XXVI
ROCHESTER SYMPOSIUM
FOR PHYSICS (ASTRONOMY & OPTICS) STUDENTS
SPS Zone 2 Regional Meeting

April 21, 2007

ABSTRACTS

Quantum Optics

The Design and Physics of Optical Trapping

Joseph Shatzel, Canisius College
Advisor: Prof. Mitra Feizabadi, Canisius College

Recent advances in optical and biomechanical techniques have demonstrated that it is possible to make observations of the dynamic behaviors of single molecules. In this talk, the design and physics behind laser tweezers will be demonstrated. The target for building and designing these devices can include the investigation of molecular motor motility, bio-filament rigidity, and to study the dynamics of complex cellular structures.

Violating the Bell-Kochen-Specker Inequality with a Single Photon Entangled State

Bryce Gadway, Colgate University
Advisor: Prof. Enrique Galvez, Colgate University

Similar to the popular family of Bell Inequalities, used to disprove local realistic hidden variable theories and support a quantum mechanical interpretation of reality, Bell-Kochen-Specker (BKS) Inequalities pertain to so-called non-contextual hidden variable theories that describe a broader class of physical systems in which locality assumptions do not necessarily come under scrutiny. Specifically, a single particle – therefore inherently local – can violate the BKS Inequality if it has non-commuting observables. Our research has been using a single photon state, entangled in polarization and momentum, to test the Clauser-Horne-Shimony-Holt formulation of the BKS Inequality. We have obtained several BKS Violations, and are currently refining our apparatus to get greater control of distance in our interferometers in hopes of improving the error of our measurements and improving reproducibility.

Trapping and Rotating Objects with Laguerre-Gaussian Beams

Nikolay Zhelev, Colgate University
Advisor: Prof. Enrique Galvez, Colgate University

The goal of the project is demonstrating transferring angular momentum of Laguerre-Gaussian optical beams to small objects – in this case, small polystyrene spheres (~5-10µm in diameter). In order to do that, I used a device called an "optical tweezer", a device that can trap and move small objects by focusing light upon them. Also, instead of using Laguerre-Gaussian beams produced by the usual methods (diffraction gratings or Spatial-Light modulator), I used an adjustable phase plate – a Plexiglas plate with a cut to its center. Passing a laser beam through the center of the plate and creating a wedge between the two sides of the cut produces higher order Laguerre-Gaussian beams. This way, we can easily create Laguerre-Gaussian beams with interesting properties, such as orbital angular momentum. The project can be separated into three stages: (1) Constructing the apparatus and testing it by using plain laser beams, (2) investigating the properties of the beams produced by the phase plate using a Mach-Zender interferometer, and (3) Passing these beams through the "optical tweezer" and achieving both trapping and rotating of the polystyrene spheres.

Construction of Optical Mode Converters for use in Bose Einstein Condensate Studies

Kristin Beck, University of Rochester
Advisor: Prof. Nicholas Bigelow, University of Rochester

Light's polarization can effect its interactions with matter. Linear and circular polarizations are two common polarization modes, but radial and azimuthally polarized beam modes can be created through use of optical mode converters. These polarization modes have a donut-shaped intensity profile, possess azimuthal phase, and can be described as a vectorial combination of Laguerre-Gaussian beams. The author constructed two optical mode converters to convert a linearly polarized TEM00 mode from a 780 nm diode laser into either a radially or an azimuthally polarized beam by cutting and then reassembling two half wave plates. In addition to exploring the underlying mechanisms of the optical mode converter, the presentation will include applications for these polarization modes of Laguerre-Gaussian beams in Bose Einstein Condensate (BEC) studies.

Electronic Speckle Pattern Interferometry (ESPI) Phase Analysis with a Temporal Hilbert Transform for Atmospheric Disturbances

Venkat Motupalli, Gregory Schwartz, and Chad Giacomozzi, United States Military Academy, West Point
Advisor: Lieutenant Colonel John Hartke, United States Military Academy, West Point

We use an Electronic Speckle Pattern Interferometer (ESPI) along with software based mathematical calculation and rendering to quantify the phase changes due to pressure differences in air. One arm of the interferometer is expanded and passes through a diffuser, creating a speckle pattern in front of a pressure chamber. The second arm is a smooth reference beam, which interferes with the first arm behind the pressure chamber. This interference pattern is imaged by a CCD array. Computer software then compiles each captured frame into a three-dimensional matrix of pixel intensity values. It then removes the bias and takes the temporal Hilbert transform to create an analytic signal. The phase is the inverse tangent of the ratio of the complex part of the Hilbert transform of the analytic signal to the real part. Thus, we can image pressure changes in air by calculating the phase change in digital images, which has the potential of imaging the air flow around an air frame without modifying the environment.

Detection of Extremely Small Silicates

Alex Kitt, State University of New York at Buffalo
Advisors: Prof. William Forrest and Ben Sargent, University of Rochester

The detection of previously unobserved small silicates (.01 micron radius grains), now called atto-rocks, is accomplished by studying the properties of extended emissions around stars. Using data reduced from the IRS module of the Spitzer Infrared Space Satellite we can model the extended source's spectrum as a function of radial distance from the star. Comparing these results to the expected radiative equilibrium temperatures can give an idea of the temperature, composition, and heating mechanism of the source. In preliminary studies it is apparent that atto-rocks must be introduced to adequately model the spectrum.

