National Radio Astronomy Observatory
REU/RET Program Report
Summer 2009

Summer Student Program

Twenty-two students participated in the 2009 NRAO Summer Student program, including 15 undergraduate students supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program, one graduating senior supported by the NRAO Undergraduate Summer Student program , and six graduate students supported by the NRAO Graduate Summer Student program. This was the 50th year of the NRAO Summer Research Program, which has graduated more than one thousand students in its tenure. Research initiated in previous years by some students and their mentors continues, giving the program a continuing impact even for students who have departed.

There were 92 applicants to the 2009 NRAO summer student program, of whom 34 (37%) were women and 8 (9%) were under-represented minorities. The 15 REU positions were filled by 8 women (53%) and 7 men (47%). Of all the (22) summer students that were hired, 12 women (55%) and 10 men (45%), 2 (9%) were under-represented minorities. Eight students were assigned to Socorro (3 REU), 8 to Charlottesville (6 REU), and 6 to Green Bank (all REU).

Summer Teacher Program

Three teachers participated in the 2009 NRAO Research Experiences for Teachers (RET) program funded by the National Science Foundation. This was the tenth year of the NRAO RET program, which has now graduated 32 teachers. The RET program offers teachers both a research experience and, with its emphasis on carryover to the classroom, encourages inquiry-based instruction. As for the REU students, a brief description of each RET participant's research project is included in this report. One of these teachers will present their research at the January 2010 American Astronomical Society meeting in Washington, DC.

There were 15 applicants to the 2009 RET program from 8 states: 3 applicants (15 %) were women; 12 applicants (85 %) were male. All three 2009 RET positions were filled by men. One teacher was resident at Socorro and two at Green Bank.

Organization of Report

This report is organized as follows. In Section 1 we list the 2009 participants for both programs. We then describe the different activities in which students and teachers participated at each of the three main NRAO sites: Charlottesville (Section 2), Green Bank (Section 3), and Socorro (Section 4). In the next two sections we provide brief descriptions of the research projects completed by each REU student (Section 5) and RET teacher (Section 6). Lastly, in Section 7 we identify the anticipated number of participants that will present at the AAS 215th Meeting — January 2010 in Washington, DC. Many of these presentations are expected to be published in astronomical journals in 2010-11.

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1. 2009 NRAO Summer Program Participants

The table below summarizes the student and teacher participants (name and school attending), research project (title, mentor, and assigned site), and the source of student support: **NSF REU** for students supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program, **NSF RET** for teachers supported by the National Science Foundation (NSF) Research Experiences for Teachers (RET) program, **NRAO GRP** for students supported by the NRAO Graduate Summer Research Program , and **NRAO uGRP** for students supported by the NRAO Undergraduate Summer Research Program. Overall, there were 22 summer student participants (15 REU, 1 uGRP, 6 GRP) and three summer teacher (RET) participants this summer.

2009 NRAO Summer Students/Mentors (N=22)					
Student	**School**	**Project**	**Mentors**	**Site**	**Program**
Crystal Anderson	New Mexico Insitute of Mining and Technology	The Relationship Between Ionized Gas and X-Rays in a Massive Star Forming Region IRAS 20126	Debra Shepherd	Soc	**NRAO GRP**

2009 NRAO Summer Students/Mentors (N=22)					
Student	**School**	**Project**	**Mentors**	**Site**	**Program**
Rogerio Cardoso	UW Madison	Disentangling AGN emission and star formation activity in deep radio continuum survey	Maurilio Pannella and Veronica Strazzullo	Soc	NSF REU
Bin Chen	University of Virginia	Studies of Solar and Interplanetary Radio Bursts	Tim Bastian	CV	**NRAO GRP**
Kiruthika Devaraj	Georgia Institute of Technology	Radio Observations and Radiative Transfer Modeling of Planetary Atmospheres	Brigette Hesman	Soc	**NRAO GRP**
Evan Kornacki	University of Texas at Austin	The Origin and Fate of Smiths Cloud	Jay Lockman	GB	NSF REU
Michael Lam	Colgate University	Exploring Systematic Effects in Millisecond Pulsar Timing	Paul Demorest	CV	NSF REU
Huilin Li	University of Virginia	Waveguide Flange Development for Terahertz Detector Technology	Tony Kerr	CV	**NRAO GRP**
Kelley Liebst	University of Kansas	The Potential Effectiveness of the HI Stripping in Virgo	Aeree Chung	Soc	NSF REU
Melissa Louie	Drew University	Searching for Jet-ISM Interactions Around X-ray Binary Systems	James Miller-Jones	CV	NSF REU
Joshua Marvil	New Mexico Tech	The properties of the radio continuum SEDs of nearby galaxies	Frazer Owen	Soc	**NRAO GRP**
Patrick McCauley	James Madison University	Locating Star Formation Sites Using K-Doublet Formaldehyde Emission	Jeff Mangum	CV	NSF REU
Christine Mennicke	Concordia University, St. Paul	Observations of Pre-Biotic Chemistry	Glen Langston 1	GB	NSF REU
Melissa Pastorius	DePaul University	Observations of Water Masers in High Mass Star Forming Regions with the VLA and VLBA	Emmanuel Momjian	Soc	**NRAO GRP**
Shannon Ramey	West Virginia University	Characterization of the Accuracy and Stability of a High-Speed Analog to Digital Converter	John Ford 1	GB	NSF REU
Maxime Rischard	University of California, Berkeley	Millimeter study of AGN OJ287 during predicted maximum	Robert Dickman	Soc	**NRAO uGRP**
Brian	Virginia	Dissecting Luminous Starburst	Aaron Evans	CV	NSF

