National Radio Astronomy Observatory
REU/RET Program Report: 2010

Overview

Summer Student Program

Twenty-three students participated in the 2010 NRAO Summer Student program, including 20 undergraduate students supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program, four 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 fifty-first 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 163 applicants to the 2010 NRAO summer student program, of whom 68 (42%) were women and 14 (9%) were under-represented minorities. The 20 REU positions were filled by 10 women (50%) and 10 men (50%). Of all the (30) summer students that were hired, 15 women (50%) and 15 men (50%), 6 (20%) were under-represented minorities. Eight students were assigned to Socorro (5 REU), 14 to Charlottesville (10 REU), and 8 to Green Bank (5 REU).

Summer Teacher Program

There were no participants in the 2010 NRAO Summer Teacher Program.

Organization of Report

This report is organized as follows. In Section 1 we list the Summer 2010 participants. We then describe the different activities in which students participated at each of the three main NRAO sites: Charlottesville (Section 2), Green Bank (Section 3), and Socorro (Section 4). In Section 5 we provide brief descriptions of the research projects completed by each REU student. These descriptions are also available on-line at http://www.nrao.edu/students/archive/projects.php, which includes links to the final written reports. Many of these presentations are expected to be published in astronomical journals in 2010-11. In the final section we identify the anticipated number of participants who will present at the 217th meeting of the American Astronomical Society in Seattle, WA January 2011).

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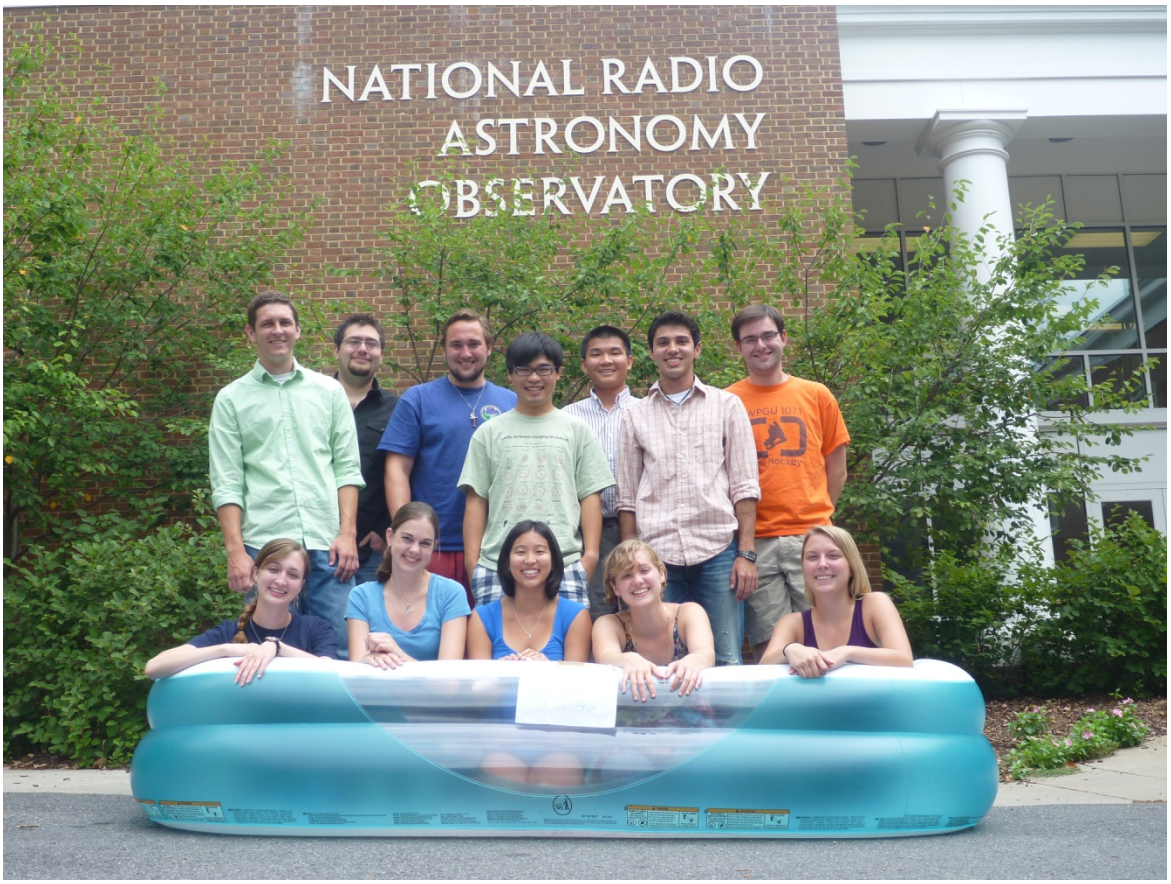
1. 2010 NRAO Summer Program Participants

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 30 summer student participants (20 REU, 4 uGRP, 6 GRP).

