NATIONAL ASTRONOMY AND IONOSPHERE CENTER
ARECIBO OBSERVATORY
Cornell University

Research Experience for Undergraduates Program

PROGRESS REPORT SUMMER 2008

(Christiano Garnett Marques Brum and Murray Lewis)

1. The Arecibo Program

Introduction: The Arecibo Observatory has conducted a summer student program since 1972. It was initially funded through NAIC's operating funds from the NSF but since 1987 most students have been funded under the NSF REU program. The main thrust of the Arecibo summer student program is to induct student interns into the research environment of the Observatory. Each student is individually mentored for ten weeks while he or she participates in a scientific (or engineering) project, and gains direct experience of scientific research and its methods. At the end of the summer, every student makes a presentation about his/her project to the scientific staff and their peers. In this way they live the life of a scientist for a few weeks, and are better able to make informed decisions about a possible research career after graduation. Moreover, since Arecibo is a somewhat remote site, our summer interns experience the tempo, life, and living conditions visiting astronomers actually face as they conduct their observing programs, and are able to meet and mingle with those in residence during the summer. The students from the US mainland also have the opportunity to learn about Puerto Rico and experience a different culture while Puerto Rican students get to mix with mainland students.

There were eight students in the summer program in the summer of 2008, six under the NSF REU program, one funded from NAIC funds, and one under the NSF's Louis Stokes Alliances for Minority Participation (LSAMP) to the University of Puerto Rico at Rio Piedras. NAIC normally provides support for one or more students who have graduated to participate in the summer program. Most of the students, including all the REU funded students, were selected this year from 86 undergraduate and 4 graduate US and Puerto Rican applicants after a competitive selection process. The number participating under the REU program was smaller than expected due to an unusually high rate of non-acceptance of our offers for participation in the program. This may have been due to the perception amongst the students' advisors at their home institutions that the Arecibo Observatory was scheduled to close as a result of the recommendations of the Senior Review. NAIC will work hard to negate this perception in the coming years.

For each participant the program lasted about ten weeks, with the earliest arriving towards the end of May and the last departing in mid-August 2008. UCAR and REU funds provided support for four of the interns to attend the Atmospheric Sciences CEDAR meeting in Boulder in June. REU funds also supported one student to attend each of the Division of Planetary Sciences meeting in Ithaca in October and the Fall AGU meeting in San Francisco, and will support the participation of three students at the AAS meeting in Long Beach in January. Most of the students were, or will be, involved in poster presentations. The Observatory's summer student program was managed by Christiano Brum, a post-doctoral associate and David Kornreich, a

visiting scientist from Humboldt State University. It was under the overall direction of Murray Lewis, Head of the Observatory's Astronomy Group.

An important component of the Arecibo summer program for the students from the US mainland is the opportunity to experience Puerto Rico and mix with students from Puerto Rico. Likewise, the Puerto Rican students have the opportunity to mix with mainland students. This year's mix of three local students and five from the mainland achieved this with the students forming a close-knit group.

Research Activities: The major research projects of the Arecibo Observatory are in the fields of Radio Astronomy, Radar Astronomy, and radio and lidar studies of the upper atmosphere. There is thus a wide range of equipment, research topics, and techniques. Accordingly, a formal seminar series is conducted for the summer interns, in which they are introduced to the fundamentals of the three fields, the applications of the Observatory's instrumentation, and some of the areas of research conducted by the scientific staff. This year's talks (see Section 3) covered subjects related to astronomy, ionospheric studies, planetary radar, electronics, and the geology of Puerto Rico. A guest speaker from the NASA Johnson Space Flight Center talked about the shuttle program. In addition, Dr. Michael Davis, a former Observatory Director, and the NAIC Director, Prof. Don Campbell, talked with the students, respectively, about the evolution of scientific programs and equipment at Arecibo, and about applying to graduate school.

Summer projects this year involved analyses of ionospheric/protonospheric and astronomical data, development of data acquisition software, and development of a feed and associated receiver. Descriptions of the individual student projects are given in Section 2. At the end of the summer, the students gave talks about their projects and, of course, had, or will have, the opportunity to present posters about their projects at the CEDAR, AGU, DPS and January AAS meetings. Four Atmospheric Science students participated in the 2008 CEDAR (Coupling, Energetic, and Dynamics of Atmospheric Regions) meeting, two of them, REU students Diana Prado Garzon and Ethan Engle, as coauthors. Similarly, one astronomy REU student, Tracy Becker, made a presentation at the fall Division of Planetary Sciences meeting, while Darlene Maldonado Nieves presented the results of her work at the Ana G. Mendez University System Student Research Development Center's 19th Undergraduate Research Symposium in San Juan. Diana Prado Garzon presented a poster at the AGU Fall Meeting in December and we are expecting presentations by REU students Tracy Becker, Anthony Smith and Kristen Jones at the winter AAS meeting in January.

