


# National Radio Astronomy Observatory
# REU/RET Program Report: 2007

# Overview

## Summer Student Program

Twenty-five students participated in 2007 NRAO Summer Student program, including 15 undergraduate students supported by the National Science Foundation (NSF) 's Research Experiences for Undergraduates (REU) program, three graduating senior supported by the NRAO Undergraduate Summer Student program , and seven graduate students supported by the NRAO Graduate Summer Student program . This was the forty-eighth 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 118 applicants to the 2007 NRAO summer student program, of whom 60 (51%) were women and 18 (15%) were under-represented minorities. The 15 REU positions were filled by 7 women (47%) and 8 men (53%). One REU position was filled by an under-represented minority. In all, 25 summer students were hired, 12 women (48%) and 13 men (52%), and 4 (16%) under-represented minorities. Seven students were assigned to Socorro (4 REU), 12 to Charlottesville (7 REU), and 6 to Green Bank (4 REU).

## Summer Teacher Program

The NRAO 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 from three states applied for the 2007 the National Science Foundation (NSF)'s Research Experiences for Teachers (RET) program. One of them was female, and she's the one we chose. She is Amy McCarty, teacher at Altavista Highschool, in Altavista, Virginia. Amy's scientist advisor was D.J. Pisano.

Similar to the REU students, a brief description of the RET project(s) is included later in this report. Amy McCarty will present a poster on her research project at the January 2008 AAS Meeting.

## Organization of Report

This report is organized as follows. In Section 1 we list *all* Summer 2007 program participants. We then separately describe the different activities in which students and teachers participated 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 identify the number of REU and RET participants who will presented at the 211th meeting of the American Astronomical Society in Austin, TX (January 2008). Many of these presentations are expected to be published in astronomical journals in 2008-09.

### Table of Contents



# 1. 2007 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 25 summer student participants (15 REU, 3 uGRP, 7 GRP), and one summer teachers participants (RET) this summer.

| 2007 NRAO Summer Students/Mentors (N=25) | | | | | |
|---|---|---|---|---|---|
| **Student** | **School** | **Project** | **Mentors** | **Site** | **Program** |
| Paula Aguirre | Universidad Católica de Chile | HI Observations of the Edge-On Spiral Galaxy UGC10043 | Juan Uson | CV | **NRAO GRP** |
| Paul Ries | University of Virginia | Low Frequency Satellite Measurements | Richard Bradley | CV | **NRAO GRP** |
| Ryan Lynch | University of Virginia | Pulsars | Scott Ransom | CV | **NRAO GRP** |
| Matthew Klimek | Rutgers University | Low Frequency Spectra of MicroJy Radio Sources | Frazer Owen | Soc | **NRAO GRP** |
| Rosa Torres | Centro de Radioastronomia y Astrofisica – UNAM | Astrometry of PMS Stars | Amy Mioduszewski | Soc | **NRAO GRP** |
| Jonathan Landon | Brigham Young University | An Array Receiver for the GB 20 Meter Telescope | Roger Norrod, Rick Fisher | GB | **NRAO GRP** |
| Katie Chynoweth | Vanderbilt University | Producing Images of the M81/M82 | Glen Langston | GB | **NRAO GRP** |
| Heidi Brooks | Reed College | Radio Emission from Interplanetary Shocks | Tim Bastian | CV | **NRAO uGRP** |
| AJ Heroux | University of Wisconsin – Whitewater | Formaldehyde Densitometry of External Galaxies | Jeff Mangum | CV | **NRAO uGRP** |
| Diana Grijalva | New Mexico Tech | Exploring Frequency-Dependent Recombination Line Effects in ON 1 | David Meier and Vincent Fish | Soc | **NRAO uGRP** |
| Steven Janowiecki | Case Western Reserve University | Dust and Gas in the Southern Milky Way | D.J. Pisano | GB | NSF REU |
| Courtney Epstein | Oberlin College | WVU, NRAO, Cornell GBT Pulsar Drift Search Survey | Maura McLaughlin, Dunc Lorimar, Vlad Kondratiev | GB | NSF REU |
| Sophia Brunner | Bennington College | Dust and Gas in the Southern Milky Way | Jay Lockman | GB | NSF REU |
| Danielle Holstine | Wheeling Jesuit University | RFI Visualization for the GBT | Carla Beaudet, Amy Shelton | GB | NSF REU |

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|---|---|---|---|---|---|
| Diane Leigh | University of Virginia | Investigating the Physical and Chemical Environments of Hot Cores in the Interstellar Medium | Anthony Remijan | CV | NSF REU |
| Charles Romero | University of Colorado | How Long Will the SKAs Baselines Need To Be? | Robert Reid | CV | NSF REU |
| Benjamin Jewell | Ohio University | Structural Health Monitoring System for ALMA Antennas | Art Symmes | CV | NSF REU |
| Michael Freed | Newport News Shipyard Apprentice School | Saturns Satellites at True Opposition | Anne Verbiscer | CV | NSF REU |
| Timothy Pennucci | Columbia University, Columbia College | More Pulsars | Scott Ransom | CV | NSF REU |
| Karen Mogren | Northern Arizona University | Radar Reflectivity of Mars | Bryan Butler | Soc | NSF REU |
| Nicholas Lee | University of California, Berkeley | A search for HCN 1-0 emission from the galaxy J1635+6612 | Chris Carilli | Soc | NSF REU |
| Jennifer Van Saders | Rutgers University | Faint Submillimeter Sources Lensed by Clusters | Wei-Hao Wang | Soc | NSF REU |
| Michael Carilli | University of Notre Dame | Galaxy formation at (sub)mm wavelengths | Jeff Wagg | Soc | NSF REU |
| Alan Aversa | University of Arizona | Searching for the Youngest Star Clusters | Kelsey Johnson | CV | NSF REU |
| Mary Wilkins | James Madison University | A Caltech Submillimeter Observatory Study of Three Promising Zeeman Molecules | Crystal Brogan | CV | NSF REU |


# 2. Site Specific Activities: Charlottesville VA

The 2007 Summer Student program at NRAO/Charlottesville was under the direction of Jeff Mangum. There were 12 students in the 2007 Summer Student Research Program at NRAO-Charlottesville, seven of them under the NSF Research Experience for Undergraduates ( NSF REU) program, three were under the NRAO Graduate Student Program (NRAO GRP), and two under the NRAO Undergraduate Summer Program. This photograph shows the 2007 Charlottesville summer students.

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. In addition to lectures on radioastronomical science, engineering, and computing the CV Summer Students were given a tour of the NRAO Technology Center (NTC). One of the highlights of the summer was the Single Dish Summer School held in Green Bank, where the CV students had the opportunity to conduct observations with the Green Bank telescope (GBT ), the world's largest steerable telescope.

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.