2010 NRAO Summer Students/Mentors (N=30)					
Student	School	Project	Mentors	Site	Program
Matthew Wahl	SUNY at Stony Brook	An Unbiased Study of SMGs - Towards Transformational Science with ALMA	Kartik Sheth 1	CV	NSF-REU
Trisha Mizusawa	Villanova University	Bar Properties and the Central Starburst/AGN in the Spitzer Survey of Stellar Structure in Galaxies	Kartik Sheth 2	CV	NRAO-uGRP
Ashley Bemis	University of Massachusetts, Amherst	Measuring the Impact of Environment on Star-Forming Clouds in a Nearby Galaxy	Adam Leroy/Rachel Friesen	CV	NSF REU
Amy Robertson	University of Arizona	Investigating the Formation Chemistry of Astronomical Molecules - a Multi-Faceted Approach	Anthony Remijan	CV	NSF REU
Justin Spilker	Iowa State University	Strategies for Emission Line Searches for High-z Galaxies with ALMA	Mark Lacy	CV	NSF REU
Anthony Ford	University of Texas at Brownsville	Exploration and Visualization of Pulsar Survey Data	Ron Duplain	CV	NSF REU
Bang Nhan	University of California at Santa Barbara	A Search for Dark Matter Decay Products in Nearby Dwarf Spheroidal galaxies	Brian Mason	CV	NRAO-uGRP
Corinne Fletcher	University of Missouri	Exgalactic Methanol	Violette Impellizzeri	CV	NSF REU
Benjamin Montet	University of Illinois, Urbana-Champaign	Magnetic Fields in Photo-Dissociation Regions	Dana Balser	CV	NSF REU

Huilin Li	University of Virginia	Waveguide Flange Development for Terahertz Instrumentation	Anthony Kerr	CV	NRAO GRP
Nicole Free	Ohio University	HI Observations of the Area Around M33	Jay Lockman	GB	NRAO GRP
Timothy Conklin	Rutgers School of Engineering	Characterization of the Accuracy and Stability of a High-Speed ADC for Radio Astronomy	John Ford	GB	NSF REU
Diana Windemuth	Barnard College of Columbia University	HI Observations of the GOALS LIRGs	David Frayer	GB	NSF REU
Andrew Battisti	SUNY at Stony Brook	The Structure and Motion of Chemistry in the Taurus Molecular Cloud	Glen Langston 1	GB	NRAO GRP
Megan Jones	University of Wisconsin-Madison	Variation in the Physical Temperature of Molecules in the Taurus Molecular Cloud	Glen Langston 2	GB	NSF REU
Michael Blatnik	Lynchburg College	Mining the GBT metadata archive: Statistics on radio frequency use, 2002-2010	Carla Beaudet	GB	NSF REU
Claire Murray	Carleton College	Methanol Masers in Andromeda	Lorant Sjouwerman	Soc	NSF REU
Kristen Koopman	Sarah Lawrence College	Near- and Mid-Infrared Color Schemes for Circumstellar Envelopes	Lorant Sjouwerman and Mark Claussen	Soc	NSF REU
Sarah Wyss	Ohio University	The CO isotope ratio in the Large Magellanic Cloud	Juergen Ott	Soc	NSF REU
Thomas Connor	Case Western Reserve University	The Host Galaxy Morphology of Faint Radio Sources: Quenched or Hidden Star Formation	Maurilo Pannella and Veronica Strazzullo	Soc	NSF REU
Jennifer Lyons	Pacific University	Searching for polarized emission from the symbiotic nova V407 Cyg	Miriam Krauss and Michael Rupen	Soc	NSF REU
Meredith MacGregor	Harvard University	Measuring the Density and Temperature of Starburst Galaxies	Jeff Magnum	CV	NSF REU