Not all the student projects were directly concerned with using or analyzing data obtained with the 305 m Arecibo telescope. To give every student the opportunity for access to our primary instrument, a "hands on" astronomy experiment was run with the students, so they themselves could control the telescope, obtain data, and quickly see the results. This introduced them to the constraints imposed by a limited steerability telescope on the choice of sources to observe at any particular time, as well as providing practical knowledge of exactly what equipment and software is required to obtain spectra.

Topical workshops at the observatory provide students a firsthand introduction to specific research topics. One such workshop this past summer was the NanoHertz Gravitational Workshop with about forty participants that discussed the application of pulsar timing measurements to the detection of nanoHertz gravitational waves. Much of the discussion

centered on how to make more precise measurements of pulsar arrival times, giving the summer students who attended a good feel for the practical problems of the field.

A unique experience was organized for the summer students this year. Our REU students from 1988 included Margaret Hanson (now associate editor of Astronomical Journal), Joe Lazio (now Project Scientist for the Square Kilometer Array project), and Sixto González (the immediate past site director at Arecibo). These folk organized a one-day event **"20 Years Later: Where are the Arecibo REU Students today?"** Most of the summer students from 1987-1989 were contacted and many contributed notes (and photos) about their experience and careers since they were interns at Arecibo. The 2008 students enjoyed interacting with Hanson, Lazio and González in a relaxed, informal setting, and certainly gained exposure to impressive role models.

Living and Recreation: A BBQ for the Observatory staff was held at beginning of the summer to welcome the students and introduce them to the staff. The Observatory's human resources director and the safety officer gave the students an orientation about conduct, safety and security inside and outside the Observatory grounds. This year the interns occupied three small offices over the telescope control room, which provided togetherness but with enough compartmentalization for effective work. Towards the end of the summer a second staff BBQ was arranged to bid them farewell.

The Arecibo Observatory is set in forested, limestone karst terrain, and is approached by a winding road along a valley between small hills. While these help isolate the site from radio frequency interference, the nearest "village" (Barrio Esperanza) is ten minutes away by car while Arecibo is about half an hour away. As has been the norm for the past few years, all the students stay on site in the Observatory Visiting Scientist Quarters. This is helpful for their research activities but it does limit their ability to travel on the Island as most students are younger than 25 and find it difficult to hire a car economically. The Arecibo program therefore ensures that a couple of shopping trips are available each week for necessities, and an event is normally organized for every weekend to allow students to get away from the Observatory to sample the life and sights of Puerto Rico. Based on suggestions, the students make the choice about what they want to do.

Observatory staff members, David Kornreich, Christiano Brum and Paulo Freire spent a good deal of time with the students, helping to organize and enable extracurricular activities. One popular excursion was to the El Yunque tropical rain forest preserve, where our interns joined the REU students in the Tropical Botany program of the University of Puerto Rico in being shown around their off-limits, off-the-beaten-track preserve, where they hiked and camped. Later in the summer our interns hosted a reciprocal visit, during which they took their botanical guests all over the telescope and Observatory site, and welcomed them with a BBQ. As opposed to some past years, the students this year generally preferred single-day excursions rather than overnight trips. They visited Old San Juan at both the beginning and end of the summer, where they explored the "El Morro" fort and shopped in the old town, the oldest urban area under US administration. Many of the visits were to local beaches, including one trip to the exotic Playa Flamenco on the off-shore island of Culebra, and a weekend-long trip to La Paguera, where they enjoyed the bio-luminescent bay. Another was to Jobos beach near Isabela on July 4th to view the impressive fireworks display provided by the US Coast Guard unit at the old Ramey base.

Ethan Engle terminated his internship after three weeks, one of which he spent in attendance at the CEDAR meeting in Boulder, Colorado. His early departure was due to a family emergency.

Ali Amirrezvani, the grad student working with the Atmospheric Sciences group, returned to the Observatory on NAIC funds for a further ten-week stay in the fall.

We acknowledge and thank the Observatory staff members, Maria Judith Rodriguez, Lucy Lopez, Wilson Arias, Carmen Segarra, Carmen Torres, Jose Cordero, and all the guards for their cooperation and time in assisting with the day-to-day needs of the students. We also had the enthusiastic help of former staff member Gerry Giles, from Aguadilla, in organizing and helping with some of the weekend activities.

