

2008 PHYSICS/ASTRONOMY REU STUDENT SYMPOSIUM

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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, fourteen summer researchers from colleges and universities throughout the country were selected from a select pool of over two 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

Daniel Elton
Rensselaer Polytechnic Institute

TURBULENCE IN THE SOLAR WIND

Dan Elton, Rensselaer Polytechnic Institute; and Miriam Forman, Department of Physics and Astronomy, Stony Brook University

The solar wind is a low density, high velocity plasma emanating from the sun. In this project the solar wind was approximated as behaving like a traditional fluid and magnetic effects were ignored. Solar wind velocity data were taken from the Advanced Composition Explorer (ACE) spacecraft. Using Excel, the statistical properties of the proton velocity data were analyzed to test the Kolmogorov 1941 theory of hydrodynamic turbulence. Turbulent behavior manifests itself at many different scales. Over time, energy from the large disturbances is transferred to smaller structures and eventually converted to heat at the dissipation scale. The $4/5^{\text{th}}$ law was used to calculate the energy dissipation rate, which is the rate of energy transfer from large to small scales. Two new expressions derived from the $4/5^{\text{th}}$ law were investigated using several different data sets and random data. A FORTRAN program was written to perform the same calculations over longer periods. As with the Excel study, the program was set to ignore bad data points rather than interpolate around them, as the results are sensitive to the method of interpolation. The results showed that the new expressions hold under homogeneous fluctuations (such as random data), but lose correlation in the solar wind, which is generally inhomogeneous. The program was also modified to read data from Ulysses, a spacecraft which travels in a polar orbit around the sun. Data from the 1995 approach showed that turbulence was not as developed at high heliographic latitudes and distances between 1.5 and 2 AU, in agreement with previous literature on the subject. This work was supported by a grant from the National Science Foundation (Phy-0552521).

Matthew Gliboff
Cooper Union

ELECTRICAL TESTING OF SILICON SEMICONDUCTOR TRACKER CHIPS FOR THE ATLAS UPGRADE

Matthew Gliboff, *Cooper Union*; Michael Rijssenbeek, Robert McCarthy, Regina Caputo, *Stony Brook University, Department of Physics and Astronomy, High Energy Group*

The ATLAS detector experiment is one of the experiments that will take place at the Large Hadron Collider (LHC) in CERN. The Inner Detector, composed of the Pixel Detector, the Silicon Microstrip Detector (SCT), and the Transition Radiation Tracker, (TRT), is used to gain precision measurements of the path of charged particles at a small radius from the beam pipe. As the SCT must function at radiation levels that fundamentally alter the physical properties of the silicon chips over time, an upgrade is planned for continued, precise operation. Electrical testing of the new model of SCT sensor chips will soon be underway at Stony Brook. A physical and software environment has been under construction to facilitate this testing. A probe station, Cascade REL 6100 in a clean room is necessary for this testing. High voltage components have been machined, including a high-voltage pad, and a small probe positioner for electrical connections. Software was written in Labview to facilitate and automate the testing process and to coordinate the scanning process with the movement of the probe card along the sensor and control the voltage source (Keithly 237 Source Measure Unit). As of the end of the summer program, this software is functional and the testing station is physically prepared; the electrical testing will begin shortly. Additionally, as an exercise, a simulation of the structure and function of the Pixel Detector was written in VPython with the aid of Scipy and Numpy. The simulation produces both a visual representation of the detector in simplified geometry and simulates tracking of B Mesons through the passage of their decay products through the layers of the detector. The program is able to predict the decay point of the B meson within 0.1% using tracking data from the simulated detector. This work was supported by a grant from the National Science Foundation (NSF Grant Phy-0552521).

Corey Griffin
St. Lawrence University

MOLECULAR DYNAMICS STUDY OF ONE DIMENSIONAL HEAT CONDUCTIVITY

Corey C. W. Griffin, *Department of Physics, St. Lawrence University, Canton, NY*; Philip B. Allen and Tao Sun, *Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY*

The behavior of individual atoms and their interaction with one another in condensed matter is not easily observed using conventional instruments in the laboratory. This leads to difficulty testing proposed theories about how such a system behaves. Molecular dynamics takes advantage of computer simulations that can test these theories by “measuring” fundamental quantities at discrete time intervals and observing how they change.

