National Radio Astronomy Observatory
REU/RET Program Report: 2011-2012

Overview

Summer Student Program

Summer 2011: Twenty-nine students participated in the 2011 NRAO Summer Student program, including 19 undergraduate students supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program, and ten undergraduate and graduate students supported by the NRAO Undergraduate and Graduate Summer Student programs.

There were 151 applicants for the 2011 NRAO summer student program, of whom 69 (46%) were women and 16 (11%) were under-represented minorities. Of all the (29) summer students that were hired, 19 were female (66%) and 10 were male (34%), while 6 (20%) were under-represented minorities. Nine students were assigned to Socorro (6 REU), 13 to Charlottesville (8 REU), and 7 to Green Bank (5 REU).

Summer 2012: Twenty-five students are participating in the 2012 NRAO Summer Student program, including 18 undergraduate students supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program, and seven undergraduate and graduate students supported by the NRAO Undergraduate and Graduate Summer Student programs. This is the fifty-third 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 167 applicants for the 2011 NRAO summer student program, of whom 68 (41%) were women and 17 (10%) were under-represented minorities. Of all the (25) summer students that were hired, 15 were female (60%) and 10 were male (40%), while 3 (12%) were under-represented minorities. Six students were assigned to Socorro (3 REU), 11 to Charlottesville (10 REU), and 8 to Green Bank (5 REU).

Summer Teacher Program

Summer 2011: Mike Mattox, an 8th grade science teacher from Linkhorne Middle School in Lynchburg, VA worked with Dr. Ron Maddalena on a project to determine if state-of-the-art weather forecasts could be used to predict the effect of rain on astronomical observations with radio telescopes. Archived forecasts and archived radio observations from the Green Bank Telescope were supplemented by new radio observations using the

GBT. As part of the project, the optics of the GBT, in particular the spillover pattern, were characterized to a new level of accuracy.

Dan Able, high school physics teachers from St. Xavier High School in Louisville, KY worked with Dr. Miller Goss on new EVLA HI observations of the structure of Galactic HI, observing lines from the warm interstellar medium.

Summer 2012: Michelle Meijer, a high school physics and astronomy teacher from Corona Norco High School in Norco, CA is working with Dr. Ron Maddalena on a research project to analyze an astronomical survey of the 90 GHz (W-band) spectral line emission from the Orion star formation.

Russell Kohrs, a high school earth science, geology, and astronomy teacher from Broadway St. Xavier High School in Louisville, KY worked with Dr. Glen Langston on several research projects which utilize the NRAO 20m telescope in Green Bank.

Table of Contents

2011 NRAO Summer Students/Mentors (N=29)					
Student	**School**	**Project**	**Mentors**	**Site**	**Program**
Stephen Clouse	Brigham Young University	Measuring the Mass of the Nuclear Black Hole in Mrk 1210	Jim Braatz	CV	NSF REU
Timothy Conklin	Rutgers School of Engineering	Astronomical Instrumentation Implementation and Commissioning	John Ford	GB	**NRAO uGRP**
Lia Medeiros	UC Berkeley	Star Formation in the Serpens Molecular Cloud	Rachel Friesen and Scott Schnee	CV	NSF REU
Ethan Kruse	Harvard University	Using GPUs to Search for New Fermi Millisecond Pulsars	Scott Ransom	CV	NSF REU

Courtney Laughlin	Virginia Polytechnic Institute and State University	Blank Field Surveys for CO-Emitting Galaxies	Mark Lacy	CV	NSF REU
Sierra Smith	James Madison University	Voices of Radio Astronomers: Digitizing the Sullivan Interviews	Ellen Bouton	CV	**NRAO GRP**
Ashley Reichardt	University of Pennsylvania	Characterizing Radio Emission from Merging Starburst Galaxies	Adam Leroy	CV	NSF REU
Raquel Chicharro-Fuertes	Universidad Complutense de Madrid/Universidad Autónoma de Madrid	Inferring Build-Up of Stellar Disks using Spitzer, GALEX and ALMA	Kartik Sheth	CV	**NRAO GRP**
Alexa Ross	Reed College	The Rare Phenomenon of Offset Bars & Implications for DM Substructure	Kartik Sheth	CV	NSF REU
Valerie Marchenko	Brandeis University	Testing Evolutionary Models of Giant Radio Sources by Comparing Observations and Simulations	Amy Kimball	CV	NSF REU
Brian Svoboda	Western Washington University	Measuring the Density and Temperature in Starburst Galaxies	Jeff Mangum	CV	NSF REU
Ajinkya Patil	Indian Institute of Technology Kharagpur	RFI Mitigation Research	Rick Fisher	CV	**NRAO uGRP**
Elizabeth McNany	Case Western Reserve University	Control System Data Analysis	John Ford	GB	NSF REU
Tyler Hise	West Virginia University	Development of the 4mm Receiver	Mike Stennes	GB	NSF REU
Kristina Nyland	New Mexico Tech	Radio Continuum and Star Formation in Early-type Galaxies (ETGs)	Joan Wrobel	Soc	**NRAO GRP**

