Annual Progress Report (Year 2)

Research Experiences for Undergraduates in
Physics and Astronomy

NSF-REU Grant PHY- 1004649

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

December 2011

Richard E. Irving
Thomas J. Kvale

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I. REU RESEARCH PARTICIPANTS, SUMMER 2011

Mentors and participants (boldface) in 2011 Summer REU:
Left to Right (Front row): **Frances Schmidt**, **Kristen Garofali**, **Olivia Eggenberger**, **Ammaarah El-Amin**, **Anthony Passero,** **Marina Kounkel**, Rupali Chandar, Joe Converse, **Nathan Callahan**, **Luke Kwiatkowski**, Left to Right (Second Row): **Lawrenzo Mosses**, **Pattlyn McLaughlin** , **Logan Stagg**, Will Fischer, **Dhruv Sengar**, Jacques Amar, **Tyler Fronk**, **Tyler Kinnier**, **Branden Saner** Left to Right (Back Row): Al Compaan, Parsai, Tom Kvale, **Jacob Buenger**, Adolf Witt, Steve Federman, **Josiah Aultman**, Rick Irving, **Jakub Prchlik**, **Chad McElvany**, Kris Weiland,

NAME	**INSTITUTION**	**MENTOR**	**RESEARCH**
Josiah Aultman	Itasca CC	Ingler	Photovoltaics
Jacob Buenger	Univ. of Cincinnati	Dennis	Medical Physics
Nathan Callahan	Purdue Univ.	Amar	Condensed Matter
Olivia Eggenberger	Albion College	Parsai	Medical Physics
Ammaarah El-Amin	Univ.. of Toledo	Heben	Condensed Matter
Tyler Fronk	Univ. of Toledo	Irving-Kvale-Compaan	Atomic
Kristen Garofali	Michigan State Univ.	Chandar	Astrophysics
Tyler Kinner	Univ. of Toledo	Heben	Photovoltaics
Marina Kounkel	Univ. of Toledo	Megeath	Astrophysics
Luke Kwiatkowski	Univ. of Toledo	Irving-Ellis-Curtis	Atomic
Philip McDonald	Itasca Comm. College	Witt	Astrophysics
Chad McElvany	Univ. of Toledo	Ellingson	Photovoltaics
Pattilyn McLaughlin	Alfred Univ.	Witt	Astrophysics
Lawrenzo Moses	Univ. of Akron	Compaan	Photovoltaics
Anthony Passero	Univ.. of Toledo	K. Bjorkman	Astrophysics
Jakub Prchlik	Univ. of Toledo	Megeath	Astrophysics
Brandon Saner	Univ.. of Toledo	Chandar	Astrophysics

Dhruv Sengar	Univ. of Toledo	Federman	Astrophysics
Frances Schmidt	Univ. of the South	Fischer	Astrophysics
Logan Stagg	Univ. of NC-Ashville	Compaan	Photovoltaics

* Supported by external grants, but fully participated in the REU program.
** Received support from the UT USRCAP and the NSF-REU program, but fully participated in the REU program.
*** Volunteered to participate in our REU program.

II. SUMMARY OF SUMMER 2011

Introduction

The Summer 2011 NSF-REU program in Physics and Astronomy, directed by Dr. Richard Irving and Professor Thomas Kvale, gave enhanced research opportunities to 20 undergraduate students from 10 colleges and universities in 7 states. Student participants were chosen competitively out of 144 applications from students in 35 different states in all regions of the U.S. The strong support of our faculty for the REU research program is evidenced by four students receiving support from faculty members' external grants and two students volunteering to participate in our REU program. One student received funding from the internal UT USRCAP (Undergraduate Summer Research and Creative Activity Program) and from the NSF-REU grant (at the level of support of fully NSF-REU funded participants). Josiah Aultman and Philip McDonald were the cohort of participants in our program from the UT-Itasca Community College collaboration. 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 2011 was a success from both the students' and faculty mentors' perspectives. At least two abstracts by this year's undergraduate researchers have been accepted for presentations at national, professional conferences and at least two manuscripts have been submitted to archival journals based on research this past summer. An additional paper was published this year by a previous REU student. Additional manuscript(s) are in preparation and will be submitted shortly to refereed journals.

Advertisement and Selection

Again this year (Summer 2011) we utilized a web-based advertisement and application system. Based on a pattern of past applications and inquiries, we believe that the internet is the main search vehicle for the vast majority of students. Because of this pattern, paper announcements were not sent, however individualized email messages were sent to approximately 30 targeted institutions. The emailing included a cover letter alerting the prospective students to our website. The selection committee was composed of Richard Irving (PI), Thomas Kvale (Co-PI), David Ellis, Rupali Chandar, and Adolf Witt. We performed the initial matches of the prospective students with their faculty mentors. Various criteria were used for the selection and matching, including the student's course background and class performance, out-of-class experiences, research interests, faculty recommendations, and personal goals. We also tried to select students with a variety of personal, educational, and geographical backgrounds. The initial web announcement (with secondary links to additional material) can be found at: http://astro1.panet.utoledo.edu/~wwwreu/reusummer2011/nsf-reu2011.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, 16 of the 20 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: Tyler Fronk, Luke Kwiatkowski, Marina Kounkel, and Dhruv Sengar assisted in the activities. Weekly activities included movie night, bowling, sand volleyball, ultimate Frisbee, board games and various ventures to local restaurants. One of the notable establishments people found fun to visit was Pizza Populous. 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, a Toledo Zoo visit and swimming at Centennial Quarry. During the REU we also had fun attending a program at the University of Michigan"s Angell Hall Planetarium. Again this year the students visited the First Energy Bay Shore coal burning power plant in Oregon Ohio. The REU calendar can be found via the REU link on our department home page at: http://www.physics.utoledo.edu.