Determining the Fate of Star-Forming Cluster Galaxies

Corey Snitchler, Siena College
Advisor: Prof. Rose Finn, Siena College

It is known that currently there are less star-forming galaxies than there were in the past. Astrophysicists and astronomers have attempted to pinpoint the cause of this phenomenon, and have suggested two possible sources. The first one is based on the idea that galaxies in-falling into galaxy clusters have all their gas stripped away and, therefore, have no gas left to form stars. The second idea suggests that galaxy clusters are the oldest environments. Consequently, they are the final resting place of older galaxies that have used up their entire supply of star forming gas. Using information gathered by the Spitzer Space Telescope and the EDiSCs cluster survey, research is being done on the far-infrared radiation being received, in order to look at vital information, such as emission lines, red shift, and morphology. This far infrared radiation, viewed in 24 microns, is necessary in order to solve this problem and determine the possible fate of all star-forming galaxies.

Period-Color and Amplitude-Color Relations in the Sloan RR Lyrae Sample

Christina Phelps, State University of New York at Oswego
Advisor: Prof. Shashi Kanbur, State University of New York at Oswego

We analyze a sample of RR Lyraes obtained from the Sloan Digital Sky Survey (SDSS). We Fourier analyze their light curves using both ordinary least squares and simulated annealing and demonstrate how this latter method can improve the Fourier fit. We use the Fourier fits to construct Period-Color and Amplitude-Color relations at maximum and minimum light and compare our results with previous work. We close with a short discussion of the physics behind these relations and possible future work.

A Theoretical Investigation into the Properties of RR Lyraes at Maximum and Minimum Light

Greg Feiden, State University of New York at Oswego
Advisor: Prof. Shashi Kanbur, State University of New York at Oswego

We construct a large grid of full amplitude hydrodynamic models of RRab stars. We confirm earlier findings that, at minimum light, the PC relation is flat and elucidate the physical reason for this: the interaction of the hydrogen ionization front and photosphere at low densities. Traditionally the properties of RRab stars at minimum light have been used to estimate reddenings. Based on our findings we propose a modification of this method: using the properties of RRab stars with periods greater than about $\log P = -0.2$ to estimate reddenings.

Nuclear and Particle Physics I

Detection and Analysis of Cosmic Ray Showers

Jordan Webster and Robert Bradford, University of Rochester
Advisor: Prof. Kevin McFarland, University of Rochester

Cosmic rays originating beyond our planet constantly collide with the Earth's atmosphere. Some of these high-energy particles, most often protons, can create swarms of muons by smashing into matter within our atmosphere. This type of behavior results in a phenomenon called a cosmic-ray shower. Using large scintillator panels from Fermilab's MINERvA experiment, muons can be detected at ground level at a frequency of approximately 1000Hz. With these detectors, and through the collaboration of the PARTICLE Program, cosmic-ray shower data was collected in various positions around the University of Rochester campus. By running multiple detectors simultaneously at different distances from each other, a measurement of the diameter of a cosmic-ray shower was determined. The data collected using this type of setup also reinforces what we know about the frequency of cosmic-ray showers, and the directions from which they come. Finally, it points towards a possible conclusion that there is no correlation between the diameter of a cosmic-ray shower, and its incoming angle.

Electron Scattering and Pion Production in Relation to Neutrino-Nucleon Interactions

Elizabeth Scherrer, University of Rochester
Advisor: Prof. Kevin McFarland, University of Rochester

Neutrino flavor oscillations offer a chance to understand whether neutrinos differ from their anti-particle. Differences, if any, may appear as neutrinos and anti-neutrinos undergo flavor oscillations, specifically when a beam of neutrinos, produced as muon neutrinos initially, will change flavors to electron neutrinos. This electron neutrino is then identified by its interaction with a nucleon because it produces an electron. However, a background from the muon neutrino is possible if the nucleon is excited to a delta baryon resonant state, which then decays back to the nucleon and produces another particle, a neutral pion. Sometimes this neutral pion, which decays into two photons, will be mistakenly detected as an electron. The detection of this "electron" suggests that the initial particle was an electron neutrino, not a muon neutrino. Using available data on electron-nucleon interactions instead, where the nucleon is still excited into a delta baryon resonant state, we can measure the ratio of pions produced from different nuclei to better understand how the environment of the nucleus effects neutral pion production. This information then can be utilized in future experiments to reduce errors from the detector efficiency involving neutrino-nucleon interactions.

Fiducial Cuts for the Jefferson Lab CLAS G3 Data Set

Richard Bonventre, Elliot Imler, and Christian Shultz, Union College
Advisor: Prof. Michael Vineyard, Union College

Fiducial cuts have been determined for protons and charged pions produced by photons with energies between 0.3 and 1.5 GeV incident on Helium targets in the CEBAF Large Acceptance Spectrometer (CLAS) at the Thomas Jefferson National Accelerator Facility. This work is part of a systematic study of neutral meson photoproduction from the proton and light nuclear targets to investigate nuclear medium modifications of nucleon resonances and the meson-nucleon interaction. The fiducial cuts are performed to eliminate data from regions of the detector with non-uniform acceptance. The cuts were determined by fitting a trapezoidal function to the phi spectra binned in scattering angle and momentum for each particle type. The phi position of the corners of the trapezoids were then fitted as a function of scattering angle, and the parameters of these fits were fitted as a function of momentum to obtain the functions that are applied to the data to produce the cuts. The procedure will be described and the results will be presented.

Momentum Corrections for the Jefferson Lab CLAS G1c and G3a Data Sets

Christian Shultz, Richard Bonventre, and Elliot Imler, Union College
Advisor: Prof. Michael Vineyard, Union College

Momentum corrections have been implemented and tested for charged particles photoproduced on Hydrogen and Helium targets in the CEBAF Large Acceptance Spectrometer (CLAS) at the Thomas Jefferson National Accelerator Facility located in Newport News, VA. This is part of a systematic study of meson photo production from proton and Helium targets with the goal of investigating possible nuclear medium modifications of nucleon resonances and meson-nucleon interactions. The momenta of charged particles detected in the CLAS detector are corrected for energy losses as the ejectiles move through the detector. This is done by integrating a FORTRAN code written for this purpose into our C++ analysis code. The corrections provided improved identification of the reaction products as well as better resolution in the generated distributions. The analysis will be described and the effects of the corrections on momentum and missing mass distributions will be presented.