Michael Blatnik	Lynchburg College	Mining the Green Bank Telescope Metadata: Statistics on Radio Frequency Use	Carla Beaudet	GB	**NRAO uGRP**
Deborah Schmidt	Franklin and Marshall College	Images of W49: Temperature and Density of Stellar Nurseries	Glen Langston	GB	NSF REU
Kevin Christiansen	Rochester Institute of Technology	Diffuse Chemistry: Temperate and Density of Molecules Surrounding Star Formation Regions	Glen Langston	GB	NSF REU
Steven Merriman	Depaul University	VLBA Observations of Water Maser Polarization in W3(OH)	Emmanuel Momjian	Soc	**NRAO GRP**
Diana Windemuth	Barnard College of Columbia University	The HI Properties of Local LIRGs	Dave Frayer	GB	**NRAO GRP**
Lorraine Bowman	Observatoire de Paris	The HI Halo of NGC 253	Juergen Ott	Soc	**NRAO GRP**
Hannah Rogers	Augustana College	VLBA Observations of Water Masers in the Water Fountain Pre-Planetary Nebula IRAS16342-3814	Mark Claussen	Soc	NSF REU
Charity Southworth	Indiana University	A Study of the Ultra Compact HII Region G31.41+0.31	Peter Hofner and Mark Claussen	Soc	NSF REU
Traci Johnson	Carleton College	Toward a Unified Understanding of Radio Emission from Novae	Miriam Krauss	Soc	NSF REU
Danna Qasim	Northern Arizona University	Molecular Abundances in the Perseus Star Forming Region	Joe McMullin	Soc	NSF REU
Kamber Schwarz	University of Arizona	Water Masers in the Large Magellanic Cloud	Juergen Ott and David Meier	Soc	NSF REU

Caroline Houston	Rochester Institute of Technology	Radio-Frequency Interference Removal in Radio Astronomy	Urvashi Rao	Soc	NSF REU
Michael Mattox	Linkhorne Middle School	State of the Art Weather Forecasting for Radio Astronomy	Ron Maddalena	GB	NSF RET
Daniel Able	St. Xavier HS	HI Structure of the Warm Interstellar Medium	Miller Goss	Soc	NSF RET

1. 2011 NRAO Summer Program Participants

This table summarizes the student 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 29 summer student participants (19 REU, 3 uGRP, 7 GRP).

2. Site Specific Activities: Charlottesville VA

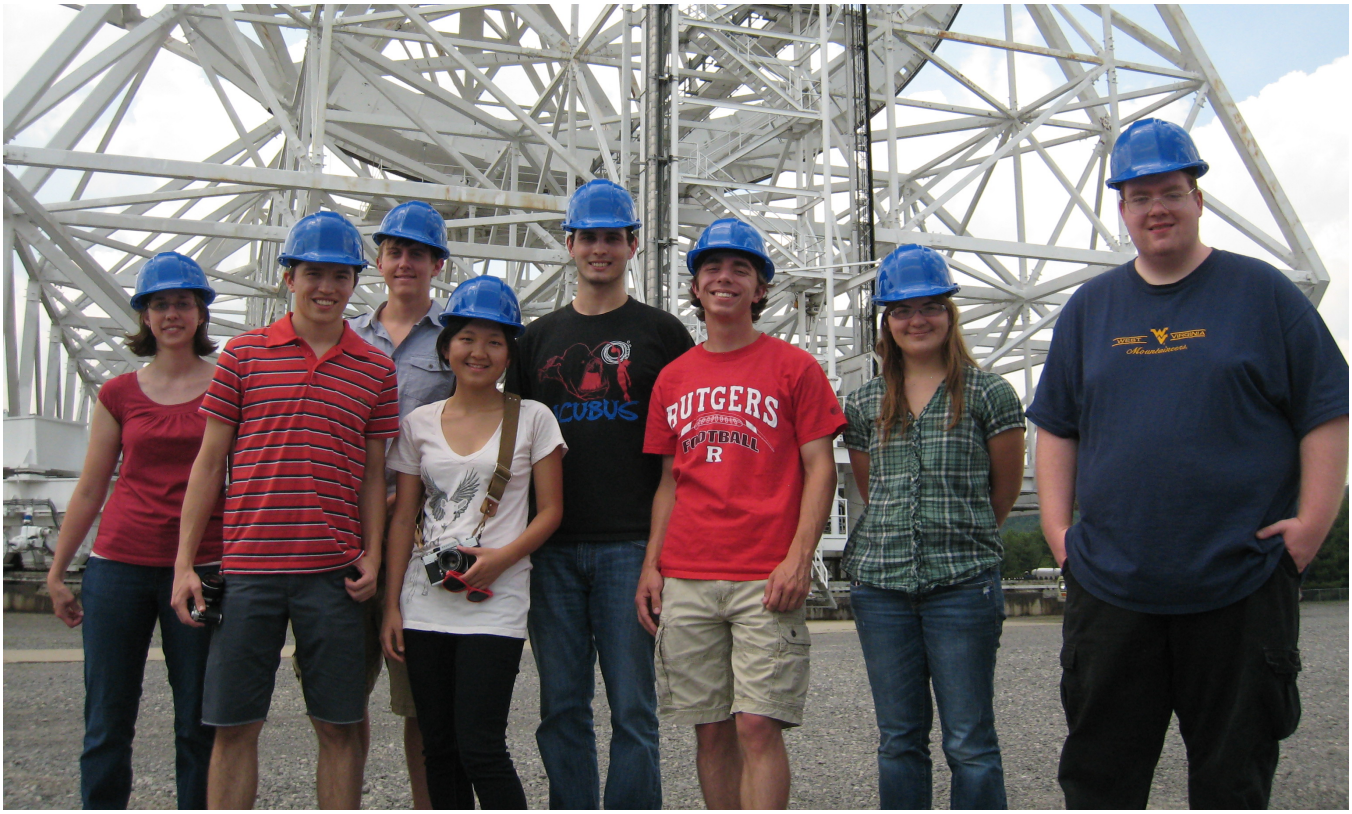
The 2011 Summer Student program at NRAO/Charlottesville was conducted under the direction of Jeff Mangum. There were 13 students in the 2011 Summer Student Research Program at NRAO-Charlottesville, eight of them under the NSF Research Experience for Undergraduates (NSF REU) program, three under the NRAO Graduate Student Program (NRAO GRP), and two under the NRAO Undergraduate Summer Program. The photograph above shows the 2011 Charlottesville summer students.

