NRAO Newsletter

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

January 2002 www.nrao.edu/news/newsletters *Number 90*

DIRECTOR'S OFFICE

Paul Vanden Bout to Step Down as NRAO Director

As most of you are aware, Paul Vanden Bout will step down as director of NRAO in about a year's time after leading the observatory for nearly 18 years.

Paul came to the NRAO as director in January 1985 from the University of Texas at Austin. At the time, the VLBA project was in the stages of final approval and the Barrett committee had just identified the need for a large millimeter array. The intervening years have seen great change at NRAO—just as in the astronomical science undertaken with the NRAO telescopes. Paul's tenure as director will have seen the construction of the VLBA and the GBT, the linkage of the VLBA Pie Town antenna with the VLA, the design and development of the MMA, now ALMA, planning for the EVLA project, the undertaking of the NVSS and FIRST surveys, and continuous attempts to improve the performance and efficiency of the existing facilities. While these achievements are the work of many on the observatory staff, Paul's leadership and vision, particularly in times of tight and even declining budgets, have enabled them. Widely respected both nationally and internationally, his role in the forging of the ALMA partnership has been key. His reputation and statesmanship have secured a promising future for NRAO with the most recent approval of the initiation of the EVLA project and funding for construction of ALMA.

The NRAO director is engaged in many management tasks that are relatively invisible and most often frustrating. In this role, Paul has been both unflappable and unyielding. His persistence and constant focus on the long-term interests of both the observatory and radio astronomy has gained him—and through him, the entire observatory—the well-deserved respect and admiration of scientists, engineers, government officials, and administrators worldwide. His legacy will be left both in the current and future scientific and technical advances his directorship has overseen and also in the excellence of the NRAO staff his leadership has assembled and enabled.

Paul has stated for some time that he would wish to turn over the NRAO helm when the GBT became operational and the EVLA and ALMA were launched. Happily, those times are upon us. Thus, while his shoes loom large to fill, AUI is preparing to undertake a full search to identify a new director who will lead NRAO into this most promising future. Claude Canizares of MIT, a member of the Board of Trustees, will chair the AUI Search Committee, which will have both staff and community representation. It is hoped that this task can be completed by next fall.

When he steps down, Paul plans to take a well-earned sabbatic to reengage himself in the science of molecular astronomy. Afterwards, he will return to the NRAO scientific staff and undoubtedly become engaged in the observatory in other ways. He looks forward to spending a bit more time with his family, and, we suspect, making his own plans for a first observing proposal for ALMA.

Martha Haynes, Chairman, AUI Board of Trustees

Index

Other Changes in NRAO Senior Management

Ulvestad is New Head of New Mexico Operations

Jim Ulvestad has assumed the position of Assistant Director for New Mexico Operations in Socorro, New Mexico, effective December 15. As Assistant Director, Ulvestad will oversee the operation and management of the Very Large Array (VLA) and the Very Long Baseline Array (VLBA). He succeeds W. Miller Goss, who stepped down as Assistant Director after serving in that capacity since 1988.

Jim previously served as NRAO's Deputy Assistant Director in Socorro. He joined the observatory in 1996 after spending 12 years on the staff of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif. We are delighted that he will assume this vital position for our observatory. His solid background as a researcher, his broad knowledge of the astronomical community and his detailed understanding of the VLA and the VLBA will help us keep these facilities at the cutting edge of science in the coming years.

P. A. Vanden Bout

Hogg Assumes New Responsibilities

With the additional responsibilities associated with moving forward on the EVLA and ALMA, I have asked NRAO Scientist David E. Hogg to take on additional management duties within the observatory. He has agreed to assume the position of Assistant to the Director in the NRAO's Charlottesville headquarters.

In addition to helping to manage the expanding program of the observatory, Hogg also will help the Director's Office in responding to NSF with the additional reporting requirements that these projects entail.

Dave's broad experience makes him highly qualified for this position. He has served in many management roles for the observatory, including site director for both Green Bank and Tucson. I am both thankful for his commitment to the observatory, and confident that these projects will receive the necessary oversight to ensure their success.

P. A. Vanden Bout

ALMA

ALMA Construction Poised To Begin

On November 26, 2001, President George W. Bush signed the Fiscal Year 2002 appropriations bill for the Veteran’s Administration, Housing and Urban Development and Independent Agencies, including the National Science Foundation. The bill appropriates $12.5 million in funding for the start of ALMA construction. The long-awaited start of construction in the U.S. can now occur once the project receives authorization by the National Science Board, expected early next year. Funding for the European part of the ALMA project is expected to be approved in mid 2002. Unfortunately, funding for Japan’s participation in ALMA construction has been delayed until at least 2004.

Recognizing the course of recent events, the ALMA Coordinating Committee (ACC) decided at its October meeting that it had no choice but to move forward with a bilateral project. In this plan, the complete work breakdown structure for the baseline scope is to be carried out by the North American and European partners. The baseline scope includes sixty-four, 12-meter antennas and four receiver bands. Any additional scope that could be made possible by a late Japanese entry in the project will be determined when the magnitude of available Japanese resources is better known.

In the meantime, activities over the next year will focus on prototype antenna evaluation. The U.S prototype antenna will be delivered to the VLA site in April 2002. The European prototype is now expected approximately one year later. Plans are in place for the rigorous testing of each antenna to verify that they meet the challenging ALMA specifications. Evaluation of the antennas will be carried out by an international team lead by Jeff Mangum (NRAO-Tucson). Antenna tests will utilize specialized hardware and software, much of which was developed by ALMA teams in Tucson, Charlottesville, and Socorro.

For the many people who have worked so hard for so many years to get ALMA off the ground, it is hard to realize that we are now at the beginning of a very exciting journey. It’s finally time to go build something grand.

M. D. Rafal

EVLA

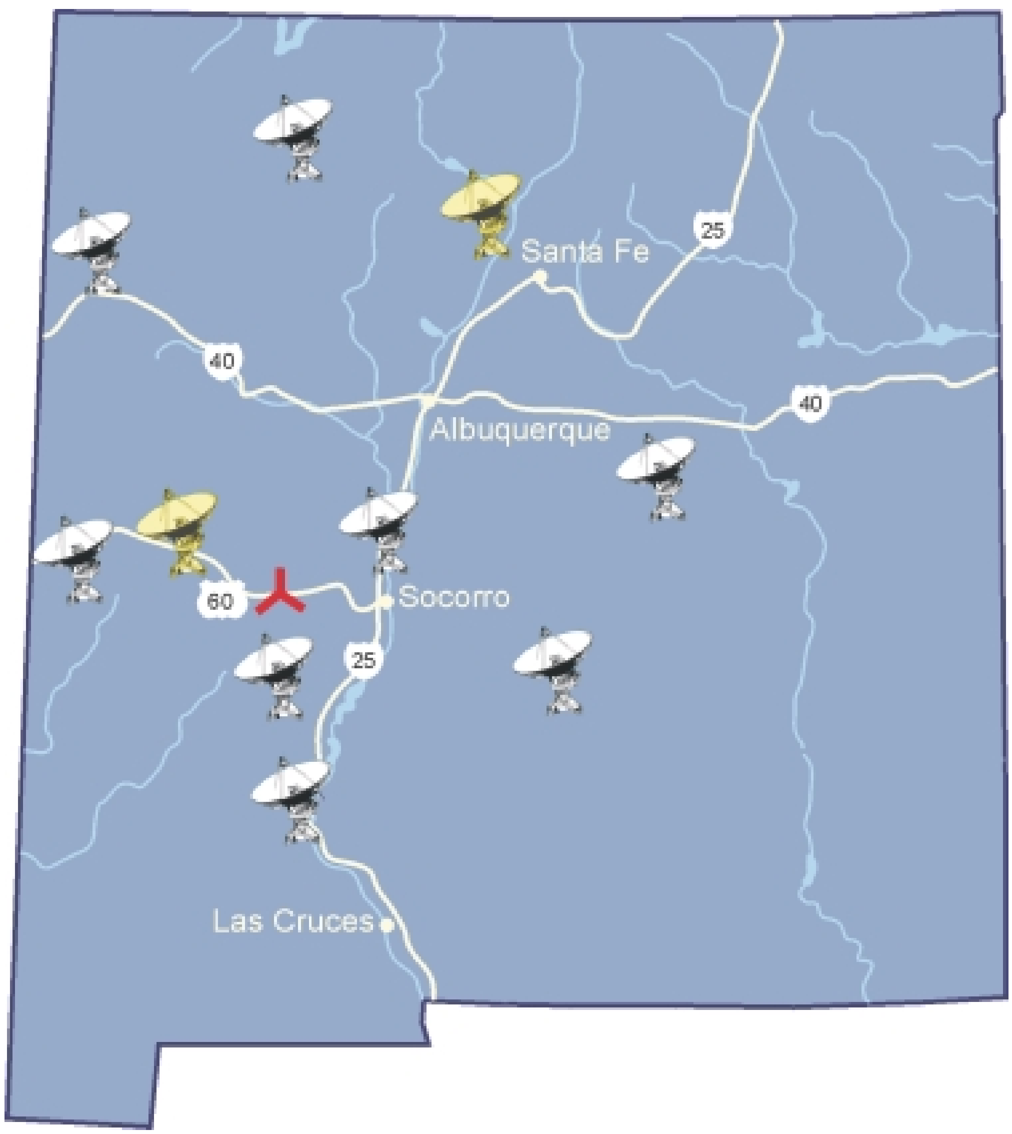
EVLA Project News

The VLA Expansion Project has received approval from the National Science Board to begin construction. The Board, at its meeting in Washington on November 15, approved an NSF award of approximately $58.3 million for the project. This total includes an allocation for predicted future inflation. The decision permits purchase of equipment and hiring of staff necessary for completion of the project in approximately 2010. The NSF award will cover "Phase I" of the project—order-of-magnitude improvements of the VLA's continuum sensitivity, frequency coverage, correlator capabilities, and data processing. A proposal to complete the project—focusing primarily on a tenfold increase in resolution of the array—is currently under development.

Meanwhile, a series of Preliminary Design Reviews for major portions of the project is now underway. The first, a "Correlator Conceptual Design Review," was held in Socorro on November 2, and resulted in approval of the overall approach being taken by the Herzberg Institute of Astrophysics, designers of the correlator. The next, the "EVLA System and Fiber Optics Review," was held December 4 and 5. Four more reviews are scheduled in January and February of 2002. Information concerning these reviews, and the reports from the review panels, when available, can be found on the web at *http://www.aoc.nrao.edu/evla/pdrs.shtml*.

