2009 PHYSICS/ASTRONOMY REU STUDENT SYMPOSIUM
SUNY, STONY BROOK

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INTRODUCTION

Stony Brook University is proud to host the Research Experiences for Undergraduates (REU) Program in Physics. Sponsored by the National Science Foundation (NSF), this program gives undergraduate students an intensive hands-on research experience and involves them in all phases of the research process. This year, ten summer researchers from colleges and universities throughout the country were selected from a select pool of over three hundred applicants. In carrying out their projects, REU participants worked alongside Stony Brook's faculty, post-docs, graduate students and other undergraduates. The summer activities culminated in a presentation of the students' work in a research symposium and in a written report.

As you read this collection of their abstracts, you will see evidence of their hard work, keen insight and enthusiasm, and be impressed at what they have accomplished in only eight weeks. I have no doubt that these individuals will continue on with successful academic and research careers.

—Erlend Graf, NSF REU Physics Site Director, Stony Brook University

Mara Anderson
Dickinson College

Systematic Investigation of Optical Activity in Sugar Solutions

Mara Anderson, *Dickinson College*; Marty Cohen and John Noé, *Laser Teaching Center, Department of Physics and Astronomy, Stony Brook University*

This project was inspired by a dramatic optics demonstration: vibrant colors appear when linearly polarized (LP) white light passes through corn syrup and is viewed through a second polarizer sheet. The colors cycle through pale yellow, aqua, blue, purple and orange as the polarizer is rotated. These effects are due to the chirality (left-or right-handed structure) of sugar molecules and their resulting ability to rotate the plane of polarization of LP light, an effect called optical activity. (The rotation comes about because LP light is equivalent to a superposition of left and right circularly polarized light, and these two forms of light experience slightly different indices of refraction in an optically-active medium.)

We decided to systematically investigate the optical activity of fructose, a left-handed sugar. The overall goal was to explain and predict the color effects seen in the demonstration. Several types of measurements were carried out with a variety of polarized lasers: 633 nm red HeNe; 594 nm yellow HeNe; 532 nm green DPSS; 488 nm blue Ar ion; and 404 nm violet diode. The optical activity was determined from the angle through which a rotatable polarizer needed to be turned to precisely offset the activity. In one set of experiments, we first varied the fructose concentration in a water solution with constant path length and then later varied the path length while the concentration was kept constant. Other experiments explored the dependence of rotation angle on wavelength in both fructose and corn syrup, a mixture of fructose and the right-handed sugar dextrose (glucose).

Our results for the path length and concentration experiments are as expected: the optical activity varies linearly with either variable. To obtain a linear relationship with respect to concentration it is important that the concentration be recorded as grams of sugar per volume of final solution. We also found that the rotation for constant concentration and path length varies as $1/\lambda^2$ in both fructose and corn syrup. This unexpectedly strong wavelength dependence is in agreement with results subsequently found in a literature search.

This research was supported by a grant from the National Science Foundation (PHY-0851594).

Maxwell Grady
Loyola University Chicago

Signal Processing and Data Analysis for the MARIACHI Project

Maxwell Grady, *Loyola University Chicago*; Subodh Chiwate, Bingxin Shen, Pingyi Xiong, Çağla Taşdemir, *Stony Brook University*; Mónica Bugallo and Petar Djurić, *Department of Electrical and Computer Engineering, Stony Brook University*

The Mariachi Project is an ongoing collaboration between departments to develop a new method of detecting Ultra High Energy Cosmic Rays via Bistatic Radar methods. The project has collected a vast amount of data, nearly 3TB. One important aspect of the project is the processing and analysis of this large data set. The signal processing is handled by the Communication Signal Processing and Networking lab (CoSiNe) in the Electrical and Computer Engineering Department. Grid Computing is utilized to deal with the large quantities of data collected by the project because one computer simply can not handle the workload. Emphasis for the processing has been placed on meteor detection because meteor detection via Bistatic radar has been well studied and documented in the past. The idea is that detection of cosmic rays should be similar to the detection of meteors.

