Annual Progress Report (Year 3)

Research Experiences for Undergraduates in
Physics and Astronomy

NSF-REU Grant PHY-0648963

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

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Richard E. Irving
Thomas J. Kvale

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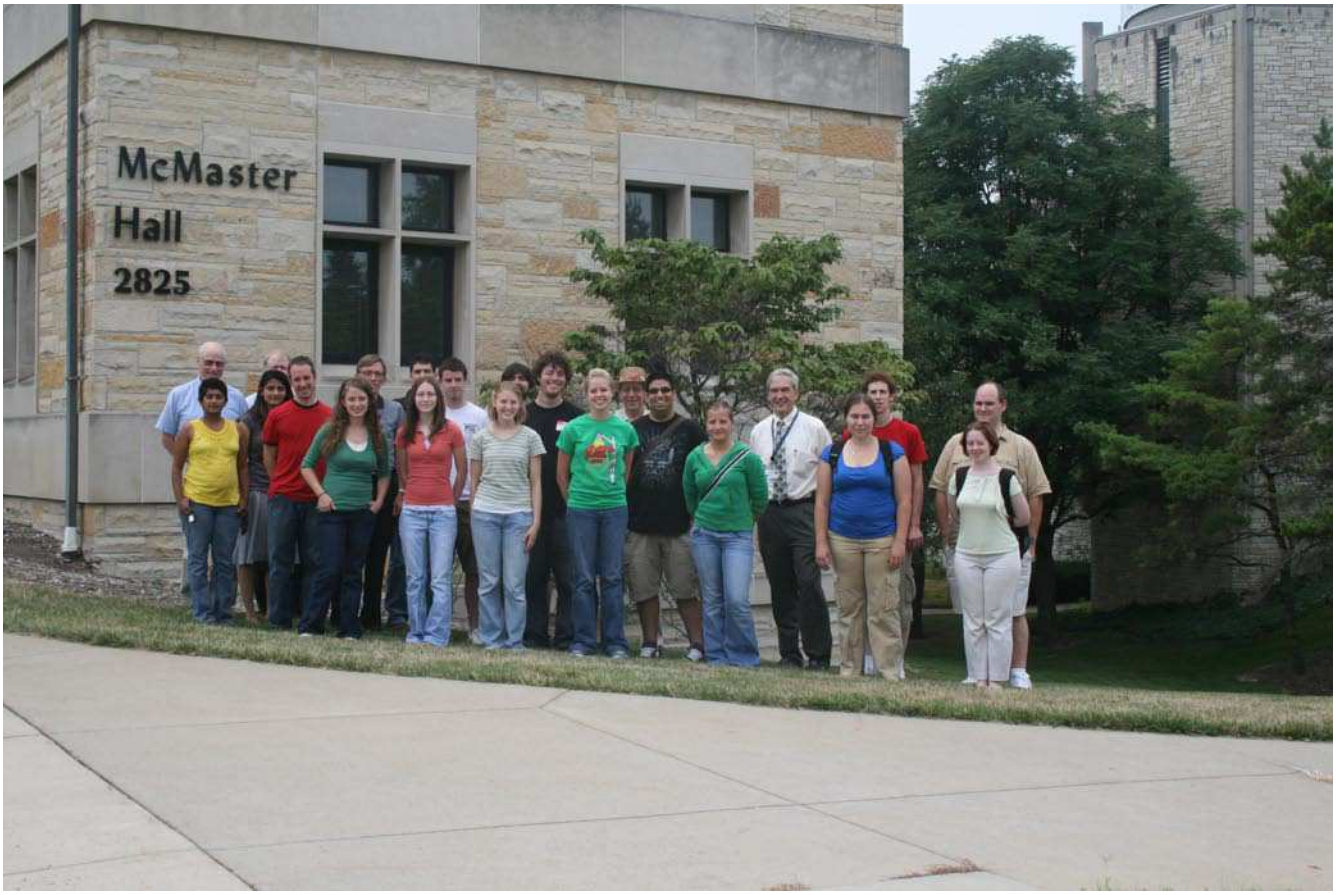
I. REU RESEARCH PARTICIPANTS, SUMMER 2009



Mentors and participants (boldface) in 2009 Summer REU:
Left to Right (Front row): Jim Walker, **Rosa Zartman**, **Rachel Gestrich**, **Stephanie Ash**, **Becky Carlson**, **Lydia Michaels**, **Catherine McGuinness**, **Marina Kounkel** Left to Right (Second Row) : Uma Vijh, Rupali Chandar, Al Compaan, **Sean Maddock, Tyler Hill, Maverick Terrazas, Michael Dennis, Casey Bennett, Bill Ingler Left to Right** (Back Row): Dave Ellis, Tom Kvale, **Casey T. DeRoo,** Rick Irving, Adolf Witt**.**

NAME	INSTITUTION	MENTOR	RESEARCH
Stephanie Ash	Ohio Northern	Robert Collins	Condensed Matter
Casey Bennett*	Owens CC	Alvin Compaan	Condensed Matter
Becky Carlson	Bethel Univ., MN	X. Deng/B.Ingler	Condensed Matter
Casey DeRoo	Concordia College	Adolf Witt	Astronomy
Rachell Gestrich	Univ. of Toledo	Rupali Chandar	Astronomy
Tyler Hill	UCLA	A.Compaan/K.Wieland	Condensed Matter
Marina Kounkel	Univ. of Toledo	Thomas Megeath	Astronomy
Sean Maddock	Wash.&Jeff.College	D. Ellis/L.Curtis	Atomic
Catherine McGuinness	Smith College, MA	Michael Dennis	Bio/Medical
Lydia Michaels	Univ. of Toledo	Michael Dennis	Bio/Medical
Corbin Taylor*	Univ. of Toledo	Steve Federman	Astronomy
Maverick Terrazas	Cal.St.Un.,San Bernardino	Uma Vijh	Astronomy
Rosa Zartman	Univ. of Toledo	S. Marsillac/J. Walker	Condensed Matter

* See Introduction for details of their participation.

II. SUMMARY OF SUMMER 2009

Introduction

The Summer 2009 NSF-REU program in Physics and Astronomy, directed by Dr. Richard Irving and Professor Thomas Kvale, gave enhanced research opportunities to 13 undergraduate students from 9 colleges and universities in 5 states spread from coast to coast. Student participants were chosen competitively out of 116 applications from students in 34 different states in all regions of the U.S. Casey Bennett for the second time (now as a new graduate of Northwood High School and has matriculated in Case Western Reserve University) and Corbin Taylor participated unofficially in our REU program are included in the total number (13) of undergraduate participants. Corbin Taylor is a sophomore our Physics & Astronomy department. Marina Kounkel was jointly funded by the NSF-REU grant and from the UT FYSRE program at the level of the other REU participants. 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 Summer 2009 was a success from both the students' and faculty mentors' perspectives. At least two manuscripts based on research this past summer are in preparation for submission to referred journals. It is anticipated that more manuscripts are in preparation and will be submitted shortly. We also had one poster presentation by one of our 2008 REU students based on their summer research this past year.

Advertisement and Selection

Again this year (Summer 2009) 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 emailings 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/reusummer2009/nsf-reu2009.htm

Registration and Housing

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 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, 10 of the 13 student participants lived in the same campus dormitory (International House) 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.

Social Activities

Social activities were coordinated with the help of the following local participants: Casey Bennett, Marina Kounkel, Lydia Michaels, and Rosa Zartman. Lesley Simanton, a new graduate student in our department and 2008 REU alumnus also assisted in the activities. Weekly activities included movie night on Mondays, sand volley ball, ultimate Frisbee, late night board games, and various ventures to local restaurants. One of the notable establishments people found fun to visit was Sakura Japanese Steak House. 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: Frisbee Golf, several BBQ's, a trip to Cedar Point Amusement Park, and a Toledo Zoo visit. However, one of the more exciting (if not terrifying!) social events this summer was sky diving at a facility in Xenia Ohio (http://www.skydiveohio.com). Eleven of the REUs participated in this experience. Each of the students performed the jump in tandem with a skydive instructor. These students can cross another one off their "bucket list"! The complete REU calendar can be found at:
http://www.google.com/calendar/embed?src=rq0k5b7jttf4jhijo3262t75i8%40group.calendar.google.com&ctz=America/New_York&dates=20090601%2F20090630

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 2009 BROWN BAG SEMINARS
(Noon – MH 4009)
June 1 REU Orientation MH 4009
June 2 Scott Lee, "Locomotion of dinosaurs and Australopithecus afarensis"
June 12 Rob Gutermuth,"Spitzer Surveys of Nearby Regions of Star Formation: Census and Structure"
June 16 Larry Curtis, "It's Time to Reinvent Introductory Physics"
June 23 Will Fischer, "Probing the Beginnings of Stellar Evolution with the Hubble, Spitzer, and Herschel Space Telescopes"
June 24 Courtney Thornberry, "Bigger is Better, Except When It's Not- The Physics of Running and Size"
June 30 REU student midterm reports
July 7 Jimmy Davidson,"A Photometric Analysis of Southern Binary Stars Using Speckle Imaging"
July 14 Larry Curtis, "It's Time to Reinvent Introductory Physics Part II"
July 16 Lawrence Anderson-Huang, "Perception of Vision"
July 20 Alison Coil, UCSD "Clustering, Quenching, and Feedback: Galaxies and AGN at z=1"
July 21 Kanti Aggarwal, "Electron temperature and density determination in astrophysical plasmas by using atomic data."

July 28 Reva Williams,"Astrophysical Black holes and Energy Extraction"
August 3 Student Final Presentations
August 4 Student Final Presentations
August 5 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.

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. Based on this year's REU students' critical evaluations of this seminar series, we plan to actively promote the importance of this course at the REU Orientation at the beginning of summer. By contrast, students participating in the other research programs generally gave this seminar series positive evaluations, so there appears to be a disconnect between the REU students and the other research students' perceptions of the value of this course.

ARS2980 Issues in Research and Scholarship
Summer Semester III

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Schedule: Thursday, 12:00pm - 1:00pm, 1 credit hour
Sullivan Hall, SL1030/50/70

Contact Persons:
Thomas Kvale Office: MH4023 Phone: x2980 Email: tkvale@utnet.utoledo.edu
Larry Connin Office: SL1240 Phone: x6037 Email:lconnin@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

Grade: Credit/NC

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Syllabus, Summer 2009

June 01: ***Welcome Reception (12:00)*** John Gaboury, Vice Provost and Dean, University Libraries
June 11: ***Laboratory Safety*** Heather Lorenz, Safety and Health
June 18: ***Research Ethics and Compliance*** Jeffrey Busch, Office of Research
June 25: ***Plagiarism and Academic Honesty*** Barb Schneider, Director, Writing Center
July 02: ***Ethics and Commitment in Research*** Thomas Barden, Director, Honors Program

July 09: ***Doing Advanced Library Research*** Wade Lee, Assoc. Prof., Library Administration
July 16: ***Business Prospects and Patents*** Mark Fox, Patent-Technology, Office of Research
July 23: ***Diversity Issues in Research*** Samuel Hancock and Sammy Giles, Institutional
July 30: ***Summer Recap & Miscellaneous*** Thomas Kvale and Larry Connin, Office of Undergraduate Research

Aug. 06: ***Research Presentations*** Undergraduate student researchers (10:00a-3:00p)
10:00a-11:45a Oral Session I
12:00n Welcome by Provost Haggett
12:15p-1:15p Poster Session
1:30p-3:00p Oral Session II

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.

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. 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 our REU students are authors on manuscripts that have been published, submitted, or are in preparation to be submitted this year.

Over the lifetime of this grant 44 students participated in our REU program from 2007 to present. We were able to track 27 of these students, of which 13 of this group are from this past summer's REU program. Twelve are continuing their undergraduate education as mentioned above and one just matriculated at Case Western Reserve Univ. majoring in physics and possibly philosophy. Five of the other 14 students have since graduated and are continuing their professional development in graduate schools. Most of the graduates have gone into graduate programs in physics or astronomy, but others have diversified into graduate programs in medical physics, planetarium education, civil engineering, mechanical engineering, chemical physics, atmospheric science, and materials science in prestigious universities.