**Charlottesville Summer 2007 Schedule**

- 21 May 2007 - **Start Date** : Paula Aguirre, Charles Romero
- 28 May 2007 - **NRAO Holiday (Memorial Day)**
- 29 May 2007 - **Start Date** : A J Heroux, Diane Leigh, Mary Wilkins, Heidi Brooks, Alan Aversa
- 04 Jun 2007 - **Start Date** : Tim Pennucci, Michael Freed
- 06 Jun 2007 - 01:00-02:30pm, **SS Lecture** : *R. Norville, Orientation* (CVAud)
- 09 Jun 2007 - 12:00-05:00pm, **NRAO Picnic (Darden Towe Park)**
- 11 Jun 2007 - 01:00-02:30pm, **SS Lecture** : *Jim Condon,* ***Physics of Radio Sources*** (CV230)
- 11 Jun 2007 - -----
- 11 Jun 2007 - **Start Date** : Ben Jewell
- 12 Jun 2007 - 01:00-02:00pm, **SS Lecture** : Ken Kellermann, ***Grote Reber: Maverick Astronomer and Father of Radio Astronomy*** (CV230)
- 12 Jun 2007 - -----
- 12 Jun 2007 - 02:00-03:00pm, **SS Lecture** : *Ellen Bouton,* ***The NRAO Historical Radio Astronomy Archive*** (CV230)
- 13 Jun 2007 - 01:00-03:00pm, **SS Lecture** : *Juan Uson,* ***Introduction to Interferometry*** (CV230)
- 14 Jun 2007 - 04:00-05:00pm, **NRAO 50th Anniversary All Staff Celebration**
- 17 Jun 2007 - **Father's Day**
- 18 Jun 2007 - 21 Jun 2007 - **NRAO 50th Anniversary Symposium**
- 20 Jun 2007 - 01:00-03:00pm, **SS Lecture** : *Megan Nunemaker and Marsha Bishop,* ***Finding the Library*** (CV230)
- 22 Jun 2007 - 24 Jun 2007 - **Transformational Science with ALMA: Through Disks to Stars and Planets**
- 27 Jun 2007 - 01:00-03:00pm **SS Lecture** : *Jeff Mangum,* ***Star Formation*** (CV230)
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- 08 Jul 2007 - 13 Jul 2007 - **Single Dish Summer School (GB)**
- 16 Jul 2007 - 01:00-3:00pm, **SS Lecture** : *Scott Ransom,* ***Pulsars*** (CV311)
- 18 Jul 2007 - 01:00-03:00pm, **SS Lecture** : *Tony Remijan,* ***Interstellar Chemistry*** (CV230)
- 20 Jul 2007 - 01:00-03:00pm, **SS Lecture** : *Dave Hogg,* ***Normal Galaxies*** (CV230)
- 27 Jul 2007 - 03:30-04:30pm, **SS Lecture** : *John Hibbard,* ***Interaction Driven Galaxy Evolution*** (CV230)
- 31 Jul 2007 - 01:00-02:30pm, **NRAO Technology Center Tour**
- 31 Jul 2007 - ---
- 31 Jul 2007 - 02:30-03:30pm, **Final Project/Presentation Discussion**
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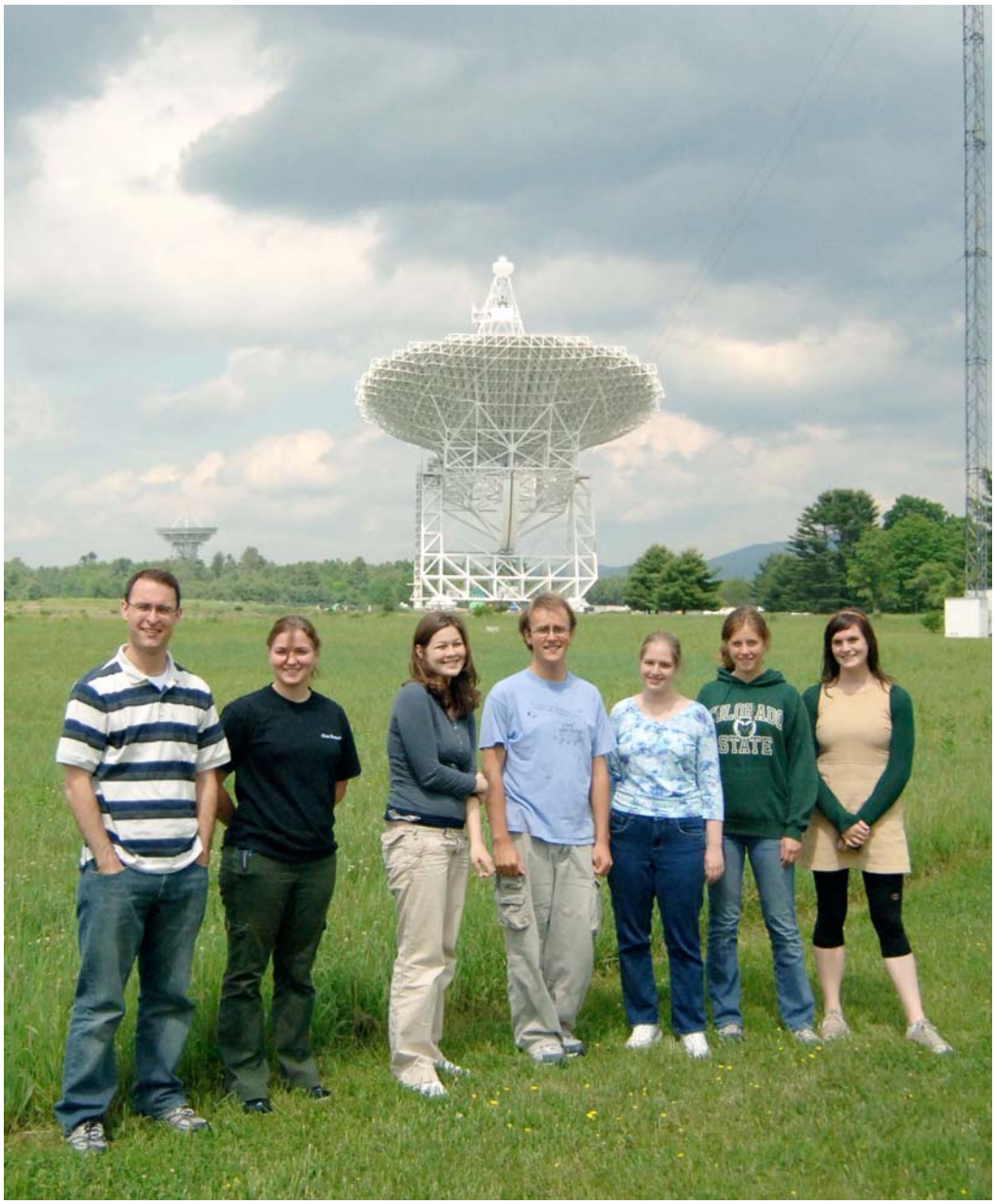
- 01 Aug 2007 - 01:00-03:00pm, **SS Lecture** : *Jim Braatz,* ***Cosmic Masers and Cosmology*** (CV230)
- 03 Aug 2007 - 12:15-1:15pm, **Lunch Talk (REU Presentation by Heidi Brooks)** (CV230)
- 04 Aug 2007 - All Day, **GB Picnic** (GB Recreation Area)
- 06 Aug 2007 - 01:00-03:00pm, **SS Lecture** : *Paul Vanden Bout,* ***Star Formation in the Early Universe*** (CV230)
- 08 Aug 2007 - 01:00-03:00pm, **SS Lecture** : *Fred Lo,* ***The NRAO*** (CV230)
- 08 Aug 2007 ---

- 08 Aug 2007 - **Last Day** : Heidi Brooks
- 10 Aug 2007 - 12:15-1:15pm, **Lunch Talk (REU Presentations by Charles Romero, Paula Aguirre, Mary Wilkins)** (CV230)
- 10 Aug 2007 - ---
- 10 Aug 2007 - **Last Day** : Paula Aguirre, Charles Romero
- 13 Aug 2007 - 12:15-1:15pm, **Lunch Talk (REU Presentations by Alan Aversa, AJ Heroux)** (CV230)
- 14 Aug 2007 - **Last Day** : Alan Aversa
- 17 Aug 2007 - 12:15-1:15pm, **Lunch Talk (REU Presentations by Mike Freed, Tim Pennucci, Diane Leigh)** (CV311)
- 17 Aug 2007 - ---
- 17 Aug 2007 - **Last Day** : A J Heroux, Mike Freed, Tim Pennucci, Diane Leigh
- 31 Aug 2007 - 12:15-1:15pm, **Lunch Talk (REU Presentation by Ben Jewell)** (CV230)



# 3. Site Specific Activities: Green Bank, WV

The 2007 REU/RET program at NRAO Green Bank was under the direction of Toney Minter and Sue Anne Heatherly. There were six students and one teacher in the 2007 Summer Research Program at NRAO-GB. Four students were supported by the NSF Research Experience for Undergraduates (NSF REU) and two of the students were supported by the NRAO Graduate Summer Student Program (NRAO GRP). The teacher was supported by the Research Experience for Teachers Program (RET).

The photograph above shows several of the summer students standing with the Green Bank Telescope in the background. From left to right are Johnathan Landon(NRAO GRP), Danielle Holstine (NSF REU),

Ilene Mitchell (HST Grant), Steven Janowiecki (NSF REU), Courtney Epstein (NSF REU), Katie Chynoweth (NRAO GRP) and Sophia Brunner (NSF REU).

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, 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 games. In late June 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 conducted their own observational projects on the GBT, performing a drift scan survey searching for extra-galactic HI. 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. Two of the REU students, and our one RET participant plan to attend the AAS meeting in Austin, Texas in January 2008 to present posters on their summer research projects.

