Annual Progress Report
Research Experiences for Undergraduates in Physics and Astronomy
Summer 2001

NSF-REU Grant PHY-0097367 (Year 1)

Department of Physics & Astronomy
The University of Toledo
Toledo, Ohio 43606

Thomas J. Kvale
Scott A. Lee

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RESEARCH PARTICIPANTS in the NSF-REU PROGRAM
SUMMER 2001
DEPARTMENT OF PHYSICS & ASTRONOMY
THE UNIVERSITY OF TOLEDO

LEFT TO RIGHT (Students in **bold**): D.G. Ellis, T.J. Kvale, R.A. Lukaszew, **Brandon McNaughton**, **Althea Moorhead**, A.D. Compaan, **Kevin Croxall**, **Joshua Thomas**, S.A. Lee **Amanda Gault**, **Thomas Crenny**, **Kathleen Hinko**, **Steve Morgan**, **Brian Sunderland**, B.G. Bagley, **Todd Hill**, R.T. Deck.

NOT PICTURED: **Blake L. Anderson**, **Lori Schmetzer**, A.N. Witt, S.R. Federman, N.D. Morrison, K. Bjorkman, J. Bjorkman, Michael Dennis

SUMMARY REPORT

Introduction

The Summer 2001 NSF-REU program in Physics and Astronomy at Toledo gave enhanced research opportunities to 12 undergraduate students from 8 colleges and universities in 6 states spread from West Virginia to California. Of these 12 participants, 11 were supported by the basic NSF-REU program and 1 by other (local) funds. Student participants were chosen competitively; we received 59 applications from students in 23 different states in all parts of the U.S., plus one from the U. K. All the participants were serious and talented young scientists, who tackled substantial problems, participating in all stages of a project, from formulation to conclusion, including oral and written presentations of results. The gender distribution of the participants this year were 8 men (67%) and 4 women (33%). This turned out to be the same percentages of male/female faculty mentors for these students even though students were not paired to the faculty members based on gender. This is the first year that one student undertook a collaborative project in Medical Physics and his time was spent both at UT and at the Medical College of Ohio, located in Toledo, OH. He was jointly mentored by Thomas Kvale (UT) and Michael Dennis (MCO). This year was also unique in that during late Spring, the roles of the P.I. (Scott Lee) and Co-PI (Thomas Kvale) were interchanged due to health-related issues.

We are pleased to report that Summer 2001 was a success from both the students' and faculty mentors' perspectives. Several talks were presented at regional and national conferences by the REU participants, in addition to presenting talks on their research at their home institutions. At least one refereed manuscript has been submitted based on the research this past summer. It is anticipated that more manuscripts are in preparation and will be submitted shortly.

Advertisement and Selection

This year we basically transferred to a web-based advertisement and application system. The only paper announcement sent to institutions was a very brief letter alerting the prospective students to our website and a paper copy of our Application form in case the students didn't have readily available access to the internet. The web materials are appended to this report. The table on pages 7 and 8 shows the geographic distribution of inquiries, applicants, offers, and participants. The selection committee was composed of Associate Prof. Karen Bjorkman, in addition to Thomas Kvale (PI) and Scott Lee (Co-PI). This committee also performed the initial matches of the prospective students with their faculty mentors. Various criteria were used for the selection and matching, including the student's course background and class performance, out-of-class experiences, research interests, faculty recommendations, and personal goals. We also tried to select students with a variety of personal, educational, and geographical backgrounds. We were successful in all of these areas except for ethnicity, even though we sent e-mail messages to every physics department of all of the historically black colleges and universities encouraging them to advertise our program. We also contacted the American Indian Science and Engineering Society (www.aises.org) and the Society for Advancement of Chicanos and Native Americans in Science (www.sacnas.org) to advertise our program. We are under the impression that this latter organization sent a special e-mail to all of its members alerting them to our program. This coming summer, we plan to redouble our efforts to attract students from colleges and universities that contain relatively large populations of students from under-represented ethnic groups.

Registration, Housing, and Social Activities

All student participants were registered in PHYS4910, *Research Problems in Physics and Astronomy*, for 1 semester hour credit. The REU program paid all the instructional and other required fees. We find that there are many advantages to having the REU participants be registered students with all associated benefits and privileges. One of the major benefits is access to the university health center. Other benefits include: course credit to transfer back to the student's home institution if desired, access to recreational facilities, and borrowing privileges at the University library. Several students took advantage of a Machine Shop practices and techniques course run by our professional Machinist under the umbrella of PHYS4910.

This year most of the student participants lived in the same campus dormitory, with the NSF-REU grant providing the housing costs. One of the goals of the NSF-REU program is to enable social interactions among the students, who will become the scientists of tomorrow. This infrastructure of friendships leads to the fruitful exchange of ideas, which is useful in the advancement of physics. We feel that we can best accomplish this goal by housing the students together on campus. The director of Student Housing on the campus of the University of Toledo has cooperated with us fully in this respect for the past 10 summers of NSF-REU support. The students stayed in the Horton International House, our newest dormitory, which includes suites and kitchens that encourage social interactions among the REU students.

Social activities included a departmental picnic, trips to Cedar Point Amusement Park, the Toledo Museum of Art, and the Toledo Zoo, plus many informal activities, including an evening at Tony Packo's, Toledo's famous ethnic restaurant and traditional jazz club. The perennial favorites are windsurfing adventures at Maumee Bay State Park, courtesy of Professor Alvin D. Compaan and his graduate students.

Weekly Seminars

A weekly "Brown Bag" seminar series is an important part of our summer program. Faculty members and/or outside speakers are asked to present a talk over the lunch hour for the chosen day. However during the first week, the students attended an orientation seminar to cover the basic items such as ID cards, parking, health services, food services, stipend checks, etc. This format fosters more of an informal atmosphere, which the students appreciate when it is their turn to give a presentation at the close of the summer session. This weekly meeting of the entire REU group also provides an opportunity to plan social events and field trips, and discuss any topics of interest to the group. The whole department is invited to attend the Bag Lunches, and the participation has been very good with many graduate students and faculty members also attending. This provides a useful departmental weekly gathering, otherwise absent in the summer. The talks at these weekly meetings are similar to standard physics research talks, but chosen to be appropriate for this REU audience, and with all the speakers being careful to give undergraduate-level introductions. The list of seminars is given below. We experimented this year with requiring the students to give a 5 minute presentation of their research about midway into their summer period. Even though the students were reluctant to do this, the midway progress talks went well and kept the students focused on their projects. We plan to repeat this mid-term Progress talks for this coming summer.