Silicon Vertex Tracker (SVTX) and the CAEN SY1527 Universal Multi-channel Power Supply System

Fook-Chin Chiang, University of Rochester and Harry Themann, State University of New York at Stony Brook
Advisor: Prof. Axel Drees, State University of New York at Stony Brook

PHENIX was designed mainly for measuring probes of electron, muon and photon and for studying the Quark-Gluon Plasma and Au-Au collisions. The finest tracking is at the Drift Chamber (DC) that was built by SUNY-SB. The Beam Beam Counter (BBC) tells us about Z vertex with uncertainty of +/-10 cm and together they give us a resolution at the primary vertex on the order of centimeters. Secondary vertices resulting from the decays of particles after the initial collision was approximately 400 _m away from the primary vertex and is way too small to be detected by DC and BBC. SVTX was proposed for PHENIX to facilitate the vertex tracking of a charged particle in highly reliable accuracy and precision near the collision point. It has four concentric cylinders; the two outer layers are the silicon strip detector developed by BNL whereas the two inner layers are the silicon pixel detectors with huge tracking ability. SUNY-SB designed and built the Front End Modules (FEM's). FEM must supply six different voltages to the pixel chips, thus The CAEN SY1527 Universal Multichannel Power Supply System has been proposed for SVTX pixel layers. My task is to explore operation of the system that consisted of one Low Voltage (LV, 7V) module with six outputs and one High Voltage (HV, 250V) module with 12 outputs. I control the channels from the remote location and customize the interface & voltage control on the main frame by using Graphical User's Interface (GUI) and Gimp Tool Kit (GTK+) in order to simplify the system for users who have unprecedented training. Since CAEN provides C subroutines that can be called by a GUI and thus an attempt was made to write a GUI to control the mainframe.

Poster Session

Mathematical Model of Cancer Treatment: Immunotherapy and Chemotherapy

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

This work presents a mathematical model, in the form of a system of ordinary differential equations (ODEs), governing cancer growth on a cell population level with combination immune and chemotherapy treatments. Results of the numerical simulations of mixed chemo-immune therapy, using mouse parameters, are presented.

The Mobility of Taxol in Microtubule Bundles

Joseph Shatzel, Canisius College
Advisor: Prof. Mitra Feizabadi, Canisius College

Taxol is an anti mitotic drug with a very specific method of action. It binds to beta-tubulin, hyper-stabilizing microtubules and altering the normally dynamically unstable nature. Without the ability to regularly depolymerize the microtubule become ineffective in manipulating chromosomes during mitosis. The Taxol/beta-tubulin bond is highly unstable, resulting in a large rate of diffusion through the lumen of microtubules. The dynamics of Taxol's movement through microtubules was examined by a process known as fluorescence recovery after photo bleaching, Using FRAP, it was determined that Taxol can diffuse laterally through a bundle of highly associated microtubules. Secondly, the rate of diffusion was determined to be a function of Taxol concentration when 63% or less of the available binding sites on the microtubule are occupied. This poster is based on the research performed in the cited works, and was assembled as a biophysics research project. WORKS CITED: Ross, Jennifer L. and D. Kuchnir Fygenson (June 2003) *Mobility of Taxol in Microtubule Bundles.* Biophysical Journal 84:3959–3967.

Investigating Nuclear Δ++ Components with the (n,2p) Reaction

Kirby Runyon, Jeffrey De Young, and Steven Wallace, Houghton College
Advisor: Prof. Mark Yuly, Houghton College

A measurement of the ^{3}He(n,2p)2n and the ^{4}He(n,2p)3n cross sections has been made at the Los Alamos Neutron Science Center (LANSCE) in order to explore the Δ++ contribution to the nuclear wave function. The incident neutron beam was incident on a high-pressure gas target and scattered protons were detected. The unique feature of this experiment was the use of two permanent magnet proton spectrometers, which operated continuously for a period of several years, and were centered 45˚ to the right and left of the beam line. Analysis codes currently being developed to reconstruct proton tracks and momenta will be used to analyze the ^{3}He(n,2p)n data and for the d(n,np) measurements currently underway at LANSCE.

Design and Construction of a Variable Temperature Atomic Force Microscope

Bethany Little, Houghton College
Advisor: Prof. Brandon Hoffman, Houghton College

A variable temperature atomic force microscope is being constructed at Houghton College. The microscope will operate in a rough vacuum and will utilize spring vibration isolation and eddy current damping to minimize mechanical vibration. A modified "Johnny Walker" beetle is being constructed for the rough approach. The sample will be mounted onto the walker scanning head and scanned across a fixed cantilever tip and laser assembly. When completed, the resolution should be on the order of nanometers. Liquid nitrogen and resistive heating will allow operation from about 100 K to 500 K.

Optimal Coupling in Acoustic Pipes

Nicholas Zufelt, State University of New York at Potsdam
Advisor: Prof. Lawrence Brehm, State University of New York at Potsdam

For standing wave patterns in acoustic pipes with both ends open, the pressure nodes exist not at the end face but at a fraction of the pipe diameter beyond the end face. This fact leads to the non-intuitive fact that, in order to achieve maximal transfer of the standing wave from one pipe to another, the two pipes must be separated by twice this distance. We report measurements made on a pair of acoustic pipes that support this fact.

