# Annual Progress Report (Year 1)

Research Experiences for Undergraduates in
Physics and Astronomy
NSF-REU Grant 1950785

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

June 2021

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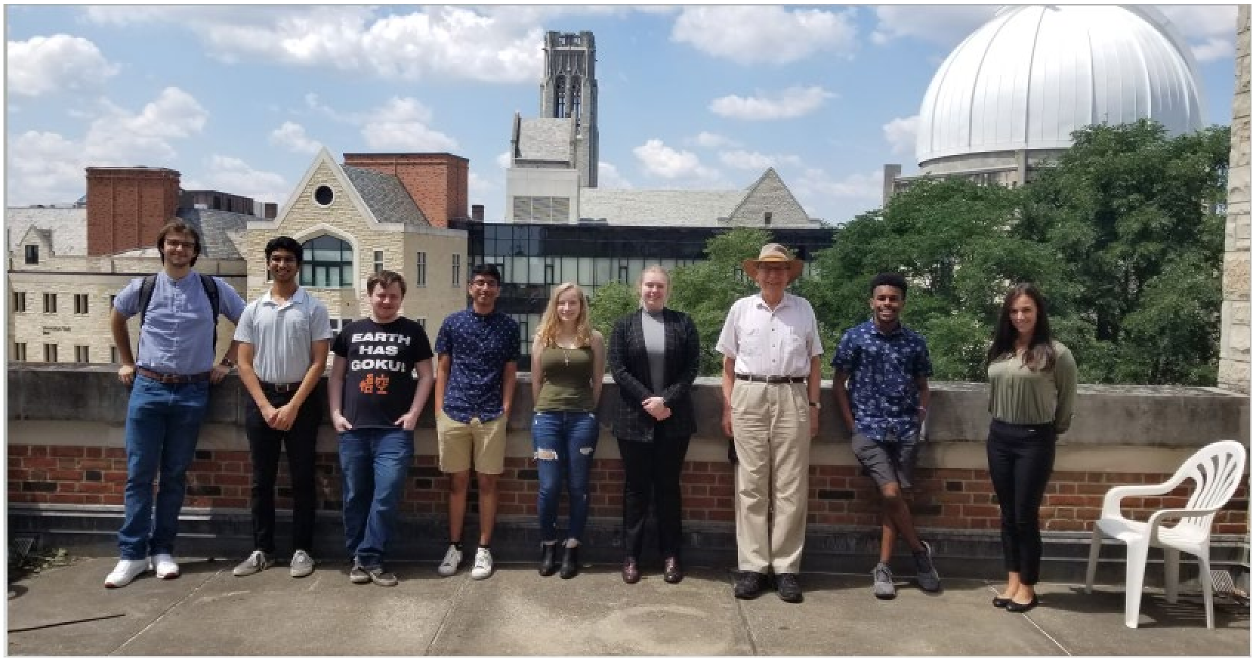
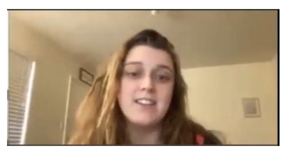



**Left to right:** Patrick Knowles, **Aman Kapoor**, **Robert Snuggs**, **Ernesto Flores**, **Rachel Paulin**, **Sarah Tucker**, Prof. Adolf Witt, **Zion Thomas**, **Shannon Costello**. (REU students: **bold face font**)

*Not shown above:* REU **Rebecca Nelson**: 

**REU Summer 2021 Participants:**

| **REU Student** | | **Home Institution** | **Mentor(s)** | **Research Area** |
|---|---|---|---|---|
| Shannon | Costello | Monroe CC | Assoc. Prof. Shvydka, Assoc. Prof. Pearson | Medical Physics |
| Ernesto | Flores | University of Texas at San Antonio | Prof. Yanfa Yan | Condensed Matter Experiment |
| Aman | Kapoor | Case Western Reserve University | Assist. Prof. Aniruddha Ray | Biophysics |
| Rebecca | Nelson | Southern Utah University | Professor Sanjay Khare | Condensed Matter Theory |
| Rachel | Pauline | University of Michigan-Dearborn | Prof. Rupali Chandar | Astrophysics |
| Robert | Snuggs | University of Toledo | Dr. Richard Irving | Atomic Physics |
| Zion | Thomas | Case Western Reserve University | Prof. Rupali Chandar | Astrophysics |
| Sarah | Tucker | Ohio Northern University | Prof. Emeritus Adolf Witt | Astrophysics |

## II. SUMMARY OF SUMMER 2021

### Introduction

The Summer 2021 NSF-REU program in Physics and Astronomy, directed by Dr. Richard Irving and Prof. Sanjay Khare, gave enhanced research opportunities to 8 undergraduate students from seven colleges and universities in six states. Student participants were chosen competitively out of 31 applications from students in 12 different states scattered throughout the U.S. In addition, Professor Michael Heben authorized funding for a REU equivalent stipend from the McMaster Endowment for Patrick Knowles, a Bowling Green State University student, to participate in our summer program. Professor Jacques Amar was the mentor for Patrick's research involving Condensed Matter Theory project. Mr. Knowles' abstract is posted later this document.

### Advertisement and Selection

This year (Summer 2021) we utilized a web-based advertisement and application system along with an email announcement to 82 Physics and Astronomy Department chairs with a concentration sent to Ohio, Michigan, and Indiana Community and 4-year colleges. Due to the COVID-19 situation our site delayed the application process until permission was granted to host the REU program. Therefore, based on a pattern of the applications and inquiries, we believe this time the email announcement was the most effective way to notify the students about our program. However, this will probably change back to the web-based advertisement as most effect next year since COVID-19 will hopefully be less of an issue and allow the application process to start on time. 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 flyer alerting the prospective students to our website. The selection committee was composed of Richard Irving (PI) and Sanjay Khare (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: https://www.utoledo.edu/nsm/physast/programs/reu/ .