Reports and Conclusion

We feel it is important to involve the students with all aspects of the scientific research process. To the extent possible, depending on the nature of the project, students participate in the selection of the problem, the choice of research method, the collection and analysis of data, the formulation of conclusions, and the presentation of the results. The research problems are parts of ongoing faculty research programs, which are in most cases supported by external grants. At the same time, every effort is made to identify a piece of the research for which the REU student has the primary responsibility. The students are asked to write a final report, including a carefully-written abstract which could be submitted as a contribution to a regional or national meeting, as well as give a 15 minute presentation at a Bag Lunch in the final week of their research period. The typical length of the final reports is about 20 - 25 pages. The abstracts are included in this Report.

Evaluation

At the end of the summer we asked the students to fill out an evaluation questionnaire. Because of the daily contacts among student participants, faculty mentors, and the program PI and Co-PI, we feel that we are pretty well aware of the students' opinions of the program. Nevertheless, the results of an anonymous questionnaire can give valuable feedback. A copy of the questionnaire is included below, along with a summary of results.

NSF-REU SUMMER 2001 APPLICATIONS

Geographical distribution by undergraduate institution

(Applications Received / REU Offers Made / REU Accepted)

Arizona
Arizona State University (1/0/0)
University of Arizona (1/1/1)

California
California State Univ., Bakersfield (1/1/1)

Colorado
Colorado College (1/1/1)
University of California, Riverside (1/0/0)
University of Northern Colorado (1/0/0)

Connecticut
Connecticut College (1/0/0)

Georgia
Clark Atlanta University (1/0/0)
Georgia Tech. (1/0/0)

Idaho
University of Idaho (1/0/0)

Illinois
Univ. of Illinois, Urbana-Champaign (1/1/0)

Indiana
Anderson University (1/1/0)
Purdue University, Calumet (1/1/0)
Valparaiso University (1/1/0)

Kentucky
Berea College (1/0/0)

Massachusetts
Harvard University (1/0/0)
Worcestser Polytechnic Institute (1/0/0)

Minnesota
Carleton College (1/0/0)
Gustavus Adolphus College (2/1/0)

Missouri
Truman State University (1/0/0)
University of Missouri-Columbia (1/0/0)

New York
Columbia University (1/0/0)
SUNY at Cortland (1/0/0)
University of Rochester (1/1/0)

Ohio
Bluffton College (1/1/0)
John Carol University (2/0/0)
The Ohio State University (1/1/1)
The University of Toledo (9/4/4)
University of Dayton (1/1/1)

Pennsylvania
Carnegie Mellon University (1/0/0)
Elizabethtown College (1/0/0)
Grove City College (1/0/0)
Juniata College (1/0/0)
St. Vincent College (1/1/0)

South Carolina
Benedict College (1/0/0)
Coastal Carolina University (1/0/0)

South Dakota
Augustana College (1/0/0)

Tennessee
Middle Tennessee State University (1/0/0)

Texas
University of Texas at Austin (2/0/0)

Utah
Brigham Young University (3/1/1)

Virginia
Radford College (1/0/0)

Washington

Gonzaga University	(1/1/0)
University of Washington	(1/0/0)

West Virginia

Wheeling Jesuit University	(2/2/1)

England

University of Hertfordshire	(1/0/0)

THE UNIVERSITY OF TOLEDO
DEPARTMENT OF PHYSICS & ASTRONOMY
NSF-REU RESEARCH PARTICIPANTS

SUMMER 2001

Blake L. Anderson, University of Dayton — Home: Lake in the Hills, IL
UT Faculty Research Advisor: T.J. Kvale

Thomas Crenny, Wheeling Jesuit University — Home: Blackwood, NJ
UT Faculty Research Advisor: S.R. Federman

Kevin Croxall, Brigham Young University — Home: Logan, UT
UT Faculty Research Advisors: N.D. Morrison & K. Bjorkman

Amanda Gault, The University of Toledo — Home: Englewood, OH
UT Faculty Research Advisor: K. Bjorkman

Kathleen Hinko, The Ohio State University — Home: Sylvania, OH
UT Faculty Research Advisor: A.D. Compaan

Brandon McNaughton, California State Univ., Bakersfield — Home: Bakersfield, CA
UT Faculty Research Advisor: R.Ale Lukaszew

Althea Moorhead, The University of Arizona — Home: Toledo, OH
UT Faculty Research Advisor: J. Bjorkman

Steve Morgan, The University of Toledo — Home: Toledo, OH
UT Faculty Research Advisor: B.G. Bagley

Lori Schmetzer, The University of Toledo — Home: Guilford, IN
UT Faculty Research Advisor: A.N. Witt

Brian Sunderland, Colorado College — Home: Wayland, MA
UT Faculty Research Advisor: A.D. Compaan

Joshua Thomas, The University of Toledo — Home: Blanchester, OH
UT Faculty Research Advisor: T.J. Kvale

<u>Additional undergraduate student participating in Summer Research</u>:

Todd Hill, The University of Toledo & Medical College of Ohio — Home: Toledo, OH
UT Faculty Research Advisor: T.J. Kvale

NSF-REU SUMMER 2001 STUDENT DEMOGRAPHICS

Gender

Female:	4
Male:	8

Class Rank (at the beginning of Summer)

Freshman:	1
Sophomore:	2
Junior:	2
Senior:	7
Higher:	0

Ethnicity

International Student:	0
American Indian:	0
Alaskan Native:	0
Asian American (or Pacific Islands):	0
African American:	0
Hispanic American:	0
Caucasian/White:	12
Other:	0

Home State:

California:	1
Indiana:	1
Massachusetts:	1
New Jersey:	1
Ohio:	7
Utah:	1

Institution:

Brigham Young University:	1
California State Univ. - Bakersfield:	1
Colorado College:	1
Ohio State University:	1
University of Arizona:	1
University of Dayton:	1
University of Toledo:	5
Wheeling Jesuit University:	1

Grade Point Average:

Average GPA (REU students):	3.50

NSF-REU SUMMER 2001 BROWN BAG SEMINARS
THURSDAY, NOON - MH 4009

June 7, 2001
Prof. P.B. James, Chair
"Explanation of Mars Research"

June 14, 2001
Prof. A.N. Witt
"Red Glow from Interstellar Space: What is it?"

June 21, 2001
Five-Minute Outlines of Research by REU Students

June 28, 2001
Cancelled - Physics Summer Camps

July 5, 2001
Prof. B.W. Bopp
"Bopp's Three Laws of PowerPoint"

July 12, 2001
Prof. R. Ale Lukaszew
"Magnetic Thin Films and Their Applications"

July 19, 2001
Prof. A. Alan Pinkerton, Chair, Dept. of Chemistry and Adjunct member, Dept. of Physics and Astronomy
"X-Ray Crystallography"

July 26, 2001
Prof. A.D. Compaan
"The Global Warming Apocalypse and the Thin-Film Photovoltaics Solution!"