2009 NRAO Summer Students/Mentors (N=22)					
Student	**School**	**Project**	**Mentors**	**Site**	**Program**
Roper	Polytechnic Institute and State University	Galaxy Mergers			REU
Francillia Samuel	DePauw University	A Search for Water Maser Emission in the Early Universe	Violette Impellizzeri	CV	NSF REU
Jennifer Shitanishi	California State University Los Angeles	Magnetic Fields in Photo-Dissociation Regions	Dana Balser	CV	NSF REU
Meagan White	University of Tennessee, Knoxville	Twenty years of observations of X-ray transient Aquila X-1	Amy Mioduszewski	Soc	NSF REU
Erica Whitfield	Southwest Baptist University	Numerical Precision Requirements of an All-Pass Digital Filter for Pulsar Applications	John Ford 2	GB	NSF REU
Kyle Woolard	University of Virginia	Observations of Pre-Biotic Chemistry	Glen Langston 2	GB	NSF REU
Katherine Wyman	Sonoma State University	Non-Radial Oscillations in Radio Pulsars	Rachel Rosen	GB	NSF REU

2009 NRAO Summer Teachers/Mentors (N=2)					
Student	**School**	**Project**	**Mentors**	**Site**	**Program**
Stephen Bartlett	George C. Marshall High School (Physics)	Non-radial Oscillations in Radio Pulsars	Rachel Rosen	GB	**NSF RET**
Chris Hynes	Louisiana School for Math, Science and the Arts (Chemistry)	Simulating wide-field focal plane cameras on the GBT	Jay Lockman	GB	**NSF RET**
Eric Fagrelius	Ouray High School	VLA Monitoring of the Water Masers in the Water-Fountain Nebula IRAS16342-3814	Mark Claussen	SO	**NSF RET**

2009 Charlottesville summer students - left to right are Francillia Samuel, Brian Roper, Patrick McCauley, Melissa Louie, Jennifer Shitanishi, and Michael Lam.

