Annual Progress Report (Year 4)

Research Experiences for Undergraduates in
Physics and Astronomy
NSF-REU Grant 1262810
Department of Physics & Astronomy
The University of Toledo
Toledo, Ohio 43606
June 2016
Richard E. Irving
Thomas J. Kvale

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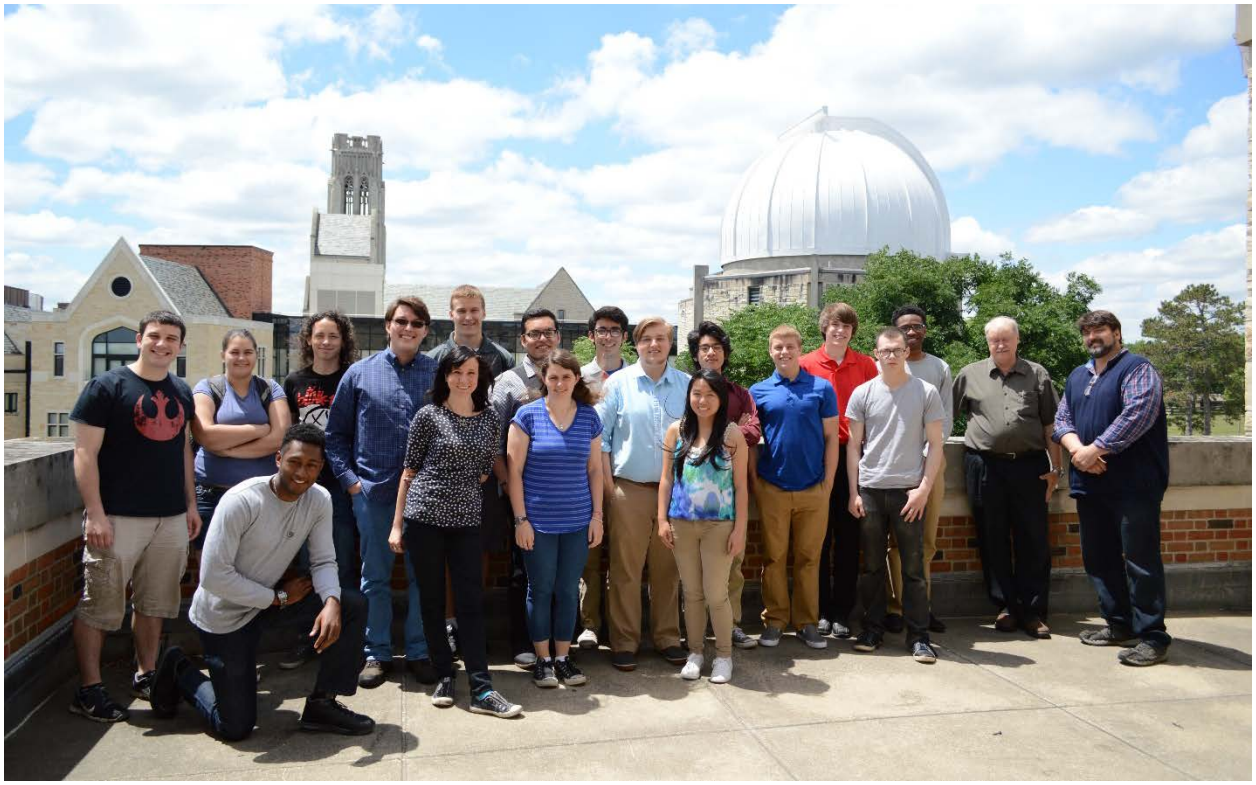
I. REU RESEARCH PARTICIPANTS, SUMMER 2016



REU students and mentors

REU Summer 2016 Participants

NAME	INSTITUTION	MENTOR	RESEARCH
Tim Alderson	University of Toledo	Khare	Condensed Matter
Ed Cichewicz	Ohio State University	Karpov/Shvydka	Condensed Matter
Sean Davis	University of Toledo	Amar	Computational Physics
Shaeley Diemer	University of Toledo	Podraza	Condensed Matter
Nicholas Dulaney	University of Toledo	Bjorkman/Richardson	Astrophysics
Aaron Harder	University of Toledo	Witt	Astrophysics
Nmandi Ike	St. Peter's University	Pearson	Medical Physics
Sarah Richie	University of Evansville	Yanfa, Grice	Condensed Matter
Logan Riney	University of Louisville	Amar, Shim	Computational C.M.
Raul Rodriguez	St. Mary's University	Shvydka	Condensed Matter
Pa Chia Thao	Mount Holyoke College	Bjorkman/Richardson	Astrophysics

Additional UT students participating in our research program but funded by OUR (UT Office of Undergraduate Research), faculty grants, or Self-supported

NAME	MENTOR	RESEARCH
Sanskar Basnet	Irving/Kvale	Atomic Physics
Hayden Graham	Irving	Computational Atomic Physics
Heidi Kuchta	Megeath	Astrophysics
Ben Shafransky	Irving	Atomic Physics
Nathan Szymanski	Khare, Liu	Condensed Matter Physics
James Windsor	Collins	Condensed Matter

II. SUMMARY OF SUMMER 2016

Introduction

The Summer 2016 NSF-REU program in Physics and Astronomy, directed by Dr. Richard Irving and Dr. Thomas Kvale, gave enhanced research opportunities to 11 undergraduate students from seven colleges and universities in six states. Student participants were chosen competitively out of 137 applications from students in 37 different states scattered throughout the U.S. In addition, the P.I., Richard Irving attended the Physics REU Site Director workshop in Houston, TX in October 2016.

