Annual Progress Report (Year 3)

Research Experiences for Undergraduates in
Physics and Astronomy

NSF-REU Grant PHY- 1004649

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

May 2013

Richard E. Irving
Thomas J. Kvale

TABLE OF CONTENTS

I. REU RESEARCH PARTICIPANTS, SUMMER 2012

Mentors and participants (boldface) in 2012 Summer REU:

Left to Right (Front row): **Marina Kounkel, Michael Huebner, Tyler Kinner, Steven Cloutier, MeiXing Dong, Derek Brinkman, Meredith McLinn, Kathleen Connolly**

Left to Right (Second Row): **Anthony Passero, Nathan Diemler, Morgan Vasilakes, Adam Smercina, Mackenzie Endres, Peter Jones,** Rick Irving

Left to Right (Back Row): **Joseph Ozbolt, Jakub Prchlik, Steven Solomon, Adnan Choudhary, Ruslina Sistryak, Matthew Kurth,** Steven Federman**, Antonio Porras,** Adolf Witt, Michael Dennis

REU Summer 2012 Participants

NAME	INSTITUTION	MENTOR	RESEARCH
Derek Brinkman	Itasca Community College	N. Podraza	Condensed Matter
Adnan Choudhary	Univ. of MD- College Park	J. Amar	Condensed Matter
Steven Cloutier	Univ. of Wyoming	M. Cushing	Astrophysics
Kathleen Connolly	SUNY-Cortland	M. Dennis	Medical Physics
Nathan Diemler	Univ. of Toledo	A.D. Compaan	Plasma Physics
MeiXing Dong	Rensselaer Polytech. Instit.	S. Khare	Condensed Matter
Mackenzie Endres	Berea College	D. Pearson	Medical Physics
Peter Jones	Alfred Univ.	R. Irving	Atomic Physics
Matthew Kurth	Univ. of Texas at Dallas	A. Witt	Astrophysics
Meredith McLinn	MN State Univ.- Moorhead	L. Anderson-Huang	Astrophysics
Anthony Passero	Univ. of Toledo	Y. Fan	Condensed Matter
Antonio Porras	Northern VA Com. College	S. Federman	Astrophysics
Ruslina Sistryak	Jacksonville State Univ., AL	E. Parsai	Medical Physics
Adam Smercina	USRCAP	J.D. Smith	Astrophysics
Morgan Vasilakes	Itasca Community College	M. Heben	Condensed Matter

Additional University of Toledo Students

NAME	UT PROGRAM	MENTOR	RESEARCH
Michael Huebner	FYSRE	T. Megeath	Astrophysics
Tyler Kinner	BOSEF-USRCAP	R. Ellingson	Photovoltaics
Joseph Ozbolt	USRCAP	V. Karpov	Condensed Matter
Jakub Prchlik	Faculty grant	T. Megeath	Astrophysics
Steven Solomon	Faculty grant	R. Chandar	Astrophysics

II. SUMMARY OF SUMMER 2012

Introduction

The Summer 2012 NSF-REU program in Physics and Astronomy, directed by Dr. Richard Irving and Professor Thomas Kvale, gave enhanced research opportunities to 15 undergraduate students from 12 colleges and universities in 9 states. Student participants were chosen competitively out of 141 applications from students in 36 different states in all regions of the U.S. The strong support of our faculty for the REU research program is evidenced by five additional students receiving support from faculty members' external grants and/or participating through the Office Undergraduate Research programs. We had three students participate in our program from community colleges. 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 their results.

We are pleased to report that our students had three refereed publications and two additional manuscripts were published in 2012 that were submitted in 2011. Two undergraduate researchers presented their research at national, professional conferences in 2012. We expect additional manuscript(s) from this summer's (2012) are in preparation and will be submitted shortly to refereed journals.

There were five additional Univ. of Toledo undergraduate students that fully participated in our REU research program in 2012, but with split and/or other funding sources. In addition to individual faculty grants, these funding sources include FYSRE, BOSEF, and USRCAP, which are programs funded and/or administered through the UT Office of Undergraduate Research.

Advertisement and Selection

Again this year (Summer 2012) we utilized a web-based advertisement and application system. Based on a pattern of past applications and inquiries, we believe that the internet is the main search vehicle for the vast majority of students. Because of this pattern, paper announcements were not sent, however individualized email messages were sent to approximately 30 targeted institutions. The emailing included a cover letter alerting the prospective students to our website. The selection committee was composed of Richard Irving (PI), Thomas Kvale (Co-PI), David Ellis, Rupali Chandar, and Adolf Witt. We 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. The initial web announcement (with secondary links to additional material) can be found at: http://astro1.panet.utoledo.edu/~wwwreu/reusummer2012/nsf-reu2012.htm.

Registration and Housing

All REU 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 UT 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. This year, 11 of the 15 REU student participants lived in the Ottawa West dormitory with the NSF-REU grant providing the housing costs to these students. This dorm is organized into suites adjoining a common area that encouraged social interactions among the REU students. This dorm also has kitchen facilities for the students to cook their meals if they choose to do so. 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 and astronomy. We feel that we can best accomplish this goal by housing the students together on campus and to foster off-hours social activities. Additional details on this housing arrangement are included in the "University-Wide" Events section later in this Report.

Networking & Social Activities

As has been the case for several years now, social activities were coordinated by the students themselves with the help of the local REU and UT participants. Activities included movie nights, bowling, sand volleyball, ultimate Frisbee, board games, and various ventures to local restaurants. One of the notable establishments people found fun to visit was Pizza Papalis. The perennial favorite is a windsurfing adventure, courtesy of Professor Alvin D. Compaan, at his pond. He also has a solar hybrid home and is proud to give tours to the students. Some of the other special events included: a UT Planetarium show, Frisbee Golf, several BBQ's, a trip to

Cedar Point Amusement Park, a Toledo Zoo visit, sky-diving, and swimming at Centennial Quarry. The REU calendar can be found via the REU link on our department home page at: http://www.physics.utoledo.edu.

Weekly Seminars

A weekly REU "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 their chosen day. 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.