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**Green Bank Summer 2007 Schedule**

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- E Thu - 12:00 - Science Lunch (Residence Hall Lounge)

- 21 May 2007 - First Official Start Date for Students
- 29 May 2007 - Second Official Start Date for Students
- 04 Jun 2007 - Third Official Start Date for Students

- 27 Jul 2007 - First Official End Date for Students
- 03 Aug 2007 - Second Official End Date for Students
- 10 Aug 2007 - Third Official End Date for Students
- 17 Aug 2007 - Fourth Official End Date for Students
- 24 Aug 2007 - Fifth Official End Date for Students

- 01 May 2007 - GBT Azimuth Track Replacement Shutdown Begins
- 01 Aug 2007 - GBT Azimuth Track Replacement Complete?

- 28 May 2007 - NRAO Holiday
- 13 May 2007 - Mother's Day
- 13 Jun 2007 - Pool Opens
- 14 Jun 2007 - 16:00, NRAO 50th Anniversary Celebration (Auditorium)
- 17 Jun 2007 - Father's Day
- 04 Jul 2007 - 17:00, Rabbit Patch 4th of July Picnic
- 04 Jul 2007 - Independence Day
- 04 Aug 2007 - 12:00-22:00, NRAO Picnic (Recreation Area)

- 03 Sep 2007 - NRAO Holiday
- 04 Sep 2007 - Pool Closes

- 20 May 2007 - 24 May 2007 - 8:00-19:00, Neutron Star/Pulsar Workshop
- 03 Jun 2007 - 08 Jun 2007 - 8:00-18:00, Chautaugua 2007 (Science Center)
- 17 Jun 2007 - 21 Jun 2007 - Radio Astronomy at the Frontiers of Astrophysics Conference (Charlottesville)
- 17 Jun 2007 - 23 Jun 2007 - 8:00-18:00, Globe Workshop (Science Center)
- 29 Jun 2007 - National Youth Science Camp Tour
- 01 Jul 2007 - 03 Jul 2007 - 8:00-18:00, Society of Amateur Radio Astronomers (Science Center)
- 04 Jul 2007 - 07 Jul 2007 - 8:00-18:00, StarQuest IV (Science Center)
- 08 Jul 2007 - 15 Jul 2007 - 8:00-18:00, NRAO Single Dish Summer School (Science Center)
- 15 Jul 2007 - 20 Jul 2007 - 8:00-18:00, NASA/NRAO Joint Institute (Science Center)
- 22 Jul 2007 - 27 Jul 2007 - 8:00-18:00, Globe Workshop (Science Center)
- 29 Jul 2007 - 11 Aug 2007 - 8:00-18:00, 2nd Annual Governor's School of Math and Science (Science Center)

- 04 May 2007 - 19:00-20:00, Dr. Who shows (Science Center)
- 04 May 2007 - Dusk, Star Party (Science Center)
- 19 May 2007 - Dusk, Star Party (Science Center)
- 01 Jun 2007 - 19:00-20:00, My Favorite Martian shows (Science Center)
- 16 Jun 2007 - Dusk, Star Party (Science Center)
- 03 Aug 2007 - 19:00, 2001: A space odyssey (Science Center)
- 11 Aug 2007 - Dusk, Star Party (Science Center)

- 07 Jun 2007 - 13:30, Lecture, "The History OF Radio and Introduction to Receivers" by Gary Anderson (Science Center Room 127/128)
- 14 Jun 2007 - 13:30, Lecture, "Pulsars" by Maura McLaughlin or Dunc Lorimer (GB 137)
- 19 Jun 2007 - 09:00, Lecture, "How to use the 40 Foot Telescope" by Sue Ann Heatherly (Science Center)
- 21 Jun 2007 - 13:30, Lecture, "Backend Electronics" by John Ford (Auditorium)
- 28 Jun 2007 - 09:00, Lecture, "Extra-galactic HI" by D.J. Pisano (GB 137)
- 03 Jul 2007 - 13:30, Lecture, "Radio Astronomy" by Jay Lockman (GB 137)
- 05 Jul 2007 - 13:30, Lecture, "Astro-chemistry and Astro-biology" by Glen Langston (GB 137)
- 17 Jul 2007 - 13:30, Lecture, "Improving The GBT Performance At High Frequencies" by Richard Prestage (GB 137)
- 19 Jul 2007 - 13:30, Lecture, "Star Formation" by Paul Ruffle (GB 137)
- 24 Jul 2007 - 13:30, Lecture, "Wintering Over At The South Pole" by Jules Harnet (Auditorium)
- 26 Jul 2007 - 13:30, Lecture, "Very Long Baseline Interferometry" by Frank Ghigo (GB 137)

- 08 Aug 2007 - 13:30, Research Presentations To GB Staff (Holstine, Epstein, Mitchell and Janowiecki (Auditorium)
- 15 Aug 2007 - 13:30, Research Presentations To GB Staff (Brunner, McCarty, Chynoweth and Landon (Auditorium)

- 05 Jun 2007 - 13:30, Summer Student Orientation [Mandatory] (GB 137)
- 06 Jun 2007 - 09:00, Safety Orientation [Mandatory] (Dungeon)

- 21 May 2007 - 9:00, Steven Janowiecki starts
- 29 May 2007 - 9:00, Danielle Holstine starts
- 29 May 2007 - 9:00, Katie Chynoweth starts
- 04 Jun 2007 - 9:00, Courtney Epstein starts
- 04 Jun 2007 - 9:00, Jonathan Landon starts
- 04 Jun 2007 - 9:00, Ilene Mitchell starts
- 04 Jun 2007 - 9:00, Sophia Brunner starts

- 17 Aug 2007 - 17:00, Steven Janowiecki's last day
- 03 Aug 2007 - 17:00, Danielle Holstine's last day
- 21 Aug 2007 - 17:00, Katie Chynoweth's last day
- 10 Aug 2007 - 17:00, Courtney Epstein's last day
- 17 Aug 2007 - 17:00, Sophia Brunner's last day
- 17 Aug 2007 - 17:00, Amy McCarty's last day
- 10 Aug 2007 - 17:00, Ilene Mitchell's last day
- 24 Aug 2007 - 17:00, Jonathan Landon's last day

- 04 Jun 2007 - 19:00, Book Release Party ("But it was fun: the first forty years of radio astronomy at Green Bank")
- 05 Jun 2007 - 18:00, Meet The Summer Student BBQ (Director's House)

- 06 Jun 2007 - 10:45, GBT Tour (meet in Jansky Lab Lobby)
- 15 Jun 2007 - 10:00, Anechoic Chamber Tour
- 12 Jun 2007 - 13:00, GBT Observations Planning Meeting (Dungeon)
- 15 Jul 2007 - 19:00-07:00, GBT Observing (GBT Control Room)

- 31 May 2007 - 16:00, Colloquium by Juergen Ott, "Ammonia in the Local (and not so Local) Universe" (GB 137, video-conference)
- 03 Jul 2007 - 10:30, Colloquium by Andy Clegg, "New Challenges in Spectrum Management for Radio Astronomy" (Auditorium)

- 18 Jul 2007 - 10:30-12:00, Meet with NSF representatives - Steven, Danielle, Sophia and Courtney only (Room 241)


# 4. Site Specific Activities: Socorro, NM

The 2007 REU program at NRAO Socorro was under the direction of Amy Mioduszewski. There were seven students in the 2007 Summer Student Research Program at NRAO Socorro. Four of the students participated via the NSF Research Experience for Undergraduates (NSF REU) program, two were supported by the NRAO Graduate Research Program (NRAO GRP), and one was supported by the NRAO Undergraduate Research Program (NRAO uGRP). The above photograph shows several of the students at the VLA visitor center. From the left there is Rosa Torres Lopez (NRAO GRP), Jennifer van Saders (NSF REU), Nickolas Lee (NSF REU), Karen Mogren (NSF REU) and Diana Grijalva (NRAO uGRP). Not shown are Michael Carilli (NSF REU) and Matthew Klimek (NREO GRP).

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 "Wednesday Lunch" (free pizza for students!), Tuesday Science Tea held in the upstairs lounge, scientific colloquia, and ultimate Frisbee on Tuesday and Thursday evenings. The group toured three observatories: the VLA, VLBA Pie Town station, and McDonald Observatory. On weekends the students gave public tours of the VLA.

