National Radio Astronomy Observatory
REU/RET Program Report: 2005

Overview

Summer Student Program

Twenty-eight students participated in NRAO's 2005 Summer Student program, including 18 undergraduate students supported by the National Science Foundation (NSF) 's Research Experiences for Undergraduates (REU) program, one graduating senior supported by the NRAO Undergraduate Summer Student program , and nine graduate students supported by the NRAO Graduate Summer Student program . This was the forty-sixth year of the NRAO Summer Research Program , which has graduated over 975 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 124 applicants to the 2005 NRAO summer student program, of whom 47 (38%) were women and 10 (8%) were under-represented minorities. The 18 REU positions were filled by 9 women (50%) and 9 men (50%). One of the REU positions was filled by an under-represented minority (6%). In all, 28 summer students were hired, 12 women (43%) and 16 men (57%), and two under-represented minorities (7%). Ten students were assigned to Socorro (7 REU), nine to Charlottesville (5 REU), and nine to Green Bank (6 REU). Twelve of the student participants, including 10 of the REU students, presented posters on their research projects at the winter meeting of the American Astronomical Society in January, 2006.

Summer Teacher Program

The NRAO's RET program offers teachers both a research experience and, with its emphasis on carryover to the classroom, encourages and supports the concept of inquiry (i.e. research) based instruction. Three teachers participated in NRAO research programs during the summer of 2005, supported by the National Science Foundation (NSF)'s Research Experiences for Teachers (RET) program.

This was the sixth year of the RET program at the NRAO, although the NRAO has offered a variety of teacher workshops for eighteen years. There were 23 applicants to the NRAO RET program from 14 states, of whom 7 (30%) were women. Three RET appointments were made, two in Green Bank and one in Socorro. In future years, appointments are anticipated in Charlottesville as well. Similar to the REU students, a brief description of the teachers' projects are included later in this report. Two RETs

presented posters on their research projects at the January 8-12, 2006 AAS Meeting, and one RET at the June 4-8, 2006 AAS Meeting in Calgary, Canada.

Organization of Report

This report is organized as follows. In Section 1 we list *all* Summer 2005 program participants. We then separately describe the different activities students and teachers participated in at one of the three main NRAO sites: Charlottesville (Section 2), Green Bank (Section 3), and Socorro (Section 4). In the following two sections we present brief descriptions of the research projects completed by each REU student (Section 5) or RET teacher (Section 6). These descriptions are available on-line at http://www.nrao.edu/students/archive/projects.php, which includes links to the final written reports. Finally, in Section 7 we list all of the REU and RET summer projects which were presented at the 207th and 208th meetings of the American Astronomical Society in Washington, D.C. (January 2006) and Calgary, Canada (June 2006) consecutively. Many of these presentations are expected to be published in astronomical journals in 2006-7.

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1. Table of 2005 NRAO Summer Program Participants

This table 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 31 summer student participants (18 REU, 1 uGRP, 9 GRP), and 3 summer teachers participants (RET).

2005 NRAO Summer Program Participants (N=28)					
Student	**School**	**Project**	**Mentors**	**Site**	**Program**
Wendy Bennett	Drake University	Fine Scale Structure in the Interstellar Medium	J-P. Marcquart	Soc	NSF REU
Kyle Borg	Austin College	CCS Emission from Infrared Dark Clouds	Claire Chandler	Soc	NSF REU
John Brewer	West Virginia University	GBT 68-92 GHz Receiver Development	Michael Stennes	GB	NSF REU
Valeria Buenrostro-Leiter	Instituto de Astrofísica de Canarias (IAC)	GBT HI Observations of High Velocity Clouds	Jay Lockman	GB	**NRAO GRP**
Jason Curtis	UC Berkeley	GBT Observations of Ammonia (NH3) Towards The Galactic Center	Glen Langston	GB	NSF REU
James Durand	NMSU	A Supervisory Control and Data Acquisition (SCADA) system for the 140ft telescope.	John Ford	GB	NSF REU
Kelly Freed	Metropolitan State College of Denver	The Star Formation Environment of the IRAM04191 Protostar	Jeff Mangum	CV	NSF REU
Soumya Ghosh	University of Houston	Frequency of Execution Metrics for the GBT	Nicole Radziwill	GB	**NRAO GRP**
Catherine Grier	University of Illinois	Statistical Study of H2O Megamaser Systems	Jim Braatz	CV	NSF REU
Nicole Gugliucci	Lycoming College	Exotic AGN from VLBI Surveys	Greg Taylor	Soc	**NRAO GRP**
Amanda Heiderman	University of California, Berkeley	A VLA HI and Spitzer mid-IR Study of Hickson Compact Group 7	John Hibbard (NRAO) & Kelsey Johnson (UVa)	CV	**NRAO GRP**
JoAnna Johnston	New Mexico Tech	Mapping Water Vapor in the Atmosphere of Mars with the VLA	Bryan Butler	Soc	NSF REU
Kasandra Jorgensen	Lewis & Clark College	The Physical Structure of the Incipient Stages of Low-mass Star Formation	Yancy Shirley	Soc	NSF REU
Eric Kearsley	High Point High School, Beltsville, MD	Measuring the Dust in Low Surface Brightness Galaxies	Karen O'Neil	GB	NSF RET

Student	School	Project	Mentors	Site	Program
John Kelly	University of Virginia	Radio Observations of the Chandra Deep Field South	Ken Kellermann	CV	**NRAO GRP**
Emily Levesque	Massachusetts Institute of Technology	Search for Interstellar OD	Vincent Fish	Soc	NSF REU
Conor Mancone	University of Florida	200-240 GHz Spectral Line Survey of IRC+10216	Phil Jewell	GB	NSF REU
Tyson Mao	California Institute of Technology	Radar mapping of Mars at Opposition	Bryan Butler	Soc	NSF REU
Michael McCarty	Morehead State University	GBT Pulsar Observations	Scott Ransom	CV	NSF REU
Vinayak Nagpal	Chalmers University of Technology	Development of an Adaptive RFI Mitigation System for the GBT	Rich Bradley	CV	**NRAO GRP**
Oluleye Olorode	Benedict College	Development and Evaluation of a 1.5-THz Heterodyne Test Receiver	Eric Bryerton	CV	**NRAO uGRP**
Vincent Pereira	Clarkstown North High School, New City, NY	Calibrating Array Detectors for the Penn Array	Brian Mason	GB	NSF RET
Robin Pulliam	Radford University	The Filling Factor of Electrons in the Warm Ionized Medium	Anthony Minter	GB	NSF REU
Ricardo Sanchez	Rutgers The State University of NJ	Gas Flows in the Barred Galaxy NGC 1365	Gustaaf van Moorsel	Soc	**NRAO GRP**
Julia Sandell	Barnard College/Columbia University	HI and GALEX Observations of Interacting Galaxies	John Hibbard	CV	NSF REU
David Sevilla	The University of Texas at El Paso	A Test Spectrometer for the Green Bank Electronics Division	Rich Lacasse and John Ford	GB	**NRAO GRP**
Benjamin Sulman	Oberlin College	GBT Pulsar Observations	Scott Ransom	CV	NSF REU
Kurt Voss	Zuni High School, Zuni, New Mexico	Green Bank Telescope Monitoring of Water Masers in Young Stellar Objects	Mark Claussen, Al Wootten	Soc	NSF RET

Student	School	Project	Mentors	Site	Program
Lawrence Weintraub	California Institute of Technology	Multi-Epoch VLBA Polarimetry of the Gamma-Ray Blazar 2255-282	Greg Taylor	Soc	**NRAO GRP**
Kassandra Wells	Carleton College	Observations of the Sunyaev-Zeldovich Effect with the CBI	Steve Myers	Soc	NSF REU
Peter Williams	Harvard College	New Generation Phase Calibrator	Steven White	GB	NSF REU

2. Site Specific Activities: Charlottesville VA

The 2005 Summer Student program at NRAO/Charlottesville was under the direction of Jeff Mangum. There were nine students in the 2005 Summer Student Research Program at NRAO-Charlottesville, five of them under the NSF Research Experience for Undergraduates (REU) program, three under the NRAO Graduate Summer Student Program (NRAO GRP), and one under the NRAO Undergraduate Summer Student Program (NRAO uGRP). The above picture shows some of the Charlottesville summer students. The students from left to right are: Amanda Heiderman (NRAO GRP), Julia Sandell (NSF REU), Ben Sulman (NSF REU), Kelly Freed (NSF REU), Oluleye Olorode (NRAO uGRP), Catherine Grier (NSF REU), Mike McCarty (NSF REU).

The summer program included a series of introductory level lectures on aspects of astronomy, particularly radio astronomy and radio instrumentation. The lectures are listed in the CV Summer Student Schedule below. The highlight of the summer was a student observing project using the Green Bank telescope (GBT), the world's largest steerable telescope.

The students did several projects on the GBT. They observed a protostellar core in the 2cm line of H2CO (formaldehyde) to search for evidence of a disk around the star, and to see how the H2CO region relates to other structures in the dark cloud. They also observed a few nearby galaxies in the 21cm line of HI to measure the redshift and rotational speed of the galaxies and search for asymmetries in their HI distribution. As a third project, they observed Galactic HI in absorption against a bright pulsar to determine the kinematic distance to the pulsar.