We are pleased to report during the 2016-2017 academic year research involving previous REU students had one refereed publication and four conference presentations. We expect additional manuscript(s) from this past summer (2016) are in preparation and will be submitted shortly to refereed journals and/or presented at conferences. Also, our 2016 REU site had a student, Tim Alderson (Mentor: S. Khare) competitively selected to participate in the Council on Undergraduate Research's Research Experiences for Undergraduates Symposium, which took place on October 23-24, 2016. Tim presented his summer research, *Calculating Optical Properties of Delafossite Nitrides from First Principles* during a poster session at the symposium. This is two consecutive years for which one of our REU students was selected to participate at this symposium.

Advertisement and Selection

Again this year (Summer 2016) 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 mode of information transference and sufficient interest in our program, paper announcements were not sent thus saving our program significant costs of printing and postal fees. The emailing included a cover letter alerting the prospective students to our website. The selection committee was composed of Richard Irving (PI) and Thomas Kvale (Co-PI). 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://www.utoledo-pa-reu.org/ .

Registration and Housing

This year, all of the student participants coming from outside of Toledo lived in the International House dormitory with the NSF-REU grant providing the housing costs to these students. This dorm is organized into suites adjoining a common area that encouraged social interactions among the REU students. This dorm also has kitchen facilities for the students to cook their meals if they choose to do so. One of the goals of the NSF-REU program is to enable social interactions among the students, who will become the scientists of tomorrow. This infrastructure of friendships leads to the fruitful exchange of ideas, which is useful in the advancement of physics and astronomy. We feel that we can best accomplish this goal by housing the students together on campus and to foster off-hours social activities. We encouraged Residence Life to house all undergraduate students participating in other research programs close to the REU students.

Networking & Social Activities

As has been the case for several years now, social activities were coordinated by the students themselves with the help of the local REU and UT participants. Activities included movie nights, sports and board games, and various ventures to local restaurants. Some of the other events included: a UT Planetarium show, a trip to Cedar Point Amusement Park, and visits to the Toledo Zoo and Toledo Museum of Art. The REU calendar can be found via the REU link on our department home page at: http://www.utoledo.edu/nsm/physast/. In July, we had a field trip to the Bowling Green Wind Turbines, located 30 miles from Toledo. We also toured First Solar manufacturing plant in suburban Toledo as discussed later in this report.

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 2016 BROWN BAG SEMINARS (Noon – MH 4009)

June 01 REU Orientation

June 07 *"Measuring Atomic Lifetimes,"* Negar Heidarian Boroujeni

June 14 *"Careers in Physics,"* Part 1 MC'ed by Dr. Jillian Bornak

June 15 *"Careers in Physics,"* Part 2 MC'ed by Grad Students!

June 21 "*Ritter Observatory: Our local gateway to the BRITE-est stars,"* Noel Richardson

June 28 REU progress reports

July 05 *"Social media talk,"* Michael Cushing

July 12 "The power of Ellipsometry," Nik Podraza

July 19 "A WISE Introduction to Our Nearest Neighbors," Jennifer Greco

July 25 "Finding the Absolute in a Relative World: the human perception of vision," Lawrence Anderson-Huang

July 26 "Elasticity and conservation of energy in the Mesozoic", Scott Lee

Aug. 02 REU Final Presentations @ 12:00 pm in MH 4009

Aug. 03 REU Final Presentations @ 12:00 pm in MH 4009

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 UGR2980 course mentioned below, OUR-UT worked with the Office of Residence Life in creating a common "Living/Researching" community for all students conducting research in the summer and living on campus. Additional university procedures were facilitated in the background by OUR-UT.

We also required our students to attend a second, university-wide seminar series that formed the basis of the course, UGR2980: "*Issues in Research and Scholarship*". This course was coordinated by the Office of Undergraduate Research. 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 listed below. Each presentation lasted about an hour and there was ample time for

Questions/Answers for each speaker. We actively promoted the importance of this course at the REU Orientation at the beginning of summer however from the evaluations, some REU students appeared not to think it was relevant to them in physics. The Jesup Scott Honors College Associate Dean, Steven Peseckis, served as UGR2980 coordinator from June 01-July 31, 2015.

UGR2980: *"Issues in Research and Scholarship"* Research Seminar Schedule Summer 2016

UGR2980 Summer Research Presentation Schedule 2016

All presentations are scheduled for Thursdays from 9-10am, in **Rocket Hall**, RH1520.