Current information on the EVLA Project will be found on the project website: *http://www.aoc.nrao.edu/evla*. Users interested in the EVLA Project Book can find it at: *http://www.aoc.nrao.edu/evla/pbook.shtml*. This document, which gives a detailed overview of the project, is under constant revision in response to evolving requirements, solutions, and constraints.

R. A. Perley, P. J. Napier



This map shows the possible locations of the antennas that will make up the EVLA. Existing VLBA antennas are shown in yellow. The current VLA is indicated in red.

GREEN BANK

The Green Bank Telescope

This autumn has seen the successful resolution of most of the remaining mechanical issues with the GBT antenna and considerable progress in scientific commissioning. Good progress has been made toward introducing general spectral line observing capability, and the first spectral line Early Science programs should be underway by the time this article appears.

In the last Newsletter, we reported that the antenna braking system applied peak torque more rapidly than was desired. Consequently, a hard stop at maximum slew rate could overstress the structure. To protect the structure until a solution could be implemented, the maximum slew rate was reduced to one-quarter of its design specification. This made antenna movement slow, and impeded commissioning progress. To solve this problem, NRAO engineers, in cooperation with the contractor, Lockheed-Martin, developed a new braking system. Most of the brakes were replaced with a newly available Stearns brake that applies torque gradually over a three-second interval. These new brakes serve as stopping and holding brakes. About one-fourth of the old, rapid-actuating brakes were left in place, and serve as slowing brakes. This brake replacement was completed successfully in mid-November. Slew rates in both azimuth and elevation have now been returned to their design specifications of 40 deg/min and 20 deg/min, respectively.

The stability of the GBT's azimuth track has been a major concern over the past year. As reported in previous newsletters, a reworking of the azimuth track was carried out by Lockheed-Martin last May and June in which the track hold-down bolts were increased in length and diameter, and tripled in number. This work appears to be very successful—track wear-plate slippage was reduced by a factor of ~50 and there have been no bolt failures since the reworking. To assess the long-term viability of this solution, NRAO let a consulting contract with VertexRSI for detailed modeling and analysis of the reworked track. The consultant concluded that the solution should be effective for the life of the wear-plate and should not require further work in the short term. However, we will continue to monitor the track as a precautional measure.

A new Antenna Coordination Group has been formed in Green Bank with overview responsibility for all aspects of the antenna structure and electro-mechanical systems. This group is led by Tim Weadon, and has members from the GBT Computing, Electronics, and Telescope Operations Divisions, as well as the NRAO structural engineering staff. This group has already been successful in addressing a number of issues with the GBT.

As an interim measure until mechanical issues were fully resolved, control of the GBT has been carried out from the Servo Room located on the lower level of the alidade structure. Both the operator and observer have worked from this room, which is rather noisy and inconvenient. As mechanical, remote control, and monitoring issues are now being resolved, control of the GBT is scheduled to move to the main Jansky Lab control room in December. The working environment is much better in this room, and assistance from the operational and technical staff is more readily available.

Commissioning effort over the past few months has focused on the spectral line capability. A number of components are required for spectral line observing, including local oscillator control and Doppler tracking, operation of the new GBT spectrometer, the synthesis of data files from the modular control system, and a rather complete implementation of the new AIPS++/DISH reduction package. In September, we brought a "tiger team" together from all the working groups to complete the implementation and testing of this capability. The team has worked very hard and been quite focused in their efforts. We are now taking test spectral line data routinely with both the GBT Spectrometer and the Spectral Processor. By mid-December, basic spectral line capability in selected observing modes and configurations should be in place and verified, and the first spectral line Early Science observations will be initiated. Further work will continue during the winter months to implement and test all common spectral line observing configurations. Some of the early results from spectral line commissioning are given in the accompanying article.

Commissioning and development activities needed for high frequency operation of the GBT are also being addressed. High frequency operation requires the implementation of the Precision Telescope Control System (PTCS) that brings together the metrology system, active surface system, focus-tracking, and finite-element model of the antenna. The PTCS group achieved an important milestone in November in which they were able to use production hardware and software to achieve an absolute XYZ trilateration measurement of a position on the GBT structure to a few hundred microns rms using a set of four laser rangefinders. The group continues to refine their techniques. The holography group also began testing instrumentation for their measurement campaign. The first holography maps are expected in January.

A number of Early Science pulsar observations were done during the autumn using the Berkley-Caltech Pulsar Machine (BCPM) and the Spectral Processor in pulsar mode. A VLBI "ties" experiement was done using the GBT and the Green Bank 20 Meter antenna to refine the coordinates of the GBT. Another bi-static radar observation was scheduled for early December.

P. R. Jewell

Status of the GBT Commissioning - Early Results

The commissioning of the GBT progresses well and we are nearing the end of phase I, at which point the telescope will be ready for observing up to 15 GHz. We have already begun some phase II commissioning tasks for preparing the telescope for 50 GHz observing. As in previous commissioning reports, the news concerning the telescope structure remains good. For example, we have determined a focus tracking algorithm that will be useful at frequencies up to about 50 GHz.

Over the last few months we have concentrated our efforts almost exclusively on developing the spectral line capabilities of the system. This includes rigorous testing of the Spectrometer, refinement of observer interfaces, and development of data calibration and reduction algorithms within AIPS++. The illustrative spectrum (Figure 1) shows essentially a flat baseline even though the data were taken during the day when most telescopes would produce spectra with noticeable ripples from standing waves in the optics.

We have also been working on other observing modes. For example, every week we are successfully taking standard data sets consisting of several types of observations—spectral line observations, continuum on-the-fly maps, skydips, pointing measurements, etc. The telescope has been involved in a few successful VLBI test sessions and should be available for first scientific observation in the first quarter of 2002. Since September, observations of pulsars have been scheduled almost every week for up to a few dozen hours. The success rate of the pulsar observations is rather good for the GBT at its current stage of commissioning. NRAO astronomers are also paving the way for other observers who will want to use GBT data to fill in the zero spacings inherently absent in interferometric data. The X-band image (Figure 2) of the Orion Nebula, which will be combined with VLA data, has a fidelity about an order of magnitude higher than is usually achieved by conventional single-dish, cm-wave telescopes. The high quality of the image is due to the clean optics of the GBT and the incredibly stable receivers and I.F. components of the telescope.

R. J. Maddalena

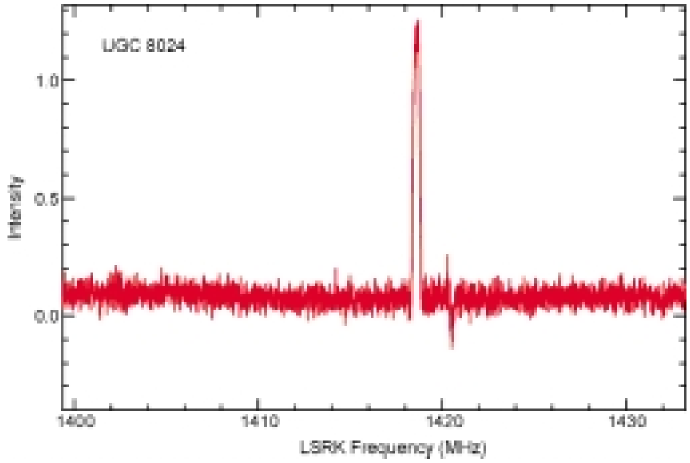


Figure 1. A five minute on-off observation of the galaxy UGC8024 taken with the GBT's Spectrometer. The observation, taken in the Spectrometer's 50 MHz, 8192 channels mode, was processed by AIPS++ and has no baseline removed. Even though the data were taken during the day, the spectrum is essentially flat. The small dip at 1420.4 MHz is due to the difference in galactic HI *emission between the on- and off-source positions.*

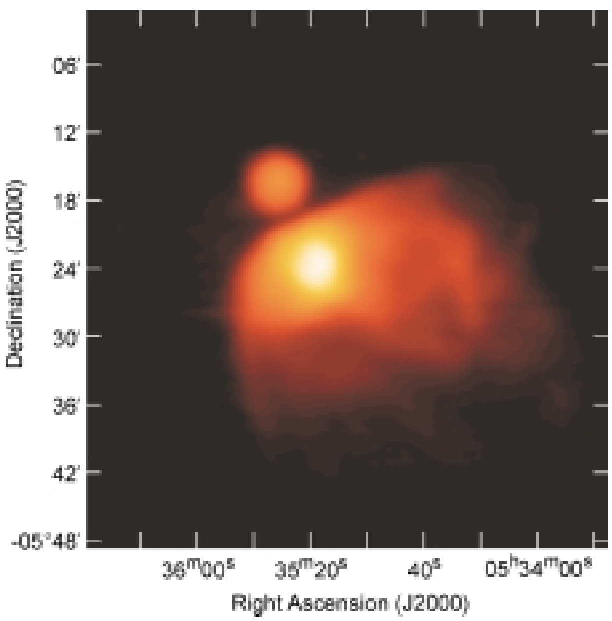


Figure 2. An 8.4 GHz, on-the-fly image of the Orion Nebula that will be used to fill in the missing zero spacings in VLA data. All data processing was performed in AIPS++. Essentially only a very slow, smooth drift in atmospheric emission has been removed from the data (D. Shepherd, R.J. Maddalena, J. McMullin).

Extragalactic HI Survey Program During GBT Commissioning

As we develop and phase in GBT spectral line observing capabilities over the next 1-2 months, some filler time will be available for extragalactic HI survey observations. With this in mind we have begun an informal program of observations of external galaxies in 21-cm HI emission. Contributions to the list of objects to be observed is open to all interested scientists.

Since the survey has not passed through the refereeing process, the ground rules are roughly as follows:

1.All data produced by the survey will immediately become public domain, both in raw form and in any partially or fully analyzed form.

2.Suggestions for candidate objects are open to anyone. Selections for each observing session will attempt to distribute the observing time roughly equally amongst all contributors to the candidate list, aside from calibrator objects. The observing mode will be simple on-off total power spectra.

3.The survey task is lowest priority in the commissioning activities and must not add to the burden of work to get the GBT functioning as a routine service to refereed proposals.

As the GBT comes into full operation in service of refereed proposals, this survey program will be phased out. If you would like more information or have objects to suggest for observation, please send me an email at *rfisher@nrao.edu*.