The scientific highlight of the summer was the two student-led observational projects, one using the VLA and the other using the VLBA. One group used the VLA to do a radio follow-up investigation of a newly discovered gravitational lens system at 20 cm. The lensed source is a high redshift galaxy. This system presents the opportunity to study the emission from what would normally be a very faint high redshift galaxy. The VLBA project targeted a cataclysmic variable, AR UMa. This binary star system which was been detected with the VLA at 20 cm and is particularly interesting as it has the highest inferred magnetic field of any known CV. The VLBA observation would help to identify the structure and emission mechanism of the CV.

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).

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## Socorro Summer 2007 Schedule

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### Weekly Events

| Day | Date | Time | Item | Location |
|---|---|---|---|---|
| Tue | | 4 pm | Science Tea (free cookies!) | 3rd Floor Lounge |
| Wed | | 12 n | Pizza Lunch (free pizza!) | Auditorium |
| Sat | Jun 16 - Aug 4 | 10 am - 4 pm | Tours | VLA Site |

### Daily Calendar

| Day | Date | Time | Item | Location |
|---|---|---|---|---|
| Fri | June 1 | | Summer program starts | AOC |
| Mon | Jun 4 | 4 pm | Student Reception + Dinner | Auditorium |
| Wed | Jun 6 | 1 pm | Safety Meeting | Auditorium |
| Thu | Jun 7 | 8 am | VLA Tour Meeting --- Robin Harrison | meet at AOC |
| Mon | Jun 11 | 11 am | Introduction to Radio Interferometry I -- R. Perley | Soc-317 |
| Tue | Jun 12 | 11 am | Introduction to Radio Interferometry II -- R. Perley | Soc-317 |
| Thu | Jun 14 | 11a-5p | NRAO 50th Anniversary Festivities | Auditorium |
| Fri | Jun 15 | 10 am | Radio Imaging -- G. Taylor | Auditorium |
| Tue | Jun 19 | 11am | Antennae/Receivers -- M. McKinnon | Auditorium |
| Thu | Jun 21 | 11 am | Radio Galaxies -- J. Eilek | Auditorium |
| Mon | Jun 25 | 8 am | Apache Point Tour/NSO/Three Rivers/White Sands Field Trip | meet at AOC |
| Tue | Jun 26 | 11 am | VLBA - C. Walker | Auditorium |
| Thu | Jun 28 | 2 pm | VLA/VLBA Observing Project Meeting | SOC-317 |
| Mon | Jul 2 | 11 am | VLA/VLBA Observing Project TAC | SOC-317 |
| Wed | Jul 4 | | NRAO Holiday (Independence Day) | |

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|---|---|---|---|---|
| Thu | Jul 5 | Evening | Barbeque with the NSO/KPNO REU students | Sedillo Park |
| Tue | Jul 17 | 5 pm | Dinner with the McDonald Observatory REU Students | Meet at the AOC |
| Wed | Jul 18 | 11 am | Solar System --- B. Butler | Auditorium |
| Thu | Jul 19 | 1 pm | Star Formation --- D. Shepherd | SOC-317 |
| Tue | Jul 24 | 11 am | Local Galaxies --- D. Meier | Auditorium |
| Thu | Jul 26 | 11 am | High Redshift Universe --- J. Wagg | Auditorium |
| Fri | Jul 27 | 10 am | Meeting with NSF --- REU students only | Auditorium |
| Wed | Aug 1 | 12 n | Summer Student Presentations -- J. van Sader, N. Lee, R. Torres | Auditorium |
| Fri | Aug 3 | 11:45am | End-of-summer lunch | Socorro Springs |
| Wed | Aug 15 | 12 pm | Summer Student Presentations -- M. Carilli, K. Morgen | Auditorium |
| Wed | Aug 22 | 12 pm | Summer Student Presentations - M. Klimek, D. Grijalva | Auditorium |
| Fri | Sep 28 | | End of Summer Write-Ups | email to Amy M. |

# 5. REU Project Summaries

This section lists short summaries of the projects for 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 Assistantship Program.

## *2007 Summer Students*

**Paula Aguirre, of Universidad Católica de Chile,**
**worked with Juan Uson on**

### HI Observations of the Edge-On Spiral Galaxy UGC10043

This project will entail an analysis of VLA Observations of the HI emission in the edge-on spiral galaxy UGC10043. The observations consist of 2 x 8h in C array plus 2.5h in D array. The galaxy is somewhat peculiar as previously published HST and WIYN observations have revealed a number of structurally and kinematically interesting features in this system, including a prolate bulge with orthogonally

decoupled components, a minor axis dust lane (implying material with misaligned angular momentum), evidence for distinct inner and outer disk components, and a large-scale galactic wind. These features may be tied to multiple episodes of gas accretion. The deep VLA HI observations will test this picture, by tracing the neutral gas distribution and kinematics of UGC10043, and will also allow a search for associated extraplanar, infalling, or otherwise anomalous HI material. The student will reduce the observations, make the corresponding images and obtain spectra and moment maps. The student shall analyze these in order to produce an observational paper with a preliminary kinematic analysis as well as a correlation of HI features with the structures revealed by the optical data.


**Alan Aversa, of University of Arizona,**
**worked with Kelsey Johnson on**

## Searching for the Youngest Star Clusters

Globular star clusters were formed prodigiously in the primordial universe and are the most ancient objects known, almost as old as the universe itself. As such, they are the only relics of the early universe that can be used to probe the detailed astrophysical processes that took place at the time of galaxy assembly. By studying relatively nearby nascent globular clusters with radio light, we can penetrate their birth cocoons and witness their formation. This REU project will use radio observations of starburst galaxies in both the northern and southern hemisphere to search for natal globular clusters and place constraints on their birth environments.

**Heidi Brooks, of Reed College,**
**worked with Tim Bastian on**

## Radio Emission from Interplanetary Shocks


**Sophia Brunner, of Bennington College,**
**worked with Jay Lockman on**

## Dust and Gas in the Southern Milky Way

The student project would be an analysis of the new galactic HI survey of the Southern sky made with the Parkes radio telescope to determine the correlation between gas and dust in the diffuse interstellar medium. The work would involve comparing the HI spectra with information on interstellar dust from surveys in the far infrared. The research would determine the general properties of the gas-dust correlation, study the thresholds for the onset of formation of molecular hydrogen, and examine the dust

in special objects such as intermediate and high-velocity HI clouds.

**Michael Carilli, of University of Notre Dame,**
**worked with Jeff Wagg on**

## Galaxy formation at (sub)mm wavelengths

The development of single-dish (and multi-element) facilities operating at submm/mm wavelengths has shed new light on our understanding of how massive galaxies formed in the early Universe. Over the past 10 years, 'Blank-field' submm/mm surveys using bolometer array cameras on single-dish antennas have discovered hundreds of optically obscured starburst galaxies, where the UV radiation from hot stars is being absorbed and re-emitted by dust as thermal radiation at far-infrared to mm wavelengths. In order to fully understand the nature of these extreme objects, there are 3 outstanding questions which current and future surveys and experiments should answer: 1) What is the redshift distribution of this population? 2) How many objects are there as a function of wavelength and limiting flux density (referred to as the 'source counts')? 3) How strongly are these galaxies clustered? In order to help plan the multi-wavelength surveys aimed at addressing these problems, a student will develop simulations in order to understand the biases (clustering, limited angular resolution, etc ...) inherent in such experiments. In particular, a student will write idl code to simulate maps of submm galaxies (based on observed number count models), that include instrument and sky noise. Once the software is in place, the student will make simulated maps of what (sub)mm interferometers (like ALMA) will observe, in order to explore the optimal design (depth and area) for future surveys. The student will Some UNIX experience and idl programming would be helpful but is not required.

**Katie Chynoweth, of Vanderbilt University,**
**worked with Glen Langston on**

## Producing Images of the M81/M82

The project that the student will be working on is producing images of the M81/M82 group from GBT spectral line observations and then combining the data with VLA observations to make a higher resolution image.

**Courtney Epstein, of Oberlin College,**
**worked with Maura McLaughlin, Dunc Lorimar, Vlad Kondratiev on**

## WVU, NRAO, Cornell GBT Pulsar Drift Search Survey

Pulsars, rapidly rotating highly magnetized neutron stars, are fascinating objects to study and can be used as probes of fundamental physics. This summer, a joint project between West Virginia University

(WVU), NRAO and Cornell will utilize part of the summer shutdown period of the Green Bank Telescope to search for new pulsars. The project will use the GBT as a transit instrument to survey the sky as it drifts overhead. We expect to find dozens of exciting new pulsars in the survey. The student will be involved with the observations and the data reduction. The student is expected to make some of the first discoveries from the survey.