The students traveled to Green Bank, West Virginia, to participate in the GBT observations on June 26 & 27. The students arrived a day and a half early in order to meet members of the Green Bank staff, meet their student counterparts in Green Bank, and tour the NRAO facilities and telescopes, including the Green Bank telescope and the GBT visitors' center . In early July the Charlottesville students returned the favor and hosted a visit from the Green Bank summer participants (July 7-8). During this visit the students gave short presentations on their research topics to each other, took a tour of the NRAO Charlottesville facilities, including the NRAO Technology Center and the future site of the North American ALMA Science Center, and were entertained by the UVa astronomy faculty and graduate students.

At the end of the summer, the students gave a series of 15 minute talks on their projects during a lunch symposium in Charlottesville, and produced a short report describing their summer research. Five REU students and one GRP student attended the AAS meeting in Washington, D.C. in January 2006 to present posters on their summer projects.

Charlottesville Summer 2005 Schedule

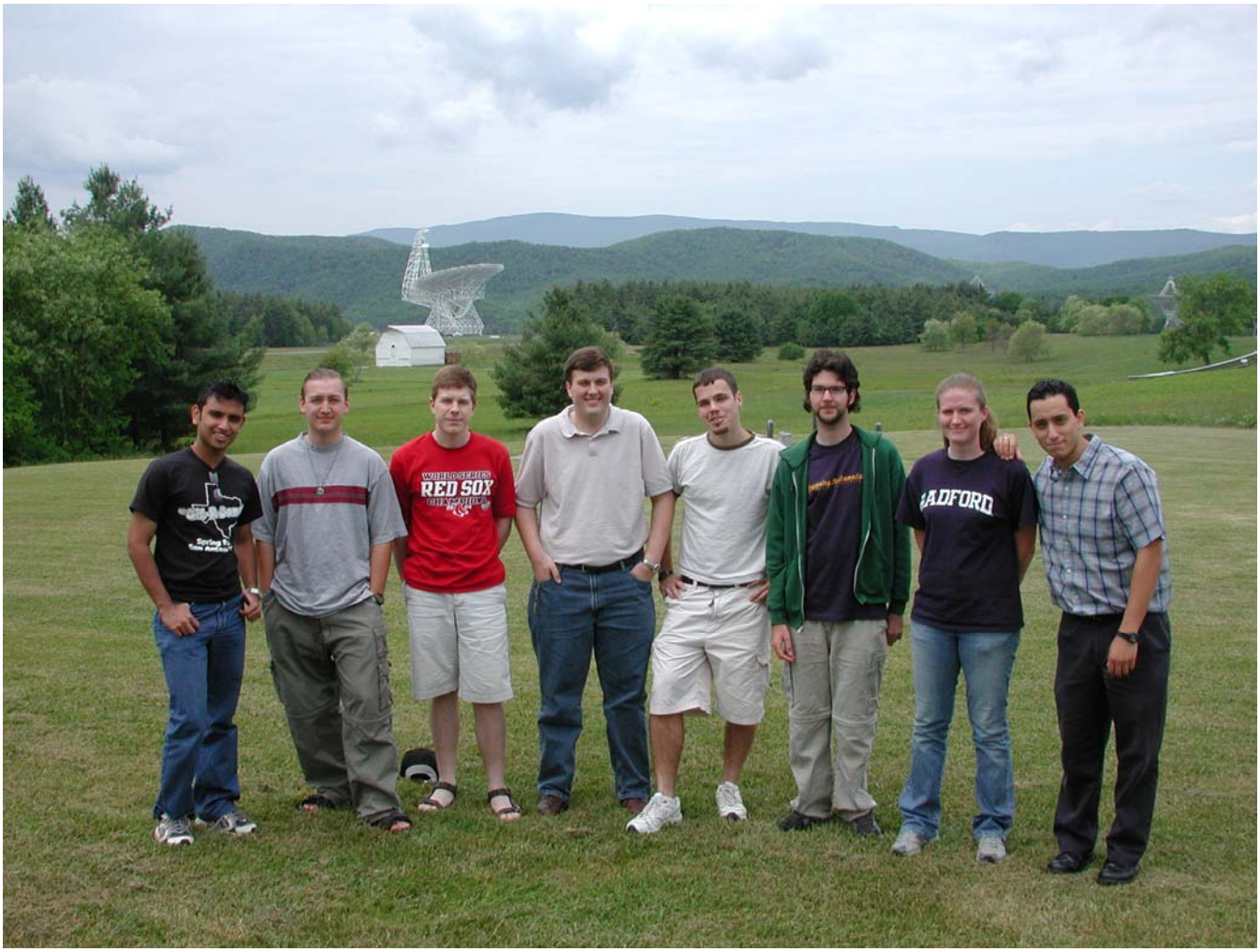
Day	Date	Time	Item	Location
Tues	May 31	10:00am	Start Date: Kelly Freed, Kate Grier, Michael McCarty, Oluleye Olorode, Julia Sandell, Benjamin Sulman	OIC
Mon	June 6	10:00am	Start Date: Amanda Heiderman, John Kelly	OIC
"	"	3:00-5:00 pm	Informal SS Lecture: Juan Uson, ***Interferometry***	CV230
Tues	June 7	3:00-5:00 pm	Informal SS Lecture: John Hibbard, ***Spectral Line Interferometry***	CV230
Wed	June 8	1:00-2:30 pm	SS Lecture : R. Norville & J. Mangum, *Orientation*	CV230

Day	Date	Time	Item	Location
“	“	2:30-3:30 pm	Orientation Reception: Students and Staff	ER Foyer
Fri	June 10	10:00-11:00 am	SS Lecture : Mentors, ***GBT Observing Projects Introduction***	CV230
Sat	June 11	12:00-4:00 pm	Charlottesville Summer Picnic	
Tues	June 14	10:00-10:30 am	Employee Picture Board Photo Session	ER Second Floor Corridor
Wed	June 15	10:00 am	Start Date: Vinayak Nagpal	OIC
Thur	June 16	1:00-2:00 pm	SS Lecture : Ken Kellermann, ***The History and Development of Radio Astronomy***	CV230
“	“	2:00-3:00 pm	SS Lecture: Ellen Bouton, ***The NRAO Historical Radio Astronomy Archive***	CV230
Fri	June 17	1:30-2:30 pm	SS Lecture: Mentors, *GBT Observing Projects Discussion*	CV230
Mon	June 20	10:30 am-12:00 noon	SS Lecture: Juan Uson, **Cosmology**	CV230
“	“	“	Student/Speaker Pizza Lunch	ER
Wed	June 22	1:30-2:30 pm	SS Lecture: Mentors, *Overview of Student Projects*	CV230
Fri	June 24	10:30 am-12:00 noon	SS Lecture: Jim Condon, *Physics of Radio Sources*	CV230
"	"	12:00 noon	Depart CV for GB	

Day	Date	Time	Item	Location
Sat	June 25	All Day	CV Summer Student Trip to GB	
"	"	Evening	**Science Ethics Discussion**	GB Lounge
Sun	June 26	9:00 pm-12:00 am	GBT Observing	GB
Mon	June 27	12:00 am-7:00 am	GBT Observing	GB
Wed	June 29	1:30-2:30pm	SS Lecture: Mentors, ***GBT Observing Projects Reduction Discussion***	CV230
Wed	July 6	1:30-3:00 pm	SS Lecture: Alwyn Wootten, ***Radio Astronomy Jargon***	CV230
Thurs	July 7	All Day	GB Students Visit to CV	CV
Fri	July 8	All Day	GB Students Visit to CV	CV
Wed	July 13	1:30-3:00 pm	SS Lecture: Jeff Mangum, ***Radioastronomical Investigations of Star Formation***	CV331
Fri	July 15	1:30-3:00 pm	SS Lecture: Alwyn Wootten, ***Molecular Spectroscopy***	CV Auditorium
Mon	July 18	1:30-2:30 pm	SS Lecture: Mentors, ***GBT Observing Projects Reduction Discussion***	CV230
"	"		Student/Speaker Pizza Lunch	ER
Fri	July 22	1:30-2:30 pm	SS Lecture: Scott Ransom, ***Pulsars***	CV230
Wed	Aug 3	1:30-3:00 pm	SS Lecture: Rich Bradley, ***Solar Radio Burst Spectrometer***	CV230
Sat	Aug 6	All Day	Green Bank Summer Picnic	

Day	Date	Time	Item	Location
Mon	Aug 8		Student/Speaker Pizza Lunch	NTC
Tues	Aug 9	12:15-1:15 pm	Lunch Talk (REU Presentations): **Grier, Freed, Olorode**	CV311
Wed	Aug 10	12:00-1:00 pm	Movie: Grote Reber:Wildcat Astronomer	CV Auditorium
Fri	Aug 12		Last Day: Catherine Grier	
Mon	Aug 15		Last Day: Kelly Freed	
Tues	Aug 16	12:15-1:15 pm	Lunch Talk (REU Presentations): **Sulman, McCarty, Sandell**	CV230
Thurs	Aug 18		Last Day: Michael McCarty	
Fri	Aug 19		Last Day: Oluleye Olorode	
Tues	Aug 23	12:15-1:15 pm	Lunch Talk (REU Presentations): **Heiderman, Nagpal**	CV230
“	“		Last Day: Julia Sandell	
Fri	Aug 26		Last Day: Benjamin Sulman, Amanda Heiderman	
Mon	Aug 29		Last Day: John Kelly	

3. Site Specific Activities: Green Bank, WV



The 2005 REU/RET program at NRAO Green Bank was under the direction of Toney Minter and Sue Anne Heatherly. There were nine students and three teachers in the 2005 Summer Research Program at NRAO-GB. Six students were supported by the NSF Research Experience for Undergraduates (REU), and three of the students were supported by the NRAO Graduate Summer Student Program (GRP). The three teachers were supported by the Research Experience for Teachers Program (RET). The above picture shows several of the summer students standing with the Green Bank Telescope in the background. From left to right are: Soumya Ghosh (NRAO GRP), James Durand (NSF REU), Peter Williams (NSF REU), John Brewer (NSF REU), Conor Mancone (NSF REU), Jason Curtis (NSF REU), Robin Pulliam (NSF REU), and David Sevilla (NRAO GRP).