The received signal after being recorded and split into various files must then be classified as either a local source (broadcast from NYC area) or reflection from distant transmitter. The distant signal reflections are the objects of interest to this project. The received reflections can then be further classified by what targets possibly caused the reflections such as lightning, meteors, airplanes or even cosmic rays. Another important research topic has been the transition to Digital TV, DTv, which occurred on June 12th, 2009 in the United States. This is important because the analog TV signals which served as the transmitter for our Bistatic radar system are no longer available thus the system must be adapted to use a new transmitter.

While research is still ongoing to determine the viability of the new DTv signals as transmitters of opportunity, more studies need to be carried out. Some progress has been made in new methods for classifying the received signals. Our current data will hopefully provide enough information about the signals to lead to processing algorithms that can properly distinguish reflected signals from local noise. After these algorithms are established we hope to find a way to transition to using DTv signals and apply similar algorithms to study the new source. *This work was supported by the National Science Foundation (NSF Grant PHY–0851594).*

Ryan Maunu
University of Minnesota-Twin Cities

Characterization of the Silicon Microstrip Sensors for the ATLAS Tracker Upgrade

Ryan Maunu, *University of Minnesota*; Burton Dewilde, Robert McCarthy, David Puldon, Michael Rijssenbeek, *Stony Brook University, Department of Physics and Astronomy, High Energy Physics Group*

The ATLAS Experiment is one of two general-purpose detector collaborations at the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland. Composed of the Pixel Detector, Semiconductor Tracker (SCT), and Transition Radiation Tracker (TRT), the Inner Detector tracks the paths of charged particles created in the proton-proton collisions produced at the center of the ATLAS detector and measures their momenta. The heavy radiation fluence experienced by the sensors of the SCT over the next ten years will unavoidably degrade the device properties, eventually preventing the sensors from working. In 2018, a luminosity upgrade of the LHC by a factor ten is planned. A future upgrade of the SCT is therefore necessary.

In this presentation, we report on characterization of prototype silicon sensors for the SCT upgrade. High voltage bias tests were performed on three parts of the sensors. The bias pad is tested to determine the sensor's depletion voltage and to verify that the sensor behaves like a proper diode. Using the AC pads located on the silicon microstrips, the dielectric current, coupling resistance, interstrip capacitance, and intrinsic capacitance of the silicon microstrips are determined. The DC pads of the silicon microstrips are used to determine the interstrip resistance, strip current, and the resistance of each strip's polysilicon HV bias resistor. All tests were initially performed by hand to verify the correct operation of the measurement equipment and the software. Intrinsic capacitances and resistances of the apparatus were corrected for. The interstrip resistance was shown to be linear.

Bulk testing began on all 1280 strips of the upgrade sensors. Results from all sensors tested thus far have been perfectly within sensor specifications. Testing is ongoing.

This work was supported by a grant from the National Science Foundation (PHY–0851594).

Matthew Onstott
Wichita State University

Vibrational Excitations of ^{60}Ni(p,p′)

Matthew Onstott, *Wichita State University*; Tom Rao, Greg Wille, *Stony Brook University*; Thomas K. Hemmick, Richard Lefferts, Andrzej Lipski, Linwood Lee, *Department of Physics and Astronomy, Stony Brook University*

The centerpiece of this research experience concerns the creation of a student-geared experiment for the Stony Brook University Center for Accelerator Science and Education (CASE). The ultimate destiny of the experiment in question is its use, application, and reanimation in Department of Physics and Astronomy Senior and Graduate Laboratory courses. An experiment was sought which would utilize beam from the Van de Graaff Accelerator and involve modern nuclear physics detectors and methodology.

The system chosen looks at vibrational excitations of the nucleus nickel-60. For this to work, a proton beam shoots through the beamline at the lead-backed nickel-60 target to spark a ^{60}Ni(p,p′) reaction. The beam energy is selected so that primarily inelastic scattering follows and the nucleus of the ^{60}Ni target excites. This excitation energy releases in the form of gamma rays.

Detection of the gamma rays rests with a High-Purity Germanium (HPGe) detector cooled via liquid nitrogen. As a semi-conductor, germanium electrons require a bit of energy to achieve the conduction band. The introduction of gamma rays to this detector liberates electron-hole pairs which, in the presence of a large bias voltage, create a small pulse of current with proportional relationship to the energy of the gamma rays. A 3.47 keV FWHM resolution resulted for measurements of the 1.33 MeV peak in ^{60}Co. Our inability to suppress Compton events (gamma-electron scattering) discouraged us from attempting fusion-evaporation experiments which result in much messier spectra than the ^{60}Ni(p, p′).