Magnetic Levitation

Zak Brown, State University New York at Fredonia
Advisor: Prof. Michael Grady, State University New York at Fredonia

The idea of magnetic levitation is an attractive concept for the trains of tomorrow. The efficiency of this idea was explored using a rotating array of magnets and a copper sheet. The array was placed on a rotating disc, with a copper plate placed at varying separation distances from the array. As the magnetic field was rotated, a magnetic force was induced in the copper plate, causing it to repel the array. The force exerted on the plate was then measured as a function of separation distance and power input to determine the maximum ratio of output force to input power. Future plans include varying the material and construction of the plate, as well as possibly trying to determine the effect of eddy currents on the project.

Quantum Optics/Nano Structures/Condensed Matter Physics

Generation of Polarized Electrons from Rubidium Gas

Joseph Tessitore, Siena College
Advisor: Prof. Mark Rosenberry, Siena College

The aim of this project is to develop a simple, relatively low-cost method of producing a beam of polarized electrons. First, we create a cell of polarized rubidium gas, and by passing an electron beam through that polarized gas, we produce a polarized electron beam. The rubidium gas is polarized through the process of optical pumping with a 10W laser set to the D1 transition of rubidium, 795 nm. The cell is made of steel, because of its durability and ease of construction. To minimize the rate of depolarization, we coated the inside of the cell with a thin layer of tetracontane ($C_{40}H_{82}$). To measure the polarization, a second laser set to the D2 transition of rubidium is used to measure the Faraday effect that is caused by the polarization in the rubidium. Our aim is to determine the best combination of variables, including cell material, temperature, and coating that yields the lowest depolarization rate, and as a result, a higher polarization of rubidium gas.

Modeling Semiconductor Quantum Dots

Steven Cowen, Siena College
Advisor: Prof. Joshua Diamond, Siena College

The popularity of quantum dots in recent years has grown as applications such as cancer detection have been discovered. Although much is already known about these nanostructures (about 1-10 nm in size), there are still some theoretical considerations that can be made. Singh and Kumar have shown the effects of an effective mass inside and outside a one-dimensional quantum well using the Ben-Daniel Duke boundary condition in a particular model for semiconductor quantum dots. We study the effects of the Ben-

Daniel Duke boundary conditions in a 3 dimensional case. In particular, we examine potential effects on the energy levels. We also explore the charge density distribution in this simplified model of quantum dots. We use the 3-dimensional Schrödinger equation with *Mathematica* to yield numerical results for our energy levels and plots.

Synthesis of Nano-Structures: A Feasibility Study

Corey Lemley, State University of New York at Oneonta
Advisor: Prof. Monisha Mahanta, State University of New York at Oneonta

Nanostructure synthesis and nanophotonics are some of the current focus areas of research in the field of nanotechnology. SUNY Oneonta is exploring these concepts on a Department of Energy (DOE)/NY Nano-Bio Molecular Information Technology (NYNBIT) Incubator project. The research is to determine the feasibility of synthesizing the growth of ZnO, InP, and/or GaN nano-wires using the thermal evaporation equipment available at SUNY Oneonta and chemical vapor deposition techniques cited in the literature, subject to the availability of equipment. The experimentation has the potential for involving the use of helical laser profiles, developed by Dr. Mahanta for the Air Force Research lab at Rome, NY during her senior fellowship from the National Academy of the Sciences. According to the nano-wire literature we have reviewed, such profiles have demonstrated the ability to move and manipulate nano-scale wires and particles due to their inherent orbital angular momentum.

We are also exploring localized tunneling by creating 'islands' of metal or molecular material on a substrate to assess the feasibility of using the available resources for the groundwork on quantum cellular automata for logic circuits and looking into how to create these island structures by depositing an ultra-thin, discontinuous layer of metal or molecular material and subsequently characterize their behavior.

Effect of Silver Content and Undercooling on Interlaced Cyclic Twinning in Near Eutectic Tin–Silver Solder

Duncan McGillivray, Binghamton University
Advisor: Prof. Eric Cotts, Binghamton University

The nucleation and growth of crystals from undercooled melts has long been the subject of fundamental and applied research. This study focuses on the solidification of Sn in undercooled Sn-Ag metals between 5.0 and 0.0 weight percent silver. Solidification temperature is measured by means of differential scanning calorimetry for samples cooled at a constant rate of 60ºC/min, 18ºC/min, and 6ºC/min from the melt. The microstructure of the solidified metal was analyzed by optical microscopy (bright field and polarized light). We find a small effect of silver content on the solidification temperature of the melt. Silver content also affects the amount of interlaced cyclic growth twinning found in the microstructure. For a particular silver content, twinning becomes more prevalent with lower solidification temperature.

Automated Beam Control to Improve a Double Pump Probe Experiment

Daniel Galgano and Gregory Schwarz, United States Military Academy, West Point
Advisor: Lieutenant Colonel John Hartke, United States Military Academy, West Point

The over-arching purpose of this project is to measure the non-linear optical characteristics of a certain material using a weak 40-picosecond probe pulse in a double pump-probe experiment. However, data collection can be an excruciatingly slow process producing numerous uncertainties as the probe beam becomes misaligned during the measurement process, requiring repeated tedious manual adjustments. To facilitate data measurement and reduce uncertainties associated with extended data collection times, we attempt to incorporate the invaluable software tool, Lab View 8.0, as well as ThorLabs ActiveX controls to control a pair of servo motors connected to a mirror. The program automatically alters the tip and tilt of the mirror, based on feedback from a quadrant detector placed in the beam path. This program will ensure the probe beam is always properly aligned with the pump beams, mitigating the amount of uncertainty in data collection.