Weekly Seminars

A weekly REU "Brown Bag" seminar series is an important part of our summer program. Faculty members and/or outside speakers are asked to present a talk over the lunch hour for their chosen day. This format fosters more of an informal atmosphere, which the students appreciate when it is their turn to give a presentation at the close of the summer session. This weekly meeting of the entire REU group also provides an opportunity to plan social events and field trips, and discuss any topics of interest to the group.

NSF-REU SUMMER 2011 BROWN BAG SEMINARS

(Noon – MH 4009)

May 31 REU Orientation

June 7 Kristopher.Wieland, "Sustainable Photovoltaics"

June 14	Scott Lee, "Locomotion of dinosaurs and Australopithecus afarensis."
June 21	Dave Corliss, "Statistical Research in Astronomy and Astrophysics"
June 28	REU Progress Reports
July 5	Steve Federman , "Carbon Monoxide in Space"
July 12	Jacques Amar, "Simulating Thin-film Growth"
July 19	Scott Lee, "The Conformational Flexibility of DNA."
July 26	Reva.Williams, "Astrophysical Black Holes and How Energy is Extracted"
Aug 1	Student Final Presentations
Aug 2	Student Final Presentations
Aug 3	Student Final Presentations

University-Wide Events

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

We also required the students to attend a second, university-wide seminar series that formed the basis of the course, ARS2980: "Issues in Research and Scholarship". This course was coordinated by the Office of Undergraduate Research and the Honors Program. It was in a seminar format and topics concentrated on the safe and ethical practices in research as described in this past year's syllabus. Each presentation lasted about an hour and there was ample time for Questions/Answers for each speaker. 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, 2011

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Class Meetings: Thursdays, 9am-10am (6/3 – 8/5)
Location: Sullivan Hall (SL), Rooms 3050-3060-3070
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

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Syllabus, Summer 2011

June 2	**Welcome Reception (11:00am – 1:30pm)**	
June 9	**Research Ethics and Compliance**	Jeffrey Busch, Office of Research
June 16	**Advanced Research in the Library**	Wade Lee, University Libraries
June 23	**Plagiarism and Academic Honesty**	Barb Schneider, Writing Center
June 30	**Math in Academic and Industrial Research**	David Corliss, PA Grad Student
July 7	**Ethics and Commitment in Research**	Tom Barden, Honors Program
July 14	**Business Prospects and Patents**	Mark Fox, Patent-Tech,Off. of Res.
July 21	**Diversity Issues in Research**	Shanda Gore, Office of Diversity
July 28	**Overview and Summation**	Tom Kvale, OUR-UT
August 4	**Research Presentations**	Student Researchers [9am-3:30pm]
August 5	**Chemistry Research Presentations**	Student Researchers [1pm-4pm]

Catalog Description:

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

Concluding Remarks

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

We are very excited about this coming summer and beyond. The University of Toledo has a national reputation of having an excellent medical school. 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.

We are pleased that at least two refereed publications have been published and/or accepted for publiucation this year from recent REU alumni of our program. In addition, three 2010 REU students have their abstracts accepted and will be presenting their research at national conferences in 2011. The details are presented later in this report in the Publications section.

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.

III. PHYSICS AND ASTRONOMY SUMMER CAMP 2011

As part of the this NSF program our REU students host the Physics and Astronomy Summer Camp. This is an outreach activity for high school students which took place July 14-15. The summer camp activities were developed and supervised with the help of our REU team. Again this year Jackie Kane, a St. Ursula high school science teacher, was extremely helpful in promoting the camp. We had in attendance 24 high school students composed of one home school person and the following 8 local area high schools: Emmanuel Christian, Ottawa Hills, St. Francis, St. Ursula, Sylvania Northview, Sylvania Southview, Toledo Early College, and Woodward.

The first day of the Summer Camp dealt with alternatives for energy generation To start this journey the group did a tour of UT's own Scott Park Campus of Energy and Innovation: led by MIcheal Green, Director of Energy Management for the University of Toledo. During this tour the students were able to visit a 1.2 MW solar and wind system at this campus. The project utilizes thin-film-on-glass photovoltaic solar technology and a 132-foot wind turbine. Both the wind and the solar system are expected to generate power equal to the amount of electricity used by 140 homes annually. Next the students experienced similar technology at the home owner level This consisted of a tour and discussion by Professor Alvin Compaan concerning his 4.3 kW CdTe rooftop PV system and his homemade electric truck. After a barbeque the afternoon provided the students with hands-on activities to explore the concepts of the day. One student activity involved building and testing dye-sensitized solar cell using fruit such as blackberries, raspberries, pomegranate seeds. The students also really enjoyed testing their endurance to power up to four incandescent light bulbs (60 Watts each) with a homemade bicycle generator. While grunting (and laughing) during this physically challenging activity the students expressed the need for conservation by at least avoiding a phantom energy wasting lifestyle.

The second day featured night time activities related to astronomy including a presentation with public viewing on a 6 inch refractor telescope at Brooks Observatory by Alex Mak, the Associate Director. Brad Rush, a graduate student in our department, did a tour of the Ritter Observatory facility which has a 1 meter telescope . Kathy Shan, a doctoral student in curiculum and instruction with a focus in science education, helped develop activities for this part of the camp too. Kathy and the REU students had the students explore the size and scale of the solar system through an interactive demonstration using toilet paper as our unit of measurement. Also Kathy introduced the high school students to astronomy research through participation in a Galaxy Zoo project, using real images from the Hubble Space Telescope archive to classify galaxies.

