Research Experiences for Undergraduates in Astronomy at Cerro Tololo Inter-American Observatory

Annual Project Report (Year 2)
1 October 2012 – 30 September 2013

The 2013 CTIO REU and PIA students pose with the sunset over La Serena and Coquimbo at the CTIO Student Welcome Barbecue. From left to right: Gonzalo Briones (PIA), Brian Chinn (REU), Emily Finney (REU), Molly Williams (REU), Alex Deich (REU), Briana Indahl (REU), Lois Smith (REU), and Diego Calderon (PIA).

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Accomplishments

What are the major goals of the project?

The National Optical Astronomy Observatory (NOAO) Research Experiences for Undergraduates (REU) site program at Cerro Tololo Inter-American Observatory (CTIO) offers undergraduate students the opportunity to engage in publishable-quality research projects with scientists working at the forefront of astronomy and astrophysics. The fundamental goals are to provide research opportunities to six (6) US undergraduates annually to further their careers as well as exposing them to the international aspects of astronomical investigation through their 10-week stay at CTIO in La Serena, Chile.

This award for the period 2012 to 2016 is to fund an REU summer program at CTIO in La Serena, Chile, which is offered annually to six qualified applicants. An emphasis on student selection is directed toward stronger publicity and recruitment at minority-serving institutions, as well as students from institutions lacking access to first-rate telescope facilities. REU students are hired as full-time research assistants to work with a CTIO, Southern Astrophysical Research telescope (SOAR), or Gemini-South astronomer-mentor on a research project from mid-January to mid-March. The students are hosted at CTIO for the entire 10-week duration of the program. Each REU student is guaranteed a minimum of two nights observing with the 1.5-m, 1.0-m, or 0.9-m telescopes at CTIO. Analysis of observational data products provided by the mentors and/or procured during the students’ own observing runs will be closely aligned with typical syllabus material in undergraduate courses such as Observational Astronomy, Stars & Galaxies, or Principles of Astronomy allowing us to bring students’ classroom and book-learning efforts in fundamental astronomy concepts into focus. All participants are encouraged to attend the American Astronomical Society winter meeting following their program to present a poster or deliver a paper. In addition to research projects, the CTIO REU site program features seminars designed by the science staff especially for the students as well as professional colloquia given by science staff and visiting astronomers, informal lunches, and group discussions. Beyond the offices, the program includes field trips to the observatories at Cerro Pachón and at least one other major, world-class astronomical facility in Chile (e.g., the Atacama Large Millimeter Array (ALMA), Las Campanas, and Cerro Paranal) and a variety of recreational and social activities. Working and interacting on a daily basis with scientists from diverse research specialties and with students from Chile and around the globe, CTIO REU students are exposed to many different aspects of a professional career in astronomy. Such day-to-day exposure to a wide range of scientific and technical occupations in astronomy and engineering is one of the chief benefits of the CTIO REU site program.

The CTIO REU site program is a vital part of NOAO’s ongoing commitment to contribute toward the nation’s need in training our future scientists, academics, and young professionals. Our REU program also will provide its participants with valuable exposure in instrumentation, technical support, and education for those interested in a broader astronomical career. In an effort to provide opportunities for REU students representing the full spectrum of the US population, we make special, programmatic efforts in advertising to and recruiting students from minority-rich backgrounds, especially those attending minority-serving institutes. The broadest goals of the CTIO REU site program are (1) to encourage undergraduates of all demographics, including women and those of minority-rich backgrounds, to pursue careers in science, (2) to foster high levels of scientific literacy among the future Science, Engineering, and Technology (SET) workforce, (3) to stimulate general awareness of
the remarkable achievements of US astronomy, and (4) to inspire interest in the future progress and welfare of US science.

What was accomplished under these goals?

Major Activities:

The 2013 National Optical Astronomy Observatory (NOAO) Research Experiences for Undergraduates (REU) Program at Cerro Tololo Inter-American Observatory (CTIO) provided an opportunity for six US undergraduate students to participate in independent, supervised research activities in astronomy in collaboration with members of the scientific staff. The program is supported by the rich scientific environment and research facilities of CTIO’s La Serena offices, as well as ready access to the national observatory facilities on Cerro Tololo. Together, these facilities provide a framework that introduces students to the operations of a major observatory and the capabilities of a variety of optical and infrared instrumentation while they are actively engaged in current astronomical research. Building upon these resources, the program includes an introduction to observational techniques and provides observing experiences for all of the participants. Furthermore, the program offers a unique cultural opportunity for participants to live in a foreign country and work alongside Chilean students who are doing similar research projects.