2. Site Specific Activities: Charlottesville VA

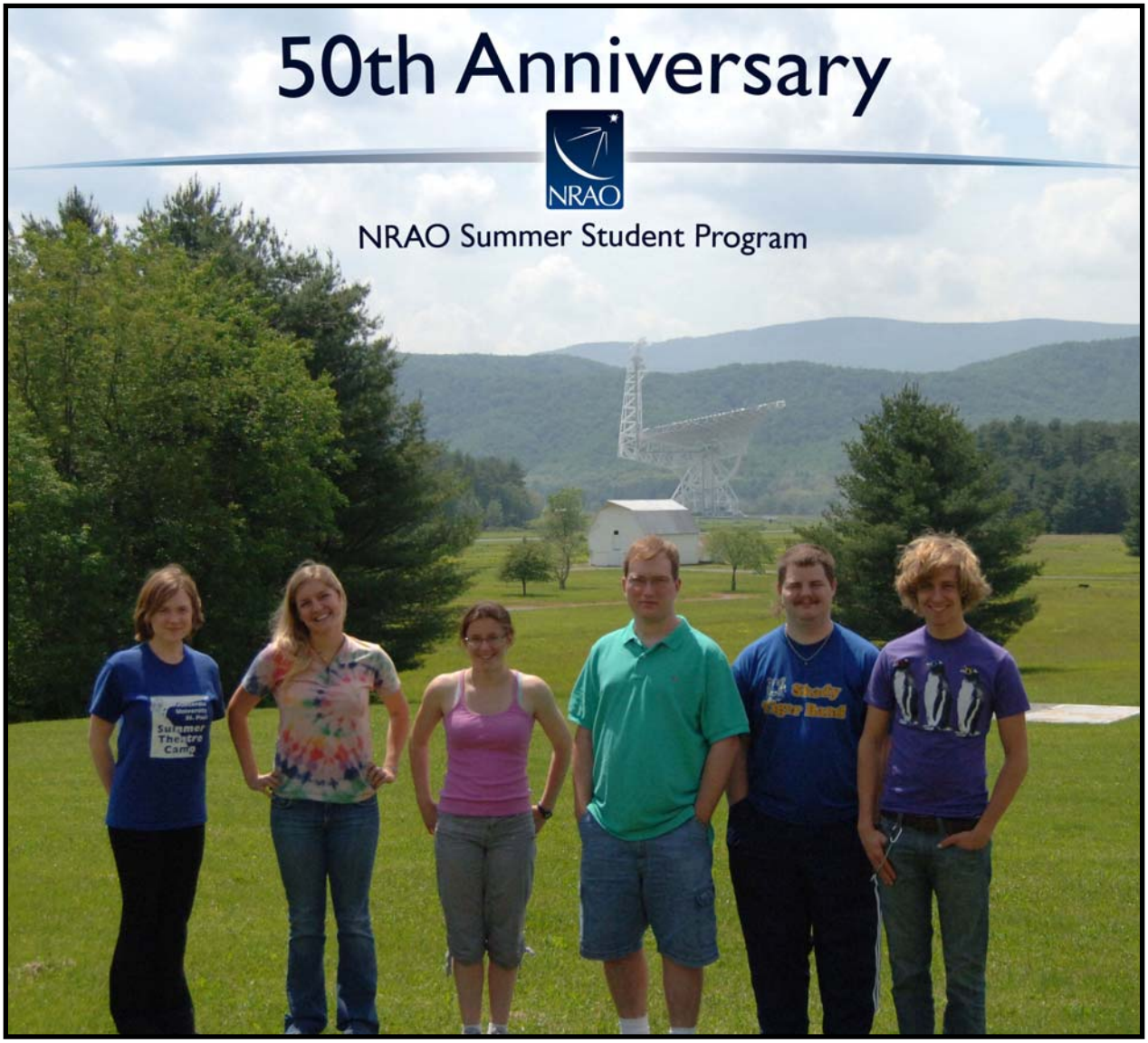
The 2009 Summer Student program at NRAO/Charlottesville was under the direction of Jeff Mangum.

There were 8 students in the 2009 Summer Student Research Program at NRAO-Charlottesville, six of them under the NSF Research Experience for Undergraduates (NSF REU) program and the other two under the NRAO Graduate Student Program (NRAO GRP).

The summer program included a series of introductory level lectures on a wide variety of astronomical topics, often with an emphasis on radio astronomy and radio instrumentation. It also included sending the students to the Single Dish Summer School in Puerto Rico.

In addition to lectures on radio astronomical science, engineering, and computing, the CV Summer Students were given a tour of the NRAO Technology Center (NTC). The CV Summer Students also joined the GB Summer Students on a series of four research projects each of which required the development and execution of an observing plan on the Green Bank Telescope (GBT). With this always popular aspect of the CV Summer Student experience the 2009 Summer Students learned how to develop, execute, and interpret an observational radio astronomy project.

At the end of the summer, the students gave a series of 15-minute talks to the NRAO staff on their projects during several lunch symposia in Charlottesville, and produced a short report describing their summer research.



2009 Green Bank Summer Students on-site - left to right are Christine Mennicke, Katy Wyman, Erica Whitfield, Evan Kornacki, Shannon Ramey and Kyle Wollard.