Matthew Rickert	DePaul University	Mapping the Distribution of the Prebiotic Molecule Methanimine and HCN in the ULIRG Arp 220	Emmanuel Momjian	Soc	NRAO GRP
Abhirup Datta	New Mexico Tech Socorro NM	Reionization Simulations and GMRT HI 21cm Absorption Search	Chris Carillia Sanjay Bhatnagar	Soc	NRAO GRP
Nickolas Sneed	Howard University	Dissecting Luminous Starburst Galaxy Mergers	Aaron Evans	CV	NSF REU
Rogerio Cardoso	University of Wisconsin-Madison	Searching for Pulsars in Large-Scale Pulsar Surveys	Scott Ransom	CV	NSF REU
Bin Chen	University of Virginia	The Sun and You	Tim Bastian	CV	NRAO GRP
Maithili Ghamande	University of Akron	Modelling the Antenna Primary Beams	Sanjay Bhatnagar and Urvashi Rao	Soc	NRAO GRP
Shannon Ramey	West Virginia University	Characterization of the Accuracy and Stability of a High-Speed ADC for Radio Astronomy	John Ford	GB	NSF REU
Erica Whitfield	Southwest Baptist University	Numerical precision in Digital Signal Processing for Radio Astronomy Applications	John Ford	GB	NSF REU



2. Site Specific Activities: Charlottesville VA

The 2010 Summer Student program at NRAO/Charlottesville was conducted under the direction of Jeff Mangum. There were 14 students in the 2010 Summer Student Research Program at NRAO-Charlottesville, ten of them under the NSF Research Experience for Undergraduates (NSF REU) program, two under the NRAO Graduate Student Program (NRAO GRP), and two under the NRAO Undergraduate Summer Program. The photograph above shows twelve of the fourteen the 2010 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 Interferometry Summer School in Socorro, NM.

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 2010 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 2010 REU/RET program at NRAO Green Bank was under the direction of David Frayer. There were eight students in the 2010 Summer Research Program at NRAO-GB. Five students were supported by the NSF Research Experience for Undergraduates (NSF REU), one student was supported by the NRAO Graduate Summer Student Program (NRAO GRP), and two students were supported by the NRAO Undergraduate Summer Program. 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 2010 REU program at NRAO Socorro was under the direction of Amy Mioduszewski. There were eight students. Five of the students participated via the NSF Research Experience for Undergraduates (NSF REU) program and three were supported by the NRAO Graduate Research Program (NRAO GRP). The Socorro summer students had a variety of activities to take part in, including the NRAO Interferometry Summer School held in Socorro. In addition to the scheduled events, there were weekly activities for the students, including "Wednesday Lunch" (free pizza for students!) with scientific talks and Tuesday Science Tea held in the 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 symbol to the right indicates students who 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.

Andrew Battisti, of SUNY at Stony Brook,
worked with Glen Langston on

The Structure and Motion of Chemistry in the Taurus Molecular Cloud

The summer student will produce images of the molecular emission in the region of the Taurus Molecular Cloud, the location of the largest molecules ever found in the interstellar medium. The student will address the question of how the peak of the Cyanopolyynes moves along the molecular ridge. The student will produce images of the distributions of molecules HC3N, HC5N, HC7N and HC9N.

Ashley Bemis, of University of Massachusetts, Amherst,
worked with Adam Leroy / Rachel Friesen on

Measuring the Impact of Environment on Star-Forming Clouds in a Nearby Galaxy

Ashley analyzed new interferometric (PdBI) observations of molecular clouds (stellar nurseries) in the nearby galaxy NGC 2403 and compared their properties to environment, especially proximity the local dust abundance and radiation field. She measured the properties (size, line width, luminosity, peak brightness) of ~20 molecular clouds in five fields and compared them to measurements from other galaxies then synthesized millimeter, radio, IR, and UV data to estimate conditions in each of 5 fields. Background: At a distance of only 3 Mpc (~10 million light years), NGC 2403 is one of the nearest star-forming galaxies outside our own Local Group. In size and evolutionary state it is in many ways a close analog to the nearby M33 ("the Triangulum galaxy"): a gas-rich, relatively small system that is forming stars quite vigorously given its size. In addition to its proximity, NGC 2403 is notable for containing ~5 giant associations of recently formed stars that are each comparable to the biggest such region in the whole Local Group of galaxies. The Plateau de Bure Interferometer --- currently the premier millimeter-wave telescope in the world and the immediate precursor to the Atacama Large Millimeter Array --- has imaged about 20 individual clouds in this galaxy. Thanks to extensive previous work there are also ultraviolet, infrared, optical, and radio data readily available. The cloud property measurements will take advantage of existing software that makes comparison to previous measurements easy. The multi-wavelength can be combined using simple models to estimate quantities like the radiation field illuminating the clouds and the local abundance of dust, both though to be important to the structure of star-forming clouds. Observations able to distinguish individual clouds in galaxies outside the Local Group are rare but will become much more common in the next few years, so this should be an interesting and fairly cutting-edge project.