STUDENT SELECTION

Six undergraduate students from the US, selected from a total of 14 qualified applicants from US institutions, participated in the 2013 REU program at CTIO. Announcements were sent to over 800 college and university science and mathematics departments and career placement offices in the US and Puerto Rico. This promotional campaign targeted the Hispanic Association of Colleges and Universities (HACU) as well as Historically Black Colleges and Universities (HBCU). The program was advertised on the CTIO REU program website (http://www.ctio.noao.edu/noao/content/REU-Program) and in the NOAO Newsletter. Advertising for the 2013 program was accomplished in August 2012, as planned; promotional activities for the 2014 CTIO REU program will start in July 2013.

SCIENCE

Each student pursued a research project guided by a staff astronomer as a mentor. The REU site director and the REU student coordinator solicited volunteers among the CTIO, Gemini Observatory, and SOAR scientific staff, looking for active astronomers who were willing to invest their time and expertise to work with a student and who had projects suitable for undergraduate students carrying out research in a 10-week program. As in previous years, there were more than enough volunteers and projects. This year three REU students were mentored by CTIO staff members; SOAR and Gemini scientists mentored the remaining three students. In addition, CTIO, SOAR, and Gemini staff members served as mentors for the students participating in the CTIO Práctica de Investigaciones en Astronomía (PIA) program, a CTIO-funded program for Chilean students, which is run concurrently with the CTIO REU program.

WEEKLY STUDENT SEMINARS

Apart from the official CTIO colloquia, the students attended a seminar series especially designed to reflect their needs and interests. The seminars covered a broad range of topics, including lectures and workshops. Additionally, several general seminars and discussions were scheduled for the students. For example, CTIO Director Dr. Nicole van der Bliek and Dr. Chris Smith, head of the AURA Observatories in Chile, welcomed the students to Chile with a presentation on CTIO, NOAO, and AURA. The seminars were given by the CTIO and Gemini scientific staff about once a week between
January 14 and March 12. The list of topics and speakers from the 2013 Student Seminar Series follows below:
- Dr. Chris Smith and Dr. Nicole van der Bliek (CTIO): “Welcome to CTIO”
- Dr. Timothy Abbott (CTIO): “CTIO Labs and Instrument Shop”
- Dr. Mischa Schirmer (Gemini): ”Data Reduction with Theli”
- Dr. Sean Points (CTIO): “Making Color Images from Astronomical Data”
- Dr. David James (CTIO): “Introduction to Telescopes”
- Dr. Andrei Tokovinin (CTIO): “Challenges of Multiple Stars”
- Juan Seguel (CTIO): “Galileoscope Workshop”
- Dr. Catherine Kaleida (CTIO): “Applying for Graduate School”

OBSERVATORY FIELD TRIPS
The REU grant provides funding for a three-day field trip to a site of astronomical significance, which allows the students to get a taste of other observatories and get acquainted with their unique telescopes, instruments, and operations. For the 2013 CTIO REU program, the students visited observatories on Cerro Paranal and Cerro Pachón.

Cerro Paranal is the site of the European Southern Observatory (ESO), one of the premier astronomical sites in the world, and home to the Very Large Telescope (VLT). The VLT is an array of four 8.2-m telescopes that operate either as stand-alone telescopes or combined through an interferometric network to act as one large aperture. The observatory is a three-hour drive from Antofagasta in northern Chile, through some of the most arid (and beautiful) terrain on Earth. While at Cerro Paranal, the students toured the telescopes and observatory facilities.

Cerro Pachón is home to two telescopes: the 8.1-m Gemini telescope, and the 4.1-m Southern Astrophysical Research (SOAR) telescope. Proximity to CTIO, both geographic and institutional, allowed for easy arrangement of a site tour for the 2013 REU students. Dr. Tiago Ribeiro (SOAR) and Dr. Rodrigo Carrasco (Gemini) led exciting tours for the REU/PIA students, introducing the various instruments and modes of observing at each telescope. This year, the students were permitted to stay on the mountain for the beginning of night operations, in order to see the new Gemini Multi-Conjugate Adaptive Optics System (GeMS) laser in action.

OTHER FIELD TRIPS
During their time in Chile, the students visited a neighboring university in La Serena, the Universidad de La Serena (ULS). The purpose of this visit was to facilitate more interactions between the US students and Chilean students and professors, and to supplement their cultural education while in Chile. The ULS and REU/PIA students attended an astronomy seminar at ULS given by CTIO’s Dr. Andrea Kunder entitled, “Galactic Bulge Kinematics from the Bulge Radial Velocity Assay (BRAVA).”