UNDERGRADUATE RESEARCH
THE UNIVERSITY OF TOLEDO

June 02	9:00am	"*Summer Schedule & Procedures*" – **Thomas Kvale**, Director, Office of Undergraduate Research
	9:15am	"*Laboratory Safety*" – **Andrew Shupp**, Office of Safety & Health
	10:15am	Refreshments
June 09	9:00am	"*Research Ethics and Compliance*" – **William Messer**, Office of Research & Sponsored Programs
June 16	9:00am	"*Advanced Research in the Library*" – **Wade Lee**, University Libraries
June 23	9:00am	No Presentation
June 30	9:00am	"*Ethical Academic and Research Conduct*" – **Steven Peseckis,** Associate Dean, Honors College
July 07	9:00am	"*Plagiarism and Academic Honesty*" – **Barbara Schneider**, Senior Assoc. Dean, College of LLSS
July 14	9:00am	"*Business Prospects and Patents*" – **Mark Fox**, Office of Research & Sponsored Programs
July 21	9:00am	"Responsible Conduct of Research" – **Pamela Suhan**, Office of Research & Sponsored Programs
July 28	9:00am	"*Overview and Summation*" – **Thomas Kvale**, Director, Office of Undergraduate Research

August 04 (All day) **Summer Research Presentations (SU2582/2584):**

- 8:30am - 9:00am **Oral and Poster Presentation Set-up**
- 9:00am - 9:15am **Welcoming Remarks, Provost Andrew Hsu**
- 9:32am - 12:00pm **Oral Session 1**
- 12:00pm - 1:00pm **Pizza Lunch and Poster Session**
- 1:12pm - 2:24pm **Oral Session 2**
- 2:24 PM Welcome **William Messer, Jr.**, Vice President for Research, University of Toledo
- 2:48pm - 4:00pm **Oral Session 2** (cont.)

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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.

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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Physics and Astronomy Summer Events 2016

As part of our REU program we have an outreach component. This past summer the students decided to volunteer at Imagination Station to help with the "Nerdy Derby". This event took place on a Saturday and Sunday afternoon where the REU students helped local area children and their parents design, build, and race their cars down the hills and valleys of a 40 foot track. The cars were made of such things as balsa wood, bolts & washers, straws, rubber bands, and glue. The coordinator of the event said that on the order of 400 cars were built each day! Part of this stock was utilized by the REU's to have their own race-off at the end of each day!

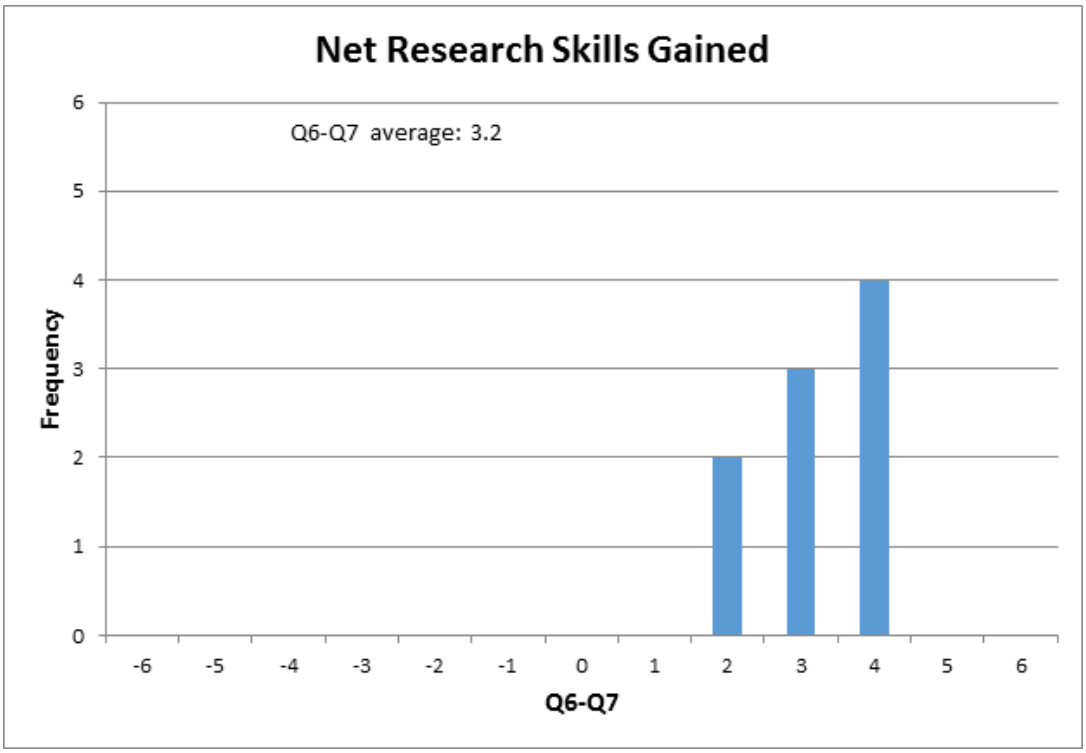
The REU group decided to check out some of the local area renewable energy technologies and so tours were organized to meet this end. A tour of Bowling Green's 7.2 megawatt wind farm provided the students with an opportunity to explore the wind turbines inside and out. Students had many good questions ranging from the impact on the wild life (e.g. birds & bats) to career opportunities as a Wind Turbine Technician. A tour of the First Solar plant was no less informative. A very illuminating presentation with question answer period preceded the tour. Our Department's history associated with the beginnings of First Solar was also discussed. The First

Solar tour guides escorted groups of students throughout the plant to view various aspects of the manufacturing process for the CdTe solar panels. People were very impressed with methodologies utilized to provide the quality control needed to produce a good solar panel.