**Michael Freed, of Newport News Shipyard Apprentice School,**
**worked with Anne Verbiscer on**

## Saturns Satellites at True Opposition

On 14 January 2005, in a rare cosmic alignment, the Earth passed directly between Saturn and the Sun. Viewed from Saturn's moons, this resulted in a transit of the Earth across the center of the solar disk. From the Earth, this event, which will not occur again until 2049, provided the opportunity to observe the saturnian satellites at "true" opposition. A world-wide space- and ground-based campaign using 9 telescopes at 7 observatories from Italy to the Western US and HST acquired ~40GB of imaging data in the visible and near-infrared. These data include the satellites "opposition effect", the dramatic increase in their brightness that occurs as the solar phase angle (between the Earth-Sun-satellite) decreases toward zero. The amplitude and width of the opposition effect reveal surface particle properties (such as porosity, grain size, and grain size distribution) that contain important clues to the thermal and weathering history of the satellites. The student will analyze a subset of this remarkable data set to extract the opposition effect of Saturn's satellites thereby revealing the physical properties of their surface microstructure.

**Diana Grijalva, of New Mexico Tech,**
**worked with David Meier and Vincent Fish on**

## Exploring Frequency-Dependent Recombination Line Effects in ON 1

The hydroxyl masers in massive star forming region ON 1 are seen to be in expansion, but the masers projected against the continuum are redshifted compared to the ultracompact Hii region, as measured from 14.7 GHz recombination line emission. However, the spectral index of the continuum emission is shallower than expected for optically thick emission. This, combined with evidence that low-frequency recombination lines may probe only the nearest ionized material rather than the velocity of the central star, call into question the assumed velocity for the continuum emission in ON 1. To test whether this is the case, the student will reduce and analyze VLA data of 8.6 and 43 GHz recombination lines toward ON 1. Comparison of the velocities will indicate whether optical depth effects skew the apparent source velocity. A moment map and spectral index map of the region may also allow conclusions to be drawn regarding the physical processes and multiplicity of sources in the ionized region.

**AJ Heroux, of University of Wisconsin - Whitewater,**
**worked with Jeff Mangum on**

## Formaldehyde Densitometry of External Galaxies

This project aims to measure H2CO in mainly starburst galaxies to derive the spatial density in these objects. Formaldehyde ($ H_2CO $) is a proven tracer of the high density environs of molecular clouds. It is ubiquitous: $ H_2CO $ is associated with 80% of the HII regions surveyed by Downes et. al. (1980), and possesses a large number of observationally accessible transitions from centimeter to far-infrared wavelengths. Because $ H_2CO $ is a slightly asymmetric rotor molecule, each rotational energy level is split by this asymmetry into two energy levels. Therefore, the energy levels must be designated by a total angular momentum quantum number, J, the projection of J along the symmetry axis for a limiting prolate symmetric top, $ K_{-1}$, and the projection of J along the symmetry axis for a limiting oblate symmetric top, $ K_{+1}$. This splitting leads to two basic types of transitions: the high-frequency $ \Delta J = 1, \Delta K_{-1}= 0, \Delta K_{+1}= -1 $ ``P-branch" transitions and the lower-frequency $ \Delta J = 0, \Delta K_{-1}= 0, \Delta K_{+1}= \pm 1 $ ``Q-branch" transitions, popularly known as the ``K-doublet" transitions. The P-branch transitions are only seen in emission in regions where $ n(H_2) \geq 10^5 cm^{-3}$. The excitation of the K-doublet transitions, though, is not so simple. For $ n(H_2) \leq 10^5 cm^{-3}$, the lower energy states of the $ 1_{10}\rightarrow 1_{11}$ through $ 5_{14}\rightarrow 5_{15}$ K-doublet transitions become overpopulated due to a collisional selection effect (Evans etal (1975); Garrison etal (1975)). This overpopulation cools the $ J\leq5 $ K-doublets to excitation temperatures lower than that of the cosmic microwave background, causing them to appear in absorption. For $ n(H_2) \geq 10^{5.5} cm^{-3}$, this collisional pump is quenched and the $ J\leq 5 $ K-doublets are then seen in emission over a wide range of kinetic temperatures and abundances. For structurally-simple molecular clouds, this density-selective property of the K-doublet transitions allows for a simple and definite identification of the highest densities. This project aims to measure the spatial density in starburst and AGN nuclei of mainly nearby galaxies to accurately derive the spatial density in these environments.

**Danielle Holstine, of Wheeling Jesuit University,**
**worked with Carla Beaudet, Amy Shelton on**

## RFI Visualization for the GBT

Radio frequency interference (RFI) in Green Bank, West Virginia presents an increasingly significant barrier to the collection of quality radio astronomy scientific data. In this project, the student will work with several staff mentors in a cross-disciplinary effort to develop the GBT's RFI monitoring and reporting mechanism for observers. The student will build tools to facilitate evaluation of the RFI impact on scientific data and will collate RFI reports into a database that can be used for RFI visualization which would enable scientists to leverage this information and, as a direct result, improve the quality of their data.

**Steven Janowiecki, of Case Western Reserve University,**
**worked with D.J. Pisano on**

## Dust and Gas in the Southern Milky Way

The student project would be an analysis of the new galactic HI survey of the Southern sky made with the Parkes radio telescope to determine the correlation between gas and dust in the diffuse interstellar medium. The work would involve comparing the HI spectra with information on interstellar dust from surveys in the far infrared. The research would determine the general properties of the gas-dust correlation, study the thresholds for the onset of formation of molecular hydrogen, and examine the dust in special objects such as intermediate and high-velocity HI clouds.


**Benjamin Jewell, of Ohio University,**
**worked with Art Symmes on**

## Structural Health Monitoring System for ALMA Antennas

In February 2007, it was determined that a joint in one of the Quadrapod legs supporting the sub-reflector of the North American 12-meter Antenna had experienced a failure involving an adhesive bond between a CFRP member and an INVAR insert. This joint failure was distorting the shape of the primary reflector to the extent that astigmatism in the surface was observed. However, the joint failure could have potentially caused serious structural damage to the Antenna or personnel injury during fast motion activities. What is of particular concern to NRAO engineers is that we have no means of knowing exactly how long this damage existed in the Quadrapod structure. The summer project will investigate methods for equipping the Antennas with a "Structural Health Monitoring System" (SHMS). Of particular interest will be what structural information could (or should) be monitored, what equipment would be necessary, and how often the monitoring or assessment of the SHMS data would need to be done.

**Matthew Klimek, of Rutgers University,**
**worked with Frazer Owen on**

## Low Frequency Spectra of MicroJy Radio Sources

The main project will be to study the properties microJy radio population in the 1046+59 deep field as a function of low frequency spectral index. We now have 20, 50 and 90cm images of the field which are deeper than anyone has published so far. The initial result for the spectral indices is that the microJy sources have flatter low frequency spectra than their milliJy counterparts. It appears that this is due to many of the sources having a spectral turnover at low frequencies. Since the median size of these sources is > 1 arcsec the turnovers are likely due mostly to free-free absorption. The 20 and 90cm data images are almost finished but the 50cm image from GMRT will improve significantly between now and June. The goal of the project is will be analyze the spectral results (spectral index histograms,

spectral curvature etc) and what types of identifications go with the sources as a function of spectral properties using our extensive data at other wavelengths. Some radio imaging may also be involved.

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**Jonathan Landon, of Brigham Young University,**
**worked with Roger Norrod, Rick Fisher on**

## An Array Receiver for the GB 20 Meter Telescope

We have a request to collaborate with a group from BYU, Rick Fisher, and Rich Bradley to install an array receiver and signal processing electronics on the GB 20-meter antenna to do experiments related to RFI mitigation. A summer student would assist in outfitting the antenna and in performing the experiments. We do not yet have approval to go ahead with this collaboration, but if we do not get approval, Rick Fisher will supervise the student in related work using existing facilities at GB. Rick and I will jointly supervise the student.