Biological Physics

The Evolution of Proliferating Cells During the Course of Chemotherapy

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

Chemotherapeutic drugs control the size of the proliferating cell population in a tumor. This work presents our numerical results for the evolution of proliferating cells during the therapy. In this study, the drug's diffusion behavior is taken into account as the drug kills cells and regulates the proliferation rate.

Light Scattering Study of Alpha Crystallin Lens Protein and its Subunits with applications to Cataract Disease

Brandy Pappas, Rochester Institute of Technology
Advisor: Prof. George Thurston, Rochester Institute of Technology

Cataracts, the leading cause of blindness, result from progressive scattering of light within the lens of the eye. Ordinarily, high concentrations of proteins in the lens cytoplasm produce a relatively uniform refractive index that scatters little light. In cataracts, aggregation and phase separation of lens proteins disrupt the liquid-like packing of proteins. The proposed work will establish the low-concentration data needed to extend our own previous studies to identify the roles of individual lens protein subunits in affecting short-range order: specifically, a-crystallin. One critical difference between the aA and aB subunits is charge; from its sequence aA is predicted to have an isoelectric pH of 5.77; aB, on the other hand, is predicted to become neutral at around 6.76. Near physiological pH, the aA subunit is predicted to be more highly charged than aB. By varying the pH at which we perform light scattering, we will examine the effects of charge on subunit assembly, including self-association, aggregate size and interactions as measured by second and third virial coefficients. In a similar fashion, we will vary ionic strength in order to examine the effects of altering the Debye length characterizing electrostatic screening between molecules.

Electrostatics of an Eye Lens Protein Solution

Stephen Baker, Ben Haehnel, and Stephanie Dorn, Rochester Institute of Technology
Advisors: Profs. George Thurston, Dawn Carter, and Vern Lindberg, Rochester Institute of Technology

In cataract disease, the lens of the eye scatters light resulting in blurred vision. As the eye ages, the lens can become opaque from phase separation of the proteins in addition to other reasons including protein aggregation. There are three principal proteins found in the eye lens cytoplasm, alpha, beta, and gamma crystallin. I have been focusing on gamma-B crystalline from calf lenses in my studies. During aging of the lens, the crystallins undergo changes in their charge. Gamma crystallin is a good choice of study because of prior information about phase diagrams, structure, and interactions. Since it is expected that the charge will affect not only gamma-gamma interactions, but also interactions with other crystallins, I have focused only on the gamma crystallin interactions. Since the gamma crystallin net charge changes from near 0 to about +8 electronic charges in the pH range we will study, we hope to determine quantitatively what the importance of charge is for determining how attractive or repulsive gamma crystallin interactions are. Since the ionic strength changes the screening length in the solution, varying the ionic strength and measuring virial coefficients will give information about the relative importance of charge for gamma crystallin interactions.

Expanding from Single to Double Stranded DNA the Polarization Effect of Water and Ions on Excess Charge

Patrick McLaughlin, University of Rochester
Advisor: Prof. Esther Conwell, University of Rochester

When an extra electron, or hole, is introduced onto a single strand of DNA (ss-DNA) it polarizes the surrounding water and ion solution. The interaction of the excess charge (or hole) with this induced polarization results in the wavefunction of the excess charge being delocalized on a small number of sites on the chain. The combination of the extra charge and the polarization is called a polaron. The model we use in these calculations is a double stranded DNA (ds-DNA) case where we place the two DNA chains of bases and the excess charge inside a cylindrical cavity having the diameter of the double helix, and each of the single strands are considered as a vertical column of bases offset a distance ±Rh from the central axis. The water and ions lie outside the cavity because of the hydrophobic nature of the nucleotide bases. Our calculations solve Laplace's equation to find the energy drop due to the interaction of the inner and outer charges.

Theoretical Estimates of Polaron Energies and Wavefunctions on double Stranded DNA

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

A model was set up to take into account the effect of the polarization of water on the energy of radical cations, or holes, in DNA. A Hamiltonian was created to calculate the hole wavefunctions and stationary energy values for a simplified model with a single strand of DNA situated along the axis of the helix [D.M. Basko and E. M. Conwell, Phys. Rev. Lett. 88, 098101 (2002)]. Later experiments by Barton and colleagues have reinforced the idea that a hole is spread out over several base pairs on DNA in a water and ion solution. In order to study a more realistic model of the hole, the Hamiltonian was generalized to incorporate two chains of DNA at distances +/- Rh from the axis of the helix. Given the earlier success of calculations for the special case of the adenine-thymine duplex, we extend our calculations to other DNA sequences. We also generalized our Hamiltonian further to incorporate sequence-dependent values of the transfer integral, which is the pi-orbital overlap between bases. Using our knowledge of DNA geometry we choose Rh equal to 3 angstroms; with this value we were able to conclude the width of the hole is very similar to what we obtained in the single stranded case for a particular sequence, and the stationary energy value of the hole is somewhat less than the single stranded case.

Experimental Tools and Techniques

Implementing a Semantic Web Knowledge Database for Scientific Control and Diagnostic Systems

Daniel Gresh, Laboratory for Laser Energetics, University of Rochester
Advisor: Prof. Richard Kidder, Laboratory for Laser Energetics, University of Rochester

A comprehensive Semantic Web implementation of a knowledge database is being designed that physicists can use to gather real-time and stored information about the OMEGA EP laser in an organized manner, making research more efficient. A solid foundation for such a Semantic Web database has been built at the University of Rochester Laboratory for Laser Energetics using the Java programming language, as well as the XML, RDF, OWL, ICE, SPARQL, Oracle, and SQL languages. At present, the implementation can obtain real-time images from cameras and display them on web pages. It can display text and images about control systems and diagnostics. Using this internet-based Semantic Web implementation, a scientist will be able to obtain specific, detailed information regarding any aspect of the OMEGA EP Control Systems in an efficient manner from a single source, as opposed to searching through numerous technical and design documents. The database will be used not only to retrieve information from technical documents, but it will also be used to organize information into a single repository, and present information from other sources such as information from e-logs, journal entries, and status documents. The LLE Semantic Web knowledge database implementation will capture real-time data, such as images and information related to the laser shot, from diagnostic services in the OMEGA EP laser bay, and current plans are to program the Semantic Web implementation to analyze the data using Matlab routines and pseudo-artificial intelligence, and then to present specific results to the user.