In this work, a computer program written in the Fortran 90 language was developed to observe heat conduction in a one dimensional crystal lattice. One dimensional crystal samples were created with random displacements in atomic positions. Forces between atoms were governed by a Lennard-Jones nearest neighbor potential. A temperature gradient was constructed by driving the ends of the sample with Langevin equations incorporating damping and Gaussian white noise driving terms. The simulations were carried out using a modified Verlet time step algorithm.

We obtain results for the effective thermal conductivity for varying chain lengths up to fifteen thousand atoms and select temperature gradients and damping factors that exemplify the anharmonicity of the Lennard-Jones potential. Work has begun on the extension of the program to two dimensions and comparing results with those obtained by phonon gas and perturbation theory. This work was supported by a grant from the National Science Foundation (Phy-0552521).

Jacob Holter
Ohio State University

UTILIZATION OF MARIACHI GROUND ARRAY SCINTILLATORS AS A TOOL TO BETTER UNDERSTAND COSMIC RAYS

Jacob Holter, Ohio State University; Jason Immerman, Bowdoin College; Greg Smith, Stony Brook University; Dmitri Vavilov, Michael Marx, Department of Physics and Astronomy, Stony Brook University

In an effort to better understand ultra high energy cosmic rays, MARIACHI (Mixed Apparatus for Radar Investigation of Cosmic-rays of High Ionization) is an experiment aimed to search for these rays by two methods. A new method of identification will try to use Radar antennas to detect broadcast TV or FM radio signals that have been reflected by the rays. Using a previously established technique, the signals will also be detected and confirmed by ground-based scintillators arrays.

Our work this summer focused on the scintillator arrays. Each scintillator array consists of five scintillators, two of which are stacked directly on top of one another, and three others placed to map out the four corners of a classroom. Scintillators were assembled, repaired, tested, and calibrated. Afterwards, they were sent to a dozen sites at high schools and community colleges around Long Island and in New York City for installation and to start collecting data. Each scintillator has an area of 0.25 square meters, and any cosmic ray passing through this area will be detected. A coincidence is defined as cosmic rays passing through several detectors simultaneously. Two-fold, three-fold, four-fold, and five-fold coincidences were detected by the ground arrays. A computer grid is used to collect the data, and the arrays are equipped with GPS devices to accurately record time stamps for each coincidence that occurs.

Scintillators were repaired by isolating their particular problem, which more often than not pertained to the electronic components of the photo multipliers. Common techniques included switching out the optical cookie, replacing the DC to DC voltage converter, re-soldering loose wires, and adding assistive capacitors. After repair, the scintillators were given an initial test for functionality. The detector in question was stacked between two other detectors known to be working correctly, creating a system of three. Using LabView software, oscilloscope data was collected in order to plot efficiency as a function of voltage and simultaneously total noise versus voltage. This was done to determine optimum voltage for each scintillator often ranging between 5 and 6 volts. Scintillators were installed on the D floor of the physics building to complement the array in the Nuclear Structure Lab (NSL). Also, scintillators were chosen and installed at Mepham High School to add to the list of more than twelve arrays throughout New York.

Data analysis was done to turn the minute-by-minute data streams into coherent readable graphs. In a combined effort of the REU students, scripts were written in both ROOT and R to process the data. After using a ROOT script that was written to average the counts per minute data over any given time interval, the new data was loaded into an R script that was able to plot the data for any and all coincidences. The R script helps to visualize the data and is used to determine how the coincidence counts depend on variables such as atmospheric pressure. By comparing coincidences we can check the functionality of each scintillator. Further work will need to be made as to gain more insight into cosmic ray showers (four and five-fold coincidences) and their behavior. This work was supported by grants from the National Science Foundation (Phy-055251).

Jason Immerman
Bowdoin College

ANALYSIS OF RAW DATA FROM SCINTILLATOR ARRAYS DESIGNED TO DETECT COSMIC RAY SHOWERS

Jason Immerman, Bowdoin College; Jacob Holter, Ohio State University; Greg Smith, Stony Brook University; Dima Vavilov, Michael Marx, Department of Physics and Astronomy, Stony Brook University

Mixed Apparatus for Radar Investigation of Atmospheric Cosmic-rays of High Ionization, MARIACHI, aspires to be a cheap and simple way to detect high-energy cosmic ray interactions with Earth's atmosphere over large areas via reflected television signals. In order to validate this method of cosmic ray detection, we have implemented an already proven system using ground-based scintillator arrays.