Our former REU students have been very successful in publishing their work. The research of the 44 undergraduate students under this grant (2007-present) resulted in 8 publications. Several more papers are currently in manuscript form and are expected to be submitted or resubmitted to professional journals shortly. Thirteen presentations were made at regional, national, or international conferences from 2007 to present.

We are very excited about this coming summer and beyond. The University of Toledo merged with the Medical University of Ohio at Toledo (MUO) in July 2006. MUO (now, HSC - Health Science

Campus) has a national reputation of being an excellent medical school. For several years now, our department of Physics and Astronomy has had a collaborative Ph.D. program in medical physics with the Medical Physics department on the Health Science Campus. This collaboration has been extended to provide enhanced opportunities for our REU students to select projects in the medical physics fields (radiation oncology and diagnostic radiology). Two REU students worked in this field for their research this summer. Several former REU students have continued into graduate school in the Medical Physics program at UT. We expect this area to grow into a very popular and rewarding area in the foreseeable future. Very recently, the UT medical physics graduate program gained CAMPEP accreditation. This attests to the excellent medical physics research experiences for our REU students.

III. PHYSICS AND ASTRONOMY SUMMER CAMP 2009

As part of the REU program, the Physics and Astronomy Summer Camp outreach activity for high school students took place July 29-30. The summer camp activities were developed and performed with the help of our REU team. Jackie Kane, a St. Ursula high school science teacher, also had a large role in developing activities and recruiting students for the camp. The first day of the Summer Camp dealt with photovoltaics and the need for alternative energy in general, and included a lecture and tour by Professor Alvin Compaan of his solar house, as well as hands-on activities involving solar cells and wind energy. One of the activities had the students make a “dye-sensitized solar cell” using fruit from a local store. They had fun measuring the cell's properties outdoors and hooking their cells together in series and parallel with other camp buddy's cells. The campers were able to keep their cells afterwards. The second day featured activities related to astronomy including presentations in Ritter Planetarium by Professor Karen Bjorkman and astronomy graduate student Brad Rush. Besides giving a tour of the One-Meter Telescope, Professor Bjorkman did a neat student activity on the scale of the solar system which utilized the length of the University's Centennial Mall and the student campers as the planets. We had 21 high school students attend! Anthony Wayne, Perrysburg, Sylvania Southview, St Ursula, and Toledo Technology Academy high schools were represented.

Many thanks to all the people who helped out during our NSF- REU, especially the office staff, Willie Brown, Sue Hickey, and Stephany Mikols. A final thanks goes to the National Science Foundation. NSF’s grant to the University of Toledo for the Research Experiences for Undergraduates made this summer program possible.

IV. DEMOGRAPHICS

NSF-REU SUMMER 2009 APPLICATIONS

Geographical distribution by undergraduate institution

(Applications Received-116 / REU Offers Made -22 / REU Accepted - 13)

ALABAMA
Alabama A&M Univ. ..... (1/0/0)

ARIZONA
Arizona St. Univ., Tempe .....(1/1/0)

CALIFORNIA
Cal.St.Univ., San Bernardino .....(1/1/1)
Pasadena City College .....(1/0/0)
Sierra College .....(1/0/0)
Univ. of Calif., Davis .....(2/0/0)
UCLA .....(1/1/1)
Univ. of Calif., San Diego ..... (1/0/0)

CONNECTICUT
Wesleyan Univ. .....(1/1/0)

FLORIDA
Florida Inst. of Tech. ..... (1/0/0)
Florida State Univ. ..... (1/0/0)
Univ. of Miami ..... (1/0/0)

GEORGIA
Georgia Inst. of Tech. .....(2/0/0)
Valdosta State Univ. .....(1/0/0)

IDAHO
The College of Idaho .....(1/0/0)

ILLINOIS
Loyola Univ., Chicago ..... (1/0/0)
Univ. of Illinois ..... (2/0/0)

INDIANA
Bethel College ..... (1/0/0)
Purdue Univ. ..... (1/0/0)
Univ. of Evansville ..... (1/1/0)

IOWA
Grinnell College ..... (1/0/0)

KANSAS
Southwestern College..... (1/0/0)

KENTUCKY
Eastern Univ ..... (1/0/0)
Morehead State Univ ..... (1/0/0)
Thomas More College ..... (1/0/0)

LOUISIANA
Grambling State Univ ..... (1/0/0)

MAINE
Colby College ..... (1/0/0)

MARYLAND
Loyola College, Maryland ..... (1/0/0)
Morgan State ..... (1/0/0)

MASSACHUSETTS
MIT ..... (1/1/0)
Mt. Holyoke ..... (3/0/0)
Smith College ..... (1/1/1)
Wellesley College ..... (1/0/0)

MICHIGAN
Albion College ..... (1/0/0)
Michigan State Univ. ..... (3/0/0)
Univ. of Michigan ..... (3/0/0)
Wayne State Univ. ..... (1/0/0)

MINNESOTA
Bethel Univ. ..... (1/1/1)
Concordia College ..... (1/1/1)
MN State Univ., Mankato ..... (1/0/0)
MN State Univ., Moorhead ..... (1/0/0)
St. Cloud State Univ. ..... (1/0/0)

MISSISSIPPI
Mississippi State Univ. ..... (1/0/0)

MISSOURI
St. Louis University ..... (1/1/0)

Truman Univ. ..... (1/0/0)
Univ. of Missouri-Columbia ..... (1/0/0)

MONTANA
Univ. of Montana ..... (1/0/0)

NEBRASKA
Univ. of Neb., Kearney ..... (1/0/0)

NEW JERSEY
The College of St. Elizabeth ..... (1/0/0)
The Richard Stockton Coll. of NJ .... (1/1/0)

NEW YORK
Bard College ..... (1/0/0)
Berea College ..... (1/0/0)
Brooklyn College ..... (1/0/0)
Rensselaer Polytechnic Inst. ..... (1/0/0)
St. Bonaventure ..... (1/0/0)
Utica College ..... (1/0/0)
Univ. of Rochester ..... (2/1/0)

NORTH CAROLINA
Wake Forest ..... (1/0/0)

NORTH DAKOTA
Univ. of North Dakota ..... (1/0/0)

OHIO
Case Western Reserve Univ. ..... (1/0/0)
Cleveland State Univ. ..... (1/0/0)
College of Wooster ..... (1/0/0)
Denison Univ. ..... (1/0/0)
Kenyon College ..... (1/0/0)
Oberlin College ..... (1/0/0)
Ohio Northern Univ. ..... (3/2/1)
Ohio Wesleyan ..... (2/0/0)
Owens Community College* ..... (1/1/1)
The Ohio State Univ. ..... (3/0/0)
The Univ. of Toledo* ..... (10/5/5)
Univ. of Akron ..... (1/0/0)

OREGON
Oregon State Univ. ..... (1/0/0)
Portland Community College ..... (1/0/0)
Williamette Univ. ..... (2/0/0)

PENNSYLVANIA
Carnegie Mellon Univ. ..... (2/0/0)
Ind.Univ. of PA/Calif.Univ. of PA ... (2/0/0)
Kutztown University ..... (1/0/0)
Thiel College ..... (1/0/0)
Univ. of Pennsylvania ..... (1/1/0)
Washington & Jefferson College ..... (1/1/1)

SOUTH CAROLINA
College of Charleston ..... (1/0/0)

TENNESSEE
Austin Peay Univ. ..... (3/0/0)

TEXAS
St. Mary's Univ. ..... (1/0/0)
Univ. of Dallas ..... (1/0/0)

VIRGINIA
Bridgewater College ..... (1/0/0)

VIRGIN ISLANDS
Univ. of the Virgin Islands ..... (1/0/0)

WASHINGTON
Gonzaga Univ. ..... (1/0/0)

NSF-REU Participant* Demographics
Summer 2009

Gender
Female: 7
Male: 6

Class Rank
Freshman: 4
Sophomore: 4
Junior: 5
Senior: 0

Ethnicity
American Indian: 0
Alaskan Native: 0
Asian American: 0
(or Pacific Islands)
African American: 0
Hispanic American: 1
Caucasian/White: 12
Other:

Home State
California 1
Massachusetts 2
Minnesota 1
Ohio 7
Pennsylvania 1

Home Institution:
Cal.St.Univ., San Bernardino 1
UCLA 1
Smith College 1
Bethel Univ. 1
Concordia College 1
Ohio Northern Univ. 1
Owens Community College** 1
The Univ. of Toledo** 5
Washington & Jefferson College 1

REU Students Grade Point Average: 3.78
* Includes all students participating in our program regardless of their source of support
** 2 Students were not supported by NSF funds, but fully participated in the summer research program.

V. RESEARCH

REU 2009 Final Presentations
Each talk is scheduled for 12 minutes allowing 3 additional minutes for questions.

Monday, August 3
12:00 Casey DeRoo: **"**Effects of an Anisotropic Radiation Field on High Galactic Latitude Interstellar Dust Cloud LDN 1780"

12:15 Casey Bennett: "Improving Temperature Dependent Measurement of PV Cells"

Tuesday, August 4
12:00 Rachell Gestrich: "Extragalactic Photometry: The Search for Stellar Clusters"

12:15 Tyler Hill: "Photoluminescence: A Study of Thin Film CdTe Solar Cells"

12:30 Sean Maddock: "Lifetime measurements in P II using beam-foil spectroscopy and theoretical calculation of polarizabilities using variational theory"

12:45 Stephanie Ash: "Improving the a-Si:H and nc-Si:H Back-Reflectors Modeled with ZnO Stacks"

1:00 Catherine McGuinness & Lydia Michaels: "The World of fMRI and LabVIEW"

Wednesday, August 5
12:00 Maverick Terrazes: "Searching for Variable Stars in the Small Magellanic Cloud"

12:15 Corbin Taylor: "Li in IC 443: Data Reduction in Iraf"

12:30 Rosa Zartman: "Spectroscopic Ellipsometry study of Transparent Conducting Oxides"

12:45 Marina Kounkel: "The search for protostellar binaries in Orion"

1:00 Becky Carlson: "Optimization of Indium Doped Tin oxide (ITO) by pulsed DC power on single junction amorphous silicon (a-Si) solar cells"

ABSTRACTS OF REU FINAL REPORTS
The University of Toledo, Department of Physics & Astronomy
SUMMER 2009
(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Casey T. DeRoo, *LDN 1780: A Translucent High-Galactic Latitude Interstellar Cloud in a UV-rich, Anisotropic Radiation Field,* (A. Witt)

We combined high-resolution optical imaging observations in 12 intermediate-band (BATC) filter and deep mid- and far-IR Spitzer maps of LDN 1780 to characterize the external radiation field illuminating this high-latitude (l = 359 deg; b = 36.5 deg; distance ~100 pc) translucent cloud and the infrared emission of dust within LDN 1780 in response to this external illumination.

The overall energy density of the incident radiation field is approximately equal to that of the ISRF near the Sun, resulting in a large dust grain equilibrium temperature ranging from 14.5 K -16.8 K. However, the incident radiation field is highly anisotropic, with the southern portions of LDN 1780 being most strongly illuminated, especially at shorter wavelengths. This anisotropy is a result of the cloud's proximity to the Sco OB2 association (est. center: l = 322 deg; b = 10 deg).

The southwestern portion and the optically-thin eastern tail of LDN 1780 exhibit strong intensity excesses at 24 micron (Spitzer MIPS) and at 8 micron (Spitzer IRAC Ch. #4) compared to dust in the diffuse ISM of the Milky Way Galaxy. We interpret these excesses as enhanced emission from stochastically-heated very small grains (VSG) and from PAH ions, respectively. These excesses, however, are not necessarily the result a greater relative abundance of these two small-particle components but rather reflect the increased frequency of photon-grain interactions (e.g. heating, excitation, or ionization) within a UV-rich radiation field.