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 Green Bank, WV.

In addition to lectures on radio astronomical science, engineering, and computing, the Charlottesville Summer Students were given a tour of the NRAO Technology Center (NTC). The Charlottesville 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 Charlottesville Summer Student experience the 2011 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.



3. Site Specific Activities: Green Bank, WV

The 2011 REU/RET program at NRAO Green Bank was under the direction of David Frayer. There were seven students in the 2011 Summer Research Program at NRAO-GB. Four students were supported by the NSF Research Experience for Undergraduates (NSF REU) and three students were supported by the NRAO Undergraduate Summer Program. Pictured above are the seven summer students and one co-op participant. There was a special set of lectures given to the students by scientists and engineers on Green Bank staff. The Green Bank summer students were also able to participate in the NRAO Interferometry Summer School in Socorro, NM. In addition, the summer students were able to participate to varying degrees in several workshops that were held in Green Bank. These included a Chautauqua Short Course on Astronomy, the Society of Amateur Radio Astronomers (SARA) meeting, the Mid Atlantic Astronomical Society Star Party and the Pulsar Research Collaboratory Workshop.

There was also a weekly Science Lunch with the students every Thursday and regular soccer and volleyball games.

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 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 towards HII regions, a survey searching for extra-galactic HI and a study of Formyldahyde in Infrared Dark Clouds. At the end of the summer, the students gave the staff a seminar where they presented the results of their summer research projects. They also produced a short report describing this work.

4. Site Specific Activities: Socorro, NM

The 2011 REU program at NRAO Socorro was under the direction of Amy Mioduszewski. There were nine students. Seven of the students participated via the NSF Research Experience for Undergraduates (NSF REU) program and two were supported by the NRAO Graduate Research Program (NRAO GRP). Pictured above are the nine summer students and one RET participant. The Socorro summer students had a variety of activities to take part in, which included "Wednesday Lunch" (free pizza for students!) with scientific talks and Tuesday Science Tea held in the DSOC upstairs lounge. The group toured two observatories: the VLA and Apache Point Observatory. They also toured the Energetic Materials

Research and Testing Center located in Socorro. The students 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 the two student-led observational projects, one using the VLA and the other using the VLBA. 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.

5. REU Project Summaries

The NSF logo indicates students who were supported under the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) and Teachers (RET) 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.

Daniel Able, of St. Xavier HS,
worked with Miller Goss on

HI Structure of the Warm Interstellar Medium

Dan Able from Lexington KY spent about 6 weeks working on HI absorption of strong extragalactic sources. We are looking for weak galactic HI absorption due to the warmer interstellar gas. The new feature of the EVLA (Expanded Very Large Array) that makes this possible is the improved spectral dynamic range of the new WIDAR correlator. The dynamic range has improved well over a factor of 10 compared to the original VLA correlator from 1980. We are now able to detect HI lines of modest widths (some km/s) with opacities of less than 0.001. About 12 sources were oberved and fully reduced. Able gave a fine talk at the end of the summer about his results. He helped in the setting up of the reduction pipeline and in debugging the procedures.