Scintillator arrays have been set up at a dozen high schools around Long Island and in the past year data has begun to flow into the MARIACHI computers ripe for analysis. Arrays are made up of five detectors distributed in a rectangle around a room with two detectors stacked in one corner. After repairing and recalibrating a few broken detectors in order to become intimate with how they work, we began sifting through the data taken in from the ten schools as well as two arrays located on Stony Brook's Campus. Once I learned the script languages R and C++ based ROOT (created by CERN), the first task was to write a program that would discard data deemed incorrect and then average the remaining data over a given interval. Unfortunately, the data's validity is subject to the accuracy of every component of the arrays, which don't always work perfectly. Periodically the detectors are down and thus count rates are zero. Other abnormalities in the data include GPS inaccuracy and time-lapse errors. As the GPS device can only handle one event per ~4ms, an error occurs when multiple events take place within this span. Time-lapse errors appear when the processor records the counts total for a period longer than the intended minute interval; at a sufficiently high rate the number rolls over to a negative. The chief correction involved enforcing a range of valid counts rates upon the data.

Following this I began working with data produced by the oscilloscope data acquisition program, which can provide precise timing and pulse height data for each event. Using the times when each detector in a given array identifies a shower I was able to deduce the direction of the shower by fitting a normal vector to the shower front. For our purposes, cosmic ray showers are defined as signals recorded between multiple detectors in the array in a given time span.

The goal is to use the coincidences that occur between multiple array locations to define extremely high-energy cosmic ray events. These events will be used to confirm the MARIACHI radar technique. This work was supported by NSF Grant Phy-0552521.

Seth McIntire
Macalester College

ANALYZING ULTRAFAST LASER SPECTRA

Seth McIntire, *Macalester College*; Uvo Hölscher, Dominik Geissler, Sarah Nichols, Steve Clow, Chien Hung Tseng, and Tom Weinacht, *Department of Physics and Astronomy, Stony Brook University*

My report on the work I have done this past summer in Professor Weinacht's lab will mainly focus on techniques for collecting and analyzing spectra from an ultrafast laser with a pulse duration of approximately 30fs. The group that I worked for had been using multiple codes to run their different types of spectrometers. I worked on condensing those codes into one coherent code whose run time was much faster than the old code, allowing for fewer discrepancies when dealing with a spectrum that has the potential to change rapidly. I then applied this code to some of the group members' spectral analysis programs, resulting in a dramatic decrease in experimental run time.

One of the main reasons for the development of my code was to be able to externally trigger the spectrometer to take data. This triggering would be in direct correlation with the arrival of each laser pulse, such that each time the spectrometer were to collect counts of pixels on each wavelength, it would do so for a specific amount of time, collecting a finite amount of peaks or laser pulses. The laser itself emits pulses at too short a timeline to be captured individually by electronics, so an average spectrum over a controlled amount of time and with a controlled number of peaks in it allows for a very accurate picture of the spectrum.

I also took on the project of setting up an amplifier circuit for a thermocouples used in the lab, which would allow my LabView program to take spectra automatically depending on the temperature of the object as it is heated or cooled by the laser. My project here is a bit more general allowing us to digitize any analog signal which changes slowly.

This work was funded by Stony Brook University and The SUNY Research Foundation/Office of the Vice President for Research. My position was supported by NSF Grant Phy-0552521.

David Miller
Harvey Mudd College

ELECTRON COUNTING ALGORITHM FOR HADRON BLIND DETECTOR - HUB AND SPOKE

David Miller, *Harvey Mudd College*; Thomas K. Hemmick, *Department of Physics and Astronomy, Stony Brook University*