2. 2008 Summer Students Projects:

REU Funded Students:

Tracy M. Becker: Triple Near-Earth Asteroid 2001 SN263 Radar Imaging and Model

Tracy worked with radar images from asteroids. Aside from being a part of current observations, her research involved the asteroid 2001 SN263, the first triple near-Earth asteroid system ever discovered. She looked at the radar images taken in February of the asteroid and gathered important data from them such as the bandwidth and range of the primary asteroid and its two companions. This work provided information about the orbits of the satellites and an estimation of the diameters of the objects in the system. She spent a large portion of the summer using light-curve data and radar images to create a three dimensional computer model of the asteroid. From the model, important information about the asteroid such as its shape, volume and density can be determined. The results of her work were presented at the 2008 DPS Meeting with the title "*First Triple Near-Earth Asteroid 2001 Sn263 Radar Imaging And Model*".

Ms. Becker is a senior at Lehigh University in Pennsylvania with a major in astrophysics. Her supervisors were Dr. Mike C. Nolan, Dr. Ellen S. Howell, and Dr. Christopher Magri.

Ethan Engle: Study of the Ionospheric Long-Trend Variability Over Arecibo

Ethan's assignment as an REU student was to prepare a graphical interface for the Fabry Perot Interferometer using Mat lab. Upon his arrival at the Observatory, Ethan received written material in order to obtain a better understanding of his project. Unfortunately, due to a family emergency, Ethan had to terminate his contract three weeks after his arrival. However, he presented a paper titled "Solar, geomagnetic and seasonal variability of the NmF2 and foF2 over Arecibo Observatory" at the 2008 Coupling, Energetic, and Dynamics of Atmospheric Regions (CEDAR) meeting. This work presented analyses of the variability with solar and geomagnetic activity of the electron density (NmF2) in the F region critical frequency (foF2) and peak height (hmF2) obtained from 402 days (142 experiments) of bottom-side, incoherent-scatter, radar data recorded at Arecibo Observatory (18.35^{o}N, 66.75^{o}W - 46.7^{o} dip angles) between 1985 and 2005. The results showed different responses of the NmF2 and foF2 with

solar activity and geomagnetic variation for equinox, summer and winter seasons. Also, the results obtained in this work were compared with previous results of the neutral winds.

Mr. Engle is a third-year undergraduate student at Case Western Reserve University and is majoring in Astronomy/Physics. He was supervised by Ms. Eva Robles in collaboration with Dr. Christiano Brum.

Kristen Jones: A Test Receiver at 600–1200 MHz for Investigating Local RFI

Kristen was the first student to arrive at the AO this year. Her goal for the summer was to model and build an antenna and receiver to investigate the local Radio Frequency Interference (RFI) below 1.2 GHz, to determine the usefulness of a cooled receiver in that frequency range. While scientific interest in the region below 1.2 GHz had already been expressed – pulsar astronomy and high-redshift neutral hydrogen surveys in particular being fields that could benefit from such a receiver – it had yet to be determined whether or not there was enough RFI -free spectrum to be scientifically useful. Kristen's test receiver is being used to answer this question.

Ms. Jones is a fifth-year senior at the University of Wisconsin-Madison pursuing a double major in Physics and Astronomy-Physics as well as a Certificate in Women's Studies. She is doing her Senior Honors Thesis on radio interferometry with Professor Peter Timbie. Her Arecibo research was supervised by Mr. Ganesh Rajagopalan and Mr. Dana Whitlow.

Darlene Maldonado Nieves: Laser Project

This summer Darlene developed data acquisition software for a test station that measures the pass band of a Faraday filter that is used for daytime observations with the potassium Doppler resonance lidar. The Faraday filter is a band pass filter whose width is between 1 and 3 GHz, depending on the configuration. This narrow width is only slightly wider than the Doppler-broadened spectrum of mesospheric potassium, which is measured to ascertain temperatures in the upper mesosphere. It is on the same order as the width of the Rayleigh scattered light from the stratosphere that is used to calibrate the measurement from the mesosphere. In order to make accurate measurements of mesospheric temperature and K density, the effect of the filter must be removed from the measurement. This requires an accurate measurement of the filter band pass. In fact, Darlene's project was a continuation of work the previous summer when an optical system for making the measurement was developed by Israel Gonzalez. This system uses a single-mode external-cavity diode laser as a light source and involves 3 measurement components in addition to the Faraday filter: Doppler-free spectroscopy of K vapor to get absolute wavelength (or frequency) markers, a Fabry-Perot etalon with a free spectral-range of 430 MHz to provide the wavelength (or frequency) scale, and a power monitor to normalize the signal, as the diode laser power varies over its scan. Darlene developed software in Lab VIEW using a digital-to-analog converter to provide a voltage ramp to scan the laser and for analog-to-digital converters to read the signals. These signals are saved to a file for post-processing.

Ms. Maldonado is a fifth-year student at Inter American University of Puerto Rico, Bayamon campus. Her major is in Electrical Engineering. She was supervised by Dr. Jonathan Friedman.