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**Nicholas Lee, of University of California, Berkeley,**
**worked with Chris Carilli on**

## A search for HCN 1-0 emission from the galaxy J1635+6612

The student will use the VLA to search for HCN 1-0 emission from the submm galaxy J1635+6612, a strongly lensed submm source at z=2.5168. Previous VLA data yielded a 3sigma detection of the HCN line in this source. HCN is well known as a tracer of dense gas (critical density for excitation > 3e4 cm-3), due to its high dipole moment. HCN is a tracer of the dense gas in GMCs directly associated with star formation, as opposed to CO, which tracers both high and lower density molecular gas. This would be the first HCN detection at high redshift in a galaxy that does not host a powerful AGN. As such, this galaxy provides an important comparison to the AGN-hosts in terms of understanding the relationship between the dense gas mass (the fuel for star formation) and the FIR luminosity (i.e. star formation rate). The data may also provide a spatially resolved image of the dense gas on kpc-scales.

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**Diane Leigh, of University of Virginia,**
**worked with Anthony Remijan on**

## Investigating the Physical and Chemical Environments of Hot Cores in the Interstellar Medium

As the number of detections of large interstellar and circumstellar molecules continues to grow, it is quite obvious that observations are clearly outpacing the predictions of the chemical models. Also, most of the 147 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. Over the last several years, the primary instrument used in detecting these large molecular species has been the NRAO Green Bank Telescope. Yet despite ongoing additions to the list of detected hot core molecules, very little is understood about the formation mechanisms for those species already detected. Recent chemical modelling work has made it apparent that the physical parameters of a hot core will greatly influence the resultant chemical evolution. This is not a surprising result, and the two hot core regions that have been examined in enough detail to provide sufficient physical constraints for these models are Orion and Sagittarius B2(N). The student or students willing to work on this project will investigate archival GBT, VLA and BIMA array data of hot cores including Orion and Sagittarius B2(N), to further investigate the physical and chemical environments of these very interesting regions. Furthermore, the student will have the opportunity to suggest their own astrochemistry projects and perhaps be the first to identify a new, unique interstellar molecule from this vast archival dataset. 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 a hot core. This project is open to both graduate and undergraduate students interested in astrochemistry, astrobiology, star formation and the physics and chemistry of the ISM. Computer programming experience is highly recommended.

**Ryan Lynch, of University of Virginia,**
**worked with Scott Ransom on**

## Searching for and then characterizing millisecond pulsars in globular clusters using data from the GBT

Ryan used highly sensitive new GBT observations of several bulge globular clusters to search for new millisecond pulsars. This computationally-intensive effort resulted in the discovery of at least four new millisecond pulsars. Follow-up efforts using the GBT are underway to establish timing solutions for the pulsars to determine what science may be probed by the new systems.

**Karen Mogren, of Northern Arizona University,**
**worked with Bryan Butler on**

## Radar Reflectivity of Mars

I have a large number of unreduced observations of the radar reflectivity of Mars (from the oppositions of 1999 and 2003). The student would reduce the data, all the way to final radar reflectivity images (which involves some unique processing steps because of the frequency resolution of the radar). Interpretation of the images will include analysis of the Stealth, Argyre, Hellas, volcanic (including the older ones), and polar regions. This would be an extension of the work done by Tyson Mao in 2005 and Malynda Chizek in 2006 (they each reduced one of the datasets from 2003).

**Timothy Pennucci, of Columbia University, Columbia College,**
**worked with Scott Ransom on**

## 350 MHz GBT Track Repair Pulsar Driftscan Survey

Tim helped to develop a stable processing pipeline for the 350 MHz GBT Track Repair Pulsar Driftscan Survey. This survey, which took data from the beginning of May until the mid-August 2007, generated almost 140 TB of data and will likely find dozens of new pulsars. Tim also developing methods to characterize the highly variable radio frequency intereference environment caused by the track upgrade activities.

**Paul Ries, of University of Virginia,**
**worked with Richard Bradley on**

## Low Frequency Satellite Measurements

Electromagnetic modeling techniques have improved the performance of low frequency antennas and phased arrays. However, it is often a challenge to confirm the actual beam pattern of the manufactured antenna, even at a single frequency, due to the inherent physical size of such structures. An alternative approach is to measure the pattern using signals from a constellation of LEO satellites. With this high dynamic range technique, the antenna is measured in situ, revealing not only the small scale structure in the pattern resulting from mutual coupling and sidelobes, but also those caused by reflections and obstructions in the vicinity of the antenna.

Paul Ries helped to develop a proof-of-concept system to measure the beam pattern of an antenna using signals at 137 MHz from the Orbcomm satellite constellation. He built a two-channel receiver and a PC-based data acquisition system that is capable of simultaneously tracking the satellites, measuring their power, and correcting for range. Paul deployed this system at our field station in Green Bank where he used it to map the beam of a dipole reference antenna and compared it with that obtained by electromagnetic modeling using CST Microwave Studio. In addition, by comparing the power levels from two identical antennas, he was able to clearly show spots in the pattern caused by diffraction from nearby objects. The dynamic range of such measurements approached 50 dB. Paul's work over the summer is documented in a brief report that is available at the PAPER project website.

**Charles Romero, of University of Colorado,**
**worked with Robert Reid on**

## How Long Will the SKAs Baselines Need To Be?

The world's next generation radio telescope, the Square Kilometer Array (SKA) is being planned, and in order for it to meet its scientific and budgetary requirements, many innovations will have to be made.

One tradeoff it faces is between resolution (antenna separation) and expense and sensitivity to extended emission. It is currently thought that the SKA will need ~1000 km maximum baselines in order to separate (i.e. avoid confusing) the many densely packed sources it will see in any given direction. It is possible, however, to wring sharper resolution out of shorter baselines using deconvolution and deeper observations. Your task would be to determine whether there really would be any advantage to making the SKA antenna placement more compact than is currently planned. This will be done using as input simulations of both the deep radio sky and a simple model of the SKA.

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**Rosa Torres, of Centro de Radioastronomia y Astrofisica - UNAM,**
**worked with Amy Mioduszewski on**

## Astrometry of PMS Stars

The distances to low mass Pre-main Sequence (PMS) stars are poorly determined because they are heavily obscured. Hipparcos typically produced 10-20% errors in the two most heavily studied low mass star formation complexes, Taurus and rho Ophiuchus. Accurate distances are very important to calculating reasonable estimates of the fundamental parameters of these systems. Fortunately some low mas PMS stars emit non-thermal radiation that can be detected by the VLBA. Rosa Torres is working on this for her thesis, we have 9 stars in total. She will reduce the data and fit parallaxes and proper motions for 6 more stars, 2 more in Taurus and 4 in rho Ophiuchus.

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**Jennifer Van Saders, of Rutgers University,**
**worked with Wei-Hao Wang on**

## Faint Submillimeter Sources Lensed by Clusters

Faint submillimeter sources contribute most of the star formation in the entire history of the universe. However, because of their faintness and the limit capability of current submillimeter telescopes, very little is known about them. In order to better understand the faint submillimeter sources, we use the gravity of galaxy clusters to enhance the sensitivity of our telescopes and aim for detecting a sample of faint sources gravitationally lensed by the clusters. We had obtained a deep submillimeter map of the cluster Abell 963 and detected a few submillimeter sources lensed by this cluster. In this summer project, the student will be provided the reduced data of this cluster and is expected to achieve the following: 1. to understand general radio/submillimeter/IR/optical observational issues in the studies of submillimeter sources and the connection to broader ideas of galaxy evolution. 2. to use an already existing gravitional lens model for the cluster Abell 963 to infer the unlensed configuration (fluxes and spatial density) of the detected submillimeter sources.

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**Mary Wilkins, of James Madison University,**

**worked with Crystal Brogan on**

### A Caltech Submillimeter Observatory Study of Three Promising Zeeman Molecules

I would like a summer student to work on reducing and analyzing a Caltech Submillimeter Observatory survey of massive star forming regions using 1mm lines of three molecules with strong Zeeman coefficients: CN, SO, and CCH. Observations of these molecules with ALMA will allow us to probe for the first time the magnetic field strengths in the very densest (thermal) gas where massive stars form. To date little is know about the distribution and strength of these lines in massive cores. The results of this survey will be an important step in identifying both the best candidates and the best molecule for future ALMA Zeeman studies.