### Registration and Housing

This year, some of the student participants lived in the Ottawa 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 over the years now, social activities were coordinated by the students themselves with the help of the local REU, UT participants and mentors. COVID-19 did limit some of the choices for social events during the 2021 program as compared with previous years. However, our group was still able to participate in a number of group activities which included a trip to the Toledo Zoo, a trip Cedar Point Amusement Park, two movie nights at a local cinema, an ice cream social using liquid nitrogen, board games, video games and various group dining events both inside and outside. Some of the other events included a Ritter Planetarium show and a tour of Ritter Observatory lead by Assistant Planetarium Director Hedi Kuchta and a tour of the Wright Center for Photovoltaics Innovation and Commercialization led by Research Assistant Professor Adam Phillips**.** *Naturally all policies during the summer program set by the University and the State of Ohio concerning COVID-19 were followed by our cohort.*

**Weekly Seminars**

A weekly REU "Brown Bag" seminar series is an important part of our summer program. Faculty members, Post Docs 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, field trips, and discuss any topics of interest with the group.

**NSF-REU SUMMER 2021 BROWN BAG SEMINARS (Noon)**

| Date | Guest Speaker | Talk Title |
|---|---|---|
| 1-Jun | Chair & Co-PI: Prof. Sanjay Khare | Welcome & Orientation for the REU students |
| 8-Jun | Prof. Scott Lee | Using Physics To Learn About Dinosaurs |
| 17-Jun | Prof. Lawrence Anderson-Huang | How We Construct Visual Experience |
| 22-Jun | Prof. David Pearson | Medical Physics As A Career: Including Some Research Examples Conducted In This Profession |
| 29-Jun | Prof. Michael Cushing | How To Give A Talk |
| 1-Jul | REUs | Progress Reports |
| 8-Jul | Prof. Sanjay Khare | A Sustainable Energy Future |
| 15-Jul | Dr. Juillian Bornak | Careers in Physics<br>And Astronomy Overview |
| 20-Jul | Assoc. Prof. of University Libraries Wade Lee | Research as a Conversation: Making the Library-Lab connection |

| | | |
|---|---|---|
| 20-Jul | Dr. Adam Phillips | Tour of Research1 |
| 29-Jul | Assist. Prof. Aniruddha Ray | A Career As A BioPhysicist |
| 30-Jul | Dr. Richard Irving | Introductory Python Workshop:<br><br>Exploring various coding environments and their setup along with introductory Python programming examples. |
| 1-Aug | Dr. Thomas Lai, Dr. Riwaj Pokhrel, Sam Federman (Grad), Victor Johnston (Grad) | PyVis Workshop: Creating quality plots and why it matters<br>-Working with fits images using a variety of python libraries<br>-Creating and viewing interactive plots<br>-Basics of working with spectral data and simple fits |
| 4-Aug | REUs | Final REU Presentations (*See Section IV: Research*) |
| 5-Aug | REUs | Final REU Presentations (*See Section IV: Research*) |

**University-Wide Events**

Due to COVID-19 pandemic the UToledo Office of Undergraduate Research (OUR-UT) did not run their program this summer as in previous years. This office has immediate, positive impact on our REU program by hosting the university wide seminars series that formed the basis of the course, UGR2980: "*Issues in Research and Scholarship*". Therefore, the PA Bag Lunch series filled some of the vacuum left from the above situation by covering some of the lecture series topics addressed in the UGR2980 such as *"Laboratory Safety*" during the REU Orientation and "*Advanced Research in the Library".* The following texts were identified as suggested reads during the "*Advanced Research in the Library*" Bag Lunch seminar: (Ethics)

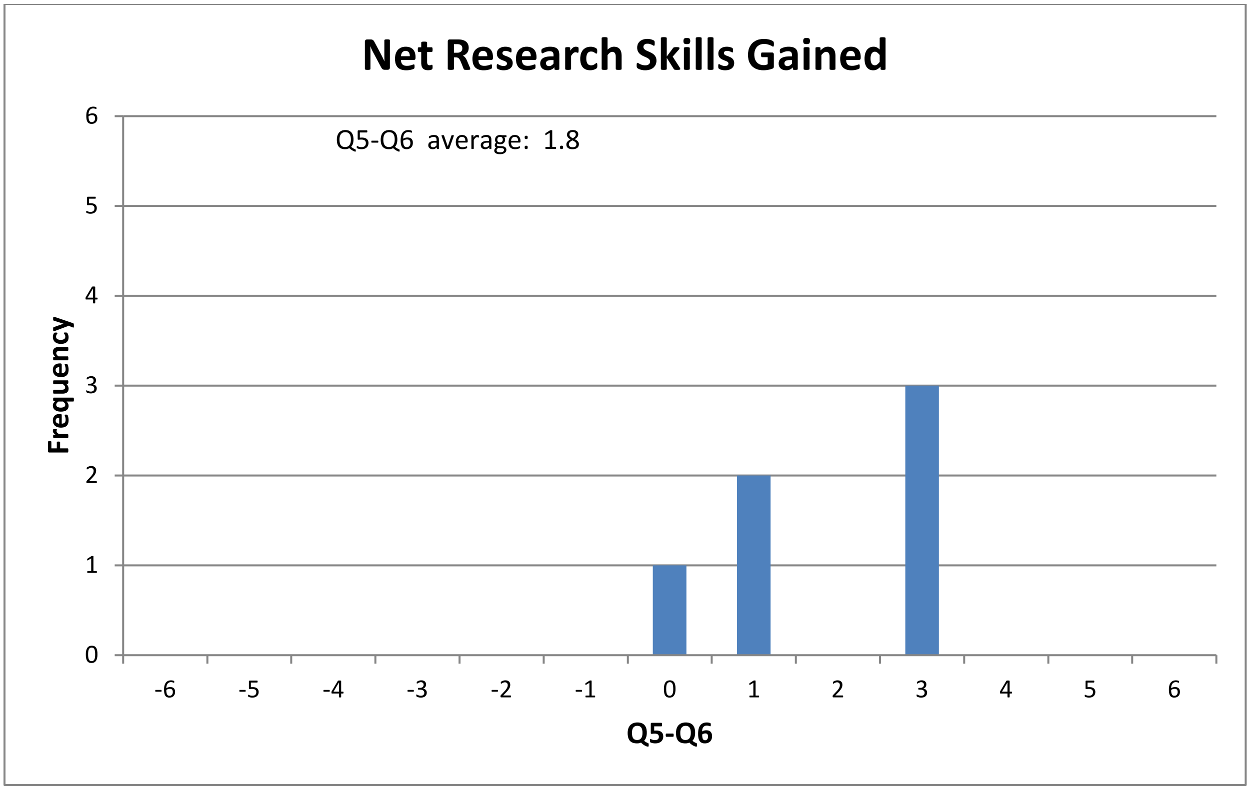
1. "Introduction to the Responsible Conduct of Research," Nicholas H. Steneck, US HHSORI publication
2. "Little Book of Plagiarism," Richard A. Posner, Publisher: Pantheon (January 16, 2007), ISBN-10: 037542475X