IV. DEMOGRAPHICS

NSF-REU SUMMER 2011 APPLICATIONS

Geographical distribution by undergraduate institution

(Applications REU - 144 / REU Offers Made-26 / REU Accepted-20)

ARIZONA
Northern Arizona Univ... ..... (2/0/0)
Univ. of Arizona ..... (2/0/0)

ARKANSAS
Arkansas Tech. Univ..... (1/0/0)
Hendrix College ..... (1/1/0)
Southern Arkansas Univ. ..... (1/0/0)

CALIFORNIA
Cal. State Univ. Stanislaus..... (1/0/0)
Claremont McKenna College ..... (2/0/0)
Harvey Mudd College..... (2/0/0)
San Jose State Univ..... (1/0/0)
UC Davis..... (2/0/0)
UCLA..... (2/0/0)
UC San Diego ..... (1/0/0)

COLORADO
The Colorado College. ..... (3/0/0)
Univ. of Colorado @Colorado Springs..... (1/0/0)
Univ. of Denver ..... (1/0/0)

CONNECTICUT
Trinity College..... (1/0/0)
Yale University..... (1/0/0)

FLORIDA
Eckerd College..... (1/0/0)
New College of Florida..... (1/0/0)
Univ. of West Florida ..... (1/0/0)

GEORGIA
Southern State Polytechnic State Univ. ..... (1/0/0)

HAWAII
Univ. of Hawaii..... (1/0/0)

IDAHO
Brigham Young Univ..... (1/0/0)

ILLINOIS
Augustana College ..... (1/0/0)
Eastern Illinois Univ. ..... (1/0/0)
Illinois Wesleyan Univ. ..... (1/1/0)
Univ. of Illinois ..... (1/0/0)
Wheaton College ..... (1/0/0)

INDIANA
Ball State Univ. ..... (1/0/0)
Indiana Univ. ..... (2/0/0)
Indiana Univ. Purdue Univ. Fort Wayne ..... (1/0/0)
Purdue Univ. ..... (1/1/1)
Rose-Hulman Inst. Of Tech. ..... (2/0/0)
Valparaiso Univ. ..... (1/0/0)

IOWA
Univ. of Iowa ..... (1/0/0)

KENTUCKY
Western Kentucky Univ. ..... (1/0/0)

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

MARYLAND
John Hopkins Univ. ..... (1/0/0)
St. John's Univ. ..... (1/0/0)
U.Maryland, College Park ..... (2/0/0)

MICHIGAN
Albion College ..... (1/1/1)
Eastern Michigan Univ. ..... (1/0/0)
Kalamazoo Valley Comm. College ..... (1/0/0)
Michigan State Univ. ..... (5/1/1)
U.Mich.-Ann Arbor ..... (1/0/0)

MINNESOTA
Gustavus Adolphus College ..... (1/0/0)
Minnesota State Univ. Mankato ..... (1/0/0)
St. Olfa College ..... (2/0/0)
Univ. Of Minnesota ..... (1/0/0)
Itasca Community College ..... (2/2/2)

MISSOURI
Truman State Univ. ..... (1/0/0)

NEW HAMPSHIRE
Keene State College ..... (1/0/0)

NEW JERSEY
New Jersey City Univ. ..... (1/0/0)
The State Univ. of New Jersey ..... (1/0/0)

NEW YORK
Alfred Univ. ..... (2/1/1)
Barnard College Columbia Univ. ..... (1/1/0)
Brandeis Univ. ..... (1/0/0)
Clarkson Univ. ..... (4/0/0)
Cornell Univ. ..... (1/0/0)
Fordham Univ. ..... (1/0/0)
Rensselaer Polytechnic Inst. ..... (2/0/0)
Stoney Brook Univ. ..... (2/0/0)
SUNY at Buffalo ..... (1/0/0)
Univ. of Rochester ..... (2/0/0)

NORTH CAROLINA
North Carolina State Univ. ..... (2/0/0)
U.North Carolina, Asheville ..... (1/1/1)

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

OHIO
Baldwin-Wallace College ..... (1/0/0)
College of Wooster ..... (2/0/0)
Kent State Univ. ..... (1/0/0)
Kenyon College ..... (1/0/0)
Ohio Northern Univ. ..... (1/0/0)
The Ohio State Univ. ..... (1/1/0)
The Univ. of Toledo ..... (16/10*/10*)
Univ. of Akron ..... (1/1/1)
Univ. of Cincinnati ..... (1/1/1)

OKLAHOMA
Univ. of Tulsa ..... (1/0/0)

OREGON
Oregon State Univ. ..... (1/0/0)

PENNSYLVANIA
Carnegie Mellon..... (1/1/0)
Dickinson College..... (1/0/0)
Grove City College ..... (1/0/0)
Kutztown Univ. of Penn ..... (1/0/0)
Lycoming College..... (1/0/0)
Univ. of Pennsylvania..... (1/0/0)
Washington & Jefferson College ..... (1/0/0)
Westminster College..... (1/0/0)

SOUTH CAROLINA
Clemson University ..... (2/0/0)

SOUTH DAKOTA
Univ. of South Dakota ..... (1/0/0)

TENNESSEE
Carson- Newman College. ..... (1/1/0)
The Univ. of the South. ..... (1/1/1)
Union Univ..... (1/0/0)

TEXAS
Baylor Univ. ..... (1/0/0)
U.Texas at Austin..... (1/0/0)

UTAH
Utah Valley Univ. ..... (2/0/0)

VIRGINIA
Lynchburg College..... (1/0/0)
Old Dominion Univ. ..... (1/0/0)

WISCONSIN
U. Wisc., Platteville ..... (2/0/0)

WYOMING
Univ. of Wyoming ..... (1/0/0)

UKRAINE
Taras Shevchenko Natl. Univ. of Kyiv..... (1/0/0)

*Includes UT undergraduate students that fully participated in our REU research program, but with split and/or other funding sources.