J. R. Fisher

Construction on Green Bank Education and Visitor Center Begins

By the end of 2002, NRAO Green Bank will have a new Education and Visitor Center serving the visiting public and the region's school children. The center will house interactive exhibits explaining radio waves and the concepts of radio astronomy, and will have dedicated educational facilities and programs for extended visits by school groups.

Construction of the facility began in October and is scheduled for completion by next December. The center will be located in the area between the Jansky Lab and the main highway, near the Reber Telescope. The architect's elevation drawings are shown in Figure 1. The facility will have over 20,000 square feet of floor space on two levels.

As shown in the floor plan (Figure 2), the focus of the facility will be the large exhibit hall. As a separate project, we have contracted for the construction of interactive exhibits. A 150-seat auditorium will be used for orientation presentations and demonstrations. The facility includes three classrooms and a computer lab that will be used primarily for visiting school groups, ranging in age from kindergarten to college. The facility will also feature an outside star patio, large lobby, gift shop, and cafe.

Visitors arriving at the center can tour the exhibit hall, watch the orientation video, then take a bus tour of the site. We expect to entertain as many as 100,000 visitors per year. Following their tour, school groups can then break out into the classrooms for instruction, demonstrations, and experiments. The center will have full-time educators on staff who will build on the extensive educational programs already in place in Green Bank. As a goal, we hope to have every school child in the state of West Virginia visit the center before they graduate from high school.

The construction project manager for the facility is Michael Holstine; the concept scientist is Jay Lockman, and the educational program director is Sue Ann Heatherly. More information on the new center, the exhibits, and the educational program can be found on the web at *http://www.gb.nrao.edu/~sheather/aec.html*.

P. R. Jewell

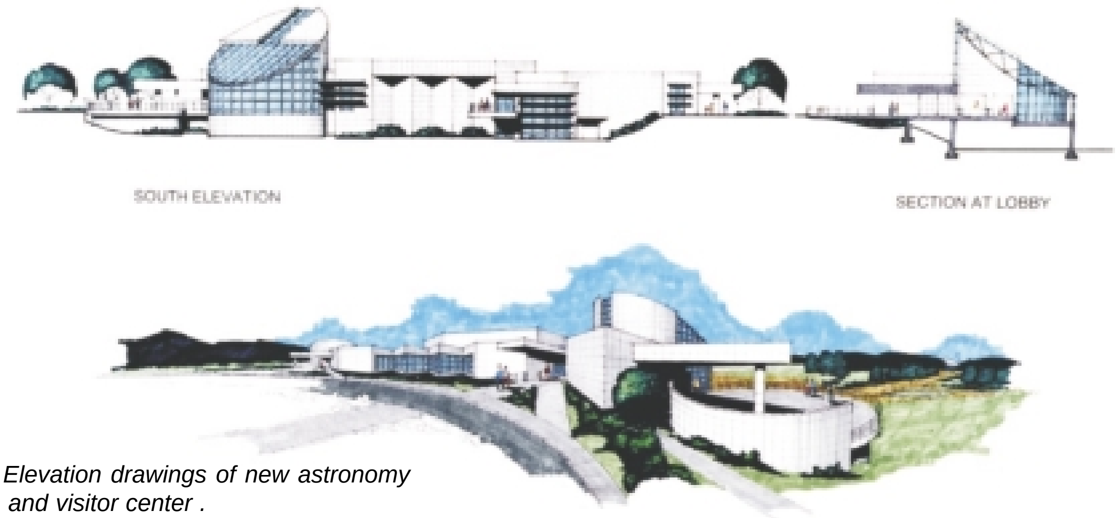


Figure 1. Elevation drawings of new astronomy education and visitor center .

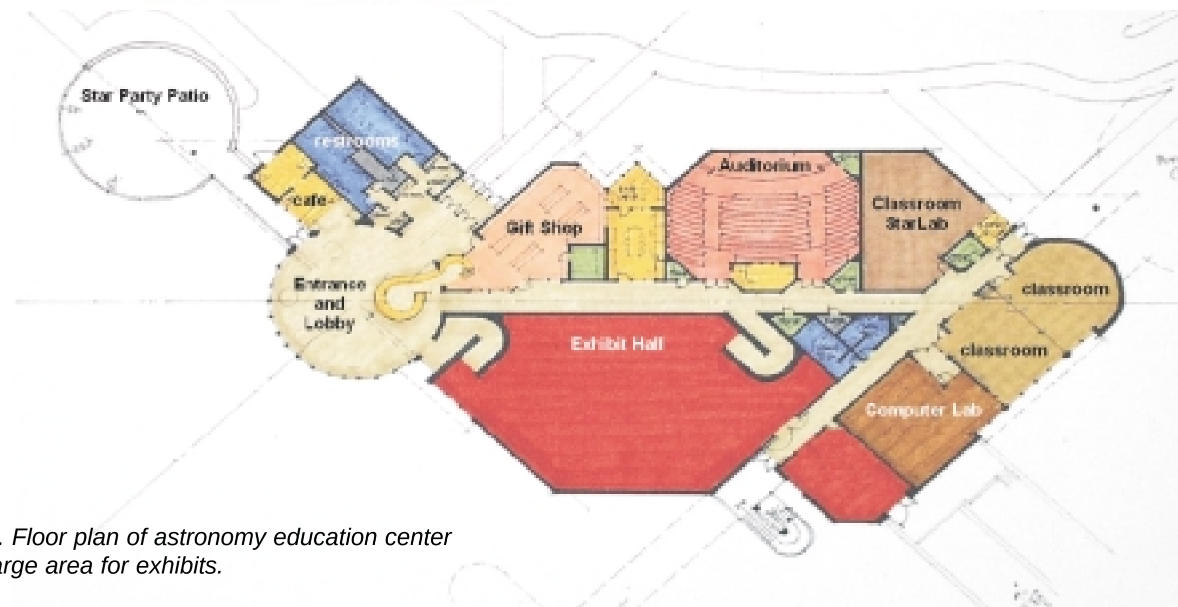


Figure 2. Floor plan of astronomy education center shows large area for exhibits.

Next GBT Proposal Deadline: February 1

As described in the accompanying articles, GBT observing capabilities are developing and we are executing Early Science proposals. Proposals received at the October 1 deadline are now selected and are queued for the winter and spring. Since these observations share time with ongoing commissioning activities, and observations are done only as the capabilities become available, the existing queue of projects will be dispatched gradually.

The next call for proposals will be for February 1. To keep the queue of proposals manageable, we anticipate that only 500-1000 hours of observations will be selected from this batch. The exact amount of time allocated will depend on status and progress at the time the selections are made. Although we will consider proposals of any standard observing type at frequencies below 26 GHz, very strong preference will be given to target of opportunity proposals, and these may be the only ones selected for this call. We anticipate that the June 1 deadline will be largely unrestricted.

P. R. Jewell

SOCORRO IN GENERAL

NRAO-New Mexico: Looking to the Future

On behalf of all the past and present users of the VLA and VLBA, I would like to thank Miller Goss for his vital work as the Assistant Director in charge of VLA/VLBA Operations since 1988, and for the high scientific and service standards that he has set. As discussed elsewhere in this issue of the Newsletter and in previous editions, we are beginning the construction phase of the EVLA, which will be an exciting time for all of us at NRAO-New Mexico. In construction of the EVLA, NRAO has agreed to reduce the cost to the National Science Foundation by making some contribution of personnel resources that previously had been allocated to VLA and VLBA operations. We intend to accept the challenge of maintaining our high standards of service to observers under these circumstances, and will be guided in this regard by comments from the NRAO advisory committees. I look forward to continuing to work with the user community in my new capacity as Assistant Director for Socorro Operations, and invite our users to make suggestions about how we can assist them in achieving the best scientific results with the VLA and VLBA.

J. S. Ulvestad

VLA Configuration Schedule; VLA / VLBA Proposals

Configuration	Starting Date	Ending Date	Proposal Deadline
D	12 Oct 2001	08 Jan 2002	1 Jun 2001
A(+PT)	25 Jan 2002	06 May 2002	1 Oct 2001
BnA	17 May 2002	03 Jun 2002	1 Feb 2002
B	07 Jun 2002	03 Sep 2002	1 Feb 2002
CnB	13 Sep 2002	30 Sep 2002	3 Jun 2002
C	04 Oct 2002	30 Dec 2002	3 Jun 2002
DnC	10 Jan 2003	27 Jan 2003	1 Oct 2002

GENERAL: Please use the most recent proposal coversheets, which can be retrieved on the web at *http://www.nrao.edu/administration/directors_office/tel-vla.shtml* for the VLA and at *http://www.nrao.edu/administration/directors_office/vlba-gvlbi.shtml* for the VLBA. Proposals in Adobe Postscript format may be sent to propsoc@nrao.edu. Please ensure that the Postscript files request US standard letter paper. Proposals may also be sent by paper mail, as described at the web addresses given above. Only black-and-white reproductions of proposal figures will be forwarded to VLA/VLBA referees.

VLA: The maximum antenna separations for the four VLA configurations are A-36 km, B-11 km, C-3 km, and D-1 km. The BnA, CnB, and DnC configurations are the hybrid configurations with the long north arm, which produce a circular beam for sources south of about -15 degree declination and for sources north of about 80 degree declination. Some types of VLA observations are significantly more difficult in daytime than at night. These include observations at 90 cm and 400 cm (solar and other interference; disturbed ionosphere, especially at dawn), deep 20 cm observations (solar interference), line observations at 18 and 21 cm (solar interference), polarization measurements at 18-21 cm (uncertainty in ionospheric rotation measure), and observations at 2 cm and shorter wavelengths in B and A configurations (tropospheric phase variations, especially in summer). Proposers should defer such observations for a configuration cycle to avoid such problems. In 2002, the B configuration daytime will involve RAs between 04^h and 15^h and the C configuration daytime will involve RAs between 12^h and 23^h.

Approximate Long-Term VLA Schedule

	Q1	Q2	Q3	Q4
2002	A	A,B	B	C
2003	D	D,A	A,B	B
2004	C	D	D,A	A
2005	B	B,C	C	D
2006	D,A	A	B	C

There has been an often expressed desire that the VLA have dynamic scheduling to better match high frequency proposals to the weather. The necessary software to handle the bookkeeping for this has been proceeding at a slow pace. It is hoped that we will have a brief test of the concept during the reconfiguration from BnA to B configuration in June.