PHOTOS
Photos of key activities, including the workplace and field trips, are included in the attached PDF file.

Specific Objectives:
• To guide 6 US undergraduate astronomy students in 10-week-long astronomy research projects
• To provide observing experience at a research-class telescope to those students
• To provide the students with practical knowledge of astronomical topics and data reduction methods and tools via approximately weekly seminars
• To expose the students to living and working in the environment of an international observatory
• To enhance the students’ understanding of astronomical instrumentation and telescope design by visiting other large observatories in Chile (Gemini, SOAR, the VLT)
• To give the students experience documenting and presenting their research to the astronomical community via weekly research meetings, the final Student Symposium, their final reports, and presentation at the AAS meeting

Significant Results:
The key result of the CTIO REU program is the research the students complete while in the program. Participant support costs were provided for the students listed below. The student research project titles are listed along with the student’s name, university affiliation, and mentor, together with abstracts of the research projects written by the students and their mentors:

** Brian Chinn (University of Florida), Research Intern to Drs. Chris Smith (CTIO), Sean Points (CTIO), and Steve Heathcote (SOAR)
- Project Title: “Understanding the Balmer Bubble in Vela Supernova Remnant”
- Abstract: We present imaging and spectroscopic data and analysis of the Balmer-dominated filament that is ahead of the eastern edge of the radiative shock of Bullet C in the Vela Supernova Remnant. This filament was discovered in 2002 by Carlin & Smith, and was suggested to be a non-radiative shock. Images of the filament were taken using Hα and R band filters on the SMARTS 0.9-m telescope at CTIO. These images were then compared to images taken in 2006 using the Mosaic II imager on the Blanco Telescope at CTIO, in an attempt to detect proper motion of the filament. Comparison over the 7-year baseline failed to show proper motion of the filament. From this result, we are able to place an upper limit of ~270 km/s on the velocity of the Balmer-dominated filament. We also obtained moderate resolution spectra of the Balmer-dominated filament and the radiative shock using the Goodman Spectrograph at SOAR Telescope. Spectroscopic analysis of the Balmer-dominated filament failed to detect a broad component of the Hα emission line, which would be expected for a high velocity non-radiative shock.

** Alexander Deich (Humboldt State University), Research Intern to Dr. Alexandre Roman (ULS) and Dr. Andrea Kunder (CTIO)
- Project Title: “Photometric Analysis of Clusters in the Vista Variables in the Via Lactea (VVV) Survey”
- Abstract: Using the 4.1-m VISTA telescope in Paranal, the VVV Survey is a multi-epoch, near-infrared search for clustering and variable activity in the galactic plane of the Milky Way. The VVV survey samples 562 sq deg of the Galactic bulge and southern disk in 5 broad band filters (Y, Z, J, H, Ks). Each VVV field, with an area of 1.65 sq deg, allows the systematic analysis and search of young stellar objects, such as young clusters, OB associations, and Wolf Rayet stars. The data used in this project were taken in 2010, and feature images in three passbands, J, H, Ks, each with a 10-second integration time. We first attempted to perform aperture photometry on the images. In order to determine the saturation point, we compared each band to the 2MASS survey. This comparison gave us the saturation points and conversion functions between the two systems.
** Emily Finney (Scripps College), Research Intern to Dr. Mischa Schirmer (Gemini)

- Project Title: “Analysis of Redshifts for a Sample of Galaxy Clusters”

- Abstract: The purpose of this project was to select a sample of galaxy clusters by mass and determine the redshifts and physical velocity dispersions of those clusters. Schirmer et al. (2007) presented 158 weak-lensing selected clusters of galaxies, about 50 of which have been followed up with multi-object spectroscopy with EMMI at 3.5-m NTT/ESO. Data reduction was performed for 12 of these galaxies, and redshifts were calculated. We obtained physical velocity dispersions for all clusters reduced, in order to look for possible sub-structure and compare to the weak lensing signal strength.