Rachell Gestrich, *The Stellar Content of the Starburst Galaxy NGC 3125, (R.Chandar)*

Star clusters are a group of gravitationally bound stars that are formed at the same time and have the same metallicity. Each cluster can contain from a few hundred to hundreds of thousands of stars and therefore are much brighter than individual stars. We can measure their ages, masses, and sizes and use this information to trace the star formation history of their parent. I used images from the Advanced Camera for Surveys on the Hubble Space Telescope, to study the content of the dwarf starburst galaxy NGC 3125. I performed aperture photometry on all objects detected in the images, and used various criteria to separate star clusters from individual stars, blends of a few stars, and background galaxies. I found that the galaxy is dominated by luminous, young (<10 Myr) clusters, with fewer older clusters.

Marina Kounkel, *The search for protostellar binaries in Orion*, (T.Megeath)

What is a star? It is a massive ball of mainly hydrogen that is held together by its own gravity. Why is it important to study stars? They produce energy and all the elements heavier than hydrogen through nuclear fusion. Planets are a byproduct of stellar formation. Without stars life couldn't possibly exist, thus they are imperative for understanding the origins of life. Stars have finite lifetimes. They form; they live; they die. Their lifespan can last from a few millions to many billions of years, depending on their mass. The Sun was formed approximately 4.6 billion years ago. We cannot revert time, but by studying other stars in the process of the formation we can recreate the history of what happened during that era.

Corbin Taylor, *Li in IC 443,* (S.Federman)

Supernovae are believed to be important to the chemical evolution of the Galaxy. In particular, they play a role in the production of the light elements Li, Be, and B which are thought to be produced via pathways that differ from elements synthesized in stellar cores. In our study, we reduced and analyzed

data from the 9.2 m Hobby-Eberly Telescope (HET) (R=98000) for two sight lines in the vicinity of the supernova remnant IC 443, toward the OB stars HD 254577 and HD 254755. We focused on the Li I doublet around 6808 Å to find the value of the column density ratio of the two isotopes of Li: N(Li-7)/N(Li-6). We also used HET data for the CH spectral line at 4300 Å as an aid in the fitting process. The goal of this research is to further our knowledge about Li and the elements in general.

Maverick Terrazas, *Infrared Variable Stars in the Small Magellanic Cloud using the Spitzer SAGE-SMC Survey*, (U. Vijh)

I am presenting my search for variable stars in the Small Magellanic Cloud (SMC) using the observations made by the Spitzer SAGE-SMC Legacy program. Three epochs of data were used, two of which taken 3 months apart and one taken three years before. Each epoch was taken using two infrared imaging instruments on the Spitzer Space Telescope: the Infrared Array Camera (IRAC) and the Multiband Imaging Photometer for Spitzer. I found 825 sources that meet the variability criteria defined: a source must have $|V_{band}| > 3$ in at least two neighboring bands in the same direction. These sources were, then, plotted on color magnitude diagrams for classifying. 57 sources have been visually verified as variable out of the 80 sources checked.

Atomic/Molecular/Optical Physics

Sean Maddock, *Lifetime measurements in P II using beam-foil spectroscopy,* (M.Brown, L. Curtis, D. Ellis,S. Federman,R. Irving,C. Theodosiou)

Beam-foil spectroscopy is a useful method for studying temporal elements of atomic structure and properties, such as lifetimes of excited states. Studies this summer were done using the Toledo Heavy Ion Accelerator (THIA) studying the $^3P_0\ 3s^2 3p^2 - {}^3P_1\ 3s3p^3$ transitions in P II. Using a forward lifetime measurement at 170 keV, a lifetime of 13.94 ± 0.59 ns was measured for the J=1 upper state at λ=1301.87Å. This is a very good measurement as shown by the reduced chi-squared and in that the uncertainty of the measurement is within 5%. Future measurements are planned using a reverse lifetime measurement and another forward lifetime measurement at 220 keV.

Sean Maddock, *Theoretical calculation of polarizabilities using variational theory,*(M.Brown, L. Curtis, D. Ellis,S. Federman,R. Irving,C. Theodosiou)

Theoretical work was also done this summer in calculating atomic dipole polarizabilites. By using the variational principle and a trial wave function, the energy of a system can be minimized to obtain an approximate solution for the complicated system. This method was used to determine a new method of calculating polarizabilites of atoms or ions with a closed-shell core. Results were promising and showed trends of agreement with literature values. More time would be needed to include more parameters in the calculations to improve future results.

Biological, Health, and Medical Physics

Catherine McGuinness & **Lydia Michaels,** *The World of fMRI and LabVIEW*,(M.Dennis)

In our ten-week research program here at the University of Toledo Medical Center, we worked in many different fields of the Medical Physics department. In the first five weeks of the summer, we analyzed the results of different smoothing functions on CT scans. CT stands for "computerized tomography." CT scans are also commonly referred to as CAT scans, from the original phrase, "computer-assisted tomography." A CT scanner is a very sophisticated x-ray machine. The patient lies on a table that is cantilevered through the scanner gantry. The gantry houses the x-ray source across from a fanned detector array. This setup rotates around the patient several hundred times per second as the patient is moved through the gantry producing helical scans. With reconstruction software, a user can produce both slice scans and three-dimensional images. Different tissue types register as different

CT numbers, which the computer uses to visualize the patient's internal organs. Air is assigned the number -1000 and always appears black. Water is defined to have a CT number of zero while bone is approximately one thousand.

Condensed Matter Physics

Stephanie Ash, *Improving the a-Si:H and nc-Si:H Back-Reflectors Modeled with ZnO Stacks***,** (Robert Collins)

This report looks to find the best model that will give the optimal reflectance from the ZnO, least absorption in the Ag, most absorption in the Si and the least amount of total reflection by creating a multi-layer ZnO with alternating indices of refraction on a Ag back-reflector. The ZnO high is an intrinsic ZnO and the ZnO low is created theoretically by introducing more free carriers modeled by the Drude behavior in the ZnO dielectric functions. Later, ITO layers with alternating indices of refraction were also placed in the model to improve its performance. The best results are shown and discussed. Finally, some suggestions of work that could be further made on this project are presented.

Becky Carlson, *Optimization of Indium Tin Oxide (ITO) by Pulsed DC Power on Single Junction Amorphous Silicon (a-Si) Solar Cells*, (Bill Ingler)

Using pulsed DC power, conditions at which production of a thin indium doped tin oxide film were achieved to produce the optimal efficiency for an amorphous silicon solar cell. Thin films of indium doped tin oxide were prepared by plasma vaporization (PEVCD) deposition using a pulsed DC power supply. Power, deposition time, pressure, gas flow and temperature were changed to find the optimal conditions. The best films were produced at a power of 40W, deposition time of seven minutes and 40 seconds, a pressure 4.0mTorr, gas flow 16sccm and at 151 °C and had 0.25 cm^2 dots with an efficiency of 6.650% (SD2785-2.12). Also, the ITO was put on a germanium silicon solar cell with an efficiency of 7.203% (SD2786-4.32). The surface morphology was compared using atomic force microscopy between 35, 40, 43W and the lower power had a lower root mean square roughness curve than the higher power samples.

Tyler Hill, *A photoluminescent study of $CdCl_2$ treated CdS/CdTe thin film photovoltaic cells of varying CdTe thickness.***, (**A. Compaan/K. Wieland)

$CdCl_2$ treated CdTe/CdS solar cells have some of the highest efficiencies of any cells currently available. In order to further improve cell efficiencies an improved theoretical understanding of the different recombination mechanisms present in the cell is essential, and photoluminescence studies are one of the easiest nondestructive methods of obtaining such information. We find evidence for an exciton transition due to CdTe at 1.595eV and a corresponding 1.553eV transition due to $CdTe_{0.94}S_{0.06}$ with the 42meV difference in Te/S replace position is consistent with the band bowing of the alloyed material. The replace follows a temperature dependence of $-3x10^{-4}$eV/K for temperatures above 30K, which is consistent with the temperature shift of the CdTe bandgap for temperatures above 30K.

Rosa Zartman, *Spectroscopic Ellipsometry study of Transparent Conducting Oxides* (S. Marsillac; J Walker)

This research focuses on using indium tin oxide (ITO) and aluminum doped zinc oxide (AZO), to make a transparent conducting oxide for copper indium gallium diselenide (CIGS) photovoltaic solar cells. To accomplish this feat, the employment of a RF Magnetron Sputtering System by a Kurt J Lester PVD75 sputter with 3in ceramic targets is the process of choice. The system was placed under high vacuum by a cryogenic pump. The necessity of using a transparent conductive oxide (TCO) at the top of the solar cell comes from the requirement of having the light passing through (hence the transparency) while being able to conduct the electrons out of the cell into the load (hence the conductivity). The ITO and AZO films were deposited on soda lime glass and on silicon wafer. The

power and DC bias applied to the deposition were varied to try to optimize the transparency and the resistivity. The duration of the deposition was also changed in order to achieve a film thickness of about 300 nm. The films were then studied for their transmission, reflection, resistivity, and other optical properties using a spectrophotometer, a four-point probe, and an ellipsometer in the solar spectral range and in the deep IR.

NSF-REU External Publications and Presentations*

(Update from Annual Report 2008)

REFEREED PUBLICATIONS - Submitted/accepted/published.

Yunsic Shim, **Mary E. Mills* (2007)**, Valery Borovikov, and Jacques G. Amar, "Effects of substrate rotation in oblique-incidence metal(100) epitaxial growth," Physical Review E 79, 051604 (2009)

Ingler Jr, W. B.; **Ong, G.* (2007)**; Deng, X. "RF Sputter Deposition of Indium Oxide – Iron Oxide Films for Photoelectrochemical Hydrogen Production" *ECS Trans.* Vol. 16, No. 7. (State-of-the-Art Program on Compound Semiconductors 49 (SOTAPOCS 49), **2008**, 49.

REFEREED PUBLICATIONS - in preparation.

PRESENTATIONS.

Ingler Jr, W. B.; **Ong, G.* (2007)**; Deng, X. "RF Sputter Deposition of Indium Oxide – Iron Oxide Films for Photoelectrochemical Hydrogen Production" *ECS Trans.* Vol. 16, No. 7. (State-of-the-Art Program on Compound Semiconductors 49 (SOTAPOCS 49), **2008**, 49. *210th Meeting of the Electrochemical Society*, *Inc.*, Honolulu, HI, October 12-17 (Oral Presentation)

PRESENTATIONS WITH PUBLISHED ABSTRACTS.

CONFERENCE PRESENTATIONS WITH PROCEEDINGS PAPERS.

R. M. Zeller (2008), J. D. Walker, K. A. Wieland, and A. D. Compaan, "R*eal-time Optical Thickness monitor for Thin Film Growth,"* 34th IEEE Photovoltaic Specialists Conference Philadelphia, PA, June 7-12, (2009)

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

VI. PROGRAM EVALUATION
NSF-REU Summer Research Program
Department of Physics & Astronomy
The University of Toledo
2009 (Total Population: 13, Responses: 9)

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

2009 mean (pop. 9): 2.2

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

2009 mean (pop. 9): 2.2

How do you rate your summer's research experience educationally?

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

2009 mean (pop. 9): 1.6

How do you rate the level of your research 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

2009 mean (pop. 9): 3.2

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

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

2009 mean (pop. 9): 1.6

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

2009 mean (pop. 9): 4.3

How do you rate the weekly seminar series in helping you learn more about safe and ethical conduct of research at UT?

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

2009 mean (pop. 9): 5.6

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

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

2009 mean (pop. 9): 4.9

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

2009 mean (pop. 9): 1.6

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

2009 mean (pop. 9): 2.7

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

2009 mean (pop. 9): 3.3

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

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

2009 mean (pop. 9): 2.1

How do you rate your summer experience personally?

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

2009 mean (pop. 9): 1.8

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

2009 mean (pop. 9): 4

What do you think about the average level of the weekly physics and astronomy Bag Lunch talks?

