

NATIONAL ASTRONOMY AND IONOSPHERE CENTER
ARECIBO OBSERVATORY
Cornell University

Research Experience for Undergraduates Program

PROGRESS REPORT
SUMMER 2007

(Written by Dr. Paulo Freire, REU Coordinator)

As every year, Arecibo Observatory organized REU summer student program. For each participant, the program lasts for 10 weeks, with the earliest arrivals at the end of May and the latest departures in Mid-September 2007. This program intends to expose students to a research environment, so that they make a more informed decision on a possible research career after graduation, and given them some experience in scientific research and its methods. The selection process is highly competitive, with 11 students getting selected from different universities out of more than 100 applicants. Ten of these students (all the undergraduates) were supported by the NSF REU grant, and one (a second year graduate student) was supported by NAIC.

Many staff members from the observatory gave a series of lectures to the students with the objective of introducing them to the fundamentals and applications of the various instruments available here. The talks included a variety of topics covering areas related to astronomy, ionosphere, planetary radar, and electronics with the focus on the current research activities using the facilities at the observatory. This was complemented by arranging a visit to the 500 ft high platform that contains several receivers. Prof D. Campbell (Cornell University) visited the observatory and presented two REU talks on planetary radar astronomy.

The Arecibo Telescope has not been active since March 2007 because of the ongoing painting project. For this reason, no hands-on experiments could be carried out this year.

The students were asked to give 20-minute presentations summarizing the project they did during their stay at the observatory. Some of the students will present their work in the meeting/conferences either this year or next year. For instance, the Aeronomy students participated in the 2007 Cedar (Coupling, Energetics and Dynamics of Atmospheric Regions). Similarly astronomy students will present posters at the meeting of the American Astronomical Society in January 2008, in Austin, Texas.

To make sure that students get chance to experience life outside the observatory, a variety of activities were arranged that gave them an opportunity to explore the culture and nature of the Caribbean island. I would like to thank all the administrative staff, especially to Maria Rodriguez, Lucy Lopez, Wison Arias, Carmen Segarra, Carmen Torres, E. Robles, Jose Cordero, and all the guards for their cooperation and time. This Summer we also had the generous help of Gerry Giles, from Aguadilla, who provided the accommodation for the students while they were taking their SCUBA certifications, and helped with many of the weekend .

As a welcome to students, a BBQ was organized near the recreational area. We encouraged students to give us feedback about their interests and tried to organize events accordingly. Most students got certified for scuba diving and then visited places like Vieques and Culebra islands that are famous for their beautiful beaches and sea life. This gave them a chance to camp, hike and snorkel at different places. The students hiked in the Guanica dry forest and also in the El Yunque rainforest; there was an educational trip to the Institute of Tropical Ecosystem Studies located in the Rain Forest, which also hosts REU students and is coordinated by Dr. Alonso Ramirez and was later reciprocated by a visit to the observatory. Also, trip to Old San Juan was arranged on two occasions. We also took them out to watch recent movies and to dance places. Toward the end, another BBQ was arranged to welcome the Rain Forest REU students and also to give a farewell to our REU students. The two groups played volley ball and exchanged their experiences. On several occasions, REU students organized evening get-togethers at the VSQ and invited staff members and vice-versa.

2007 Summer students projects

Supported by NSF REU Funds:

Megan Ansell: Physical Modeling of Near Earth Asteroid 2004 WG1

Megan spent her Summer processing asteroid radar data obtained at Arecibo from April 11th-19th 2006. The Continuous Wave (CW) and Delay-Doppler image data illustrated an irregularly shaped object exhibiting several interesting topographical features. Preliminary analysis of radar delay-Doppler images made at 15m resolution revealed a double-lobed object with a range-depths fluctuating from 0.3km to 1.0km corresponding to Doppler bandwidths of 7.01Hz to 4.2Hz. Since range-depth is indicative of the size of the asteroid and Doppler bandwidth is indicative of its rotation speed, this data implied a highly elongated object. The delay-Doppler images were used in conjunction with CW data to determine possible physical models of the asteroid using the SHAPE modelling program. The best result suggested asteroid 2004WG1 to have a 9.6 hour rotation period with a spin-pole angle of ecliptic latitude = +43 degrees and ecliptic longitude = 200 degrees, as well as a maximum elongation of 2 km.