VLBA: Time will be allocated for the VLBA on intervals approximately corresponding to the VLA configurations, from those proposals in hand at the corresponding VLA proposal deadline. VLBA proposals requesting antennas beyond the 10-element VLBA must justify, quantitatively, the benefits of the additional antennas. Any proposal requesting a non-VLBA antenna is ineligible for dynamic scheduling, and fixed date scheduling of the VLBA is severely constrained. Adverse weather increases the scheduling prospects for dynamics requesting frequencies below about 10 GHz. Scheduling prospects are also enhanced for dynamics requesting only two to three hours of time away from popular right ascensions.

See *http://www.aoc.nrao.edu/vlba/schedules/this_dir.html* for a list of dynamic programs which are currently in the queue or were recently observed. VLBA proposals requesting the GBT, the VLA, and/or Arecibo need to be sent only to the NRAO. Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the European VLBI Network (EVN) is a Global proposal, and must reach BOTH the EVN scheduler and the NRAO on or before the proposal deadline. VLBA proposals requesting only one EVN antenna, or requesting unaffiliated antennas, are handled on a bilateral basis; the proposal should be sent both to the NRAO and to the operating institution of the other antenna requested. Coordination of observations with non-NRAO antennas, other than members of the EVN and the Deep Space Network, is the responsibility of the proposer.

B. G. Clark

VLA Archive to Go On-line

The VLA archive contains over 20 years of observations in the form of about 2TB of Exabyte tapes. Currently, to access data from the data base, one has to ask the AOC data analysts to make and ship a tape copy or to load the data to a staging area from which it can be retrieved by ftp. We plan to move the VLA archive online over the next year, with the result that it will be possible to fulfill data requests via ftp or http transfer. A Storage Area Network is being purchased for this purpose and for subsequent high data volume use.

We expect that the first data will be available in the middle of 2002, but that full access will take longer, depending upon the rate at which we can transfer tapes to disk.

Initially we may have to limit the use of this facility depending on the available bandwidth. Safeguards to protect proprietary data will be put in place (see *http://www.aoc.nrao.edu/vla/vladb/POLICY.html*).

This initiative is a collaboration between the AOC Computing Division and the NRAO End-to-End (e2e) project. The experience gained in putting together this interim archive will guide the e2e project in development of more capable archives for all NRAO telescopes.

The End-to-End project has the goal of improving access to NRAO telescopes and data archives. All aspects of a user's interaction with NRAO telescopes are being addressed: from proposal submission to pipeline processing to archive access. More details of the e2e project can be found in the project book at: *http://www.nrao.edu/e2e*.

T. J. Cornwell and G. A. van Moorsel

NRAO-NM Computing

As a result of increasing demands on office space caused by the expected arrival of new staff in ALMA, EVLA, and Data Management, it has become necessary to reduce the number of 'public' areas at the AOC from five to three. The two 'open' areas on the second and third floor have now been converted to office space. At the same time, the number of public machines has been reduced from 12 to 10. On a more positive note: 8 out of the 10 public machines are newly purchased dual 1.7 GHz Xeon PCs with 512MB of memory and 2 x 73GB of SCSI disk. We intend to have AIPSmarks for these machines determined shortly; we are expecting a number in the eighties for each processor. The other two public machines are our existing two top-of-the line Sun Ultra 10s. We hope that in spite of the decrease in absolute number our data reduction facilities have improved in quality and performance.

JObserve 1.6.4 was released in October 2001. To 1.6.3 it adds a fully updated list of calibrators. JObserve 1.6.5 will be a bug-fix release and is expected in January or February 2002.

G. A. van Moorsel

VLBA

3mm Upgrade Status

Construction and upgrading of 3 mm (W-band) receivers progressed substantially during 2001. Seven systems are currently installed, including five new receivers, at the North Liberty, Fort Davis, Pie Town, Owens Valley, and Mauna Kea stations, and two hybrids, at Kitt Peak and Los Alamos. An eighth system, another new receiver, is scheduled for installation at Hancock during January 2002. All these receivers have in common low receiver temperatures, in the range 50 - 70 K, and low passband ripple. The principal difference is that the new receivers cover a wider frequency range, 80 - 96 GHz, while the hybrid systems are limited to 80 - 90 GHz by the old LO chains that are still in use. During 2002, one additional new receiver will be built, for eventual installation at the Brewster station, and spares of most parts will be acquired. Four of the new receivers were funded by the Max-Planck-Institut fuer Radioastronomie in Bonn, Germany, while the remaining new and upgraded systems were made possible using NRAO operations funding.

Commissioning observations started slowly in 2001, due mainly to difficulties in dynamic scheduling of the relatively small array then available, all stations of which were considered essential for most observations to succeed. Six dynamically scheduled commissioning programs, plus the April CMVA session, were observed through early May, 2001, when an informal summer shutdown took place to allow extensive retrofits to many of the existing systems. Observing resumed in October, including another CMVA session and two additional commissioning programs (through the end of November). It is anticipated that dynamic scheduling will become significantly more flexible when the 3mm array reaches eight stations early in 2002.

For the February 1 deadline, proposals at 3mm will be accepted on the same basis as any other observing wavelength, although only for stand-alone use of the eight dynamically scheduled VLBA stations. Information on the VLBA's 3mm capability is available on the NRAO web site. Observations requiring non-VLBA stations should continue to be submitted to the CMVA.

The 12-GHz transportable local holography system is undergoing several upgrades after comprehensive initial tests. The holography feed mount is being redesigned to accommodate more flexible repositioning around the feed circle, while the reference feed is being moved to a new mount above the subreflector focus/rotation drive, to minimize phase errors arising from pointing offsets. The control and data acquisition software has been moved to a larger PC, which now also runs AIPS to make data analysis possible in the field.

Development of techniques for manual reworking of the subreflector surfaces has begun. A FaroArm coordinate measuring engine, with a coordinate repeatability specification of 75 microns, has been procured and will be incorporated into a work and measurement station to be built during 2002.

Work also has started on improving the pointing of VLBA antennas, with a goal of limiting pointing errors to about 5 arc seconds. Periodic errors have been identified as a major constituent of the overall error budget. Five VLBA antennas have periodic errors, due to miscalibrated angle encoders, that exceed 5 arc seconds. One successful retuning has been completed at the Los Alamos station, reducing the periodic error in elevation from 9 to less than 1 arc second. Results from a similar corrective action at North Liberty in December are not yet available. Another periodic pointing error has been detected, at a period consistent with the tooth spacing on the elevation bull gear, but no fix has yet been devised.

J. D. Romney, W. F. Brisken, V. Dhawan, R. Hayward, J. Thunborg

VLBA Ionospheric Calibration and Phase Referencing

Application of global ionospheric models has been found, in many cases, to greatly improve the calibration of the phases of VLBA visibility data, particularly near solar maximum. This can be especially important in phase-referencing observations, where determination of the relative phase ambiguity between two adjacent calibrator scans is necessary to calibrate the program source properly. The calibration can be performed by correcting the ionospheric dispersive delay using global GPS models for the ionosphere in the AIPS task TECOR; for details see the TECOR explain file as well as VLBA Scientific Memos 22 and 23. TECOR has been upgraded to permit the use of global ionospheric models that cover multiple UT days, necessary for any observations that approach or cross UT midnight.

We recently have determined that, in at least some circumstances, the ionospheric effects are large enough to have a significant impact at observing frequencies as high as 5 GHz or 8 GHz. This result has been reported in VLBA Test Memo No. 68; the Test Memo and the aforementioned Scientific Memos are available on the VLBA web site. We strongly recommend that VLBA observers using phase-referencing at frequencies up to 8 GHz run TECOR before final fringe-fitting on the calibrator. The most careful observers may wish to compare fringe-fit solutions with and without TECOR to insure that the correction has helped their data, since at times, it may not be necessary at the higher frequencies. However, using TECOR when it is not necessary is unlikely to harm the data.

We recommend strongly that observers use a calibrator as close to their target source as possible, preferably much closer than 5 degrees. Even with global ionosphere corrections, phase referencing with reference-target separations of 5 degrees or more may work poorly, or not at all.

A. J. Mioduszewski, J. S. Ulvestad

Short Ad Hoc VLBA Proposals

There is often a need for a short VLBA observation just to check if a calibrator is suitable for a planned observation, or a simple determination of whether a source is compact or not. To simplify the process of getting such observations, we will accept such proposals at any time, and, after a quick determination that the requested observation does not duplicate or interfere with a proposal already submitted, accept an observe file for insertion into the VLBA dynamic queue at very low priority. This low priority means that unless the requested observation is very short - perhaps two or three hours - and can fit between other proposals already in the queue, it will surely not be scheduled.

Proposals should be written in the usual form, with a cover sheet, and sent to propsoc@nrao.edu, with a copy to bclark@aoc.nrao.edu.

B. G. Clark

VLBI Global Network Call For Proposals

Proposals for VLBI Global Network observing are handled by the NRAO. There are usually four Global Network sessions per year, with up to three weeks allowed per session. The Global Network sessions currently planned are:

Date	Bands	Proposals Due
07 Feb to 28 Feb 2002	6 cm, 18 cm, other?	01 Oct 2001
23 May to 13 Jun 2002	6 cm, 18 cm, other?	01 Feb 2002
07 Nov to 28 Nov 2002	6 cm, 18 cm, 3.6 cm	03 Jun 2002

Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the European VLBI Network (EVN) is a Global proposal, and must reach BOTH the EVN scheduler and the NRAO on or before the proposal deadline. In general, FAX submissions of Global proposals will not be accepted. A few EVN-only observations may be processed by the Socorro correlator if they require features of the JIVE correlator which are not yet implemented. Other proposals (not in EVN sessions) that request the use of the Socorro correlator must be sent to NRAO, even if they do not request the use of NRAO antennas. Similarly, proposals that request the use of the JIVE correlator must be sent to the EVN, even if they do not request the use of any EVN antennas. All requests for use of the Bonn correlator must be sent to the MPIfR.

Please use the most recent proposal coversheet, which can be retrieved on the web at *http://www.nrao.edu/administration/directors_office/vlba-gvlbi.shtml*. Proposals may be submitted electronically in Adobe Postscript format. For Global proposals, those to the EVN alone, or those requiring the Bonn correlator, send proposals to proposevn@hp.mpifr-bonn.mpg.de. For proposals to the VLBA or Global proposals, send proposals to propsoc@nrao.edu. Please ensure that the Postscript files sent to the latter address request U.S. standard letter paper. Proposals may also be sent by paper mail, as described at the web address given. Only black-and-white reproductions of proposal figures will be forwarded to VLA/VLBA referees.