NSF-REU SUMMER 2012 BROWN BAG SEMINARS

(Noon – MH 4009)

May 29 **REU Orientation**
June 05 **Victor Karpov**, "Plasmonic mediated nucleation of nano-particles and nano-cavities"
June 12 **Ranjan Gupta**, "Circumstellar Dust and Its Modeling"
June 19 **Scott Lee**, "DNA and Water: The Dynamic Duo of Life"
June 26 **REU Progress Reports**
June 28 **REU Progress Reports**
July 03 **Independence Day Celebration** -- bag lunch cancelled
July 10 **Randy Ellingson**, "Energy for 7 Billion People"
July 17 **Will Fischer**, "Adding HOPS to the Hunter's Brew: Insights from the Herschel Space Observatory on Star Formation in Orion"
July 24 **Steve Federman**, "Life In The Universe"
July 30 **Student Final Presentations**
July 31 **Student Final Presentations**
Aug 01 **Student Final Presentations**

University-Wide Events

The Co-P.I. (Thomas Kvale) also served as the director of the UT Office of Undergraduate Research (OUR-UT). This office had an immediate, positive impact on our REU program. In addition to the ARS2980 course mentioned below, OUR-UT worked with the Office of Residence Life in creating a "Living/Researching" community for students living in the dorm. Additional university procedures were facilitated in the background by OUR-UT. This was the first year of the NSF-REU Chemistry program. The Physics/Astronomy REU participants interacted with the Chemistry REU participants at the ARS2980 presentations, housed in the same wing of the dorm, and holding some joint social events.

We also required the students to attend a second, university-wide seminar series that formed the basis of the course, ARS2980: "Issues in Research and Scholarship". This course was coordinated by the Office of Undergraduate Research and the Honors Program. It was in a seminar format and topics concentrated on the safe and ethical practices in research as described in this past year's syllabus. Each presentation lasted about an hour and there was ample time for Questions/Answers for each speaker. We actively promoted the importance of this course at the REU Orientation at the beginning of summer. This coming year, we plan to go a step further by providing (with discussions) the book, "Plastic Fantastic: How the Biggest Fraud in Physics

Shook the Scientific World" by Eugenie Samuel Reich to the students to illustrate that, unfortunately, physics is not immune to human failings.

ARS2980 Issues in Research and Scholarship
Summer Semester III, 2012

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Class Meetings: Thursdays, 9am-10am (6/3 – 8/5)
Location: Sullivan Hall (SL), Rooms 3050-3060-3070
Contact Person:
Thomas Kvale Office: MH4023 Phone: x2980 Email: tkvale@utnet.utoledo.edu
Suggested Texts:

1. "Introduction to the Responsible Conduct of Research," Nicholas H. Steneck, US HHSORI publication
2. "Little Book of Plagiarism," Richard A. Posner, Publisher: Pantheon (January 16, 2007), ISBN-10: 037542475X
3. selected readings provided by the speakers

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Syllabus, Summer 2012

May 31 "*Meet and Greet*" – **William McMillen**, Exec. Vice Pres. & Provost, Main Campus
Summer Schedule & Procedures" – **Thomas Kvale**, Office of Undergraduate Research
"Laboratory Safety" – **Heather Lorenz**, Office of Safety & Health
Pizza Lunch
June 07 "*Research Ethics and Compliance*" – **Walter Edinger**, Office of Research
June 14 "*Math in Academic and Industrial Research*" – **David Corliss**, Ford Motor Company
June 21 "*Advanced Research in the Library*" – **Wade Lee**, University Libraries
June 28 "*Plagiarism and Academic Honesty*" – **Barbara Schneider**, UT Writing Center
July 05 **Independence Day Celebration** -- presentation cancelled
July 12 "*Ethics and Commitment in Research*" – **Thomas Barden**, Honors College
July 19 "*Business Prospects and Patents*" – **Mark Fox**, Office of Research
July 26 "*Overview and Summation*" – **Thomas Kvale**, Office of Undergraduate Research
Aug. 02 (All day) **End-of-Summer Research Symposium (Student presentations)**

Catalog Description:

Seminar series addressing various issues in research, including safe laboratory practices, regulatory compliance issues, and ethics issues in research, scholarship, and creative activities. Topics are chosen to be relevant to students in both the STEMM (Science, Technology, Engineering, Mathematics, and Medicine) and the non-STEMM disciplines.

Concluding Remarks

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 10-20 pages. These requirements have helped the students to become experienced in technical writing and presentations. The success of this philosophy is attested by the fact that many of our REU students are authors on manuscripts that have been published, submitted, or are in preparation.

We are very excited about this coming summer and beyond. This summer will be the first year of our collaborative agreements with three national research facilities where some of our students will conduct part of their research. Specifically, the collaboration with the Nevada Terawatt Facility (NTF) at the University of Nevada, Reno (UNR) will increase the numbers of our students conducting research in atomic, molecular, optical physics (AMO) and/or plasma physics. This collaboration is made possible through the long-standing collaboration that we, individually, have had with researchers at UNR. In order for the students to gain a meaningful research experience and not just as an "observer", the proposed format is for the REU students to spend the first 6 weeks or so at UT working on (and preparing for) their research project at the NTF. They, and their UT faculty mentors, will then spend 1-2 weeks at the NTF conducting research that they prepared for and then travel back to UT for the last two weeks of the summer to continue to work on their project. The actual schedule may vary from that described above depending on the research schedule of the national facility. We also have secured comparable, collaborative agreements with the National Renewable Energy Laboratory (NREL) and the Discovery Channel Telescope (DCT) should appropriate UT physics research projects be indentified in those fields. This UT-national research facility experience for our students is an exciting addition to our REU program. Finally, the University of Toledo has a national reputation of having an excellent medical school and our department (Physics and Astronomy) has a close collaboration in medical physics with the Medical Physics department on the Health Science Campus. This collaboration has provided enhanced opportunities for our REU students to select projects in radiation detector physics and researching the physics of living systems. We expect continued research in these areas most summers.