Ms. Ansdell is an undergraduate student at St. Andrews University, in St. Andrews, Scotland. She was supervised by Drs. Ellen Howell and Michael Nolan, from June 29 to Sept. 7 2007.

John Barrett: Report on Boundary Detection Techniques in Plasmopause Determination from EUV images.

John investigated various image processing techniques, with the intention of providing a background in the methods used for the automated detection of the plasmopause from IMAGE satellite EUV images. He evaluated the efficacy of various boundary detection algorithms, such as the Canny edge detection method and active contour modeling in determining plasmopause location. Upon experimenting with the efficacy of each approach, intensity thresholding, edge detection, and active contour modeling, it was decided that a combination of edge detection and active contour modeling; wherein edge detection would provide a rough estimate to initialize the active contour model, would perform best in the task of locating the plasmopause position. This approach appears to provide satisfactory data, more or less on par with that obtained by manually tracing the plasmopause in each image.

Mr. Barrett is a 3rd year undergraduate student the University of Massachusetts, Amherst, MA. He was supervised by Hien Vo, from June 4 to August 13 2007.

Charles Cheung: Vector Network Analysis of a Radio Telescope

I worked in the electronic group of the Arecibo Observatory in the past summer, and Dana Whitlow is my mentor throughout the REU program. I work on the analog and digital signal processing blocks primarily. First, I extracted the astronomical data between 100MHz and 400MHz using low-pass filters. After that, I downconverted them to baseband signal using local oscillators. I measured the baseband signal in time domain from the oscilloscope and transformed them into frequency domain both in phase and magnitude using Matlab. I also calculated the group delay of the data. Then I repeated the same process while I used an impulse response as the input. Finally, I calculated the transfer function of the system by dividing the normal output by the impulse output in frequency domain. In this way, I can study the transfer function. In addition to that, I also input noise into the system and studied the effect of the distraction of signals due to noise. At the end, I gave a presentation about my work in the summer, and the topic is "Vector Network Analysis of a radio telescope".

Mr. Cheung is a 3rd year undergraduate student at Cornell University, Ithaca, NY. He was supervised by Dana Withlow, from May 29 to August 7 2007.

Jamie Gardner: Searching for pulsars in the Cygnus Region

I spent this summer analyzing data from a pulsar survey of the Cygnus region. This part of the galaxy is expected to have many young pulsars, given its large number of supernovae. However, given the large amounts of ionized gas in this region, dispersive smearing has undermined the success of previous surveys, which were carried out at frequencies of 400 and 1400 MHz. The current survey was carried out at a central frequency of 1.95 GHz, using the GBT S-band receiver and the pulsar SPIGOT, most of the data was taken in January 2005. At these higher frequencies the pulsar signals are less susceptible to scattering and dispersion. Nevertheless, because of the high amounts of ionized gas in this region, the data had to be dedispersed at a wide range of dispersion measures (DMs). After dedispersion, each time series was searched for periodic signals. I've worked out a versatile spreadsheet that can be modified to calculate DM sequences for any signal, and I've written shell scripts that search data at thousands of dispersion measures using PRESTO software package (Scott Ransom, <http://www.cv.nrao.edu/~sransom/presto/>). To sort through the ensuing lists of candidates, we developed a routine for examining the pulsed signal's intensity with varying DM. No new pulsars were discovered, but I could only finish the processing of about 5% of the beams. This processing was a very challenging and CPU-intensive task, with about a week of CPU time needed to process each beam.

This summer so far has given me a great deal of experience with the research process. While it wasn't always predictable or easy, I've found every bit of it rewarding.