The Green Bank summer student/teacher calendar is given below. 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 NASA Goddard/NRAO teacher workshop, the RARECATS teacher workshop, a Chautauqua Short Course on Astronomy, the Society of Amateur Radio Astronomers (SARA) meeting and the Mid Atlantic Astronomical Society Star Party. There was also a weekly Science Lunch with the students every Thursday and regular volleyball and soccer games. In early July the Green Bank summer participants traveled to Charlottesville to meet their counterparts. During this visit the students gave short presentations on their research topics to each other and took a tour of the NRAO Charlottesville facilities, including the NRAO Technology Center and the future site of the North American ALMA Science Center, and were entertained by the UVa astronomy faculty and graduate students.

During the summer, the Green Bank students conducted their own observational project on the GBT: a search for CII regions around B stars. A CII region can occur when a dense cloud lies near a B star. The radiation from the star ionizes the carbon but B stars do not emit enough UV to ionize much hydrogen. The resulting cool ionized carbon is detectable in recombination lines. At the end of the summer, the students gave the staff a one day seminar where they presented the results of their summer research projects. They also produced a short report describing this work. Three of the students (REU), and both RET participants attended the AAS meeting in Washington, D.C. in January 2006 to present posters on their summer research projects.

Green Bank Summer 2005 Schedule

Day	Date	Time	Item	Location
Every Thursday	all summer	12:00-1:00pm	Science Lunch	Lounge
Mon	May 16	9:00 am	Start Date: John Brewer	
Tues	May 17	3:30 pm	Colloquium: Tom Statler	Jansky Auditorium
Fri	May 20	3:30 pm	Colloquium: Ben Zuckerman	Jansky Auditorium
Mon	May 23	9:00 am	Start Date: Robin Pulliam	
Mon-Wed	May 23-25	8:00 am-6:00 pm	NRAO's Chautauqua Course	Science Center
Thur-Sat	May 26-28	8:00 am-6:00 pm	Gareth's Chautauqua Course	Science Center
Tues	May 31	9:00 am	Start Date: Conor Mancone, James Durand, David Sevilla	
Thurs	June 2	4:00 pm	Colloquium: Marijke Haverkorn, Jansky Fellow	GB 137

Day	Date	Time	Item	Location
Fri	June 3	7:00 pm	Film	Science Center
Mon	June 6	9:00 am	Start Date: Peter Williams, Souyma Ghosh, Jason Curtis	
Mon	June 6	2:00 pm	Summer Student GBT Project Discussion	Basement
Tues	June 7	1:30 pm	Summer Student Orientation (Mandatory)	Jansky Auditorium
Wed	June 8	9:00 am	New Employee Safety Meeting (Mandatory)	GB 137
Wed	June 8	2:00 pm	Summer Student GBT Project Discussion	Basement
Wed	June 8		Pool Opens	
Thurs	June 9	1:30 pm	Lecture: Gary Anderson, ***The History of Radio***	Jansky Auditorium
Fri	June 10	7:00 pm	Film	Science Center
Sat	June 11	30 Minutes Before Dusk	Star Party	Science Center
Mon	June 13	9:00 am	Start Date: Valeria Beunrostro-Leiter	
Tues	June 14	10:00 am	GBT Tour	Meet in Basement
Tues	June 14	1:30 pm	Lecture: Sue Ann Heatherly, ***How to Use the 40 Foot Telescope***	Jansky Auditorium
Wed	June 15	10:00 am	Summer Student GBT Project Discussion	Basement
Thurs	June 16	3:00 pm	Lecture: Jay Lockman, ***Introduction to Radio Astronomy***	GB 137
Fri	June 17	7:00 pm	Film	Science Center

Day	Date	Time	Item	Location
Sun-Tues	June 19-21	8:00 am-6:00 pm	Society of Amateur Radio Astronomers	Science Center
Tues	June 21	1:30 pm	Lecture: Dana Balser, ***Radiative Processes***	Jansky Auditorium
Thurs	June 23	1:30 pm	Lecture: Roger Norad, ***Receivers***	Jansky Auditorium
Thurs	June 23	5:00 pm	Colloquium: John Bally	GB 137 via video
Sat-Mon	June 25-27	All Day	CV Summer Students Visiting GB	
Sat	June 25	1:30 pm	Movie and Discussion: ***Ethics in Science***	Residence Hall Lounge
Tues-Thurs	June 28-30	8:00 am-6:00 pm	Quiet Skies Detector Teacher Workshop	Science Center
Wed	June 29	10:00 am	Summer Student GBT Project Discussion	Basement
Wed	June 29	3:00 pm	Colloquium: Rikkard Olssen	Science Center Room 127
Thurs	June 30	1:15 pm	Summer Student Meeting (Mandatory)	Jansky Auditorium
Thurs	June 30	1:30 pm	Lecture: Wes Sizemore, ***RFI***	Jansky Auditorium
Fri	July 1	7:00 pm	Film: Race to Space	Science Center
Sat	July 2	5:00 pm	Colloquium: Nissim Kanekar	GB 137 via video
Sun	July 3	12:30-5:00 pm	GBT Observations	GBT Control Room
Mon	July 4	5:00 pm	4th of July Picnic	Rabbit Patch
Tues	July 5	1:30 pm	Lecture: Toney Minter, ***Pulsars***	Jansky Auditorium

Day	Date	Time	Item	Location
Wed-Sat	July 6-9	8:00 am-6:00 pm	StarQuest II	Science Center
Thurs-Fri	July 7-8	All Day	Trip to Charlottesville	
Sun-Sun	July 9-17, 2006		Single Dish Summer School at Arecibo Observatory (Curtis, Mancone, Pulliam)	
Wed	July 13	3:30 pm	Seminar: Doug Hayman	Jansky Auditorium
Sun-Sat	July 17-23	8:00 am-6:00 pm	NASA Goddard/NRAO Workshop	Science Center
Mon	July 18	4:00 pm	Colloquium: Yashwant Gupta	GB 173 via video
Tues	July 19	1:30 pm	Lecture: Frank Ghigo, ***VLBI***	Jansky Auditorium
Thurs	July 21	1:30 pm	Lecture: Brian Mason, ***Cosmology***	Jansky Auditorium
Sun-Sat	July 24-30	8:00 am-6:00 pm	Hands On Universe	Science Center
Mon	July 25	3:30 pm	Colloquium: Leonid Petrov	Jansky Auditorium
Tues	July 26	3:30 pm	Lecture: Ron Maddalena, ***Holography***	Jansky Auditorium
Tues	July 26	2:00 pm	Lecture: Larry Morgan, ***The Interstellar Medium and Star Formation***	Jansky Auditorium
Thurs	July 28	3:30 pm	Colloquium: Peter Dewdney	Jansky Auditorium
Tues	Aug 2	1:30 pm	Lecture: Karen O'Neil, ***HI in Galaxies***	Jansky Auditorium
Fri	Aug 5	1:30 pm	Summer Student Presentations: Mancone and Brewer	Jansky Auditorium
Fri	Aug 5	5:00 pm	Last Day: John Brewer	
Fri	Aug 5	7:00 pm	Film: Galileo's Battle for the Heavens	Science Center
Sat	Aug 6	12:00 noon-10:00 pm	NRAO Picnic	Recreation Area

Day	Date	Time	Item	Location
Tues	Aug 9	1:30 pm	Summer Student Presentations: Pulliam, Williams, Sevilla	Jansky Auditorium
Tues	Aug 9	5:00 pm	Last Day: Conor, Mancone	
Thurs	Aug 11	3:30 pm	Summer Student Presentations: Ghosh, Durand, Curtis	Jansky Auditorium
Fri	Aug 12	5:00 pm	Last Day: John Brewer, David Sevilla	
Mon	Aug 15	5:00 pm	Last Day: James Durand	
Fri	Aug 19	5:00 pm	Last Day: Robin Pulliam, Souyma Ghosh, Jason Curtis	
Sat	Aug 27	Dusk	Star Party with Star Quest	Science Center
Tues	Sept 13	5:00 pm	Last Day: Valeria Buenrostro-Leiter	

4. Site Specific Activities: Socorro, NM

The 2005 REU program at NRAO/Socorro was under the direction of Amy Mioduszewski and Mark Claussen. There were 11 students in the 2005 Summer Student Research Program at NRAO-Socorro. Seven 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 NSF Research Experience for Teachers (NSF RET). The above photograph shows several students seated in the Array Operations Center lobby area. From left to right: (back row) JoAnna Johnston, Wendy Bennett, Kassandra Wells, Kasandra Jorgensen, Emily Levesque, Kyle Borg, and Ricardo Sanchez, (front row) Nicole Gugliucci and Tyson Mao.