Michael Blatnik, of Lynchburg College,
worked with Carla Beaudet on

Mining the Green Bank Telescope Metadata: Statistics on Radio Frequency Use

In a previous Summer Project, the metadata from all standard archived Robert C. Byrd Green Bank Telescope (GBT) data were mined to develop accurate and detailed statistics on radio frequency use. The purpose of the exercise was to help answer several long-standing questions within the radio astronomy spectrum management

community: What fraction of observing time is actually spent within exclusive allocated radio astronomy bands? What fraction of observing time is spent within bands shared with transmitting services? What fraction of observing time is spent in bands that have no allocation to the radio astronomy service? Which shared bands, or bands with no radio astronomy allocation, are most heavily used, and therefore most relevant to the development of interference mitigation techniques? In last year's project, not all the data at the GBT could be accounted for, but we were able to build a good framework for statistics building for radio astronomy at Green Bank. This year we would like to expand that work to include all the GBT receivers and data from other telescopes such as Arecibo, the VLA, and the VLBA.

Lorraine Bowman, of Observatoire de Paris,
worked with Juergen Ott on

The HI Halo of NGC 253

Energetic deposits of Supernovae and stellar winds have a huge impact on the ISM in starburst galaxies. NGC253, THE nearby prototype of a starburst galaxy has large lobes of outflow visible in Xray and Halpha reaching far into the halo of the host. This is potentially a important mechanism to distribute metals away from the disk of galaxies. We obtained EVLA HI data of this object at high spatial and spatial resolution. The student worked on the basic data reduction and imaging of this galaxy. The data was analyzed to determine the amount, extent and dynamics of extraplanar atomic gas. These numbers were compared to the energetics of the starburst and to the X-ray and ionized gas outflow.

Raquel Chicharro-Fuertes, of Universidad Complutense de Madrid/Universidad Autónoma de Madrid,
worked with Kartik Sheth on

Inferring Build-Up of Stellar Disks using Spitzer, GALEX and ALMA

As part of the large Spitzer project, S4G, our team has been analyzing mid-infrared data for about 2000+ galaxies in order to assemble an inventory of mass and stellar structure in the nearby Universe. While the Spitzer data allow us to trace the old stellar population with superb precision and depth (down to < 1 solar mass per sq pc), addition of GALEX data to this data set would provide a invaluable boost to the overall project for a large variety of projects. Raquel spent her summer doing two distinct but parallel projects using the GALEX + S4G data. In her first project, she used the GALEX+S4G radial profiles to look for the characteristic "U-shaped" radial profiles of the disk color. The outer parts of the disk show a reddening of the disks indicating a possible migration of stars to the outer parts. She is now writing up the paper to understand how much migration has occurred in different types of galaxies and what this means in a cosmological context where more massive disks formed first. For her second project, she also identified bars in the ultraviolet GALEX images and was able to quantify for the first time the number of bars that are visibile and those that can be inferred from the GALEX data. Although the fraction of these bars is low, the analysis is critical for our understanding of the bar fraction at high redshift where only the rest-frame ultra-violet data is available.

Kevin Christiansen, of Rochester Institute of Technology,
worked with Glen Langston on

Diffuse Chemistry: Temperate and Density of Molecules Surrounding Star Formation Regions

The student worked on observing ammonia inversion transitions in molecular cloud W51. The student processed these data using the GBT Pipeline. The student created spectral plots, intensity maps, and wrote a program to fit gaussian models to these data. Results showed a vast range of temperatures and densities within several star forming regions of W51.

Stephen Clouse, of Brigham Young University,
worked with Jim Braatz on

Measuring the Mass of the Nuclear Black Hole in Mrk 1210

Water vapor megamasers arise in the circumnuclear accretion disks of active galaxies. When viewed edge-on, the classic examples of these masers have characteristic spectral profiles showing three distinct clusters of maser components centered on the systemic recession velocity. Maser components trace the disk along the line of sight to the black hole, as well as from the edges of the disk where the masers become redshifted and blushifted because of the rotation. Unlike classic examples, the maser in Mrk 1210 has an unusual spectral profile with only a few maser lines, spread over a large velocity range of ~ 500 km/s. Here we present a sub-milliarcsec resolution map of the water megamaser in the Seyfert 2 galaxy Mrk 1210, as observed with the VLBA. The map shows that the masers fall within 0.8 pc of the central black hole. We present a model that fits the maser positions, velocities, and accelerations. In our model, the masers arise in a slightly inclined disk with some features coming from intermediate azimuthal angles within the disk. With this model, the masers determine the mass of the black hole: 1.3x10^7 solar masses.