Mr. Gardner is a 3rd year undergraduate student at McGill University, in Montreal, Canada. He was supervised by Dr. Paulo Freire, from May 22 to August 3 2007.

Diana I. Husmann: Mars

Diana analyzed radar images taken during the 2005 Mars opposition. These images were taken using the S-band radar (12.6 cm wavelength): coded-long pulses were sent to Mars, and the beam reflection was used to create a two-dimensional image of the planet. These snapshots were created using delay-Doppler imaging, which identifies the reflection point of any portion of the coded-long pulse by noting its time delay in returning to Earth and Doppler shift from the original frequency. She compared the delay-Doppler images with optical and near-IR images of several regions of Mars, like Elysium, Athabasca Valles, and the Tharsis region, in particular Pavonis Mons. Radar waves can penetrate the upper few cm of the Martian surface, revealing underlying materials which are normally hidden from optical/IR cameras. In the case of the Arecibo radar images, most of these materials are lava flows, and in some cases solid ice. A study of the distribution of lava flows in relation to known topographic features allowed new insights into Martian geology.

Ms. Husmann is a 3rd year undergraduate student at the Massachusetts Institute of Technology, in Cambridge, MA. She was supervised by Dr. John Harmon, from May 24 to August 2 2007.

Rouwenna M. Lamm: Galaxy Searches

This summer I worked with data taken in from the Arecibo Zone of Avoidance (ZOA) Survey. The ZOA Survey is a blind survey designed to map the distribution of low Galactic-latitude galaxies and large-scale structure through the detection of neutral hydrogen, HI, emission. The survey uses Arecibo's ALFA detector. The ZOA team hopes to find new HI galaxies behind the Milky Way and to provide redshifts, HI masses, and other HI parameters for galaxies previously identified at other wavelengths but partially obscured by the Milky Way. I worked with Robert Minchin and Emmanuel Momjian to process and begin to analyze the data from the 100-square degree area around $l = 190$. The observing was done from July to September 2005. The region has a right ascension of 4.5 ± 0.72 hours and a declination of 27.3666 ± 5.71 degrees and the velocities range from about -2600 to 10400 km/s (radio velocity). I processed the data using software originally developed for the Parkes multibeam surveys. LiveData did the flux calibration and bandpass subtraction, corrected for the heliocentric frame, and applied a spectral smoothing. Using Gridzilla, the data was gridded into data cubes. With Cubecat I concatenated the data into two data cubes. The data cubes displayed right ascension, declination, and velocity on their axes.

We found 48 galaxies in our data. Sixteen of those had not previously been identified and 11 of them were too

dim to see in the 2MASS images. We also had two cases in which multiple objects could not be distinguished in the beam and two cases in which the galaxy fell outside the region observed by 2MASS or was behind stars.

We also noticed gaps in galaxy distribution around 40 and 60 mega parsecs, which may indicate large-scale structure. Finally, we found some interesting high HI mass or low surface brightness galaxies.

Ms. Lamm is 3rd year undergraduate student at Smith College. She was supervised by Drs. Robert Minchin and Emmanuel Momjian from June 11 to August 21 2007.

John Lee: OH/IR stars

At some point copious mass-loss from asymptotic giant stars stops, and these objects develop hollow, expanding, circumstellar shells. They are then called proto planetary nebulae (PPN), as a few thousand years later they evolve into planetary nebulae with largely ionized shells. The Arecibo sample of OH/IR stars includes several. My project consisted of modelling the circumstellar dust shell of IRAS 18095+2704, using the public radiative transfer code DUSTY. This is a step by step process, wherein one postulates a set of physical parameters for a shell (such as its size, dust opacity, and the temperature of the hottest dust), and use DUSTY to generate the corresponding spectral energy distribution (SED) for comparison with the observed optical to mid-IR spectrum. The objective is to reproduce the observed spectrum, and hence deduce the likely parameters for the hollow, expanding shell. This requires many iterations, as one homes in on suitable parameters. These were assessed by generating a chi-square statistic for every model, using mathematica code and interpolation of the SED generated by DUSTY, and a cold silicate opacity function. The final fits were excellent.