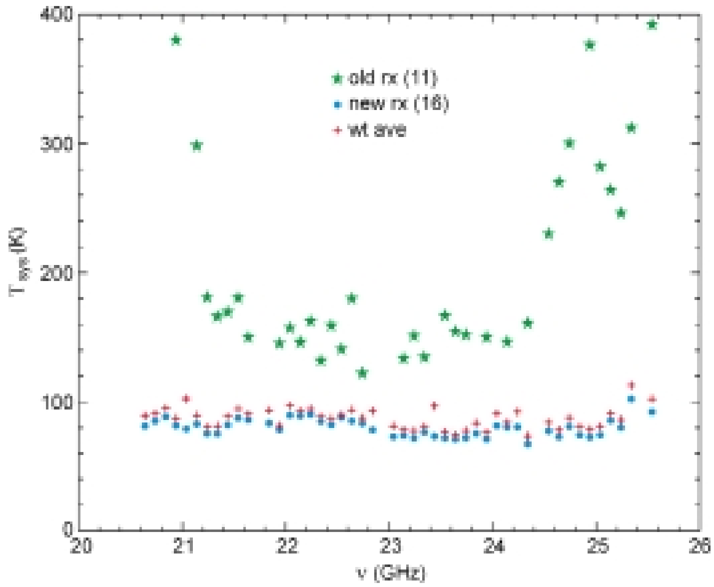
B. G. Clark

VLA

22 GHz at the VLA

As of November 30, 2001, 17 of the VLA antennas have the new low-noise 22 GHz (K-band) receivers installed. The figure shows a comparison of the system temperature as a function of frequency for the new and old receivers, measured in June 2001 when the VLA contained 16 new receivers (and the sky contributed significantly to T_{sys}). Also plotted is the weighted average obtained if data are loaded using AIPS task FILLM with the visibility weights scaled by the system temperature. The sensitivity of the VLA at K-band is now dominated by the new receivers. The available tuning range provided by these receivers is 20.6-25.2 GHz, and the band edges are now limited by the number of antennas for which the local oscillators will lock rather than by the gain of the low noise amplifiers. This increase in tuning range enables sensitive observations of the NH_3 (5,5) and (6,6) inversion transitions, at 24.533 and 25.056 GHz respectively, along with a number of methanol lines at around 25 GHz.

C. J. Chandler and C. L. Carilli



Comparison of the system temperature for the new and old receivers.

VLA Hosts "Flag Across America"

NRAO hosted the runners and support personnel of the "AAmericans United Flag Across America" run as the transcontinental memorial and fund raising effort came through New Mexico. The flag run arrived at the VLA early in the post-Midnight morning of Monday, November 5, and departed after sunrise that morning en route to the Arizona border.

Drivers, runners and support personnel stayed overnight at the VLA. During the night, a "VLA Night Owl Run" kept the flag moving around the VLA area until the westward trek resumed after dawn.

"AAmericans United Flag Across America" run leaves the VLA in Socorro, New Mexico.

NRAO staff members joined the run. As the flag left the VLA headed for Arizona, Ramon Molina, Richard Murillo, Bob Broilo, Steve Aragon and Jim Ulvestad led the first few miles. Dave Finley ran during the "Night Owl" portion of the event.

The run began October 11, one month after the terrorist attacks on New York and Washington. Organized by employees of American and United Airlines to honor the flight crews lost in those attacks, to show support for U.S. troops and to raise funds to help the victims' families, the run took an American flag from Boston Logan Airport to Los Angeles International Airport.

The 3,872-mile Boston-to-Los Angeles trip represents the intended journey of American Flight 11 and United Flight 175, both of which were crashed by terrorists into the World Trade Center.

"Our observatory was proud to host this group and honored that they brought this flag through our facility," said Miller Goss, NRAO's director of VLA operations.

Dee Friesen, a Captain for American Airlines and New Mexico coordinator for the flag run, called the VLA visit "a terrific experience," adding that, "for me, it was the highlight of the trip."

The runners carried a flag that flew in a U.S. F-16 over Iraq in support of Operation Southern Watch on Oct. 2, and has visited Ground Zero in Manhattan. Thousands of runners carried the flag on its cross-country journey and tens of thousands of Americans touched it.

The flag arrived in Los Angeles on Veterans Day, November 11, carried for the last mile by the families of flight crews and passengers lost in the terrorist attacks.

For more information about the run, see: *http://www.flagrun.org*

D. G. Finley

IN GENERAL

Data Management: Important Computing Security Changes

Since the NRAO Computer Security Policy was issued two years ago, we have made a number of changes that have greatly reduced the risk of a serious break-in at the NRAO. One of the remaining steps to be taken primarily affects those who need to connect to NRAO computers from non-NRAO locations.

In several previous issues of the NRAO Newsletter, we described programs that use encryption to protect sensitive account information such as passwords, so that they are not exposed to network monitoring while you are making a connection. We encouraged our user community to begin using these programs, which are secure alternatives to commands such as telnet, rlogin, and rsh. Since early 2001, unencrypted access has been limited to a small number of systems at each major NRAO site.

We are now announcing our intention to block all connections using telnet, rlogin, rsh, and rcp from non-NRAO systems. We note that other major astronomical centers, such as the NOAO, Jodrell Bank, and the Chandra X-ray telescope data center, have recently adopted similar policies with respect to such insecure connection protocols.

Effective July 1, 2002, when you wish to connect to NRAO systems from another location, you will need to use slogin, ssh, and scp under UNIX; several Windows and Macintosh implementations are also available (e.g. SecureCRT, TTSSH, MacSSH). These programs are widely supported at academic and research institutions around the world, and are included in Linux. Please contact your local computer support staff if you are not sure of availability at your site.

We realize that there may be some inconvenience associated with this change, and are therefore providing this 6-month advance notice so that you can prepare for it. This step will help to ensure the reliability and integrity of the computing environment for all users of our facilities.

If you have any questions or concerns about this change, please feel free to contact Ruth Milner, the NRAO Computing Security Manager *(rmilner@nrao.edu)*.

M. R. Milner

AIPS++

The AIPS++ project issued the fifth public release of the package, v1.6, in December 2001. A copy of the package can be obtained by sending e-mail to *aips2-request@nrao.edu*, or by visiting our web site, *http://aips2.nrao.edu*, for details on how to download the package over the network. At present we issue public releases for Linux and Solaris. The v1.6 CD-ROMS will also be available at the AIPS++ booth at the 199th meeting of the AAS to be held 6-10 January in Washington, DC.

The AIPS++ package is a data reduction system for radio astronomy developed by a consortium of observatories, including the NRAO, BIMA, ATNF, NRAL and ASTRON. It supports an instrument-independent model of data reduction, for both synthesis and single-dish telescopes. A toolkit is also provided with strong scripting capabilities for scientific end-users. Full details of the current package capabilities can be obtained from the project web site listed above.

The current release features a re-editing of large parts of the user-level documentation, improved data display and editing capabilities, and expanded calibration and imaging modes. The current focus of development within the package is on scientific completeness, robustness and user interface improvements. The VLA cookbook chapter has been substantially revised, and now uses example datasets and associated reduction scripts which are distributed with the system to illustrate the reduction path for VLA data in several observing modes. AIPS++ has also been used extensively in recent commissioning activities for the Green Bank Telescope, as described fully in other articles in the newsletter.

For further information regarding the package, please contact AIPS++ at aips2-request@nrao.edu, or submit comments via our defect tracking system, which is available at the AIPS++ command line.

A. J. Kemball

K. R. Anantharamaiah 1952-2001

Our colleague K. R. Anantharamaiah (Anantha) died on October 29, 2001, in Bangalore, India. He had been diagnosed with lung cancer in mid-2001. Anantha is survived by his wife, Dr. Jyotsna Anantharamaiah and his son, Avinash.

Anantha joined the Raman Research Institute (RRI) in Bangalore in 1974 after a B.Sc. and M.Sc. in Physics from the University of Mysore. His Ph.D thesis at RRI and Bangalore University was completed in 1985 based on Ooty Radio Telescope observations. In 2000, Anantha became the chair of the Astronomy and Astrophysics Division of RRI. He had become a professor at RRI in 1997.

Anantha was well known in Socorro, having spent five of the last 15 years at the VLA/VLBA. Anantha was a Jansky Fellow from 1986-1989, spending most of his time on radio recombination line research (with Farhad Yusef-Zadeh, Alan Pedlar, Peter Dewdney and Miller Goss) and solar scattering of radio sources (with Tim Cornwell and Ramesh Narayan), both with the VLA. The work centered around an experiment with the VLA to confirm coherences in the speckles of scattering of sources near the Sun but it led to continuing work with others on astrophysical applications of scattering.

The new field of high resolution observations of the weak radio recombination lines from extragalactic spiral galaxies was begun in this period with collaborators: Pedlar, Jun-Hui Zhao, Francois Viallefond, Bikram Phookun and Goss. Anantha was the driving force for this innovative, difficult and exciting research. He carried out a number of Galactic Center projects with Jacqueline van Gorkom, Ulrich Schwarz, Pedlar, Ron Ekers and Goss. The nature of Sgr A West, East, and the linear filaments was a theme of this research.

An additional groundbreaking research area in the 1980s was the confirmation of carbon recombination lines at low frequencies in the direction of Cas A by Anantha, Radhakrishnan, Bill Erickson and Harry Payne using the 140 Foot Telescope at Green Bank. The initial observations had been made by Konovalenko and Sodin at Kharkov in the Ukraine in 1981 at 26 MHz. This work at the 140 Foot showed the importance of line broadening at low frequencies due to pressure or radiation broadening. In addition, Anantha et al. demonstrated the smooth transition of these carbon recombination lines from emission at higher frequencies due to stimulated emission to absorption at lower frequencies, in agreement with the behavior expected from dielectronic-like recombination in the CII gas.

In the 1990s Anantha began a program of active research at RRI involving a number of Ph.D. students: Nimisha Kantharia (Ph.D. 1998) from the Indian Institute of Science and Anish Roshi from the Tata Institute of Fundamental Research (TIFR , Ph.D. 1999) completed theses based on low frequency observations of carbon and hydrogen recombination lines using the Ooty and GEETEE (at Gauribidanur) telescopes. Nimisha is currently a member of the scientific staff at the National Centre for Radio Astrophysics (NCRA) of TIFR in Pune, while Anish is a Jansky Fellow at Green Bank. Both have continued the research started by Anantha on low frequency recombination lines. More recently, in 2001, two students were working with Anantha towards their Ph.D.s: Niruj Mohan and Amitesh Omar.