Diana C. Prado Garzon: Study of the Topside Constituents' Behavior Over Arecibo: Evidence for Wave Propagation in the Topside Ionosphere

Diana worked with incoherent-scatter radar data from the topside ionosphere at the Arecibo Observatory. In this task, the data analysis was performed with H^+, helium ion concentrations, electron density, and ion and electron temperatures for the period of March 7–11, 2008 (after the telescope remodeling this was the first data set recorded by the radar facilities). These records display radar data from 28 different altitudes (224–1248 km with an altitude step of ~38 km) at 20-minute intervals. Analysis of harmonic dependence by altitude and local time was performed using Fourier analysis, giving dominant frequencies that allowed the reconstruction of the signal with periodicities bigger than 45 minutes. Finally, analysis of the data using a Wavelets Transform method was applied in order to determine what the dominant frequencies at the different altitudes were. Diana looked for periodicities shorter than 16 hours. Preliminary results from the H^+ and electron density and temperature show some remarkable evidences of waves with periodicity of about 7.5 hours propagating in the topside ionosphere that weaken with decreasing altitude in the range studied. More work and analysis need to be done in order to identify the source of these waves. Also, during her time in the REU program, Diana participated in the 2008 Coupling, Energetic, and Dynamics of Atmospheric Regions (CEDAR) meeting in Midway, Utah and wrote an abstract to the AGU Fall Meeting, December 15-19, San Francisco title "*Signatures Of Wave Propagation In The Topside Ionosphere*".

Ms. Prado is a fourth-year undergraduate student at University of Puerto Rico, Mayaguez Campus and she is majoring in the area of geology. She was supervised by Dr. Christiano Garnett Marques Brum, Dr. Sixto González and Dr. Nestor Aponte.

Anthony Allen Smith: Calibrating Input Data for OH/IR Star Light Curves

OH/IR stars are long-period, thermally-pulsating, asymptotic giant branch (AGB) stars with cool photospheric temperatures of 2000-3300 K. They are surrounded by enormous, expanding, dusty, shells. Mass continuously leaves an AGB star as molecules that are shielded by embedded dust for a long time against degradation by interstellar ultraviolet radiation. Eventually, however, the shell expands to such large radii that its dust density no longer suffices to protect the molecules: in particular H_2O breaks down to produce OH, which at yet larger radii break into its constituent atoms. The dusty shell intercepts much of the radiation leaving the AGB star, and reradiates it in the infra red. This pumps the long radial column densities of OH molecules, which support the 1612 MHz OH masers Arecibo detects so easily. 1612 MHz emission shows up as two peaks, since the expanding shell Doppler shifts the maser to higher (blue) frequencies on the near side, and to lower (red) frequencies on the far side. The objective of the observing program is to measure the 6-40 day time delay between the cyclical changes in the intensity of the blue and red peaks, as both are pumped by the same source. This delay enables the physical size of the shell to be directly estimated, as it is caused by the time it takes light to travel across the diameter of the shell, which constrains dust-shell models. This summer Anthony learned FORTRAN and wrote a general purpose subroutine to be used with ANALYZ to improve the day-to-day calibration of data collected over five years. The data were taken with noise-diode calibration signals that need to be compared from time to time with natural flux-calibration sources observed with the telescope. Over five years there are a variety of changes to the telescope, the noise-diodes, and the receiver to be calibrated out of the light curves. Anthony determined the noise-diode values as

they changed over time, and installed these in his code. The efficacy of this work is to be tested by producing a light curve for IRAS 19396+2338, which Anthony expects to complete with Dr. Lewis from home.

Mr. Smith is a fourth-year undergraduate student at the University of Missouri in Columbia, MO. He was supervised by Dr. Murray Lewis.

NAIC Funds:

Ali S. Amirrezvani: Preliminary Results of the Geocorona H-α Variability According to the Geomagnetic Activity at Arecibo

During the summer of 2008, Ali worked with geocorona H-α emission intensity. The goal was to evaluate and analyze geocorona H-α emission intensities according to geomagnetic activity for 60 nights (i.e., ~3300 images) of Fabry-Perot interferometer data acquired at Arecibo during 2006 and 2007. The geocorona Ḥ-α nightglow emission is excited by resonant fluorescence of solar Lyman α photons that are produced by successive resonant scatterings of Lyman α photons by hydrogen with the geocorona. The Lyman α photons are either of direct solar origin or from resonantly scattered hydrogen atoms in the atmosphere. The preliminary results showed that there is evidence of H-α intensity influence from geomagnetic activity. In addition, under equivalent solar and seasonal conditions, the H-α intensity is higher during disturbed periods, mainly for Winter Solstice (F10.7cm> 84) and Equinox (F10.7cm <=71). Detailed studies are proceeding to analyze each period individually to improve the quantification of the dependence. During his time in the REU program Ali participated in the 2008 Coupling, Energetic, and Dynamics of Atmospheric Regions (CEDAR) meeting, Midway, Utah.