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

Mining the GBT metadata archive: Statistics on radio frequency use, 2002-2010

The purpose of our project was to extract data from the Green Bank Telescope archives to create histograms of frequencies observed vs. time. To do this, we created programs that could retrieve the data out of the FITS storage files and into an Excel readable file. From here, we could export histograms of the usage. We were finding that 14.6% of all the observing occurs within a 1400-1427 MHz band due to HI searches. We also looked at how much observing occurred within astronomy-allocated bands (including footnote bands) such as the 1400-1427 MHz band, and found that 18.8% of the observing occurred entirely within an allocated band while 55.7% of observing occurred at least partially within an allocation. Although we did not account for all the data, we got a good idea of where observing takes place, and created a framework for extracting data for the future.

Rogerio Cardoso, of University of Wisconsin- Madison,
worked with Scott Ransom on

Searching for Pulsars in Large-Scale Pulsar Surveys

This summer an international group of researchers will be ramping up the processing of two large pulsar surveys: the Green Bank North Celestial Cap survey and the 2nd-generation P-ALFA survey using Arecibo. Each of these surveys is generating many hundreds of terabytes of data and requires a huge amount of computing to process the data. In this project, we will use the computer cluster at NRAO Charlottesville to process many beams from the surveys and help to characterize the radio frequency interference as well as the survey sensitivity (compared to our predictions). In the process, we hope to find many pulsars.

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

Characterization of the Accuracy and Stability of a High-Speed ADC for Radio Astronomy

The student will work on the characterization of high-speed (6 Giga-samples/second) samplers for astronomy. The work involves designing a test plan, constructing FPGA personalities to collect the required data, and analysis of the data collected to determine the stability and accuracy of the Analog-to-digital converters.

Thomas Connor, of Case Western Reserve University,
worked with Maurilio Pannella and Veronica Strazzullo on

The Host Galaxy Morphology of Faint Radio Sources: Quenched or Hidden Star Formation

Faint radio sources are thought to be powered by star formation or low luminosity AGN. In our recent work on the nature of the sub-mJy populations in the SWIRE VLA deep field, we have found a significant population of sources with intermediate colors (between blue star forming galaxies and red quiescent systems), whose powering source is still unclear. These might be highly extincted starbursts, or systems with the bulk of their star formation quenched, with

either an active low--power AGN or a central, very localized reddened starburst. Crucial insight on the nature of such sources may be provided by analysing their structural properties, both from a broader point of view (overall structure of the galaxy in terms of Hubble sequence morphology) and from more detailed features (e.g. presence of dust structures, unresolved central components). We will carry out such a study in the GOODS North field, where multiwavelength photometry and extensive spectroscopy is available, including (and most importantly) HST/ACS imaging in 4 optical passbands. These will allow us to probe structures, and high resolution color distribution, for a sample of faint radio sources in the GOODS-North VLA survey (rms$~4.3mu$Jy). The student will work with Maurilio Pannella, Veronica Strazzullo and Frazer Owen and will learn i) how to carry out parametric morphological analysis using widely used software (GIM2D, GALFIT), ii) how to properly measure multi-wavelength photometry to consistently sample the spectral energy distribution of a large galaxy sample, iii) how to model the spectral energy distributions to derive photometric redshifts and stellar population properties.

Abhirup Datta, of New Mexico Tech, Socorro, NM,
worked with Chris Carilli and Sanjay Bhatnagar on

Reionization Simulations and GMRT HI 21cm Absorption Search

1. Simulations of the effects of calibration errors on the detectability of the HI 21cm signal from reionization. 2. A search for the most distant HI 21cm signal through HI 21cm absorption observations of z = 5 radio loud quasars with the GMRT.