We present performance of a "Hub and Spoke" algorithm designed to determine the number of electrons that hit a particular location on the Hadron Blind Detector (HBD). PHENIX tracking can identify high-momentum electrons ($p_t > \sim 200$ MeV) and trace them to reconstructed locations on the HBD. Many Dalitz pion conversions (a type of double-electron decay) however create only one electron that makes it to tracking, and so the HBD was designed to distinguish 1 vs. 2 electron hits at this reconstructed location. We present an algorithm that evaluates a multiple-pad sum at the reconstructed location known as the "hub", and searches for a nearby maximum multiple-pad sum known as the "spoke". We apply our algorithm to a simulation that uses virtual Dalitz electron decays created from Exodus (a PHENIX custom event generator) and a range of uniform scintillation from 0.0 to 2.0 mean scintillation photons per pad. We find that performing a 2D cut on hub and spoke exhibits best separation between signal and background. Open questions remain as to the hub size, spoke size, and maximum spoke radius that the algorithm will search for a spoke. We present the pros and cons for choosing particular values for these parameters. My position was supported by NSF Grant Phy-0552521.

Crystal Moorman
Lynchburg College

**ANALYSIS OF STELLAR SPECTRA FOR SELECTED YOUNG MOVING GROUP
CANDIDATES**

Crystal Moorman, *Lynchburg College*; and Michal Simon, *Department of Physics & Astronomy, Stony Brook University*

The goal of this project is to assist in determining whether particular low mass field stars may be identified as members of nearby, young moving groups. We begin with an analysis of stellar spectra for late, main sequence stars. Of the spectra analyzed, we are particularly interested in those stars that are strong X-ray sources and/or display strong H-alpha emission lines. H-alpha line emission and X-ray emission typically indicate stellar youth. Using the public, astronomical database, SIMBAD (simbad.u-strasbg.fr/), we determine the hardness ratios, HR1 and HR2, of the stars with X-ray emission and compare these ratios to those of previously identified members of nearby young moving groups. I wrote a procedure in IDL to compare the hardness ratios of field stars to those of identified moving group members found in earlier research. We also determine the X-ray luminosity and bolometric luminosity of each candidate star to determine each star's absolute visual magnitude, and thus, each star's bolometric magnitude. The bolometric magnitude will, in turn, give us the total amount of energy radiated from a given star. This project was funded through Stony Brook University by the National Science Foundation (NSF). This position was supported by NSF Grant Phy-0552521.

Chantale Neira
Florida Institute of Technology

DETECTING NUCLEAR RADIATION

Chantale Neira, Florida Institute of Technology; Linwood Lee, Rich Lefferts, Department of Physics and Astronomy, Stony Brook University

We began by setting up a facility for measuring alpha, gamma, and neutron radiation. We continued our testing with Si semiconductor detectors to collect spectra for alpha particles emitted from a ^{241}Am source. By introducing steady pressure increases to the testing environment we measured the continued energy loss of these particles. The same statistical phenomena that governs energy loss also leads to fluctuations in path length for individual particles of the same initial energy, known as range straggling. The effects of straggling as a function of pressure were easily observed in the data. In these detectors, an electric field is applied to the detector volume and the radiation is measured by the movement of electron-hole pairs produced along the path taken by a charged particle.

To begin collecting our gamma-ray spectra we started with Sodium Iodide (NaI) detectors. As ionizing energy enters the detector, it hits the NaI crystal which in turn fluoresces photons at wavelengths read by a photomultiplier tube (PMT) converting them to an easily read electrical signal. However, a dramatic increase in the resolution of our data and the efficiency of our detector was noted when we continued this same experiment with a high purity Germanium (HPGe) detector. Gamma-ray spectroscopy requires larger thicknesses for detectors which are provided by these HPGe detectors. Within these detectors, electron-hole pairs move across an applied electric field and the ionization currents that are produced as particles pass are measured. In addition to the ^{60}Co , we were also collecting spectra from ^{133}Ba and ^{152}Eu . In the area of neutron detection, we modified a commercial radiation monitoring system known as the Bonner Ball. Like the NaI detector, this system makes use of a scintillator, in this case a Li^6I crystal, which fluoresces in the presence of incoming ionizing radiation that it converts to energy readable by a PMT.

The project was funded through Stony Brook University and the SUNY Research Foundation/Office of the Vice President for Research. My position was supported by NSF Grant Phy-0552521.