Initial Results from the Houghton College Cyclotron

Andrew Loucks, Houghton College
Advisor: Prof. Marl Yuly, Houghton College

Initial performance characteristics for the Houghton College cyclotron have been measured. The cyclotron consists of a cylindrical vacuum chamber with diameter 15.3 cm and height 2.5 cm containing a hollow "dee" electrode and a ground electrode. At resonance, an RF source creates an oscillating electric potential of several thousand volts between the electrodes that can be tuned to frequencies between 2 MHz and 15 MHz. The chamber is placed between the 15.3 cm diameter poles of a 1.1 T electromagnet and is evacuated to a pressure of about 10^{-6} torr. Hydrogen, helium of deuterium gas may be introduced and ions created by electron bombardment from a hot cathode. The magnetic and oscillating electric fields cause the ions to spiral outwards, gaining energy as the orbit radius increases. We anticipate maximum kinetic energies for protons, deuterons and helium nuclei to be about 280 keV, 140 keV, and 70 keV, respectively.

Considerations in the Design of Electrostatic Accelerator Columns

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

Several generations of acceleration columns have been tested for use in the electrostatic electron accelerator at Houghton College. Early designs allowed charge to build up in the column causing the beam to be deflected. The previous design, which used a series of alternating plastic and aluminum rings held together and sealed with vacuum epoxy, was too fragile and was prone to leak when evacuated. A new design eliminates many of these problems. An alternating series of 50.8 mm OD plastic and stainless steel rings are compressed by six pre-stretched, 1⁄4-inch threaded nylon rods. Glands machined into the plastic rings hold Viton o-rings that provide a good vacuum seal. The high voltage is supplied by a Van de Graaff generator mounted in-line with the accelerator column and electron gun. The entire assembly is supported by an insulating acrylic base with rigid but adjustable joints.

A Remotely-Controlled Electron Gun for a 200 keV Electrostatic Accelerator

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

One problem encountered in the design for the Houghton College electrostatic electron accelerator is the electron source, which must be operated while floating at a potential of 200 kV. The simple two-grid electron gun used previously did not have electrodes to provide focusing and positioning of the beam. A new electron gun was constructed using an RCA 3RP1 cathode ray tube. This electron gun may be remotely controlled via an Ethernet-GPIB-RS232-Fiber optic link to a BASIC stamp-2 microcontroller inside the high voltage terminal. This microcontroller controls the intensity, focus, and acceleration grids of the cathode ray tube using a 12-bit 4 channel DAC7624 digital-to-analog converter, which, after current amplification, drives four EMCO G20 DC to HV DC converters.

Highly Uniform Magnetic Fields and Nuclear Magnetic Resonance

Dave Antanavige, Siena College
Advisor: Prof. Mark Rosenberry, Siena College

This project focuses on constructing a highly uniform magnetic field (magnitude 10 Gauss, with gradients limited to 10 µGs/cm) for NMR studies in a cell 2.0 cm in diameter. Using the Biot-Savart Law one can determine with good accuracy the magnetic field generated by any given configuration of current loops, allowing the system to be designed. The constraints imposed by material availability will be discussed. After construction of the simple solenoid, additional corrections can be added to improve the gradient, such as end corrections and trim coils. When complete, the system will be used to characterize a noble gas maser for studies of fundamental symmetries.

Guest Speaker Session

The Physics of Baseball

Professor Charles Freeman, State University of New York at Geneseo

Baseball is a particularly interesting game for physicists to study. What makes a curve ball curve? How much farther does the ball really travel at Coors Filed in Denver than at Shea Stadium in New York? Why do left-handed pitchers have more success against left-handed batters (and right-handed pitchers have more success against right-handed batters)? What is the difference between two-seam and four-seam fastball? How do you through a split-fingered fastball? An ex-pitcher and current physicists sheds some light on these questions and discusses some other interesting physics at work in a baseball game… Feel free to bring your glove, you just might catch a souvenir.

Physics Education and Physics Laboratories

Development of an Air-Water Rocket Experiment

Andrew Wasicek, Colgate University
Advisor: Prof. Joseph Amato, Colgate University

The goal of this project is to measure acceleration versus time during the launch of an air-water rocket. Our desire is to build a quantitative rocket lab for first-year college physics students. Many schools only have qualitative air-water rocket demonstrations, and those schools that do have quantitative rocket labs measure maximum height or time of flight rather than acceleration. A physical model for air-water rockets contains many topics suitable for an introductory college physics course, including: Newton's laws, momentum conservation, rocket thrust, fluid dynamics (Bernoulli's equation), and gas expansion. Our apparatus is made from simple, inexpensive components that are easily assembled and duplicated. Sample acceleration data and analysis will be provided.