** Briana Indahl (University of Wisconsin-Madison), Research Intern to Dr. Peter Pessev (Gemini)

- Project Title: “A Search for Carbon-Rich AGB Stars in the Milky Way Globular Clusters”

- Abstract: From our current understanding of stellar evolution, it would not be expected to find carbon-rich asymptotic giant branch (AGB) stars in Milky Way globular clusters. Recently, however, there have been seven serendipitous discoveries of these types of stars. They are known to exist in mass transfer binary systems with a carbon white dwarf companion and as products of stellar mergers. This is the first comprehensive search into all of the Milky Way globular clusters for these types of stars. I have found 128 carbon star candidates using methods of comparing the color magnitude diagrams of the clusters with the carbon stars of the Large Magellanic Clouds and picking out very red stars in the red giant branch range. Further observations will need to be done of these candidates to further confirm if they are carbon stars and if they are members of their respective globular cluster.

** Lois Smith (University of Colorado at Boulder), Research Intern to Dr. Tiago Ribeiro (SOAR)

- Project Title: “Near-infrared Photometry of Low Accretion Rate Polars”

- Abstract: Low accretion rate polars (LARPs) are thought to be the progenitors of magnetic Cataclysmic Variables (CVs). Polars are comprised of a highly magnetic white dwarf and a low-mass dwarf in a semi-detached configuration. LARPs show little indication of accretion onto the white dwarf, which is how they are identified from other polars. By viewing these systems in the infrared, we can identify and model the properties of the low-mass red dwarf. We analyzed the photometry obtained with SOAR telescope with OSIRIS with the aid of a light curve modeling tools to estimate the Roche lobe filling factor of this star. Our results enable us to constrain the mass accretion mechanism and give the evolutionary state of these systems.

** Molly Williams (Eastern Kentucky University), Research Intern to Dr. Catherine Kaleida (CTIO)

- Project Title: “The Size Scales of Stellar Groupings in NGC 628 and NGC 2841”

- Abstract: We present size histograms of manually selected star clusters and stellar associations in NGC 2841 and NGC 628, in order to better understand the size scales of stellar clustering in nearby galaxies and the disruption times of these groupings. Furthermore, we present color-magnitude (CM) and color-color (CC) diagrams for these two galaxies as a way to better understand the completeness of the manual and automated stellar grouping selection processes used. It is determined by a variety of measures, including the CM and CC diagrams, that individual stars in the galactic field are not resolvable for NGC 2841; however, more conclusive tests are needed in order to say the same for NGC 628.
Key outcomes or other achievements:
The students’ primary focus while in Chile was to work on their individual research projects, supervised by their respective scientific mentors, the REU site director, and the REU student coordinator. At the end of the program, the students were asked to write a final report on their project. The students were encouraged to work independently and to develop the skills and expertise to define the direction and scope of their projects. Students who lacked research experience were given more direct guidance when necessary. In addition, the REU student coordinator was available to any of the students who had procedural, administrative, or scientific questions.

At the end of the program, the students presented their work in a mini-symposium. Each student gave a 10- to 15-minute talk, which was followed by five minutes for questions from the audience. The symposium took place in the AURA auditorium and was attended by the observatory scientific staff and visitors. The REU students also will present their work in the form of a poster paper at the 223rd meeting of the American Astronomical Society (AAS), scheduled for 5–9 January 2014.

What opportunities for training and professional development has the project provided?

SCIENCE
The main goal of the CTIO REU program is to provide an opportunity to carry out a research project, supervised by one of the staff astronomers at CTIO, SOAR, or Gemini and by the REU student coordinator. At the end of the program, the students report on their work in the form of a written report and short presentation. The students were encouraged to work independently, but those who lacked research experience were given more direct guidance when necessary by their mentor or the REU student coordinator. The CTIO summer students also had the opportunity to observe on Cerro Tololo using the CTIO/SMARTS 0.9-m telescope. The objective of the observing run was to introduce the students to observing techniques and to allow them to sample different methods of observing, as dictated by various projects that had different scientific objectives. Thus, the students experienced the three main tasks of a professional observational astronomer: observation, analysis of results, and subsequent reporting and publication.

OBSERVING
As part of the CTIO REU program, the students observed on Cerro Tololo using the Small & Moderate Aperture Research Telescope System (SMARTS) Consortium’s 0.9-m telescope. The objective of the observing run was to introduce the students to observing techniques and allow them to sample different methods of observing. The observing time, eight nights in total, was requested via the regular NOAO Time Allocation Committee (TAC) procedure (program ID: 2013A-0494). This proposal was ranked highly by the TAC, receiving a grade of 9.7, where 10 was the highest grade achievable. These eight nights corresponded to two observing nights for each group of two students.