Christopher Presuto
Stony Brook University

**DESIGN AND CONSTRUCTION OF A HIGH VACUUM SYSTEM FOR USE IN
MEASUREMENTS OF STIRAP-EXCITED RYDBERG STATE (N=26) HELIUM ATOMS**

Christopher Presuto, Jonathan Kaufman, Xiaoxu Lu, Yuan Sun, and Harold Metcalf, Department of Physics and Astronomy, Stony Brook University

Through exploitation of the Stark effect and Stimulated Raman Adiabatic Passage (STIRAP), the excitation of helium atoms in the 2^3S_1 metastable state to an $n=26$ Rydberg state becomes, in theory, completely efficient. Metastable helium is produced in a DC discharge source chamber where a differential pressure mechanism forms an atomic beam directed into our interaction chamber. Here, the atoms are exposed to red and blue laser beams at $\lambda=796$ nm and $\lambda=389$ nm, respectively, while in the presence of a uniform electric field to excite them to the Rydberg state. This counterintuitive excitation order forms the basis of STIRAP. A hexapole lens is then used to focus the beam into a detection chamber.

Our efforts throughout the summer were a continuation of a project which began its redesign stage earlier this year. Oil contamination of the vacuum system due to backstreaming from diffusion pumps as well as leaks and an inconsistent and fragile metastable helium source lead to the decision to redesign and construct a completely new high vacuum system using a new source and more efficient high vacuum pumps and flanges. The new source, created at Universiteit Utrecht along the designs of Kawanaka, et al., uses a reverse flow design and a DC discharge to produce a metastable helium beam. Two turbo-molecular pumps serve as the main vacuum pumps for the source and interaction chambers each backed by a rotary vane mechanical pump. Foreline traps are used to help prevent oil backstreaming from the mechanical pumps into the vacuum chamber. An ion pump along with two liquid nitrogen-cooled sorption pumps is used to maintain low pressure on the detection end. Helium leak tests indicate that the system is leak-free to our satisfaction, however, a residual gas analysis shows significant water vapor and several hydrocarbon groups which could indicate a pump oil leak. Further baking of the system should resolve some of this residual gas problem.

My position was supported by a grant from the National Science Foundation (PHY-0552521) and the project was funded through Stony Brook University and The SUNY Research Foundation.

Kieran Ramos
Stony Brook University

**CONSTRUCTION OF THE PI-ZERO DETECTOR FOR THE T2K LONG BASELINE
NEUTRINO OSCILLATION EXPERIMENT**

Kieran Ramos, Chang Kee Jung; Department of Physics and Astronomy, Stony Brook University

The purpose of the T2K experiment is to search for neutrino oscillations of the muon neutrino into an electron neutrino. An assumption of the current standard model of elementary particle interactions is that the neutrino has zero mass. In June 1998, however, the Super Kamiokande experiment in Kamioka, Japan, observed atmospheric neutrino oscillations of muon neutrinos to tau neutrinos. According to quantum mechanics this observed neutrino oscillation can only occur if neutrinos have mass. Thus it is now well accepted that neutrinos have mass and this was the first hint of physics beyond the standard model.

To verify the results, the K2K (KEK to Kamioka) experiment was created to test neutrino oscillation over a long baseline of 250 kilometers using an accelerator generated neutrino beam. A 12 GeV Proton Synchrotron made the neutrino beam and was analyzed at the KEK near detector complex and at 250 kilometers at Super Kamiokande for muon neutrino disappearance. This experiment confirmed the results of the Super Kamiokande experiment.

The T2K experiment is expected to observe electron neutrino appearance over a long baseline of 295 kilometers with a near detector (ND280) at 280 meters from the neutrino beam production and Super Kamiokande as the far detector at 295 kilometers. The high intensity proton synchrotron (PS) for producing the neutrino beam is being built at J-PARC and is 50 times more powerful than the previous 12 GeV PS at KEK. The near detector primarily determines the neutrino beam direction, profile, neutrino flux, and neutrino energy spectrum. The P0D is a sub-detector of ND280 and its goal is to determine the π^0 event background at Super Kamiokande for electron neutrino appearance.

In Super Kamiokande a muon neutrino can produce a π^0 which has the possibility of mimicking an electron neutrino event. To estimate this background the P0D is structured as a sandwich of water, scintillator, and lead. A π^0 made from a muon neutrino interaction in the water layers decays into high energy gammas which then produce an electromagnetic shower from the layers of lead. The charged particles passing through the scintillators generate scintillating light and this light is transferred into wavelength shifting fiber. This in turn is detected by silicon photomultiplier (SiPM) which is a pixilated device capable of measuring the number of photons detected. Through use of the information gathered with multiple layers of water, lead, scintillator, and SiPM it is possible to track particles and determine the π^0 event background in Super Kamiokande.