Anantha spent two profitable years (1997-1999) working at the Array Operations Center in Socorro. He worked on a number of VLA and VLBA projects as well as working on AIPS++ testing. Anantha and Craig Walker carried out an innovative VLBA observation of possible recombination lines in the thermally absorbed counter-jet of 3C84. One of Anantha's most enjoyable projects in this period was a VLA and IRAM study of the remarkable radio and mm recombination lines from the starburst galaxy Arp 220. A three-component model with a total ionized mass of 30 million solar masses and 300,000 O5 stars is required in the presence of 45 magnitudes of visual extinction. Anantha was very proud of this paper, published in the *Astrophysical Journal* in July 2000.

Anantha's leadership role in Galactic Center research intensified in 1997-1999. He began a lasting collaboration with Cornelia Lang (then an NRAO pre-doc from UCLA) based on VLA observations of newly discovered non-thermal linear filaments at the Galactic Center, allowing new insights into the magnetic field configuration in the center of the Galaxy. Namir Kassim, Jim Cordes, and Joe Lazio also were collaborators in these Galactic Center projects. At the last Galactic Center workshop in Tucson (September 1998), Anantha played a major role in many of the discussions and sparked many suggestions for ways to extend Galactic Center work into his familiar low frequency domain and subsequently he encouraged people to use the GMRT. His earlier 330 MHz (VLA and Ooty) work motivated the first

74 MHz VLA Galactic Center observations (under the leadership of Kassim), and he was the first to wrestle sensible images from those data. His recognition that those early maps contained important and unique information about a previously poorly constrained component of ionized gas towards the Galactic Center helped inspire the ongoing Ph.D. thesis (University of New Mexico) of Michael Nord.

While Anantha was recognized as the world's expert in radio recombination lines, his research interests were diverse and he made significant contributions in many areas, including interstellar and interplanetary scattering, the cosmic deuterium abundance, and the understanding of noise in radio interferometric imaging. Anantha also was one of the last of the rare breed of instrumental astrophysicists who was as comfortable with correlator boards and low noise amplifiers as he was with the physics of the interstellar medium.

Anantha's presence at the AOC always seemed to elevate the intellectual activity. He was never content to simply apply a technique, but had a fundamental desire to understand the observing technique as well as the objects of those observations. We all can recall many stimulating conversations (arguments, even) with Anantha on the fundamentals of radio interferometry, such as the van Cittert-Zernike theorem, intensity interferometry and wave noise.

It was not only Anantha's incredible insightfulness into all areas of astronomy for which he will be missed; Anantha was also well known and loved for his intense humor, warm personality and thoughtfulness which permeated all aspects of life. His skills as a raconteur are legendary. As his friend Deshpande has said, Anantha could tell your own story better than you could. In Socorro, he will be remembered as an avid skier and someone who loved adventurous travel. For these reasons, he has enriched both the NRAO and the worldwide astronomy communities.

W. M. Goss (NRAO), C. C. Lang (U. Mass), C. L. Carilli (NRAO)

Training Tomorrow's Astronomers Through Summer Research

For forty-two years, NRAO has welcomed university students to participate in summer research projects with its staff; over 800 students have participated during that period. Twenty-eight students undertook research projects in 2000, fifteen of them sponsored by the National Science Foundation's Research Experiences for Undergraduates Program. The students gain experience and develop expertise accessing and using NRAO's telescopes and receivers, reducing and analyzing astronomical data, and presenting it to the community. Many of the 28 students from the 2001 program will be attending the January AAS meeting presenting posters on their research, with NSF support. There will be a guide to these research presentations at the NRAO booth, please visit. You may also read a summary of the program at *http://www.cv.nrao.edu/~awootten/reu00.html*.

NRAO is now recruiting students for the 2002 Program; the salary for undergraduates is $1600 per month; $1850 for graduates, with travel costs covered. Information and application forms have been mailed soliciting applications for research assistantships next summer. The majority (15) of the assistantships will be offered to undergraduate students who are currently enrolled in U. S. undergraduate institutions and who will not receive their degrees before or during the summer of 2002. A limited number of assitantships will be available for graduating seniors, graduate students or students from non-U. S. institutions.

The deadline for receipt of application materials will be January 25, 2002; notice of decisions will be sent by March 1, 2002. Forms are available from Department Heads, on the web at *http://www.nrao.edu/administration/directors_office/summer-students.shtml* or by writing to:

National Radio Astronomy Observatory
c/o Program Director, Summer Student Program
520 Edgemont Road
Charlottesville, VA 22903-2475

H. A. Wootten

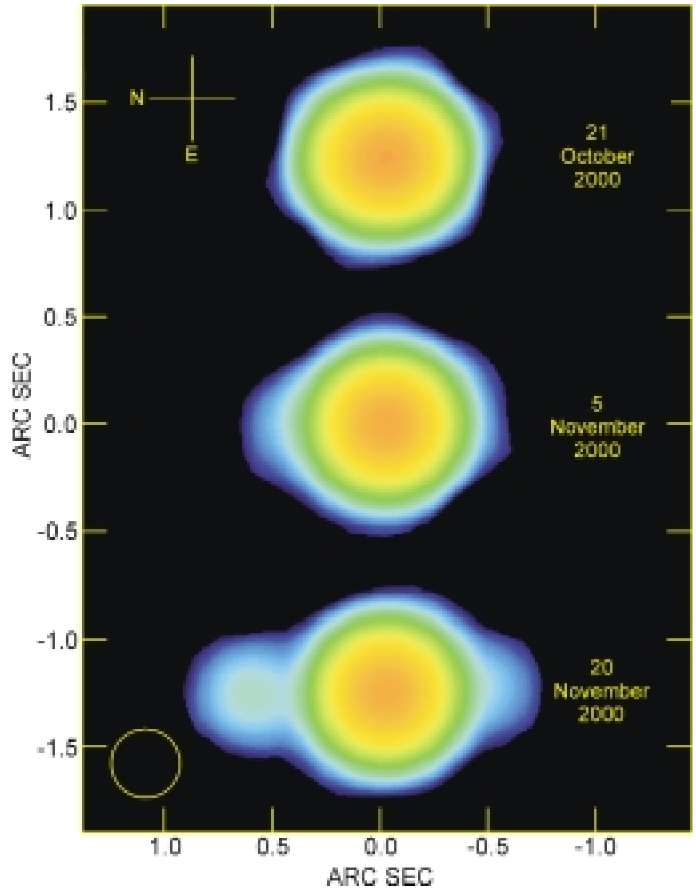
NEW RESULTS

Bipolar Relativistic Expansion in CYGNUS X-3

The X-ray binary Cygnus X-3 is among the most famous and active microquasars in the Galaxy. The system contains a massive Wolf Rayet star with a powerful wind, while the compact companion is likely to be a black hole or a neutron star. Originally discovered as an X-ray source by the Giacconi team more than three decades ago, Cygnus X-3 soon attracted the attention of astronomers worldwide during a series of strong radio outbursts in 1972 (Gregory et al. 1972). In those early times, the radio flux density of Cygnus X-3 suddenly increased by a factor of 1000 in merely a few days. These flaring events have repeated ever since at an irregular pace of one or two per year. We know today that during radio flares Cygnus X-3 undergoes the ejection of collimated jets that generate the observed synchrotron radio emission. The ability to produce non-thermal relativistic jets is in fact the main “fingerprint” of microquasar behavior in an X-ray binary, thus resembling extragalactic quasars and AGNs (see e.g. Mirabel & Rodríguez 1999).

After decades of interferometric radio observations of Cygnus X-3, many authors consistently reported elongated structures with position angle in the North-South direction. However, there was no such consensus concerning other ejection parameters such as the jet velocity and angle with the line of sight. This kind of information can be derived by imaging the source ejecta and being able to track the jet blobs from epoch to epoch, usually after a strong outburst. A textbook example of this work was carried out with the VLA by Mirabel & Rodríguez (1994) on the superluminal GRS 1915+105. In a microquasar, both the jet and counter-jet can be seen and the measure of their proper motion provides a lot of information on the source kinematics. This is not generally possible in an ordinary quasar, where only the jet approaching towards the observer is seen due to relativistic aberration. Unfortunately, a true “movie of the jets” for Cygnus X-3 was not available for such purposes. This is not surprising when considering the difficulties of this kind of observation.

In this context, we submitted a VLA Target-of-Opportunity (ToO) proposal aimed to image Cygnus X-3 in the weeks following one of its major radio flares and using the A configuration. Based on previous VLA observations (Martí et al. 2000), we had gathered evidence that the Cygnus X-3 radio jets were able to reach arcsecond angular scales weeks after a strong event. Of course the jet brightness has significantly decayed by then, but still is within the sensitivity limits of the VLA. This approach is somewhat different from previous ToO VLBI work, which mainly focused on imaging the jets with milli-arcsecond resolution in the immediate days after an outburst.



This sequence shows the development of radio jets in Cygnus X-3 at arcsecond angular scales. Colors are coded in a logarithmic scale. The maps were obtained with the VLA in A configuration at the wavelength of 6 cm. Uniform weight was used to compute all of them and the clean components were restored using a circular beam of 0.3 arcsecond, approximately. This is the first time, since the discovery of Cygnus X-3 more than 30 years ago, that the arcsecond jets are observed so clearly and its bipolar nature becomes evident. The vertical separation of the images is proportional to the time elapsed between the epochs of observation (about 15 days). All images in this panel have been rotated 90 degree counterclockwise for better display of the expanding jets.

Observing with the VLA has also the advantage that the jets move a small fraction of the synthesized beam during the observation. This may not be the case when using a VLBI array. The only serious trouble that we anticipated was the possible intra-hour variability of the central core, that may introduce some artifacts when CLEANing the maps.

Our ToO proposal had to wait for a couple of years until in September 2000 the right conditions for ToO triggering were fulfilled. At last, a strong ~7 Jy was detected by the Green Bank Interferometer (GBI) at a time when the VLA antennas started to move towards A configuration. Incidentaly, the GBI warning arrived soon before it was sadly closed by NASA due to lack of funds. The NRAO did an excellent job scheduling our VLA observations soon after the triggering request. Three epochs of observations were obtained at an interval of two weeks. Fortunately, the variability problems were not as severe as expected and enough *uv* data was available for a standard data reduction.