The Socorro summer students had a variety of activities to take part in, as listed in the calendar below. In addition to the scheduled events, there were weekly activities for the students, including a "Wednesday Lunch" (free pizza for students!), a Tuesday Science Tea held in the upstairs lounge, weekly scientific colloquia, and ultimate frisbee on Tuesday and Thursday evenings. The group toured

five observatories: the VLA, VLBA Pie Town station, Apache Point (Sloan Digital Sky Survey), Lowell, and McDonald. During weekend trips, the group also visited a few of New Mexico's, West Texas', and Arizona's most scenic locations: The Guadalupe Mountains, Carlsbad Caverns, North Baldy, The Grand Canyon, and White Sands.

The scientific highlight of the summer was the four student-led observational projects, three using the VLA and one using the VLBA. One group used the VLA to search for water masers toward dense molecular cloud cores which are being observed with the Spitzer Space Telescope and may harbor nascent or very low-mass protostars. A second group looked for a bridge of HI gas between two neighboring members of the M81 galaxy group. The third VLA project used the VLA in a non-standard mode to search for emission, both pulsed and unpulsed, from an Anomalous X-ray pulsar. The fourth group used the VLBA to attempt to resolve the morphological classification of the core-jet source J2022+6133.

At the end of the summer, the students gave a series of 15 minute talks on their projects during a lunch symposium, and produced a short report describing their summer research (sent under separate cover). At least one (Nicole Gugliucci) has a draft of a paper ready to submit to the astronomical journals. Two REU students and one NRAO GRP student attended the AAS Meeting in Washington, D.C. in January of 2006, and the 2005 RET participant attended the AAS Meeting in Calgary, Canada to present the results of their summer research.

Socorro Summer 2005 Schedule

Day	Date	Time	Item	Location
Tue	May 31	All Day	1st DAY OF ARRIVAL	AOC
Wed	June 1		Earliest Check-In Date at Tech Apartments	
Fri	June 3	4:00 pm Onward	Student Reception and Dinner	Auditorium
Sat	June 4	Leave at 8:00 a.m.	North Baldy Hike	Tech Apts S Parking
Mon	June 6	1:30-4:00 pm	**Safety Meeting**	Auditorium

Day	Date	Time	Item	Location
Tues	June 7	11:00 am-12:00 noon	SS Lecture: ***Antennas & Receivers,*** Peter Napier	Auditorium
Wed	June 8	11:00 am-12:00 noon	SS Lecture: ***Introduction to Interferometry 1,*** Rick Perley	Auditorium
Thu	June 9	Leave at 9:00 am	**VLA Site Tour**	Meet at NRAO
Fri	June 10	11:00 am-12:00 noon	SS Lecture: ***Introduction to Interferometry 2,*** Rick Perley	Auditorium
Sat	June 11	Leave at 8:00 am	Apache Point Tour/White Sands Field Trip	Meet at NRAO
Mon	June 13	11:00 am-12:00 noon	SS Lecture: ***Correlators,*** Walter Brisken	Auditorium
Tue	June 14	11:00 am-12:00 noon	SS Lecture: ***VLBI,*** Craig Walker	Auditorium
Wed	June 15	11:00 am-12:00 noon	SS Lecture: ***Imaging,*** Sanjay Bhatnagar	Auditorium
Thu	June 16	2:00 pm	**Tour of Engineering Labs**	AOC First Floor
Tue	June 21	11:00 am-12:00 noon	SS Lecture: ***Masers,*** Mark Claussen	Auditorium

Day	Date	Time	Item	Location
Thu	June 23	1:00-2:00 pm	**VLA/VLBA Observing Project Meeting**	Upper Conf. 317
Tue	June 28	11:00 am-12:00 noon	SS Lecture: ***Pulsars,*** Shami Chatterjee	Auditorium
Wed	June 29	1:00-4:00 pm	**VLA/VLBA Observing Project TAC**	Upper Conf. 317
Sat-Mon	July 2-4	Leave at 7:00 am	Guadalupe Mountains/Carlsbad Caverns/McDonald Observatory Excursion and Observing Trip	Meet at NRAO
Mon	July 4	Evening	4th of July BBQ	Lorant/Tech Campus
Tue	July 5	11:00 am-12:00 noon	SS Lecture: ***Star Formation,*** Yancy Shirley	Auditorium
Sat	July 9	Leave at 9:00 am	Gila Cliff Dwellings	Tech Apts. S Parking
Mon	July 11	11:00 am-12:00 noon	SS Lecture: ***Ruby Payne-Scott: The First Woman Radio Astronomer,*** Miller Goss	Auditorium

Day	Date	Time	Item	Location
Tue	July 12	11:00 am-12:00 noon	SS Lecture: ***Solar System,*** Bryan Butler	Auditorium
Fri-Sun	July 15-17	Leave at 8:00 am	Lowell Observatory/Grand Canyon Field Trip	Meet at NRAO
Sat	July 16	8:00 am-2:00 pm	Trinity Site Open	Trinity Site
"	"	11:00 am-4:00 pm	**Special VLA Tour**	VLA Site
Tue	July 19	11:00 am-12:00 noon	SS Lecture: ***Active Galactic Nuclei,*** Greg Taylor	Auditorium
Tue	July 26	11:00 am-12:00 noon	SS Lecture: ***Gamma Ray Bursts,*** Dale Frail	Auditorium
Tue	Aug 2	11:00 am-12:00 noon	SS Lecture: ***Cosmic Microwave Background,*** Steve Myers	Auditorium
Fri	Aug 5	11:30 am-1:00 pm	End of Summer Lunch	Socorro Springs
"	"	1:00 pm Onward	**Careers in Astronomy Discussion Panel**	Auditorium
Mon	Aug 8		Latest Check-Out Date at Tech Apartments	
"	"	12:00 noon-1:00 pm	Summer Student Presentations: **Emily, Ricardo, Kyle**	Auditorium

Day	Date	Time	Item	Location
Tue	Aug 9	12:00 noon-1:00 pm	Summer Student Presentations: **Nicole, Kasandra**	Auditorium
Wed	Aug 10	12 noon-1:00 pm	Summer Student Presentations: **JoAnna**	Auditorium
Thu	Aug 11	12 noon-1:00 pm	Summer Student Presentations: **Kurt, Wendy, Kassandra**	Auditorium
“	“	10:00 pm Onward	Perseids Star Party	Box Canyon
Tue	Aug 23	12:00 noon-12:20 pm	Summer Student Presentations: **Tyson**	Auditorium

5. REU Project Summaries

This section lists short summaries of the projects for REU participants in the NRAO Summer Student program. The symbol to the right indicates students who were supported under the National Science Foundation (NSF)'s Research Experiences for Undergraduates (REU) program. All other students were supported under the NRAO Summer Student Research Assistant Program.

Wendy Bennett, of Drake University, worked with J-P. Macquart on

Fine Scale Structure in the Interstellar Medium

The Intra-Day variable quasar J1819+3845 undergoes variations on a time scale of 20 mins in total intensity, linear polarization and circular polarization. The variations are caused by the focusing and defocusing of the radiation as the nearby (20pc distant) interstellar medium of our Galaxy wafts past the line of sight. W. Bennett quantified the variability in this source, thus using the interstellar medium as a telescope to chart the source's microarcsecond evolution over the course of several years. Results are presented in AAS Abstract 127.02 in Section 7.

Kyle Borg, of Austin College, worked with Claire Chandler on

CCS Emission from Infrared Dark Clouds

The association of CCS emission with dense cores in molecular clouds is thought to be an indicator of extreme youth. Surveys of starless cores and young protostars show that CCS seems to be destroyed once a protostar has formed, although there are one or two of the youngest, Class 0, protostars that do exhibit CCS emission. Chemical models are consistent with the interpretation of CCS as an early-time tracer of dense gas. The MSX 8 micron Galactic plane survey identified a large population of dark clouds that appear in absorption at low Galactic latitudes against the warm mid-IR Galactic emission, known as infrared dark clouds (IRDCs). They suffer from hundred of magnitudes of visual extinction, contain large column densities of cold dust, and often have filamentary morphologies. These regions may represent molecular clouds on the very cusp of forming protostellar cores. We obtained GBT time to search for CCS and NH3 emission towards five IRDCs in order to determine their chemical and physical evolutionary states. Kyle reduced these data, and retrieved archival SCUBA data in order to make detailed comparisons between the dust and CCS emission. He found: (1) an anticorrelation between the CCS and NH3 emission, indicative of gradients in the chemical "age" within the dark clouds; (2) a range of abundance ratios of CCS/NH3, indicative of variations in the chemical age from cloud to cloud; and (3) the dust peaks tended to coincide with broad line widths and/or locations where multiple velocity components overlap along the line of sight, suggesting that the dark clouds may form where multiple molecular clouds interact, and supporting models for triggered star formation.