Corinne Fletcher, of University of Missouri,
worked with Violette Impellizzeri on

Exgalactic Methanol

The 6.7 GHz transition of methanol (CH3OH) is one of the most prominent galactic maser lines known. In our Galaxy, this line reaches extremely high flux densities, not quite as much as their brightest water counterpart but exceeding the flux density of any known OH maser. CH3OH emission at 6.7GHz is observed exclusively in star forming regions, sometimes coinciding with OH masers. Hundreds of galactic 6.7GHz methanol masers have been discovered in our Galaxy since the early 1990s. The 6.7GHz CH3OH line is also found to show absorption in certain regions; notably, deep absorption was found toward our galactic center region. Existing surveys for extragalactic methanol have surprisingly obtained no detections. The only three detections reported so far are from the Large Magellanic Cloud. Since no 6.7GHz CH3OH masers were found and since absorption is a plausible scenario, a search for methanol absorption has been conducted with the Effelsberg telescope. As a result to this survey, a galaxy tentatively showed emission. This tentative detection was followed up with the EVLA to a) confirm our detection and b) map where emission is originating from. It will be the aim of this summer project to analyze this EVLA dataset. This will require learning basic interferometric techniques and use of reduction packages such as AIPS or CASA to do the data reduction. After data reduction, we will go through an interpretation of the results, in the frame of the properties of this galaxy and whether the emission is associated with star formation in the galaxy or if it may be associated with an active galactic nucleus.

Anthony Ford, of University of Texas at Brownsville,
worked with Ron DuPlain on

Exploration and Visualization of Pulsar Survey Data

Have you met GBNCC? It is a 350-MHz Pulsar Survey of the Northern Celestial Cap using GUPPI, the latest pulsar instrument on the GBT. This project produces a visualization of GBNCC which provides an instant feel of GBNCC\'s pointings, coverage, progress, and cone search tools to explore further. This visualization is assuring GBNCC\'s quality while it\'s observed and coordinating collaborators across several institutions. Survey investigators can immediately see progress and dig into anomalies such as pointing errors, duplicate observations, missing observations, and gaps in coverage. Technical achievements in this project include indexing hundreds of terabytes of data, building a cone search web service ready for virtual observatories, and a high resolution interactive visualization of pointing data from a pulsar survey.

Nicole Free, of Ohio University,
worked with Jay Lockman on

HI Observations of the Area Around M33

The student would be working on observations and analysis of HI in the area of M31, M33 and the Wright Cloud. The Wright Cloud is a large high-velocity HI cloud that may be part of the Milky Way's high-velocity cloud population, may be part of the Magellanic Stream, or may be associated with M33. Recent GBT data suggest that a portion of the cloud may be interacting with M33 which would make it an unusual object, indeed. Furthermore, there is some evidence for an HI "bridge" between M31 and M33, probably the remnant of a past encounter. The emission is extremely weak and was detected with the Westerbork array in single-dish mode. It has not been confirmed on any other instrument. The student will analyze existing GBT 21cm spectra toward Wright's Cloud and the M31-M33 bridge, and take new spectra as well, to explore these issues.

Maithili Ghamande, of University of Akron,
worked with Sanjay Bhatnagar and Urvashi Rao on

Modeling the Antenna Primary Beams

The incoming radiation from the sky, when measured with dish antennas, is modulated by the precise shape of the antenna far field power pattern, also called the "antenna primary beam". This pattern is typically not constant across the visible sky and changes with time as the antennas track a target source in the sky to compensate for the earth rotation. This results in instrumental effects which change with time and direction in the sky and corrupt the observed data. For high precision imaging with radio telescopes, such primary beam (PB) effects need to be corrected as part of the imaging algorithms. Due to high sensitivity and wide band width of the EVLA, antenna primary beam effects will be the dominant instrumental effect requiring correcting for even moderate wide-field imaging with the EVLA. Furthermore, full polarization imaging with the EVLA, covering even a moderate part of the inner primary beam requires correction for the beam polarization effects. Correcting for such effects will require either measuring or modeling the effects of PB as a function of time, frequency and polarization. New algorithms developed for correcting for such effects require a model

or measured antenna primary beams. This project will involve (1) understanding the effects of the primary beams and the resulting limits on imaging dynamic range and (2) using the existing models and measured data do a simple assessment of a few ideas for PB corrections during imaging. This will require reading a few chapters from standard radio interferometry text books, attending the Synthesis Imaging workshop in Socorro, and moderate Python level programming for 2D function fitting using the CASA package and publicly available non-linear minimization tools in Python.

Megan Jones, of University of Wisconsin-Madison,
worked with Glen Langston on

Variation in the Physical Temperature of Molecules in the Taurus Molecular Cloud

Understanding the physical conditions of molecular clouds is critical for determining the chemical processes in these clouds. The Cyanopolyynes have very simple structures and are therefore very good diagnostics of the temperature in TMC. The student will gather, accurately calibrate and model the molecular line intensities, which will lead to separate determinations of the physical temperatures of each of the molecules HC3N, HC5N, HC7N and HC9N.