Social events during the 2016 program included two camping expeditions with star gazing in mind. One site recommended by the Toledo Astronomical Society was at Lake Hudson in Michigan. This is Michigan's First Dark Sky Preserve. In fact with the passage of Michigan Public Act 57, 1993 (MCL 322.821-826), Michigan became the first state in the nation to designate a tract of public land as a "Dark Sky Preserve." One of the UT REU students, Aaron Harder, brought his own telescope for the occasion. The other campsite visited by our group was Sterling State Park in Michigan, right next to Lake Erie. On the Ohio side of Lake Erie one of the last group outings was to none other than Cedar Point! Screams filled the air as our group experienced the best in which Cedar point had to offer.

Program Evaluation Summary

Every year we have had the students fill out a Summer Research Evaluation survey. We have two related questions to see how they view the value of the research experience. The questions are: Q6. "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?" and Q7 similar except for "... at the end of summer?". The numerical choices ranged from 1 to 7 with 1-"Very skilled/knowledgeable", 4-"Neutral", and 7-"Not Very skilled/knowledgeable". By subtracting Question 7 from Question 6, the students reported their net research skills gained from participation in our program last summer. The graph below shows their assessment that they have grown in the field. The full evaluation is included later in this report.



NSF-REU External Publications and Presentations (REU students' names in **bold face type** and their year of participation in parenthesis also in **bold face type**.)

Refereed Publications

"A Spectroscopic Orbit for the Late-Type Be Star β CMi," **Nicholas A. Dulaney (2016)**, et al., The Astrophysical Journal 836:112 (2017). doi:/10.3847/1538-4357/836/1/112

Conference Presentations

Tim Alderson (2016), "Calculating Optical Properties of Delafossite Nitrides from First Principles." Submission ID: 248609, Council on Undergraduate Research's Research Experiences for Undergraduates Symposium, NSF Atrium, Arlington, VA, October 23-24, 2016.

Nicholas A. Dulaney (2016), et al., Presentation 151.08 – "A spectroscopic orbit for the late-type Be star β CMi," The 229th American Astronomical Society Meeting, Grapevine, TX, 3-7 January 2017.

Pa Chia Thao (2016), et al., Presentation 151.06 – "The Be Population in 10 Galactic Open Clusters From the Discovery Channel Telescope," The 229th American Astronomical Society Meeting, Grapevine, TX, 3-7 January 2017.

Anthony Burrow (**Pa Chia Thao (2016)** co-author), et al., Presentation 151.07 – "Variable Circumstellar Disks: Prevalence, Timescales, and Physical Mechanisms," The 229th American Astronomical Society Meeting, Grapevine, TX, 3-7 January 2017.

Other Presentations

Pa Chia Thao (2016) presented her research on Be Stars at the Mount Holyoke College's SPS Annual Poster Session, October 25, 2016.

Tim Alderson (2016), **Nicholas Dulaney (2016)**, and **Aaron Harder (2016)** presented their research at the UT's Annual Department of Physics and Astronomy Undergraduate Research Colloquium, September 22, 2016.

Concluding Remarks

We feel it is important to involve the students with all aspects of the scientific research process. To the extent possible, depending on the nature of the project, students participate in the selection of the problem, the choice of research method, the collection and analysis of data, the formulation of conclusions, and the presentation of the results. The research problems are parts of ongoing faculty research programs, which are in most cases supported by external grants. At the same time, every effort is made to identify a piece of the research for which the REU student has the primary responsibility. The students are asked to write a final report, including a carefully-written abstract which could be submitted as a contribution to a regional or national meeting, as well as give a 15 minute presentation at a Bag Lunch in the final week of their research period. The typical length of the final reports is about 10-20 pages. These requirements have helped the students to become experienced in technical writing and presentations. The success of this philosophy is attested by the fact that many of our REU students are authors on manuscripts that have been published, submitted, or are in preparation.

III. DEMOGRAPHICS

NSF-REU Summer 2016 Applications
Geographical distribution by undergraduate institution
(Applications REU - 137 / REU Offers Made- 14 / REU Accepted- 11)

ARKANSAS	
The University of Arkansas	(1/0/0)
ALABAMA	
Samford University	(1/0/0)
Auburn University	(1/0/0)
ARIZONA	
Arizona State University	(1/0/0)
University of Arizona	(1/0/0)
CALIFORNIA	
Calif. State Univ., Long Beach	(1/1/1)
Harvey Mudd College	(1/0/0)
University of California Berkeley	(3/0/0)
San Diego State University	(1/0/0)
Cali. Polytechnic State University	(2/0/0)
Oberlin College	(1/0/0)
Calif. State Univ., Chico	(1/0/0)
COLORADO	
Brown University	(1/0/0)
Pueblo Community College	(1/0/0)

Colorado College (1/0/0)

CONNECTICUT
Barnard College (1/0/0)

DISTRICT OF COLUMBIA
American University (1/0/0)

FLORIDA
University of Florida (1/0/0)
University of North Florida (1/0/0)
Florida International University (2/0/0)
University of South Florida (2/0/0)