Finding the Fun in Physics – Teaching Science with Summer Camp Activities

Lia Stelljes, Bruce Thompson and Alexis Abramo, Ithaca College
Advisor: Prof. Michael Rogers, Ithaca College and the Ithaca Sciencenter

In my high school physics class, I was discouraged by the numbers of my peers who were intimidated by physics, who were resistant to even the thought of learning such difficult, confusing, and boring topics. Perhaps if we had been exposed to physics concepts at an early age, in more relaxed, fun atmosphere, these theories would seem more manageable for more people. Making physics more attainable became my goal for my summer internship at the Sciencenter, a family science museum, in Ithaca, NY. I worked as a camp counselor for a summer program designed to provide young kids with hands-on science experience through experiments and field trips. I had the opportunity to design, teach, and develop activities, most of which were based on physics concepts including density, circuits, states of matter, planetary motion, and the electromagnetic spectrum. Throughout the different camp sessions, I was able to make adjustments to my activities and learn how to teach physics concepts to elementary students. During my presentation I will review some of the activities I developed and the lessons I learned while implementing them. I also hope to inspire you to become involved in such rewarding outreach programs.

Modification of Laboratory Experiments for use in a New Performance-Based Physics Classroom

Rhea Hanrahan, Luke Keller, and Mathew Sullivan, Ithaca College
Advisor: Prof. Michael Rogers, Ithaca College

The installation of a new performance-based physics teaching laboratory at Ithaca College required an adaptation of the current traditional laboratory experiments. I revised the experiments to work in the new room that has eleven 6.5-foot-diameter tables that seat 9 students who work in groups of three. The format of the class also changed from a 50 minute lecture MWF and a 3 hour lab once per week to an hour and 50 minute integrated class MWF. The revisions included some changes in equipment used as well as adjusting the way the experiment itself was conducted. First I performed the traditional laboratory experiments to get a feel for the purpose and effectiveness of the experiment. Then I revised the laboratory experiment to fit the new classroom and teaching style. After executing the revised labs I took an inventory of the materials needed for each experiment, ordered new equipment, received the equipment, and devised an organization scheme for easy storage in the new room. The physics department is currently engaged in a physics education research project to assess the impact of the new space on student learning. I and other undergraduate researchers will be analyzing the first year's data summer 2007.

Chaos in a Resistor-Inductor-Diode Circuit

Joseph Murphy, State University of New York College at Brockport
Advisors: Profs. Richard Mancuso and Mohammed Tahar, State University of New York College at Brockport

In the investigation of the sinusoidally-driven resistor-inductor-diode circuit, data collection techniques have pointed out that the circuit was feeding back into the driver. Using an operational amplifier, the generator was isolated from the feedback provided by the circuit. This allows data collection from the circuit using National Instruments' LabVIEW. This data allows for the creation of a bifurcation diagram for two of the possible parameters, DC offset and temperature. A differential equation that models this circuit has been non-dimensionalized and is in qualitative agreement with laboratory observations.

Astronomy/Gravitational Physics II

Materials using X-26A X-Ray Microprobe Beamline

Ilona Sitnitsky, State University of New York at Plattsburg
Advisor: Prof. George Flynn, State University of New York at Plattsburg

On January 15th, 2006 NASA's spacecraft, Stardust, delivered material from Comet 81P/Wild 2, deposited along entry tracks in low-density silica aerogel. The chemical compositions of 23 of these tracks was determined. We analyzed 5 of these tracks by x-ray fluorescence, using the X-26A X-Ray Microprobe beamline at the National Synchrotron Light Source (Brookhaven National Laboratory). We summed the data for these five tracks and subtracted the background from contamination in the aerogel capture medium to find the element abundances that Wild 2 is composed of. The total 23 tracks were collected in aerogel and residue in 7 impact craters in Al-foils. According to analysis of all 23 tracks the mean chemical composition of Wild 2 is similar to the CI carbonaceous meteorites. CI carbonaceous meteorites are believed to represent the composition of the non-volatile starting material of our Solar System. From calculations and data analysis, Wild 2 and CI composition agree within 35% of Magnesium, Silicon, Chromium and Nickel, and 50% for Calcium and Manganese. Furthermore, our data indicate that Wild 2 is enriched with moderately volatile minor elements as Copper, Zinc and Gallium, and suggests that CI meteorites may not indicate the Solar System composition for these elements.

Fourier Transform Infrared (FTIR) Analysis of Meteorites

Michelle Dragoon, State University of New York at Plattsburgh
Advisor: Prof. George Flynn, State University of New York at Plattsburgh

Meteorites contain a small amount of organic matter, delivered to the surface of the Earth by impacts. This organic matter may have been important for the origin of life. Characterization of this organic matter is potentially important for the study of the origin of life. The organic matter is a minor component of meteorites, typically <2% by weight. It is generally extracted from the meteorite by acid treatment that dissolves the minerals leaving the insoluble organic matter (IOM). However, the harsh acid treatment that dissolves the minerals may also alter the organic matter.

Fourier transform infrared (FTIR) spectroscopy is an analytical tool based on interferometry that compares the transmitted light energy of the IR spectrum to the emitted source spectrum. Via this technique, spectrums are generated from meteorite samples, which were previously prepared on copper grids. Analysis of each spectrum, for the presence of the four aliphatic C-H stretches between 2800 and 3000 cm^{-1} and the aromatic C-H stretches between 3000 and 3100 cm^{-1} is indicative of organic matter. We are examining samples of the Murchison and Tagish Lake meteorites, both rich in organic matter, comparing the aliphatic and aromatic C-H stretching intensities in the meteorite with those on IOM from the same meteorite.