John Brewer, of West Virginia University, worked with Michael Stennes on

GBT 68-92 GHz Receiver Development

Currently under development in Green Bank is a set of receivers that will give the GBT capability for observing in the 3mm atmospheric window, for both continuum and spectral line experiments. The basis of the design is a pseudo-correlation receiver, modeled after the WMAP radiometers, which will achieve sensitivities on the order of 2mK in one second. Added to this continuum receiver will be standard heterodyne channels, capable of converting the sky frequency to intermediate frequencies suitable for a variety of radio astronomy backends. John participated in the development of the first in the proposed set of 3mm instruments - a 68-92 GHz receiver for the Green Bank Telescope, completing a detailed mechanical design of a rotating optical platform that will be mounted on top of the receiver dewar. The optical platform is to be used for the precise positioning of various optical components such as blackbody radiators, mirrors, polarizing grids, and lenses, above the receiver's feed horns. The rotation angle of the optical table will be controllable remotely, giving the user a wide range of calibration capabilities and polarization choices. John completed the detailed design of the optical table, producing a set of mechanical drawings and technical reports. At the time of this writing, the NRAO machine shop is in the process of fabricating the optical table components, using John's drawings.

Valeria Buenrostro-Leiter, of Instituto de Astrofísica de Canarias (IAC), worked with Jay Lockman on

GBT HI Observations of High Velocity Clouds

A region around the high velocity HI cloud 'Complex H' was mapped in the 21cm line using the Green Bank Telescope. During the course of the summer the data were assembled and reduced and new techniques were developed for reduction of spectral line maps over large areas. The new data confirm previous suspicions of an interaction between the high velocity HI cloud and the outer parts of the Milky Way.

Jason Curtis, of UC Berkeley, worked with Glen Langston on

GBT Observations of Ammonia (NH3) Towards The Galactic Center

See AAS Abstract 81.23 in Section 7.

James Durand, of NMSU, worked with John Ford on

A Supervisory Control and Data Acquisition (SCADA) system for the 140 Foot

Telescope

The 140 foot (43m) telescope has been retired for several years. NRAO intends to reactivate this telescope and run it remotely. The control system must be redesigned to allow remote operations to safely monitor and control the hydraulic and mechanical systems on the telescope. For this project, James went to the telescope, verified what equipment was there, and created graphical representations of the hydraulic circuits, including motors, pumps, valves, and tanks. In addition to this, James also connected the graphical control software to a Programmable Controller (PLC). All James' work was used as a prototype for the system, which is currently being built.

Kelly Freed, of Metropolitan State College of Denver, worked with Jeff Mangum on

The Star Formation Environment of the IRAM04191 Protostar

IRAM 04191+1523 has been identified by André, Motte, and Bacmann (1999) as a protostar on the basis of its outflow, stellar to circumstellar mass ratio, centimeter continuum emission, and low bolometric temperature. In these youngest Class 0 spectral energy distribution (SED) sources, the flattened molecular gas envelopes appear to show a “rigid" rotation, with the rotational velocity proportional to the radial distance from the embedded protostar, as measured through observations of HH111, HH212 and HH211. In these young objects, a centralized accretion disk is just beginning to form, and the highly collimated outflow provides the primary means for loss of core angular momentum, allowing the formation of the condensing star.

Kelly accomplished the following during her research into this project:

- Analyzed the correlation between the spatial and spectral structures measured in the NH_3, N_2H^+, and C_2H (obtained from James DiFrancesco) images of IRAM04191. This correlation was compared to current chemical models which track the "early-time" evolution of these molecular species, which we hoped would lead to a scenario whereby the abundance drops in NH_3, N_2H^+, and C_2H could be explained.

- Tested various physical and chemical models to explain the NH_3, N_2H^+, and C_2H distributions in IRAM04191.

- Related the molecular gas structure observed in IRAM04191 to other protostellar regions. At this point, IRAM04191 appears to be unique, which likely represents our lack of understanding of the early physical and chemical phases of the star formation process.

See AAS Abstract 176.06 in Section 7 for further results.

Soumya Ghosh, of University of Houston, worked with Nicole Radziwill on

Frequency of Execution Metrics for the GBT

There are at least three different categories of observing on the GBT, including: observations performed by observers whose proposals have been approved and accepted, astronomical observations conducted by the GBT staff for tests, and observations conducted to support maintenance activities. To best determine priorities for required software development, fault reports must be evaluated with respect to what type of observing was being done at the time. This project involved expanding the schema for the GBT observation management database, writing prototype software applications to populate the database with test data, implementing a process for automatically updating the database with details from new observations, and developing a means of retrieving historical information from the database in a streamlined way. The research portion of the project involved identifying ways to cross-correlate observational details with fault reports to provide a realistic assessment of which faults have the greatest impact on observers. Although much additional future work is required (e.g. examining the populated database for trends and patterns) the information gathered during this summer project will be used to plan an upcoming project to improve dynamic scheduling, and was presented at an August 2005 brainstorming meeting.

Catherine Grier, of University of Illinois, worked with Jim Braatz on

Statistical Study of H2O Megamaser Systems

The student conducted a statistical analysis of known H2O maser systems. Given the jump in the number of known H2O megamasers over the past few years, statistical comparisons between galaxies detected and undetected in H2O masers are warranted. We produced a catalog of galaxy parameters including morphological type, inclination, X-ray column density, and infrared fluxes and luminosities. The megamaser-detected population of galaxies were then compared to general populations of AGNs, especially nonmaser Seyfert 2 galaxies, using statistical comparisons including the K-S test. We are seeking trends that will provide an understanding into the underlying factors which lead to megamaser emission as well as practical aids to improve the efficiency of future surveys for masers in AGNs. See AAS Abstract 176.06 in Section 7 for further results.

Nicole Gugliucci, of Lycoming College, worked with Greg Taylor on

Exotic AGN from VLBI Surveys

See AAS Abstract 127.01 in Section 7.

Amanda Heiderman, of University of California, Berkeley, worked with John Hibbard (NRAO) & Kelsey Johnson (UVa) on

A VLA HI and Spitzer mid-IR Study of Hickson Compact Group 7

Hickson Compact Groups (HCGs) provide a unique environment to study the mechanisms by which star formation occurs amid continuous gravitational encounters. These dense groups host a variety of modes

of star formation, and they can provide insight into the role of gas in galaxy evolution. VLA archival HI data was reduced for HCG 7 and the integrated flux and mass of HI for each galaxy and the group was computed. The predicted mass of HI was compared to that measured to find the deficiency of HI for each galaxy and the group. The mass of HI in the group was found to be 5.2E9 Msun. The resulting HI Deficiency of 0.61 indicates that the group as a whole has 1/4 the amount of neutral gas as field galaxies of the same Hubble Types. Data from the Spitzer IRAC imaging detector was used to measure the infrared flux for each member in HCG 7. The Spectral Energy Distribution for each galaxy was compared to its individual HI Deficiency, and it was found that the more gas rich galaxies (lower HI Deficiency) are more likely to be forming stars. HCGs span three stages of a proposed evolutionary sequence: pre-interaction, shocked intergroup medium, and smooth intergalactic medium. HCG 7 was found to be in the pre- interaction phase due to the fact that most of its atomic hydrogen is contained in the galaxies, with no obvious signs of large scale disturbances. Further studies of other HCGs using data from the VLA, Spitzer, and 2MASS survey, will allow us to determine how in the dynamical state of these groups are linked the the level of star formation activity, and how the gas content evolves along the evolutionary sequence.

See AAS Abstract 179.16 in Section 7 for further results.

JoAnna Johnston, of New Mexico Tech, worked with Bryan Butler on

Mapping Water Vapor in the Atmosphere of Mars with the VLA

Joanna worked on observations of Mars taken during the Mars opposition of 2003. The 22 GHz water transition was observed around the limb of the planet. We have observations on 4 dates, and Joanna did the data reduction on the first of these. She calibrated and self-calibrated the data (the bandpass calibration is particularly tricky because the line is wide and we have to overlap IFs in the VLA backend to cover it). She did most of the imaging.

Significant results from this work are:

- The whole-disk average PWV is 14 +- 2 um
- Mid-Northern latitudes are slightly wetter
- Northern polar latitudes are devoid of water, to the level it can be measured in this way
- All of these results are consistent with TES water column retrievals from that period
- The water vapor is well mixed to at least 40 km, which is something the TES results cannot yield directly.

Kasandra Jorgensen, of Lewis & Clark College, worked with Yancy Shirley on

The Physical Structure of the Incipient Stages of Low-mass Star Formation

See AAS Abstract 184.11 in Section 7.

John Kelly, of University of Virginia, worked with Ken Kellermann on

Radio Observations of the Chandra Deep Field South

This summer John completed data reduction of approximately 50 hours of VLA 20 cm observations of the Chandra Deep Field South, which includes the new Hubble Ultra Deep Field, taken February and March 2004. The elevation of the CDFS field at the VLA is very low, compounding problems with ground pickup and interference, as well as limiting the observable time to only six hours per day. To obtain the highest fidelity image possible, John broke the data into small time segments and cleaned each of these separately before combining them in the image plane. This removed time variable effects and allowed much improved images to be made. The deepest image made using the 2004 data had a noise of ~15 uJy in the center of the field, somewhat higher than the theoretical, likely due to dynamic range effects from the bright sources. This was combined with a previous set of observations to produce an image with a noise ~7 uJy. John also began preliminary work on optical and X-ray comparisons with data from Hubble, Chandra and the VLT. The Chandra data contained about 50 obvious X-ray counterparts to radio sources, as well as a systematic offset in both RA and DEC which must be accounted for in future analysis

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Emily Levesque, of Massachusetts Institute of Technology, worked with Vincent Fish on

Search for Interstellar OD

Emily worked on previously-obtained data from the Westerbork Synthesis Radio Telescope to detect interstellar OD in the first excited state at 1190 MHz. These data allowed her to place an upper limit on the OD/OH abundance ratio in several sources and obtain a tentative detection toward Cas A. This latter result is substantially higher than the D/H ratio due to chemical fractionation, although confirmation of the detection awaits follow-up observations. The results may have implications for models of cloud chemistry.