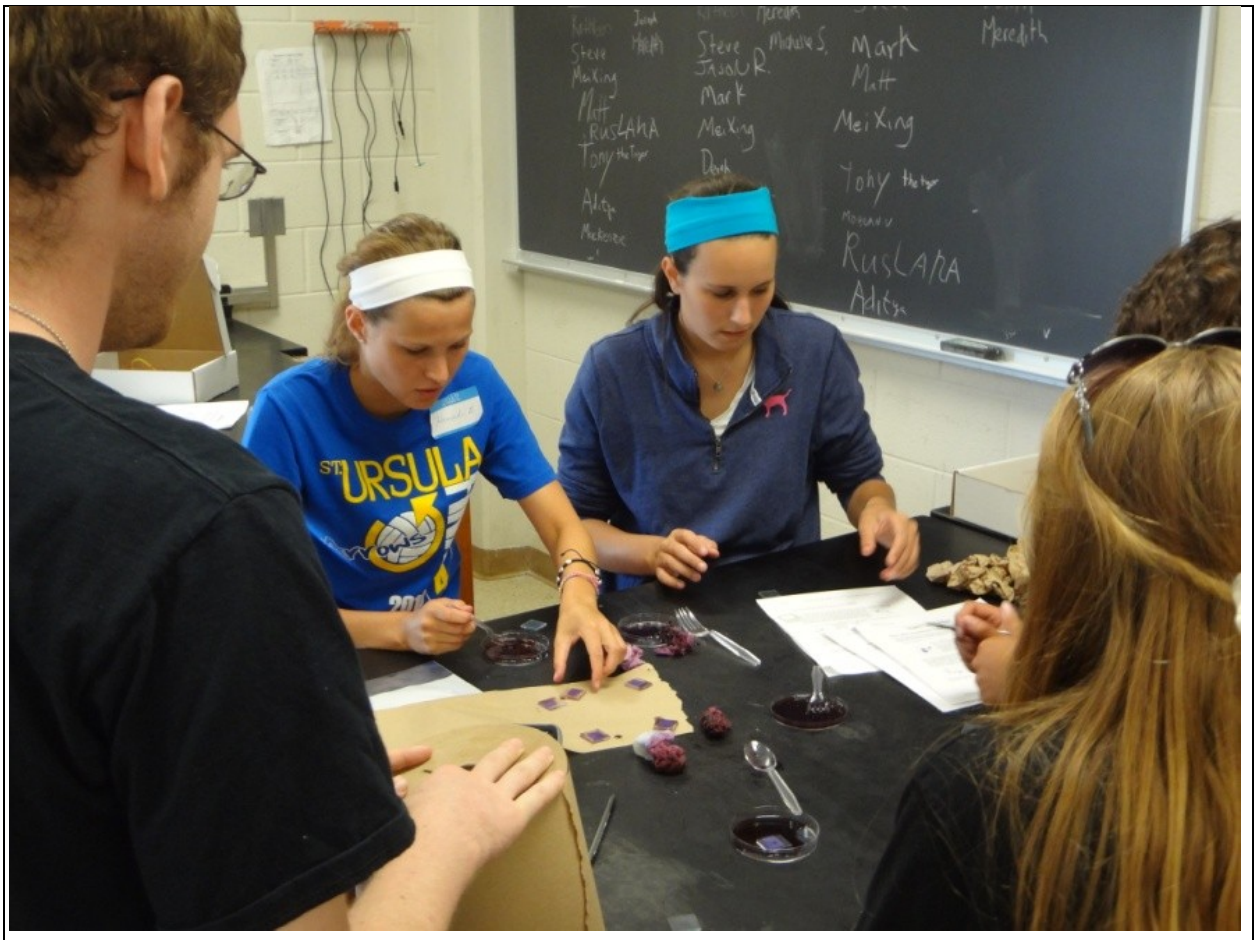
III. PHYSICS AND ASTRONOMY SUMMER CAMP 2012

As part of our NSF program the REU students hosted the Physics and Astronomy Summer Camp. This is an outreach activity for high school students which took place July 18-19. The summer camp activities were developed and supervised with the help of our REU team. Again this year Jackie Kane, a St. Ursula high school science teacher, was extremely helpful in promoting the camp. We had in attendance 22 high school students composed of one home school person and the following 6 local area high schools: Emmanuel Christian, St. Francis, St. Ursula, Sylvania Southview, Toledo Early College, and Woodward.

The first day of the Summer Camp dealt with alternatives for energy generation. Our exploration of the topic included a tour of UT's own Scott Park Campus of Energy and Innovation: led by Michael Green, Director of Energy Management for the University of Toledo. During this tour the students were able to visit a 1.2 MW solar and wind system at this campus. The facility utilizes thin-film-on-glass photovoltaic solar technology and a 132-foot wind turbine. Both the wind and the solar system are expected to generate power equal to the amount of electricity used by 140 homes annually. Off campus the students were exposed to similar "Green" technology implemented at a smaller scale of the home owner. This consisted of a tour and discussion by Professor Alvin Compaan concerning his 4.3 kW CdTe rooftop PV

system and his homemade electric truck. After a barbeque the afternoon provided the students with hands-on activities to explore the concepts of the day. One student activity involved building and testing dye-sensitized solar cell using fruit such as blackberries, raspberries, and pomegranate fruit. During this lab activity students enjoyed testing their endurance on the homemade bicycle generator. to power various household items. This activity really helped to spark a lively conversation about avoiding a phantom energy wasting lifestyle.

The second day featured night time activities related to astronomy. Alex Mak, Associate Director of Ritter Planetarium, along with the help of Cody Gerhartz, an astronomy graduate



REU and Summer Camp students building organic solar cells.

student, gave informative tours of both the Brooks Observatory and the Ritter Observatory facilities. This included a great planetarium show with the state of the art world's first Spitz SciDome XD projection system. Kathy Shan, a doctoral student in curriculum and instruction with a focus in science education, helped develop activities for this part of the camp too. Kathy and the REU students involved the students with an exploration of the size and scale of the solar system through an interactive demonstration using toilet paper as our unit of measurement. Also Kathy introduced the high school students to astronomy research through participation in a Galaxy Zoo project, using real images from the Hubble Space Telescope archive to classify galaxies.

IV. DEMOGRAPHICS

NSF-REU SUMMER 2012 APPLICATIONS

Geographical distribution by undergraduate institution

(Applications REU - 141 / REU Offers Made-26 / REU Accepted-15)