July 31-Aug. 2, 2001
Student Oral Reports

NSF-REU SUMMER 2001 FINAL ORAL PRESENTATIONS
Department of Physics & Astronomy
The University of Toledo

TUESDAY, JULY 31

12:00-12:15	**Brian Sunderland**	*"Nickel Phosphide as a Copper-Free Back Contact for Cadmium Telluride-based Solar Cells"*
12:15-12:30	**Amanda Gault**	*"Be Stars: Modeling Their Polarization and Infrared Excess"*
12:30-12:45	**Stephen Morgan**	*"Designing a Side-pumped Planar Fiber Laser"*
12:45-1:00	**Todd Hill**	*"Functional MRI, Data Analysis for Image Production"*

WEDNESDAY, AUGUST 1

12:00-12:15	**Lori Schmetzer**	*"Photofragmentation of Interstellar Nanoparticles"*
12:15-12:30	**Kevin Croxall**	*"Spectroscopy of Be stars Kappa Dra and 60 Cyg"*
12:30-12:45	**Blake Anderson**	*"Implementing a Energy Analyzer on UT-P/Niels"*
12:45-1:00	**Joshua Thomas**	*"Design Improvements in Data Collection Faraday Cups"*

THURSDAY, AUGUST 2

12:00-12:15	**Althea Moorhead**	*"The Role of Boundary Conditions in Stellar Wind Topology and Hydrodynamics"*
12:15-12:30	**Brandon McNaughton**	*"Construction of a MOKE Station Using LabVIEW"*
12:30-12:45	**Kathleen Hinko**	*"Photoluminescence of CdTe Films: Varying Sputter Targets, Substrates, and Annealing Conditions"*
12:45-1:00	**Thomas Crenny**	*"Measurements of Carbon Monoxide Abundance in Diffuse Interstellar Gas Clouds"*

NSF-REU SUMMER 2001 EXTERNAL PRESENTATIONS AND PUBLICATIONS

PRESENTATIONS. (Summer 2001 REU students. Students in **bold**.)

Joshua Thomas, "*Design Improvements in Data Collection Faraday Cups*," SPS Zone 7 Regional Meeting, University of Michigan, Ann Arbor, MI, Oct 06, 2001.

Joshua Thomas, "*Design Improvements in Data Collection Faraday Cup Detectors*," 2002 National Conference on Undergraduate Research (NCUR), University of Wisconsin-Whitewater, April 25-27, 2002.

R. Alejandra Lukaszew, **Brandon McNaughton**, Z. Zhang, V. Stoica, Roy Clarke, "*Surface Reconstruction and Induced Uniaxial Magnetic Fields on Ni Films*," Symposium N: "Current Issues in Heteroepitaxial Growth-Stress Relaxation and Self Assembly", Fall Meeting of the MRS, Boston, MA, November 26-29, 2001.

Kathleen Hinko and A.D. Compaan, "*Photoluminescence of magnetron sputtered CdTe films: dependence on target purity, substrate, and annealing conditions*," 2002 March Meeting of the American Physical Society, Indianapolis, IN, March 18-22, 2002.

Brian R. Sunderland, A. Gupta and A.D. Compaan, "*Nickel Phosphide as a Copper Free Back Contact for CdTe-Based Solar Cells*," 2002 March Meeting of the American Physical Society, Indianapolis, IN, March 18-22, 2002.

PUBLICATIONS (Summer 2001 REU students. Students in **bold**.)

R. Alejandra Lukaszew, **Brandon McNaughton**, Vladimir Stoica, Roy Clarke, "*Surface Reconstruction and Induced Uniaxial Magnetic Fields on Ni Films*," Proceedings of Symposium N: Current Issues in Heteroepitaxial Growth-Stress Relaxation and Self Assembly, Fall meeting of the MRS, Boston, MA, November 26-29, 2001. submitted (Refereed)

PRESENTATIONS AND PUBLICATIONS (Previous REU students. Students in **bold**.)

W. J. Fischer and N. D. Morrison, *"Spectrum variability of the A-type supergiant star HD223960*," Publications of the Astronomical Society of the Pacific, volume 113, 821-828 (2001).

R. L. Cooper and S. A. Lee, "*Differential scanning calorimetry study of deoxyadenosine and its water of hydration*," 2002 March Meeting of the American Physical Society, Indianapolis, IN, March 18-22, 2002.

ABSTRACTS OF REU FINAL REPORTS
The University of Toledo
Department of Physics & Astronomy
SUMMER 2001

Implementing a Energy Analyzer on UT -P/NIELS

Student: Blake Anderson
Advisor: Thomas Kvale

Abstract:

The energy analyzer installed in the UT -P/NIELS accelerator at the University of Toledo produced data, which was inconsistent from what was expected. The energy analyzer supported the fact that two different values of energy were going through the hemispherical energy selector. This supported the fact that the optics of the deceleration column, the zoom lens, and the energy analyzer was a focus of a hollow beam at the entrance of the hemisphere. Simion 6.0, a computer program that numerically solves the Laplace Equation to produce simulations of ion trajectories was used to create all models in this study. Through the creation of different models, in Simion, it was found that the hollow beam was being created. A hollow beam is created by a combination of multiple focal points and large spherical aberrations. In comparison the first focal point in a system is much tighter than that of the second and third of which the focus has been spread out. There are also large spherical aberrations created by equipotentials, which do not have one radius of curvature.

Measurements of Carbon Monoxide Abundance in Diffuse Interstellar Gas Clouds

Student: Thomas Crenny
Advisor: Steven R. Federman

Abstract:

In this project the abundance of carbon monoxide in gas clouds toward bright stars was obtained and will be used for input into chemical models. The ultraviolet data were obtained with the Copernicus Satellite in the 1970's. My re-analysis of the data was done because there are now more sophisticated tools available to extract column density, Doppler shift, and excitation temperature and more precise molecular data. The goal of the project was to determine approximately how much CO, the second most abundant molecule in the universe, exists in interstellar gas clouds toward bright stars such as Delta Sco and Alpha Cam. The column densities were found to be in the range of 8×10^{11} to 6×10^{14} molecules cm^{-2}. These values were compared to the column densities of other molecules such as H_2, CH, and CH^+ as an aid to understanding the chemistry of diffuse interstellar gas clouds.