Mr. Lee is a 3rd year undergraduate student at Columbia University, in New York City, NY. He was supervised by Dr. Murray Lewis from May 29 to August 7 2007.

Amanda Sheffield: Creating a Graphical User Interface for the Arecibo Observatory Optical Laboratory

Airglow is an upper atmospheric phenomenon that occurs in the altitudes of 90 – 100 km in the atmosphere. Understanding of airglow is important to understanding many of the dynamics and chemistry of the upper atmosphere. The Airglow Facility and the Aeronomy Department of the Arecibo Observatory Optical Laboratory is a location where measurement of airglow is occurring. They are also in the process of converting working systems of measuring airglow to modern windows PCs. In the REU summer of 2007, I was given the task of creating a Graphical User Interface (GUI) that would enter a user's parameters for measuring and pass these values to FORTRAN programs which then continue into the system to take the airglow measurements. This GUI is part of the process of updating the measurement system. This GUI was to be created in Visual Studio 2005 in Visual C++ code with an Intel FORTRAN compiler, all of which was purchased by the Aeronomy Group. During the summer I learned the mechanics of C++ and Visual Studio and created a GUI for one airglow instrument, the Fabry-Perot Interferometer. After many challenges in variable definition and C++ calling FORTRAN issues, a GUI is created that passes entered values to measuring tools. At the conclusion of the summer, my work is going to be continued by my mentor Craig Tepley to create more GUIs for other instruments of the Airglow Facility of Arecibo Observatory. I was also able to attend the Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) workshop in Santa Fe, NM to learn more on topics in atmospheric science today. This was sponsored by CEDAR and Arecibo.

Ms. Sheffield is a 2nd year undergraduate student at Purdue University, in Lafayette, IN. She was supervised by Dr. Craig Tepley from June 5 to August 14 2007.

Camille B. Smith: Calibration of topside and MRCAF data to compute the Burnside Factor

The purpose of the project was to determine a correction factor for the atomic oxygen (O) ion-neutral collision frequency through a combination of Arecibo radar and optical measurements. To that end, Camille worked on processing data taken with the Arecibo 430 MHz incoherent scatter radar. At Arecibo, the 430 MHz radar is operated in different modes, and Camille combined information from the multi-radar autocorrelation function (MRACF)

mode and the Topside mode to improve the calibration of electron density measurements from the topside ionosphere above Arecibo.

Ms. Smith is a 4th year undergraduate at Utah State University, in Logan, UT. She was to be supervised by Dr. Néstor Aponte and Dr. Sixto González from May 14 to July 24 2007, but in the end her stay at the Arecibo Observatory was extended for a few more weeks.

Matthew Sunderland: Digital Receivers

Matt has compared various techniques for improving the performance of digital radar receivers. Direct digital frequency synthesis systems enjoy benefits of the digital domain such as replication, flexibility, and compactness at the cost of finite precision arithmetic. He employed methods such as phase dithering, Taylor Series approximations, and amplitude-difference storage to minimize the effects of finite precision. Focus is aimed at limiting the presence of spectral impurities and improving the signal-to-noise ratio while minimizing logic resources.

Mr. Sunderland is a 3rd year undergraduate at Penn State University, State College, P.A. He was supervised by Tamara Hall from May 21 to July 30 2007.