For the 2013 program, the student observing plan consisted of target-of-opportunity (ToO) observations of Gamma-ray bursts (GRBs), supernovae (SNe), and near-Earth objects (NEOs), in collaboration with Dr. Francisco Virgili (Liverpool John Moores University) and Dr. Joe Masiero (California Institute of Technology/Jet Propulsion Laboratory). Some of the students’ observations resulted in the publication of a GRB circular (D. Calderón Espinoza, B. Indahl, L. Paredes Alvarez, C. Kaleida (CTIO), and F. J. Virgili (LJMU), GCN Circ. 14202, “GRB 130131B: CTIO 0.9-m optical upper-limits,” 2013). A portion of the observing time was left open for the students to observe objects of their own choosing, including observations for their own research projects in some cases. The students imaged Southern Hemisphere galaxies, star clusters, and nebulae. In choosing their own targets, they learned how to determine what objects are visible in the night sky from a certain location
at a certain time and how to determine appropriate exposure times, and they gained experience in deciding what filters to use to meet different scientific goals.

WEEKLY RESEARCH GROUP MEETINGS
The students attended weekly research group meetings. At these meetings, the students presented their projects, their progress during the previous week, and their plans for the upcoming week. These presentations helped them to track their research progress and discuss issues encountered with their REU peers and mentors. These group meetings were an excellent way to ensure that substantial and steady progress was made, while at the same time allowing the students to practice their presentation skills. Over the course of the 10-week program, their presentations improved dramatically, and their confidence grew equally fast.

SCIENTIFIC INTERACTIONS
An essential component of the CTIO REU program is the opportunity students have for interaction with scientists, not only with the observatory staff, but also with the flow of visiting astronomers who pass through on their way to the observatory. The generally informal atmosphere at CTIO provides a climate that promotes these interactions, which take place naturally at “Staff Tea” (every Friday morning at 11 am, the CTIO and SOAR scientific staff gather to discuss science, observatory matters, and other topics of interest), at regular scientific colloquia, and in the public computer area that the students share with visiting astronomers and other interns. Informal meetings with various CTIO staff members and visiting astronomers while students were on the mountain typically resulted in an on-the-spot introduction to an instrument or research specialty. This year during the REU observing run on the 0.9-m telescope, two of the students met with Dr. Pat Seitzer (University of Michigan) while watching sunset on the top of Cerro Tololo. This chance encounter led to Dr. Seitzer showing the students the Curtis-Schmidt telescope and explaining the importance of the space debris program he is carrying out for NASA.

OTHER
See also “Weekly Student Seminars” and “Field Trips” in the Major Activities section.

How have the results been disseminated to communities of interest?

SCIENTIFIC RESULTS
At the end of the program, the students presented their work in a mini-symposium. Each student gave a 10- to 15-minute talk, which was followed by five minutes for questions from the audience. The symposium took place in the AURA auditorium, on the AURA compound in La Serena, and was attended by the CTIO, Gemini, and SOAR scientific staff and visitors. The REU and PIA students also will present their work in the form of a poster paper at the 223rd meeting of the American Astronomical Society (AAS), scheduled for 5–9 January 2014 in National Harbor, Maryland.

OUTREACH
Public outreach is an important aspect of the CTIO REU program. This year, the students researched the telescopes on Cerro Tololo and Cerro Pachón and wrote “Telescope Fact Sheets” for use in the upcoming Family Day on Cerro Tololo. Each REU student was given a small telescope, called a Galileoscope, which they assembled themselves and learned to use in a mini-workshop given by the CTIO Education and Public Outreach team. With these Galileoscopes, the students can assist with public outreach at their home universities by showing stars, planets, and star clusters.
What do you plan to do during the next reporting period to accomplish the goals?

During the next reporting period, we will host the 2014 CTIO REU program, building and improving upon the process used in previous years. The following is a timeline of the CTIO REU program for the period from July 2013–June 2014:

- July–August 2013:
  Answer student inquiries about the 2014 CTIO REU program.
  Update the CTIO REU poster website for the 2013 program and print REU posters.
  Mail REU recruitment posters and letters for the 2014 program.
  Identify mentors and select student projects for the 2014 program.
  Make the application form available for the 2014 program.

- September 2013:
  Submit 2013 CTIO REU students’ abstracts for AAS meeting.
  Finalize 2013 CTIO REU Students’ AAS travel plans.
  Submit an NOAO observing proposal for the 2014A observing program of the incoming 2014 REU students.

- October 2013:
  Deadline for 2014 CTIO REU applications.
  Convene Student Selection Committee.
  Send out acceptance emails for 2014 CTIO REU program to successful students.
  “Reply by” date for first offers.
  Fill all 2014 CTIO REU positions by the end of October.