Spectroscopy of Be Stars Kappa Draconis and 60 Cygnus

Student: Kevin V. Croxall
Advisors: Nancy D. Morrison, and Karen S. Bjorkman

Abstract:

New spectroscopic data for Be stars K Dra and 60 Cyg were collected and analyzed. For purposes of clarifying data, by removing water lines, a library of telluric calibration files, for use at Ritter Observatory, were created. Of special note is the loss of emission by the star 60 Cyg in the month of June 2001. Equivalent width of the Ha line, radial velocities, delta V, V/R quantities and polarization data were analyzed to reveal new periods for each star. While the periods are still in preliminary stages, the periods seem very promising. Most striking is an apparent period of about 2000 days in the equivalent width of κ Dra. Data is also suggestive that the 61.55 day period of κ Dra may not be due to binary motion as was previously reported. Strong evidence for a correlation between the equivalent width of the Hα line and the polarization is found. Possible implications on the evolution of the star are discussed.

Be STARS: Modeling their Polarization and Infrared Excess with Respect to Inclination and Optical Depth

Student: Amanda C. Gault
Advisor: Karen Bjorkman

Abstract:

The circumstellar disks of B-type emission line stars polarize the light emitted by the star and also cause there to be an excess infrared radiation. The observed polarization and infrared excess are affected by the inclination and the optical depth. We modeled the effects of these two parameters on the polarization and infrared excess of Be stars of 5 stellar radii with a stellar temperature of 25,000 K and a disk temperature of 19,000 K. The resulting model gave us a grid system with lines of equal inclination and equal density. Our model reproduces the distinct triangular shape characteristically seen in empirical plots of observational data. Also, an explanation for the upper limit of the polarization can be drawn from the model. Once the inclination reaches 70° to 75° the polarization reaches a maximum of 2% and then decreases again at higher inclinations until, nearing 90°, the polarization is about half of its maximum value. Thus, the upper limit of the diagram is created by a combination of the maximum polarization produced and the maximum infrared excess resulting from a specific model. We carried out a preliminary comparison of our model results with observational data by overplotting data points onto the model grid. However, the interpretation of the model results and comparison with observational data will require additional model runs to be made for stars of other sizes and temperatures. This will be carried out in future work continuing this project.

Functional MRI, Data Analysis for Image Production

Student: Todd M. Hill
Advisors: Thomas Kvale, University of Toledo and Michael Dennis, Medical College of Ohio

Abstract:

Magnetic Resonance Imaging (MRI) has become one of the most powerful and widely used techniques in neurological imaging. Most often, it is used to create highly detailed anatomical images that can be used by physicians for identification and diagnosis of physiological problems. With some manipulation of the MRI signal though, one can obtain images representative of brain activity (BOLD imaging) and/or blood flow via perfusion analysis. This technique is termed functional MRI (fMRI).

From May to July of 2001, I was allowed the opportunity to work with Medical Physicist, Dr. Michael Dennis on a funded project exploring the possibility that migraine headaches may predispose certain individuals to stroke by identifying cerebral arterial narrowing. In this case, the objective of the medical physicists was to use a powerful new software package, entitled MedX, to analyze to fMRI data and to produce images useful in supporting the hypothesis.

The primary goal was understanding and implementing the MedX software. This proved more difficult than planned. As it turns out, using the software required more than just opening MRI image data files and clicking buttons. When a MRI scan is performed, the imaged are saved in sequential order (slice 1 is followed by slice 2 and so on, in the order they were produced). When the image files were first opened in MedX, they did not appear in the proper sequence. We found out that when the files were converted to DICOM format, the file transfer standard, the file names were also changed. The reason this is a problem is due to the naming format. Each file was named numerically starting with image 1. The problem lied with the fact that the software could not sort the files numerically. What was needed was to add preceding zeros to the file names in order for them to be sorted. File 1 became 001, file 2 became 002 and so on. After this was done, the data analysis could continue.

A future requirement for implementation of this software requires an automated file renaming procedure to minimize analysis time. This will be accomplished by using tools provided with the MedX software (which has yet to be found) or by writing a Linux OS based computer program to perform the renaming outside of MedX. By doing this, the data analysis will be completed in a timely manner providing the medical researchers quality perfusion based images that are necessary for identification of cerebral arterial narrowing.

Photoluminesence of CdTe Films: Varying Sputter Targets, Substrates, and Annealing Conditions

Student: Kathleen Hinko
Advisor: Alvin D. Compaan

Abstract:

We altered several parameters relating to the CdTe layer in CdTe-based solar cells and analyzed the effects of these changes on low temperature photoluminescence. Polycrystalline CdTe films were grown by radio frequency sputtering from three different targets, two purchased commercially and one pressed at the University of Toledo, as well as on two different substrates,

soda lime and borosilicate glass. Samples from the films were either kept as a control or were annealed in the presence of $CdCl_2$ in the conditions used for solar cell fabrication. The purpose of the $CdCl_2$ treatment was to increase PL and facilitate comparisons with future studies. We then compared photoluminescence spectra from the various samples. The PL results suggest that films grown from the UT target were of comparable quality to those grown from commercial targets. Also, a comparison between the films grown on different substrates shows much weaker PL for borosilicate glass versus soda lime glass. This may indicate that the sodium in the soda lime glass has a positive effect on the PL of the CdTe film.

Construction of a MOKE Station using Lab-View

Student: Brandon McNaughton
Advisor: R. Ale Lukaszew

Abstract:

Magnetic thin films and mu1ti1ayers containing layers of magnetic material have generated a large amount of interest in recent years due to the richness and complexity of their magnetic spin configuration. In addition, nano-magnets are very attractive for their possible application to magnetic-data-storage. A powerful technique to study the magnetization reversal behavior of magnetic thin films is MOKE (magneto-optic Kerr effect). The magnetic field required for magnetization switching (i.e. the coercive field) can be obtained from MOKE measurements. A convenient setup for ruming MOKE experiments utilizes Lock-In techniques and can be computer controlled and automated using Lab- View software. Such setup was developed at the Physics Department at the University of Toledo and was utilized to study the azimuthal dependence of the coercive field in epitaxial, annealed and non-annealed Ni films grown using MBE (molecular beam epitaxy) on MgO substrates. These studies allowed the correlation between the different surface morphology observed in these films with their magnetic properties. These studies will be relevant to a bigger project led by Dr. Lukaszew, dedicated to study the magnetic properties of artificially patterned magnetic nano-structures.

The Role of Boundary Conditions in Stellar Wind Topology and Hydrodynamics

Student: Althea Moorhead
Advisor: Dr. Jon Bjorkman

Abstract:

Mass loss from luminous early-type stars occurs via a line-driven stellar wind. The accepted model for these winds was developed by Castor, Abbot, & Klein (1975; hereafter CAK). Originally the CAK model treated the star as a point source of radiation; however, close to the star the finite apparent solid angle of the star reduces the radiation force, modifying the mass loss rate (Friend & Abbott 1986; Pauldrach, Puls, & Kudritzki 1986). Friend & Abbott also included the effects of rotation; however, they were unable to perform a systematic study of all possible wind solutions,

owing to the non-linear nature of the wind momentum equation. This permitted a critical point analysis of the CAK wind similar to that used by Parker (1960) to systematically determine all possible outflow solutions. This analysis showed that for a CAK point source wind, there was only one outflow solution with an x-type critical point. However, Bjorkman (1995) did not include the finite disk correction factor nor did he include rotation. In the present study we use Bjorkman's method to obtain the wind topology of rotating winds by adding the centrifugal rotation force and the finite disk correction factor to the CAK wind equation. We present topology plots of the finite disk corrected CAK for varying rotation speeds. After matching the surface density boundary condition (by varying the mass loss eigenvalue), we obtain the mass loss rate as a function of rotation.