Supported by NAIC Funds

Catherine Wu: Modeling OH Masers in OH/IR stars

Every mid-IR source with colors appropriate to an OH/IR star in the Arecibo-accessible sky has been observed: those with detectable 1612 MHz masers are known as OH/IR stars. These objects come from the phase of stellar evolution when stars like our Sun lose a large fraction of their mass to interstellar space: the infra red (IR) signature comes from the dust that condenses in this efflux. My research focused on high-latitude ($|b| > 10^\circ$) stars, which are Asymptotic Giant Branch stars arising from low-mass, ~ 1 solar mass, progenitors. These exhibit a red limit to their mid-IR colors, which may arise from the limited, ~ 500 year duration of copious mass-loss following after a helium shell flash. Working with Dr. Murray Lewis, I used the public domain radiative transfer code DUSTY to test this hypothesis. I used a high numerical precision model of a thick circumstellar shell formed by a continuous, high mass-loss rate to determine how its opacity and expansion velocity change as a function of radial distance from the central star. To generate an initial 'high-latitude' model, I limited the shell thickness to mimic a short burst of mass loss. I then produced self-consistent, expanding shells from this initial model by using the radial profile of velocity to determine where the inner and outer radii would lie after a given period of time: the net opacity required from a shell was kept consistent with the original density profile. I was able to conclude that a short burst of high mass-loss is a plausible explanation for the observed MIR color distribution of these stars.

Ms. Wu is a 2nd year graduate student at New Mexico State University, in Las Cruces, NM. She was supervised by Dr. Murray Lewis, from June 4 to August 15 2007.

RET Program

Gloria Isidro: Touching the Moon and the Stars: Astronomy for the Visually Impaired Public

Ms. Gloria Isidro worked at the Visitors Center under the supervision of Drs Carmen Pantoja and José Alonso with a scholarship from the "Fundacion Comunitaria de Puerto Rico". This Summer she continued her work in the development of exhibits for the visually impaired public.

Ms. Isidro is a graduate student at the Department of Mathematics of the University of Puerto Rico, at Rio Piedras.

Presentations by AO staff and visitors

Time	Speaker	Title
June 12, 3:00 p.m.	Dr. Mikael Lerner	Time and Coordinate Systems
June 15, 2:00 p.m.	Dr. Christopher Salter	The Radio Sky
June 19, 3:00 p.m.	Dr. Amy Lovell	Comets
June 21, 11:00 a.m.	Dr. Steven Gibson	The Interstellar Medium
June 25, 11:00 a.m.	Dr. Murray Lewis	OH/IR Stars
June 28, 11:00 a.m.	Dr. Paulo Freire	An Introduction to Pulsar Astronomy
July 3, 10:30 a.m.	Dr. Emmanuel Momjian	Interferometry in Radio Astronomy
July 5, 11:00 a.m.	Dr. Michael Sulzer	Incoherent Scatter Radar
July 10, 11:00 a.m.	Dr. Jonathan Friedman	Atmospheric Circulation: Thermal Structure and the Mesospheric Refrigerator
July 12, 11:00 a.m.	Dr. Hien Vo	Living with a Star – Space Weather
July 17, 11:00 a.m.	Dr. Ellen Howell	The Geology of Puerto Rico
July 19, 3:00 p.m.	Prof. Donald Campbell	Radars
July 20, 11:00 a.m.	Prof. Donald Campbell	Titan
July 24, 11:00 a.m.	Dr. Michael Nolan	Asteroids
July 26, 11:00 a.m.	Dr. Robert Minchin	Galaxies
July 31, 11:00 a.m.	Ganesh Rajagopalan	Receivers
August 2, 11:00 a.m.	Dana Withlow	The IF/LO system.
August 7, 3:00 p.m.	Tamara Hall	Back-ends

Presentations by Students:

July 26, 3:00 p.m.	Matthew Sunderland	Digital Receivers
July 31, 3:00 p.m.	Diane Husmann	Mars
August 2, 3:00 p.m.	Charles Cheung	Vector Network Analysis of a Radio Telescope
August 2, 3:45 p.m.	Jamie Gardner	Pulsar Searching
August 6, 3:00 p.m.	John Lee	OH/IR stars
August 6, 3:45 p.m.	Amanda Sheffield	Creating a GUI for AO's Optical Laboratory
August 13, 9:00 a.m.	John Barrett	Boundary Detection Techniques in Plasmopause Determination from EUV images
August 14, 3:00 p.m.	Catherine Wu	Modeling OH/IR stars
August 16, 3:00 p.m.	Rowenna Lamm	Galaxy Searches
August 16, 3:45 p.m.	Camille Smith	Calibration of topside and MRCAF data to compute the Burnside Factor