The target, an isotopically pure foil of ^{60}Ni, is backed by a layer of Lead-208. This backing foil stops the recoiling of ^{60}Ni to eliminate broadening of the gamma rays due to the Doppler effect. The beamline includes instrumentation for vacuum and beam diagnostics. A glass shell target chamber mates to the beampipe with a circumferential seal; glass minimizes scattering of the gamma rays before detector contact.

Through proper use of the equipment and coordination between all those involved, the physics checks out and the experiment concluded successfully. Our success, this abstract, and the project in which all is encased are made possible thanks to NSF grant PHY-0851594.

Thomas Rao
Stony Brook University

Design of the ^{27}Al(p,n)^{27}Si Experiment for Senior and Grad Lab

Thomas Rao, *Stony Brook University*; Mathew Onstott, *Wichita State University*;
Greg Wille, *Stony brook University*; Andrzej Lipski, Linwood Lee, Richard Lefferts,
Thomas K. Hemmick, *Department of Physics and Astronomy, Stony Brook University*

The purpose of this summer's research position was to design an experiment to be used in the Stony Brook University Department of Physics and Astronomy Senior and Graduate Laboratory classes (Phy445/515). The experiment would utilize the Tandem Van de Graaff accelerator and facilities of the Center for Accelerator Science and Education.

One of these experiments was to find the threshold energy for an incoming proton to fuse with an aluminum nucleus and eject a neutron ^{27}Al(p,n)^{27}Si. Precise measurement of this energy can be used to measure the mass difference between ^{27}Al and ^{27}Si. Similar experiments in other systems can reveal properties of low lying nuclear states. The threshold for a neutron to be ejected from the nucleus would be measured by using a BF_3 detector encased in a cylinder of paraffin to detect the ejected neutrons resulting from fusion events, although a commercial Bonner Ball detector is currently being used. The amount of neutron radiation versus proton energy can then be plotted. Proton energy would be determined by measuring tandem voltage since they are directly proportional. The expected neutron count versus proton energy plot would be constant followed by a linear increase in radiation after the threshold energy. Therefore this line can be extrapolated backwards to find the threshold. Furthermore since the proton mass plus the proton's kinetic energy plus the mass of aluminum must equal the mass of silicon plus the mass of the neutron plus the neutron energy, due to conservation of energy, the threshold energy is the energy of the proton when the neutron energy is zero.

In order to run this experiment a high vacuum beamline with an aluminum target had to be constructed. The Tandem Van de Graaff was used to produce a proton beam that would be sent into the target room where a beamline consisting of focusing magnet, a steering magnet, a collimator, a beam viewer, and an aluminum target were setup. The experiment was run in a brief trial with students from the Davis-Bahcall Fellowship program and the result was 6.1+0.0-.25 MeV, in agreement with the accepted value of 5.972±.010. We plan to increase the precision by two orders of magnitude with our next measurement.

Research supported by NSF Grant Phy-0851594.

Max Tolkoff
Tufts University

Understanding Image Formation in the Wave Theory of Light

Max Tolkoff, *Tufts University*; Marty Cohen and John Noé, *Laser Teaching Center, Department of Physics and Astronomy, Stony Brook University*

This project came about through a chance observation while re-creating Young's classic two-slit interference experiment. The intensity pattern being recorded with a moveable photodetector was somewhat too large for the range of the translation stage, so a convex lens was placed between the slits and the detector. This had an unexpected result -- in the focal plane of the lens, we saw the two slit diffraction pattern but at increased distances, the pattern changed to something resembling a magnified image of the two slits. From the point of view of ray optics one expects a lens to produce an image, but how the lens converts the complex wave field of the diffraction pattern into an image is less obvious. We also noticed that the apparent width of the slits relative to their separation could be made significantly narrower than the actual ratio by adjusting the position of the lens.

We soon found that these effects were not dependent on the number of slits, so we considered just a single slit in our further studies. In one experiment a 150 μm wide slit was illuminated with light from a red (632.8 nm) helium-neon laser, and the resulting diffracted light was projected through a 35 mm focal-length lens to a wall about 11.5 m away. Careful adjustments of the slit-lens distance brought an image of the slit into sharp focus, and this image was 49 mm wide in perfect agreement with the 328X magnification predicted by the image/object distance ratio. The formation of the image and the "narrowing effect" noted previously were recorded in a series of photographs.