- November 2013:
  Pair 2014 CTIO REU students and mentors.
  Complete booking of 2014 CTIO REU student travel to Chile.
  Finalize educational activities for the 2014 program.

- December 2013:
  Mentors and student coordinator help 2013 students prepare AAS posters.
  Awards of telescope time for 2014A announced by NOAO.

- January 2014:
  2013 REU students present at AAS Conference.
  Student coordinator meets new students at Dallas-Ft. Worth airport to escort them to Chile.
  Official start of the 2014 CTIO REU program.
  Students meet their mentors and begin work on projects.
  First student seminar is given.
  First REU weekly research meeting occurs.

- February 2014:
  Take field trip to Cerro Pachón, including the Gemini-South and SOAR telescopes.
  External Project Evaluator for the REU program (Dr. Isabel Hawkins) visits CTIO.
  Take field trip to another major observatory in Chile.
- March 2014:
  Final 2014 REU student presentations occur in AURA Lecture Hall.
  Official end of Chilean phase of the 2014 CTIO REU program.
  2014 REU students depart from Chile to return home.

- June 2014:
  Submit 2014 CTIO REU Annual Project Report to the NSF.

**Products**

**Journals:**

**Books:**
None to report

**Book Chapters:**
None to report

**Thesis/Dissertations:**
None to report

**Conference Papers and Presentations:**
Emig, K. & Kaleida, C. 2013, BAAS, 45, #250.08, “Simulated Star Clusters with MASSCLEAN: Testing a Stellar Grouping Selection Method”
Gilfrich, C. 2013, BAAS, 45, #142.19, “Orbital Period of SDSSJ0256 (a DA + M Binary System)”
Meyer, S. & Pessev P. 2013, BAAS, 45, #250.05, “Near-IR Integrated-Light Magnitudes of Young LMC Star Clusters: Extending the Sample to the Fainter Objects”
Thomann, C. & James, D., Boberg, O., Cargile, P., & Aarnio, A. 2013, BAAS, 45, #250.29, “A Photometric and Spectroscopic Analysis of Young, Nearby Open Cluster Collinder 70”

**Other Publications:**
Calderón-Espinoza, D., Indahl, B., Paredes-Alvarez, L., Kaleida, C., and Virgili, F. J. 2013, GCN Circ. 14202, “GRB 130131B: CTIO 0.9-m optical upper-limits”
Technologies or Techniques:
None to report

Patents:
None to report

Inventions:
None to report

Licenses:
None to report

Websites:
The CTIO REU Program website can be found at http://www.ctio.noao.edu/noao/content/REU-Program. On this website, potential students can find information about the program and peruse the results of research completed by current and past students while at CTIO. The website also contains a page that lists the publications related to work carried out during the CTIO REU summer student programs, going back to the start of the CTIO REU program in 1995. Furthermore, the website shows photos from each year’s program, which gives a good impression of the programs, and the start of an English-Spanish Astronomy Dictionary, developed by the 2012 and 2013 REU/PIA groups.

Other Products:
As part of the Weekly Research Meeting, the REU and PIA students participated in an Astronomy Language Exchange. At the beginning of each meeting, the students came up with astronomy-related technical terms in English to translate to Spanish, and from these suggestions compiled the beginnings of an English-Spanish Astronomy Dictionary. The intention is to continue this practice in future year’s REU and PIA programs with the aim of creating a comprehensive English-Spanish Astronomy Dictionary to post on the Web for public use.

Participants

What individuals have worked on the project?
Name: Nicole van der Bliek
Email: nvdbliek@ctio.noao.edu
Project Role: Principal Investigator, CTIO REU Site Director
Nearest Person Month Worked: 0
Contribution to Project:
Funding Support: CTIO base budget AST-0950945
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, indefinite (resident)

Name: David James
Email: djj@ctio.noao.edu
Project Role: Co-Principal Investigator
Nearest Person Month Worked: 1
Contribution to Project:
Funding Support: CTIO base budget AST-0950945
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, indefinite (resident)

Name: Brian Chinn
Email: bwchinn@ufl.edu
Project Role: REU Student
Nearest Person Month Worked: 3
Contribution to Project: Student Research Project
Funding Support:
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, 2.5 months

Name: Alexander Deich
Email: xdeich@gmail.com
Project Role: REU Student
Nearest Person Month Worked: 3
Contribution to Project: Student Research Project
Funding Support:
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, 2.5 months