# 6. RET Project Summaries

This section lists a short summary of the project for the RET participant in the NRAO 2007 Summer Teacher Program.

**Identifying Extended Regions of Neutral Hydrogen Surrounding Isolated Galaxies**

McCarty, A., [1] Pisano, D. J.

[1]*National Radio Astronomy Observatory, Green Bank, WV. dpisano@nrao.edu*

Interferometers (like the VLA) and single-dish radio telescopes (like the GBT) see the sky in different ways. By properly comparing VLA and GBT observations of neutral hydrogen (HI) in a sample of galaxies, we can search for signatures of very diffuse, extended gas associated with these galaxies. These data will permit a more accurate measure of the total mass of these galaxies and provide insight into the total extent of galaxies. By studying a large sample of galaxies in different environments, we can try and determine how the environment affects the galaxy's properties.

# 7. Participation in the AAS 211th Meeting, January 7-11, 2008

Eight of the NRAO summer program participants, including five of the REU students, three of the GRP students, and the one RET participant, will travel to Austin, Texas, to attend the 211th Meeting of the American Astronomical Society , from January 7-11, 2008.

The deadline for submission of abstracts to the Austin meeting is October 17, 2007. The deadline for late submissions is December 5, 2007. We anticipate that the Abstracts will be available for review on the AAS schedule web page at http://www.aas.org/meetings/aas211/schedule.php by mid December 2007.

# Poster Abstracts for the AAS 209th Meeting, January 5-10, 2007

Eleven of the NRAO summer program participants, including six of the REU students, and four of
the GRP students, and one RET participant, will travel to Austin, Texas to attend the 211th Meeting of the American Astronomical Society , from January 7-11, 2008. One REU student presented their summer research at the AAS DPS meeting in Orlando, Florida. Below are the titles and abstracts of the posters they will present describing the results of their summer research. Many of the abstracts will specifically acknowledge the NSF REU program. In the interest of concision the acknowledgments are omitted here.

## A 19-Element L-band Focal Plane Array for Interference Mitigation with Auxiliary Reference Antenna on the Green Bank 20-meter Telescope

**Jonathan Landon**[1], R. Norrod[2], R. Fisher[2]

*[1]Brigham Young University, [2]NRAO.*

**Presentation Number:** 011.10

**Facility Keywords:** Green Bank 20 meter

A fully-sampled, electrically small focal plane array (FPA) was installed on the 20 meter telescope at the Green Bank NRAO facility during the summer of 2007 to demonstrate adaptive beamforming for sensitivity optimization and interference mitigation in Radio Astronomy. The array consists of 19 dipoles tuned to 1600MHz, 0.25ë above a ground plane, spaced 0.6ë from each other. Synchronously-sampled voltages from all receivers are streamed to disk, then digitally filtered and complex-basebanded prior to spectrum analysis, electronic beamsteering, and square-law detection in post-processing. A 3.6m reference antenna is set up to obtain a high-gain reference copy of interferer data for higher interferer-to-noise ratio measurements. Experiments study multiple beam formation and spatial interference cancellation using common beamformers such as LCMV and Max-SNR adapted to a parabolic reflector. Antenna test range measurements show significant effects of mutual coupling on individual element beampatterns with a closely-packed array. Preliminary results of interference mitigation will also be presented.

## Discovery of a Small Group that Drives the Evolution of the Peculiar Edge-on Sbc Spiral Galaxy UGC100043.

**Paula Aguirre**[1], J. M. Uson[2], L. D. Matthews[3]

*[1]Pontificia Universidad Catolica & NRAO, Chile, [2]NRAO, [3]CfA.*

**Presentation Number:** 013.05

**Facility Keywords:** VLA

UGC10043 is an edge-on Sbc spiral galaxy with several peculiar morphological characteristics that distinguish it from typical Sb-Sc galaxies, suggesting a complex formation history and evolution. Despite its thin, dynamically cold stellar disk, it shows a vertically elongated, triaxial bulge that is bisected on its SW quadrant by a dust lane perpendicular to its major axis. It also exhibits a large-scale galactic wind powered by a faint central starburst. Such features relate UGC10043 to families of relatively rare objects such as polar ring galaxies, orthogonally decoupled bulge systems, and minor-axis dust-lane ellipticals, suggesting that its evolution must have included a significant merger or accretion event. New HI spectral imaging observations carried out with the VLA in its C and D configurations have provided us with new insight into the complex evolutionary history of UGC10043. Our observations reveal that the galaxy is located in a small group, and we detect HI emission from four of its galaxies. We also have uncovered a kinematically continuous HI bridge parallel to the major axis of UGC10043 that connects it to a previously unknown companion, MGC+04-37-035, which is being dynamically heated by the interaction. We will discuss how the current interaction has likely affected the present morphological and kinematic peculiarities of UGC10043 and more generally how studies of this system can offer important insights into how the group environment affects the structure and evolution of typical disk galaxies.

## The GASS HI Survey And FIR Emission From The Magellanic Stream

**Steven Janowiecki**[1], S. Brunner[2], D. J. Pisano[3], F. J. Lockman[3], N. McClure-Griffiths[4], A. Ford[5], L. Staveley-Smith[6], M. R. Calabretta[4], T. Murphy[7], P. M. W. Kalberla[8], H. Nakanishi[4]

*[1]CWRU, [2]Bennington, [3]NRAO, [4]ATNF, Australia, [5]Swinburne, Australia, [6]U. West. Australia, Australia, [7]Sydney, Australia, [8]Bonn, Germany.*

**Presentation Number:** 014.17

**Facility Keywords:** Parkes (), IRAS ()

The new Galactic All Sky Survey (GASS) measured 21cm neutral hydrogen using the Parkes Multibeam instrument at high velocity resolution over all declinations south of the equator. We use a preliminary reduction of these data to study the correlation between HI and far-infrared emission (as derived from the IRIS reprocessing of the IRAS 100-micron survey) across the Southern Hemisphere, and particularly in the Magellanic Stream. While the Magellanic Stream is prominent in HI, it is essentially invisible in the FIR with a FIR emissivity per HI atom at most one tenth that of Galactic disk gas. The low FIR emissivity of the Magellanic Stream allows to trace it in maps of the FIR/HI ratio as a shadow across the sky, even where its HI is blended with local around V(lsr) = 0.

## FIR Emissivity of Selected Regions of the Magellanic Stream

**Sophia Brunner**[1], S. Janowieki[2], D. J. Pisano[3], F. J. Lockman[3]

*[1]Bennington College, [2]Case Western Reserve University, [3]NRAO.*

**Presentation Number:** 014.18

Using HI from the new GASS survey of the southern sky, and reprocessed IRAS 100-micron data (IRIS) we have studied the FIR emissivity of three selected regions of the Magellanic Stream (MS), chosen so that the Stream is kinematically distinct from local gas and bright enough to contribute significantly to the total HI column density in those directions. We divided the HI spectra into local and MS components, and compared these to the FIR emission across each field, where the FIR data were convolved to the same angular resolution as the HI. Within each field, a constant emissivity was assumed for each component. The results for the local gas are consistent from one field to the next, and comparable to previous determinations (e.g. Boulanger and Perault 1988). However, no trace of FIR emission was found from the Magellanic Stream. We will present the quantitative results and their implications for questions of abundances and dust heating in the MS.

## GOODS 850-5 - A z>4 Galaxy Discovered In The Submillimeter?

**Jennifer Van Saders**[1], W. Wang[2], L. L. Cowie[3], A. J. Barger[4], J. P. Williams[3]

*[1]Rutgers, The State University of New Jersey, NRAO, [2]NRAO, [3]Institute for Astronomy, University of Hawaii, [4]Department of Astronomy, University of Wisconsin-Madison.*

**Presentation Number:** 052.18

We report an SMA interferometric identification of a bright submillimeter source, GOODS 850-5. This source is one of the brightest 850 $\mu$m sources in the GOODS-N but is extremely faint at all other wavelengths. It is not detected in the GOODS HST ACS images and only shows a weak 2$\sigma$ signal at 1.4 GHz. It is detected in the Spitzer IRAC bands and the MIPS 24 $\mu$m band, however, with very low fluxes. The large observed 850 $\mu$m /1.4GHz and 850 $\mu$m /24 $\mu$m flux ratios both suggest a z>4 galaxy. The optical and near-IR photometric data only provide reasonably fitted photometric redshifts for z=5.2-8.0.