Search for a Diurnal Variation of a Gravitational Stochastic Background

Chad Forrest, University of Rochester
Advisor: Prof. Adrian Melissinos, University of Rochester

Einstein's theory of General Relativity predicts the existence of gravitational radiation. Based on this prediction, a gravitational signal should exist in the stochastic background (analogous to the cosmic microwave background left over from the big-bang). The LIGO interferometers can search for this stochastic signal even if the corresponding metric strain is below the noise floor of a single interferometer. This is achieved by correlating the signal from two different detectors. An alternate method, that uses a single interferometer, is to search for a diurnal variation of the detected strain. If the signal originates from a single point in the sky, or from a region such as the galactic plane, discrete lines in the frequency spectrum corresponding to the earth's sidereal rotation frequency and its harmonics should be observed. First, the power spectral density (PSD) of the data, using 64 s long segments, is obtained. Second, integrate the spectrum over a +/- 50 Hz band around the free spectral range (which corresponds to 37.52 kHz) where the interferometer is most sensitive. The integrated power forms a time series (sampled with 1/64 Hz resolution) and it is Fourier analyzed using the Lomb-Scargle algorithm, and examined for the diurnal frequency and its harmonics.

Quantum Field Theory

Para – Statistics I

Matthew Barbery, Binghamton University
Advisor: Prof. Charles Nelson, Binghamton University

In general, the boson and fermion canonical commutation relations of Quantum Field Theory (QFT) have provided a solid theoretical framework for the probabilistic analysis of field properties. However, there is no reason a priori why QFT ought to be utilized in this respect over an alternate field theory for particles with more general statistics, called "para-statistics." An interesting application of "para-statistics" stems from the Spontaneous Symmetry Breaking (SSB) phenomena that occur when the ground state of a system exhibits less symmetry than the Hamiltonian of that system.

Para – Statistics II

Joshua Julian, Binghamton University
Advisor: Prof. Charles Nelson, Binghamton University

In general, the boson and fermion canonical commutation relations of Quantum Field Theory (QFT) have provided a solid theoretical framework for the probabilistic analysis of field properties. However, there is no reason *a priori* why QFT ought to be utilized in this respect over an alternate field theory for particles with more general statistics, called "para-statistics." An interesting application of "para-statistics" stems from the Spontaneous Symmetry Breaking (SSB) phenomena that occur when the ground state of a system exhibits less symmetry than the Hamiltonian of that system.

Para – Quantum Field Theory

Shan Huang, Binghamton University
Advisor: Prof. Charles Nelson, Binghamton University

Para-quantum field theory offers a general scheme of quantization, describing particles that do not obey the well known Bose-Einstein and Fermi-Dirac statistics.   As it is well known, fermions exist in completely asymmetric states while bosons exist in symmetric states. Para-quantum field theory adds a new parameter in which the maximum number of fermions (bosons) that can exist in completely symmetric (asymmetric) states depends on the order of the particle p. Hence $p = 2$ allows two para-fermions of that order to exist in the same state. For ordinary bosons and fermions, it is very useful to rewrite operators in a normal ordered form in which all particle annihilation operators are on the right side and all particle creation operators are on the left side. In para-quantum field theory operators can be rewritten in a $(p+1) \times (p+1)$ normal ordered matrix (NOM) representation, similar to the reduced matrix elements of the well known Wigner Eckart theorem.

Nuclear and Particle Physics II

Transformation Algebras between a New Coupling in Top Quark Decay and the Standard Model

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

With our current knowledge there exists the possibility of a new coupling in top quark decay, which can be tested using spin correlation functions. Investigating the structure of the new coupling showed that the new helicity amplitudes for t → W+b decay with the new coupling can be related to the standard model helicity amplitudes through 4x4 matrices. These transformation matrices form an algebra whose structure will be discussed, as well as the properties of the algebra under various limiting cases of the parameters that the matrices depend on. This coupling and associated algebraic structure could have application to other processes involving the top quark, or both of the third generation quarks.

Additional Couplings in the Standard Model at the High Energy Limit

Patrick Gan, Binghamton University
Advisor: Prof. Charles Nelson, Binghamton University

The Top Quark Sector of the Standard Model may offer new physics in the form of a new tensorial coupling. This new coupling is driven by the t → W b vertex. Feynman amplitudes are calculated with the new coupling seeking the goals of gauge invariance and good high-energy behavior as E → infinity. Series expansions in E are used to systematically break down each amplitude per diagram. Additional couplings at other vertices will need to be introduced. One then hopes that the E divergences cancel out when all amplitudes are summed in order to conserve gauge invariance and good high energy behavior as E → infinity.

Investigating the Effects of a New Lorentz Structure in $Z \rightarrow b\bar{b}$ Decay

Alessandra Borgia, Binghamton University
Advisor: Prof. Charles Nelson, Binghamton University

The third generation of quarks is unusually heavy suggesting the possibilities of new properties existing within it. Presently, there is a search for possible effects of additional Lorentz structures in the on shell decay of $Z \rightarrow b\bar{b}$. Various amplitudes that are affected by the Lorentz structures have been worked out with Feynman diagrams including affected vertices. This new coupling may affect not only the CP violation of the decay but also three observables, A_{FB}, A_{LR} and R_b. Currently the A_{FB} is the most affected with this additional Lorentz structure, in that it brings the Standard Model's prediction closer to the experimental data taken at LEP.

A Three-Body Partial Decay Width in the Littlest Higgs Model

Andrew Whitbeck, University of Rochester
Advisor: Prof. Lynne Orr, University of Rochester

The Littlest Higgs model, an extension to the Standard Model of Particle Physics, requires the existence of several extra particles. One of those, Z_H, is a heavy version of the standard model neutral vector boson. The decay width for the Z_H has previously been calculated but only through considering 2-body decays. The 3-body decay process, $Z_H \rightarrow Z_L HH$, is considered here. The width is calculated via a Monte Carlo simulation and plotted as a function of some mixing angle in the Littlest Higgs model that results in mass diagonalization. From this the branching ratio for this process is calculated in order to quantify its significance.