ALABAMA	
Alabama A&M Univ.	(1/1/0)
Jacksonville State Univ.	(1/1/1)
ARIZONA	
Arizona State Univ.	(1/0/0)
Univ. of Arizona	(1/0/0)
ARKANSAS	
Hendrix College	(1/0/0)
CALIFORNIA	
Calif. State -San Marcos	(1/0/0)
Claremont McKenna	(1/0/0)
Harvey Mudd College	(3/0/0)
Humboldt State	(1/0/0)
Univ. of Calif. - Riverside	(2/0/0)
Univ. of Calif. - Berkley	(1/0/0)
Univ. of Redlands	(1/0/0)
COLORADO	
Colorado College	(1/0/0)
Univ. of Colorado-Denver	(1/0/0)
Univ. of Colorado	(1/0/0)
CONNECTICUT	
Connecticut College	(1/0/0)
FLORIDA	
Florida A&M Univ.	(1/0/0)
Florida Atlantic Univ.	(1/0/0)
Univ. of Florida	(1/0/0)
Valencia College	(1/0/0)
GEORGIA	
Northern GA Col. &State Univ.	(1/0/0)
Southern Polytechnic State	(1/0/0)
Univ. of West Georgia	(1/0/0)
Wesleyan College	(1/0/0)
ILLINOIS	
Chicago State Univ.	(1/0/0)
DePaul Univ.	(1/0/0)
Illinois Institute of Technology	(2/0/0)
Southern Illinois Univ.	(1/0/0)
Univ. of IL- Urbana	(1/0/0)
INDIANA	
DePauw Univ.	(2/0/0)
Indiana Univ. - Bloomington	(1/0/0)
Rose-Hulman Institute	(1/0/0)
KANSAS	
Univ. of Kansas	(1/0/0)
KENTUCKY	
Berea College	(1/1/1)
Morehead State	(1/0/0)
Murray State Univ.	(1/0/0)
MARYLAND	
Univ. of MD, College Park	(2/1/1)
MASSACHUSETTS	
Boston College	(1/0/0)
Mass. College of Liberal Arts	(1/0/0)
Mouth Holyoke College	(1/0/0)
Stonehill College	(1/0/0)
Suffolk Univ.	(1/0/0)
MICHIGAN	
Albion College	(1/1/0)
Calvin College	(2/0/0)
Grove City College	(1/0/0)
Kalamazoo College	(1/0/0)
Macomb Community College	(1/0/0)
Michigan State Univ.	(1/0/0)
Univ. of Michigan	(2/0/0)

MINNESOTA

Augsburg College	(1/0/0)
Bethel Univ.	(1/0/0)
Itasca Community College	(2/2/2)
Macalester College, St. Paul	(1/0/0)
MN State Univ. - Moorhead	(1/1/1)
St. Cloud State Univ.	(1/0/0)
St. Olaf College	(2/1/0)

MISSISSIPPI

Jackson State Univ.	(1/0/0)
Univ. of Southern MS	(1/0/0)

MISSOURI

Park Univ.	(1/0/0)
Univ. of Missouri	(1/0/0)

MONTANA

Montana State Univ.	(2/0/0)

NEW JERSEY

The College of NJ	(1/0/0)
Columbia University	(1/0/0)
Hudson County Com. College	(1/0/0)
Montclair State Univ.	(1/0/0)

NEW YORK

Alfred Univ.	(2/1/1)
New York Univ.	(1/0/0)
Rensselaer Polytechnic Institute	(2/1/1)
St. Lawrence Univ.	(1/0/0)
SUNY-Stony Brook	(1/0/0)
SUNY - Cortland	(1/1/1)
Univ. of Rochester	(1/1/0)

NORTH CAROLINA

Duke Univ.	(1/0/0)

OHIO

Case Western Reserve Univ.	(1/0/0)
Cleveland State Univ.	(1/0/0)
College of Wooster	(1/0/0)
Hiram College	(1/0/0)
John Carroll Univ.	(2/0/0)
Kent State	(2/0/0)
Kenyon College	(1/0/0)
Univ. of Akron	(1/0/0)
Univ. of Toledo	(16/3/3)
Wittenberg Univ.	(1/0/0)
Xavier University	(1/0/0)
Youngstown Univ.	(1/0/0)

OKLAHOMA

Cameron Univ.	(1/0/0)

OREGON

Univ. of Portland	(1/0/0)

PENNSYLVANIA

Bryn Mawr College	(1/1/0)
Univ. of Pittsburgh	(2/1/0)

PUERTO RICO

Univ. of Puerto Rico	(2/1/0)

TENNESSEE

Austin Peay State Univ.	(2/0/0)
Univ. of Christian Brothers	(1/0/0)

TEXAS

Univ. of Dallas	(1/0/0)
Univ. of Texas - Dallas	(1/1/1)

UTAH

Westminster College	(1/0/0)

VERMONT

Middlebury College	(1/0/0)

VIRGINIA

Blacksburg	(1/0/0)
Bridgewater College	(1/0/0)
Northern VA Com. College	(1/1/1)

WASHINGTON

Western Wash. Univ.	(1/0/0)
Whitman College	(1/1/0)

WASHINGTON, DC

Catholic Univ. of America	(1/0/0)

WISCONSIN

Beloit College	(1/0/0)
Marquette Univ.	(1/0/0)
Univ. of Wisconsin - Eau Claire	(1/0/0)
Univ. of Wisconsin - Madison	(1/0/0)

WYOMING

Univ. of Wyoming	(2/1/1)

CANADA

Quest Univ., Canada	(1/0/0)

NSF-REU Participant* Demographics

Summer 2012

Gender

Female:	5
Male:	10

Class Rank (As of Spring semester 2012)

Freshman:	5
Sophomore:	3
Junior:	7
Senior:	0

Ethnicity

American Indian:	0
Alaskan Native:	0
Asian American: (or Pacific Islands)	2
African American:	0
Hispanic American:	1
European American:	12
Other:	

Home State

Alabama	1
Maryland	1
Massachusetts	1
Minnesota	3
New York	2
Ohio	4
Texas	1
Virginia	1
Wyoming	1

Home Institution

Berea College	1
Alfred Univ.	1
Itasca Community College, MN	2
Northern Virginia Community College	1
Minnesota State Univ.- Moorhead	1
Rensselaer Polytechnic Institute, NY	1
SUNY-Cortland, NY	1
Univ. of Maryland- College Park	1
Univ. of Wyoming	1
Univ. of of Texas at Dallas.	1
Jacksonville State, AL	1
Univ. of Toledo….	3

REU Students Grade Point Average: 3.57

V. RESEARCH

REU 2012 Final Presentations
Each talk is scheduled for 12 minutes allowing 3 additional minutes for questions.