## The Low-Frequency Spectra of µJy Radio Sources in the 1046+59 Deep Field

**Matthew Klimek**[1], F. Owen[2]

*[1]Rutgers Univ./NRAO, [2]NRAO.*

**Presentation Number:** 052.19

**Facility Keywords:** VLA, GMRT

The 1046+59 Deep Field has been observed at 20- and 90-cm with the VLA and at 50-cm with the GMRT. These are the deepest images ever made at these wavelengths, with RMS noise levels of 2.7 micro-Jy and 70

micro-Jy respectively in the 20- and 90-cm images. The field has also been covered in submillimeter, NIR, optical, and X-ray bands. We investigate the low-frequency spectral properties of the field's micro-Jy radio population through a stacking analysis of 20-cm selected sources. We find evidence for a flattening of the radio spectrum at low frequencies, with 90/20-cm spectral indexes of ~0.5. There is also some evidence that higher luminosity sources may have flatter spectral indexes than their lower luminosity counterparts. Free-free absorption seems the most likely mechanism for this flattening, and we discuss the implications of the presence of large volumes of ionized gas on scenarios for galaxy evolution. Finally, we compare the spectra of the micro-Jy sources to examples of ULIRGs and star-forming galaxies in the local universe.

## A Radio Search for Natal Star Clusters in Nearby Star-Forming Galaxies

**Alan Aversa**[1], K. E. Johnson[1], C. L. Brogan[1], M. Goss[2], D. J. Pisano[3]

*[1]National Radio Astronomy Observatory, Charlottesville, [2]National Radio Astronomy Observatory, Socorro, [3]National Radio Astronomy Observatory, Greenbank.*

**Presentation Number:** 058.25

To search for evidence of extragalactic natal star clusters, we observed a total of 28 star-forming galaxies in K- and X-bands with the Australia Telescope Compact Array (ATCA) and the Very Large Array (VLA). Spectral indices $\alpha$, where $S\nu \propto \nu^{\alpha}$, determine whether a radio source is a potentially embedded star cluster. The ionizing flux of massive embedded stars powers the dominant thermal free-free emission of those sources with $\alpha > -0.1$. Based on the radio emission flux densities we can infer the ionizing flux of the star cluster and determine how many equivalent O7.5 V stars are necessary to produce the observed radio flux densities.

Within the $1\sigma$ errors of our spectral indices, we detected only 8 galaxies with natal star formation regions out of the 28 selected for our sample. Because we selected all the galaxies in our sample based upon their likelihood of harboring young star formation, the dearth of massive natal star formation regions suggests that this evolutionary stage of the massive clusters is very short-lived. The largest clusters we detected have an equivalent of ~$10^4$ O7.5 V stars and the smallest only have an equivalent of ~$10^2$ stars, thus these clusters are not massive super-star clusters (SSCs), which generally contain >$10^4$ type O stars. Therefore, our observations help us to understand the relationship between star forming environments and the mass of the resulting stellar clusters.

## Presentation of Results From the Study of Radio Properties of Lyman Break Galaxies in the COSMOS Field

**Nicholas Lee**[1], C. Carilli[2]

[1]*UC Berkeley and NRAO,* [2]*NRAO.*

**Presentation Number:** 095.31

An analysis of the radio properties of Lyman Break Galaxies in the COSMOS field is presented. There are 6457 U-Dropouts, 1447 B-Dropouts, and 614 V-Dropouts in this field. The percentage of radio loud AGN in Lyman Break Galaxies is found to be around 0.3% for all dropouts, in good agreement with previously measured values by Shapley et al. (2003). A stacking analysis is performed on the data sets for each of the dropouts, and an average flux density for each dropout is found. Average star formation rates and dust extinctions are derived using these average values. The U-dropouts had a median radio flux density of 0.90 microJy with an RMS of 0.21 microJy, which leads to an average star formation rate of 13.5 Msun/year, and an average dust extinction of 5. The B-dropouts had a median radio flux density of 0.83 microJy with an RMS of 0.42 microJy, which leads to an average SFR of 23.65 Msun/year and a dust extinction of 9. Finally, the V-Dropouts had a median radio flux density of 1.72 microJy with an RMS of 0.68 microJy. This leads to an average SFR of 80.64, and a dust extinction of 25. By reaching sub-microJy sensitivity at 1.4 GHz, we are able to do SKA science without the SKA.

## Testing SKA configurations

**Charles Romero**[1], R. I. Reid[2]

[1]*University of Colorado and NRAO,* [2]*NRAO.*

**Presentation Number:** 133.01

The Square Kilometer Array (SKA) is a next generation radio telescope with a collecting area of one square kilometer. Its purpose is to provide a powerful tool to any group observing within the possible frequencies; however, some projects require high sensitivity, whereas others require sharp angular resolution to avoid confusion. Because the stations will have fixed locations, it is essential to find the optimal configuration before construction begins. We will present the results of our simulations (the advantages and disadvantages of several configurations), as well as the method used to simulate observations.

## The Distance to Rho-Ophiuchus

**Rosa M. Torres-Lopez**[1], A. J. Mioduszewki[2], L. R. Loinard[1], L. F. Rodriguez[1]

[1]*UNAM, Mexico,* [2]*NRAO.*

**Presentation Number:** 147.01

Using multi-epoch VLBA 3.6 cm observations, we have recently determined the trigonometric parallax of several

young stars in Rho-Ophiuchus, and found that two sources associated with the sub-cloud Oph-A are at 120 +/- 5 pc, whereas two sources in the sub-cloud Oph-B are at 160 +/- 5 pc. The difference is significant, and our results suggest that Oph-A and Oph-B do not belong to the same star-forming complex; instead, they appear to be two distinct regions of star-formation, unrelated to one another, but projected in the same direction of the celestial sphere. This "resolves" a long-standing debate, as to whether Rho-Ophiuchus is at 120 or 160 pc: it is at both.

## Research Experience for Teachers at NRAO-Green Bank: Identifying Extended Regions of Neutral Hydrogen Surrounding Isolated Galaxies

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**Presentation Number:** 005.13

**Facility Keywords:** GBT, VLA

Funded by the National Science Foundation's Research Experience for Teachers program, we compared single dish and interferometer data in order to facilitate the identification of regions of diffuse neutral hydrogen surrounding a pre-selected set of isolated galaxies. These galaxies are also being utilized as the focal point of a curriculum on scientific research for high school physics students.

The spectra of 31 isolated galaxies at 21 cm were previously observed with the VLA and the Green Bank Telescope. It was expected that areas of diffuse neutral hydrogen surrounding a galaxy would be manifested by a greater flux density in the GBT spectrum data than in the VLA spectrum. Twenty two of the galaxies exhibited a significant flux difference between the VLA and GBT spectrum. Of these, ten had VLA flux that was greater than the GBT flux - an unexpected result. Several of these galaxies will be re-observed with the GBT in order to determine if there was a calibration or pointing error resulting in the GBT flux being less than the VLA flux. The study of these galaxies is ongoing.

The curriculum that we have designed for physics students focuses on the nature of astronomical research. Students are traditionally instructed that scientific research is carried out according to the rigid structure of the "scientific method." This fails to expose them to the evolutionary nature of research that occurs in astronomy and its largely descriptive nature. Students will utilize online astronomical databases to facilitate the characterization, and then categorization, of the isolated galaxies. The culmination of the unit will be student presentations and defenses of their categorization of the galaxies to an astronomer.

The following poster presentation was made at the AAS DPS meeting in Orlando, Florida.

## Near-infrared Observations of Saturn's Satellites at True Opposition

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**Presentation Number:** 41.01

The 2005 opposition of Saturn presented the rare opportunity to observe its satellites at the smallest possible phase angles attainable at Saturn's heliocentric distance. Here we present the analysis of observations obtained at Pic du Midi Observatory using Moicam, an infrared imaging instrument mounted on the 2-m Telescope Bernard Lyot during the period 10 - 17 January 2005 at phase angles ranging from 0.37° to 0.01°. Using broadband near-infrared filters JHK, centered at 1.2, 1.6, and 2.2 microns, respectively, we observed the opposition effect on Enceladus, Tethys, Dione, and Rhea. In addition, observations using the narrow band Paschen beta filter, centered at 1.28 microns, reveal the opposition effect on Titan and Iapetus.