GEORGIA
Valdosta State University (1/0/0)

IDAHO
Brigham Young University - Idaho (1/0/0)
Willamette University (1/0/0)

ILLINOIS
Monmouth College (1/0/0)
University of Illinois Urbana (1/0/0)
University of Illinois (1/0/0)
Adrian College (1/0/0)
Luther College (1/0/0)

INDIANA
DePauw University (1/0/0)
Manchester University (1/0/0)
Univ. of Evansville (1/0/0)

IOWA
Grinnell College (1/0/0)

KANSAS
The University of Kansas (2/0/0)
Kansas Wesleyan University (2/0/0)

KENTUCKY
Transylvania University (1/0/0)
University of Kentucky (1/0/0)

LOUISANIA
Louisiana State University (2/0/0)

MAINE
Bowdoin College (1/0/0)

MARYLAND
Carnegie Mellon University (1/0/0)

MASSACHUSETTS
Smith College (1/0/0)
Tufts University (1/0/0)
Mount Holyoke College (1/0/0)
Brandeis University (1/0/0)

MICHIGAN
Saginaw Valley St. U (1/0/0)
University of Mich. (2/0/0)
Wayne State University (1/0/0)

MINNESOTA
Univ. of Minnesota-Twin Cities (1/0/1)
Gustavus Adolphus College (1/0/0)
Bethel University (1/0/0)
St. Olaf College (2/0/0)

NEW JERSEY
Saint Peter's University (1/0/0)

NEW MEXICO
New Mex-Institute of Mining Tech (1/0/0)

NEW YORK
Stony Brook University (2/0/0)
Queens College (1/0/0)
Fordham University (1/0/0)
Rochester Institute of Tech. (1/0/0)
Columbia University (1/0/0)
Le Moyne College (1/0/0)
SUNY Geneseo (2/0/0)
Bard College (1/0/0)
Hamilton College (1/0/0)

NORTH CAROLINA
Univ. of North Carol. at Chapel Hill (1/0/0)

OHIO
Bowling Green State University (2/0/0)
John Carroll University (3/0/0)
The University of Akron (1/0/0)
University of Toledo (11/0/0)
Ashland (1/0/0)
Wright State University (1/0/0)
Ohio State University (2/0/0)

OKLAHOMA
University of Oklahoma (2/0/0)
Oklahoma Baptist University (1/0/0)

OREGON
Oregon State University (1/0/0)
Reed College (1/0/0)

PENNSYLVANIA
Millersville Univ. (1/0/0)
Lycoming College (2/0/0)

West Chester Univ.	(1/0/0)
Carnegie Mellon University	(3/0/0)
University of Rochester	(1/0/0)
Ursinus College	(1/0/0)
Dickinson College	(1/0/0)
Grove City College	(1/0/0)
Penn State Univ.	(1/0/0)

PUERTO RICO

University of Puerto Rico	(1/0/0)
Univ. of PR at Humacao	(2/0/0)

RHODES ISLAND

Charelton College	(1/0/0)

SOUTH CAROLINA

Clemson University	(1/0/0)

TEXAS

Carleton College	(1/0/0)
Univ. of Tex-Dallas	(1/0/0)
Southwestern University	(1/0/0)
St. Mary's University	(1/0/0)

VIRGINIA

University of Mary Washington	(1/0/0)

WASHINGTON

Western Washington University	(1/0/0)
University of Washington	(1/0/0)
Lewis and Clark College	(1/0/0)
University of Puget Sound	(1/0/0)
The Evergreen St. College	(1/0/0)

WISCONSIN

University of Wisc. Madison	(2/0/0)
Beloit College	(1/0/0)

NSF-REU Participant* Demographics Summer 2016

Gender

Female: 3
Male: 8*
*In addition, 5 other men participated in our program funded by other sources.

Class Rank (As of Spring semester 2016)

Freshman: 1
Sophomore: 5
Junior: 5
Senior: 0

Ethnicity

American Indian: 0
Alaskan Native: 0
Asian American: 1
(or Pacific Islands)
African American: 2
Hispanic American: 1
European American: ……..… 7
Other:

Home State

New Jersey ….....…… 1
Kentucky……..…… 1
Massachusetts 1
Ohio 6
Texas 1
Tennessee ….....…… 1

Home Institution

The Ohio State University ... 1
St. Peter's University…..... 1
University of Evansville 1
University of Louisville 1
St. Mary's University 1
Mount Holyoke College ….. 1
University of Toledo ….... 5
Students with minor REU funding or from other sources
University of Toledo …..... 5

REU Students Grade Point Average: 3.5

IV. RESEARCH

REU 2016 Final Presentations
Each talk is scheduled for 12 minutes allowing 3 additional minutes for questions.