My contribution to the T2K experiment is the construction of the P0D. The P0D is primarily comprised of 40 individual podules of scintillator. Each podule has a PVC frame, two layers of scintillator (x-bars and y-bars), and two polystyrene sheets that make a light-tight seal. They are assembled together with epoxy which has a long work time and cure time. Once the podule is glued together with epoxy it is set under a vacuum for at least 18 hours. The podules are then stored until super podule assembly begins. I have participated in every phase of this construction.

This work was supported by a grant from the National Science Foundation (PHY-0552521) and a grant from the US Department of Energy (DEFG0206ER41416).

Brandon Ruzic
University of Illinois

HBD TESTING AND THE CARBON-14 UPDATE

Brandon Ruzic, University of Illinois; Richard Lefferts, and Thomas K. Hemmick, Department of Physics and Astronomy, Stony Brook University

This summer's research position was concentrated in two different projects: creating a data acquisition system for the Hadron Blind Detector (HBD) as part of the PHENIX experiment for the RHIC collaboration and creating a LabVIEW VI which could calibrate and regulate the voltage on the Tandem Accelerator using a generating voltage meter (GVM). The HBD was made to measure Cherenkov light from superluminal electrons in CF_4 which will be used as a trigger for other parts of PHENIX without detracting much energy from the hadrons. The HBD consists of 10 GEM stacks which consist of one gold GEM coated in CsI and two copper GEMs each. When the Cherenkov light comes into contact with the CsI, an electron is produced in a strong electric field and is forced to avalanche through the copper GEMs creating 10^4 times as many electrons. This signal is sent to a nuclear instrumentation module (NIM) logic system consisting of two LeCroy ADCs. In order to test and calibrate the HBD, a scintillating cosmic ray detector was placed next to a certain stack. A NIM logic system was used to create a coincidence trigger for cosmic rays by using the signal from the scintillating detector as a gate for the ADCs. The data from the ADCs is then read by a NIM controller operated by LabVIEW and is then converted into an n-tuple for analysis. We were involved in cleaning and voltage testing the HBD as well as creating the NIM logic system and data acquisition programs.

The Tandem Accelerator effectively works by sputtering a desired material with Cs ions and accelerating the negative ions released towards a selecting magnet which is designed to pick out a certain mass of ion. This mass of ion is then accelerated towards a 9MV anode while being focused many times, made incident on a thin film of carbon which strips away some of its electrons, and is then repelled by the same 9MV anode. The highly accelerated beam is then bent 90 degrees and is made incident on a target. The goal of this particular project is to create an interface for high school students interested in high energy physics to be able to quickly determine the ratio of carbon-14 to carbon-12 in a particular sample and thus determine how long ago the sample cease to produce carbon-14 or in other words died. If a carbon-14 beam is used, then the current system which uses a signal from the beam current to stabilize the anode voltage won't work due to the low beam current. Therefore, we were involved in creating a LabVIEW VI which would automatically calibrate the actual Tandem's anode voltage with a generating voltage meter (GVM) near the anode and then use the calibrated GVM itself to set and stabilize the anode voltage by using a fast Fourier transform to read the signal from the GVM instead of old-fashioned circuits or beam stabilization. We also worked on improving last summer's REU students' interface. This position at Stony Brook was funded by the NSF grant PHY0552521.

Greg Smith
Stony Brook University

PRELIMINARY ANALYSIS OF THE MARIACHI SCINTILLATOR DATA

Greg Smith, Stony Brook University; Jacob Holter, Ohio State University; Jason Immerman, Bowdoin College; Dima Vavilov, Michael Marx, Department of Physics and Astronomy, Stony Brook University

The Mixed Apparatus for Radar Investigation of Atmospheric Cosmic-rays of High Ionization (MARIACHI) experiment uses antennae and scintillator ground arrays to detect Ultra High Energy Cosmic Rays (UHECR - particles with energies of $>10^{20}$ eV). UHECRs have been detected by previous experiments, but only with low statistics -- their existence remains a mystery. The goal of the MARIACHI experiment is to record UHECR events by detecting reflected radio signals. Until this new method of detection is properly developed, the project will confirm events with ground-based scintillator arrays. The scintillator arrays consist of five detectors arranged in a rectangle, such that one corner has two detectors stacked vertically. Most of the arrays are located in high school classrooms across Long Island (with two arrays located on Stony Brook University's campus). A computer records the data and uploads files to a central MARIACHI server on a daily basis.