NSF-REU Participant* Demographics

Summer 2011

Gender*

Female: 14
Male: 6

Class Rank*

Freshman: 4
Sophomore: 9
Junior: 6
Senior: 1

Ethnicity*

American Indian: 0
Alaskan Native: 0
Asian American: 0
(or Pacific Islands)
African American: 1
Hispanic American: 0
European American: …… 19
Other:

Home State*

Indiana…….....…… 1
Michigan ……..……. 2
Minnesota 2
New York ……..... 1
North Carolina 1
Ohio 11
Tennessee ….....…… 1

Home Institution*

Albion College …….... 1
Alfred Univ. …….. 1
Itasca Comm. College, MN … 2
Michigan State Univ. …… 1
Purdue Univ. ……. 1
Univ. of Akron …… 1
Univ. of Cincinnati ……. 1
Univ. of NC-Ashville. …… 1
Univ. of the South …….. 1
Univ. of Toledo…. …… 10

*Includes UT undergraduate students that fully participated in our REU research program, but with split and/or other funding sources.

REU Students Grade Point Average: 3.57
Includes all students participating in our program regardless of their source of support

V. RESEARCH

REU 2011 Final Presentations
Each talk is scheduled for 12 minutes allowing 3 additional minutes for questions.

Monday, August 1
12:00 **Marina Kounkel**, "WFC3 Imaging of Protostars in the Orion Molecular Clouds″
12:15 **Nathan Callahan**, "Simulation of diffusion of nanoparticle clusters on an interface″
12:30 **Kristen Garofali**, "Recent Chandra observations of the starburst galaxy NGC 4449 have discovered several black hole x-ray binaries which are located within or near very young star clusters"
12:45 P**hilip McDonald**, "The Interstellar Cloud MBM6"
1:00 **Logan Stagg**, "Study of Cuprous Oxide thin Films for Use as Photovoltaic absorber Layers″
1:15 **Jacob Buenger**, "MRI Research″

Tuesday, August 2
12:00 **Josiah Aultman**, "Indium oxide and cobalt oxide thin films on amorphous-silicon solar cells for hydrogen production″
12:15: **Tyler Fronk**, "Ion Implantation in CdTe Solar Cells"
12:30 **Anthony Passero**, "Spectroscopic Data Reduction Using Spextool″
12:45 **Luke Kwiatkowski**, "Theoretical Calculations of Atomic Polarizabilities″
1:00: **Brandon Saner**, "How Globular CLusters Can Help Us Understand the Origins of the Galaxies″
1:15 **Olivia Eggenberger**, "Thermoluminescent Dosimetry System Calibration″

Wednesday, August 3
12:00 **Jakub Prchlik**, "A Spectroscopic Study of CepOB3b″
12:15 **Dhruv Sengar**, "Chemical Study of Diffuse Interstellar Clouds″
12:30 **Lawrenzo Moses**, "A study of CdCl2 treatment on CdS/CdTe Solar Cells″
12:45 **Pattilyn McLaughlin**, "The Distance to LDN 1780″
1:00 **Frances Schmidt**, "Class I Protostar Mass Accretion″

ABSTRACTS OF REU FINAL REPORTS

The University of Toledo, Department of Physics & Astronomy
SUMMER 2011
(Faculty Mentor on parenthesis)

Astrophysics/Astronomy

Jakub Prchilk, *A Spectroscopic Study of CepOB3b,* (Tom Allen, Dr. Tom Megeath)

Spectra for ~1900 sources were classified in theCep OB3b region of the sky. Cep OB3b is an excellent location for the studying Young Stellar Objects. It is one of two clusters, the other being the ONC, nearby (<1kpc), young (< 5 Myr), and rich (>1000 stars). The MMT Telescope was used with the Hectospec instrument attached. The spectra obtained from the MMT is being used to determine the age and properties of YSOs in Cep OB3b. Also, probable new members of the cluster have been identified by searching the spectral features of CaII, Li, and Halpha in the objects being observed. These features indicate stellar youth and accretion.. Approximately 600 of the stars observed were known members of CepOB3b by either infrared excess or x-ray detection. However, this spectroscopic analysis showed that of the ~1300 spectra captured that were not known members of CepOB3b there were 22 with Lithium detections. Lithium being an indicator of stellar youth allows us to add these YSOs to the CepOB3b catalog.

Kristen Garofoli, *Recent Chandra observations of the starburst galaxy NGC 4449 have discovered several black hole x-ray binaries which are located within or near very young star clusters*, (Rupali Chandar)

Here we present the results from a suite of N-body simulations of N = 16, 384 (~ 6000 M?) star clusters through the first 10 Myr of their lives in order to determine whether such systems are capable of forming from purely dynamically means in such clusters. These simulations span a wide range of initial size and density profiles, both with and without primordial mass segregation, testing both realistic systems and extreme cases in order to find under what circumstances tight binaries are able to form within this limited timeframe. Clusters without primordial mass segregation are found to only be able to dynamically produce binaries this quickly when they are extremely compact and concentrated. The introduction of a large degree of primordial mass segregation, however, greatly increases the rapidity with which the binary systems form. Yet even in those cases the number of binaries formed are quite small, and are found to often not be good candidate x-ray binaries. The relative fraction of those found still within their parent cluster versus ejected from it also appear to be inconsistent with the observations. This leads us to conclude that x-ray binaries do not form dynamically in clusters of this size, and are likely instead the result of primordial binaries present from the cluster?s birth.