The finite-disk CAK equation produces quite varied solution topologies as the rotation rate is increased, eliminating some critical points while creating others. In particular we find that at high rotation rates the inner x-type critical point's existence becomes increasingly sensitive to the mass loss eigenvalue, while new x-type critical points appear at large radii. In addition, the CAK wind equation has two solutions for the velocity, which leads, more or less, to a doubling of the number of critical points (up to 10 total). Most importantly, two x-type critical points were found that satisfied the boundary conditions of finite pressure at the star's surface and zero pressure at infinite distance from the star. This results, for rotation rates between 77% and 79% of the critical rotation rate, in multiple outflow solutions for the star, leading to the possibility of multiple mass loss rates. At 79% of the critical rotation rate, the inner critical point ceases to satisfy the outer boundary condition; however, we postulate that it may still provide a viable condition if the hydrostatic solution jumps discontinuously in y but not in u. Depending on the unknown time-dependent stability of these solutions, we conclude that it may be possible for a star to switch between high and low mass loss states. This effect could explain the notorious variability of Be stars, where it is observed that the wind can switch on and off as a function of time. Similarly, the fact that the outer critical point solutions have lower wind speeds offers the possibility that the outer solution could lead to disk formation, while the inner solution does not. Thus the multiple wind solutions offer a potential mechanism for explaining the occasional disappearance of the disks around Be stars.

We have attempted to determine the time-dependent stability of the wind solutions by using numerical hydrodynamics. Although we are not able to say anything conclusively about the stability of our solutions, our difficulties have led to insight in the arena of boundary conditions. We had previously believed that if the pressure at infinite radius were greater than that pressure determined by the hydrostatic solution, an inflow would result. We have reconsidered that idea, since that pressure is of the order of about ten to the negative six hundred.

Designing a Side-Pumped Planar Fiber Laser

Student: Steve Morgan
Advisors: Brian Bagley and Robert Deck

Abstract:

In broadband communications using optical fibers there exists a need for a source of photons at a wavelength of 1550 nanometers. Ideally, this photon source would be part of an optical integrated circuit and would have sufficient power to guide a signal through the entire circuit and into the transmission fibers. A good source for 1550 nanometer light in an OIC is erbium doped

silicate glass, which can be pumped by a solid-state laser at 980 nanometers. In order to maximize the amount of output from the lasing chamber of erbium doped silicate glass, one must optimize the amount of light coupled into the chamber from the solid-state laser. Since there is a discrepancy on the order of 10^3 in the ratio of sizes between the lasing chamber and the solid-state laser when coupled from the end, it seems logical to attempt to couple the light into the chamber from the side in order to couple more than only 10^{-3} of the incident light. In this REU program, I used BeamPROP, a simulation program, to model one possible circuit design to side-pump a waveguide with 980 nanometer light. The circuit used a grating of tiny holes drilled along the incident side of the lasing chamber to change the k_z vector of the photons, thus coupling some light along the desired axis in the waveguide. The preliminary results yielded about an order of magnitude more light being coupled into the chamber than with the end-pumping method. I believe that these findings merit further investigation, and I will continue to explore this problem at the University of Toledo. This program taught me a great deal about a career in physics research.

The Size Dependence of ERE Properties and the Effects of Photofragmentation On the Size Distribution of SNPs

Student: Lori Schmetzer
Advisor: Adolf Witt

Abstract:

Ever since the ERE was discovered 20 years ago, astronomers have been trying to decipher what causes this extended red emission. To do this they look at the various features of the ERE and try to match them to a suitable carrier. In this paper we explore the size dependence of several of these features, relying on the silicon nanoparticle, or SNP, model. We find that the intrinsic quantum efficiency decreases with size, while the ERE intensity increases with size. Both relationships are roughly linear and follow predictions. We also made size distributions of several radiation environments and explored the effects of photofragmentation on those size distributions. We found that large particles were virtually unaffected, while smaller particles were greatly affected, and almost completely destroyed. Further interpretations of these plots showed that the destruction of SNPs by photofragmentation went as d^{-5}.

Nickel Phosphide as a Copper-Free Back Contact for CdTe-Based Solar Cells

Student: Brian R. Sunderland
Advisor: Alvin D. Compaan

Abstract:

Nickel phosphide was deposited onto CdS/CdTe solar cells, using DC magnetron sputtering, to serve as a back contact. Deposition duration, diffusion temperature, etching procedure, substrate heating, as well as the use of graphite as an inter-facial layer were parameters examined in this study. We found that nickel phosphide can serve as a replacement to Cu-based back contacts, whose tendency to diffuse along grain

boundaries degrading cell efficiency would like to be avoided. Average efficiencies of over 8.6% were achieved and stability shows promise, making Ni_2P an attractive candidate as a Cu-free back contact.

Design Improvements in Data Collection Faraday Cups

Student: Joshua Thomas
Advisor: Thomas Kvale

Abstract:

Reliable detectors are necessary in atomic physics for measuring the true particle beam currents which are used in determining cross sections. The Faraday cup detector is ideally suited for measuring ion beam currents in the range from picoamps to microamps, which are the typical ion beam currents produced by the ion accelerators at the University of Toledo. Previous Faraday cup designs were based on a cylindrically symmetric system, which limited the maximum capturing electron kinetic energy of less than the electric charge times the potential applied to the detector. This research project involved the redesign of the Faraday cup detector by introducing a transverse electric field and thus breaking the cylindrical symmetry. Data using the Faraday cup detectors of both designs are compared and much higher capturing kinetic energies were achieved for the same applied potential for the new design.

Faculty Research Profile, Dept. of Physics & Astronomy
The University of Toledo

JACQUES AMAR (Ph.D., Temple Univ., 1985)
Dynamics of thin-film and epitaxial growth, kinetics of phase separation, scaling and fractal aspects of materials, theory of condensed matter systems far-from-equilibrium, computational physics.

LAWRENCE S. ANDERSON-HUANG (Ph.D., Univ. of Calif. Berkeley, 1977)
Surface mapping of W UMa stars (contact binary stars); theory of stellar atmospheres: spectral line formation, line blanketing, atmospheres with incident radiation.