Timothy Conklin, of Rutgers School of Engineering,
worked with John Ford on

Astronomical Instrumentation Implementation and Commissioning

The project involved the design and construction of a spectrometer based on FPGA technologies. This spectrometer will be used for testing purposes in the receiver lab. A python script to create FITS files for the spectrometer was also written for easy data analysis. The project included assistance with the implementation of the spectrometer for the 20 m telescope on site.

Tyler Hise, of West Virginia University,
worked with Mike Stennes on

Development of the 4mm Receiver

The student was involved in the redesign of the prototype 4mm receiver in order to have all 4 channels function in the complete receiver. This involved the fabrication of new wave guides and new cover plates to protect various electrical equipment from temperature changes and damage. The student was also responsible for coming up with a way to filter infrared radiation that had been coming into the receiver and heating up various components.

Caroline Houston, of Rochester Institute of Technology,
worked with Urvashi Rao on

Radio-Frequency Interference Removal in Radio Astronomy

The student (a) learned the basics of interferometric data acquisition and how radio-frequency interference manifests itself in the measured data, (b) learned a few signal-processing techniques and implement several RFI identification/excision algorithms (using existing signal-processing tools in python/matlab), (c) applied these algorithms to EVLA data and compare with existing methods in our software (casa and aips). The algorithms were the following : singular-value-decomposition methods, fringe-fitting methods, pattern recognition in the time-frequency domain, delay-space filtering. From this project, the student learned about the interferometric measurement process, some signal-processing/pattern-recognition methods, and gained experience from a real-world application of these tools.

Traci Johnson, of Carleton College,
worked with Miriam Krauss on

Toward a Unified Understanding of Radio Emission from Novae

The most common energetic outburst in the universe, novae result when the accretion of matter onto a white dwarf in a binary from its companion star leads to a thermonuclear explosion. There is a long history of radio observations of nova but they have never been studied in a unified way. Also recent observations showed that

the classic model for nova, the Hubble flow model, didn't fit the observations very well. The student goal was to compare these new data with past observations in detail, to understand whether these differences are fundamental, or simply a function of earlier and more consistent observation. The student compiled all the radio observations of old novae, 12 in total, some published some not. She then fit the those data with a Hubble flow model, finding that many of the old data also did not fit the model is similar ways to the current data.

Ethan Kruse, of Harvard University,
worked with Scott Ransom on

Using GPUs to Search for New Fermi Millisecond Pulsars

Searching blindly for pulsars in gamma-rays is incredibly difficult -- you need hundreds or thousands of photons, yet we receive only about 1 gamma-ray a day from the brightest gamma-ray pulsars. There are some simple brute-force "folding" techniques (where you keep track of every rotation of the pulsar and assign the gamma-rays to the correct rotational phases given a trial spin period) which can do it, yet they take an incredible (i.e. ridiculous) amounts of computer time. In this project, we will take one of these highly-optimized algorithms and implement it on a Graphics Processing Unit (GPU). With a large enough speed-up, a cluster of GPUs could be used to search for and detect gamma-ray millisecond pulsars. In addition, we will analyze in detail the possibility of using "phase modulation" searches to blindly detect binary millisecond pulsars in Fermi data. During the process, we will search several promising sources for pulsations.

Courtney Laughlin, of Virginia Polytechnic Institute and State University,
worked with Mark Lacy on

Blank Field Surveys for CO-Emitting Galaxies

The student will examine data cubes (a series of images taken over a range of frequencies) obtained with the EVLA to search for CO line emission from field galaxies. Within the next few years, as new telescopes such as ALMA and the EVLA are fully commissioned, such surveys will be common, and indeed some "blank field" detections have already been claimed, but the reliability of such detections is unclear. This project will use some existing data to examine the noise properties of such cubes and determine a good threshold level at which an object might be considered "real", thus helping the planning of such future surveys. Although the cubes being used do not have a large enough frequency coverage to be sure of finding a real object, we will be able to use data on these fields at different wavelengths to search for counterparts to any candidates we do find.

Valerie Marchenko, of Brandeis University,
worked with Amy Kimball on

Testing Evolutionary Models of Giant Radio Sources by Comparing Observations and Simulations

The evolutionary process of large, powerful radio quasars and radio galaxies is not well-understood. Work by Barai & Wiita (2006, 2007) tested evolutionary models by comparing simulated versions of the radio sky to observational catalogs, but their tests were limited by the rather small observational samples. New, larger radio surveys will allow more extensive tests that should yield insight into the nature of these exotic radio sources. The student will work with these new observational catalogs and determine selection criteria to produce the best sample for such tests, based on plots as well as radio images. There is also a coding side to this project: The student will experiment with different input parameters in the model code to produce different simulated versions of the radio sky. The student will compare the observational sample to these "mock catalogs" in order to find the model Universe that best describes the true evolutionary path of radio galaxies.