Name: Emily Finney
Email: equinney35@gmail.com
Project Role: REU Student
Nearest Person Month Worked: 3
Contribution to Project: Student Research Project
Funding Support:
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, 2.5 months

Name: Briana Indahl
Email: indahl@wisc.edu
Project Role: REU Student
Nearest Person Month Worked: 3
Contribution to Project: Student Research Project
Funding Support:
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, 2.5 months

Name: Lois Smith
Email: lois.smith317@gmail.com
Project Role: REU Student
Nearest Person Month Worked: 3
Contribution to Project: Student Research Project
Funding Support:
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, 2.5 months

Name: Molly Williams
Email: molly_williams131@mymail.eku.edu
Project Role: REU Student
Nearest Person Month Worked: 3
Contribution to Project: Student Research Project
Funding Support:
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, 2.5 months

Name: Catherine Kaleida
Email: ckaleida@ctio.noao.edu
Project Role: CTIO REU Student Program Coordinator
Nearest Person Month Worked: 3
Contribution to Project: Managing program
Funding Support: CTIO base budget AST-0950945
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, indefinite (resident)

Name: R. Chris Smith
Email: csmith@ctio.noao.edu
Project Role: REU Student Program Advisor
Nearest Person Month Worked: 1
Contribution to Project: Help managing program
Funding Support: CTIO base budget AST-0950945
Collaborated with Individual in Foreign Country? Yes
If Yes, Country of Foreign Collaborator: Chile
Traveled to Foreign Country? Yes
If Yes, List Which and Duration of Stay: Chile, indefinite (resident)

**What other organizations have been involved as partners?**
Not applicable
Have other collaborators or contacts been involved?

Yes. Additional collaborators include the project mentors listed in the “Significant Results” section, and the collaborators on the REU observing proposal listed in the “OBSERVING” section of “What opportunities for training and professional development has the project provided?”

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The main goal of this program is to allow students, mainly astronomy and physics majors, but also the occasional math major, to participate in research, get hands-on experience in astronomical observing, work in a research institute (non-university-based, for a different perspective), and experience the international nature of astronomy (working in Chile, at an international observatory) alongside Chilean students. The students directly contribute to making new discoveries in the field of astronomy and frequently publish these results in peer-reviewed journals. A summary of the specific astronomical discoveries of the 2013 REU students can be found in the “Key Outcomes” section of this report.

What is the impact on other disciplines?

The major impact of this program on other disciplines is to help produce the next generation of highly educated and skilled scientists to enter the STEM workforce.

What is the impact on the development of human resources?

The goal of this program is the development of young scientists who will be the astronomers of the future. Fourteen applications for the 2013 CTIO REU program were received. Of these applicants, 50% (7 out of 14) were women and 50% (7 out of 14) were men. For the 2013 REU program, 67% (4 out of 6) of the students selected were women and 33% (2 out of 6) were men.

The underrepresentation of certain minority groups in the sciences seen across the US is apparent in the racial diversity of the applicant pool for the CTIO REU program. Out of the 14 applicants, 11 reported themselves to be White and not of Hispanic, Latino, or Spanish origin, and 2 reported Asian Indian. (As of the 2011 National Academy of Science, National Academy of Engineering, and Institute of Medicine report, “Expanding Underrepresented Minority Participation,” Asian Indians are no longer considered a group underrepresented in the sciences. For more information, see http://www.nap.edu/catalog.php?record_id=12984.) One applicant declined to answer, as this was an optional question on the application form. The six accepted students this year were White/Caucasian and not of Hispanic, Latino, or Spanish origin. Clearly, the underrepresentation of minorities in the sciences is reflected in the 2013 REU cohorts. We will continue our efforts to advertise heavily at historically minority-serving institutions and conferences in the US. One of the 2012 students, Kimberly Emig, presented her project from the CTIO REU program at the National Conference of the Society for Advancement of Chicanos and Native Americans in Science in October 2012. While at the conference, Kimberly spoke with many students about the CTIO REU program. We hope that other students who attended this conference will be inspired to apply for the 2014 program after seeing Kimberly’s work and hearing her enthusiasm for the CTIO REU program.

While the diversity in the 2013 REU group itself is limited, the fact that the NSF-funded REU program is run in parallel with the PIA program for Chilean students ensures a high level of diversity in the overall program and student interactions.
Geographically, the applicants were from 9 states in the US: 5 from the South, 4 from the Midwest, and 5 from the West. In years prior to 2012, there has been a smaller proportion of applicants from the South and Midwest, and it is gratifying to see that the advertising efforts for the program are now reaching those parts of the country that have been underrepresented in our program alumni.