BRIAN G. BAGLEY (Ph.D., Harvard Univ., 1968)
Phase transformations in condensed systems, glasses, and disordered solids, preparation and properties of thin films, materials science, high temperature superconductivity.

RANDY G. BOHN (Ph.D., Ohio State Univ. , 1969)
Thermal conductivity and specific heat of crystalline and disordered solids from 0.07K to 100K. Heat transport in glasses and glass-ceramics. Electrical transport in thin semiconductor films.

BERNARD W. BOPP (Ph.D., Univ. of Texas at Austin, 1973)
Stellar Chromospheres and surface activity. Variable stars; emission-line stars.

JON BJORKMAN (Ph.D., Univ. of Wisconsin-Madison, 1992)
Theory of rotating stellar winds and the formation of circumstellar disks. Radiation transport and the calculation of observable properties using Monte Carlo Simulation.

KAREN BJORKMAN (Ph.D., Univ. of Colorado-Boulder, 1989)
Observational astronomy, spectroscopy and polarization of massive stars. Circumstellar disks, their structure, physical properties and sizes.

SONG CHENG (Ph.D., Kansas State University, 1991)
Intermediate-energy, atomic and molecular ion collisions.

ALVIN D. COMPAAN (Ph.D., Univ. of Chicago, 1971)
Growth and characterization of semiconductor thin films, laser ablation-deposition, rf sputtering, plasma CVD, ion implantation, laser annealing, solar cell fabrication, II-VI semiconductor light emitters.

LORENZO J. CURTIS (Ph.D., Univ. of Michigan, 1963)
Atomic spectroscopy and atomic structure. Experimental fast ion beam atomic spectroscopy and theoretical and semiempirical systematization of atomic data.

XUNMING DENG (Ph.D., Univ. of Chicago, 1990)
Amorphous silicon solar cell materials and device research, thin film depositions, development of novel electronic and optical materials.

ROBERT T. DECK, *Emeritus* (Ph.D., Univ. of Notre Dame, 1961)

Theoretical problems in nonlinear optics. Of particular current interest is the theory of the surface and waveguide modes of the electromagnetic field. Recent work has produced an improved theory of a "nonlinear directional coupler" which can be envisioned to serve as a switching element in light signal processing devices and an all-optical computer. Other interests include the structure of physical theories and the foundations of quantum mechanics.

DAVID G. ELLIS (Ph.D., Cornell Univ. , 1964)

Theoretical atomic physics, with special interest in spectroscopy of multiply ionized atoms, Rydberg states, relativistic effects in atomic structure, electron-atom collisions, coherent states produced by impulsive excitation.

STEVEN R. FEDERMAN (Ph.D., New York Univ., 1979)

Observational and theoretical investigations into physical processes in interstellar matter.

BO GAO (Ph.D., 1989, Univ. of Nebraska)

Theoretical atomic, molecular, and optical physics. Cold-atom spectra and collisions. Multiphoton processes.

PHILIP B. JAMES (Ph.D., Univ. of Wisconsin, 1966)

Planetary astronomy; atmospheric phenomena on Mars; radiative transfer in dusty atmospheres; climate modeling.

THOMAS J. KVALE (Ph.D., Univ. of Missouri-Rolla, 1984)

Intermediate-energy, experimental atomic physics concentrating on the dynamical interaction of ions and atoms in collisions. Spectroscopy and structure of negative ions and multiply-excited, near-neutral positive ions and atoms.

SCOTT A. LEE (Ph.D., Univ. of Cincinnati, 1983)

Brillouin and Raman light scattering, molecular and solid state physics under ultra-high pressure, DNA/drug and DNA/protein interactions, phase transitions in DNA, and physical properties of hyaluronic acid.

R. ALEJANDRA LUKASZEW

The correlation between structure, surface morphology and physical properties in thin films. The study of magnetic thin films and patterned nano-structures (nano-magnets). The application of magnetic thin films to devices (e.g. spin-dependent tunneling applications) The study of the growth mode of thin films.

NANCY D. MORRISON (Ph.D., Univ. of Hawaii, 1975)

Determination of orbital elements and study of brightness variations in spectroscopic binary stars. Spectroscopic study of atmospheres and winds of supergiant stars.

RICHARD M. SCHECTMAN, *Emeritus* (Ph.D., Cornell Univ., 1962)

Alignment and orientation in fast ion beam collision processes, beam foil spectroscopy, and Monte Carlo calculations of atomic scattering processes. *(Emeritus-superannuate)*

CONSTANTINE E. THEODOSIOU (Ph.D., Univ. of Chicago, 1977)

Atomic structure and atomic collision processes; photoionization and multiphoton processes.

ADOLF N. WITT (Ph.D., Univ. of Chicago, 1967)

The nature of interstellar dust grains. Scattering and absorption properties of grains in the UV and visible. Near-IR luminescence by hydrogenated amorphous solids. Radiative transfer in reflection nebulae and globules. Depletion of heavy elements in space. Structure of interstellar clouds.

PROGRAM EVALUATION

NSF-REU Summer Research Program
Department of Physics & Astronomy
The University of Toledo
2001

To help us improve our summer research program in future years, please give us your confidential opinion on the following questions. Thanks very much.

Did this summer's experience live up to your expectations in general?

Definitely Yes			Neutral		Definitely No	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 1.89)					
2	6	1	0	0	0	0

How do you rate your research experience this summer in helping you get a better idea of what a career in scientific research might be like?

Very Helpful			Neutral		Not Helpful	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 1.56)					
5	3	1	0	0	0	0

How do you rate your summer research experience in helping prepare you for graduate study?

Very Helpful			Neutral		Not Helpful	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 1.56)					
4	5	0	0	0	0	0

How do you rate your faculty advisor's interactions in helping you in your summer research experience?

Very Helpful			Neutral		Not Helpful	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 2.11)					
3	3	2	1	0	0	0

How do you rate the weekly seminar series in helping you learn more about physics and astronomy?

Very Helpful			Neutral		Not Helpful	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 2.44)					
2	3	2	2	0	0	0

How do you rate the Social Activities organized by the REU Staff?

Very Enjoyable			Neutral		Not Enjoyable	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 2.33)					
1	5	2	1	0	0	0

How do you rate your summer experience personally?

Great Fun			**Neutral**		**A Real Drag**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 2.56)					
1	3	4	1	0	0	0

How do you rate your summer experience educationally?

Learned a Lot			**Neutral**		**Not Worth Much**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 1.56)					
5	3	1	0	0	0	0

How would you change the division of time between general activities (seminars, visits, outings) *vs.* research work.