Michael Mattox, of Linkhorne Middle School,
worked with Ron Maddalena on

State of the Art Weather Forecasting for Radio Astronomy

Mike Mattox, an 8th grade science teacher from Linkhorne Middle School in Lynchburg, VA worked with Dr. Ron Maddalena on a project to determine if state-of-the-art weather forecasts could be used to predict the effect of rain on astronomical observations with radio telescopes. Archived forecasts and archived radio observations from the Green Bank Telescope were supplemented by new radio observations using the GBT. As part of the project, the optics of the GBT, in particular the spillover pattern, were characterized to a new level of accuracy.

Elizabeth McNany, of Case Western Reserve University,
worked with John Ford on

Control System Data Analysis

The student worked on engineering software upgrades. The student took an old version of software called Logview, used to view logs from various sensors on the GBT, and rewrote it to provide critical functionality which was previously lacking. The new version of Logview is in Python, replacing and improving upon the old version written in the now-obsolete Glish language. Some examples of upgrades include plotting many data sources simultaneously, editing the resulting graph, and allowing different formats of log files.

Lia Medeiros, of UC Berkeley,
worked with Rachel Friesen and Scott Schnee on

Star Formation in the Serpens Molecular Cloud

In our Galaxy, most stars form in clustered environments. The Serpens South Cluster is a nearby cluster of embedded young stellar objects identified in the Serpens molecular cloud through mid-infrared imaging as part of the Spitzer Gould Belt Legacy Survey. Star formation in the cluster has likely only very recently begun, as many of the detected sources are extremely young. The cluster star formation rate is also very high, suggesting that many more stars will be able to form before the surrounding dense gas is removed through radiation and stellar winds. This cluster thus offers an unusual chance to study an extremely young system before gas dispersal and stellar dynamics have dramatically altered the landscape. The student will work on analysis of a large (~ 0.5 square degree) map of ammonia (NH3) emission towards the Serpens South Cluster taken with the Green Bank Telescope. NH3 observations selectively probe the dense gas associated with the cluster, revealing the regions where stars may yet be forming. The student will gain familiarity with data cubes, spectral line analysis, and dark cloud chemistry, and will analyse the kinematics of the gas on small- and large-scales with the goal of comparing the results to theoretical models of star cluster formation.

Steven Merriman, of Depaul University,
worked with Emmanuel Momjian on

VLBA Observations of Water Maser Polarization in W3(OH)

The student worked on two epochs of VLBA spectral line observations that targeted the 22 GHz water maser emission from W3(OH). The two epochs were carried out at different phases of the maser activity, one near the peak of a flaring event, and another at a quiescent phase. The objective of the project was to derive the line of sight magnetic field values through detecting and measuring the Zeeman effect, and to establish whether the magnetic field strengths are dependent on or related to the maser activity.

Kristina Nyland, of New Mexico Tech,
worked with Joan Wrobel on

Radio Continuum and Star Formation in Early-type Galaxies (ETGs)

We completed a pilot EVLA project to make high sensitivity continuum images at 1.4 GHz of a subset of the volume-limited Atlas3D sample of ETGs. A substantial fraction of these ETGs contain molecular gas. We observed them deeply enough, with high enough spatial resolution, to be able to detect the predicted level of star formation or to set useful constraints on its absence. We tested empirical star formation "laws" which have been developed for spiral galaxies. This led to a deeper understanding of the star formation process and so improve modern simulations of galaxy evolution. We also probed the physical basis of the radio-FIR relation and its deviations from linearity at low luminosities, with implications for the use of the radio-FIR relation in high redshift surveys. Finally, we incorporated the results of the pilot project into a follow-up EVLA proposal on the entire Atlas3D sample.

Ajinkya Patil, of Indian Institute of Technology Kharagpur,
worked with Rick Fisher on

RFI Mitigation Research

The student's primary task will be to record and analyze RFI signals at the GBT to determine their coherence as received by the GBT and by one or more monitor antennas and to determine how this coherence varies with time and GBT pointing direction. From this information the student will design and evaluate RFI cancellation algorithms that could be used for enhancing the science of the GBT. The prmary focus of the student's work will be signal processing and may include algorithms for removing pulsar pulse broadening due interstellar scattering.

Danna Qasim, of Northern Arizona University,
worked with Joe McMullin on

Molecular Abundances in the Perseus Star Forming Region

The student investigated the molecular fractional abundances in star forming regions in Perseus. The student worked with reduced data cubes of molecular emission, analyzing the line properties and deriving LTE column densities. Comparison with other regions was done to deduce patterns in molecular tracers as dyes of different levels of energetic activity in star formation.