Kristen Koopman, of Sarah Lawrence College,
worked with Lorant Sjouwerman and Mark Claussen on

Near- and Mid-Infrared Color Schemes for Circumstellar Envelopes

We propose an REU project in which the student will investigate a universal translation between the near- and mid-infrared color schemes used in the different space missions (IRAS and AKARI, as well as MSX and perhaps Spitzer). The project will include the retrieval of the data from the individual web servers, apply computer programs to match data from the different missions to single sources, possibly fit infrared spectrum energy distributions and, as a final goal, predict from the colors of one space mission the colors in the other space missions (with their approximate errors). In first instance the scheme should be applied and working for evolved stars with circumstellar envelopes, after which it can be tuned to include, e.g., proto-planetary systems, planetary nebulae, or even high-z starburst galaxies.

Huilin Li, of University of Virginia,
worked with Anthony Kerr on

Waveguide Flange Development for Terahertz Instrumentation

Although it has become, by default, the standard for frequencies as high as 2200 GHz, the UG-387 waveguide flange is not well suited for use above ~110 GHz. In 2009, a new interface, the "ring-centered" flange was shown to have superior repeatability while still being compatible with the old standard [1]. In the course of this work it became clear that while the repeatability of a waveguide joint could be measured relatively easily, no satisfactory technique existed for measuring the small (complex) mismatch at a flange interface. Measurement accuracy is limited by lack of accurate standards for the precise calibration of vector network analyzers at submillimeter wavelengths. For the 2010 Graduate Research Assistantship, it is proposed to continue this work and to determine the absolute mismatch of two types of waveguide interface: a high-precision variant of the UG-387 flange, and the ring-centered flange. Improved methods of vector network analyzer calibration will be investigated, and equivalent circuit models will be derived for misaligned

waveguides with loss at the junction to aid in the interpretation of measured data. The tolerancing of the ring-centered flange will be investigated to determine the minimum practical clearance between the boss and the alignment ring in the presence of gold plating (required to passivate the flange surface). [1] H. Li, A. R. Kerr, J. L. Hesler, H. Xu, and R. M. Weikle, "A Ring-Centered Waveguide Flange for Millimeter- and Submillimeter-Wave Applications," to be presented at the 2010 IEEE MTT International Microwave Symposium, May 2010.

Jennifer Lyons, of Pacific University,
worked with Miriam Krauss and Michael Rupen on

Searching for polarized emission from the symbiotic nova V407 Cyg

The recent nova V407 Cyg has been monitored by the EVLA since ~ 2 weeks after the outburst discovery. In addition to thermal emission from the expanding remnant, the dense circumstellar environment of this symbiotic binary will likely result in shocked, non-thermal emission. To search for such signatures, the student will reduce the monitoring data to look for polarized emission.

Meredith MacGregor, of Harvard University,
worked with Jeff Mangum on

Measuring the Density and Temperature of 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.

Trisha Mizusawa, of Villanova University,
worked with Kartik Sheth on

Bar Properties and the Central Starburst/AGN in the Spitzer Survey of Stellar Structure in Galaxies

The Spitzer Survey of Stellar Structure in Galaxies (S^4G) is the ultimate survey of the distribution of stellar structure in the nearby universe using IRAC\'s 3.6 and 4.5 micron channels during the Spitzer Warm Mission. S^4G will survey the stellar mass distribution in 2,331 nearby (d<40Mpc) galaxies to create an unprecedented data set for studies of structure formation during galaxy evolution. These observations will provide answers to some of the most fundamental questions of our field: how are outer disks and halos formed? How do galaxy interactions affect the formation and evolution of galactic structures? Which structural parameters govern internal galaxy evolution? Although there are a multitude of projects that one can do with the S^4G data, the summer program will be focused on addressing how the structural properties of bars control the central star formation and/or AGN activity. It is known that bars drive gas to the centers of galaxies and that the central star formation activity is elevated in early Hubble type bars. It is not known what physical properties of bars control this phenomenon? The student will analyze the properties of bars in a sub-sample of the S^4G survey for which spectroscopic data for the nuclear activity are already available (e.g., Ho et al. 1997, ApJ 487, 579). The student will also compare the on-going activity with molecular gas and HI data from existing and new, on-going surveys with CARMA, Nobeyama and the VLA. The project is well-defined and it is expected that the results from this project should lead to a refereed publication before the end of the calendar year.

