV, 0.14 MeV, and 0.07 MeV respectively. By using the d-d reaction, it should be possible to use this machine as a generator of 2.8 MeV neutrons that can be used for other experiments.

The d(n,np)n Reaction as a Probe for the Three Nucleon Force

Steven Wallace, Mickael Cressman, Alexander Lipnicki, and Joshua Troyer, Houghton College
Advisor: Prof. Mark Yuly, Houghton College

The strong force has traditionally been modeled using only the interactions between pairs of nucleons. However, evidence, such as the disagreement of the tritium binding energy predicted by these models with experimental measurements, provides evidence for the existence of a three-nucleon component. An experiment is being performed at the Los Alamos Neutron Science Center by researchers from MIT, Los Alamos National Laboratory, the University of Kentucky, and Houghton College to study the d(n,np)n reaction, the simplest system which could exhibit three-nucleon forces. A previous experiment used CsI detectors for the charged particles, which unfortunately provided inadequate energy resolution and solid angle, and suffered from detector-to-detector scattering. The experiment has been redesigned by replacing the CsI detectors with two permanent magnet spectrometers using drift chambers, covering more solid angle and having much better energy resolution. Deflected neutrons are detected by two arrays of nine large plastic scintillator bars at forward angles on each side of the beam line.

Frequency and Angular Distributions of Muons Detected in Atmospheric Showers

Kara Morris and Aimee Slaughter, University of Rochester; Mr. Paul Sedita and Dan Wigent, Canandaigua Academy; Laura Arnold, Greece Arcadia; Yuri Shadunsky, Brighton High School; Jeff Parvin, Zach Noyes, and Greg Meade, Pittsford Mendon High School; Mr. Robert Meek, Oakfield-Alabama High School; Prof. Richard Thorley, The Harley School
Advisor: Prof. Kevin McFarland

Muons detected on Earths's surface typically originate from high energy collisions occurring in the outer atmosphere. Muons created from the same collision will travel in a wave front and, if the wave front is directed at the Earth's surface, may be detected using scintillating panels. Utilizing a linear array of three large scintillating panels and detailed timing information, we were able to determine that about 28% of the 6200 events recorded followed the pattern consistent with a wave front. In a second array, a rectangular arrangement was used to measure the directions of the muon showers. We concluded that the directions of these multimuon showers are similar to those of single cosmic ray muons. This project was supported in part by NSF award PHY-0242483.