Mr. Amirrezvani earned his bachelor degree in Animal Sciences at Rutgers University, Cook College, New Brunswick, NJ, his associate in Computer Programming at Globe Institute of Technology, in New York, NY, and his masters in Earth and Atmospheric Sciences at The City College of New York, New York, NY. He was supervised at Arecibo by Dr. Pedrina Santos and collaborated with Dr. Robert Kerr (then the Site Director of AO) and Dr. John Noto (Scientific Solutions, Inc.).

NSF LSAMP Funds:

Elvin Vega-Vega: Real Time Cluster Linux Based MPI and Intel Math Kernel Library Approach

Elvin worked in the development of a parallel Unix (Linux or OS X) computing cluster for real-time processing and display of atmospheric radar data from the main Observatory radar system (transmitting 2 MW at 430 MHz). He had as objectives to create the MPI cluster, setup the cluster for the parameters of the Observatory radar system, and to create the code to process the data obtained. In fact, this cluster will analyze backscatter data from the E and F regions of the ionosphere obtained with the Arecibo 430 MHz radar. These data use a coding (pulse modulation) technique in which radar pulses are transmitted each 10 millisecond with a length of 500 microseconds. The coding is binary phase modulation with a baud length of 1 or 2 microsecond; a different random code is used with each pulse. When used with the plasma

line, for example, it can obtain extremely accurate plasma densities (.02%) in a few seconds. New analysis techniques are now being developed that will use these measurements combined with the ion line measurements to do a better job of measuring the ionic constituents of the F1 region of the ionosphere. This technique requires a huge amount of computation (4096 point FFTs for every radar pulse, as well as additional computations).

Mr. Vega is a fifth-year undergraduate at Inter American University of Puerto Rico, Bayamón Campus and his major is in Computer Engineering. He was supervised by Dr. Michael Sulzer, and Dr. Nestor Aponte.

3. 2008 staff and visitor talks and students presentations

REU seminars were regularly scheduled each Monday and Thursday and all the staff were invited to attend.

Date:	Speaker:	Title:
June 12	**Christopher Salter**	An Overview of the Radio Sky
June 16	**Mikael Lerner**	Time and Co-ordinate Systems
June 19	**Dana Whitlow**	The Arecibo RF Chain and Components Thereof
June 23	**Steven Gibson**	The Interstellar Medium
June 26	**David Kornreich**	Simulating Galaxies
June 30	**Jonathan Friedman**	The Mesospheric Refrigerator: Why the Upper Mesosphere in Summer is the Coldest Place on Earth
July 3	**Mike Nolan**	Asteroids
July 7	**David Kornreich**	Crashing Galaxies
July 10	**Luis Ramirez** Guest speaker: NASA Johnson Space Center	The Space Shuttle Program
July 11	**Paulo Freire**	Pulsars
July 14	**Murray Lewis**	OH/IR Stars
July 17	**Michael Sulzer**	Incoherent Scatter
July 21	**Ellen Howell**	The Geology of Puerto Rico
July 24	**Robert Minchin**	Galaxy Astronomy
July 28	**Michael Sulzer**	Incoherent Scatter
July 31	**Ellen Howell**	Comets
August 4	**WORKSHOP: "20 years later. Where are the Arecibo summer students today?"**	
	Margaret Hanson	
	Joe Lazio	
	Sixto González	
	Kristin Jones	Project presentation
	Tracy Becker	Project presentation
	Anthony Smith	Project presentation
	Ali Amirrezvani	Project presentation
August 5	**Diana Prado Garzon**	Project presentation
	Elvin Vega-Vega	Project presentation
August 7	**Darlene Maldonado-Nieves**	Project presentation

4. Papers presented and to be present in meetings/conferences:

Christiano Garnett Marques Brum; Sixto González; Nestor Aponte and **Diana Prado Garzon**, *Solar and geomagnetic variability of nighttime topside hydrogen, oxygen and helium ion fractions over Arecibo*, 2008 Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) meeting, Midway, Utah.

Eva Robles, **Ethan Engle,** Christiano Garnett Marques Brum, Craig Tepley, Sixto González and Pedrina Terra Santos. Solar, geomagnetic and seasonal variability of the NmF_2 and foF_2 over Arecibo Observatory. 2008 Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) meeting, Midway, Utah.