**Physics and Astronomy Summer Events 2021**

As part of our REU program we usually have an outreach component but did not this year due to COVID-19 restrictions and concerns. Department events usually involve not only REU students, but include undergraduates, graduate students, and faculty.

**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: Q5. "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>?" and Q6 similar except for "... <u>at the end of summer</u>?". The numerical choices ranged from 1 to 7 with 1-"Very skilled/knowledgeable", 4-"Neutral", and 7-"Not Very skilled/knowledgeable". By subtracting Question 6 from Question 5, 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**

**<u>Refereed Publications</u>**

No refereed publications to report yet for this cohort.

**<u>Conference Presentations</u>**

No conference presentations to report yet for this cohort.

**<u>Other Presentations</u>**

Our site has at least one nomination, Robert Snuggs, for the 2021 Research Experiences for Undergraduates (REU) Symposium in October.

**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 encouraged to write a final report in the format utilized by a peer reviewed paper from their area of interest. With the help of their mentor, the students are required carefully-write an abstract for their research. This abstract could be submitted as a contribution to a regional or national meeting. The students are required as well as give a 15-minute presentation at a Bag Lunch in the final week of their research period. 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 past REU students are authors on manuscripts that are in preparation, submitted or have been published. and this year's students have manuscripts in preparation.

Also, this past summer our site reached out to Kim Spencer, Assistant Director of Research & Evaluation at the University of Wisconsin-Madison to explore the possibility of working with the CIMER assessment platform which is the common program assessment tool accepted by the NPRLG community. We hope our site can set up assessment surveys for the participants and mentors where the results can help devise methods/techniques to benefit our participants and mentors to be more effective in research and possibly benefit the NPRLG community at the same time. Kim communicated the current cost for building a Project Group is $4,000. Kim also said changes have been made to increase project autonomy for teams using the Platform. These changes impact the survey administration process, which is different than when REU groups used the Platform several years ago. In an email to the Physics REU site directors from Daniel Serrano in March, our site learned APS has secured funding to cover common assessment usage by all NPRLG sites for the next three years using the CIMER platform. Offsetting the expense to setup the CIMER assessment platform for our site, allows our site to easily consider doing this assessment program. Due to the pandemic, there was uncertainty involved with our 2021 REU program start. This prevented us from trying to implement the CIMER assessment platform this year. The PI and Co-PI are in the process of scheduling an initial consultation meeting with Kim to determine the feasibility of our site to use the CIMER Assessment Platform for data collection.

## III. DEMOGRAPHICS

**NSF-REU Summer 2021 Applications**
**Geographical distribution by undergraduate institution**
**(Applications REU – 31 / REU Offers Made- 11 / REU Accepted- 8)**

**CALIFORNIA**

| | |
|---|---|
| Humboldt State University | (1/1/0) |
| Univ of Calif, Santa Barbara | (1/0/0) |

**DISTRICT OF COLUMBIA**

| | |
|---|---|
| American University | (1/0/0) |

**GEORGIA**

| | |
|---|---|
| Georga State University | (1/0/0) |

**MICHIGAN**

| | |
|---|---|
| University of Michigan. | (2/0/0) |
| Univ of Michigan at Dearborn | (1/1/1) |
| Monroe Community College | (1/1/1) |

**NORTH CAROLINA**

| | |
|---|---|
| N Carolina Ag &Tech State Univ. | (1/1/0) |

**OHIO**

| | |
|---|---|
| Bowling Green State University | (1/0/0) |
| Ballwin Wallace | (1/0/0) |
| Case Western | (3/2/2) |
| John Carroll University | (1/0/0) |
| Hiram | (1/0/0) |
| Lorain County Community College | (1/0/0) |
| Marietta | (2/0/0) |
| Ohio Northern University | (1/1/1) |
| University Of Cincinnati | (1/0/0) |
| University of Toledo | (1/1/1) |

**OREGON**

| | |
|---|---|
| Oregon State University | (1/0/0) |

**PENNSYLVANIA**

| | |
|---|---|
| Allegheny | (1/0/0) |
| Washington And Jefferson | (1/0/0) |

**PUERTO RICO**

| | |
|---|---|
| University of Puerto Rico | 1/0/0) |

**TEXAS**

| | |
|---|---|
| Univ. of Texas-Dallas | (1/0/0) |
| Univ. of Texas at San Antonio | (1/1/1) |
| Univ. of Texas at Austin | (1/1/0) |

**UTAH**

| | |
|---|---|
| Southern Utah University | (1/1/1) |

**VIRGINIA**

| | |
|---|---|
| Washington and Lee University | (1/0/0) |

**NSF-REU Participant Demographics**

**Summer 2021**

**(Number of this REU students /Percentage of the REU students)**

| **Gender** | |
|---|---|
| Female | (4/50%) |
| Male | (4/50%) |
| **1st Generation College Student** | |
| Yes | (3/37.5%) |
| No | (5/62.5%) |
| **Class Rank** (As of Spring semester 2021) | |
| Freshman | (2/25%) |
| Sophomore | (3/50%) |
| Junior | (3/25%) |
| Senior | (0/0%) |
| **Ethnicity** | |
| American Indian | (0/0%) |
| Alaskan Native | (0/0%) |
| Asian American (or Pacific Islands) | (1/12.5%) |
| African American | (1/12.5%) |
| Hispanic American | (1/12.5%) |
| European American | (5/62.5%) |