Tuesday, August 2nd Room: MH 4009

Schedule	Name	Home Institution	Mentor(s) .
12:00 PM	Raul Rodriguez	St. Mary's University	Shvydka
12:15 PM	Ed Cichewicz	Ohio State University	Karpov
12:30 PM	James Windsor	University of Toledo	Collins
12:45 PM	Shaeley Diemer	University of Toledo	Podraza, Koirala
1:00 PM	Nmandi Ike	Saint Peter's University	Pearson
1:15 PM	Aaron Harder	University of Toledo	Witt
1:30 PM	Sanskar Basnet	University of Toledo	Irving, Kvale
1:45 PM	Hayden Graham	University of Toledo	Irving

Wednesday, August 3rd Room: MH 4009

Schedule	Name	Home Institution	Mentor(s) .
12:00 PM	Logan Riney	University of Louisville	Amar
12:15 PM	Sean Davis	University of Toledo	Amar
12:30 PM	Sarah Richie	University of Evansville	Yanfa,Grice
12:45 PM	Tim Alderson	University of Toledo	Khare, Liu
1:00 PM	Nathan Szymanski	University of Toledo	Khare, Liu
1:15 PM	Pa Chia Thao	Mount Holyoke College	Richardson, Bjorkman
1:30 PM	Nicholas Dulaney	University of Toledo	Richardson, Bjorkman

ABSTRACTS OF REU FINAL REPORTS SUMMER 2016
The University of Toledo, Department of Physics & Astronomy
(Faculty Mentor in parenthesis)

Astrophysics

Nick Dulaney *Detection and Understanding of the Companion to β CMi* (J. Bjorkman)

β CMi is a late Be type star which has shown to be particularly stable as it has been studied. This led to realistic modelling by Klement et al (2015) showing the outward flow of the material of the disk; This modelling showed the disk is likely truncated at some radius from the star. Truncation of a decretion disk like the results show is well known to be caused by an orbiting binary star in many cases. This project uses an analysis of spectroscopic data form Toledo's Ritter Observatory of β CMi in an attempt to locate this supposed companion star. We have detected orbital motions caused by this companion star in small shifts in the Hα emission line. Subsequently, we compared the small changes in the violet-to-red peak height (V/R) with the detected orbital motion. Although we were able to detect slight variability in the V/R ratio in the Hα emission, evidence that it follows orbital motion, as suggested by recent binary models by panoglou et al (2016), is weak. We have also analyzed near infrared moderate resolution spectra from the SpeX spectrograph on NASA's InfraRed Telescope Facility. The results of these analyses show variations in the Paβ and Brγ emission lines which shows that there could be some structure present in the inner part of the disk. These results suggest that β CMi is the result of binary evolution where roche lobe overflow has spun up the Be star and has left behind a white dwarf or hot subdwarf in orbit around β CMi.

Aaron Harder *Diffuse Interstellar Bands: Strengths in Relation to Ultra-Violet Radiation Intensity* (A. Witt)

Diffuse Interstellar Bands (DIBs) are absorption features ubiquitous in the spectra of reddened stars. The correlation of their strengths with color excess suggests that their carriers reside within the interstellar medium, intermingled with the dust. We take a look at the relationship between the intensity of local ultraviolet radiation fields and the normalized strengths of the DIBs in search of a possible correlation to better understand the nature of the DIB carriers.

Pa Chia Thao *The Search for Be stars in 8 Galactic Open Star Clusters* (J. Bjorkman)

As part of a multi-site, multi-epoch campaign to study the time-scales of disk growth and dissipation for classical Be stars, we have studied ten Galactic open clusters with multi-color photometry (Johnson BVRIJK and narrow band H-alpha and an adjacent continuum filter). We have created color-magnitude and color-color diagrams to isolate the Be stars in the targeted clusters. These clusters have previously been determined to contain multiple Be stars. From our early analysis of the clusters we have found a number of new candidate Be stars**,** as well as a few stars in each cluster that appear to have lost their gaseous disks. Such studies of clusters will provide a statistical basis for understanding the evolution of the disks around these stars and may provide insights into the formation processes for the Be stars.

Computational Physics

Sean Davis *Simulating Diffusion-Annihilation Reactions: Anomalous Diffusion,* (J. Amar)

Diffusion-controlled annihilation plays an important role in a variety of contexts including particle-antiparticle annihilation, electron-hole recombination in semiconductors, vortex-antivortex diffusion annihilation in a superfluid, binary reactions in one dimension, and exciton fusion kinetics. Of particular interest is the exponent α governing the long-time decay of the particle density n(t), e.g. $n(t) \sim t^{-\alpha}$ and its dependence on substrate dimension and diffusion kinetics. While the exponents characterizing the decay of the particle density have been studied for the case of ordinary diffusion, the case of particle subdiffusion (due for example to disorder) has not previously been studied. In order to investigate the effects of subdiffusion on the exponent α we have carried out extensive kinetic Monte Carlo simulations in both one-dimension (d = 1) and two-dimensions (d = 2). In our simulations, the diffusion exponent μ - defined such that the mean-square displacement $(\Delta r(t))^2 \sim t^{2\mu}$ - was varied between $\mu = 0$ and $\mu = 1$. In order to efficiently carry out simulations for large system sizes, we have developed and implemented a binary heap algorithm which improves the scaling of the simulation time from N^1 to log(N) as a function of the total system-size N. For the case of one-dimension (d = 1) we find good agreement between results for $\alpha(\mu)$ and a mean-field theory prediction $\alpha = \mu d/2$. However, in d = 2 we find that logarithmic corrections need to be taken into account, e.g. $n \sim \log(t)/t^{\mu}$. Taking this correction into account we find excellent agreement with mean-field theory.