Darlene Maldonado-Nieves and Jonathan Friedman, *A high-resolution spectroscopy test-station for a Faraday anomalous dispersion optical bandpass filter*, Ana G. Mendez University System Student Research Development Center 19th Undergraduate Research Symposium. September 13, 2008, Normandie Hotel, San Juan. (Sponsored by NSF).

Diana Prado Garzon, Christiano Garnett Marques Brum, Sixto González and Nestor Aponte, *Signatures of wave propagation in the topside ionosphere*, AGU Fall Meeting – December 15-19, San Francisco.

Tracy M. Becker, Michael C. Nolan, Ellen S. Howell and Chris Magri, *First Triple Near-Earth Asteroid 2001 SN263 Radar Imaging and Model*, 2008 Division of Planetary Sciences Meeting, Ithaca, NY

5. Extra-Curricular Activities:

Shopping trips for groceries, etc.
Welcome BBQ near the pool
Visit to Culebra
Trip to the Institute for Tropical Studies in El Yunque
Two trips to Old San Juan
Trip to Cabo Rojo
Trip to La Parguera and bio-luminescent bay
BBQ at AO with the REU students of the Institute for Tropical Studies in El Yunque
Yoga classes with Diana Prado Garzon
Beach days at Aguadilla; 4^{th} of July Fireworks display
Beach days at Arecibo
Farewell BBQ near the pool

6. Student experience in their own words

"…*I am very grateful to my three advisers, from whom I have learned so much. I thank them for giving me the opportunity to work on such a fascinating object, as well as being patient with me and teaching me everything they could*…" - **Tracy M. Becker**

" *… I was here at the world's largest single-dish radio telescope to do research—really interesting research, research that was quite close to the field I plan to pursue in graduate school… My experiences at Arecibo Observatory will serve as a brilliant light to guide me and inspire me as I proceed into unfamiliar territory and continue on to pursue my Ph.D…* " - **Kristin Jones**

"…*I had a great time this summer. It was an amazing experience working and living at the Arecibo Observatory. The scientists and staff are very nice and friendly. I made new friends. I learned about numerous exciting aeronomy and astronomy research topics during the lectures and student discourses. I had an incredible time learning about and exploring the radiotelescope…*" - **Ali Amirrezvani**

"…*The Arecibo Summer Program gives the students the opportunity to experience the life and work of a scientist. We were given the opportunity to learn from these people and to gain experience in our fields of study. The advisors are comprehensive, supportive and helpful. The seminars were very instructive and helpful and I was honored to meet some of the respectful scientists and their work*…" **– Diana Prado Garzon**

7. REU, Other Summer Students & RET Participants statistics:

Participants Status	1972-2007	2008	Total
Undergraduate Level	260	7	**267**
Graduate Level	64	1	**65**
RET	9	0	**9**
		Total Number of Participants:	**341**

Participants Status	1972-2007	2008	Total
Minorities	70	4	**74**
Women	138	4	**142**
		Total Number of Participants:	**216**

Number of REU, Other Summer Students & RET Participants – Scientific Field

Scientific Field	1972-2007	2008	Total
Radio/Radar Astronomy	199	2	**201**
Atmospheric Science	85	5	**90**
Computer Sciences	21	0	**21**
Electronics	17	1	**18**
Education	11	0	**11**
		Total Number of Participants:	**341**

8. Educational Institutions Represented in the NAIC Summer Student Program:

(1972 through 2008)

Agnes Scott College
Amherst College
Arizona State University
Bates College
Bethel College
Boston University
Brigham Young University
Bryn Mawr College
California Institute of Technology
California Polytechnic State University
Cambridge University, UK
Carleton College
Carthage College
Case Western Reserve University
Centenary College of Louisiana
City College of New York
Clemson University
Colgate University
Columbia University
Cornell University
Dartmouth College
Ecole Normale Superieure of Lyon
Embry-Riddle Aeronautical University
Georgetown University
Globe Institute of Technology
Gorky University, Russia
Harvard University
Haverford University
Indiana University
Interamerican in Bayamon
Johns Hopkins University
Lehigh University
Louisiana State University
Massachusetts Institute of Technology
McGill University, Canada
Miami University, Ohio
Missouri State University
New College of Florida
New Mexico State University
New Mexico Tech
North Carolina State University
Northwestern University
Oberlin College
Oxford University, UK
Pennsylvania State University
Pomona College
Princeton University
Purdue University
Rensselaer Polytechnic Institute, NY
Rice University
Rutgers University
Saddlebeck University
San Diego State University
Smith College
Southwest Missouri State University
St. Andrews University
Stanford University
SUNY Albany
SUNY Binghamton
Texas Technological College
Trinity College Dublin, Ireland
Universidad Interamericana de PR
Universidad Metropolitana, San Juan
University of Akron
University of Alabama
University of Arkansas
University of British Columbia
University of California, Berkeley
University of California, Los Angeles
University of California, San Diego
University of California, San Luis Obispo
University of California, Santa Cruz
University of Chicago
University of Colorado
University of Georgia
University of Grenoble, France
University of Hawaii
University of Houston
University of Illinois, Urbana-Champaign
University of Iowa
University of Maryland
University of Massachusetts (Amherst)
University of Michigan
University of Minnesota
University of Montana
University of Missouri in Columbia
University of Nebraska-Kearney
University of Northern Iowa
University of Pennsylvania
University of Puerto Rico, Arecibo
University of Puerto Rico, Humacao
University of Puerto Rico, Mayagüez
University of Puerto Rico, Río Piedras
University of Rochester
University of Texas, Austin
University of Texas, Dallas
University of Toronto (Canada)
University of Virginia
University of Washington
University of Wisconsin
Utah State University
Vassar College
Villanova University
Virginia Polytechnic Institute
Washington & Lee University
Wellesley College
Wesleyan University
Western Washington University
Williams College
Wittenberg University
Yale University