Ashley Reichardt, of University of Pennsylvania,
worked with Adam Leroy on

Characterizing Radio Emission from Merging Starburst Galaxies

The student will work on new radio continuum observations of merging starburst galaxies (LIRGs and ULIRGs) taken with the EVLA. The student will help analyze these EVLA data to diagnose the physical origin of the radio continuum emission, measure the sizes of the star-forming events at the hearts of the galaxies, and compare these measurements to the properties of these galaxies measured from other wavelengths.

Hannah Rogers, of Augustana College,
worked with Mark Claussen on

VLBA Observations of Water Masers in the Water Fountain Pre-Planetary Nebula IRAS16342-3814

Twelve new epochs of VLBA observations of the high-velocity water masers in the pre-planetary nebula IRAS16342-3814 were observed in 2008/2009. The observations were taken approximately at one month intervals. The 0student project reduced the data, and to compared the relative positions of the masers with earlier data taken in 2002. The detailed structure of the 2002 data shows that the water masers appears to be that of bow shocks on either side of a collimated jet that stretches over 3000 milliarcseconds. The new 2008/2009 data was compared with the 2002 data which showed several interesting features: 1) both the old and new masers were found; and 2) the maser "spots" appeared to quit moving. This last discovery is very puzzling.

Alexa Ross, of Reed College,
worked with Kartik Sheth on

The Rare Phenomenon of Offset Bars & Implications for DM Substructure

For the first part of Alexa's summer, she looked through every single S4G galaxy and began to identify barred, unbarred and candidate barred galaxies. As she did this work, she also identified the offset bars, which have a center that is offset from the photometric center of the galaxy disk. This phenomenon, although rare may provide a vital clue to the dark matter substructure because interactions with the clumpy DM halo can move the bar from the center of the galaxy. Interactions with external galaxies may also play a role in creating offset bars by moving the disk out of place or by creating lopsided disks which could also give the appearance of an offset bar. Alexa is working on a paper to describe the occurence of these offset bars and constraining the DM substructure that would be required to create the observed offsets.

Deborah Schmidt, of Franklin and Marshall College,
worked with Glen Langston on

Images of W49: Temperature and Density of Stellar Nurseries

Kamber Schwarz, of University of Arizona,
worked with Juergen Ott and David Meier on

Water Masers in the Large Magellanic Cloud

The Large Magellanic Cloud (LMC) has sites of massive star formation. The student will analyze ATCA data cubes of a survey aimed to find water masers in these regions. The student found the masers and created a catalog. Statistics of the fluxes were compared to those in our Galaxy and other galaxies. The number, fluxes, line widths etc. were also be compared to other tracers of star formation in the targeted regions such as dust, YSO and dense molecular gas maps - for all of which data exits.

Sierra Smith, of James Madison University,
worked with Ellen Bouton on

Voices of Radio Astronomers: Digitizing the Sullivan Interviews

Professor Woodruff T. Sullivan III's book, Cosmic Noise: A History of Early Radio Astronomy, was published in 2009 by Cambridge University Press. The book covers the history of radio astronomy from its beginning in 1933 through 1953, and represents 30 years of intensive research by Dr. Sullivan. In 2010 Dr. Sullivan donated to the NRAO Archives the 188 audio tapes and related paperwork for the extensive set of interviews he conducted between 1971 and 1988 with 255 radio astronomers around the world, many of whom are now deceased. The interview tapes are a unique resource for the history of radio astronomy, which was still a relatively young field when Sullivan began his interview project in 1971. Using processes and protocols already developed and tested, the student will digitize the audio tapes, edit digitized files as necessary, format digitized files for potential future Web presentation, work on obtaining permissions from interviewees still living and the heirs/estates of those who have died, assist the Archivist in preparing finding aids, and, if time allows, transcribe key interviews for which transcriptions do not already exist. The student will work under the direct supervision of Ellen N. Bouton, NRAO Archivist, with technical assistance as needed from Josh Malone and other NRAO staff.

Charity Southworth, of Indiana University,
worked with Peter Hofner and Mark Claussen on

A Study of the Ultra Compact HII Region G31.41+0.31

The ultracompact HII region G31.41+0.31 contains at least three sites of massive star formation, which are likely in a different evolutionary phase. The student reduced the radio continuum data of this region with and explored the physics of the massive star formation process, including topics like ionization models, expansion, age sequence etc. Data reduction and analysis was carried out in AIPS and/or CASA of already existing multi-

wavelength and multi-configuration data. This data set was augmented by existing archival data both in the radio and infrared.