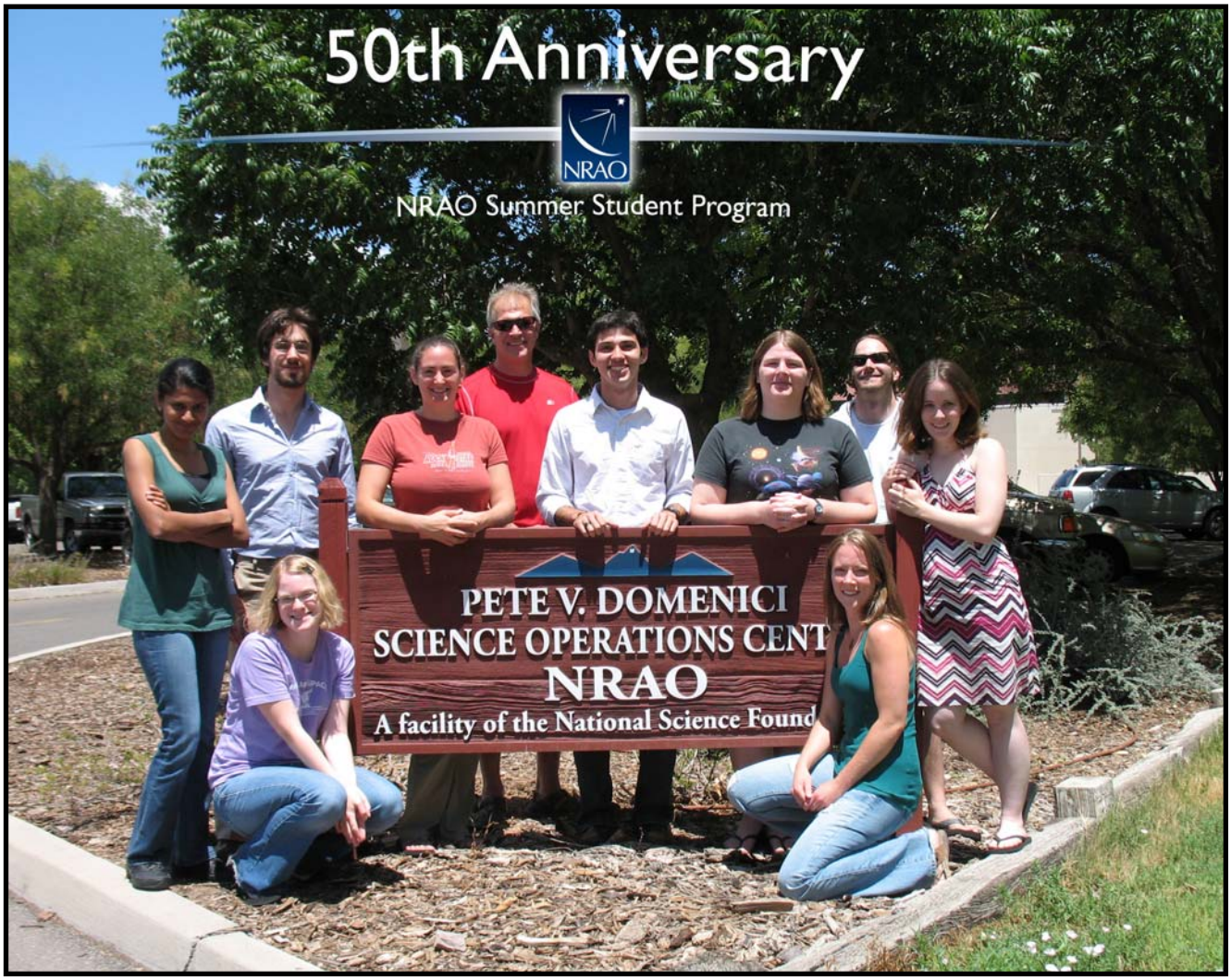
3. Site Specific Activities: Green Bank, WV

The 2009 REU/RET program at NRAO Green Bank was under the direction of Toney Minter and Sue Anne Heatherly. There were six students and two teachers in the 2009 Summer Research Program on site. Six students were supported by the NSF Research Experience for Undergraduates (NSF REU). The two teachers were supported by the Research Experience for Teachers Program (RET). The photograph above shows several of the summer students standing in front of the Green Bank Telescope. There was a special set of lectures given to the students

by scientists and engineers on Green Bank staff. In addition, the summer students were able to participant to varying degrees in several workshops that were held in Green Bank. These include the Society of Amateur Radio Astronomers (SARA) meeting, the Mid Atlantic Astronomical Society Star Party, and the Pulsar Research Collaboratory Teacher Workshop. There was also a weekly Science Lunch with the students every Thursday.

In early July the Green Bank summer students hosted a site visit by the NRAO Charlottesville summer students. They were responsible for showing the Charlottesville students all of the facilities at Green Bank as well as taking the students on a tour of the Robert C. Byrd Green Bank Telescope (GBT). During the summer, the Green Bank students, in conjunction with the NRAO Charlottesville students, conducted their own observational projects on the GBT, performing OH observations of several comets, a study of Radio Recombination Lines toward HII regions, a survey searching for extra-galactic HI and a study of Formaldahyde in Infrared Dark Clouds. In July, the astronomy REU students traveled to Arecibo Observatory in Puerto Rico to attend the Single Dish Summer School. At the end of the summer, the students gave the staff a seminar where they presented the results of their summer research projects.