The home institution size of the accepted applicants was also tabulated: 50% (3 out of 6) were from schools with fewer than 10,000 enrolled undergraduates. The CTIO REU program continues to be committed to providing astronomy research experiences to students whose home institutions cannot provide them with similar opportunities.

The CTIO REU groups are chosen based on merit as well as how much they will benefit from the program. However, we continue to strive to have a diverse applicant pool and to have groups that are balanced in gender and include students from underrepresented minorities in the sciences. As such, the CTIO REU program is directly contributing to broadening participation in the science, technology, engineering, and mathematics (STEM) disciplines.

**What is the impact on physical resources that form infrastructure?**
Nothing to report

**What is the impact on institutional resources that form infrastructure?**
Nothing to report

**What is the impact on information resources that form infrastructure?**
Nothing to report

**What is the impact on technology transfer?**
Nothing to report

**What is the impact on society beyond science and technology?**
One of the unique characteristics of the CTIO REU program is that it offers the opportunity to live and work in an international setting at an observatory in a foreign country. The US students work alongside Chilean students who participate in the parallel PIA program, and the cultural experience these young astronomers obtain is as invaluable to their growth into successful astronomers as the research projects themselves.

**Changes / Problems**

**Changes in approach and reason for change:**
For the future participants in the program, we are making changes to strengthen our sensitivity to and training program for harassment issues. These changes include a presentation and discussion dedicated to harassment issues at the beginning of the program together with an online anti-harassment training program. Together, these will bring to the students’ attention the broad range of issues involved, help them to recognize issues of this nature at an early stage, and help prepare them to deal with and report such issues with confidence. The online training will be given in English to the REU students and in Spanish to the PIA students to make sure that all details of the training are clearly understood. We are implementing these changes due to an incident of harassment during the 2013 program.
issue was resolved quickly, it could have been addressed much earlier if the students had been more aware of what behaviors are unacceptable and had been more proactive in reporting their discomfort.

At the same time, we plan to offer the students regularly scheduled opportunities to express and seek advice on harassment or other issues. To this end, we will implement regular one-on-one meetings between the students and the CTIO REU student coordinator to better monitor progress. These meetings will at the same time give the students the opportunity to talk about any work-related or other issues that have come up during the program.

**Actual or Anticipated problems or delays and actions or plans to resolve them:**
Nothing to report

**Changes that have a significant impact on expenditures:**
Nothing to report

**Significant changes in use or care of human subjects:**
Not applicable

**Significant changes in use or care of vertebrate animals:**
Not applicable

**Significant changes in use or care of biohazards:**
Not applicable
Photos from 2013 CTIO REU Program:

Figure 1: The 2013 CTIO REU and PIA students pose with the sunset over La Serena and Coquimbo at the CTIO Student Welcome Barbecue. From left to right: Gonzalo Briones (PIA), Brian Chinn (REU), Emily Finney (REU), Molly Williams (REU), Alex Deich (REU), Briana Indahl (REU), Lois Smith (REU), and Diego Calderon (PIA).
Figure 2: The REU and PIA students at work in the student office in the CTIO building. From left to right: Diego Calderon (PIA), Brian Chinn (REU), Alex Deich (REU), Emily Finney (REU), Briana Indahl (REU), Molly Williams (REU), and Lois Smith (REU).
Figure 3: The REU/PIA students visit the beautiful dormitory facilities on Cerro Paranal, just south of Antofagasta in northern Chile. From left to right, back row: Molly Williams (REU), Emily Finney (REU), Diego Calderon (PIA), Brian Chinn (REU); front row: Alex Deich (REU), Lois Smith (REU), Briana Indahl (REU).
Figure 4: The 2013 CTIO REU and PIA students and Student Coordinator at a visit to the Universidad de La Serena. From left to right: Gonzalo Briones (PIA), Molly Williams (REU), Brian Chinn (REU), Alex Deich (REU), Briana Indahl (REU), Emily Finney (REU), Diego Calderon (PIA), Lois Smith (REU), and Dr. Catherine Kaleida (REU/PIA Student Coordinator).

Figure 5: The REU/PIA students enjoy the cultural experience of seeing the Chilean national soccer team play at the stadium in La Serena. Present in this photo: Diego Calderon (PIA), Briana Indahl (REU), Molly Williams (REU), Gonzalo Briones (PIA), Alex Deich (REU), Emily Finney (REU), and Brian Chinn (REU).