Students Experience in their own words

The lectures were an excellent part of the program. Many things covered—like the signal processing aspects of radio astronomy—were things that I'm not likely to learn elsewhere. It was a wonderful opportunity to attend so many talks by such prominent scientists. The AO staff was friendly and supportive. I felt comfortable and even invited to ask questions about people's work. I learned more during lunch hours at the observatory than in some classes at university. - Jamie Gardner

Some of my favorite parts of the Arecibo Summer REU Program were the summer student lectures. I believe it can be unfortunately easy to spend a summer at an establishment such as an astronomical observatory and not gain a comprehensive understanding of the science behind the telescope, so these talks were very much appreciated by the summer students. The number, frequency, and subject matter of the talks were all appropriate; it was essential to have talks describing the technical workings telescope, and they were nicely complimented by the ones describing the research of the various astronomers and the geology of Puerto Rico. They were generally presented at the appropriate level of our understanding, though occasionally too advanced for me when dealing with subjects out of my field of study, such as electrical engineering. - Megan Ansdell

Extra-Curricular Activities:

Every Monday and Thursday we organized shopping trips to Arecibo, where the students could buy groceries. Apart from that, we organized several weekend activities:

Trip to Old San Juan (on 2 occasions),

Trip to El Yunque, followed by visit to the Institute for Tropical Studies in El Yunque,

Trip to Camuy Caves,

Trip to Vieques Island and bio-luminescent bay,

Trip to Culebra Island,

Trip to Cabo Rojo,

Trip to Guanica Dry Forest and La Parguera,

Farewell BBQ at Pool

Most students got SCUBA diving certifications in Aguadilla, on July 5th 2007. They went on several dives after that.

Papers to be presented in meetings/conferences

Rouwenna Lamm will present the poster “The ALFA Zone of Avoidance Survey: Results from the Taurus Region” at the 211th AAS meeting in Austin, TX, 7-11th of January 2008.

Matthew Sunderland presented “Optimizations for Digital Radar Receivers“, at the 2007 Cedar Workshop in Santa Fe, NM, 24-29th of June 2007.

REU, Other Summer Students & RET Participants
(1972 through 2007)

Undergraduate Level Participants	260
Graduate Level Participants	64
*Minorities	70
* Women	138
(4 minorities, 6 women in 2007)	
RET participants	1*
(1 in 2007, 1 minority, 1 woman)	
Total Number of Participants	333

* Note: Not all RET students have been accounted in this number. A total of 8 were listed before 2007.

●Number of REU, Other Summer Students & RET Participants - Scientific Field
(1972 through 2007)

Radio/Radar Astronomy	199
Atmospheric Sciences	85
Computer Sciences	21
Electronics	17
Education	11
Total Number of Participants	333

Educational Institutions Represented in the NAIC Summer Student Program
(1972 through 2007)

Agnes Scott College	Miami University, Ohio
University of Akron	University of Michigan
University of Alabama	University of Minnesota
Amherst College	Missouri State University
Arizona State University	University of Montana
University of Arkansas	New Mexico Tech
Bates College	New Mexico State University
Bethel College	New College of Florida
SUNY Binghamton	
SUNY Albany	University of Nebraska-Kearney
Boston University	University of Northern Iowa
Brigham Young University	North Carolina State University
University of British Columbia (Canada)	
Bryn Mawr College	Northwestern University
California Institute of Technology	Oberlin College
University of California, Berkeley	Oxford University, UK
California Polytechnic State University	Pennsylvania State University
University of California, Los Angeles	University of Pennsylvania
University of California, San Diego	Ponoma College
University of California, Santa Cruz	Princeton University
University of California, San Luis Obispo	Purdue University
Cambridge University (UK)	University of Puerto Rico, Mayagüez
Carleton College	University of Puerto Rico, Arecibo
Carthage College	University of Puerto Rico, Humacao
Case Western Reserve University	University of Puerto Rico, Río Piedras
Centenary College of Louisiana	Rice University