9. NAIC Summer Student Participants (1972 through 2008):

Most affiliations, particularly for the most recent years, refer to the students' affiliations at the time of they attended the Arecibo summer student program.

Participant:	Affiliation:	Year
Dr. Vincent J. Abreu	University of Michigan	1972
Dr. Linda Dressel	Space Telescope Science Institute	1972
Dr. Alan Hirshfeld	Univ. of Massachusetts, Dartmouth	1972
Dr. Thomas Balonek	Colgate University	1973
Dr. James Cordes	Cornell University	1973
Dr. Lee Hartmann	Center for Astrophysics	1973
Dr. Martha Haynes	Cornell University	1973
Dr. William Newman	Univ. of California Los Angeles	1973
Dr. James F. Vickery (deceased)	Stanford Research Institute	1973
Dr. Randy Kimble	NASA/Goddard Space Flight Center	1974
Dr. James Breakall	Pennsylvania State University	1974
Dr. Matthew Malkan	Univ. of California @Los Angeles	1976
Dr. Bruce Wilking	University of Missouri, St. Louis	1976
Dr. Kristen Sellgren	Ohio State University	1976
Dr. Richard L. White	Space Telescope Science Institute	1976
Dr. Robert J. Hanisch	Space Telescope Science Institute	1977
Dr. Keith D. Horne	University of St. Andrews, Scotland	1977
Dr. Leslie Hunt	Arcetri Observatory, Italy	1978
Dr. Emilio Falco	Smithsonian Inst., Whipple Observatory	1979
Dr. Jacqueline Hewitt	MIT	1980
Dr. Richard Edelson	UCLA	1981
Dr. Michael Bicay	Caltech	1982
Dr. Perry Hacking	Jet Propulsion Laboratory	1982
Dr. Brett Isham	EISCAT, Tromso, Norway	1983
Dr. Michael A. Strauss	Princeton University	1983
Dr. Douglas O. Wood	NRAO Socorro	1983
Dr. Blaise Canzian	U.S. Naval Observatory	1984
Dr. JoAnn Eder	Arecibo Observatory (retired)	1984
Ms. Inge Heyer	Space Telescope Science Institute	1984
Dr. Steven T. Myers	NRAO	1984
Dr. Joshua Roth	Sky Publishing Corp.	1984
Dr. Myeong-Gu Park	Kyungpook National Univ., Korea	1985
Dr. Daniel Holden	Los Alamos National Laboratory	1985
Dr. William Reach	Caltech	1985
Dr. Nicholas Stacy	Surveillance Research Lab, S. Australia	1985
Dr. Leila Belkora	Self-employed	1987
Dr. Peter Lawson	Jet Propulsion Laboratory	1987
Dr. Brian A. McLeod	Center for Astrophysics	1987
Dr. Margaret Meixner	Univ. of Illinois, Urbana-Champaign	1987
Dr. John M. Carpenter	Caltech	1988
Dr. Tracey Evans	Caltech	1988
Dr. Sixto González	Arecibo Observatory	1988
Dr. Richard Collins	University of Alaska	1988
Dr. Margaret Murray Hanson	University of Cincinnati	1988
Dr. Joseph Lazio	Naval Research Laboratory	1988
Dr. Crystal L. Martin	Caltech	1988
Dr. Bruce Campbell	National Air & Space Museum	1989
Dr. Jayaram Chengalur	NCRA-TIFR, Pune, India	1989
Dr. Eric Schulman	NRAO Charlottesville	1989