**REU Students Grade Point Average:** 3.64

| **Home State** | |
|---|---|
| Michigan | 3 |
| Missouri | 1 |
| North Carolina | 1 |
| Ohio | 1 |
| Texas | 1 |
| Utah | 1 |

| **Home Institutions Degrees offered*** | **(BS/MS/PhD)** |
|---|---|
| Case Western Reserve University | (BS/MS/PhD) |
| Monroe Community College | (NA/NA/NA) |
| Ohio Northern University | (BS/NA/NA) |
| Southern Utah University | (NA/NA/NA) |
| University of Michigan-Dearborn | (BS/NA/NA) |
| University of Texas at San Antonio | (BS&BA/MS/PhD) |
| University of Toledo | (BS&BA/MS-/PhD) |

*** Degrees offered in Physics or Astronomy**

## IV. RESEARCH

**REU 2021 Final Presentations**
Each talk is scheduled for 12 minutes allowing 3 additional minutes for questions.

| REU Student | Home Institution | Talk Title | Mentor(s) |
|---|---|---|---|
| **Wednesday, Aug. 4th , Starting at 12:00 PM:** | | | |
| Aman Kapoor | Case Western Reserve University | Improving Low-Cost Microscopy Images with Deconvolution | Assist. Prof. Aniruddha Ray |
| Patrick Knowles | Bowling Green State University | Activation barriers for the diffusion of Se interstitials in CdTe and CdSe | Prof. Jacques Amar |
| Ernesto Flores | The University of Texas at San Antonio | Performance of Substrate-Typer Sb2(S, Se3) Solar Cells | Prof. Yanfa Yan |
| Sarah Tucker | Ohio Northern University | Finding ERE in the Horsehead Nebula | Prof. Emeritus Adolf Witt |
| **Thursday, Aug. 5th , Starting at 12:00 PM:** | | | |
| Rebecca Nelson | Southern Utah University | Characterizing Opto-electronic Properties of MgxZn1-xSnN2 ($0 \leq x \leq 1$) | Professor Sanjay Khare |
| Shannon Costello | Monroe Community College | Segmentation: An analysis of automatic versus manual segmentation in radiation therapy | Assoc. Prof. Shvydka, Assoc. Prof. Pearson |
| Rachel Pauline | University of Michigan-Dearborn | Creating Globular Cluster Catalogs | Prof. Rupali Chandar |
| Zion Thomas | Case Western Reserve University | Creating Globular Cluster Catalogs | Prof. Rupali Chandar |
| Robert Snuggs | University of Toledo | Transitions in S II Including Diagnostic Techniques in Atomic Physics | Dr. Richard Irving |

**ABSTRACTS OF REU FINAL REPORTS SUMMER 2021**
**The University of Toledo, Department of Physics & Astronomy**
(REU Student **bold** face font except for Patrick Knowles*, Faculty Mentor in parenthesis)

## Astrophysics

**Rachel Pauline, Zion Thomas** *Creating Globular Cluster Catalogs in PHANGS Galaxies* (Rupali Chandar)

The PHANGS-HST group studies thirty-eight spiral galaxies in the universe using data from the Hubble Space Telescope. The members of the group that are focused on creating catalogs of the star clusters in these galaxies provided our research group with data to use to determine the age of these clusters based on their color, using wavelength magnitudes, with ancient red clusters being the targets of the project. Using Python coding, images of the galaxies on the interactive Sundog web tool, and color-color diagrams, we were able to pick out all of the objects that could fall in the ten- to the twelve-billion-year-old range. The ultraviolet, blue, visible, and infrared filters were used to create the color-color diagrams, with color cuts of B-V=0.50 and V-I=0.73 to find the reddest objects. By finding these objects we were able to start creating catalogs of these ancient clusters and determine the percentages of how many clusters in each galaxy are ancient. This helps other astronomers age-date the galaxies and look for conditions for star formation. The end goal of this project is to obtain data for all thirty-eight galaxies in the PHANGS group and publish the research for other scientists' use.

**Sarah Tucker** *Finding Extended Red Emission in the Horsehead Nebula* (Adolf Witt)

Extended Red Emission (ERE) is a generic term for the energy that the smallest particles in interstellar space with low-lying electronic states give off when they release vibrational energy as red photons. While thought to have been a unique phenomenon when first observed in 1975 in the Red Rectangle nebula, ERE has since been found throughout our galaxy in reflection nebulae and emission nebulae alike as well as in diffuse interstellar medium. Of special interest are cases where ERE is found on the surfaces of dark nebulae that are illuminated by nearby hot O/B stars, known as photo-dissociation regions (PDR). Investigating a dark nebula in the Orion Constellation, the Horsehead nebula, I was able to confirm the occurrence of ERE on the surface of this dark nebula that is illuminated by the close-by star Sigma Orionis. By using an image taken with a red filter (620 nm – 700 nm) and a narrow-band H-alpha filter (FWHM = 5 nm), I was able to create a program in Python that aligned the two images, scaled the H-alpha image to the desired ratio, and then subtracted the H-alpha emission present in the red-filter image. The resulting image was expected to retain structures due to ERE as well as a dust-scattered light continuum. To eliminate confusion due to the dust-scattered light, I divided the difference image by an image taken in the nearby continuum around 525 nm (green), with the result revealing the location and morphology of the ERE in the Horsehead Nebula PDR. Using the imaging software SAO/ds9 I was able to analyze the final image further and create contour maps that outline the position of the ERE relative to the emission from ionized polycyclic aromatic hydrocarbons (PAH) within the dust cloud, obtained from maps produced by the Spitzer Infrared Space Telescope, as well as the H-alpha emission surrounding the Horsehead. The resulting image shows that the ERE present in the Horsehead nebula rests in a narrow zone between the ionized atomic hydrogen and the neutral molecular hydrogen within the dust cloud. This leads to the conclusion that the excitation of the ERE process requires photons with less than 13.6 eV, the ionization potential of atomic hydrogen, but more than 7 – 8 eV, the energy required to ionize PAH molecules. This identifies the most likely process involved in producing the ERE as recurrent fluorescence by isolated particles consisting of about 20 to 35 atoms, most likely carbon, heated by far-ultraviolet photons from a nearby O/B star. This research will allow the James Webb Space Telescope to further examine the ERE in the Horsehead nebula in greater detail.