More general learning			**Neutral**		**More research time**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 3.78)					
0	1	2	5	0	1	0

What do you think about having some of the seminar talks on subjects such as: "choosing a graduate school", "careers in physics and astronomy", "how to achieve greater diversity among physicists", etc., rather than only the traditional scientific talks such as we had this summer?

A great idea			**Neutral**		**A waste of time**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 2.22)					
4	2	2	0	0	1	0

What do you think about the average level of the weekly seminar talks?

Much Too Advanced			**About Right**		**Much Too Elementary**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 3.00)					
0	1	7	1	0	0	0

How do you rate your research experience in terms of the freedom you had to do things your own way?

None: I did what I was told			**About Right**		**Too much: I got lost**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 3.67)					
0	1	2	5	1	0	0

Were you given enough advance information before coming to Toledo to begin the summer?

Yes, the mailings in May were very helpful			**Neutral**	**No, I didn't know what to expect.**		
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 3.44)					
1	3	0	2	2	1	0

Were you made to feel welcome when you arrived and comfortable overall in the program?

Yes, very much so			**Neutral**		**No, definitely not**	
☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7
Respondents:	(Average: 1.78)					
6	0	2	1	0	0	0

Please list the **best** thing(s) about your summer experience (research and/or social/recreational).

See following pages for written comments

Please list the **worst** thing(s) about your summer experience (research and/or social/recreational).

See following pages for written comments

Please list any additional comments.

See following pages for written comments

Thanks again for your time, and best wishes for continued success in everything you do. As part of the tracking we need (and want) to do, we need for you to tell us about your degrees received and your career activities (grad school, work, etc) after participating in our program. Please keep in touch with us!

Please return this questionnaire in the anonymous envelope provided to:

Department of Physics & Astronomy
The University of Toledo
Toledo, Ohio 43606

Written comments about the **best** thing(s) about your summer experience (research and/or social/recreational).

Windsurfing events were great. Working along side a post-doc was perfect. I was able to constantly ask him questions, get reading material about our work, and have input on our project. Based on the comments of other students, it seems like the advisors are not always available for the same feedback that grad students and postdocs can provide. During the project I never felt like I was wasting time, and there always seemed like there were things I could be working on. In addition, I felt very fortunate to have a project that had such a direct application to everyday life. I have a hard time caring about work that lacks an obvious or important real-world application. That was terrific.

Learning from Greg Hodges and Dr. Kvale. I also enjoyed windsurfing!

I learned a lot about a career in Physics research. I learned a great deal about my field and from the weekly talks as well. I enjoyed the social activities and the ability to pursue something interesting.

I liked the learning and the opportunity to become familiar with new computer programs. I think the bag lunches were a great idea as well as encouraging the REUs to eat together regularly. All REU events were fun, it was good to meet other people.

Recreation setup by faculty and Ian. Being able to work on your own. Different subjects that I worked on. I liked living on a different floor than the rest of the students.

1) Feeling as though I learned how to use computers better and execute a project. 2) Feeling that I've put my work on scientific research field by helping gain information for others to use in their research. 3) I liked going to the museum and having get togethers, i.e., cookouts. 4) In the beginning of the summer everybody was close knit and it felt good to hang out and do recreational things together.

Feeling as if I put together a successful presentation of my research. The other REU and grad students -- we had a lot of fun and everyone was willing to help. My advisor -- willing to give advise, provide direction, challenge me with an interesting an relevant project.

Interaction with graduate students was nice. Research was fun and educational. My professor took care to make sure I learned new skills.

Written comments about the **worst** thing(s) about your summer experience (research and/or social/recreational).

I know there aren't many alternatives, but living in the dorms did not provide a whole lot of connection with the other students at the university my age. This is tough to change, I realize. The social reu events were fine.

Getting up early in the morning.

The worst thing was not knowing what I was doing. I did not have a clear project and felt barraged with random information, that I was expected to know but not told what the point would eventually be.

The university it's self was a little depressing.

1) The dorms felt like cell blocks -- absolutely no community (although I understand it is summer). I was bored alot on nights. 2) Not enough parties at people's house or "movie nights" 3) The group of reu's started to separate and not do things together toward the end of the summer leaving those who aren't from here bored out of their minds.

Not getting outside enough -- only a short lunch break in the fresh air :-) Missing the first few weeks, I came in and didn't really have any instructions/assistance on email, parking passes, keys.

All good. Well, I wasn't very fond of the fourth-week presentations.

Please list any additional comments.

Being the only student to an advisor would be a big help.

I think that REU social events are a great idea. I think more should be planned in advance and possibly during the week since lots of people are excluded during the weekends (A lot of people go home or have previous plans).

Although the talks were a little bit a pain in the a[- -] *they were extremely helpful.*

Thanks to Ian for keeping up on the organized events. He kept the summer from being completely boring and Dr. Compaan for windsurfing, and the tuna steaks. The research aspect is excellent. I learned a lot, which is the most important part, I feel confident going into grad school.

This was a great summer program. I really felt all the faculty supported the REUs in their research and by sharing at lunch seminars. I had a lot of fun with everyone, we were from all different backgrounds. I felt privileged to be included though I have less classroom experience than many of the other students in the program. I also learned many things about my own interests and abilities working in experimental physics. Thanks for all the advise, support and motivation.

Research Experiences for Undergraduates in Physics and Astronomy Summer 2001

Department of Physics & Astronomy
The University of Toledo
Toledo, Ohio 43606

Appendix I: Program announcement and application form

Welcome to the NSF/UT REU 2001 Program!

The University of Toledo
Department of Physics and Astronomy in McMaster Hall
and Ritter Observatory

Some of our former participants

Why Participate? | The Program | Where Are They Now? | Requirements | Application

Why participate in the REU Program?

- Our program provides each student with an exciting opportunity to do **cutting-edge research**. Possible areas of research include astronomy/astrophysics, atomic physics, biological physics, condensed matter physics, materials science, medical physics, and plasma physics. Students may work on computational, experimental or theoretical problems.

- Our students **work directly with faculty members** on their research problem. The faculty member provides background information about the area in which the student is working as well as detailed guidance about how to work on the student's individual problem. This regular contact with the faculty is very valuable. Unlike other programs in which REU students rarely see the faculty and only work with a postdoctoral research associate or a graduate student, our program places a high value on the personal interactions of the REU students with the faculty.

- The opportunity to work on the research frontier while still an undergraduate student is unique. The work is challenging, but the rewards are tremendous. You will be working on **your own project in the field of your choice**. You will be the first person to work on this problem and your results will be of interest to the entire scientific community.

- There can be no greater thrill for a scientist than to discover something new. Our students have this opportunity and many have contributed new and fundamental knowledge to the world of science. Many of our students **publish** their **findings in the refereed literature**. Many of them also **present** their **research at a professional meeting**. The students have the opportunity to discuss their research with the scientists working in their area. They also learn many new things at such meetings. It is an exciting experience to learn that one can participate in the highest level discussions about their chosen area.