Much Too Advanced			**About Right**			**Much Too Elementary**
1	2	3	4	5	6	7

2009 mean (pop. 9): 3.1

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

2009 mean (pop. 9): 3.8

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

2009 mean (pop. 9): 2.3

Critical Reflection Questions (Use additional pages and/or backs of these pages if desired.)

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

I wanted to experience scientific research first hand and contribute to the scientific community. Also this is my first experience in astrophysics, which is the discipline I'm interested in.

I wanted to prepare for graduate school and expand my horizons.

I plan to research as a career but my studies during the school year prevent me from devoting significant time to research, so I really wanted time to devote to research full time.

I wanted help in trying to decide whether I wanted to go to medical school or graduate school.

To continue my research from last year and learn more about the field of study I am planning on going into.

Prep for grad school, good academic + social experience

look good on apps

I wanted to learn more about physics and more about what research

why not

I wanted to see what research was like outside the classroom.

==========

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

Courses

Prior knowledge limited use in conducting research but helpful in understanding theory.

My astronomy courses, optics courses, and discovery channel science shows.

Basic knowledge of quantum mechanics, computer experience, introduction to astronomical principles.

Previous research experience

The little bit of knowledge that I had from my heat light and sound course was helpful but I still had a lot to learn

I did research before

General Physics, Quantum Mechanics

==========

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

Background information and the status of my field/previous research on my object.

I wish I would have taken a course on Mathematica.

Advanced knowledge of semiconductors….most knowledge can learn on the spot.

I wish I would have had a course in quantum mechanics.

Didn't have any previous classes in subject or any experience computer programming courses

If I would have had more knowledge on solar cells that would have been helpful

Higher level in math

Knowledge about plasma

==========

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

Polarizabilities, quantum mechanics, variational theory

How solar cells work, how photoluminescence works, how to analyze photoluminescence data.

The amount of work that requires programming in astronomy.

The definitions of specific things related to my project and how different data visualization and analysis programs work (ds9, vi, Linux OS).

Previous studies or analysis done on my research and their observations

lots and lots of little things

not that much

I learned about circuits/biasing

==========

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

How to interpret data/graphs and how to go about reading a scientific paper for optimal understanding.

I learned how to use several new programming languages which will be very helpful.

I understand how to run a photoluminescence experiment and what specific experiments can yield interesting results.

New theoretical methods, accelerator work.

Astronomy resources I didn't know existed.

Found lots of new methods, and got hardened to the rigors of research

not that much since I did a lot of computer work

I learned the software

==========

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

Increase understanding of CdS/CdTe junction for very thin CdTe films.

Many people are waiting for the results of my research, hopefully it gives more understanding.

My research may be helpful in settling a debate in the literature about the incident radiation field as well as show the validity of certain theoretical models.

It won't

Alternative energies

solar cells are getting better so once it gets out to the community energy could be saved

In no way at all!

The results will be beneficial for future results to make efficient solar cells

==========

Please list any additional comments

The "Ethics in Research" seminars are a waste of time. They are poorly scheduled (right in the middle of the morning; is prime-time for meeting with my advisor) and focus predominantly on experiences as a UT student. Any topic that is relevant outside UT has already been covered much more effectively (and efficiently) at my home institution. They are not applicable to REU students (as I should hope that these students should be of sufficient caliber to be aware of the ethics involved in a research project).

I had a lot more fun than I expected, and gained a lot of insight into graduate life.

I just want say Rick did a great job and helped make my stay more enjoyable. I definitely felt welcome to talk to him about anything. He is really concerned about the students and enthusiastic about physics. Overall great experience. Also I had a lot of freedom which was great. The question about freedom in research perhaps misleading as having a lot of freedom does not equal you will get lost.

I wish things would have gotten off to a faster start in the beginning of the summer. I spent a couple of weeks not doing much but reading.

Weekly seminars are a waste of time!

I had a Great Time!

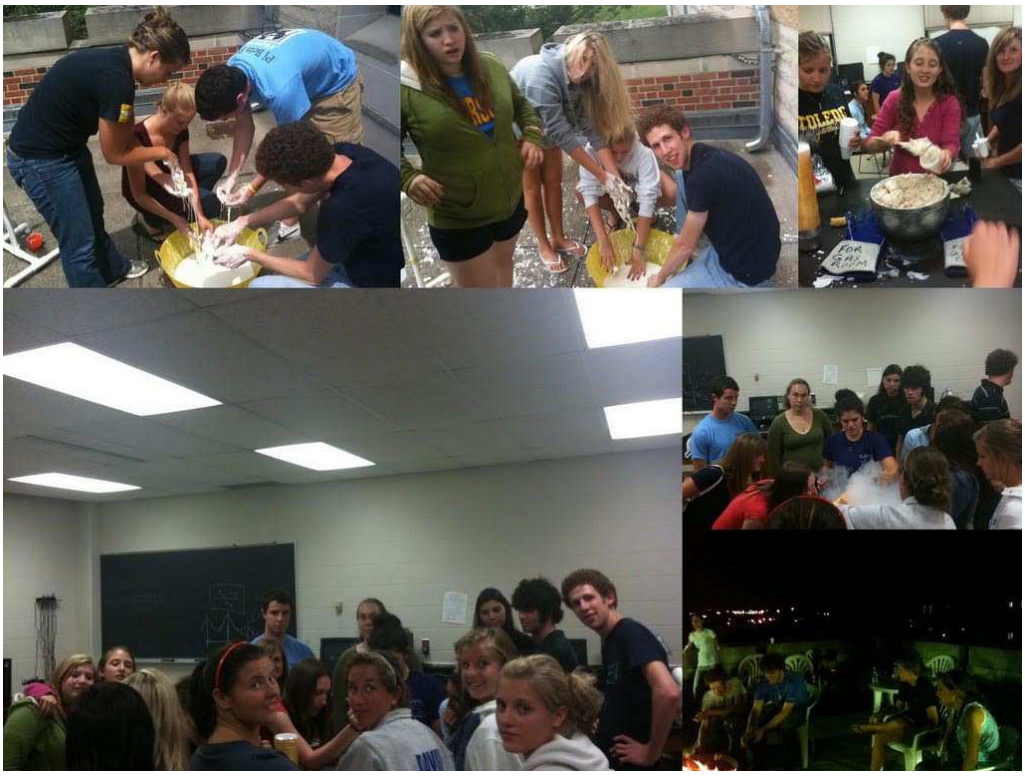
Thanks again for your time, and best wishes for continued success in all of your endeavors. As part of the tracking we need (and want) to do, please tell us about your degrees received and your career activities (grad school, work, etc) after participating in our program. Please keep in touch with us!

Rick Irving and Thomas Kvale, Program directors, NSF-REU

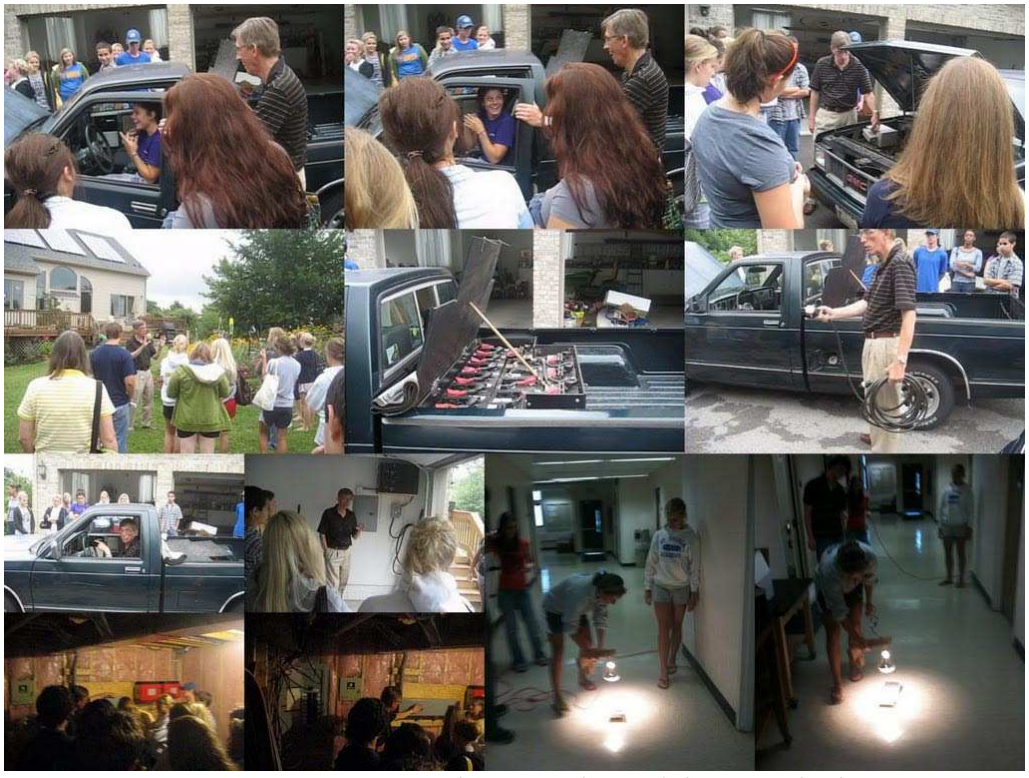
Please return this questionnaire to:

Sue Hickey
The University of Toledo
Department of Physics and Astronomy, MS111
Toledo, Ohio 43606

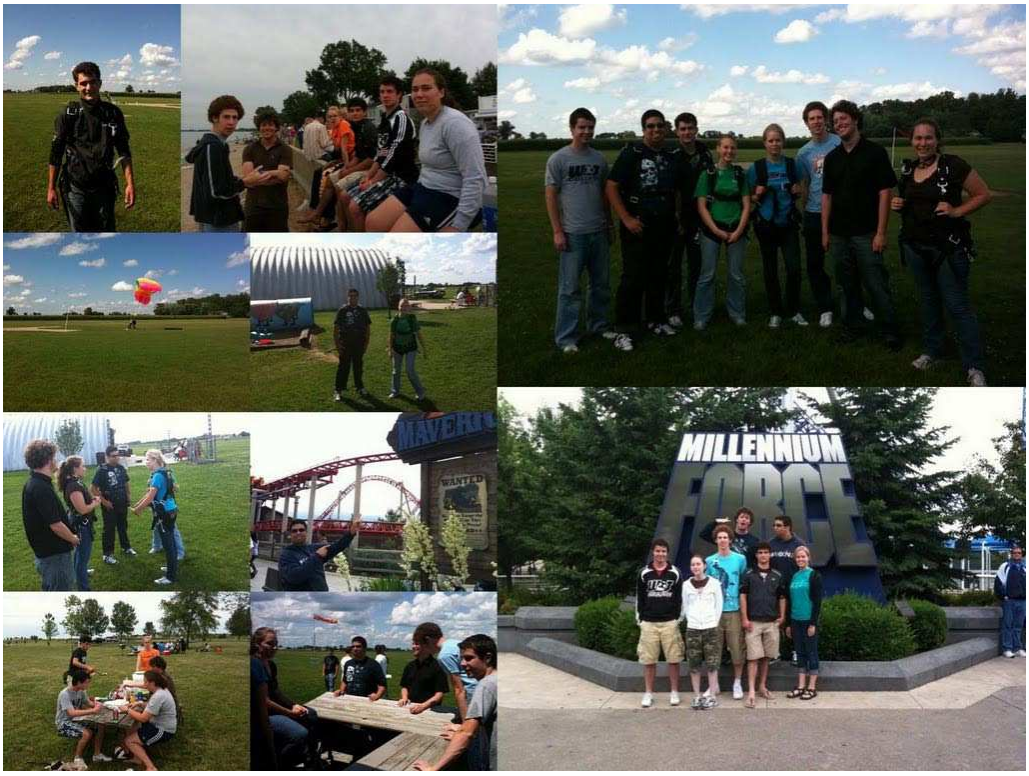
VII. SUMMER 2009 PICTURES



Summer Camp: Corn Starch,LN2 Ice Cream, Roasting Marshmallows



Summer Camp: Experiments, Al's E-pickup, & Picnic



REUs having fun

Final Report Presentations

Annual Progress Report (Year 3)