According to Huygens' principle we can model the diffraction and propagation of light by summing the complex scalar wave amplitudes contributed by all the wavefront sources within the slit at some distant location, for example a point on a screen. For paraxial rays the phase factor is just exp(ikz), where $k = 2\pi/\lambda$ is the wave number and z is the exact distance between the source and field points. As described by Goodman [1] the lens produces a phase shift $kr^2/2f$ proportional to radius squared and inversely proportional to focal length. Thus the overall computation involves propagating the light field from the slit forward to the lens, applying the phase shift, and finally propagating the modified wave forward to the screen. The intensity distribution on the screen is given by the product of the field U and its complex conjugate U*. The computations were carried out by numerical integration in Mathematica. The program easily gave the diffraction pattern at any realistic distance after the slit, and also nicely reproduced the process of bringing a plane wave incident on the lens into focus. The full calculation requires hours of computational time and we are currently exploring ways to improve its efficiency.

We thank Prof. Lowell Wood (Univ. of Houston) for helpful conversations. This research was supported by a grant from the National Science Foundation (PHY-0851594).

[1] Joseph W. Goodman, Introduction to Fourier Optics, Roberts & Co., 2004.

Rachael Tomasino
Central Michigan University

What Is the Age of that M-Star?

Rachael Tomasino, *Central Michigan University*; and Michal Simon, *Stony Brook University, Department of Physics and Astronomy*

In the astronomical field, studying young ($\leq$50 Myr) low-mass (< 1 solar mass) stars has many benefits. Some of these benefits are insight to the star formation process, and to studying the formation of circumstellar disks and the birth of planetary systems. Stars which are considered low-mass are the most abundant stars in the universe, but they are difficult to observe due to their low intrinsic luminosities. To combat the low luminosities, restricting the proximity to within 100 pc has helped make observations more favorable. These young stars near the sun are sometimes found in groups which have a common motion through the galaxy. These are called nearby young moving groups (NYMG). Unlike star clusters, which uses the 'guilt by association' technique for determining new members, finding new NYMG members is very difficult because the members are spread all over the sky. The goal of the summer was to determine whether youth could be determined by analyzing the features in the spectra of an individual star. Since it is common that late type M stars all have H-alpha emission lines, other spectral features, such as possible gravity indicators, were pursued. The spectral features which were analyzed were the sodium doublets located at ~5890 angstroms and ~8200 angstroms. After comparing the data, it seems that the sodium doublet ~5890 and ~8200 could indicate youth for late spectral type M stars.

This research was supervised by Michal Simon, Stony Brook University, and was in collaboration with Sebastien Lépine, American Museum of Natural History. This project was funded through Stony Brook University by the National Science Foundation (NSF) and this position was supported by NSF Grant Phy-0851594.

Thomas Videbaek
Stony Brook University

Visualizing the Gouy Phase of a Laser Beam

Thomas E. Videbaek, Marty Cohen and John Noé, *Laser Teaching Center, Department of Physics and Astronomy, Stony Brook University*

The propagation of laser beams is described by a precise theory that specifies the amplitude, curvature and phase of the evolving wavefronts as a function of radius r and distance z. The simplest such beams have a radially-symmetric Gaussian intensity profile I(r) which remains Gaussian-shaped as the beam propagates through space or radially-symmetric optical elements. The changing beam radius w(z) follows a hyperbola, and the point of minimum radius w_0 at a "focus" is called the waist.

An interesting and easily over-looked feature of the theory is the Gouy phase [1], a small correction to the on-axis wavefront phase compared to a reference plane wave; it varies from $-\pi/2$ to $+\pi/2$ as a beam moves through a waist. The Gouy phase can be visualized using a Mach-Zehnder interferometer setup by placing a suitable lens in one arm. Peatross and Pack [2] have described an alternative method that utilizes the "ghost beam" created by internal reflections in an uncoated plano-convex (PC) lens. When the PC lens is used to collimate diverging laser light the weak ghost beam forms a compact waist within the broad main beam and the resulting ring-shaped interference patterns can be viewed with a camera. The intensity pattern inverts as the camera is moved through the waist as a result of the changing Gouy phase.