- Another benefit of such interactions is that the student gets to **meet the "big shots" of** their **chosen scientific area**. Making contacts with these people is exciting and invigorating! Such contacts are also very useful, particularly when one is trying to decide which graduate school to attend.

Undergraduate research is a very useful experience since it **teaches you how to ask the right questions**. This is an enormously important skill and, like riding a bicycle, can only be learned by doing. The regular classroom courses which every student takes provide an excellent education to understand the framework of scientific knowledge. However, these courses teach you how to generate the right answer, they don't teach you how to ask the right question.

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The program

- $3250 stipend for 10 weeks on campus
- On-campus housing provided
- Travel expenses to and from the University of Toledo provided
- Schedule: 29 May 2001 - 3 August 2001 (different schedules possible if necessary)

Deadline: 15 March 2001 for full consideration. Applications will be considered up until 20 April 2001, depending on the availability of funds.

Our students are fully engaged in research at the "frontier of knowledge". On the basis of their stated interests, students are managed to faculty members working in those areas. At the beginning of the program, there is usually a period of time in which the student learns the background information relevant to her research. This usually consists of reading books and research articles as well as discussions with the faculty mentor. Once the student has become familiar with the basics in the field, the student studies the details of her problem. Usually, this means mastering the techniques to be used in working on the problem. These techniques depend on the nature of the work. A student working on a computational problem would learn the relevant computational techniques. A student working on an experimental problem would learn the details of performing the experiments. A student working on a theoretical problem would study the details of the theory.

Our program is not just all work. Students are housed in suites in the International House, our most advanced dormitory. A sense of camaraderie is encouraged by housing the students close together. There are a number of social activities in the Metropolitan Toledo area available to the students. One high point of the summer is always the trip to Cedar Park, a nearby amusement park which specializes in roller coasters. Students have a great time studying conservation of energy! The Toledo Museum of Art has a world renowned collection, surprising considering the size of Toledo. The Toledo Zoo has a number of interesting exhibits, including the world's only hippoquarium. There is also an active night life in the city as well as many coffee houses.

The exact projects available each summer changes as the interests of the faculty and students evolve. In order to get an idea of the kinds of projects which are available, click on the link below:

Summer 2000 projects

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Where are our former students?

Our former students have had a very successful rate at admission to the premier graduate and professional schools in the nation. Click on the link below to see this list:

Graduate and professional schools

What are the requirements for our program?

- Be a student interested in physics or astronomy.
- Be a U.S. citizen or permanent resident.
- Be a freshman, sophomore or junior in an accredited program at this time.

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How to apply?

- Fill out our online application form.
- Have an official transcript sent from your home institution.
- Have two letters of recommendation sent to our program.

Please have your letters of recommendation and official transcripts sent to:

Prof. S. A. Lee, REU director
Department of Physics & Astronomy
Mail Stop 111
University of Toledo
Toledo, OH 43606

To find out about past REU programs and about the UT Department of Physics and Astronomy, click here to go to the REU Homepage.

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Last updated: 12/02/2001

APPLICATION

Please fill out this form and click on the "Submit" button if you are interested in the R.E.U. program.

First Name | Middle Initial | Surname

Current Address:

Street

Apartment

City

State

Zip Code

Current e-mail adddress

College or university you are currently attending

Telephone number (incl. area code)

The possible research areas are:

1. Astronomy/Astrophysics
2. Atomic physics
3. Biological physics
4. Condensed matter physics
5. Materials science
6. Medical physics
7. Plasma physics

Choose 3 areas from the above list that you are interested in and list them in descending order, using the numbers provided for each area.

First preference: Second preference: Third preference:

Please indicate your preference in descending order for doing experimental (E), computational (C) or theoretical (T) work.

First preference: Second preference: Third preference:

Please provide contact information of two references:

Reference #1:

Name

Street

City

State

Zip code

Tel. number

E-mail

Reference #2:

Name

Street

City

State

Zip code

Tel. number

E-mail

Please have your letters of recommendation and the official transcript sent to:

Prof. S. A. Lee, REU director
Department of Physics & Astronomy
Mail Stop 111
University of Toledo
Toledo, OH 43606

Please indicate the dates you are available:

If you have any comments or questions, please fill in the box below. If you have any problems sending a long comment, please send them in a separate email message to sal@physics.utoledo.edu.

Submit Reset

In case you don't receive a message confirming the receipt of your submission within 48 hours, please send an email message to sal@physics.utoledo.edu.

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Research Experiences for Undergraduates in Physics and Astronomy
Summer 2001

Department of Physics & Astronomy
The University of Toledo
Toledo, Ohio 43606

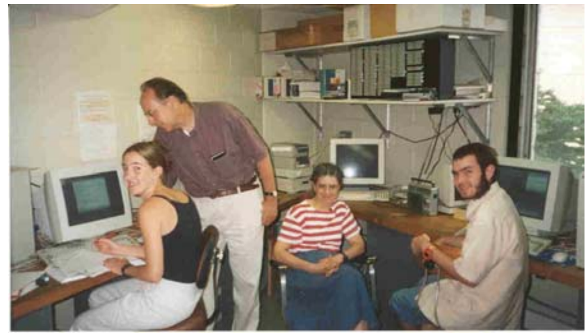
Appendix II: Miscellaneous Pictures from the Summer 2001

Maumee State Park REU windsurfing expedition

REU Bag Lunch seminars, Thursdays at 12 noon

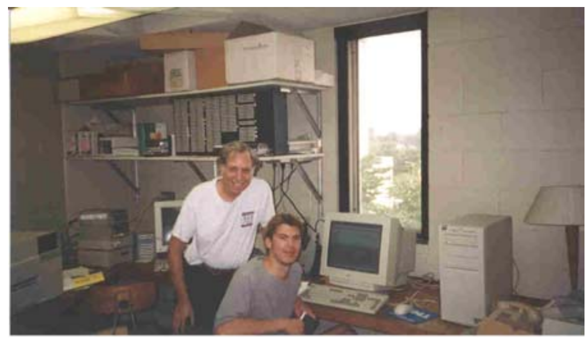
Astronomy/Astrophysics

Althea Moorhead



Lori Schmetzer Kevin Croxall
with A.N. Witt and N.D. Morrison

Amanda Gault



Thomas Crenny with S. R. Federman

Atomic Physics

Blake Anderson

Josh Thomas

Condensed Matter/Material Science/Optoelectronics

Brandon McNaughton with R. A. Lukaszew

Brian Sunderland

Katie Hinko

Steve Morgan
with G. Chen, R. T. Deck, and B. G. Bagley