Benjamin Montet, of University of Illinois, Urbana-Champaign,
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 develop models of several HII regions and use recently reduced GBT carbon recombination line data along with Zeeman observations from the literature 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.

Claire Murray, of Carleton College,
worked with Lorant Sjouwerman on

Methanol Masers in Andromeda

I propose an REU project in which the student will investigate the occurrence of 6.7 GHz methanol masers in Andromeda. The project will entail the reduction and analysis of VLA data (already taken) with the main goal being to derive the prospects of EVLA A-array and/or VLBA follow-up observations. Furthermore, with this data the student will categorize and study of the star formation rate in M31 with respect to the Galaxy and other Local Group galaxies.

Bang Nhan, of University of California at Santa Barbara,
worked with Brian Mason on

A Search for Dark Matter Decay Products in Nearby Dwarf Spheroidal galaxies

Many standard theories of high energy particle physics predict dark matter particles which are unstable, and which would therefore have potentially detectable decay products. A search for these decay products in the radio continuum has been carried out with the GBT and the VLA with results forthcoming. Radio spectral line data have also been acquired which will allow us to study the neutral Hydrogen content of the dwarf galaxies which were the targets of our search. This will provide valuable information about the interstellar medium in these systems that is essential to understanding the context in which the dark matter decay products potentially exist. The goal of this summer project is to analyze the continuum & spectral line data and set limits upon, or characterize, the radio emission from and hydrogen content of these galaxies. It should result in a short paper or authorship on a paper in progress.

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

Characterization of the Accuracy and Stability of a High-Speed ADC for Radio Astronomy

The student will study the characterization of high-speed samplers. The work involves designing and constructing RF signal conditioning circuits, and working with another REU student to collect and analyze the required data using Field Programmable Gate Arrays to drive the hardware and collect the data on disk.

Matthew Rickert, of DePaul University,
worked with Emmanuel Momjian on

Mapping the Distribution of the Prebiotic Molecule Methanimine and HCN in the ULIRG Arp 220

EVLA spectral line observations have been carried out to image two, recently discovered, cm-wave molecular transitions in the prototype merger/megamaser galaxy Arp 220 at C-band. These two lines are of the pre-piotic molecule Methaninime (CH2NH) seen in emission at 5196 MHz, and the Hydrogen Cyanide (HCN) seen in absorption at 6612 MHz. The methanimine line is most likely originating from the blending of all six 1_10-1_11 transitions of the C-band multiplets, while the HCN line corresponds to the J=5 vibration level of the direct l-type transitions of its molecule. These two molecular species have been observed simultaneously in A-configuration. The student will reduce this data set to

image the spatial and velocity distribution of these two molecules in the two nuclei of Arp 220, analyze the results to derive their physical properties on sub-arcsecond scales, and compare them to other, and abundant, spectral line studies available on Arp 220.

Amy Robertson, of University of Arizona,
worked with Anthony Remijan on

Investigating the Formation Chemistry of Astronomical Molecules - a Multi-Faceted Approach

As the number of detections of large astronomical molecules continues to grow, it is quite obvious that observations are clearly outpacing the predictions of the chemical models. Also, most of the 155 interstellar molecules have been identified from their rotational emission spectra in hot core regions, where the gas and dust around a newly formed star have been heated sufficiently to release grain surface species and drive a complex network of grain surface and gas phase chemistry. Recent chemical modeling work has made it apparent that the physical parameters of a hot core will greatly influence the resultant chemical evolution but they have been severely lacking in their predictive power to ascertain what molecule should be present given the formation processed believed to form these species or what the overall morphology of the spatial distribution of the molecular emission will be. The student or students willing to work on this project will be able to work with team members of the Center for the Chemistry of the Universe (CCU) www.virginia.edu/ccu) and investigate archival GBT, VLA, BIMA and CARMA array data of astronomical environments to further investigate the physical and chemical properties of these very interesting regions. Furthermore, the student will have the opportunity to work with laboratory spectroscopists in the department of Chemistry, preparing experiments to search for new molecular species in archival datasets. Finally, the student will have access to experts in theoretical chemical modeling of astronomical environments that are used to try and explain the molecular inventory seen in astronomical environments. Overall, the project is aimed at extending the list of molecules and transitions for which we have observational constraints for both the physical environment and the complex chemistry, allowing us to investigate the correlations between the physical and chemical evolution of astronomical environments. This project is open to undergraduate students interested in astronomy, chemistry, physics, biology, mathematics, astrochemistry, astrobiology, star formation and the physics and chemistry of the ISM.