In this project we investigated the ghost-beam method and compared it to the classic interferometer setup. We found that the former method has numerous advantages, including several not mentioned in Ref. [2]. We also found that the secondary lens used [2] to control the divergence of the beam incident on the primary PC lens is unnecessary. It is sufficient to pick a primary lens that matches the intrinsic divergence of the laser beam, which is easily determined by beam profile measurements at one or more distances from the laser. Our recorded interference patterns are in generally good agreement with a model of the interference process that we created in Mathematica. Finally, we were able to derive some interesting mathematical relationships relevant to our simplified ghost-beam method.

This work was supported by the National Science Foundation (Phy-0851594)

[1] R.W. Boyd, J. Opt. Soc. Am. **70**, 877-880 (1980).
[2] J. Peatross and M.V. Pack, Am. J. Phys. **69**, 1169-117 (2001).

Andrea Welsh
Boston University

Testing of High Voltage Filter Modules of the Liquid Argon Calorimeter and Simulations for ATLAS

Andrea Welsh, *Boston University*; Michael Rijssenbeek, Jack Steffens, *Stony Brook University, Department of Physics and Astronomy, High Energy Physics Group*

The Large Hadron Collider (LHC) at CERN is home of four particle physics experiments including A Toroidal LHC ApparatuS (ATLAS) which will probe proton-proton collisions. Studying these collisions will provide new information about the Standard Model and will guide theories of physics beyond the Standard Model (such as the existence of supersymmetric particles).

The ATLAS detector consists of multiple layers: the inner tracking detectors for measurement of charged particles, the calorimeters for energy measurement of all known particles except muons and neutrinos, and finally the muon spectrometer on the outside. The first and finely segmented part of the ATLAS calorimeter is a shower sampling calorimeter, with lead sheet absorbers interspaced with liquid argon (LAr) layers as the detection medium. Ionization electrons created in the LAr by the passing charged particles of the shower, are drifted to collection electrodes and provide an electrical signal proportional to the number of particles in the shower, which in turn is proportional to the shower initiating particle's energy. The electron drift is caused by an electric field gradient between electrodes and lead sheets across the LAr gap. The high voltage (HV) required is 2 to 2.5 kV, dependent on gap size (2 – 2.5 mm), and must be exceedingly stable because any fluctuations are perceived as collected charges on the electrodes. HV wires from the calorimeter cells inside the LAr cryostat (70 K) lead to gas-tight HV Feedthroughs (HVFT) through the cryostat walls, and then via 100 m long cables to HV power supplies. To prevent any pick-up noise on the HV cables from entering the cryostat, HV filters are installed on the HVFT. We describe the construction and testing of such filters.

Separately, Monte Carlo techniques were used to model quark collisions to generate Z bosons and their subsequent decays into electron-positron pairs. This illustrates how calorimeter resolution affects the measurement of the Z boson mass, which is the most important calibration tool for the LAr calorimeter.

This work was supported by a grant from the National Science Foundation NSF (Grant Phy-0851594).

Amanda White
Drexel University

The Mid-IR Spectrum of a Young, Cool Brown Dwarf

Amanda White, *Drexel University*; and Stanimir Metchev, *Department of Physics and Astronomy, Stony Brook University*

Brown dwarfs are a class of sub-stellar objects which are believed to form in the same way as stars but do not obtain a high enough mass to fuse hydrogen in their cores. Because of this, brown dwarfs continually cool over their lifetimes and reach low enough temperatures for molecular dust clouds to form in their atmospheres. At temperatures of 1400K, these molecular clouds are expected to "rain out" of the dwarf's atmosphere causing the dwarf to change in appearance. This process marks the transition between the L and T spectral types, and is thought to be important for explaining the photometric appearance of recently imaged extrasolar giant planets.

In this talk, I will present new mid-infrared spectroscopic data of HN Peg B, an extremely low temperature T-dwarf near the L/T transition. I will explain how spectroscopic data from the *Spitzer Space Telescope* was reduced and why spectroscopy of an object such as HN Peg B is important to understanding sub-stellar evolution, planetary atmospheres, and the transition phase between L dwarfs and T dwarfs.

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