The students also produced a short report describing this work. REU students and RET participants plan to attend the AAS meeting in Washington, D.C., in January 2010 to present posters on their summer research projects.



2009 Socorro students at the Domenici Science Operations Center. Back row, l-r, are Kiruthika Devaraj, Maxime Rischard, Amy Kimball, Eric Fagrelius, R. Fernando Cardoso, Meagan White, Josh Marvil & Melissa Pastorius. Front row, l-r, are Kelley Liebst & Crystal Anderson.

4. Site Specific Activities: Socorro, NM

The 2009 REU program at NRAO Socorro was under the direction of Amy Mioduszewski. There were eight students and one high school teacher in the 2009 Summer Research Program at NRAO Socorro. Three of the students participated via the NSF Research Experience for Undergraduates (NSF REU) program, four were supported by the NRAO Graduate Research Program (NRAO GRP), and one was supported by the NRAO Undergraduate Research Program (NRAO uGRP). The one teacher participated via the NSF Research Experience for Undergraduates (NSF RET). The above photograph shows all of the participants at the

Domenici Science Operations center in Socorro. In addition to the scheduled events, there were weekly activities for the students and teachers, including "Wednesday Lunch" (free pizza for students!) with scientific talks and Tuesday Science Tea held in the upstairs lounge. The group toured three observatories: the VLA, the VLBA telescope at Pie Town, NM, and Kitt Peak National Observatory. They also toured the Energetic Materials Research and Testing Center located in Socorro.

The participants also gave public tours of the VLA, which is an important outreach activity since it is the only period of the year that there are public tours at the VLA every weekend.

The scientific highlight of the summer was three student-led observational projects, two using the VLA and the other using the VLBA. One group used the VLA to observe Venus. Venus was shown in VLA data from 1996 to be warmer in the southern hemisphere, an unexpected result, the current observations were to confirm this and further study it. The other VLA project involved HI observations of galaxy UGC 7690. This galaxy has a decoupled core and the students hoped to examine the dynamics of the neutral hydrogen (HI) in the galaxy. The VLBA project was to observe the stellar maser source IRAS 16293-2422, twice with a two week gap in order to measure is peculiar motion in the galaxy. At the end of the summer, the students gave a series of 15 minute talks on their projects, and produced a short report describing their summer research (sent under separate cover).

5. REU Project Summaries

The symbol to the right identifies the students that were supported under the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program. All other students were supported under the NRAO Summer Student Research Assistant Program. Follow this link for a list of all student programs at the NRAO. You can also find student projects titles from 1991 to present in tabular form.

2009 Summer Students

Rogerio Cardoso, of UW Madison,
worked with Maurilio Pannella and Veronica Strazzullo on

Disentangling AGN Emission and Star Formation Activity in Deep Radio Ccontinuum Survey

The SWIRE Deep Field is the deepest radio continuum survey at 1.4GHz, overlapping with the Spitzer SWIRE Legacy Survey in the Lockman Hole. A wide multiwavelength coverage is available on this field, from X-rays to optical and near--infrared, up to mid--infrared IRAC and MIPS imaging. The data in the observed wavelength range 3500-46000\AA has been used to study the populations of radio galaxies hosts, and in particular the debated relative contribution of AGNs and star--forming galaxies to the faint micro--Jy radio samples as a function of redshift. This study will obviously benefit from including in the picture the available X--ray information, which is specifically related to AGN emission. The proposed student project will thus consist of investigating the X--ray properties of the 1.4GHz micro--Jansky galaxy population, by means of stacking of the deep X-ray (Chandra Observatory) imaging available on this field. The student will work with Maurilio Pannella, in collaboration with Veronica Strazzullo and Frazer Owen, and will have to build on--purpose X-ray stacking routines, which will allow very faint signals to be extracted and analysed.

Evan Kornacki, of University of Texas at Austin,
worked with Jay Lockman on

The Origin and Fate of Smiths Cloud

Smith's Cloud is an object containing several million solar masses of gas that is on a collision course with the Milky Way's disk. The student project will be to reduce and analyze an extensive new GBT data set on Smith's Cloud to determine its properties more precisely and try to understand its origin and fate. Some observing using the GBT will be part of this project.