Research Experiences for Undergraduates in
Physics and Astronomy

NSF-REU Grant PHY-0648963

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

December 2009

Richard E. Irving
Thomas J. Kvale

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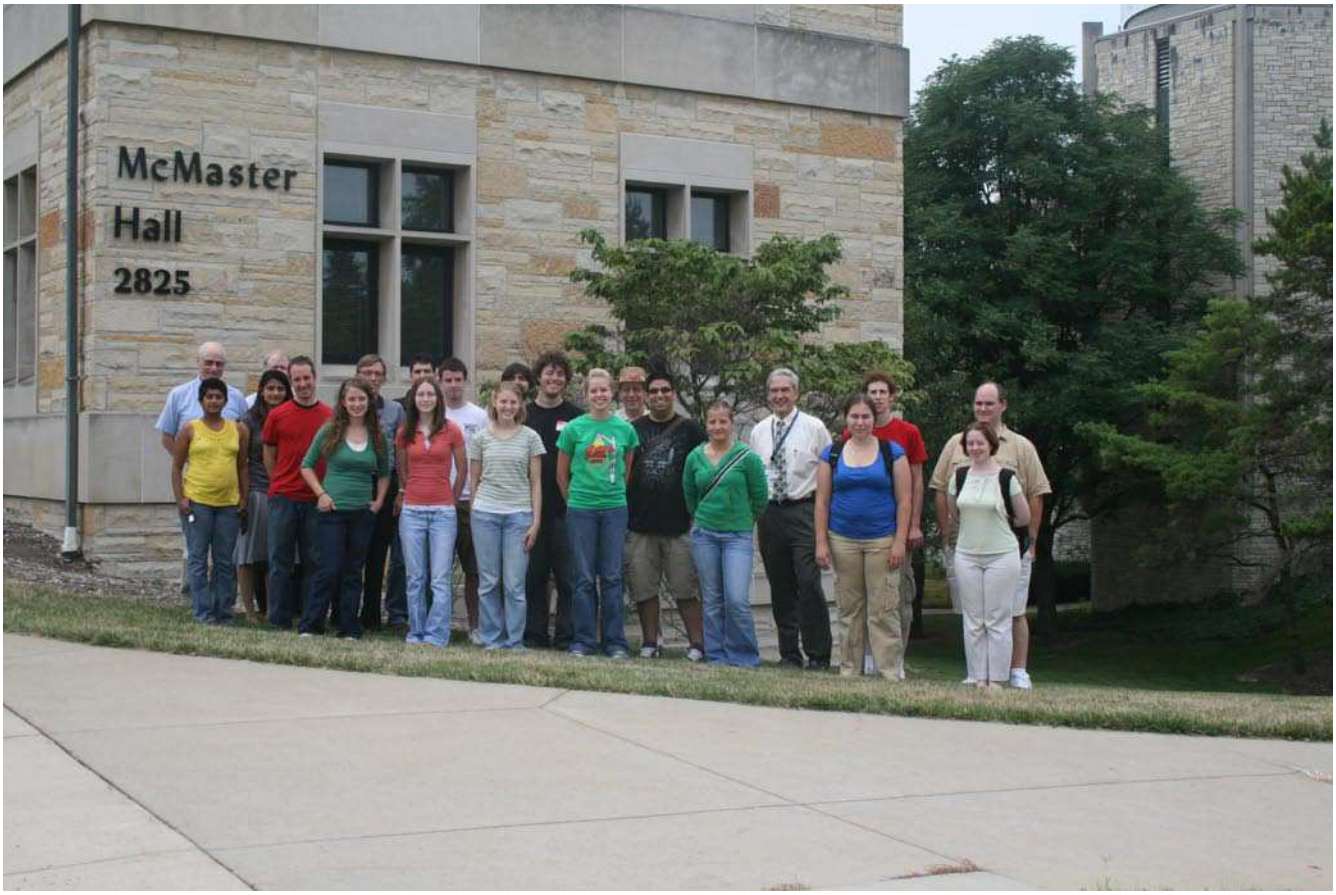
I. REU RESEARCH PARTICIPANTS, SUMMER 2009



Mentors and participants (boldface) in 2009 Summer REU:
Left to Right (Front row): Jim Walker, **Rosa Zartman**, **Rachel Gestrich**, **Stephanie Ash**, **Becky Carlson**, **Lydia Michaels**, **Catherine McGuinness**, **Marina Kounkel** Left to Right (Second Row) : Uma Vijh, Rupali Chandar, Al Compaan, **Sean Maddock, Tyler Hill, Maverick Terrazas, Michael Dennis, Casey Bennett, Bill Ingler Left to Right** (Back Row): Dave Ellis, Tom Kvale, **Casey T. DeRoo,** Rick Irving, Adolf Witt**.**

NAME	INSTITUTION	MENTOR	RESEARCH
Stephanie Ash	Ohio Northern	Robert Collins	Condensed Matter
Casey Bennett*	Owens CC	Alvin Compaan	Condensed Matter
Becky Carlson	Bethel Univ., MN	X. Deng/B.Ingler	Condensed Matter
Casey DeRoo	Concordia College	Adolf Witt	Astronomy
Rachell Gestrich	Univ. of Toledo	Rupali Chandar	Astronomy
Tyler Hill	UCLA	A.Compaan/K.Wieland	Condensed Matter
Marina Kounkel	Univ. of Toledo	Thomas Megeath	Astronomy
Sean Maddock	Wash.&Jeff.College	D. Ellis/L.Curtis	Atomic
Catherine McGuinness	Smith College, MA	Michael Dennis	Bio/Medical
Lydia Michaels	Univ. of Toledo	Michael Dennis	Bio/Medical
Corbin Taylor*	Univ. of Toledo	Steve Federman	Astronomy
Maverick Terrazas	Cal.St.Un.,San Bernardino	Uma Vijh	Astronomy
Rosa Zartman	Univ. of Toledo	S. Marsillac/J. Walker	Condensed Matter

* See Introduction for details of their participation.

II. SUMMARY OF SUMMER 2009

Introduction

The Summer 2009 NSF-REU program in Physics and Astronomy, directed by Dr. Richard Irving and Professor Thomas Kvale, gave enhanced research opportunities to 13 undergraduate students from 9 colleges and universities in 5 states spread from coast to coast. Student participants were chosen competitively out of 116 applications from students in 34 different states in all regions of the U.S. Casey Bennett for the second time (now as a new graduate of Northwood High School and has matriculated in Case Western Reserve University) and Corbin Taylor participated unofficially in our REU program are included in the total number (13) of undergraduate participants. Corbin Taylor is a sophomore our Physics & Astronomy department. Marina Kounkel was jointly funded by the NSF-REU grant and from the UT FYSRE program at the level of the other REU participants. 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 Summer 2009 was a success from both the students' and faculty mentors' perspectives. At least two manuscripts based on research this past summer are in preparation for submission to referred journals. It is anticipated that more manuscripts are in preparation and will be submitted shortly. We also had one poster presentation by one of our 2008 REU students based on their summer research this past year.

Advertisement and Selection

Again this year (Summer 2009) 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 emailings 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/reusummer2009/nsf-reu2009.htm

Registration and Housing

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 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, 10 of the 13 student participants lived in the same campus dormitory (International House) 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.

Social Activities

Social activities were coordinated with the help of the following local participants: Casey Bennett, Marina Kounkel, Lydia Michaels, and Rosa Zartman. Lesley Simanton, a new graduate student in our department and 2008 REU alumnus also assisted in the activities. Weekly activities included movie night on Mondays, sand volley ball, ultimate Frisbee, late night board games, and various ventures to local restaurants. One of the notable establishments people found fun to visit was Sakura Japanese Steak House. 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: Frisbee Golf, several BBQ's, a trip to Cedar Point Amusement Park, and a Toledo Zoo visit. However, one of the more exciting (if not terrifying!) social events this summer was sky diving at a facility in Xenia Ohio (http://www.skydiveohio.com). Eleven of the REUs participated in this experience. Each of the students performed the jump in tandem with a skydive instructor. These students can cross another one off their "bucket list"! The complete REU calendar can be found at:
http://www.google.com/calendar/embed?src=rq0k5b7jttf4jhijo3262t75i8%40group.calendar.google.com&ctz=America/New_York&dates=20090601%2F20090630

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 2009 BROWN BAG SEMINARS
(Noon – MH 4009)
June 1 REU Orientation MH 4009
June 2 Scott Lee, "Locomotion of dinosaurs and Australopithecus afarensis"
June 12 Rob Gutermuth,"Spitzer Surveys of Nearby Regions of Star Formation: Census and Structure"
June 16 Larry Curtis, "It's Time to Reinvent Introductory Physics"
June 23 Will Fischer, "Probing the Beginnings of Stellar Evolution with the Hubble, Spitzer, and Herschel Space Telescopes"
June 24 Courtney Thornberry, "Bigger is Better, Except When It's Not- The Physics of Running and Size"
June 30 REU student midterm reports
July 7 Jimmy Davidson,"A Photometric Analysis of Southern Binary Stars Using Speckle Imaging"
July 14 Larry Curtis, "It's Time to Reinvent Introductory Physics Part II"
July 16 Lawrence Anderson-Huang, "Perception of Vision"
July 20 Alison Coil, UCSD "Clustering, Quenching, and Feedback: Galaxies and AGN at z=1"
July 21 Kanti Aggarwal, "Electron temperature and density determination in astrophysical plasmas by using atomic data."

July 28 Reva Williams,"Astrophysical Black holes and Energy Extraction"
August 3 Student Final Presentations
August 4 Student Final Presentations
August 5 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.

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. Based on this year's REU students' critical evaluations of this seminar series, we plan to actively promote the importance of this course at the REU Orientation at the beginning of summer. By contrast, students participating in the other research programs generally gave this seminar series positive evaluations, so there appears to be a disconnect between the REU students and the other research students' perceptions of the value of this course.

ARS2980 Issues in Research and Scholarship
Summer Semester III

-- --

Schedule: Thursday, 12:00pm - 1:00pm, 1 credit hour
Sullivan Hall, SL1030/50/70

Contact Persons:
Thomas Kvale Office: MH4023 Phone: x2980 Email: tkvale@utnet.utoledo.edu
Larry Connin Office: SL1240 Phone: x6037 Email:lconnin@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

Grade: Credit/NC

-- --

Syllabus, Summer 2009

June 01: ***Welcome Reception (12:00)*** John Gaboury, Vice Provost and Dean, University Libraries
June 11: ***Laboratory Safety*** Heather Lorenz, Safety and Health
June 18: ***Research Ethics and Compliance*** Jeffrey Busch, Office of Research
June 25: ***Plagiarism and Academic Honesty*** Barb Schneider, Director, Writing Center
July 02: ***Ethics and Commitment in Research*** Thomas Barden, Director, Honors Program

July 09: ***Doing Advanced Library Research*** Wade Lee, Assoc. Prof., Library Administration
July 16: ***Business Prospects and Patents*** Mark Fox, Patent-Technology, Office of Research
July 23: ***Diversity Issues in Research*** Samuel Hancock and Sammy Giles, Institutional
July 30: ***Summer Recap & Miscellaneous*** Thomas Kvale and Larry Connin, Office of Undergraduate Research

Aug. 06: ***Research Presentations*** Undergraduate student researchers (10:00a-3:00p)
10:00a-11:45a Oral Session I
12:00n Welcome by Provost Haggett
12:15p-1:15p Poster Session
1:30p-3:00p Oral Session II

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.

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. 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 our REU students are authors on manuscripts that have been published, submitted, or are in preparation to be submitted this year.

Over the lifetime of this grant 44 students participated in our REU program from 2007 to present. We were able to track 27 of these students, of which 13 of this group are from this past summer's REU program. Twelve are continuing their undergraduate education as mentioned above and one just matriculated at Case Western Reserve Univ. majoring in physics and possibly philosophy. Five of the other 14 students have since graduated and are continuing their professional development in graduate schools. Most of the graduates have gone into graduate programs in physics or astronomy, but others have diversified into graduate programs in medical physics, planetarium education, civil engineering, mechanical engineering, chemical physics, atmospheric science, and materials science in prestigious universities.