Dr. Adam Showman	NASA	1989
Dr. Thomas E. Vaughan	University of Oklahoma	1989
Dr. Jonathan Williams	University of Florida	1989
Dr. Rachel Akeson	Caltech	1990
Dr. Bryan W. Miller	AURA	1990
Dr. Liese van Zee	Jansky Fellow, NRAO VLA	1990
Dr. Jeremy Heyl	Caltech	1991
Dr. Jenny Patience	UCLA	1991
Dr. James Rhoads	Space Telescope Science Institute	1991
Dr. Keith Rosema	Blue Operations, LLC	1991
Dr. Shoko Sakai	UCLA	1991
Dr. Jose F. Salgado	Adler Planetarium, Chicago	1995
Dr. Nestor Aponte	Arecibo Observatory	1992
Ms. Heather Elliott	Michigan State University	1992
Mr. Adam Trotter	Harvard University	1992
Ms. Lorraine Allen	Center for Astrophysics	1992
Mr. Jason Johnson	Harvard University	1992
Ms. Vanessa Galarza	New Mexico State	1992
Ms. Erin Hatch	George Washington University	1992
Mr. Antonio Algaze	Ohio State University	1993
Mr. James Anderson	US Geological Survey	1993
Mr. Yevgeniy Dorfman	MIT	1993
Dr. Mayra Lebrón Santos	Arecibo Observatory	1993
Dr. Ben R. Oppenheimer	American Museum of Natural History	1993
Dr. Alison Peck	Center for Astrophysics	1993
Mr. Christopher DeVries	University of Massachusetts	1994
Mr. Mark Lemon	Letter Press Software	1994
Ms. Rebecca Morley	Japan	1994
Mr. Marcel Agueros	University of Washington	1995
Ms. Ann Bragg	Harvard University	1995
Dr. Genene Fisher	American Meteorological Society	1995
Ms. Nicole Lloyd	Stanford University	1995
Ms. Kristin Nelson	University of Rochester	1995
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Mr. Matthew Schwartz	Princeton University	1996
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Mr. Adam Mott	Arizona State University	2003
Ms. Catherine Neish	University of British Columbia	2003
Mr. Matthew Phillips	University of Colorado	2003
Mr. Kristopher Reilly (deceased)	New College of Florida	2003
Ms. Elizabeth Schmidt	Carthage College	2003
Ms. Coral Wheeler	University of Akron	2003
Ms. Nerlyn Echevarría	UPR Mayagüez	2003
Mr. Carlos Trinidad	Daskalos Middle School	2003
Dr. Romina Nikoukar	University of Illinois, Urbana-Champaign	2003
Mr. Michael Jouteux	Ecole Normale Superieure, Lyon, France	2003
Ms. Laura Chomiuk	Wesleyan University	2004
Ms. Megan DeCesar	Pennsylvania State University	2004
Ms. Laura Kinnaman	Wittenberg University	2004
Ms. Melissa Rice	Wellesley College	2004
Mr. Karles Saucedo-McQuade	Oberlin College	2004
Mr. Drew Turner	Embry-Riddle Aeronautical	2004
Mr. Jan Ulrich	University of Texas-Austin	2004
Ms. Yang Yang	Miami University	2004
Mr. Harus J. Zahid	University of California-Berkeley	2004
Mr. Jose Casillas	UPR Mayagüez	2004

Ms. Regina Flores	Columbia University	2004
Ms. Giselle Miranda	Wesleyan College	2004
Mr. Evan J. Anzalone	Louisiana State University	2005
Ms. Fonda Day	University of Colorado	2005
Mr. Casey Dreier	Oberlin College	2005
Ms. Igneris Franco	UPR Mayagüez	2005
Ms. Rhea C. George	University of California, Berkeley	2005
Mr. Israel Gonzalez Perez	UPR Mayagüez	2005
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Ms. Laura Kushner	University of Washington	2005
Mr. Iain Mansfield	Cambridge University	2005
Mr. Alex J. Rivera Irizarry	UPR Mayagüez	2005
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Ms. Mellisa Rivera	UPR, Mayaguez	2006
Mr. Edvier Cabassa	UPR, Mayaguez	2006
Mr. Israel Gonzalez	UPR, Mayaguez	2006
Ms. Gloria Isidro	UPR, Rio Piedras	2006
Ms. Megan Ansdell	University of St. Andrews, Scotland	2007
Mr. John Barrett	University of Massachusetts, Amherst	2007
Mr. Charles Cheung	Cornell University	2007
Mr. Jamie Gardner	McGill University, Canada	2007
Ms. Diana Husmann	Massachusetts Institute of Technology	2007
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Mr. John Lee	Columbia University	2007
Ms. Amanda Sheffield	Purdue University	2007
Ms. Camille Smith	Utah State University	2007
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Ms. Tracy Becker	Lehigh University	2008
Ms. Kristin Jones	University of Wisconsin-Madison	2008