Conor Mancone, of University of Florida, worked with Phil Jewell on

200-240 GHz Spectral Line Survey of IRC+10216

See AAS Abstract 182.06 in Section 7.

Tyson Mao, of California Institute of Technology, worked with Bryan Butler on

Radar mapping of Mars at Opposition

Tyson worked on data taken with the joint Goldstone/VLA radar during the Mars opposition of 2003. We have observations on 4 dates at this time, and Tyson did the data reduction on the first of these

dates. He calibrated and self-calibrated the data (the self-calibration is tricky because of the frequency resolution in the experiment). He did the imaging, which is also tricky because of the interaction between frequency channels and spatial response ("doppler strips"). He combined the frequency channel maps into 40 final snapshot images, which display the rotation of radar reflectors which are tied to surface features across the disk of the planet.

Significant results from this work are:

- "Stealth" is confirmed
- There is a "Mini-Stealth" near Elysium Mons
- There is a bright reflection centered on the Elysium Mons volcano
- There is a significant enhancement from the South Polar Ice Cap, and not only from the seasonal cap (which was seen in earlier experiments), but also from the residual cap

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Michael McCarty, of Morehead State University, worked with Scott Ransom on

GBT Pulsar Observations

See AAS abstract 183.07 in Section 7.

Vinayak Nagpal, of Chalmers University of Technology, worked with Rich Bradley on

Development of an Adaptive RFI Mitigation System for the GBT

Vinayak participated in the development of real-time, adaptive interference canceling algorithm suitable for implementation in Field-Programmable Gate Array (FPGA) technology. Several permutations of the LMS and RLS algorithms were evaluated on a PC-based signal processing system using data from the Green Bank RFI monitoring station and synthesized data. The results underscore the need for a high quality reference for each interfering signal. In addition, we are beginning to understand how these algorithms breakdown in the presence of multiple interference signals within the filter's passband and explored the use of multi-channel feedback to combat this problem.

Oluleye Olorode, of Benedict College, worked with Eric Bryerton on

Optimization of a THz Heterodyne Test Receiver

The student made significant improvements to a 600-720 GHz test receivers for HEB mixers. He designed and built a beamsplitter to replace the Martin-Puplett LO diplexer. This improved the overall receiver noise performance from 900K to 500K at 660 GHz. The student also made significant improvements to the mechanical test apparatus by designing stands and brackets for the test dewar and LO source. These improvements allowed the student to efficiently test and compare different HEB mixer designs. This work addresses the THz technology gap, helping to exploit many new and exciting applications in this under-utilized frequency range, including but not limited to radio astronomy.

Robin Pulliam, of Radford University, worked with Anthony Minter on

The Filling Factor of Electrons in the Warm Ionized Medium

See AAS abstract 81.09 in Section 7.

Ricardo Sanchez, of Rutgers The State University of NJ, worked with Gustaaf van Moorsel on

Gas Flows in the Barred Galaxy NGC 1365

The student re-analyzed previous HI observations of the barred galaxy NGC1365 with the expectation that innovations in imaging and modeling and strongly reduced computing limitations would lead to better results to be compared to recent Fabry-Perot data taken at CTIO. He was indeed able to refine the original results, but did not have the time for a detailed comparison with the Fabry-Perot data.

Julia Sandell, of Barnard College/Columbia University, worked with John Hibbard on

HI and GALEX Observations of Interacting Galaxies

One of the fascinating results of the Galaxy Evolution Explorer (GALEX) far- and near-UV imaging mission was the detection of UV-bright regions outside the optical disks of galaxies. For several of these systems, neutral hydrogen (HI) maps from the VLA were available (many from the HI Rogues Gallery). In these cases, the extra-disk star forming regions were found to be contained within HI extensions. Together with Jacqueline van Gorkom and David Schiminovich (both at Columbia University) and others, we have targeted other systems from the Rogues Gallery with GALEX to look for similar sites of extra-disk star formation. J. Sandell reduced archival VLA HI data on several of these systems and compared the GALEX FUV and NUV images with the HI maps. Results are discussed further in AAS Abstract 64.11 in Section 7.

David Sevilla, of The University of Texas at El Paso, worked with Rich Lacasse and John Ford on

A Test Spectrometer for the Green Bank Electronics Division

The instrumentation on the GBT operates at very wide bandwidths and at very low noise levels. It is difficult for ordinary laboratory instrumentation to be used for diagnosis and testing of these sensitive instruments. We have obtained a test spectrometer to be used in the lab for these tests. The student's task here was to work with the engineers at Green Bank to modify this spectrometer to suit the needs that we have for it. Disciplines needed included digital design, computer programming, hands-on digital troubleshooting. Good writing skills were needed to document the final product. The bulk of the work

involved programming in C++ with "real-time" constraints. By the end of the summer, David Sevilla had the system 99% operational. In addition he left us with documentation and examples of the problems that still need to be resolved.

Benjamin Sulman, of Oberlin College, worked with Scott Ransom on

Searching for Weak, Isolated Pulsars in the Globular Cluster Terzan 5

See AAS Abstract 183.08 in Section 7.

Lawrence Weintraub, of California Institute of Technology, worked with Greg Taylor on

Multi-Epoch VLBA Polarimetry of the Gamma-Ray Blazar 2255-282

Kassandra Wells, of Carleton College, worked with Steve Myers on

Observations of the Sunyaev-Zeldovich Effect with the CBI

The Cosmic Background Imager (CBI) has observed a sample of nearby ($z<0.1$) X-ray luminous clusters of galaxies. The observations and results from the first 7 clusters was reported in Udomprasert et al. 2004, and the analysis of an additional 2 clusters was carried out by Adrienne Stilp in the summer of 2004. There are several more clusters to be analyzed, in particular southern clusters for which I obtained ATCA data on point sources in Oct 2004. K. Wells analyzed the CBI data and the ATCA data, and compared them with the X-ray data.

Peter Williams, of Harvard College, worked with Steven White on

New Generation Phase Calibrator

The phase calibrators currently in the GBT IF system contain obsolete parts, emit RFI when not in use and employ expensive microwave switches as part of their design. This project entails development of an economical next generation phase calibrator, so that a unit may be produced for each receiver. Improvements include elimination of the RFI problem by proper mechanical packaging, increasing the power of the spectrum at higher frequencies, and reducing the size and cost of the unit. Three separate issues are to be addressed for these improvements: identify a high speed digital divider with a low time delay versus temperature specification, select a driver amplifier and tunnel diode circuit for generating calibrator pulses, and develop a PIN diode with TTL driver circuit which will be integrated into a microwave strip line circuit. Finally all these elements are to be integrated into a RFI tight mechanical package. Durning this session, the digital divider and driver amplifier sections were upgraded to surface

mount components. Modeling of the PIN diode components in Microwave Office proved inconclusive for an in-house design; however, a source of MMIC PIN diode switches were found, tested, and integrated into the design. The availability of tunnel diode manufacturers proved to be limited. The tunnel diode selected proved to have too large package inductances limiting the amplitude of frequency components greater than 6 GHZ. However, the problematic tunnel diode enabled the testing of all the components and mechanical designs.

6. RET 2005 Project Summaries

This section lists short summaries of the projects for RET participants in the NRAO 2005 Summer Teacher program.

Eric Kearsley of High Point High School, Beltsville, MD, worked with Karen O'Neil on

Measuring the Dust in Low Surface Brightness Galaxies

Archival data from the IRAS, 2MASS, NVSS, and FIRST catalogs, supplemented with new measurements of HI, were used to analyze the relationship between the relative mass of the various components of galaxies (stars, atomic hydrogen, dust, and molecular gas) using a small sample of nearby ($z<0.1$), massive low surface brightness galaxies. The sample was compared to three sets of published data: a large collection of radio sources from the UGC having a radio continuum intensity >2.5 mJy (Condon, Cotton, & Broderick 2002 AJ 124, 675); a smaller sample of low surface brightness galaxies (Galaz, et al 2002 2002 AJ 124, 1360); and a collection of NIR low surface brightness galaxies (Monnier-Ragaigne, et al 2002 Ap&SS 281, 145). Overall, our sample properties are similar to the comparison samples in regard to NIR color, gas, stellar, and dynamic mass ratios, etc. Based on the galaxies' q-value (determined from the FIR/1.4 GHz ratio), it appears likely that at least two of the 28 galaxies studied harbor AGN. Notably, we also find that if we naively assume the ratio of the dust and molecular gas mass relative to the mass of HI is a constant we are unable to predict the observed ratio of stellar mass to HI mass, indicating that the HI mass ratio is a poor indicator of the total baryonic mass in the studied galaxies. HI measurements obtained during this study using the Green Bank Telescope also provide a correction to the velocity of UGC 11068.