University of Chicago
Clemson University
Colgate University
University of Colorado
Columbia University
Cornell University
Dartmouth College
Embry-Riddle Aeronautical University
Ecole Normale Supérieure of Lyon
Georgetown University
University of Georgia
Gorky University (Russia)
University of Grenoble (France)
Harvard University
Haverford University
University of Hawaii
Johns Hopkins University
University of Houston
University of Illinois, Urbana-Champaign
Indiana University
University of Iowa
Louisiana State University
University of Maryland
University of Massachusetts (Amherst)
Massachusetts Institute of Technology
McGill University (Canada)
Universidad Metropolitana, San Juan

University of Rochester
Rutgers University
Rensselaer Polytechnic Institute, NY
St. Andrews University
Saddlebeck University
San Diego State University
Smith College
Stanford University
Texas Technological College
Trinity College Dublin, Ireland
University of Texas, Austin
University of Texas, Dallas
University of Toronto (Canada)
Utah State University
Vassar College
Villanova University
University of Virginia
Virginia Polytechnic Ins
University of Washington
Washington & Lee University
Wellesley College
Wesleyan University
Western Washington University
Williams College
Wittenberg University
University of Wisconsin
Yale University

NAIC Summer Student Participants (1972 through 2007)

Most affiliations, particularly for the most recent years, refer to the students' affiliations at the time of their REU program. Detailed information concerning the present status of all previous student or teacher participants is given for some former students, particularly for the earlier years. The following is representative of those students/teachers who have attended the NAIC's program at the Arecibo Observatory:

Participant	Affiliation	Summer of Participation
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	
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 Bica	Caltech	1982
Dr. Perry Hacking	Jet Propulsion Laboratory	1982
Dr. Brett Isham	EISCAT, Tromsø, 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. Genevieve Fisher	American Meteorological Society	1995
Ms. Nicole Lloyd	Stanford University	1995
Ms. Kristin Nelson	University of Rochester	1995
Ms. YuLing Su	Steward Observatory	1995
Mr. Matthew Schwartz	Princeton University	1996
Mr. Brent W. Grime	US Air Force	1997
Ms. Zoe M. Leinhardt	University of Maryland	1997
Ms. Melissa Nysewander	Univ. of North Carolina, Chapel Hill	1997
Mr. Albin Alonso Rosario	University of Puerto Rico	1997
Mr. Anil C. Seth	University of Washington	1997
Mr. Angel Alejandro Quinones	University of Houston	1998
Ms. Monique Aller	University of Michigan	1998
Ms. Yira Cordero Lebron	UPR Humacao	1998
Ms. Ingrid Daubar	University of Arizona	1998
Mr. Simon DeDeo	Princeton University	1998
Mr. David Kaplan	Caltech	1998