## Biophysics

**Aman Kapoor** *Low-cost microscopy* (A. Ray)
Low-cost microscopy is essential for imaging viruses, bacteria, and fungi in developing countries and in contexts when large-scale, low-cost testing is needed. One of the techniques used to create low-cost images is lensless microscopy, where a sample is placed directly on a sensor and reconstructed computationally with the optical transfer function (OTF) of free space. Such lensless microscopes cost no more than a few hundred dollars, whereas conventional instruments may be as much as $100,000. We sought to make an improvement on the existing lensless microscope by increasing its capability to image multiple samples simultaneously. We have designed a novel setup with a Raspberry Pi 3B+, four Raspberry Pi Camera Modules, an Arducam Multicamera V2.2 Adapter, four monochromatic LEDs, and a 3D printed baseboard and sample cover. Our current setup is being troubleshooted, as the multicamera adapter is assumed to be defective by the manufacturer. We are in the process of receiving replacement hardware and are optimistic that this will produce a functioning multicamera, lensless microscope.

## Condensed Matter Physics: Theory

**Patrick Knowles*** *Activation barriers for diffusion of Se interstitials in CdTe and CdSe* (J. Amar)
Recent progress in the development of CdTe solar cells has involved the use of CdTe absorber layers combined with CdSe and/or CdSeTe layers. One area of particular interest is the interdiffusion between the CdSe layer and the CdTe layer. As a first step in understanding this, we have carried out preliminary molecular dynamics (MD) simulations of Se interstitial diffusion in both CdTe and CdSe using an empirical bond-order potential for CdSeTe [1] which has been fitted to both experimental measurements and theoretical (density functional theory) calculations

**Rebecca J. Nelson**, *Characterize Opto-Electronic Properties of $Mg_xZn_{1-x}SnN_2$ Using First Principles Methods* (Bishal B. Dumre, Richard E. Irving, and Sanjay V. Khare)
We implement density functional theory (DFT) and hybrid theory HSE06 to perform computations on $Mg_xZn_{1-x}SnN_2$ () using a quantum mechanical computer program called the Vienna Ab initio Simulation Package (VASP). Our motivation is to calculate the optoelectronic properties of $Mg_xZn_{1-x}SnN_2$ () and determine its capacity for usefulness as the absorption layer of a solar cell. $MgSnN_2$ and $ZnSnN_2$ in disordered wurtzite structure have been proven to show bandgaps of 2.3 eV and 1 eV respectively. By alloying them, we are hoping that the bandgap for the best alloy will approach 1.4 eV, which is the bandgap for the most efficient solar cell absorber layer according to the Shockley-Queisser limit.

## Condensed Matter Physics: Experimental

**Ernesto Flores** *Performance of Superstrate-Type $Sb_2(S, Se)_3$ Solar Cells* (Y.Yan)
The interest in the research of solar cells with higher efficiency, cheaper, and less toxic has been increasing due to the increase in the necessity of green energy. Antimony Sulfo-Selenide, $Sb_2(S,Se)_3$, is one of the promising photovoltaic materials as it is earth-abundant and less toxic compared to other materials. Here, we made a solar cell with the structure FTO-CdS-$Sb_2(S,Se)_3$-HTL-Au. CdS is deposited by the chemical bath deposition (CBD) into the FTO,

$Sb_2(S,Se)_3$ is deposited onto the CdS substrate by hydrothermal method, hole transport layer (HTL) is deposited by spinning coating method and gold (Au) is deposited by the evaporator. The films that we got from the hydrothermal were annealed at different temperatures i.e 350, 390, and 410 °C in the glove box at nitrogen environment. We optimized the annealing temperature at 390 °C and used three different materials i.e copper thiocyanide (CuSCN), P3CT, and spiro as potential HTL. Spiro is found to be the best HTL in comparison with others in terms of efficiency however we found spiro is unstable and degrade rapidly than other HTL. Solar cells with P3CT as HTL also performed very well and their efficiency is much close with spiro. Also, P3CT is found to be very stable in comparison with any others HTL. For now, the highest efficiency that we got from spiro is -8% and from P3CT is 7.6%. However, still, a lot of parameters are left to be optimized and can be done in the future to get better device performance.

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## Atomic Physics

**Robert Snuggs** *Transitions in S II including Diagnostic Techniques in Atomic Physics* (R. Irving)

There is continued interest in the structure and radiative properties of Sulfur II. Utilizing the Toledo Heavy Ion Accelerator (THIA), we have previously obtained the first experimental lifetimes associated with S II transitions for the 906, 910, and 912 Å lines. In the recent past, we have collected emission spectra for these transitions. These transitions are seen in astronomical environments, such as the Io plasma torus, with the Far Ultraviolet Spectroscopic Explorer (FUSE). Analysis of our emission spectra suggests the possibility of the presence of cascades arising from high-lying levels in the quartet terms of the $3s^2 3p^2 4p$ and $3s^2 3p^2 5p$ configurations. We set out to verify the impact of these cascades such that we can obtain more accurate experimental branching fractions from our emission spectra. In parallel to this work, we have updated and validated our program *Beaming* utilizing Python. This program aids us in characterizing THIA's beam-foil interaction to help set up experimental runs.