The final results are shown in the panel of Figure 1, that appeared in the cover page of *Astronomy & Astrophysics* in a recent August issue (Martí, Paredes & Peracaula 2001). The panel clearly shows the development of bipolar radio jets in Cygnus X-3 extending over arcsecond angular scales, equivalent to ~0.05 pc at a 10 kpc distance. These images are useful to constrain the ejection parameters of the system. The proper motion for both the jet and counter-jet could be estimated and we obtained 9.3 ± 0.3 mas d^{-1} and 7.0 ± 0.2 mas d^{-1}, respectively. The asymmetry in both proper motion and brightness between the jet components is consistently interpreted in the frame work of special relativity effects. At 10 kpc, our images point to an ejection velocity of (0.48 ± 0.04)*c* with a 73 ± 4 degree angle with the line of sight. No apparent superluminal motion was observed.

It is worth noting that the appearance of Cygnus X-3 at milli-arcsecond angular scales is significantly different from that of the arcsecond-scale bipolar radio jets. The VLBA maps by Mioduszewski et al. (2001) taken days after another flaring event in 1997 reveal a one-sided radio jet extending over ~100 milli-arcsecond or ~10^{-3} pc. In Martí et al. (2001), we tentatively suggest that absorption effects in the vicinity of the binary system are likely to be responsible for the different morphology at different angular scales. The new high estimates by Ogley et al. (2001) of the wind mass loss in Cygnus X-3 based on ISO data (~10^{-4}-10^{-3} $M_{\odot} yr^{-1}$) appear to support this interpretation. However, other possible explanations cannot be ruled out (jet deceleration, over-resolving effects, etc.). In any case, Cygnus X-3 still deserves a lot of observation to better understand this exciting source and we continue working on it.

References:

Gregory, P.C., et al., 1972, Nat. Phys. Sci., 239, 114

Martí, J., Paredes, J.M., Peracaula, M., 2000, ApJ, 545, 939

Martí, J., Paredes, J.M., Peracaula, M., 2001, A&A, 375, 476

Mioduszewski, A.J., et al., 2001, ApJ, 553, 766

Mirabel, I.F., Rodríguez, L.F., 1994, Nat, 371, 46

Mirabel, I.F., Rodríguez, L.F., 1999, Annu. Rev. Astron. Astrophys., 37, 409

Ogley, R.N., et al., 2001, MNRAS, 322, 177

Further information available at:

http://www.am.ub.es/~josep/cygX3/index.html

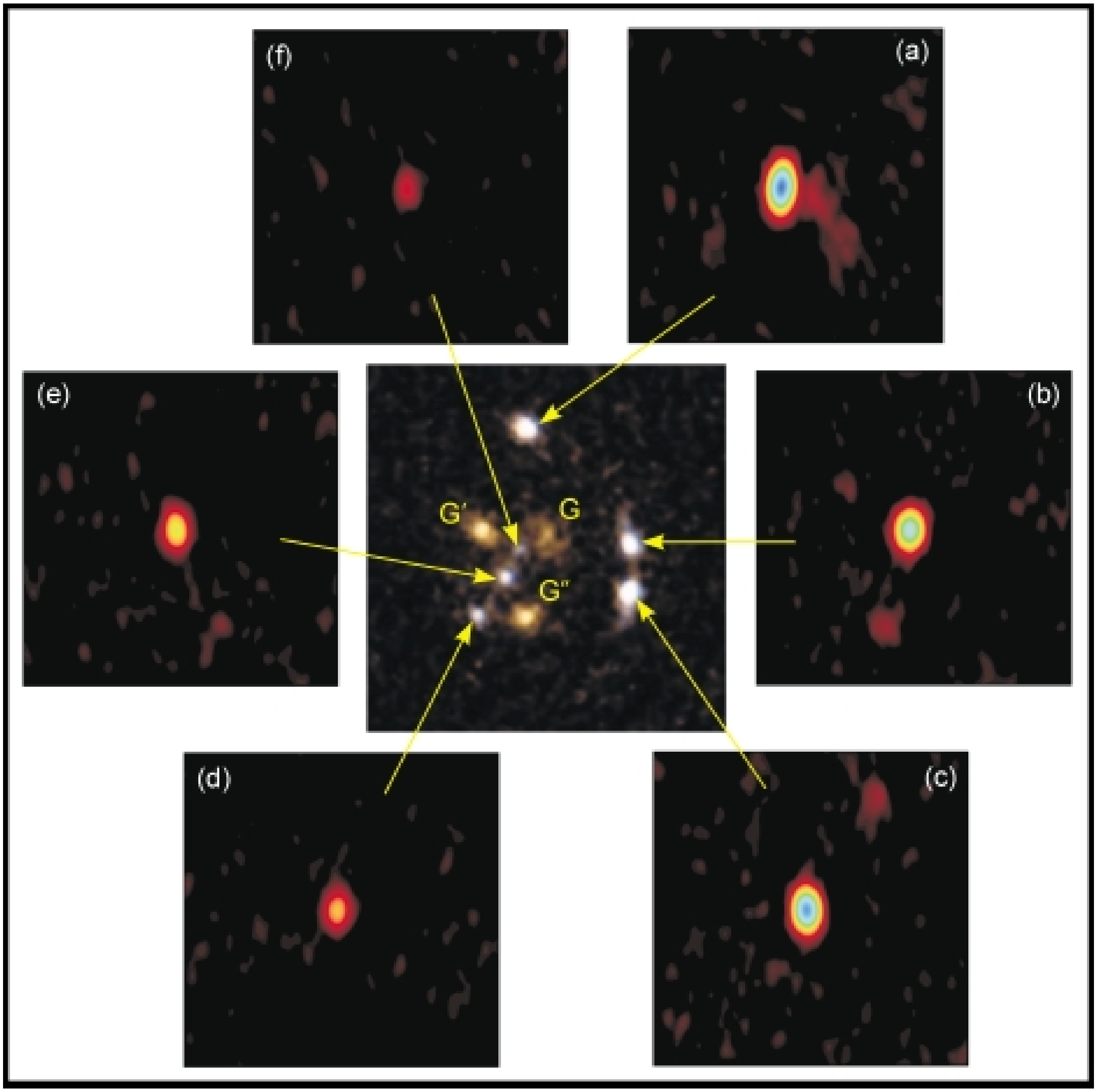
Josep Martí
U. Jaén, Spain
Josep M. Paredes & Marta Peracaula
U. Barcelona, Spain

A Six-Image Gravitational Lens from CLASS

Following the discovery of several dozen multiple-image gravitational lenses over the past two decades, we might have thought that we had seen it all. Nature, however, always seems to have another surprise in store. Recent observations with the Very Long Baseline Array (VLBA) and Hubble Space Telescope (HST) demonstrate that B1359+154 is truly unique among gravitational lenses, consisting of six images of a single background source. This is the first arcsecond-scale system in which a source is lensed into more than four detectable images. The complexity of the system is due to the compound nature of the lensing mass — a compact group of three galaxies at z ~ 1.

B1359+154 was discovered in the third phase of the Cosmic Lens All-Sky Survey (CLASS), an international collaboration that searches for new cases of gravitational lensing among compact radio sources. From the outset it was clear that B1359+154 was no ordinary lens. Initial observations of the source with the Very Large Array (VLA) showed a total of six radio components (Myers et al. 1999). Four of these are in a typical quad-lens configuration, with two additional components residing within the 1.7 arcsecond ring defined by the outer images. Preliminary radio spectral studies could not determine whether or not the central components were related to the outer ones, and the working hypothesis was that they might be core-jet emission from a weak AGN in the lensing galaxy or galaxies. Mass modeling yielded another surprise. Single-galaxy mass models provided extremely poor fits to the system, thereby suggesting that the deflector may be compound in nature. Adaptive optics observations of B1359+154 conducted with the Canada-France Hawaii Telescope (CFHT) at 2.2 µm (Rusin et al. 2000) dramatically confirmed this suspicion, finding three extended emission peaks bracketing the expected positions of the central radio components. These features were identified as three possible lensing galaxies, comprising the core of a compact galaxy group.

The true nature of B1359+154 was revealed by a pair of complementary high-resolution observations. Deep VLBA imaging of the system showed that each of the six components is dominated by a compact core, with the brightest three components also exhibiting weak jet emission. All six radio components have the same surface brightness and are therefore morphologically consistent with images of a single background source. The final confirmation of the six-image hypothesis was provided by HST, where V and I-band observations revealed the three lensing galaxies as well as compact counterparts to each of the six radio components. The galaxies are each very red, implying a photometric redshift of z ~ 1 for the group, while the six compact components are each very blue and have consistent colors. The combined HST and radio observations therefore offer definitive evidence that B1359+154 consists of six images of the same background source.



Composite image showing the six VLBA images of the lensed background radio source (15 by 15 milliarcsecond boxes), which correspond to the blue optical images shown in the HST figure (2.9 by 2.9 arcseconds). The VLBA images were made from a 10 hour observation at 1.7 GHz. The HST images were made from a 5000 second observation at I band.

Lens systems like B1359+154 are expected to be rare, as very special circumstances are needed for their creation. Most gravitational lens systems are dominated by single galaxies, which produce the two and four-image lenses that are commonly observed. Added complexity in the mass distribution is required for a six-image system. This is most effectively achieved by a compound deflector, which can create additional saddle points in the lensing potential and thus additional images (e.g., Kochanek & Apostolakis 1988). Because the source must also be very precisely placed behind the lens to produce a non-standard image configuration, it is not surprising that other lenses with compound deflectors (e.g., Koopmans & Fassnacht 1999) resulted in the familiar doubles and quads. For B1359+154, however, everything fell into place for a spectacular result. Yet, the "miracle" is easily reproduced by mass models consisting of three lens galaxies at their observed positions: the outer four images form a standard quad, while the triangle of galaxies creates two additional saddle points in which the central images reside.

B1359+154 is much more than a mere novelty. The system is a potentially powerful laboratory for studying the structure of compact galaxy groups at high redshift, and the relationship between the galaxies and their parent dark matter halo. The first step will be to obtain improved constraints on the mass distribution. HST NICMOS imaging of lensed extended emission from the quasar host galaxy is promising, as is global VLBI mapping of milliarcsecond-scale substructure in the radio components.