Mr. Dale Kocovski	University of Hawaii	1998
Ms. Myriam Lopez	Escuela Intermedia Barahona, Morovis	1998
Mr. Benjamin D. Oppenheimer	University of Arizona	1998
Mr. Felix Mercado Cortes	UPR Rio Piedras	1998
Ms. Celia Salmeron	University of Houston	1998
Ms. Heidi Brandenburg	Caltech	1999
Mr. Carlos Vargas Alvarez	San Diego State University	1999
Mr. Shawn M. Allison	Penn State	2000
Ms. Sarah Boswell	University of Wisconsin	2000
Ms. Alyson Brooks	Columbia University	2000
Ms. Diane Chin	Binghamton University	2000
Ms. Laura J. Hainline	Caltech	2000
Mr. Justin B. Kinney	Cornell University	2000
Ms. Ruth Murray	UC Berkeley	2000
Mr. Homero Cersosimo	UPR Humacao	2000
Mr. Miguel F. Irizarry	Arecibo Observatory	2000
Ms. Karin Menendez	Caltech	2000
Ms. Sun Mi Chung	Wesleyan University	2001
Mr. Daniel Dougherty	University of Alabama	2001
Ms. Lindsay DeRemer	Wellesley College	2001
Ms. Natalia Figueroa	UPR Mayaguez	2001
Mr. Marko Krco	Cornell University	2001
Mr. Mike Nicolls	Cornell University	2001
Ms. Betzaida Ortiz	University of Puerto Rico	2001
Ms. Val Phillips	University of Colorado	2001
Ms. Karin Sandstrom	UC Berkeley	2001
Ms. Ivelisse Cabrera	Johns Hopkins University	2001
Mr. Homero Cersosimo	UPR Humacao	2001
Mr. Mike Eydenberg	New Mexico Tech	2001
Mr. Derek Kopon	Cornell University	2001
Ms. Esther Santos	UPR Mayaguez	2001
Mr. Carols Vargas Alvarez	UPR Mayaguez	2002
Ms. Martha Boyer	University of Minnesota	2002
Ms. Laura Chomiuk	Wesleyan University	2002
Mr. Jose Gerena	Luis Munoz Marin Public School	2002
Mr. Andrew Helton	University of Iowa	2002
Mr. Chi-Feng (Daniel) Kao	Penn State	2002
Ms. Stephanie Morris	University of Chicago	2002
Ms. Danielle Moser	Univ. of Illinois, Urbana-Champaign	2002
Mr. Martin Rodgers	Miami University, Ohio	2002
Ms. Rebecca Wilcox	University of Washington	2002
Ms. Julia Deneva	Cornell University	2002
Ms. Ingrid Pla Rodriguez	UPR Mayaguez	2002
Ms. Samantha Stevenson	Wesleyan University	2002
Mr. Graham Alvey	University of Illinois, Urbana-Champaign	2003
Ms. Jaqueline Hodge	California Polytechnic State University	2003
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
Ms. 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. Ignieris Franco	UPR Mayagüez	2005
Ms. Rhea C. George	University of California, Berkeley	2005
Mr. Israel Gonzalez Perez	UPR Mayagüez	2005
Ms. Talia Kohen	Cornell University	2005
Ms. Laura Kushner	University of Washington	2005
Mr. Iain Mansfield	Cambridge University	2005
Mr. Alex J. Rivera Irizarry	UPR Mayagüez	2005
Mr. Anthony Salvagno	SUNY-Albany	2005
Ms. Sarah Scoles	Agnes Scott College	2005
Mr. Brandon Taylor	University of Texas, Austin	2006
Mr. Clinton Mielke	University of Arizona, Tuscon	2006
Mr. Daniel Rucker	University of Arkansas, Little Rock	2006
Mr. David Bowen	Cornell University	2006
Ms. Heather Hanson	University of Wyoming	2006
Ms. Heidi Brooks	Reed College	2006
Ms. Isobel Ojalvo	Rensselaer Polytechnic Institute, NY	2006
Mr. Kevin Graf	Cornell University	2006
Ms. Knicole Colon	College of New Jersey	2006
Ms. Sonia Buckley	Trinity College Dublin, Ireland	2006
Ms. Ximena Fernandez	Dartmouth College	2006
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
Ms. Rouwenna Lamm	Smith College	2007
Mr. John Lee	Columbia University	2007
Ms. Amanda Sheffield	Purdue University	2007
Ms. Camille Smith	Utah State University	2007
Mr. Matthew Sunderland	Penn State University	2007
Ms. Catherine Wu	New Mexico State University, Las Cruces	2007