## Medical Physics

**Shannon Costello** *Atlas Based Automatic Segmentation in a Radiation Therapy Setting* (D. Shvydka, David Pearson)

Radiation Oncology treatment planning is an elaborate process that includes multiple steps and reviews before a plan is approved for delivery. One of the most time-consuming tasks during the process is contouring or outlining, the patient's organs at risk on computed tomography (CT) scan in order to prevent unnecessary radiation exposure to healthy tissue. In addition to the time concern, there is also a significant amount of intra- and inter-observer inconsistencies during the contouring procedure: the different clinicians may interpret the boundaries of each organ differently. A solution to these two hurdles incorporates the implementation of an atlas-based automatic contouring software. The accuracy of such an approach has to be evaluated to determine if the software is able to produce contours similar to those manually drawn, which are used as the "gold standard" contours. For this purpose, atlases were created in various portions of the body using MIM software package and applied to previously treated and already drawn contours on patient CTs. The individual organs of both atlas-based contours and manually drawn contours were compared volumetrically with the Dice Similarity Coefficient (DSC) ranging from 0, meaning no volumetric overlap, to 1, meaning complete volumetric overlap. The average DSC value for all software-generated contours was found to be 0.674813 for all regions considered, a modest comparison between automatically generated segmentations and manually generated segmentations.

## V. STUDENT PROGRAM EVALUATION RESULTS

This survey is available to the student via a link as a confidential Google Form. Response data for each option is given for each question in the form: (number of responses for an option if >0, percentage of the total responses for an option). The mean response is also posted for each question.

**UToledo Physics and Astronomy NSF-REU Student Program Evaluation 2021**

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 **Selecting** the number. Please enter and comments you have for the critical reflection questions that follow. (This survey is available to the student via a link as a confidential Google Form.)

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

| **Definitely Yes** | | | **Neutral** | | | **Definitely No** |
|---|---|---|---|---|---|---|
| 1(4, 66.7%) | 2(1,16.7%) | 3(1,16.7%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.5

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

| **Learned a Lot** | | | **Neutral** | | | **Not Worth Much** |
|---|---|---|---|---|---|---|
| 1(3, 50%) | 2 (2, 33.3%) | 3(1,16.7%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.7

**3.** Was there mentoring and information provided about research and other careers including graduate school programs?

| **Strongly Yes** | | | **Neutral** | | | **Not At All** |
|---|---|---|---|---|---|---|
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1

**4.** Did you gain skills in making oral presentations in the REU program?

| **Great Gain** | | | **Neutral** | | | **No Gain** |
|---|---|---|---|---|---|---|
| 1(3, 50%) | 2(2, 33.3%) | 3(1,16.7%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.7

**5.** 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, 33.3%) | 2(0%) | 3(1,16.7%) | 4(1,16.7%) | 5 (1,16.7%) | 6(0%) | 7(1,16.7%) |

2021 mean (6 responses/pop. 8): 3.5

**6.** 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, 33.3%) | 2(3, 50%) | 3(0%) | 4(1,16.7%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 2.0

**7.** How much combined time did your faculty mentor and other mentors spend per week personally mentoring you on your research project?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1(0%) | 2(0%) | 3(0%) | 4(4, 66.7%) | 5(0%) | 6(1,16.7%) | 7(1,16.7%) |
| 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 |

2021 mean (6 responses/pop. 8): 4.8

**8.** Did you gain skills in working with computers, specialized software, and/or specialized equipment?

| **Great Gain** | | | **Neutral** | | | **No Gain** |
|---|---|---|---|---|---|---|
| 1(4, 66.7%) | 2(1,16.7%) | 3(1,16.7%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.5

**9.** Did you gain skills in understanding journal articles?

| **Great Gain** | | | **Neutral** | | | **No Gain** |
|---|---|---|---|---|---|---|
| 1(2, 33,3%) | 2(1,16.7%) | 3(2, 33.3%) | 4(1,16.7%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 2.3

**10.** Did you gain skills in conducting database or internet searches?

| **Great Gain** | | | **Neutral** | | | **No Gain** |
|---|---|---|---|---|---|---|
| 1(2, 33.3%) | 2(2, 33.3%) | 3(2, 33.3%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 2.0

**11.** 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(4, 66.7%) | 2(2, 33.3%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.3

**12.** How do you rate your summer research experience in terms of personal development?

| **Great Fun** | | | **Neutral** | | | **A Real Drag** |
|---|---|---|---|---|---|---|
| 1(5, 83.3%) | 2(1,16.7%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.3

**13.** How do you rate your mentor's (including both faculty and non-faculty) interactions in helping you with your research experience?

| **Very Helpfu** | | | **Neutral** | | | **Not Helpful** |
|---|---|---|---|---|---|---|
| 1(5, 83.3%) | 2(0%) | 3(1,16.7%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.3

**14.** How many hours per week did you work at research-related activities in this research experience?

| 1(0%) | 2(1,16,7%) | 3(1,16.7%) | 4(1,16.7%) | 5(0%) | 6(2, 33.3%) | 7(1,16.7%) |
|---|---|---|---|---|---|---|
| 10-15hrs/wk | 15-20 hrs/wk | 20-25 hrs/wk | 25-30 hrs/wk | 30-35 hrs/wk | 35-40 hrs/wk | >40 hrs/wk |

2021 mean (6 responses/pop. 8): 4.7

**15.** How do you rate the Workshops on Python scientific programing and data visualization?

| **Very Informative** | | | **About Right** | | **Not Very Informative** | |
|---|---|---|---|---|---|---|
| 1(4, 66.7%) | 2(2, 33.3%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.3

**16.** How do you rate the Physics and Astronomy Seminars (Bag Lunches) presentations?

| **Very Informative** | | **About Right** | | **Not Very Informative** | | |
|---|---|---|---|---|---|---|
| 1(5, 83.3%) | 2(1,16.7%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.2

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

| **Very Fun** | | | **Neutral** | | **Boring Waste of Time** | |
|---|---|---|---|---|---|---|
| 1(5, 83.3%) | 2(1,16.7%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1.2

**18.** Was the general social environment inclusive and welcoming throughout the REU program?

| **Very Welcome** | | | **Neutral** | | **Not Welcome** | |
|---|---|---|---|---|---|---|
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 8): 1

**Critical Reflection Questions/Comments**

**From 2021 REU Summer Program**

**<u>Critical Reflection Questions:</u>**

1. Why did you choose to become involved in a research project this summer?
    - I wanted to gain experience in the career field I'm interested in.
    - I wanted to get a better understanding of the professional world of research/ great experience/ furthering my education.