Michael Lam, of Colgate University,
worked with Paul Demorest on

Exploring Systematic Effects in Millisecond Pulsar Timing

High-precision timing of millisecond pulsars (MSPs) provides us with a useful tool to investigate a variety of topics in fundamental physics and astrophysics. These include the nature of matter at extremely high density (neutron star structure); the behavior of objects in highly relativistic orbits; and potentially a direct detection of gravitational radiation. However, MSP timing is also sensitive to many undesired effects such as pulsar spin irregularities, perturbations due to the interstellar medium, and calibration errors once the data are recorded. Using existing MSP data taken with the Arecibo and Green Bank telescopes, the student will explore the relative strengths of these different systematic timing effects and possible methods for removing them. This work will further our understanding of what must be done to improve pulsar timing precision with current and future large-area radio telescopes.

Kelley Liebst, of University of Kansas,
worked with Aeree Chung on

The Potential Effectiveness of the HI Stripping in Virgo

In our recent VLA HI imaging study of 53 selected Virgo galaxies (VIVA: VLA Imaging of Virgo in Atomic gas), we have found a number of galaxies in the outskirts showing some evidence for recent ISM stripping. In those locations, the intergalactic medium density is expected to be low and the ICM pressure alone is not high enough to strip the ISM from most galaxies. Alternatively, it has been suggested that the tidal field due to neirboring galaxies can weaken the galactic potential and hence galaxies become vulnerable even to the lower ICM pressure. In this project we will test this idea by computing the tidal pertubation parameter and quantifying the effect of the potential field on the ISM stipping in the VIVA galaxies.

Melissa Louie, of Drew University,
worked with James Miller-Jones on

Searching for Jet-ISM Interactions Around X-ray Binary Systems

X-ray binaries are systems which comprise a compact object (black hole or neutron star) accreting matter from a less-evolved companion star. Such systems harbor relativistic jets, which are launched from the inner regions of the accretion flow, and propagate away from the systems at velocities approaching the speed of light. Recent work attempting to quantify the amount of energy channeled into these jets has shown that they can be responsible for carrying away the bulk of the liberated accretion power. Where the jets propagate through a dense external medium, the signature of their impact on their environment can be seen, either as shells of swept-

up shock-compressed gas, or as lobes of synchrotron-emitting plasma. In such cases, the energy required to inflate the lobes can be calculated, constraining the product of the jet power and jet lifetime. While such shells and lobes have only been definitively detected in a handful of cases, optical surveys have detected a number of candidate structures. The student will use archival VLA data to image a candidate jet-blown bubble around the X-ray binary system GRO J1655-40. These data will be used in conjunction with multiwavelength data to ascertain whether this bubble has any connection with the X-ray binary jets. If time permits, other candidate systems will also be studied.

Patrick McCauley, of James Madison University,
worked with Jeff Mangum on

Locating Star Formation Sites Using K-Doublet Formaldehyde Emission

All current theories which describe the star formation process predict that an essential ingredient is a dense core which seeds the collapse process. Many star formation regions have been identified through molecular spectral line and dust continuum measurements, and the physical properties of many of these regions have been derived. Due to the non-selective nature of many of the physical probes used to derive these properties, the exact identification of the highest density regions, and thus the regions which are most likely to form stars, have not been identified. For structurally-simple molecular clouds, this density-selective property of the K-doublet transitions allows for a simple and definite identification of the highest densities.

Christine Mennicke, of Concordia University, St. Paul,
worked with Glen Langston 1 on

Observations of Pre-Biotic Chemistry

The REU students will organize molecular line survey data towards the Taurus Molecular Cloud, one of the prime locations for discovery of new molecules in the interstellar medium. They will prepare a spectral line survey for publication, model the cloud temperature by comparison of line strengths and fitting the data to a temperature model. The students will experiment with new methods of search and detection of molecular species, by weighted model fits to extensive molecular line strength models. This work is important because of its relationship to prebiotic chemistry and is the strongest astronomical indicator that life on earth was due, in part, to chemical processes in the interstellar medium.

Shannon Ramey, of West Virginia University,
worked with John Ford on

Characterization of the Accuracy and Stability of a High-Speed Analog to Digital Converter

Perform research into the accuracy and stability of a high-speed ADC, and relate the results to effects on radio astronomy observations. Characterization will require development of specialized FPGA programs as well as data collection and analysis software using Matlab and Simulink.