Monday, July 30

12:00	**Steve Cloutier**	"*An effort towards completing a solar neighborhood survey of Brown Dwarfs*,"
12:15	**Steve Solomon**	"*Threshold/FWHM Parameters in detecting GC's/Planetarium Update*,"
12:30	**Jakub Prchlik**	"*Accretion in CepOB3b: A Spectroscopic Study of Hα*,"
12:45	**Derek Brinkman**	"*Spectroscopy Ellipsometry Studies of Vanadium Oxide Nano-composite Etching*,"
1:00	**Kathleen Connolly**	"*The Future of MRI and PTSD*,"
1:15	**Anthony Passero**	"*Production of Cuprous Oxide and Copper Sulfide Solar Cells*,"

Tuesday, July 31

12:00	**Meredith McLinn**	"*Graphic Visualization of 3D Radiation Hydrodynamics*,"
12:15	**Matt Kurth**	"*Extended Red Emission in Pleiades Reflection Nebula*,"
12:30	**Morgan Vasilakes**	"*Investigating Process Parameters of Cadmium Telluride Solar Cells*,"
12:45	**Peter Jones**	"*Semi-Empirical Methods of Intermediate coupling in electrons of atoms in Iso-Electronic Sequences*,"
1:00	**Tony Porras**	"*Interstellar OH^+*,"
1:15	**Adnan Choudhary**	"*An Analysis of Strain in a Substrate/Monolayer System*,"

Wednesday, August 1

12:00	**Nathan Diemler**	"*Characterization of Argon Plasma in Magnetron Sputtering*,"
12:15	**Adam Smercina**	"*After the Fall – Dust and Gas in Post-Starburst Galaxies*,"
12:30	**Mackenzie Endres**	"*Radiation Brachytherapy:SAVI (Strut Adjusted Volumetric Implant) Dose Distribution Simulation*,"
12:45	**MeiXing Dong**	"*Properties of Ga_2O_3*,"
1:00	**Ruslina Sistryak**	"*Effect of Beam Configurations in Treatment of Nasopharyngeal Carcinoma*,"

End-of-Summer Research Symposium Thursday, August 2

Joseph Ozbolt	"*A Theory of Multilayered Thin-Film Radiation Detectors*,"
Michael Huebner	"*Searching for Binary Stars in the Orion Molecular Cloud,*"

ABSTRACTS OF REU FINAL REPORTS
The University of Toledo, Department of Physics & Astronomy
SUMMER 2012 (Faculty Mentor on parenthesis)

Astrophysics

Steven Cloutier, "*An effort towards completing a solar neighborhood survey of Brown Dwarfs*," (Michael Cushing)

The opportunity to study ultra-cool atmospheres in the universe has been largely nonexistent for the better part of the last century. With the advent of surveys in the near infrared, our ability to identify and study these objects, primarily Brown Dwarfs, has materialized. One of the outstanding questions is how these objects form. To this end the spatial density of brown dwarfs is being determined within 20 pc of our sun. Using observational data from the Folded-port InfraRed Echellette (FIRE), the spectra of six brown dwarf candidates was analyzed. As a result we have added six new brown dwarfs to the census of brown dwarfs known to be within this region, along with respective distance, temperature, and gravity estimates, further refining our spatial density estimates.

Matthew Kurth, "*Extended Red Emission in Pleiades Reflection Nebula*," (Adolf Witt)

The Extended Red Emission (ERE), a dust-related interstellar photoluminescence phenomenon, is observed in many star forming regions, but is often overshadowed by multiple other processes occurring in those environments. In an interstellar dust cloud, the ERE is simpler to identify and work with. To observe the ERE in an interstellar dust cloud, the dust in the cloud must be in the vicinity of stars that illuminate it. This is why we are observing the Pleiades star cluster and the nebula that surrounds it. In particular, we initially placed special focus on the Merope nebula, which is the nebular region south of Merope. This system containing stars and interstellar dust is known as a reflection nebula, and in this case is the result of an accidental encounter of the Pleiades star cluster with an interstellar cloud.

Meredith McLinn, "*Graphic Visualization of 3D Radiation Hydrodynamics*," (Lawrence Anderson-Huang)

Antonio Porras, "*Cosmic Rays in Space*," (Steven Federman)

To further understand the origin of cosmic rays, we analyze CH and CH^+ found in a variety of diffuse molecular clouds in order to find OH^+ in this environment. OH^+ is produced by cosmic ray ionization. Our goal is to extract the cosmic ray ionization rate in clouds from the OH^+ absorption lines. We do this by first measuring clouds Doppler effect. After finding each velocity, we search for consistencies. We compare our column densities for OH^+ with the OH^+ column densities of the Krelowski et al. paper (2010) and expand that survey to 41 stars. We want to further understand cosmic-rays ionization in space by extracting the rates from the OH^+ data.

Adam Smercina, "*After the Fall – Dust and Gas in Post-Starburst Galaxies*," (J.D. Smith)

Atomic, Molecular, Optical Physics

Peter Jones, "*Semi-Empirical Methods of Intermediate coupling in electrons of atoms in Iso-Electronic Sequences*," (Larry Curtis, David Ellis, Richard Irving)

Examinations of iso-electronic sequences reveal trends in intermediate coupling as one travels up the sequence in order of ascending atomic number. These trends, once analyzed, were modeled and predicted for the ground np3 configuration in the N and P sequences. By fitting the observed energy intervals in terms of the Slater and spin-orbit parameters F, ζ, we formed the Hamiltonian energy matrices in pure L-S coupling basis. From the resulting eigenvectors we predict the mixing amplitudes and the resulting M1 transition rates. Although further tests remain, the code developed is promisingly accurate in accordance with NIST energy- level values for the full range of the sequence up to at least Tungsten. The software utilized was a combination of Maple, Excel, and Multi-configuration Hartree-Fock calculations. Another project examined spectral and decay curves of S II and Pb II to reveal transition probabilities, oscillator strengths, and potential cascades. These decays are of general interest to the scientific community and Pb II is of particular interest to astronomers studying diffuse matter and galaxy formation. Further data decay is needed to strengthen the signal and increase accuracy but initial results are promising. Data was obtained from THIA (Toledo Heavy Ion Accelerator) and processed with Root version 3.2b, Excel, and Lab View.

Condensed Matter Physics

Derek Brinkman, "*Spectroscopy Ellipsometry Studies of Vanadium Oxide Nanocomposite Etching*," (Nikolas Podraza)

This report looks at the creation of a model that dynamically fits in situ ellipsometric spectra collected during the etching of nanocomposite Vanadium Oxide (VOx) samples by a solution of water and over-the-counter (OTC) hydrogen peroxide. Two samples with different thin film resistivities and amorphous + nanocrystallite compositions were etched at two different hydrogen peroxide concentrations. Three different structural models were evaluated to describe the etching of these films. For these VOx thin films on silicon substrates, the more amorphous VOx etched almost 30 % faster than the predominately nanocrystalline VOx. The more amorphous VOx etched at an average rate of 1.76 A/sand the more nanocrystalline VOx etched at an average rate of 1.27 A/s. These measurements were all taken in the visible spectra. This report will highlight the procedure involved, the models used, the results that were gathered, and further work that can be done to gain further knowledge of VOx.