- I choose to become involved in a research project this summer because it was going to help me gain the skills necessary to be a successful researcher.
- Gain experience and skills related to physics as well as narrow down the field of study I want to pursue.
- In order to expand my research experience and develop as a scientist
- I wanted the experience and I wanted to learn as much as I could

2. What prior knowledge did you find useful in your research project (e.g., courses, experiences, etc.)?
   - Astrophysics and astronomy classes, along with some MatLab experience, helped with the project, general physics classes helped me understand other students' projects.
   - The many facets of research my research topic spilled over too.
   - Prior this summer Research I was working already in a research lab
   - Modern Physics
   - Culmination of my past research experience and also my long history of programming experience
   - Personal experience, previous courses

3. What knowledge was missing that would have helped you in your research project (e.g., courses, experiences, etc.)?
   - I went into the program with no Python experience
   - Maybe more introductory resources at the beginner level so we don't have to jump directly into reading journals and published research at first (would create a smooth transition and give students a more concrete understanding).
   - Something that would've help me a lot in the project could be knowing more about material science.
   - Programming class
   - Exact tolerances of the hardware I had been working with
   - Nothing really.

4. What new knowledge central to your project did you discover in your research?
   - Python coding related to astronomy and how star clusters are classified and found in galaxies.
   - The effectiveness of computer generated simulation in research.
   - I learn a lot about material science and how to work in a lab environment
   - Python programming and how it can help you in physics
   - New strategies in troubleshooting hardware
   - The process of planning radiation oncology as a whole, the use of their software.

5. What new knowledge tangential or incidental to your project did you discover in your research (e.g., new methods, connections, resources, etc.)?
   - Received important information on how to create good presentations and about the physics/astronomy career options.

- How the techniques of my research topic can be applied to almost all forms of physics.
- I learned how to work with equipment in the lab. Also, I was able to talk about different paths that other people took to obtain their Ph.D
- The amount of careers a person with a physics degree can pursue.
- What resources are available for modifying hardware and also some resources on programming I was not aware of.
- Too much to list. This project opened up an entire new world.

6. How might your research project impact the greater community (professional and/or societal)?
    - Publishing a paper for the project is in progress and this will benefit other scientists in the field.
    - By improving green power availability and affordability for all.
    - I had the ability to work making solar cells that may have promising results. Solar cells have a big impact in our community due to the increase demand of solar cells.
    - I can bring back what I learned about python and apply it in my home institutions lab.
    - Clarification of disagreement between observational and theoretical models.
    - It could lead to evolving radiation treatment planning process in radiation oncology for the better by determining if this implication is helpful or hindering.
7. How did you grow professionally and personally through the completion of the UToledo REU program?
    - I learned how to communicate with my mentors, give better presentations, and learned what the work environment is like. This all helped solidify that this is the career I am looking for.
    - I now understand how professional research is conducted and how to efficiently present those findings to members of my team.
    - I learn a lot professionals and personally. I had more responsibilities during the program which help me be better at organizing. Also, I was able to practice my communication skills and teamwork.
    - Narrowing down what careers best suit my talents and interests
    - I expanded my skillset both in experimental physics as well as in physics modeling utilizing software. I have also gotten better at giving presentations.
    - Through the additional seminars, I was able to articulate my questions better, I was able to prepare for our presentations better, I was able to start picking up programming language. I was able to define my goals more concretely and set a more specific plan for how I want to attain them. Personally, I was able to define why I want to accomplish these goals this specific field of physics.

8. Do you have any suggestions to help improve this REU program?
    - N/A

- None right now.
- The REU Program was great.
- I know Covid messed up a lot of things but it would have been helpful if the beginning on the program was more organized.
- I think it is good as is.
- No. It is a great program that I believe benefits every person involved.

9. Please list any additional comments:
    - N/A
    - Had a great time, hope to stay in touch with everyone!
    - It's been fun!

## VI. MENTOR PROGRAM EVALUATION RESULTS

This survey is available to the mentor via a link as a confidential Google Form. Response data for each option is given for each question in the form: (number of responses for an option if >0, percentage of the total responses for an option). The mean response is also posted for each question.

**UToledo Physics and Astronomy NSF-REU Mentor Survey of 2021**
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 **Selecting** the number. Please enter and comments you have for the critical reflection questions that follow. (This survey is available to the mentor via a link as a confidential Google Form.)

**1.** 1. What is your current position during the REU program of 2021?

| **Faculty** | **Prof. Emeritus** | **Research Prof.** | **Other** |
|---|---|---|---|
| (4 responses) | (1 response) | (1 response) | (0 responses) |

**2.** Do you think your assigned student had the necessary education and skills for this program?

| **Very skilled/knowledgeable** | | | **Neutral** | **Not Very skilled/knowledgeable** | | |
|---|---|---|---|---|---|---|
| 1(1,16.7%) | 2 (3,50%) | 3(1,16.7%) | 4(1,16.7%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 6): 1.7

**3.** Would you participate in this program again next year?

| **Strongly Yes** | | | **Neutral** | | | **Not At All** |
|---|---|---|---|---|---|---|
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) | 5(0%) | 6(0%) | 7(0%) |