Brian Roper, of Virginia Polytechnic Institute and State University, worked with Aaron Evans on

Dissecting Luminous Starburst Galaxy Mergers

The Great Observatories All Sky LIRGs Survey, or GOALS, is a multi-wavelength space-based telescope campaign designed to assess the nature of star formation and supermassive black hole accretion in a complete sample of Luminous InfraRed Galaxies (LIRGs). The activity in these galaxies is triggered by gas-rich galaxy collisions - during the collisions, significant amounts of dust, produced by mass loss from newly-formed stars, enshrouds the central regions of these galaxies where > 90% of their total energy is generated. Understanding the role these galaxies play in terms of their star formation and black hole activity will ultimately have bearing on unraveling the nature of the infrared/submillimeter background radiation, which contains half of the light generated in the Universe since the Big Bang and is likely comprised of luminous infrared galaxies at cosmological distances. The student working with Professor Evans and the GOALS team will analyze one of the galaxies in the GOALS sample. The focus will be on analyzing the galaxy at one or more wavelengths to assess the nature of its star formation and black hole activity. The work will likely lead to a publication.

Francillia Samuel, of DePauw University, worked with Violette Impellizzeri on

A Search for Water Maser Emission in the Early Universe

Active galactic nuclei (AGN) are beacons of accretion onto supermassive black holes. The presence of dense molecular clouds around these powerful central engines can result in luminous line emission, the most spectacular of which is seen in the water maser transition at 22 GHz. Luminous extragalactic water masers (which is the microwave equivalent of a laser) are therefore closely associated with the nuclear activity of their host galaxies. Because they are close to the central engine, water masers can trace the geometry of accretion disks, yield estimates of the enclosed masses, determine accurate distances to the parent galaxies with an entirely geometrical method. Due to the limitations of instrument sensitivities, however, almost all water masers known to date are found in nearby galaxies ($z<0.06$, with only two exceptions at higher redshift). However, the discovery of water masers at cosmological distances ($z>1.5$) would be important as it would allow us to study the parsec-scale environment around powerful AGN at earlier evolutionary stages. In order to probe AGN activity at even higher redshifts, we have started a new project to find water masers from gravitationally lensed quasars. By observing gravitational lens systems we targeted luminous quasars already known to be at cosmological distances and used the lens as a `cosmic telescope' to probe a luminosity regime

not easily reachable with current instrument sensitivities (lens magnifications can increase the flux-density by 10-100 times the intrinsic source flux-density). The student will be given a sample of five highly magnified sources with known molecular emission observed with Effelsberg. All of the targets are in the redshift range 2.5 to 2.8. The single dish datasets will be reduced during the course of the project to search for the 22.235 GHz water line emission. A short summary with a table of the measured parameters will be compiled after data reduction, together with a detailed literature research on each of these interesting systems.

Jennifer Shitanishi, of California State University Los Angeles, worked with Dana Balser on

Magnetic Fields in Photo-Dissociation Regions

Stars form in molecular clouds when gravity overcomes competing forces including thermal pressure, turbulent flows, magnetic pressure, and angular momentum. In the last few decades the best accepted theory predicts that magnetic fields are the dominant competing force against gravity. More recently, there has been growing observational evidence that suggests that star formation is controlled by supersonic turbulence and that molecular clouds are transient phenomena that sometimes have sufficient mass to collapse and form stars. Measurements of the magnetic field are therefore important in understanding star formation. Roshi (2007) suggests that the non-thermal line widths observed in carbon recombination lines from photo-dissociation regions near ultra-compact HII regions are dominated by hydromagnetic waves and can be used to determine the Alfven speed and also the magnetic field strength. The student will use GBT carbon recombination line data along with Zeeman observations from the literature toward several HII regions to test this hypothesis. If we confirm that the carbon non-thermal line widths have a magnetic origin, then another tool will become available to measure the magnetic field strength in star formation regions.

Meagan White, of University of Tennessee, Knoxville, worked with Amy Mioduszewski on

Twenty Years of Observations of X-ray Transient Aquila X-1

Soft X-ray transient Aquila X-1 is a neutron star binary with a low mass companion. It is one of the brightest X-ray sources in the sky and has a orbital period of 19 hours. This period is seen in the modulation of the optical and IR light curves. It also experiences outburst in the X-ray every 123 days, but they don't know why. This source has been observed with the VLA for twenty years but the data have never been put together to form a coherent picture of this source in the radio. The student will gather the data, putting together light curves, spectra and comparing with optical and X-ray.

Erica Whitfield, of Southwest Baptist University,
worked with John Ford on

Numerical Precision Requirements of an All-Pass Digital Filter for Pulsar Applications

Perform research into the precision required to properly calculate the results of an all-pass digital filter for the purposes of removing the effects of the interstellar medium on pulsar timing observations. Using simulation tools, quantify the results of changing the precision used to calculate the output of the filters.