Vincent F. Pereira of Clarkstown North High School, New City, NY, worked with Brian Mason on

Calibrating Array Detectors for the Penn Array

See AAS Abstract 34.08 in Section 7.

Kurt S. Voss of Zuni High School, worked with Mark Claussen and Al Wootten on

Green Bank Telescope Monitoring of Water Masers in Young Stellar Objects

From April 2003 to March 2004, we monitored the water maser emission from a sample of approximately 30 low-to-intermediate mass young stellar objects (YSOs) in different environments approximately every two weeks (excluding the summer months), using the 100-meter NRAO Green Bank Telescope. In this project we addressed the questions of variation timescales, the underlying causes of the maser excitation and variations, and the role of YSO evolution in the water maser phenomenon. We report the results of a search for high-velocity (+/- 350 km/s) water maser emission toward these objects, obtained as a byproduct of this monitoring project. Finally, we will report on a detailed case study: the very strong and highly variable water masers in the low-mass YSO IRAS 16293-2422 in the rho Ophiuchi star-forming region.

7. Poster Abstracts for the AAS 207th Meeting, January 8-12, 2006

Fourteen of the NRAO summer program participants, including 10 of the REU students, 2 of the GRP students, and 2 of the RET participants, traveled to Washington, D.C. to attend the 207th Meeting of the American Astronomical Society , from January 8-12, 2006. One RET participant traveled to the 208th AAS Meeting in Calgary, Canada, June 4-8, 2006. Below are the titles and abstracts of the posters they presented describing the results of their summer research. Many of the Abstracts specifically acknowledged the NSF REU program. In the interest of concision the acknowledgments are omitted here.

Session 34 Information Services and Databases
Poster, Monday, 9:20am-7:00pm, January 9, 2006, Exhibit Hall

[34.08] Research Experience for Teachers at NRAO--Green Bank. Calibrating Array Detectors.

V.F. Pereira (NEST+m), B.S. Mason (NRAO--Green Bank)

Realistic simulations of the sky, that include spread in detector gains, telescope pointing errors, detector and sky noises, were used as an input, for an algorithm developed by Fixsen, Moseley and Arendt to analyze sky data. Results of this algorithm were then compared to another algorithm in which pixel gains were calculated assuming that the contribution of the atmosphere is constant. Preliminary results indicate that the Fixsen, Moseley and Arendt algorithm produced better images of the sky as measured

by noise and maximum signal to noise ratio. Finally, a lesson plan based on this summer experience is presented.

Session 81 ISM: From Dark to Blinded
Poster, Tuesday, 9:20am-6:30pm, January 10, 2006, Exhibit Hall

[81.23] Molecular and Recombination Lines in the Central Region of Sagittarius B2

J. Curtis (UC Berkeley and National Radio Astronomy Observatory), G. Langston (National Radio Astronomy Observatory)

We present observations of recombination and molecular lines towards Sgr B2 in the frequency range 12.4 to 15.0 GHz. In this frequency range, H\alpha, \beta, and \gamma lines, He\alpha recombination lines and emission from the SO molecule are detected. Molecular absorption lines from OH, H_2CO, and CH_3CO are detected at velocity 62±3 km/s. Measurements of the line widths and intensities are presented for the central region of Sgr B2. We detect two previously un-reported molecular absorption lines at 12388.0 and 14625.8 MHz (v=0. in LSR Frame). For selected recombination and molecular lines, we present images of a 10x10 arc-minute region centered on Sgr B2(M). We discuss the sources of three H_2CO absorption features detected at 62±3, 6±5, and 100±10 km/s.

Session 81 ISM: From Dark to Blinded
Poster, Tuesday, 9:20am-6:30pm, January 10, 2006, Exhibit Hall

[81.09] The Filling Fraction of Electrons in the Warm Ionized Medium

R.L. Pulliam (Radford University), A. Minter (NRAO, Advisor)

Pulsars found in globular clusters allow for the determination of the filling fraction of electrons in the warm interstellar medium by comparing the measured DM and EM values along the line of sight to the cluster. Reynolds, et al. (1991, ApJ, 372, 17L) used pulsars towards 4 globular clusters and found that the filling fraction of electrons along the line of sight was about 0.20. Over the past decade, many more pulsars in globular clusters have been discovered and therefore it is of interest to further investigate the filling fraction within the medium. Currently there are 8 clusters containing pulsars that can be used. Using these 8 clusters we have found an average filling fraction of 0.19. There is marginal evidence that the filling factor increases with increasing distance out of the plane. The data indicate that more detailed analysis is needed with the effects of the local bubble needing to be taken into account.

Session 64 ISM outside the Milky Way
Poster, Tuesday, 9:20am-6:30pm, January 10, 2006, Exhibit Hall

[64.11] Extra-Disk Star Formation: A Comparison of VLA HI and GALEX UV data

J.S. Sandell, J.E. Hibbard (NRAO), J. van Gorkhom, D. Schminovich (Columbia University), NRAO Collaboration, Columbia U. Collaboration

We present GALEX FUV (1530A) and NUV (2310) and VLA HI spectral line observations of the interacting/merging systems Mk 348, NGC 7252, VV 114, and NGC 4038/9. All systems exhibit extended low surface brightness UV emission outside of their main bodies, in extended gaseous disks or tidal features. We find a good correlation between the HI surface density and UV surface brightness, with FUV emission consistently present when the gas surface density exceeds 2 Mo/pc2. This supports the idea of a star formation threshold surface density for extra-disk star formation.

Session 127 Polarization and Magnetic Fields in AGN
Poster, Wednesday, 9:20am-6:30pm, January 11, 2006, Exhibit Hall

[127.02] Circular Polarization in PKS 1519-273

W. Bennett (Drake University), J.P. Macquart (NRAO), H. Johnston (University of Sydney), D. Jauncey (ATNF)

The intra-day variable BL Lac PKS 1519-273 exhibits variations at centimeter wavelengths in total intensity, linear polarization, and circular polarization. Their variability is caused by scintillation due to the interstellar medium. PKS 1519-273 displays 4% circular polarization at 4.8 GHz and the variability has persisted as long as the source has been observed. We present observations of this source over several years, showing that the circularly polarized emission is highly variable on micro-arcsecond scales. We determine properties of the structure of the emission by examining the light curves and associated scintillation theory.

Session 127 Polarization and Magnetic Fields in AGN
Poster, Wednesday, 9:20am-6:30pm, January 11, 2006, Exhibit Hall

[127.01] Polarimetry of Compact Symmetric Objects

N.E. Gugliucci (University of Virginia), G.B. Taylor (University of New Mexico), A.B. Peck (Harvard-Smithsonian Center for Astrophysics), M. Giroletti (INAF Istituto di Radioastronomia)

We present multi-frequency VLBA observations of two polarized Compact Symmetric Objects (CSOs), J0000+4054 and J1826+1831, and a polarized CSO candidate, J1915+6548. The former two sources were the first CSOs to have detectable polarization. Using the wavelength-squared dependence of Faraday rotation, we obtained rotation measures (RMs) of -180±10 rad/m^2 and 1540±7 rad/m^2 for the latter two sources, which are lower than what is expected of CSOs (few 1000 rad/m^2) and, depending on

the path length of the Faraday screens, require magnetic fields from 0.03 to 6 micro Gauss. These CSOs may be more heavily affected by Doppler boosting than their unpolarized counterparts, suggesting that a jet-axis orientation more inclined towards the line of sight is necessary to detect any polarization. This allows for low RMs if the polarized components are oriented away from the depolarizing circumnuclear torus. These observations also add a fourth epoch to the proper motion studies of J0000+4054 and J1826+1831, constraining their kinematic age estimates to >610 yrs and 2600±490 yrs, respectively. The morphology, spectrum, and component motions of J1915+6548 are discussed in light of its new classification as a CSO candidate.

Session 134 Irregular Galaxies
Poster, Wednesday, 9:20am-6:30pm, January 11, 2006, Exhibit Hall

[134.09] From 20 cm - 1 micron: Measuring the Gas and Dust in Massive Low Surface Brightness Galaxies

E. Kearsley (NRAO - Green Bank/Albert Einstein HS, Kennsington, MD), K. O'Neil (NRAO - Green Bank)

Archival data from the IRAS, 2MASS, NVSS, and FIRST catalogs, supplemented with new measurements of HI, are used to analyze the relationship between the relative mass of the various components of galaxies (stars, atomic hydrogen, dust, and molecular gas) using a small sample of nearby (z<0.1), massive low surface brightness galaxies. The sample is compared to three sets of published data: a large collection of radio sources from the UGC having a radio continuum intensity >2.5 mJy (Condon, Cotton, & Broderick 2002 AJ 124, 675) ; a smaller sample of low surface brightness galaxies (Galaz, et al 2002 2002 AJ 124, 1360); and a collection of NIR low surface brightness galaxies (Monnier-Ragaigne, et al 2002 Ap&SS 281, 145). Overall, our sample properties are similar to the comparison samples in regard to NIR color, gas, stellar, and dynamic mass ratios, etc. Based off the galaxies' q-value (determined from the FIR/1.4 GHz ratio), it appears likely that at least two of the 28 galaxies studied harbor AGN. Notably, we also find that if we naively assume the ratio of the dust and molecular gas mass relative to the mass of HI is a constant we are unable to predict the observed ratio of stellar mass to HI mass, indicating that the HI mass ratio is a poor indicator of the total baryonic mass in the studied galaxies. HI measurements obtained during this study using the Green Bank Telescope also provide a correction to the velocity of UGC 11068.