2021 mean (6 responses/pop. 6): 1

**4.** If you said no to number 3, please give some reasons why.

**No Responses**

| **5.** How satisfied were you with your assigned student? | | | | |
|---|---|---|---|---|
| **Very Satisfied** | **Satisfied** | **Dissatisfied** | **Very Dissatisfied** | **NA** |
| 1(4,66.7%) | 2(2, 33.3%) | 3(0%) | 4(0%) | 5 (0%) |
| 2021 mean (6 responses/pop. 6): 1.3 | | | | |

| **6.** How satisfied were you with your interaction with project staff? | | | | |
|---|---|---|---|---|
| **Very satisfied** | **Satisfied** | **Dissatisfied** | **Very Dissatisfied** | **NA** |
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) | 5 (0%) |
| 2021 mean (6 responses/pop. 6): 1 | | | | |

| **7.** How satisfied were you with the PA UToledo-REU program in general? | | | | |
|---|---|---|---|---|
| **Very Satisfied** | **Satisfied** | **Dissatisfied** | **Very Dissatisfied** | **NA** |
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) | 5 (0%) |
| 2021 mean (6 responses/pop. 6): 1 | | | | |

| **8.** How satisfied were you with your Department's support of the program? | | | | |
|---|---|---|---|---|
| **Very satisfied** | **Satisfied** | **Dissatisfied** | **Very Dissatisfied** | **NA** |
| 1(5,83.3%) | 2(1,16.7%) | 3(0%) | 4(0%) | 5 (0%) |
| 2021 mean (6 responses/pop. 6): 1 | | | | |

| **9**. How satisfied were you with the University's support of the program? | | | | |
|---|---|---|---|---|
| **Very satisfied** | **Satisfied** | **Dissatisfied** | **Very Dissatisfied** | **NA** |
| 1(5,83.3%) | 2(1,16.7%) | 3(0%) | 4(0%) | 5 (0%) |
| 2021 mean (6 responses/pop. 6): 1 | | | | |

| **10.** I think my experience as a PA UToledo-REU mentor was a valuable one. | | | |
|---|---|---|---|
| **Strongly Agree** | **Strongly Agree** | **Disagree** | **Strongly Disagree** |
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) |
| 2021 mean (6 responses/pop. 6): 1 | | | |

| **11.** The program has given my assigned student an introduction to what graduate school would be like. | | | |
|---|---|---|---|
| **Strongly Agree** | **Strongly Agree** | **Disagree** | **Strongly Disagree** |
| 1(5,%) | 2(1,%) | 3(0%) | 4(0%) |
| 2021 mean (6 responses/pop. 6): 1.2 | | | |

| **12.** I think the UToledo-REU experience has helped my assigned student become a better researcher. | | | |
|---|---|---|---|
| **Strongly Agree** | **Strongly Agree** | **Disagree** | **Strongly Disagree** |
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) |
| 2021 mean (6 responses/pop. 6): 1 | | | |

**13.** How satisfied were you with your department's support of the program? I think participating in this program as a mentor was a mistake.

| Strongly Agree | Strongly Agree | Disagree | Strongly Disagree |
|---|---|---|---|
| 1(0%) | 2(0%) | 3(0%) | 4(6,100%) |

2021 mean (6 responses/pop. 6): 4

**14.**.This program has changed the likelihood that my assigned student will attend graduate school at UToledo.

| Strongly Agree | Strongly Agree | Disagree | Strongly Disagree |
|---|---|---|---|
| 1(1,16.7%) | 2(4,66.7%) | 3(1,16.7%) | 4(0%) |

2021 mean (6 responses/pop. 6): 2

**15.** I would like to have my assigned student in a graduate program at UToledo.

| Strongly Agree | Strongly Agree | Disagree | Strongly Disagree |
|---|---|---|---|
| 1(3,50%) | 2(3,50%) | 3(0%) | 4(0%) |

2021 mean (6 responses/pop. 6): 1.5

**16.** I think the UToledo-REU program will make my assigned student more successful in graduate school.

| Strongly Agree | Strongly Agree | Disagree | Strongly Disagree |
|---|---|---|---|
| 1(6,100%) | 2(0%) | 3(0%) | 4(0%) |

2021 mean (6 responses/pop. 6): 1

**Critical Reflection Questions/Comments**

**From 2021 REU Summer Program**

**<u>Critical Reflection Questions:</u>**

17. What has been the most beneficial aspect of the PA UToledo-REU program for you?
    - It is stimulating to me to carry out research with an undergraduate.
    - The interaction with a bright, highly motivated student gives me hope for the future of our country.
    - Mentoring a student and getting them excited about research, particularly in bio-photonics.
    - I got to mentor a strong student and expose them to physics research as UG student. I did not have this exposure when I was UG student and I believe more students should receive this exposure. She does not even have a MS or PhD program in Physics at her home institution so it was even more satisfying to guide her in research at UToledo.

18. What could be done to improve the PA UToledo-REU mentoring experience for you?
    - nothing
    - Eliminate Covid-19!

- It was very well designed
- Nothing at all.

19. Is there anything else you would like to share with us about your experience as a PA Utoledo-REU mentor?
    - I enjoyed it and I think it was very beneficial for the student.
    - I was greatly impressed by the level of excellence demonstrated by ALL the REU students this summer.
    - No
    - Beyond the advising I did for her research project I was able to give her lot more mentoring. Specifically, she received mentoring from me and my group about the diversity of careers that PhD physicists are engaged in. She was also given guidance on how to search for and choose a graduate program aligned with her interests, how to apply and prepare a graduate school application and so on. She truly appreciated all of it since her program is only a BS degree granting program in the sciences at her home institutions.

20. Do you have any suggestions to help improve this REU program?
    - no
    - Increase the number of students so that more could work in teams of two or more on a given project. Working in teams could strengthen their research experience significantly.
    - No
    - No.

21. Please list any additional comments.
    - none
    - I was extremely happy that we could carry out a successful REU program under the difficult conditions imposed by Covid-19.
    - N.A.
    - None.

## VI. NSF-REU Physics and Astronomy Picture Collage 2021