Adnan Choudhary, "*Strain Analysis in Submonolayer Cu/Ni(100) - Continuum and Atomistic Perspectives*," (Jacques Amar)

We compare LLL continuum theory predictions for submonolayer Cu/Ni(100) growth to results from atomistic simulations using EAM potentials. Results show that LLL continuum theory is unable to predict the exponential behavior for strain in the substrate that is observed in atomistic simulations. As a result we question the application of LLL theory for film applications.

MeiXing Dong, "*Structural and electronic properties of β-Ga_2X_3 (X=O, S, Se, Te) using ab initio calculations*," (Sanjay Khare)

I participated in on going work in Prof. S. V. Khare's group studying the structural, electronic and energetic properties of Al_{2}X_{3}, (X = O, S, Se, Te), in the I4_{1}/amd space group. The study was done using density functional theory (DFT). I helped a graduate student to analyze structural models of the material which came as output from DFT computations. I tabulated some of these results and compiled data for different materials from existing files.

Anthony Passero, "*Synthesis of Cu_2O and Cu_2S Thin Films for Photovoltaic Application*," (Yanfa Yan)

Thin films of the P-type materials Cu_2O and Cu_2S are synthesized and characterized for use in photovoltaic application. Cu_2O films were synthesized on copper substrates using a thermal oxidation method. Following this, CdS films were synthesized using a chemical bath deposition (CBD) for use as an N-type material in a completed Cu_2O solar cell. The CdS films were deposited onto glass substrates, to optimize the deposition parameters. Characterization of these two films was performed, but not by myself (due to my shift to the Cu_2S project) and as such is not discussed in this paper. Cu_2S films were synthesized onto borosilicate glass (BSG) using sputtering deposition, in order to optimize the deposition parameters. Characterization was used to determine thickness, electrical properties, optical properties, grain morphology, and composition. The data is not yet completely analyzed, but preliminary examination suggests optimal sputtering deposition under high temperature (220ºC) and low pressure (5-10 mTorr).

Morgan Vasilakes, "*Investigating Process Parameters of Cadmium Telluride Solar Cells*," (Michael Heben)

This summer I studied the effect of changing our process parameters for cadmium telluride (CdTe) solar cells. There are two processes that I focused on. The first one is called the cadmium chloride ($CdCl_2$) treatment. The other process is called the annealing process. We already had parameters, but the problem with this was that no one really knew where those numbers came from. It was just what they had used before and kept using. I did three main experiments. In the first one I studied the effect of changing the annealing temperatures and time. I found that doing the annealing process for 30 minutes at 200°C gave me the best efficiency. In my second experiment I wanted to confirm the results from the first experiment. This did not happen. In this experiment 30 minutes at 225°C gave me the best efficiency. In my third experiment I studied the effects of changing the $CdCl_2$ treatment temperatures as well as the annealing process temperatures. In this experiment I found the best efficiency when I did the $CdCl_2$ treatment at 410°C and the annealing process at 225°C. Now we know there are better parameters to use, we are just not sure which are the best. One way this can be determined is by doing more experiments and therefore obtaining a larger amount of data.

Medical Physics

Kathleen Connolly, "*The Future of MRI and PTSD*," (Michael Dennis)

During my research this summer I joined a group of students and professionals on their research team. This group of scientists were interested in learning if there is anything in the brain that will predetermine if you are more likely to develop Post Traumatic Stress Disorder after a traumatic event. While I was here over the summer, the research team was working on gathering a group of test participants and moving their fMRI images into a program where all of them can be compared and normalized. An fMRI works exactly like an MRI, using strong magnetic fields and radio frequencies that interact with hydrogen protons, to create an image. The fMRI instead of looking at an entire body, looks only at the brain and differentiates between areas that are being activated and ones that are not in use. It does this by looking at the flow of blood to different areas in the brain and differentiating between the deoxygenated and oxygenated blood, since they have a different magnetic susceptibility. The test participants had all been in a car accident and were given three stress level tests over a period of twelve weeks. They had two fMRI's, one hours after the time of the incident and one at the end of the twelve week period.

Mackenzie Endres, "*Simulation of the SAVI, Strut Adjusted Volumetric Implant, Brachytherapy Treatment*," (David Pearson)

The Strut Adjusted Volumetric Implant, SAVI, is a relatively new device for breast cancer treatments. The goal of this project was to create a model of the geometry of the device and a template for actual treatment plan simulations. The template will work in mcnp5, the newest Monte Carlo N-Particle code used for neutron, photon, electron, or coupled neutron/photon/electron transport, to create accurate dose distributions of normalized breast cancer treatments. The mcnp5 results will be useful as a second check of the treatment plan to verify that accurate doses could be delivered to SAVI treatment patients.

Ruslana Sistryak, "*Effect of Beam Configurations in Treatment of Nasopharyngeal Carcinoma*," (E. Parsai)

The goal of this project was to develop the best possible treatment for a given nasopharyngeal carcinoma (NPC). We CT scanned a Rando Phantom's head and neck (H&N) region and transferred the scans into our treatment planning computers. We created a gross tumor volume (GTV) in the nasopharyngeal area and expanded it to make a planned treatment volume (PTV) with appropriate margins and contouring critical structures in the area. Using 3D conformal radiotherapy technique (CRT), we created an optimized deliverable plan with proper blocks around each beam to save the critical structures. Then we created an intensity-modulated radiotherapy (IMRT) plan using the contours that we had. We reviewed the dose volume histograms (DVHs) for the target NPC, and for organs at risk (OARs) that we had delineated, and made comparisons.

Finally, we made diode measurements to verify that the plans were accurate and deliverable.

Plasma Physics

Nathan Diemler, "*Characterization of argon plasma energies by comparison between Langmuir probe and optical emission spectra*," (Alvin Compaan)

Plasma characteristics in magnetron sputtering deposition are the topic of interesting this research project. The variation in plasma optical emission and plasma temperature are

examined at various deposition pressures and radio frequency (RF) powers. The goal is to find a relationship between the ratio of two optical spectral lines and the electron temperature. Plasma characteristics are analyzed through use of a Langmuir probe and diode-array spectrometer.

Abstracts of Additional UT Summer Research Students

Michael Huebner, "*Searching for Binary Stars in the Orion Molecular Cloud,*" (Thomas Megeath)

Tyler Kinner, *"Synthesis and Characterization of FeS_2 Quantum Dots,"* (Randy Ellingson)

Pyrite (FeS_2) is a novel, promising material for use in photovoltaics. Earth-abundant, non-toxic, and easily processed (through a quantum dot method), pyrite adds sustainability to the solar renewable energy field. With indirect and direct band gaps of approximately 0.9eV and 1.3eV, respectively, pyrite is appropriate for band gap tuning to suit AM1.5G (the standardized solar radiance at the Earth's surface). Several syntheses have been developed for producing pyrite quantum dots, namely thermal injection methods yielding crystalline, well-passivated, and phase pure quantum dots. Another method, an inverse-micellar synthesis, is used to yield monodisperse, quantum-confined pyrite quantum dots. Further work is also being performed to create photoresponsive films of the quantum dots.