Kyle Woolard, of University of Virginia,
worked with Glen Langston 2 on

Observations of Pre-Biotic Chemistry

The REU students will organize molecular line survey data towards the Taurus Molecular Cloud, one of the prime locations for discovery of new molecules in the interstellar medium. They will prepare a spectral line survey for publication, model the cloud temperature by comparison of line strengths and fitting the data to a temperature model. The students will experiment with new methods of search and detection of molecular species, by weighted model fits to extensive molecular line strength models. This work is important because of its relationship to prebiotic chemistry and is the strongest astronomical indicator that life on earth was due, in part, to chemical processes in the interstellar medium.

Katherine Wyman, of Sonoma State University,
worked with Rachel Rosen on

Non-Radial Oscillations in Radio Pulsars

One of the greatest mysteries in astrophysics is the nature of neutron stars. Most work in the field of the structure and composition of neutron stars is purely theoretical, as neutron stars are only observable in the form of pulsars. We have developed a model based on asteroseismological techniques to explain the rich and diverse phenomena seen in the individual pulses, or sub-pulses, emitted from radio pulsars. We have shown that this pulsational model can qualitatively describe the morphology of various pulsars. In addition, we used PSR 0943+10 for the initial quantitative tests of our model because it has a simple geometry, it has been exhaustively studied in the literature, and its behavior is well-documented. Our fits of a non-radial oscillation model were able to successfully reproduce the observed behavior in this pulsar. However, from an astroseismological perspective, PSR 0943+10 is not the most interesting target for study. The simplicity that makes it attractive for testing our model limits the useful physics that can be extracted. There are pulsars that show multiple subpulse frequencies and others that appear to

show correlated oscillations between the magnetic poles. It is an interesting challenge to apply our pulsational model to these objects. To this end, we have received time on both the GBT and Arecibo to investigate pulsars with more complex behavior and to definitively test predictions of the model. In our non-radial oscillation model, we expect the subpulse phase to behave according to standard asteroseismological theory. For example, in the oscillations are global oscillations, we expect the subpulse phase to be correlated for those pulsars in which we can observe both magnetic poles. Furthermore, if a pulsar shows simultaneous periodicities, we can begin to place constraints on the structure and composition of the neutron star. By studying the subpulse phase and multiple periodicities, we can distinguish our model from other standard pulsar models, as well as learn new physical properties of neutron stars. In this trimester, we will receive high time resolution observations on pulsars that show unique phase behavior and/or have multiple periods. This goal of this project will be to conduct quantitative fitting of our pulsational model to GBT data.

6. RET Project Summaries

The symbol to the right indicates that these teachers were supported under the National Science Foundation (NSF) Research Experience for Teachers program.

2009 RET Participants

Stephen Bartlett, George C. Marshall High School (Physics)
Worked with Rachel Rosen on

"Non-radial Oscillations in Radio Pulsars"

We conducted a quantitative analysis of GBT data of pulsars with drifting subpulses to a non-radial oscillation model for pulsar morphology. The goal of this project was to use asteroseismological techniques to learn about the physical properties of the neutron star structure and composition, specifically near the stellar surface.

Chris Hynes, Louisiana School for Math, Science and the Arts (Chemistry)
Worked with Jay Lockman on

"Simulating wide-field focal plane cameras on the GBT"

The NRAO is beginning a program to develop multi-pixel wide-field focal plane cameras for the GBT, and we need to understand the scientific drivers for such instruments so that they can be optimized for the most important project. The goal of this project was to simulate GBT observations of a comet entering the solar system and with evolving chemical properties. The results of the simulation will be used in the design of the 3 mm focal plane array camera.

Eric Fagrelius, Ouray High School

Worked with Mark Claussen on

"VLA Monitoring of the Water Masers in the Water-Fountain Nebula IRAS16342-3814"

To learn the basics of radio astronomy and the use of AIPS. At the same time, conduct specific research related to IRAS 16342. The science was a proper extension to the normal high school curriculum with some fascinating conceptual highlight. The results were somewhat unexpected and may indicate some new understandings about the water masers around IRAS 16342.

7. Participation in the AAS 215th Meeting

January 3-7, 2010

One of our RET participants and nine of our REU students will travel to Washington, DC, to attend the 215th Meeting of the American Astronomical Society in January.

The deadline for submission of abstracts to the Washington was October 1, 2009, while the deadline for late submissions is December 1, 2009. We anticipate that the Abstracts will be available for review on the AAS schedule by mid December 2009.