Marina Kounkel, *WFC3 Imaging of Protostars in the Orion Molecular Clouds*, (Thomas Megeath)

The Orion molecular clouds contain the largest sample of protostars within 500 pc of the Sun. As part of our survey, we have used WFC3 imaging at 1.6 um to observe 124 fields in Orion containing previously confirmed protostars.The focus of this survey was to identify companions around the protostars at distances as small as 100 AU at the distance of Orion. By combining the WFC3 imaging with a Spitzer Space Telescope survey of the Orion clouds, as well as NICMOS and IRTF imaging, we determine the density of candidate YSOs as a function

of distance from each of the targeted protostars. We also look at scattered light from the individual protostars.

Philip McDonald, *MBM6, (Adolf Witt)*

In this paper we present the results of studying the interstellar cloud MBM6. Using optical data obtained by ground-based telescopes located in New Mexico we were able to produce an optical SED through surface brightness differential photometry. Other observations were available in the form of infrared data from the Spitzer Space Telescope. These IR data were used to determine the dust temperatures and optical depths in different parts of MBM 6 along with determining the polycyclic aromatic hydrocarbons (PAH) mass fraction. From these data we found evidence of extended red emission (ERE) in the optical SED. The temperatures of the dust grains were found to be in the range from 14 K to 17 K, which is lower then the temperature of average interstellar dust (17.8 K) found by the Planck satellite. From the IR data we also found that the PAH mass fraction was considerably higher in the southern section of the cloud. When compared to published models of dust emission by Draine & Li (2007) we find that the PAH mass fraction of this southern section lay between 2.5%-4.6% while the rest of the cloud is below .47%. The southern portion of MBM 6 containing the higher PAH mass fraction is also a region of small optical depth; furthermore it faces away from the plane of the Milky Way, which is contrary to what is expected.

Pattilyn McLaughlin, *The Distance to LDN 1780,* (Adolf Witt)

It was hypothesized in Franco's 1989 paper that if the interstellar cloud LDN 1780 was a part of the cloud complex LDN 134, then its distance would be approximately 110 ± 10 pc. This paper will prove that LDN 1780 is indeed a part of this complex. Since the distance to a cloud cannot be directly determined through trigonometric or spectrophotoscopic parallax due to the nature of its brightness, stars directly in front of and behind the cloud were examined. Spectrophotoscopic parallax was used to determine the distances to 130 stars and therefore determining the distance to LDN 1780 by plotting these distances against their extinction due to the cloud. In order to find the magnitude of these stars at the V band, photometry was performed using a program called DS 9 with an add-on called Funtools. Counts from the program were then converted into fluxes and plotted against the wavelength of the respective filter. Absolute magnitude was determined by comparing stellar SEDs to Kurucz (1993) stellar atmosphere models corrected for extinction. The number of magnitudes of extinction for each star was then found by using a map produced by Ridderstadt (2006) and the IPAC 100 micron emission map. Once these three variables were found we were able to calculate the distances to these stars and then plot them. LDN 1780 was located where there occurred a sharp jump from 0 magnitudes of extinction to extinctions greater than 1 on the "Distance vs. Av" map. Using these techniques we found LDN 1780 to be located at a distance of approximately 103 ± 5pc.

Anthony Passero, *Spectroscopic Data Reduction Using Spextool,* (Karen Bjorkman)

The underlying mechanics of circumstellar disks are not well-understood, due to the complexity of the systems in which most of these disks arise. Observing these disks in a relatively simple systems, such as circumstellar disks around Be stars, is the key to understanding more complicated systems. Additionally, the infrared spectral region offers unique insight into understanding these disks. I reduced spectroscopic data taken from the NASA Infrared Telescope Facility in Hawaii, which covers near-infrared wavelengths. Spextool is the

program used for this reduction, necessary for its ability to reduce the cross-dispersed data from the SpeX instrument, on-board the IRTF. The data promise to be useful for observing emission lines present in circumstellar disks, and ultimately for learning about the structure and time-evolution of these disks.

Brandon Saner, *How Globular CLusters Can Help Us Understand the Origins of the Galaxies* **,** (Rupali Chandar)

My summer research experience was both enlightening and intimidating. I learned as much as I discovered I have yet to learn, and I met a lot of interesting and intelligent individuals in my department. I really had no idea what it would be like going into it, but I think that overall I picked up some essential tools and set the foundations for building the necessary experience and relationships for continuing on in this field. Since I plan on going on to get a master's degree and PhD in astrophysics, the fact that I am involved with current research, gaining that exclusive view of the subject from the non-classroom, non-textbook side, and building a list of accomplishments will be great for getting accepted into the graduate and doctoral programs that will be best for me. I was thrilled that I got to participate in the research programs this summer, my freshman year, as it will definitely set me up to be as attractive as possible to future institutions. My goal of becoming a professor of physical science at a university will be made much more easily attainable this way.