Brian Svoboda, of Western Washington University,
worked with Jeff Mangum on

Measuring the Density and Temperature in Starburst Galaxies

Studies of the distribution of Carbon Monoxide (CO) emission in external galaxies (cf. Young & Scoville (1991)) have pointed to the presence of large quantities of molecular material in these systems. These studies have yielded a detailed picture of the molecular mass in many external galaxies. But, because emission from the abundant CO molecule is generally dominated by radiative transfer effects, such as high optical depth, it is not a reliable monitor of the physical conditions, such as spatial density and kinetic temperature, quantities necessary to assess the possibility of star formation. Emission from less-abundant, higher-dipole moment molecules are better-suited to the task of deriving the spatial density and kinetic temperature of the dense gas in our and external galaxies. For this reason, emission line studies from a variety of molecules have been made toward mainly nearby galaxies (see Mauersberger & Henkel (1989) (CS), Gao & Solomon (2004a) (HCN), Nguyen-Q-Rieu et al. (1992) (HCO+), Mauersberger et al. (1990) and Meier & Turner (2005) (HC3N), Mauersberger et al. (2003) (NH3), or Henkel, Baan, & Mauersberger (1991) for a review). The most extensive sets of measurements of molecular line emission in external galaxies has been done using the J=1-0 transitions of CO (Helfer et al. 2003) and HCN (Gao & Solomon 2004a). Since the J=1-0 transitions of CO and HCN are good tracers of the more generally distributed and the denser gas, respectively, but do not provide comprehensive information about the individual physical conditions of the dense, potentially star-forming gas, other molecules must be observed for this purpose. Formaldehyde (H2CO) and ammonia (NH3) are particularly well suited to the tasks of measuring the spatial density and kinetic temperature, respectively, in star formation environments. To this end, measurements of these two molecules toward a sample of starburst galaxies using the GBT and VLA will be used to derive the spatial density and kinetic temperature in starburst galaxies.

Diana Windemuth, of Barnard College of Columbia University,
worked with Dave Frayer on

The HI Properties of Local LIRGs

The project involved the analysis of GBT HI data toward Luminous Infrared Galaxies (LIRGs) which make up the Great Observatories All-sky LIRG Survey (GOALS). The project included measurements of the HI line strengths and analysis of the HI properties as a function of merger stage and infrared luminosity. The HI results were compared with the vast collection of multi-wavelength data available for the GOALS sample (e.g., stellar masses, molecular gas mass).

6. Participation in the AAS 219th Meeting January 8-12, 2012

Twenty-two of the NRAO summer students travelled to Austin, TX, to attend and present the results from their summer research projects at the 219th meeting of the American Astronomical Society in January 2012. The following lists the summer student presentation titles:

- **Michael Blatnik**: Mining the Green Bank Telescope Metadata Archive: Statistics on Radio Frequency Use, 2002-2011
- **Raquel Chicharro-Fuertes**: Ultra-Violet Analysis of the S4G Sample
- **Stephen Clouse**: H_2O Megamasers: Measuring the Mass of the Black Hole in the AGN of Mrk1210
- **Caroline Houston**: Comparison and Verification of RFI Excision Techniques
- **Traci Johnson**: Toward a Unified Understanding of Radio Emission from Novae
- **Ethan Kruse**: Speeding Up Blind Gamma-Ray Pulsar Searches with GPUs
- **Courtney Laughlin**: Search for CO-Emitting Galaxies in Blank Field Surveys
- **Valerie Marchenko**: Testing Evolutionary Models of Giant Radio Surveys by Comparing Observations and Simulations
- **Lia Medeiros**: Molecular Line Studies of Serpens South Star Forming Region
- **Steven Merriman**: Water Maser Polarization in W3(OH)
- **Kristina Nyland**: Star-Formation and LLAGN in Early-Type Galaxies
- **Sierra Smith**: The Search for Extraterrestrial Intelligence in the 1960s: Science in Popular Culture
- **Ajinkya Patil**: Measurement of Flux Density of Cas A at Low Frequencies
- **Danna Qasim**: Understanding the Evolution of Sun-Like Stars: IRAS4
- **Hannah Rogers**: Water Masers of Water Fountain Pre-Planetary Nebula IRAS 16342-3814
- **Ashley Reichardt**: Characterizing Radio Emission from Nearby LIRGs and ULIRGs
- **Alexa Ross**: Measuring the Fraction of Bars and Offset Bars Using the Spitzer Survey of Stellar Structure in Galaxies
- **Deborah Schmidt**: A New Search of Unidentified Radio Point Sources for Fast Pulses and Bursts
- **Kamber Schwarz**: Water Masers in Star Forming Regions of the Large Magellanic Cloud
- **Charity Southworth**: The Ultra-Compact HII Region G31.41+0.31 Revisited: A Radio Continuum and Infrared Study
- **Brian Svoboda**: Temperature and Heating Mechanisms in the Polar Ring Galaxy NGC660
- **Diana Windemuth**: HI Properties of the GOALS Luminous Infrared Galaxies