Nickolas Sneed, of Howard 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.

Justin Spilker, of Iowa State University,
worked with Mark Lacy on

Strategies for Emission Line Searches for High-z Galaxies with ALMA

ALMA will have the capability to find emission lines from galaxies well beyond the most distant spectroscopically-confirmed galaxies at z~7. A number of fine structure and molecular emission lines are available, but as yet no coherent plan has been defined for an optimal blind survey strategy. Such a strategy would involve determining areas in depths to survey in multiple ALMA bands, optimal ways of confirming a redshift if only one emission line is seen, and how best to use archival optical and infrared data to help define the survey regions. The student will undertake a thorough literature review to determine likely emission line fluxes from high redshift galaxies, and use the latest information on ALMA sensitivities to derive a survey plan that could find extremely distant galaxies.

Matthew Wahl, of SUNY at Stony Brook,
worked with Kartik Sheth on

An Unbiased Study of SMGs - Towards Transformational Science with ALMA

Submillimeter galaxies account for a majority of the cosmic infrared background and are pivotal in our understanding of galaxy evolution because the majority of stars formed in these systems. Although conventional wisdom states that these galaxies are progenitors to massive ellipticals and are primarily between $2 < z < 3$, clues are emerging from our on-going CARMA campaign that this paradigm will require modification. By observing SMGs with CARMA at the nearly the same wavelength as single dish surveys, we are finding SMGs at both very high ($z>4$) and very low ($z<1$) redshifts. We are conducting a systematic, flux-limited survey of SMGs in COSMOS to better understand the detailed nature of SMGs, their redshift distribution and relative contribution to the cosmic background. The study is a prelude to the statistically robust survey(s) that will be possible (even) with the Early Science capability of ALMA to pinpoint and decipher the nature of all SMGs in the COSMOS field. The student will learn to reduce millimeter interferometric data using MIRIAD and/or CASA with new and existing CARMA data for these SMGs. S/he will then determine the counterparts for the detected SMGs using the existing multi-wavelength COSMOS data focusing primarily on the VLA-COSMOS and HST- And Spitzer-COSMOS data. The project is well-defined and straightforward and it is expected that the results from the survey should lead to a refereed publication by the end of the year.

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

Numerical precision in Digital Signal Processing for Radio Astronomy Applications

Research the tradeoffs in designing Digital Signal Processors with custom floating point and fixed-point arithmetic. These formats are possible because the new Field Programmable Gate Array (FPGA) based systems allow a great deal of flexibility. Using simulation tools, quantify the results of changing the precision used to calculate the output of standard algorithms such as the FFT and Fast Convolution. Implement non-standard floating point formats in simulation and in FPGA test hardware to deal with any limitations of fixed-point numbers.

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

HI Observations of the GOALS LIRGs

Diana studied the HI properties of the GOALS sample of Luminous Infrared Galaxies (LIRGs). She undertook new GBT observations and data reduction and learn to deal with baseline issues and RFI. She measured the HI gas mass for about 160 LIRGs and studied the relationship of HI mass with IR luminosity and stellar mass. The highest luminosity objects show a decrease of HI mass and a slight increase of stellar mass, consistent with gas being converted into stars as the luminosity of the sample increases.

Sarah Wyss, of Ohio University,
worked with Juergen Ott on

The CO isotope ratio in the Large Magellanic Cloud

This project is to study the 13CO/12CO isotope ratio of molecular gas in the Large Magellanic Cloud. The data to be analyzed has been obtained in a large project (MAGMA) at the single dish ATNF Mopra telescope. All clouds are resolved and were mapped in on-the-fly mode. The CO isotopomere line ratio may depend on local or global parameters and the aims are to produce a total integrated line ratio spectrum across the LMC based on the observations of the individual molecular complexes. Further goals are to determine if the isotope ratio depends on factors such as galactocentric radius, cloud sizes, and evolutionary status of the molecular clouds as they proceed to form stars. In addition to the analysis of the already reduced maps, the project starts by understanding and reducing single dish on the fly maps.

6. Participation in the AAS 217th Meeting January 9-13, 2011

Nineteen of the NRAO summer students will travel to Seattle, WA, to attend the 217th meeting of the American Astronomical Society in January 2011.