Using R, a statistical analysis software, several scripts were written to systematically analyze the data from the scintillator arrays. The first task was to optimize a previously written script that averaged the scintillator data over time, combining it with data from a local weather station. In the end, our group decided to use a faster ROOT script to average the scintillator data. A BASH shell script was written to quickly apply the ROOT script to any collection of data. Next, the effects of barometric pressure on cosmic ray flux were studied; it was found that the flux was linearly dependent on the barometric pressure. Since barometric pressure has a such strong influence on flux, the pressure dependency of the flux was removed before any additional analysis was done. Also, the quality of the data was assessed by checking how well the flux depended on the barometric pressure; certain intervals of data had to be removed before proceeding.

In its original form, the data from the individual arrays cannot be directly compared, as each array has a unique geometry and efficiency (the flux of each array is unique). By comparing the relative changes in cosmic ray flux, we were able to compare data from several schools, finding similar variations in flux over time. By correcting for the pressure variations and the flux differences between individual schools, we were able to combine the data properly. We hope to identify periods of high solar activity using this combined data. This work was supported by the National Science Foundation (NSF Grant Phy-0552521).

William Weiss
Western Washington University

MODELING DIFFRACTION BY A CIRCULAR APERTURE ILLUMINATED BY A DIVERGING GAUSSIAN WAVEFRONT

William Weiss, *Western Washington University*; Marty Cohen and John Noé, *Stony Brook University*

This project came about through a chance observation while examining the diverging Gaussian wavefront emerging from a single-mode optical fiber. While shining this light through a pinhole we observed an unexpected and interesting diffraction pattern with an unmistakable dark spot in its center. As the distance between the tip of the fiber and the pinhole was varied this pattern changed to others with a bright or dark center surrounded by dark rings. Only at relatively large distances did we observe the familiar Airy pattern that we initially expected.

The patterns were studied systematically by mounting a 100 μm diameter pinhole on a 3-D translation stage. This setup allowed the pinhole to be accurately centered in front of the fixed fiber and the pinhole-fiber separation to be varied in steps as small as 25 μm from 0 to 20 mm. As before, the source feeding the fiber was a low-power red He-Ne laser ($\lambda = 632.8 \text{ nm}$). The diffraction patterns were observed by eye and photographed on a small screen placed about 35 cm from the pinhole. The divergence of the light emerging from the fiber was measured in a separate experiment by scanning a small photodetector across its profile. The profile was found to have a Gaussian shape as expected, with a $1/e^2$ full-width angular divergence of 0.168 radians. The corresponding beam diameter at the tip of the fiber is 4.8 μm , in reasonable agreement with the manufacturer's specification of 4.0 μm .

The observed patterns can be understood by considering the Fresnel number $N = a^2 / \lambda L$, where a is the aperture radius, λ is the wavelength, and L is the fiber-to-pinhole or pinhole-to-screen distance. Before the pinhole N is of order unity while after it $N \sim 0.01$. The former value indicates that the phase of the light reaching the pinhole varies significantly with radius, while $N \ll 1$ indicates that the path length from any point on the pinhole to a given point on the screen is essentially the same (the Fraunhofer approximation). In the Fraunhofer approximation each pattern is the Fourier transform (FT) of its (complex) aperture function, $T(r)$. The FT integrand reduces to the product of a Gaussian intensity function, an r -dependent phase function, and a zero-order Bessel function. Mathematica was used to numerically evaluate the integral across the screen and plot its square, the intensity distribution $I(r)$, for a number of appropriate fiber-pinhole separations. Each plot took a few minutes. The calculated distributions are in very good qualitative agreement with the sequence of observed and photographed patterns. Work is in progress to extract numerical intensity profiles from the images in order to make a more precise comparison.

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