Joseph Ozbolt, *"A Theory of Multilayered Thin-Film Radiation Detectors,"* (Victor Karpov)

The goal of our project was to develop a theory for a new type of multilayered thin-film radiation detector with N>>1 micron thick cadmium telluride (CdTe) semiconductor layers stacked on top of one another. The research conducted this summer only dealt with the one layer case for which physical intuition was pursued. Between each layer is either an aluminum or copper plate connected to terminals that may reveal certain data about particles' nature, energy, dispersion of spectrum and the angle of incidence. Several Monte Carlo simulations were ran for the single-layer case of different thicknesses for 2MeV and 4MeV photons. Results were then analyzed.

Jakub Prchlik, "*A Spectrographic Study of CepOB3b*," (S. T. Megeath)

Presented is data obtained from the Hectospec and Hectochelle instruments located at the MMT in Mount Hopkins, Arizona. The Hectospec instrument was used to obtain moderate resolution spectra of ~1900 sources. The Equivalent Widths (EW) of several features were measured, as well as the spectral type for these sources. Data was able to be gathered from the sources concerning the age, luminosity class, and accretion. Using the Hectochelle instrument the Hα Full Width at Ten Percent Maximum (FWTPM) was determined for 41 previously identified Class II sources. The FWTPM then can be used to estimate the accretion rates. Accretion rates are important for understanding how gas evolves in a star disk system.

Steve Solomon, "*Globular Cluster Detection and Planetarium Experience*," (Rupali Chandar)

My REU experience this summer can be characterized by two different experiences that will greatly benefit me this next school year and into the future. My first experience consisted of undergraduate research under the supervision of esteemed professor, Dr. Rupali Chandar.

This research was a continuation of research from last summer and last school year. Work in this area consisted of finding globular clusters. Analyzing data from this summer in terms of color-color plots and luminosity will be work accomplished next school year. My second experience involved working in the planetarium under Alex Mak and graduate student Cody Gerhartz. I learned many things at Ritter Planetarium and Brooks Observatory including how to: use the SciDome XD projector, use the program Starry Night to write ATM scripts (planetarium shows), play full dome Spitz content shows,give live public planetarium shows, and give live viewing presentations using Brooks Observatory. I also helped to work in public outreach programs that Ritter Planetarium and The Department of Physics and Astronomy hosted. I will also talk about some ideas that I am throwing around as far as some possible future publications in astronomy and in the field of education. Lastly, there are many acknowledgements that will need to be addressed.

NSF-REU External Publications and Presentations*

REFEREED PUBLICATIONS - Submitted/accepted/published.

Kathyrn E. Hoepfl (2010), Andrew Solocha, Alvin D. Compaan, Eldon Johnson, *"Comparison of Solar and Wind Power Output and a look at Real-Time Pricing,"* International Journal of Technology, Policy and Management, Vol. 12, No.2/3 pp. 233 - 243 (2012). DOI: 10.1504/IJTPM.2012.046928

D. Moomey (2006), S. R. Federman, and Y. Sheffer, *"Revisiting the Chlorine Abundance in Diffuse Interstellar Clouds from Measurements with the Copernicus Satellite,"* Astrophysical Journal 744, 174 (2012).

C. J. Taylor (2010), A. M. Ritchey, S. R. Federman, and D. L. Lambert, *"The $^{7}Li/^{6}Li$ Isotope Ratio near the Supernova Remnant IC 443,"* Astrophysical Journal (Letters), 750, L15 (2012).

PRESENTATIONS

Kristen Garofali (2011), Joseph Converse, Rupali Chandar, and Blagoy Rangelov, "*The Dynamical Formation of Young Black Hole Binaries in Dense Star Clusters,*" American Astronomical Society, Meeting #219, #151.28 (2012).

Kounkel, Marina (2010, 2011), Megeath, T., Fischer, W., Poteet, C., "*WFC3 Imaging of Protostars in the Orion Molecular Clouds*," American Astronomical Society, AAS Meeting #219, #337.11 (2012).

Update from Annual Report 2011

Kristen Garofali (2011), Joseph Converse, Rupali Chandar, and Blagoy Rangelov, "*On The Dynamical Formation of Very Young, X-Ray Emitting Black Hole Binaries in Dense Star Clusters,*" Astrophysical Journal 755:49 (2012). -- Refereed, Published

William J. Fischer, S. Thomas Megeath, John J. Tobin, Amelia M. Stutz, Babar Ali, Ian Remming, **Marina Kounkel (2010, 2011)**, Thomas Stanke, Mayra Osorio, Thomas Henning, P. Manoj, and Thomas Wilson, "*Multiwavelength Observations of V2775 ORI, an Outbursting Protostar in L 1641: Exploring the Edge of the FU Orionis Regime,*" Astrophysical Journal 756, 99 (2012) doi:10.1088/0004-637X/756/1/99. -- Refereed, Published

*REU students' names in **bold face type*** with year of participation.

VI. RESEARCH PROGRAM EVALUATION

NSF-REU Physics and Astronomy
RESEARCH PROGRAM EVALUATION - STUDENT
2012

To help us improve our summer research program in future years, please give us your confidential opinion on the following questions. Indicate your selection by **CIRCLING** the number. You may use the backs of these pages and/or additional pages if extra space is needed for comments.

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

Definitely Yes			**Neutral**			**Definitely No**
1	2	3	4	5	6	7

2013 mean (pop. 13): 1.7

2. How much do you think that your research experience has helped you educationally?

Learned a Lot			**Neutral**			**Not Worth Much**
1	2	3	4	5	6	7

2013 mean (pop. 13): 1.7

3. How do you rate your summer research experience personally?

Great fun			**Neutral**			**A Real Drag**
1	2	3	4	5	6	7

2013 mean (pop. 13): 2.1

4. 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

2013 mean (pop. 13): 1.8

5. How do you rate the <u>level of your research</u> project this summer in regards to your educational level?

Far above my level			**About Right**			**Far below my level**
1	2	3	4	5	6	7

2013 mean (pop. 13): 3.5

6. How skilled in the tools/techniques/methods of inquiry in the profession of the research project did you start with at the <u>beginning of the summer</u>?