Logan Riney *Temperature Accelerated Dynamics Simulation of Cu/Ni(110) Growth* (J. Amar)

The significant advance in experimental techniques over the past few decades has enabled the creation and investigation of materials on the atomic scale. One interesting system is Cu/Ni(110) growth in which it was found that there was significant atomic intermixing on the surface of Ni(110) after the deposition of Cu, while there is negligible or no intermixing in Cu/Ni(100) and Cu/Ni(111). The intermixing that takes place on Cu/Ni(110) results in the formation of quasi-1D nanostructures. In order to understand the embedding mechanisms in the system, we have carried out temperature accelerated dynamics (TAD) simulations of Cu/Ni(110) growth using empirical many-body AFW EAM Cu/Ni potential. After careful study of many different attempted and accepted configurations, we have identified a low-energy, two-step embedding mechanism. This process, named nearby Atom-Mediated Embedding, takes place when Cu atoms near each other cause the embedding of Cu into the Ni substrate. This results in the decrease in the total energy of the system. The energy barrier for this mechanism is 0.45 eV, which is lower than the single atom process of 0.54 eV. In addition, the embedding sites act as nucleation sites for the other diffusing atoms on the surface, leading to the strip-like formations. It was also found that the degree of embedding increases with increasing temperature and vacancy density, consistent with experimental results. At 300K the event is estimated to occur at a rate of every 13.3 μsec. This nearby atom-mediated embedding process seems to be the dominant mechanism associated with the atomic intermixing of the Cu/Ni(110) system. More calculations and simulations need to be done in order to have better understanding of the subtle effects of complex interactions between atomic species on intermixing process in Cu/Ni(110).

Condensed Matter Physics

Tim Alderson *Optical Properties of Delafossite Structured ABN_2 (A = Cu, Ag, Au; B = V, Nb, Ta) Using Density Functional Theory* (S. Khare)

We have computed the structural, energetic, electronic and optical properties of the family of ternary nitrides of the form ABN_2 with A = Cu, Ag, Au and B = V, Nb, Ta in their delatfossite structure using first principles calculations based on density functional theory. All nine compounds

were structurally optimized with respect to ionic positions using the generalized gradient approximation. Electronic and optical properties were computed with hybrid GGA and Hartree-Fock functionals for accurate results. We further computed reflectance, absorbance and positions of quasi-particle excitation energies and the complex index of refraction. We find good agreement of the properties for $AgTaN_2$ and $CuNbN_2$ where experimental measurements exist in the literature. For the other compounds we make predictions and discuss their implications for applications in solar cells and other optoelectronics.

Ed Cichewicz *Bipolar and Unipolar Behavior of The Coherer's I-V Characteristic Curve* (V. Karpov and D. Shvydka)

Coherers were a circuit element used to detect RF pulses during the advent of the radio era. Experimentally, they had not been revisited for decades. This inquiry breaks from that trend, seeking to find characteristics linking modern resistive memory and coherers. To do so, a source meter was used to apply a range of voltages and record resulting currents. Upon analysis of current-voltage characteristics, certain features appear to reflect the unipolar and bipolar characteristics of resistive memory. These findings are discussed in detail, and implications explored.

Shaeley Diemer *Spectroscopic Elipsometery and Quantum Efficiency Analysis of Cadmium Telluride Solar Cells* (N. Podraza and Prakash Koirala)

Renewable energy has been a hot topic in the world in recent years. People are trying to push for cleaner and more reliable sources of energy while scientists try to farther improve the efficiency for these new energy sources. Solar energy in particular has seen major improvements in the efficiency, with constant research being made to continue this progress. The reason behind this research was to measure the quantum efficiency of the different layers in individual solar cells, specifically the cadmium telluride layer. These solar cells were different from the typical cadmium telluride solar cells on account of the cadmium telluride being oxygen doped. Being oxygen doped, the hope was to increase the overall efficiency in the cells by increasing the absorption in the cadmium telluride layer of the solar cell. The quantum efficiency was calculated by taking measurements from a spectroscopic ellipsometer and fitting the data to a model.

Sarah Richie *$Mg_xZn_{1-x}O$ Buffer Layers via Atomic Layer Deposition for CdTe Solar Cells* (Y. Yan)

In a previous study, $Mg_xZn_{1-x}O$ was deposited through RF sputtering to be used as a HRT layer and window layer for CdTe devices, but has not been optimized. $Mg_xZn_{1-x}O$ has not been deposited through other means such as ALD and reported in literature. In this study, ALD was used as a deposition means and the film was characterized by grain size through SEM, phases through XRD, band gap through UV-vis spectrophotometry, sheet resistance, resistivity, carrier concentration, mobility through Four Point probe and Hall Effect. The layer ratio of the $Mg_xZn_{1-x}O$ film via ALD was determined that matched the composition of the film in the previous study. The $Mg_xZn_{1-x}O$ film was used in a CdTe device, but did not exhibit as high of efficiency in the reference.