Our former REU students have been very successful in publishing their work. The research of the 44 undergraduate students under this grant (2007-present) resulted in 8 publications. Several more papers are currently in manuscript form and are expected to be submitted or resubmitted to professional journals shortly. Thirteen presentations were made at regional, national, or international conferences from 2007 to present.

We are very excited about this coming summer and beyond. The University of Toledo merged with the Medical University of Ohio at Toledo (MUO) in July 2006. MUO (now, HSC - Health Science

Campus) has a national reputation of being an excellent medical school. For several years now, our department of Physics and Astronomy has had a collaborative Ph.D. program in medical physics with the Medical Physics department on the Health Science Campus. This collaboration has been extended to provide enhanced opportunities for our REU students to select projects in the medical physics fields (radiation oncology and diagnostic radiology). Two REU students worked in this field for their research this summer. Several former REU students have continued into graduate school in the Medical Physics program at UT. We expect this area to grow into a very popular and rewarding area in the foreseeable future. Very recently, the UT medical physics graduate program gained CAMPEP accreditation. This attests to the excellent medical physics research experiences for our REU students.

III. PHYSICS AND ASTRONOMY SUMMER CAMP 2009

As part of the REU program, the Physics and Astronomy Summer Camp outreach activity for high school students took place July 29-30. The summer camp activities were developed and performed with the help of our REU team. Jackie Kane, a St. Ursula high school science teacher, also had a large role in developing activities and recruiting students for the camp. The first day of the Summer Camp dealt with photovoltaics and the need for alternative energy in general, and included a lecture and tour by Professor Alvin Compaan of his solar house, as well as hands-on activities involving solar cells and wind energy. One of the activities had the students make a “dye-sensitized solar cell” using fruit from a local store. They had fun measuring the cell's properties outdoors and hooking their cells together in series and parallel with other camp buddy's cells. The campers were able to keep their cells afterwards. The second day featured activities related to astronomy including presentations in Ritter Planetarium by Professor Karen Bjorkman and astronomy graduate student Brad Rush. Besides giving a tour of the One-Meter Telescope, Professor Bjorkman did a neat student activity on the scale of the solar system which utilized the length of the University's Centennial Mall and the student campers as the planets. We had 21 high school students attend! Anthony Wayne, Perrysburg, Sylvania Southview, St Ursula, and Toledo Technology Academy high schools were represented.

Many thanks to all the people who helped out during our NSF- REU, especially the office staff, Willie Brown, Sue Hickey, and Stephany Mikols. A final thanks goes to the National Science Foundation. NSF’s grant to the University of Toledo for the Research Experiences for Undergraduates made this summer program possible.

IV. DEMOGRAPHICS

NSF-REU SUMMER 2009 APPLICATIONS

Geographical distribution by undergraduate institution

(Applications Received-116 / REU Offers Made -22 / REU Accepted - 13)

ALABAMA
Alabama A&M Univ. ..... (1/0/0)

ARIZONA
Arizona St. Univ., Tempe .....(1/1/0)

CALIFORNIA
Cal.St.Univ., San Bernardino .....(1/1/1)
Pasadena City College .....(1/0/0)
Sierra College .....(1/0/0)
Univ. of Calif., Davis .....(2/0/0)
UCLA .....(1/1/1)
Univ. of Calif., San Diego ..... (1/0/0)

CONNECTICUT
Wesleyan Univ. .....(1/1/0)

FLORIDA
Florida Inst. of Tech. ..... (1/0/0)
Florida State Univ. ..... (1/0/0)
Univ. of Miami ..... (1/0/0)

GEORGIA
Georgia Inst. of Tech. .....(2/0/0)
Valdosta State Univ. .....(1/0/0)

IDAHO
The College of Idaho .....(1/0/0)

ILLINOIS
Loyola Univ., Chicago ..... (1/0/0)
Univ. of Illinois ..... (2/0/0)

INDIANA
Bethel College ..... (1/0/0)
Purdue Univ. ..... (1/0/0)
Univ. of Evansville ..... (1/1/0)

IOWA
Grinnell College ..... (1/0/0)

KANSAS
Southwestern College..... (1/0/0)

KENTUCKY
Eastern Univ ..... (1/0/0)
Morehead State Univ ..... (1/0/0)
Thomas More College ..... (1/0/0)

LOUISIANA
Grambling State Univ ..... (1/0/0)

MAINE
Colby College ..... (1/0/0)

MARYLAND
Loyola College, Maryland ..... (1/0/0)
Morgan State ..... (1/0/0)

MASSACHUSETTS
MIT ..... (1/1/0)
Mt. Holyoke ..... (3/0/0)
Smith College ..... (1/1/1)
Wellesley College ..... (1/0/0)

MICHIGAN
Albion College ..... (1/0/0)
Michigan State Univ. ..... (3/0/0)
Univ. of Michigan ..... (3/0/0)
Wayne State Univ. ..... (1/0/0)

MINNESOTA
Bethel Univ. ..... (1/1/1)
Concordia College ..... (1/1/1)
MN State Univ., Mankato ..... (1/0/0)
MN State Univ., Moorhead ..... (1/0/0)
St. Cloud State Univ. ..... (1/0/0)

MISSISSIPPI
Mississippi State Univ. ..... (1/0/0)

MISSOURI
St. Louis University ..... (1/1/0)

Truman Univ. ..... (1/0/0)
Univ. of Missouri-Columbia ..... (1/0/0)

MONTANA
Univ. of Montana ..... (1/0/0)

NEBRASKA
Univ. of Neb., Kearney ..... (1/0/0)

NEW JERSEY
The College of St. Elizabeth ..... (1/0/0)
The Richard Stockton Coll. of NJ .... (1/1/0)

NEW YORK
Bard College ..... (1/0/0)
Berea College ..... (1/0/0)
Brooklyn College ..... (1/0/0)
Rensselaer Polytechnic Inst. ..... (1/0/0)
St. Bonaventure ..... (1/0/0)
Utica College ..... (1/0/0)
Univ. of Rochester ..... (2/1/0)

NORTH CAROLINA
Wake Forest ..... (1/0/0)

NORTH DAKOTA
Univ. of North Dakota ..... (1/0/0)

OHIO
Case Western Reserve Univ. ..... (1/0/0)
Cleveland State Univ. ..... (1/0/0)
College of Wooster ..... (1/0/0)
Denison Univ. ..... (1/0/0)
Kenyon College ..... (1/0/0)
Oberlin College ..... (1/0/0)
Ohio Northern Univ. ..... (3/2/1)
Ohio Wesleyan ..... (2/0/0)
Owens Community College* ..... (1/1/1)
The Ohio State Univ. ..... (3/0/0)
The Univ. of Toledo* ..... (10/5/5)
Univ. of Akron ..... (1/0/0)

OREGON
Oregon State Univ. ..... (1/0/0)
Portland Community College ..... (1/0/0)
Williamette Univ. ..... (2/0/0)

PENNSYLVANIA
Carnegie Mellon Univ. ..... (2/0/0)
Ind.Univ. of PA/Calif.Univ. of PA ... (2/0/0)
Kutztown University ..... (1/0/0)
Thiel College ..... (1/0/0)
Univ. of Pennsylvania ..... (1/1/0)
Washington & Jefferson College ..... (1/1/1)

SOUTH CAROLINA
College of Charleston ..... (1/0/0)

TENNESSEE
Austin Peay Univ. ..... (3/0/0)

TEXAS
St. Mary's Univ. ..... (1/0/0)
Univ. of Dallas ..... (1/0/0)

VIRGINIA
Bridgewater College ..... (1/0/0)

VIRGIN ISLANDS
Univ. of the Virgin Islands ..... (1/0/0)

WASHINGTON
Gonzaga Univ. ..... (1/0/0)

NSF-REU Participant* Demographics
Summer 2009

Gender
Female: 7
Male: 6

Class Rank
Freshman: 4
Sophomore: 4
Junior: 5
Senior: 0

Ethnicity
American Indian: 0
Alaskan Native: 0
Asian American: 0
(or Pacific Islands)
African American: 0
Hispanic American: 1
Caucasian/White: 12
Other:

Home State
California 1
Massachusetts 2
Minnesota 1
Ohio 7
Pennsylvania 1

Home Institution:
Cal.St.Univ., San Bernardino 1
UCLA 1
Smith College 1
Bethel Univ. 1
Concordia College 1
Ohio Northern Univ. 1
Owens Community College** 1
The Univ. of Toledo** 5
Washington & Jefferson College 1

REU Students Grade Point Average: 3.78
* Includes all students participating in our program regardless of their source of support
** 2 Students were not supported by NSF funds, but fully participated in the summer research program.

V. RESEARCH

REU 2009 Final Presentations
Each talk is scheduled for 12 minutes allowing 3 additional minutes for questions.

Monday, August 3
12:00 Casey DeRoo: **"**Effects of an Anisotropic Radiation Field on High Galactic Latitude Interstellar Dust Cloud LDN 1780"

12:15 Casey Bennett: "Improving Temperature Dependent Measurement of PV Cells"

Tuesday, August 4
12:00 Rachell Gestrich: "Extragalactic Photometry: The Search for Stellar Clusters"

12:15 Tyler Hill: "Photoluminescence: A Study of Thin Film CdTe Solar Cells"

12:30 Sean Maddock: "Lifetime measurements in P II using beam-foil spectroscopy and theoretical calculation of polarizabilities using variational theory"

12:45 Stephanie Ash: "Improving the a-Si:H and nc-Si:H Back-Reflectors Modeled with ZnO Stacks"

1:00 Catherine McGuinness & Lydia Michaels: "The World of fMRI and LabVIEW"

Wednesday, August 5
12:00 Maverick Terrazes: "Searching for Variable Stars in the Small Magellanic Cloud"

12:15 Corbin Taylor: "Li in IC 443: Data Reduction in Iraf"

12:30 Rosa Zartman: "Spectroscopic Ellipsometry study of Transparent Conducting Oxides"

12:45 Marina Kounkel: "The search for protostellar binaries in Orion"

1:00 Becky Carlson: "Optimization of Indium Doped Tin oxide (ITO) by pulsed DC power on single junction amorphous silicon (a-Si) solar cells"

ABSTRACTS OF REU FINAL REPORTS
The University of Toledo, Department of Physics & Astronomy
SUMMER 2009
(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Casey T. DeRoo, *LDN 1780: A Translucent High-Galactic Latitude Interstellar Cloud in a UV-rich, Anisotropic Radiation Field,* (A. Witt)

We combined high-resolution optical imaging observations in 12 intermediate-band (BATC) filter and deep mid- and far-IR Spitzer maps of LDN 1780 to characterize the external radiation field illuminating this high-latitude (l = 359 deg; b = 36.5 deg; distance ~100 pc) translucent cloud and the infrared emission of dust within LDN 1780 in response to this external illumination.

The overall energy density of the incident radiation field is approximately equal to that of the ISRF near the Sun, resulting in a large dust grain equilibrium temperature ranging from 14.5 K -16.8 K. However, the incident radiation field is highly anisotropic, with the southern portions of LDN 1780 being most strongly illuminated, especially at shorter wavelengths. This anisotropy is a result of the cloud's proximity to the Sco OB2 association (est. center: l = 322 deg; b = 10 deg).

The southwestern portion and the optically-thin eastern tail of LDN 1780 exhibit strong intensity excesses at 24 micron (Spitzer MIPS) and at 8 micron (Spitzer IRAC Ch. #4) compared to dust in the diffuse ISM of the Milky Way Galaxy. We interpret these excesses as enhanced emission from stochastically-heated very small grains (VSG) and from PAH ions, respectively. These excesses, however, are not necessarily the result a greater relative abundance of these two small-particle components but rather reflect the increased frequency of photon-grain interactions (e.g. heating, excitation, or ionization) within a UV-rich radiation field.