Very skilled/knowledgeable			**Neutral**			**Not very skilled/knowledgeable**
1	2	3	4	5	6	7

2013 mean (pop. 13): 5.5

7. How skilled in the tools/techniques/methods of inquiry in the profession of the research project did you acquire by the <u>end of the summer</u>?

Very skilled/knowledgeable			**Neutral**			**Not very skilled/knowledgeable**
1	2	3	4	5	6	7

2013 mean (pop. 13): 2.8

8. How much time did your faculty mentor spend per week personally mentoring you on your research project?

1	2	3	4	5	6	7
0-1hrs/wk	1-2 hrs/wk	2-3 hrs/wk	3-4 hrs/wk	4-5 hrs/wk	5-6 hrs/wk	>6 hrs/wk

2013 mean (pop. 13): 3.8

9. How do you rate your faculty mentor/supervisor's interactions in helping you in your research experience?

Very Helpful			**Neutral**			**Not Helpful**
1	2	3	4	5	6	7

2013 mean (pop. 13): 1.8

10. 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

2013 mean (pop. 13): 3.8

11. How do you rate the Physics/Astronomy Bag Lunches and the ARS2980 seminar presentations?

Very informative			**Neutral**			**Not very informative**
1	2	3	4	5	6	7

2013 mean (pop. 13): 3.4

12. How do you rate the REU social activities this summer?

Very fun			**Neutral**			**Boring: waste of time**
1	2	3	4	5	6	7

2013 mean (pop. 13): 2.6

13. 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

2013 mean (pop. 13): 4.2

one comment: I was not really involved in the group activities.

14. Were you made to feel welcome by the department and REU staff this summer?

Very welcome			**Neutral**			**Not welcome**
1	2	3	4	5	6	7

2013 mean (pop. 13): 1.0

15. 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

2013 mean (pop. 13): 2.8

two comments: Miscommunication on hospital visitor requirements.
was not told to bring blankets/pillows.

Critical Reflection Questions (Questions and Responses on the following pages.)

Critical Reflection Questions

1. Why did you choose to become involved in a research project this summer?

I wanted to learn about a different field of physics than I had exposure to before.

Experience.

Experience, $.

I want to be a part of the scientific [endeavor].

Good way to expand knowledge while not giving up having a summer job.

I wanted to [gauge] my interest in CMO research and graduate studies in physics.

I was interested in astronomy and wanted to see if it would be a field I would want to go into.

To get a research experience & work on green technology.

Strong desire to understand what research "is".

I wanted to see what it was like, and I like the idea getting paid to learn.

I was unsure of whether I was pursuing the major that I wanted to, and this helped me determine that.

I wanted to find out whether or not I would enjoy a research career.

Excellent reviews from a previous REU student.

2. What prior knowledge did you find useful in your research project (e.g., courses, experiences, etc.)?

This project was outside of my prior knowledge.

Lab work.

Previous Research.

Last year's REU

Mostly professional skills, having basic physics knowledge helped as well.

Linear Algebra, Calc. I, II, III, Basic Physics Sequence

The physics courses I had taken.

general physics for engineering & science students.

Computer programming. General astronomy ideas/concepts.

I didn't really have any knowledge that helped me.

Physics I and Physics II.

Comp. Sci., astrophysics, general math/physics courses.

My knowledge of quantum mechanics and optics were invaluable.

3. What knowledge was missing that would have helped you in your research project (e.g., courses, experiences, etc.)?

computer programming.

Coursework in my specific area.

More coding experience.

Some theories that are often referenced in my research are detailed in higher level courses than I have taken.

I think having taken Physics 2 would have helped polarization of light.

More experience with programming.

Experience writing/reading code. Astronomy courses.

PV knowledge as well as advanced physics classes.

More programming, particularly in IDL. Prior knowledge of my project.

Programming classes would have helped.

[no response].

A little more background on what I was working with.

Perhaps a Quantum II or Advanced Lab II course.

4. What new knowledge central to your project did you discover in your research?

computer programming basics.

PV information.

Mainly Coding.

How and why I am studying what I am studying.

Specific knowledge about ellipsometry and the polarization of light.

That the strain does not simply correlate to the energy barrier it seems.

How to manipulate images, writing/reading code, and general knowledge on astronomy.

The atomic physics related to plasma.

[no response].

[no response].

[no response].

The mechanics of my system, coding techniques, software/command-line tools.

A wealth of Atomic Physics and vacuum and high voltage accelerator technology.

5. What new knowledge tangential or incidental to your project did you discover in your research (e.g., new methods, connections, resources, etc.)?

I found problems in the geometry and source definitions used in brachytherapy simulations that may increase accuracy.

Lab procedures.

More Coding.

New programming languages

I have connections with both a graduate student and my mentor to ask questions of for advice.

Programming/Mathematics. I have connections at UT now, and a recommender.

[no response].

How to make and use simple Langmuir probes.

The general way in which research in astronomy is conducted (methods of obtaining data/data reduction and analysis).

That there are better parameters to use for cadmium telluride cells but from the data I got, we aren't sure what those are.

[no response].

Command-line familiarity, how grad. school process works.

M-Theory, Grad. school applications, politics.

6. How might your research project impact the greater community (professional and/or societal)?

I made a template for second checking treatment plans for high dose radiation treatments for SAVI breast cancer treatments.

Renewable Energy.

An education paper that I am looking into.

It gives a building block to a greater understanding of where we come from.

It will allow for studying of data that my research produced. Hopefully also to allow for appropriate [future] uses of the material.

Well we have reason to believe that a widely acknowledged theory is incorrect, this will change what people think of the theory.

It will have impact in understanding star formation.

The use of optical emission spectra to measure a desired electron temperature.

[no response].

[no response].

Someone may find the information about my materials useful and not be able to create new solar cells with it.

[no response].

We have precise decay curve measurements for Pb II and S II which will aid astrophysicists.

Please list any additional comments.

It is difficult commuting by bus to the medical campus and the events on the main campus. There was poor communication with medical campus students, and I felt left out of group activities and decisions. The guys at the medical campus really took me under their wing, were good mentors and involved. For outside of research activities, they made us feel included and welcome. Dr. Pearson was a great mentor.

[no response].

[no response].

[no response].

[no response].

[no response].

[no response].

[no response].

[no response].

[no response].

It would have been helpful if living arrangements were more clear before we got here, i.e., bedding. If we had known we were only getting a thin mattress cover and a pillow case, we would have brought some of our own things from home.

[no response].

Excellent experience in every regard. Highly recommend it to any undergraduate.