Session 184 Masers, Millimeter and Centimeter Observations of Protostars
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[184.08] The Star Formation Environment of the IRAM 04191+1522 Protostar

K. M. Freed (Metropolitan State College of Denver), J. G. Mangum (National Radio Astronomy Observatory)

Many protostars have been studied with the use of nitrogen bearing molecules because of their volatile nature and low binding energy. Short chemical history, large abundance, and simple radiative transfer

have made N_2H^+ and NH_3 excellent molecular tracers of the dense cold regions within the cores of protostars. However, high resolution observations of the IRAM 04191+1522 protostar have shown a significant depletion of N_2H^+ and NH_3 in its core. IRAM 04191+1522, a class 0 protostar, is identified by an age ~ 10^4 years, a central density ~ 10^6 cm^{-3} and a temperature ~ 12K. N_2H^+ and NH_3 were thought to be unaffected by depletion to densities of 10^7 cm^{-3}, so the cause of the disappearance remains a mystery. There are four scenarios which will be discussed in this talk that may be able to account for some depletion of N_2H^+ and NH_3: 1) N_2 (the parent molecule of both N_2H^+ and NH_3) condenses onto dust grains, 2) an underestimation of the molecular cloud temperature results in severe depletion of N_2H^+ and NH_3, 3) high levels of deuterium fractionation create deuterated species of N_2H^+ and NH_3, and 4) isotopic fractionation of nitrogen create species of N_2H^+ and NH_3 that contain the ^{15}N isotope.

Session 176 Radio - Loud AGN
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[176.06] Statistical Comparisons of H_20 Megamaser Galaxies and Type 2 Active Galaxies

C. Grier (NRAO/UIUC), C. Johnson (Breck School), J. Braatz (NRAO)

Luminous water maser emission has been detected so far in more than 66 galaxies beyond the LMC, mainly in type 2 active galaxies. The masers provide important information about the shape, orientation, and kinematics of gas in AGN accretion disks. In order to investigate the maser-host connection and to help guide future maser surveys, we performed a statistical comparison of host galaxy properties between galaxies detected in water maser emission and samples of Type 2 Active Galaxies undetected in maser emission. Among the properties examined were the B magnitude, Hubble type, and galactic disk inclination. We also examined near- and far-infrared flux and power, as well as nuclear 2-10 keV luminosity and hard X-ray absorbing column density. In general megamasers prefer AGN with large ($\log N_H > 22$ cm^{-2}) X-ray column densities, but the N_H distribution of maser-detected and maser-undetected galaxies among Seyfert 2's specifically is similar. The other properties examined are also similar between maser detected and undetected Seyfert 2 galaxies. Our results suggest that luminous water masers may be present in many Seyfert 2 galaxies and our ability to detect them depends largely on the geometry of the nuclear region of the galaxy.

Session 179 Evolution of Galaxies, and Galaxies Surveys at Low Redshift
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[179.16] VLA HI and Spitzer Study of HCG 07 and HCG 19

A. L. Heiderman (NRAO/REU), J. E. Hibbard (NRAO), K. E. Johnson (UVa), S. C. Gallagher (UCLA), J. C. Charlton (PSU), A. E. Hornschemeier (GSFC)

Hickson Compact Groups (HCGs) provide a unique environment to study the role of gas in galaxy evolution. We use new Spitzer IRAC (3.6, 4.5, 5.8, and 8.0 microns) and MIPS (24 micron) data in combination with archival VLA HI observations to examine star formation and HI gas content in HCG

07 and HCG 19. The HI observations show that gas is confined to the individual galaxies, which are HI deficient compared to isolated galaxies. The gas kinematics are fairly regular, indicating that these systems are at an early stage of the proposed evolutionary scenario for compact groups. We examine the relationship between the HI deficiency and the infrared spectral energy distributions of the individual galaxies to help understand how the cold gas content and star formation activity evolve in compact groups.

Session 184 Masers, Millimeter and Centimeter Observations of Protostars
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[184.11] Radiative Transfer Modeling of Preprotostellar Cores

K. Jorgensen (Lewis & Clark College, National Radio Astronomy Observatory Summer REU Student), Y. Shirley (National Radio Observatory Jansky Fellow, University of Arizona)

A pre-protostellar core is the earliest detectable stage of star formation and are undoubtedly the least understood formation phase of low-mass stars. In order to better understand the pre-protostellar phase, parameters such as the central densities of the cores, how embedded the cores are, and the strength of the interstellar radiation field around them are needed. These properties are found by radiative transfer modeling of these systems. This project focused on starless cores observed with the Sub-millimeter Common User Bolometer Array (SCUBA) at the James Clerk Maxwell Telescope. Nearly every pre-protostellar core with a distance < 400 pc that has been observed with SCUBA in jiggle mapping mode at 850 and 450 microns was obtained from the CADC archive and reduced. From this sample, 32 cores fit the criteria to undergo radiative transfer modeling. Using pressure-bounded isothermal spheres in hydrostatic equilibrium as our physical model we obtain central density values for each core, finding median central density of log nc = 5.3. We also constrain values for the strength of the interstellar radiation field and Av for 31 of these cores. Many of the cores were found to have central densities too high to be in static equilibrium implying that either the cores observed are in their collapse phase or there is some non-thermal form of support (.e.g, turbulence or magnetic forces). Observations with high resolution spectroscopy are needed to determine the stability of these pre-protostellar cores.

Session 182 Stellar Winds, Circumstellar Matter, and Activity
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[182.06] A Spectral Survey of IRC+10216 From 206-232 GHz

C. L. Mancone (University of Florida), W. B. Latter (Spitzer Science Center), P. R. Jewell (National Radio Astronomy Observatory), F. J. Lovas (Optical Technology Division, National Institute of Standards and Technology)

A spectral survey of the carbon rich asymptotic giant branch star IRC+10216 was performed with the NRAO 12 Meter telescope between the frequencies of 206 and 232.5 GHz. Approximately 100 spectral lines were detected in this band with an average rms sensitivity of 10 mK. Most of the spectral lines can

be assigned to known species, but a number cannot presently be identified. A summary of the results of the survey will be presented.

Session 183 Radio and X-Ray Pulsars
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[183.07] GBT Pulsar Observations

M McCarty (NRAO, MSU), S Ransom (NRAO)

Searching for binary pulsars is a relatively new science due to the development of computing technology allowing astronomers to implement complex algorithms that reduce and analyze data. One such algorithm creates a Dynamic Power Spectrum, yielding an extremely large matrix where binary millisecond pulsar (MSP) signals are represented as (typically) sinusoidal curves. These curves are often discontinuous and have very low signal-to-noise. The crux of the DPS algorithm is to automatically identify these curves while keeping the number of false positives low, all using a reasonable amount of computing time. We describe two independent methods for searching data sets from the Green Bank Telescope (GBT) for MSP signals. One of these methods has already uncovered a previously unknown MSP in the globular cluster Terzan 5. This new binary pulsar, Ter5AE, is 3.65ms pulsar in a 4.1 hour orbit with an approximately 20 Jupiter mass companion. The DPS method, used to find Ter5AE, shows strong potential for additional future discoveries.

Session 183 Radio and X-Ray Pulsars
Poster, Thursday, 9:20am-4:00pm, January 12, 2006, Exhibit Hall

[183.08] Searching for weak, isolated pulsars in the globular cluster Terzan 5

B. Sulman (Oberlin College), S. Ransom (NRAO), D. Stinebring (Oberlin College)

The Terzan 5 star cluster is one of the richest globular clusters in the Milky Way. It contains 32 known recycled millisecond pulsars, 16 of which are binary systems. We searched for very weak, isolated pulsars in Terzan 5 using an incoherent "stack-search" method that sums power spectra from several observations. The stable frequencies of isolated pulsars cause their corresponding peaks in the power spectrum to grow faster than the noise. We added power spectra from over a year's worth of GBT observations, and have so far uncovered at least one new, weak, isolated millisecond pulsar using this method. We plan to continue using this method to search GBT data from several star clusters and anticipate discovering several additional millisecond pulsars.

AAS 208th Meeting
June 4-8, 2006,
Calgary, Canada
Session 8 Topics in Star Formation

Poster, Monday, June 6, 2006, 9:20am-7:00pm, Exhibit Hall DE

[8.06] A High Time Resolution Study of Water Masers Near Young Stellar Objects

Kurt S. Voss (Zuni High School), M. J. Claussen (NRAO), H. A. Wootten (NRAO), K. B. Marvel (AAS), B. A. Wilking (University of Missouri-St Louis)

From April 2003 to March 2004, we monitored the water maser emission from a sample of approximately 30 low-to-intermediate mass young stellar objects (YSOs) in different environments approximately every two weeks (excluding the summer months), using the 100-meter NRAO Green Bank Telescope. In this poster we present the spectra from this monitoring project, and address the questions of variation timescales, the underlying causes of the maser excitation and variations, and the role of YSO evolution in the water maser phenomenon. We report the results of a search for high-velocity (+/- 350 km/s) water maser emission toward these objects, obtained as a byproduct of this monitoring project. Finally, we will report on a detailed case study: the very strong and highly variable water masers in the low-mass YSO IRAS 16293-2422 in the Rho Ophiuchi star-forming region.