Frances Schmidt, *Class I Protostar Mass Accretion***, (**Will Fischer)

Class II stars have been studied in much greater detail that Class I stars. Class II sources are known to accrete matter from the inner disk to the star along funnel flows that trace magnetic field lines in a process called magnetospheric accretion. Hydrogen emission lines form in these funnel flows. The strengths of these hydrogen lines are proportional to the rate of mass flow (Muzerolle et al. 1998, AJ, 116, 2695). Current star-formation theory predicts that Class I sources have higher mass accretion rates than do Class II sources. If this is correct, and the magnetospheric accretion model holds true for Class I objects, then their hydrogen lines should be stronger than those of the Class II objects. Using a sample of spectra obtained from SpeX on NASA's Infrared Telescope Facility, we analyzed Paschen Beta and Brackett Gamma emission lines of 32 Class I protostars in Orion and 19 Class II stars in Taurus and Auriga. We found the equivalent width and flux for each Paschen Beta and Brackett Gamma detection, and the upper limits for these values in each case of non-detection. We determined the reddening of each source by comparing its (J-H) and (H-K) colors to the Class II locus (Meyer et al. 1997, AJ, 114, 288), and then corrected the line fluxes for reddening and distance (420 pc) to obtain line luminosities. After comparing Class II luminosities to the Class I luminosities, we concluded that they were surprisingly similar. This indicates either that Class I sources accrete matter more slowly than was previously believed, or that the accretion flow in Class I and Class II objects differs in a way that reduces the Class I line fluxes.

Dhruv Sengar, *Chemical Study of Diffuse Interstellar Clouds,* (Steve Federman)

Space is vast and mainly empty, yet there are molecules in large quantity. In some regions there are clumps of CO, CN, CH, etc. Diffuse molecular clouds are regions of space that have relatively low density of gas and dust, but still reveal the presence of molecules. Diffuse clouds are not visible; the main way that they can be seen is by the light of the stars that pass through them. Analysis of chemical abundances helps us determine the densities in the clouds.

Ultraviolet radiation breaks apart molecules, but the dust in space scatters the radiation. The goal of this project was to determine the optical depth of the dust at 1000Å (τ_{uv}). Using the optical depth, I will then be able to find density using chemical analyses.

Atomic/Molecular/Optical Physics

Tyler Fronk, *Ion Implantation in CdTe Solar Cells***,** (Rick Irving and Thomas Kvale)

The effects of doping cadmium telluride (CdTe) solar cells with Phosphorous (P+) ions at different doping concentrations are explored. The goal was to create an electron reflector near the back surface that would prevent back surface recombination and therefore increase open circuit voltage and efficiency. Photoluminescence data will be shown detailing the problems with damage caused by ion implantation and further areas of experimentation will be discussed.

Luke Kwiatkowski, *Theoretical Calculations of Atomic Polarizabilities,* (David Ellis, Larry Curtis, Rick Irving)

Using the calculus of variations to minimize the energy of an atom in a uniform electric field, an expression for the electric dipole polarizability can be found as a function of electrons' radial coordinate. Minimizing the energy leads to a differential equation that must be solved numerically. Approximations to this solution were found which yield good results but more time will be needed to find an efficient way to solve the differential equation. This will provide a convenient way to calculate polarizabilities using multiconfiguration atomic wavefunctions, and will provide insight into the behavior of electrons in atom under the influence of an applied field.

Biological, Health, and Medical Physics

:**Jacob Buenger**, *MRI Research,* (Micheal Dennis)

This summer I joined a research team that involved several projects regarding the structure and function of the cerebral cortex of the brain. The evaluation of the grey matter of the cerebral cortex was performed using Magnetic Resonance Imaging (MRI). MRI images the brain by using very strong magnetic fields and radio waves at resonant frequencies to obtain signals from hydrogen nuclei. The structure of the grey matter of the brain was evaluated using the Freesurfer software package which measures the grey matter thickness over thousands of vertices and reports the average thickness for each area of the brain. The principle project that I worked on was the Amputee Project, which looked to identify cortical areas where cortical thickness is related to depression, pain, anxiety, or other amputation-related factors. The subjects were given questionnaires and had MRI images taken of their brains. There were 10 amputees and 15 controls. My role in this project consisted of data entry from the questionnaires, running correlations, and analyzing results. We found correlations between the thickness and questionnaires in several different areas of the brain. Our next step is to continue recruiting subjects and looking at other types of analyzes.

Olivia Eggenberger, *Thermoluminescent Dosimetry System Calibration***,** (E. Ishmael Parsai)

This paper describes the process involved in calibrating a thermoluminescent dosimetry system. Each TLD was given an element correction coefficient (ECC) to eliminate variation and the reader was given a reader calibration factor (RCF) to convert a reading in nC to a dose value in cGy. The ECCs are unit less numbers around 1 and the final RCF value is 20.31 cGy/nC.

When tested, the percent error for the TLDs with buildup was 2.4% and the percent error for the TLDs without buildup was 26.97%. The larger percent error was due to the unpredictability of radiation dosage without buildup and so it was more acceptable.

Condensed Matter Physics

Josiah Aultman, *Indium oxide and cobalt oxide thin films on amorphous-silicon solar cells for hydrogen production,* (William B. Ingler Jr.)

This paper focuses on depositing indium oxide and cobalt oxide as thin film semiconductors or TCCRs (transparent, conductive and corrosion resistant) on amorphous-silicon solar cells, used for hydrogen production. We found that depositing the cobalt oxide at a higher power of about 100 W and the indium oxide at a lower power of around 30 W is going to produce the greatest current density. However, the higher the powers the transparencies of the films tend to decrease as well. Adding about .6 sccm of $Ar/1\%O_2$ optimized the current density and also slightly increased the transparency. As we decreased sputtering time from 15 to 10 minutes, the current density and transparency of the film both seemed to increase. Making depositions at 200°C gave us the best results although we did not diverge from it often. We were able to draw a few conclusions from the data we gathered, but more research could be done in order to determine more exact values for these parameters.