Rachell Gestrich, *The Stellar Content of the Starburst Galaxy NGC 3125, (R.Chandar)*

Star clusters are a group of gravitationally bound stars that are formed at the same time and have the same metallicity. Each cluster can contain from a few hundred to hundreds of thousands of stars and therefore are much brighter than individual stars. We can measure their ages, masses, and sizes and use this information to trace the star formation history of their parent. I used images from the Advanced Camera for Surveys on the Hubble Space Telescope, to study the content of the dwarf starburst galaxy NGC 3125. I performed aperture photometry on all objects detected in the images, and used various criteria to separate star clusters from individual stars, blends of a few stars, and background galaxies. I found that the galaxy is dominated by luminous, young (<10 Myr) clusters, with fewer older clusters.

Marina Kounkel, *The search for protostellar binaries in Orion*, (T.Megeath)

What is a star? It is a massive ball of mainly hydrogen that is held together by its own gravity. Why is it important to study stars? They produce energy and all the elements heavier than hydrogen through nuclear fusion. Planets are a byproduct of stellar formation. Without stars life couldn't possibly exist, thus they are imperative for understanding the origins of life. Stars have finite lifetimes. They form; they live; they die. Their lifespan can last from a few millions to many billions of years, depending on their mass. The Sun was formed approximately 4.6 billion years ago. We cannot revert time, but by studying other stars in the process of the formation we can recreate the history of what happened during that era.

Corbin Taylor, *Li in IC 443,* (S.Federman)

Supernovae are believed to be important to the chemical evolution of the Galaxy. In particular, they play a role in the production of the light elements Li, Be, and B which are thought to be produced via pathways that differ from elements synthesized in stellar cores. In our study, we reduced and analyzed

data from the 9.2 m Hobby-Eberly Telescope (HET) (R=98000) for two sight lines in the vicinity of the supernova remnant IC 443, toward the OB stars HD 254577 and HD 254755. We focused on the Li I doublet around 6808 Å to find the value of the column density ratio of the two isotopes of Li: N(Li-7)/N(Li-6). We also used HET data for the CH spectral line at 4300 Å as an aid in the fitting process. The goal of this research is to further our knowledge about Li and the elements in general.

Maverick Terrazas, *Infrared Variable Stars in the Small Magellanic Cloud using the Spitzer SAGE-SMC Survey*, (U. Vijh)

I am presenting my search for variable stars in the Small Magellanic Cloud (SMC) using the observations made by the Spitzer SAGE-SMC Legacy program. Three epochs of data were used, two of which taken 3 months apart and one taken three years before. Each epoch was taken using two infrared imaging instruments on the Spitzer Space Telescope: the Infrared Array Camera (IRAC) and the Multiband Imaging Photometer for Spitzer. I found 825 sources that meet the variability criteria defined: a source must have $|V_{band}| > 3$ in at least two neighboring bands in the same direction. These sources were, then, plotted on color magnitude diagrams for classifying. 57 sources have been visually verified as variable out of the 80 sources checked.

Atomic/Molecular/Optical Physics

Sean Maddock, *Lifetime measurements in P II using beam-foil spectroscopy,* (M.Brown, L. Curtis, D. Ellis,S. Federman,R. Irving,C. Theodosiou)

Beam-foil spectroscopy is a useful method for studying temporal elements of atomic structure and properties, such as lifetimes of excited states. Studies this summer were done using the Toledo Heavy Ion Accelerator (THIA) studying the $^3P_0\ 3s^2 3p^2 - {}^3P_1\ 3s3p^3$ transitions in P II. Using a forward lifetime measurement at 170 keV, a lifetime of 13.94 ± 0.59 ns was measured for the J=1 upper state at λ=1301.87Å. This is a very good measurement as shown by the reduced chi-squared and in that the uncertainty of the measurement is within 5%. Future measurements are planned using a reverse lifetime measurement and another forward lifetime measurement at 220 keV.

Sean Maddock, *Theoretical calculation of polarizabilities using variational theory,*(M.Brown, L. Curtis, D. Ellis,S. Federman,R. Irving,C. Theodosiou)

Theoretical work was also done this summer in calculating atomic dipole polarizabilites. By using the variational principle and a trial wave function, the energy of a system can be minimized to obtain an approximate solution for the complicated system. This method was used to determine a new method of calculating polarizabilites of atoms or ions with a closed-shell core. Results were promising and showed trends of agreement with literature values. More time would be needed to include more parameters in the calculations to improve future results.

Biological, Health, and Medical Physics

Catherine McGuinness & **Lydia Michaels,** *The World of fMRI and LabVIEW*,(M.Dennis)

In our ten-week research program here at the University of Toledo Medical Center, we worked in many different fields of the Medical Physics department. In the first five weeks of the summer, we analyzed the results of different smoothing functions on CT scans. CT stands for "computerized tomography." CT scans are also commonly referred to as CAT scans, from the original phrase, "computer-assisted tomography." A CT scanner is a very sophisticated x-ray machine. The patient lies on a table that is cantilevered through the scanner gantry. The gantry houses the x-ray source across from a fanned detector array. This setup rotates around the patient several hundred times per second as the patient is moved through the gantry producing helical scans. With reconstruction software, a user can produce both slice scans and three-dimensional images. Different tissue types register as different

CT numbers, which the computer uses to visualize the patient's internal organs. Air is assigned the number -1000 and always appears black. Water is defined to have a CT number of zero while bone is approximately one thousand.

Condensed Matter Physics

Stephanie Ash, *Improving the a-Si:H and nc-Si:H Back-Reflectors Modeled with ZnO Stacks***,** (Robert Collins)

This report looks to find the best model that will give the optimal reflectance from the ZnO, least absorption in the Ag, most absorption in the Si and the least amount of total reflection by creating a multi-layer ZnO with alternating indices of refraction on a Ag back-reflector. The ZnO high is an intrinsic ZnO and the ZnO low is created theoretically by introducing more free carriers modeled by the Drude behavior in the ZnO dielectric functions. Later, ITO layers with alternating indices of refraction were also placed in the model to improve its performance. The best results are shown and discussed. Finally, some suggestions of work that could be further made on this project are presented.

Becky Carlson, *Optimization of Indium Tin Oxide (ITO) by Pulsed DC Power on Single Junction Amorphous Silicon (a-Si) Solar Cells*, (Bill Ingler)

Using pulsed DC power, conditions at which production of a thin indium doped tin oxide film were achieved to produce the optimal efficiency for an amorphous silicon solar cell. Thin films of indium doped tin oxide were prepared by plasma vaporization (PEVCD) deposition using a pulsed DC power supply. Power, deposition time, pressure, gas flow and temperature were changed to find the optimal conditions. The best films were produced at a power of 40W, deposition time of seven minutes and 40 seconds, a pressure 4.0mTorr, gas flow 16sccm and at 151 °C and had 0.25 cm^2 dots with an efficiency of 6.650% (SD2785-2.12). Also, the ITO was put on a germanium silicon solar cell with an efficiency of 7.203% (SD2786-4.32). The surface morphology was compared using atomic force microscopy between 35, 40, 43W and the lower power had a lower root mean square roughness curve than the higher power samples.

Tyler Hill, *A photoluminescent study of $CdCl_2$ treated CdS/CdTe thin film photovoltaic cells of varying CdTe thickness.***, (**A. Compaan/K. Wieland)

$CdCl_2$ treated CdTe/CdS solar cells have some of the highest efficiencies of any cells currently available. In order to further improve cell efficiencies an improved theoretical understanding of the different recombination mechanisms present in the cell is essential, and photoluminescence studies are one of the easiest nondestructive methods of obtaining such information. We find evidence for an exciton transition due to CdTe at 1.595eV and a corresponding 1.553eV transition due to $CdTe_{0.94}S_{0.06}$ with the 42meV difference in Te/S replace position is consistent with the band bowing of the alloyed material. The replace follows a temperature dependence of $-3x10^{-4}$eV/K for temperatures above 30K, which is consistent with the temperature shift of the CdTe bandgap for temperatures above 30K.

Rosa Zartman, *Spectroscopic Ellipsometry study of Transparent Conducting Oxides* (S. Marsillac; J Walker)

This research focuses on using indium tin oxide (ITO) and aluminum doped zinc oxide (AZO), to make a transparent conducting oxide for copper indium gallium diselenide (CIGS) photovoltaic solar cells. To accomplish this feat, the employment of a RF Magnetron Sputtering System by a Kurt J Lester PVD75 sputter with 3in ceramic targets is the process of choice. The system was placed under high vacuum by a cryogenic pump. The necessity of using a transparent conductive oxide (TCO) at the top of the solar cell comes from the requirement of having the light passing through (hence the transparency) while being able to conduct the electrons out of the cell into the load (hence the conductivity). The ITO and AZO films were deposited on soda lime glass and on silicon wafer. The

power and DC bias applied to the deposition were varied to try to optimize the transparency and the resistivity. The duration of the deposition was also changed in order to achieve a film thickness of about 300 nm. The films were then studied for their transmission, reflection, resistivity, and other optical properties using a spectrophotometer, a four-point probe, and an ellipsometer in the solar spectral range and in the deep IR.

NSF-REU External Publications and Presentations*

(Update from Annual Report 2008)

REFEREED PUBLICATIONS - Submitted/accepted/published.

Yunsic Shim, **Mary E. Mills* (2007)**, Valery Borovikov, and Jacques G. Amar, "Effects of substrate rotation in oblique-incidence metal(100) epitaxial growth," Physical Review E 79, 051604 (2009)

Ingler Jr, W. B.; **Ong, G.* (2007)**; Deng, X. "RF Sputter Deposition of Indium Oxide – Iron Oxide Films for Photoelectrochemical Hydrogen Production" *ECS Trans.* Vol. 16, No. 7. (State-of-the-Art Program on Compound Semiconductors 49 (SOTAPOCS 49), **2008**, 49.

REFEREED PUBLICATIONS - in preparation.

PRESENTATIONS.

Ingler Jr, W. B.; **Ong, G.* (2007)**; Deng, X. "RF Sputter Deposition of Indium Oxide – Iron Oxide Films for Photoelectrochemical Hydrogen Production" *ECS Trans.* Vol. 16, No. 7. (State-of-the-Art Program on Compound Semiconductors 49 (SOTAPOCS 49), **2008**, 49. *210th Meeting of the Electrochemical Society*, *Inc.*, Honolulu, HI, October 12-17 (Oral Presentation)

PRESENTATIONS WITH PUBLISHED ABSTRACTS.

CONFERENCE PRESENTATIONS WITH PROCEEDINGS PAPERS.

R. M. Zeller (2008), J. D. Walker, K. A. Wieland, and A. D. Compaan, "R*eal-time Optical Thickness monitor for Thin Film Growth,"* 34th IEEE Photovoltaic Specialists Conference Philadelphia, PA, June 7-12, (2009)

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

VI. PROGRAM EVALUATION
NSF-REU Summer Research Program
Department of Physics & Astronomy
The University of Toledo
2009 (Total Population: 13, Responses: 9)

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

2009 mean (pop. 9): 2.2

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

2009 mean (pop. 9): 2.2

How do you rate your summer's research experience educationally?

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

2009 mean (pop. 9): 1.6

How do you rate the level of your research 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

2009 mean (pop. 9): 3.2

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

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

2009 mean (pop. 9): 1.6

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

2009 mean (pop. 9): 4.3

How do you rate the weekly seminar series in helping you learn more about safe and ethical conduct of research at UT?

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

2009 mean (pop. 9): 5.6

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

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

2009 mean (pop. 9): 4.9

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

2009 mean (pop. 9): 1.6

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

2009 mean (pop. 9): 2.7

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

2009 mean (pop. 9): 3.3

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

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

2009 mean (pop. 9): 2.1

How do you rate your summer experience personally?

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

2009 mean (pop. 9): 1.8

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

2009 mean (pop. 9): 4

What do you think about the average level of the weekly physics and astronomy Bag Lunch talks?