Raul Rodriguez *Promoting Sn Whisker Growth using Ir-192 Irradiation* (D. Shvydka)

This project involved irradiating Sn thin films on glass with the gamma-ray source of Ir-192 (clinical high-dose rate brachytherapy source). The idea is to create charged defects within glass substrate under irradiation, with charges resulting in electric field in the direction perpendicular to the film. In preparation for the experiments, a Monte Carlo model of irradiation

geometry was developed, which gave the radiation dose distribution within a sample of Sn film on 3 mm soda-lime glass. This model was then compared to the dose distribution obtained from a commercial treatment planning system, BrachyVision, and some small differences were found. The Monte Carlo model is thought to be more accurate in predicting the dose because the planning system does not account for inhomogeneities.

Medical Physics

Nnamdi Ike *Study of SBRT spine patients and MRI's role in Spinal Cord Delineation* (D. Pearson)

The study tested the hypothesized correlation between the spinal cord positioning in the spinal canal channel relative to the spinal vertebrae. With this, an assessment is made on whether or not an MRI image is needed for a stereotactic body radiation therapy spine patient's spinal cord delineation during treatment planning. From the full vertebral column population we obtained two sample sizes, the cervical and thoracic vertebrae. After forming a value from measuring the space between the spinal cord relative to the vertebral body and pedicle, approximate contours were made. The contoured approximate cord resulted in a cervical and thoracic spinal cord inaccuracy of 12.17% and 16.14% respectively. The results are promising as the MRI cord and approximate cord are subjected to similar dosage but due to the limited sample size a more extensive study with new patients are needed.

V. STUDENT PROGRAM EVALUATION

NSF-REU Physics and Astronomy
2016

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

2016 mean (9 responses/pop. 11): 1.7

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

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

2016 mean (9 responses/pop. 11): 1.7

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

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

2016 mean (9 responses/pop. 11): 2.0

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

2016 mean (9 responses/pop. 11): 1.6

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

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

2016 mean (9 responses/pop. 11): 3.7

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

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

2016 mean (9 responses/pop. 11): 5.7

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**			**Notvery skilled/knowledgeable**
1	2	3	4	5	6	7

2016 mean (9 responses/pop. 11): 2.4

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

2016 mean (9 responses/pop. 11): 3.9

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

2016 mean (9 responses/pop. 11): 2.0

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

2016 mean (9 responses/pop. 11): 3.6

11. How do you rate the Physics/Astronomy Bag Lunches and the UGR2980 seminar presentations?

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

2016 mean (9 responses/pop. 11): 1.6

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

2016 mean (9 responses/pop. 11): 1.7

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

2016 mean (9 responses/pop. 11): 3.8

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

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

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

2016 mean (9 responses/pop. 11): 1.4

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

2016 mean (9 responses/pop. 11): 3.4

Critical Reflection Questions/Comments

From 2016 REU Summer Program
Critical Reflection Questions:

1. Why did you choose to become involved in a research project this summer?
    - Physics professor recommended that I participate
    - Obtain experience in my career field
    - I wanted research experience
    - Research seems to be a critical part of learning physics
    - I wanted to learn more about the subject and I thought it would look really good
    - To learn more about medical physics as a career
    - To continue my project from during the school year
    - Because I wanted to take on a project that I wouldn't be able to back at my institution

2. What prior knowledge did you find useful in your research project (e.g., courses, experiences, etc.)?
    - Courses and research experience
    - REU here last summer
    - Pretty much all physics courses I've taken so far (up to QM)
    - Modern physics
    - My quantum physics class, optics class, and various papers about the subject
    - Lab courses in general
    - Leadership/self-motivation
    - Scientific papers/research assignments
    - Basic physics classes
    - Modern physics
    - Computer skills, college math/physics

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

- Programming skills
- Programming, atomic/particle physics
- None
- Sometimes the hardest thing is knowing what to do when you get stuck
- Knowing about the software and various types of programming
- Anatomy
- There were a few courses I wish I took before coming here but regardless, my advisor helped me a lot

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

- The subject my research was on was something new
- I lack in coding and that's a skill I need to improve
- We fixed an issue in our program that persisted for months before hand, so we were finally able to move on in our project
- Radio therapy software
- How the solar cells work, what all goes into it and the study of how to make them better
- Experimental techniques + expectations for representing data
- Medical physics and radiation oncology
- Basic programming, basic logic, analytical skills

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

- Programming, modeling
- I discovered how to replicate results using a different method
- Motivation/inspiration can come from anywhere. A good scientist is well-rounded
- Made lots of new connections to many people who are very knowledgeable to the subject.
- Radiation oncology procedures
- New python methods for better quality analysis of results
- New methods: reducing images, using a telescope

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

- Photovoltaic applications
- Improves treatment for cancer patients
- Working with solar cells can better help understand how to make them more efficient, which can help to make them more common; better to use the renewable energy
- My research showed that things can be connected in unexpected ways, and anyone can do research
- Solar cells will be useful in society
- Innovative productions and improvement of safety in products made in industry

- New research on a subject that has been overlooked

Please list any additional comments:

- It would have been nice to have regulated hours, so all REU students would be working similar hours, mostly so students would not be worked consistently over 40 hrs a week. Also it would have been nice to know id I would be working mainly was a grad student and never meeting with my faculty mentor 1 on 1.
- Thank you for a great summer!
- I'm so thankful for my experience here

VI. NSF-REU Physics and Astronomy Picture Collage 2016