Nathan Callahan, *Simulation of diffusion of nanoparticle clusters on an interface,* (Jacques Amar)

The diffusion behavior of clusters of nanoparticles confined to an interface is studied. The relationship between the size of the cluster and the diffusion coefficient is investigated. A simulation is run using molecular dynamics with brownian kicks and langevan damping. The diffusion coefficient was seen to decrease inversely proportionally to the size.

Ammaarah El-Amin, *The effects of a thin Molybdenum Oxide (MoOx) layer inserted between the CdTe absorber layer and various metal back electrodes of CdTe solar cells*, (Micheal Heben)
The effects of a thin Molybdenum Oxide (MoOx) layer inserted between the CdTe absorber layer and various metal back electrodes of CdTe solar cells were studied. The current-voltage (I-V) characteristics of the cells were compared with those of CdTe solar cells without this MoOx layer. Experimental results show a decrease in efficiency for the cells with the MoOx layer, in contrast to expectations based on published reports. [ref] However, the results are inconclusive because the MoOx was unevenly deposited and several of the cells with the MoOx layer were shunted. Consequently, the properties of MoOx as back contact merits further investigation. As a secondary finding of this project, we determined that, on average, a Mo/Al/Cr back contact produced slightly higher efficiency cells than a standard Cr/Al/Cr contact.

Chad L. McElvany, *Determination of Energy Band-Edge Locations for PbS Semiconducting Quantum Dots Using Cyclic Voltammetry***,** (Randy J. Ellingson)

Colloidal semiconductor quantum dots (QDs) offer a promising route to serve as light-absorbing materials in inexpensive, efficient photovoltaic solar cells. Evaluating the conduction band and valence band edge positions of QDs and QD-based thin films from cyclic voltammetry (CV) measurements is a relatively new technique, and has been applied to just a few QD materials. Reports in the literature often fail to address important aspects of the CV data, sometimes omitting analysis of the anodic peak and/or omitting band gap energy analysis

(instead relying solely on the optical assessment of the band gap). I attempted to locate the conduction and valence band edge positions from cathodic *and* anodic peaks in the CV plots, and relate them to the optical band gap; a size-dependent trend emerges. The optical band gap (Eg) of lead sulfide QD solutions were obtained through spectrophotometric analysis and compared to plots of Current vs. Potential acquired from CV experiments performed upon QD-based thin film samples. The QD thin films were fabricated using a layer-by-layer (LbL) method, by dipping a 1" x 1" glass substrate, coated with a transparent conducting thin film of ITO (indium-doped tin oxide), into a solution of oleic acid capped QDs in hexane solvent, followed by a dip into a solution of acetonitrile containing 1,2-ethanedithiol (EDT); approximately 20 cycles of this deposition process resulted in a film thickness of ~100 nm. Noticeable degradation of the PbS QD-based thin films was observed after several cycles, so the presented data was limited to the first or second cycle.

Lawrence Moses, *A study of CdCl2 treatment on CdS/CdTe Solar Cells***,** (Alvin Compaan)

CdS/CdTe solar cells are a rapidly-growing sector of the photovoltaics industry. A CdCl2 treatment improves the quality and performance of CdS/CdTe cells. In this study, we seek to understand how the length of treatment time affects the photoluminescence of a CdS/CdTe cell. We first created a CdS/CdTe cell through RF sputtering. We then cut the sample into 6 pieces. One piece was left untreated, and the remaining 5 were treated for different lengths of time. These samples were mounted into a cryo-stat chamber and their PL spectrum were measured both film side and junction side. Then we measured the power dependence of the peaks of some of our samples. Finally, we measured the temperature dependence of a sample. Our results are shown.

Logan Stagg, *Study of Cuprous Oxide thin Films for Use as Photovoltaic absorber Layers*, (Alvin Compaan, Kristopher Wieland)

With a bandgap of 2eV, cuprous oxide is of interest as an absorber layer in multijunction solar cells. Cuprous oxide thin films are deposited by reactive magnetron sputtering. Parameters including RF Power, substrate temperature and deposition pressure are varied. Films are analyzed using Raman spectroscopy, x-ray diffraction and UV-Vis transmission. After optimization of sputtering conditions, complete devices are made using CdS and Cu2O.

NSF-REU External Publications and Presentations*

REFEREED PUBLICATIONS - Submitted/accepted/published.

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

"*Multiwavelength Observations of V2775 ORI, an Outbursting Protostar in L 1641: A Transition to the FU Orionis Regime*," William J. Fischer, S. Thomas Megeath, John J. Tobin, Amelia M. Stutz, Babar Ali, Ian Remming, **Marina Kounkel**, Thomas Stanke, Mayra Osorio, Thomas Henning, P. Manoj, and Thomas Wilson, Astrophysical Journal (Submitted 2011).

Carlson, R. K. (2009), Shim, Y, Ingler Jr., W. B. "*Optimization of Indium Tin Oxide by pulsed DC power on single junction amorphous silicon solar cells*," Thin Solid Films 519, 6053-6058 (2011).

PRESENTATIONS WITH PUBLISHED ABSTRACTS.

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

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

REFEREED PUBLICATIONS - in Preparation.

Aultman, J., Ingler Jr., W. B. "*Indium oxide and cobalt oxide thin films on amorphous-silicon solar cells for hydrogen production*" (to be submitted 2012).

(Update from Annual Report 2010)

J. Bancroft Brown*(2008), M. S. Brown, S. Cheng, L. J. Curtis, D. G. Ellis, S. R. Federman and R. E. Irving, "Experimental and Semiempirical Branching Fractions of the $3s^2 3p^2 - 3s3p^3$ transition array in P II," Can. J. Phys. 89, 413-6 (2011).