Much Too Advanced			**About Right**			**Much Too Elementary**
1	2	3	4	5	6	7

2009 mean (pop. 9): 3.1

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

2009 mean (pop. 9): 3.8

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

2009 mean (pop. 9): 2.3

Critical Reflection Questions (Use additional pages and/or backs of these pages if desired.)

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

I wanted to experience scientific research first hand and contribute to the scientific community. Also this is my first experience in astrophysics, which is the discipline I'm interested in.

I wanted to prepare for graduate school and expand my horizons.

I plan to research as a career but my studies during the school year prevent me from devoting significant time to research, so I really wanted time to devote to research full time.

I wanted help in trying to decide whether I wanted to go to medical school or graduate school.

To continue my research from last year and learn more about the field of study I am planning on going into.

Prep for grad school, good academic + social experience

look good on apps

I wanted to learn more about physics and more about what research

why not

I wanted to see what research was like outside the classroom.

==========

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

Courses

Prior knowledge limited use in conducting research but helpful in understanding theory.

My astronomy courses, optics courses, and discovery channel science shows.

Basic knowledge of quantum mechanics, computer experience, introduction to astronomical principles.

Previous research experience

The little bit of knowledge that I had from my heat light and sound course was helpful but I still had a lot to learn

I did research before

General Physics, Quantum Mechanics

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

Background information and the status of my field/previous research on my object.

I wish I would have taken a course on Mathematica.

Advanced knowledge of semiconductors….most knowledge can learn on the spot.

I wish I would have had a course in quantum mechanics.

Didn't have any previous classes in subject or any experience computer programming courses

If I would have had more knowledge on solar cells that would have been helpful

Higher level in math

Knowledge about plasma

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

Polarizabilities, quantum mechanics, variational theory

How solar cells work, how photoluminescence works, how to analyze photoluminescence data.

The amount of work that requires programming in astronomy.

The definitions of specific things related to my project and how different data visualization and analysis programs work (ds9, vi, Linux OS).

Previous studies or analysis done on my research and their observations

lots and lots of little things

not that much

I learned about circuits/biasing

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

How to interpret data/graphs and how to go about reading a scientific paper for optimal understanding.

I learned how to use several new programming languages which will be very helpful.

I understand how to run a photoluminescence experiment and what specific experiments can yield interesting results.

New theoretical methods, accelerator work.

Astronomy resources I didn't know existed.

Found lots of new methods, and got hardened to the rigors of research

not that much since I did a lot of computer work

I learned the software

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

Increase understanding of CdS/CdTe junction for very thin CdTe films.

Many people are waiting for the results of my research, hopefully it gives more understanding.

My research may be helpful in settling a debate in the literature about the incident radiation field as well as show the validity of certain theoretical models.

It won't

Alternative energies

solar cells are getting better so once it gets out to the community energy could be saved

In no way at all!

The results will be beneficial for future results to make efficient solar cells

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Please list any additional comments

The "Ethics in Research" seminars are a waste of time. They are poorly scheduled (right in the middle of the morning; is prime-time for meeting with my advisor) and focus predominantly on experiences as a UT student. Any topic that is relevant outside UT has already been covered much more effectively (and efficiently) at my home institution. They are not applicable to REU students (as I should hope that these students should be of sufficient caliber to be aware of the ethics involved in a research project).

I had a lot more fun than I expected, and gained a lot of insight into graduate life.

I just want say Rick did a great job and helped make my stay more enjoyable. I definitely felt welcome to talk to him about anything. He is really concerned about the students and enthusiastic about physics. Overall great experience. Also I had a lot of freedom which was great. The question about freedom in research perhaps misleading as having a lot of freedom does not equal you will get lost.

I wish things would have gotten off to a faster start in the beginning of the summer. I spent a couple of weeks not doing much but reading.

Weekly seminars are a waste of time!

I had a Great Time!

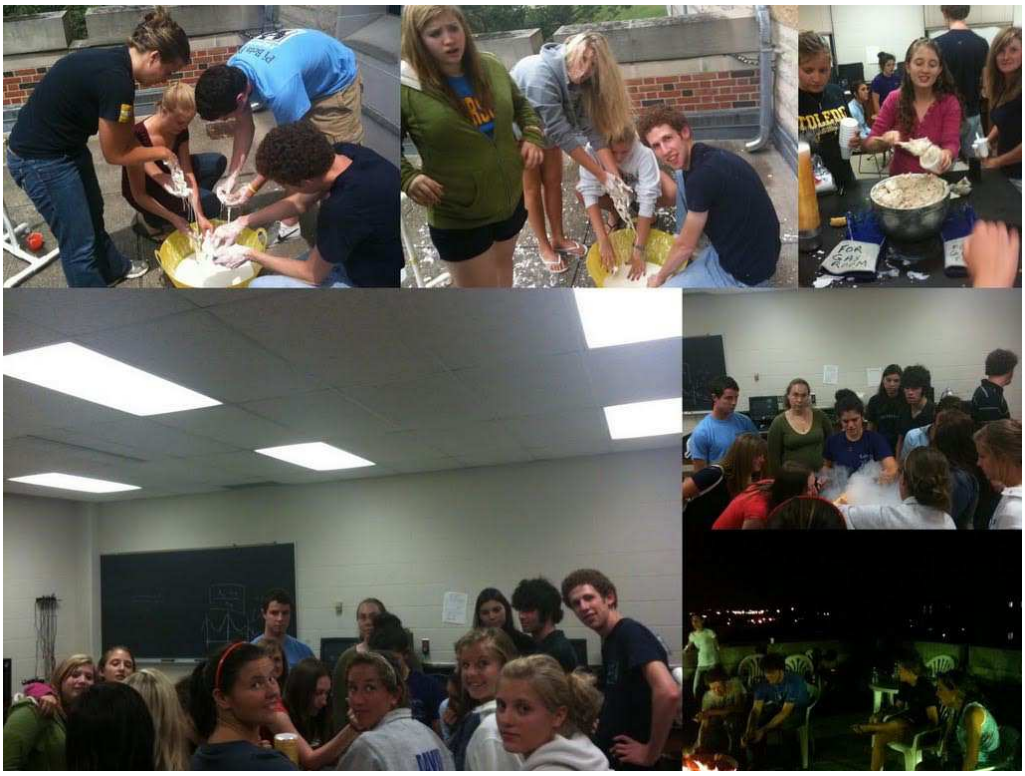
Thanks again for your time, and best wishes for continued success in all of your endeavors. As part of the tracking we need (and want) to do, please tell us about your degrees received and your career activities (grad school, work, etc) after participating in our program. Please keep in touch with us!

Rick Irving and Thomas Kvale, Program directors, NSF-REU

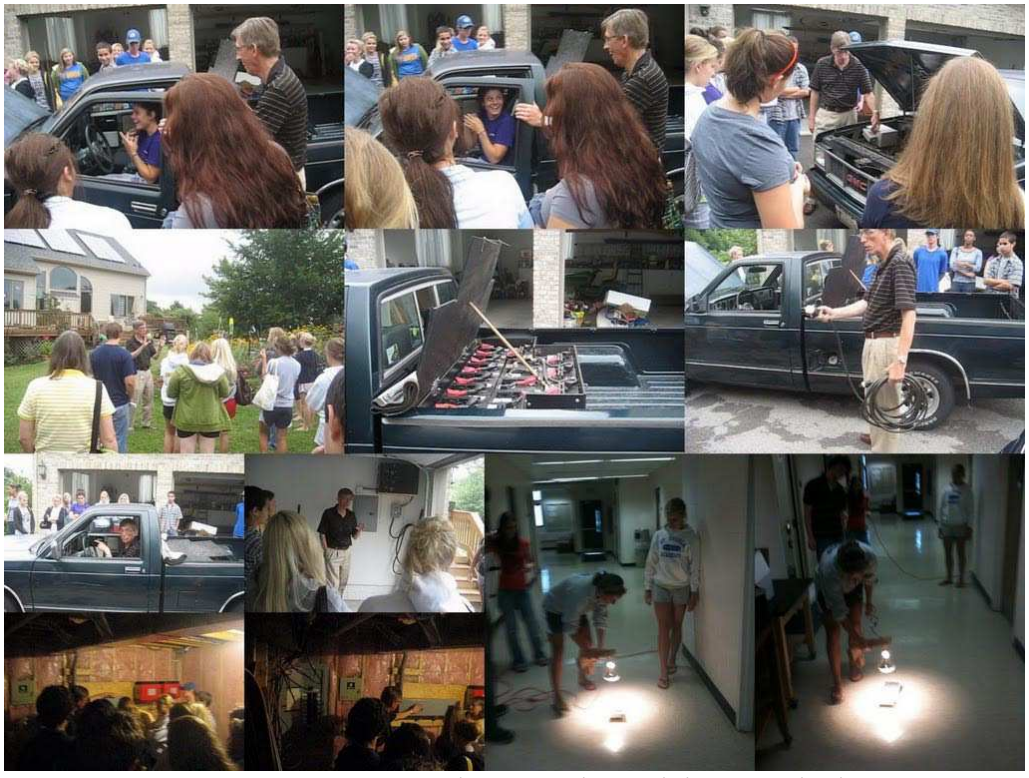
Please return this questionnaire to:

Sue Hickey
The University of Toledo
Department of Physics and Astronomy, MS111
Toledo, Ohio 43606

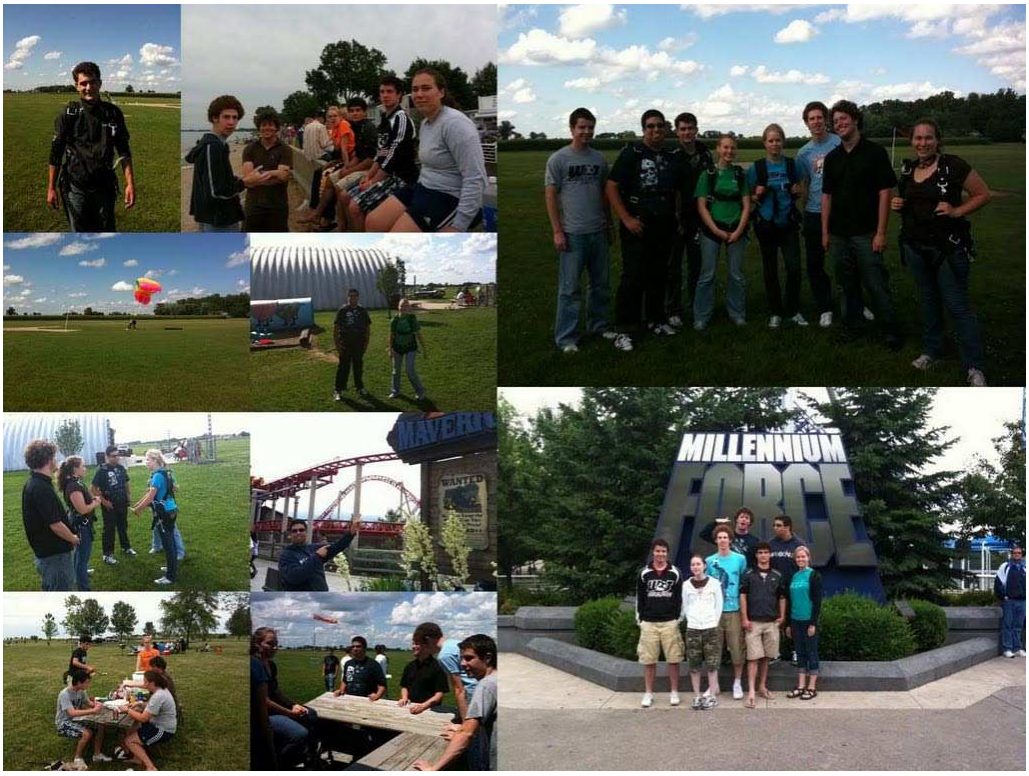
VII. SUMMER 2009 PICTURES



Summer Camp: Corn Starch,LN2 Ice Cream, Roasting Marshmallows



Summer Camp: Experiments, Al's E-pickup, & Picnic



REUs having fun

Final Report Presentations