Katie Hoepfl*(2010), Alvin Compaan, Andrew Solocha, "Comparison of Solar and Wind Power Output and a look at Real-Time Pricing," International Journal of Policy and Management, 2011 (in press).

*REU students' names in **bold face type*** with year of participation if not from summer 2011.

NSF-REU Physics and Astronomy
RESEARCH PROGRAM EVALUATION - STUDENT
2011

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

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

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

2011 mean (pop. 13): 1.8

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

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

2011 mean (pop. 13): 1.4

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

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

2011 mean (pop. 13): 1.5

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

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

2011 mean (pop. 13): 1.5

5. 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

2011 mean (pop. 5): 3.8

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

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

2011 mean (pop. 13): 5.8

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

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

2011 mean (pop. 13): 2.9

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

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

2011 mean (pop. 13): 3.8

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

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

2011 mean (pop. 13): 2.2

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

None: I did what I was told			**About Right**			**Too much: I got lost**
1	2	3	4	5	6	7

2011 mean (pop. 13): 3.9

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

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

2011 mean (pop. 13): 3.8

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

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

2011 mean (pop. 5): 2

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

More general learning			**Neutral**			**More research time**
1	2	3	4	5	6	7

2011 mean (pop. 13): 3.5

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

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

2011 mean (pop. 13): 1.2

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

Yes, the mailings in May were very helpful			**Neutral**			**No, I didn't know what to expect.**
1	2	3	4	5	6	7

2011 mean (pop. 13): 2.6

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?
    - To Expand my astronomical experiences
    - I wanted to get good research experience before attending grad school so that I would be better prepared.
    - To find out what research was about
    - opportunity, see if something I may want to do
    - The experience
    - Sounded like a good way to gain experience.
    - To get experience
    - To gain experience in producing useful scientific information
    - To get a foot into the field in preparation for graduate studies
    - Wanted to do something related to my future career
    - I wanted to try research before entering a commitment like grad school. As a bonus, it looks really good on a resume
    - I wanted experience in conducting academic research
    - To gain experience and help decide if a career in research is right for me
    - I wanted experience with experimental research as opposed to my previous experience with computational and analytical research

2. What prior knowledge did you find useful in your research project (e.g., courses, experiences, etc.)?
    - Previous Astronomy Coursework
    - I found some prior research experience and knowledge of programming helpful. My astronomy courses were a good background.
    - not really anything
    - presenting in classes
    - LAB WORK
    - Math classes, computer skills
    - 2 years of classes, no research
    - Mathematics is important
    - The fact I was familiar with Linux helped considerably
    - Computer Knowledge
    - My previous interest in astronomy was helpful in understanding the terminology
    - My knowledge of previous courses helped me a lot
    - Physics courses I took were helpful.
    - Hardly any

3. What knowledge was missing that would have helped you in your research project (e.g., courses, experiences, etc.)?
    - programming
    - more knowledge of IDL would have been useful.
    - Anatomy of the brain, magnetism/electricity, physics
    - Excel experience
    - Quantum physics

- Theoretical explanations of computer routines
- The electronics lab would have been beneficial
- My astronomical background was somewhat lacking
- none
- It would have helped if I had entered the program with a more extensive knowledge of programming
- I had no previous experience, but that was not an obstacle
- More advanced courses could have been helpful.
- Advanced lab, solid state physics

4. What new knowledge central to your project did you discover in your research?
- lots of things
- I discovered how to use he software STARLAB as well as how to write useful scripts in IDL.
- Cartical thickness charges
- New Astrophysics computer programs
- Atomic theory
- Data Reduction
- Accelerator physics and photovoltaics
- Physical properties of globular clusters
- A lot of information about dosimetry
- Programming!
- The LSAD Method definitely speeds computation and 22 Paedre's Diffusion Coefficient goes as 1/5
- Learned about Cuporous oxide thin films, Reactive magnetron sputtering ....
- Knowledge of solar cells and solid state physics

5. What new knowledge tangential or incidental to your project did you discover in your research (e.g., new methods, connections, resources, etc.)?
- plenty
- I learned a lot of computer science this summer.
- Not sure
- Not enough space to name them all
- Programming with excel
- Computer Programming
- Surface soldering, beam foil spectroscopy, beam characterization
- How to do rudimentary things like image correction or photometry
- Information about grad schools, different disciplines in Physics, etc.
- Not sure
- Nothing really unexpected showed up.
- Learned the general process of research, atmosphere, ...
- Knowledge of experimental methods

6. How might your research project impact the greater community (professional and/or societal)?
- Hopefully my publication will impact observationalists and theorists alike (working with binaries in star clusters).

- Help amputees deal with pain. Better understanding of pain in general.
- Energy!
- It is a new data set for mbmg that can be [used] for future property
- Providing Useful Data
- increase solar cell efficiency
- It may very well lead to an understanding of the beginning
- It will help the department in the future
- Not sure
- I have no idea... ask me in 20 years.
- ENERGY CRISIS AVERTED
- Hopefully my research will provide vital information about CdCl2 treatments

Please list any additional comments.

- air condition to the dorm room would have been nice
- great fun man !!
- Having The students in two separate dorms seemed to make serial events more difficult
- I am extremely pleased I got to have this tremendous learning experience as a first year. It truly sets me on the right path.
- Amazing program with amazing people. My mentor was fantastic, my roommates were great, and the program director went above and beyond to be sure we had an amazing summer!
- I had an amazing summer. This program must continue.

VIII. SUMMER 2010 PICTURES

REU's @ Work!

REU's having fun!

Images of A Successful Summer Camp 2011