References:

Kochanek, C.S., & Apostolakis, J. 1988, MNRAS, 235, 1073
Koopmans, L.V.E., & Fassnacht, C.D. 1999, ApJ, 527, 513
Myers, S.T., et al. 1999, AJ, 117, 2565
Rusin, D., et al. 2000, ApJL, 533, L89
Rusin, D., et al. 2001, ApJ, 557, 594

David Rusin & Chris Kochanek
Harvard-Smithsonian Center for Astrophysics
Martin Norbury
Jodrell Bank Observatory

Ultra-High-Resolution Imaging and Spectroscopy of Ultracompact HII Regions

While great progress has been made in the last decade in our understanding of the earliest stages of *low mass* star formation, the earliest stages of *high mass* star formation are still poorly understood. Considerable observational and theoretical effort has been made, but the relative rarity, short lifetime and dense clustering of massive protostars have made the task of developing an evolutionary sequence for massive star formation difficult. For example, Shepherd & Churchwell (1996) have shown that a significant fraction of young massive stars experience molecular outflows, and the work of Cesaroni et al. (1998) and others has pinpointed the hot cores in molecular clouds that are likely to be the location of the youngest massive protostars.

Much of this ongoing work has made it clear that in order to explore the earliest phases of massive star formation, radio wavelength investigations are not only desirable, but indispensable. The host molecular clouds of the youngest massive star clusters are dense and optically thick. The W49A region is a representative example: almost the entire region is obscured optically, and only some of the peripheral sources are visible in the near infrared (Conti & Blum 2001). One of the few windows that we do have into such dense cloud cores is at centimeter and millimeter wavelengths, and since the Galaxy's youngest, most luminous massive star forming regions are distant (W49A: 11.5 kpc; Sgr B2: 8.5 kpc), subarcsecond angular resolution is needed to probe the emission on relevant spatial scales.

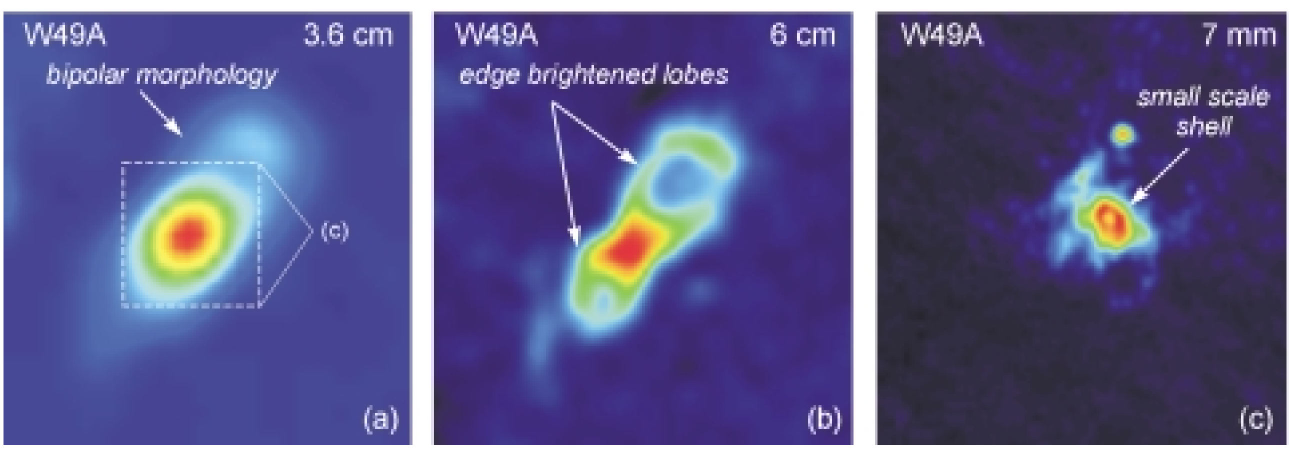


Figure 1. The bipolar W49A/A region as imaged with the VLA at (a) 3.6 cm, (b) 6 cm, and (c) 7 mm. This comparison indicates the importance of multifrequency, subarcsecond resolution imaging in determining the nature of UC HII regions like W49A/A. Source A has a distinctly bipolar morphology at the resolution of the 3.6 cm observations (θ_{beam}=0.8"). The high-resolution 6 cm VLA image (θ_{beam}=0.4"; Welch et al. 1987) indicates that the bipolar lobes are strongly edge-brightened. Finally a high-resolution (θ_{beam}=0.04") 7 mm view of the source indicates that the central peak is itself an edge-brightened "shell", having a center-to-edge brightness ratio consistent with an inclined ring of emission (see De Pree et al. 2000).

Some of the observational clues gathered in the past five years concerning the earliest stages of massive star formation are the extreme physical parameters of the ultracompact (UC) HII regions found in dense cloud cores like W49A and Sgr B2. Emission measures of 10^{10} pc cm^{-6} and electron densities of 10^6 cm^{-3} are not uncommon in the ultracompact sources detected in these two regions (e.g. De Pree et al. 1998; De Pree et al. 2000). What is becoming clear is that the ultracompact regions of ionized gas that we detect in regions like W49A are not simply small versions of the HII regions described in such classic texts as *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei* (Osterbrock, 1989), but comprise a unique class of objects.

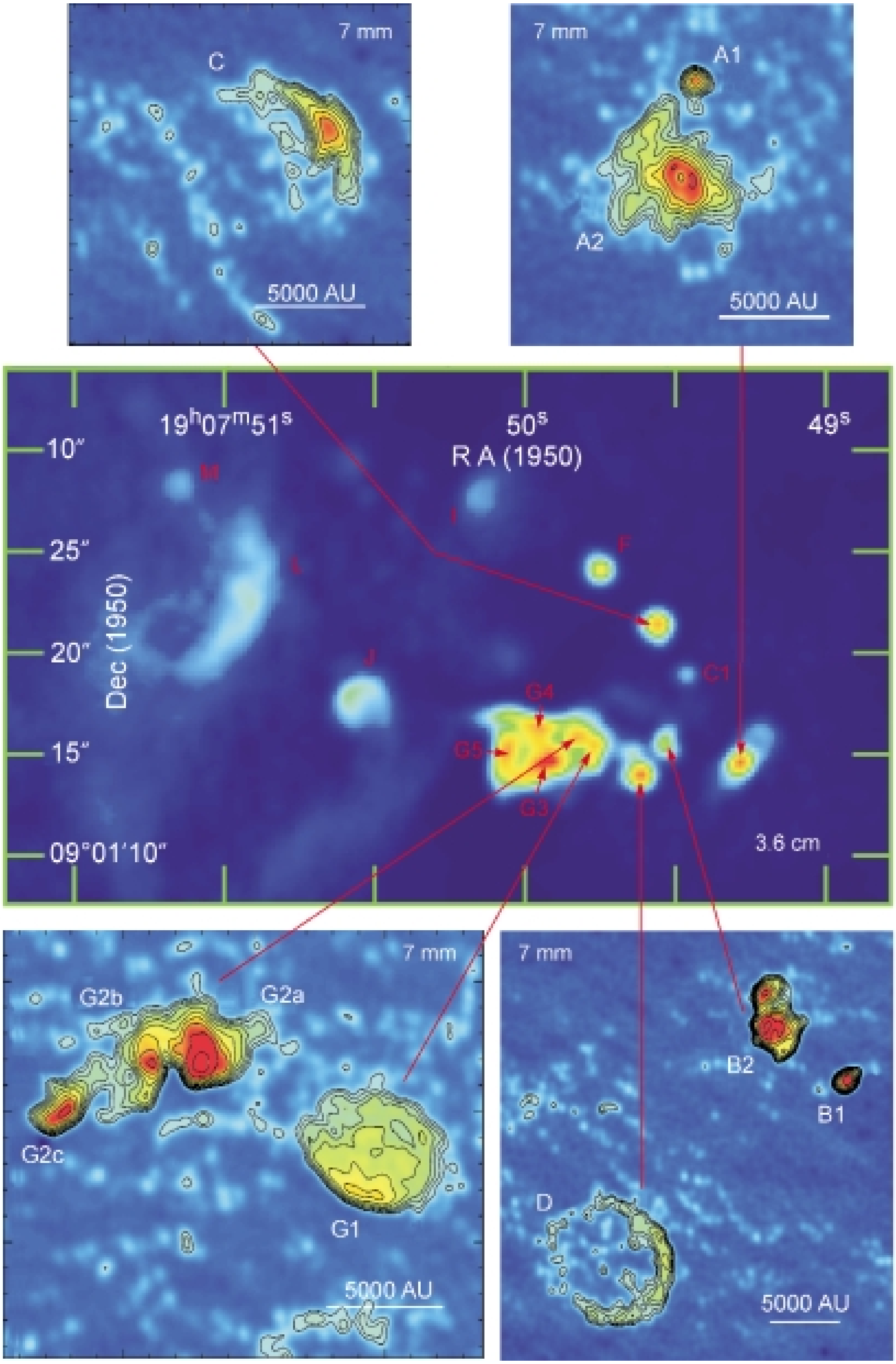


Figure 2. Views of the ultracompact (UC) HII regions in W49A with the full resolution of the VLA at 7 mm (θ_{beam}=0.04") are inset in the 3.6 cm image of the W49A region. The 7 mm image includes data collected from the A, B, and D configurations of the VLA over the past 3 years. Note that at this resolution and observing frequency, source A reveals a central "shell". Source B breaks into a multiplicity of distinct sources, with B1 having an elongated morphology, and B2 a central "shell" of its own. The horizontal bar in each inset frame indicates 5000 AU.

Early efforts to characterize UC HII regions culminated at the end of the 1980s and early 1990s with the surveys of Wood & Churchwell (1989), and Kurtz et al.(1994), in which snapshot observations of large numbers of HII regions (~75 sources in each survey) were used to tabulate their morphology and physical parameters. A large fraction of sources were found to have cometary morphologies, and as a result, there was considerable effort towards the development of a "cometary bow shock" model (e.g. Mac-Low et al. 1991). The model proposed that the observed cometary structures arose from the motion of the host star and its HII region through the parent molecular cloud, and that this shock served to confine the UC HII region and keep it from expanding as an overpressured source would naturally tend to do. Our recent multi-frequency, multi-configuration observations of the W49A, Sgr B2 and several other Galactic regions have been made in order to probe the physical parameters and morphologies of an equally large number of UC HII regions within only a few massive star clusters, with the addition of radio recombination line (RRL) spectroscopy. Early results in the W49A and Sgr B2 regions indicate that the cometary morphology is relatively uncommon, with a large fraction of sources appearing to have asymmetrically bright shells or rings on the smallest scales, and bipolar lobes on larger scales. The prevalence of small-scale shells and bipolar morphologies suggests that at least in the youngest sources, circumstellar material might be distributed equatorially, and be related to the accretion process. We are beginning the process of modeling the early evolution of UC HII regions in dense environments with the new distribution of morphologies as a motivator.

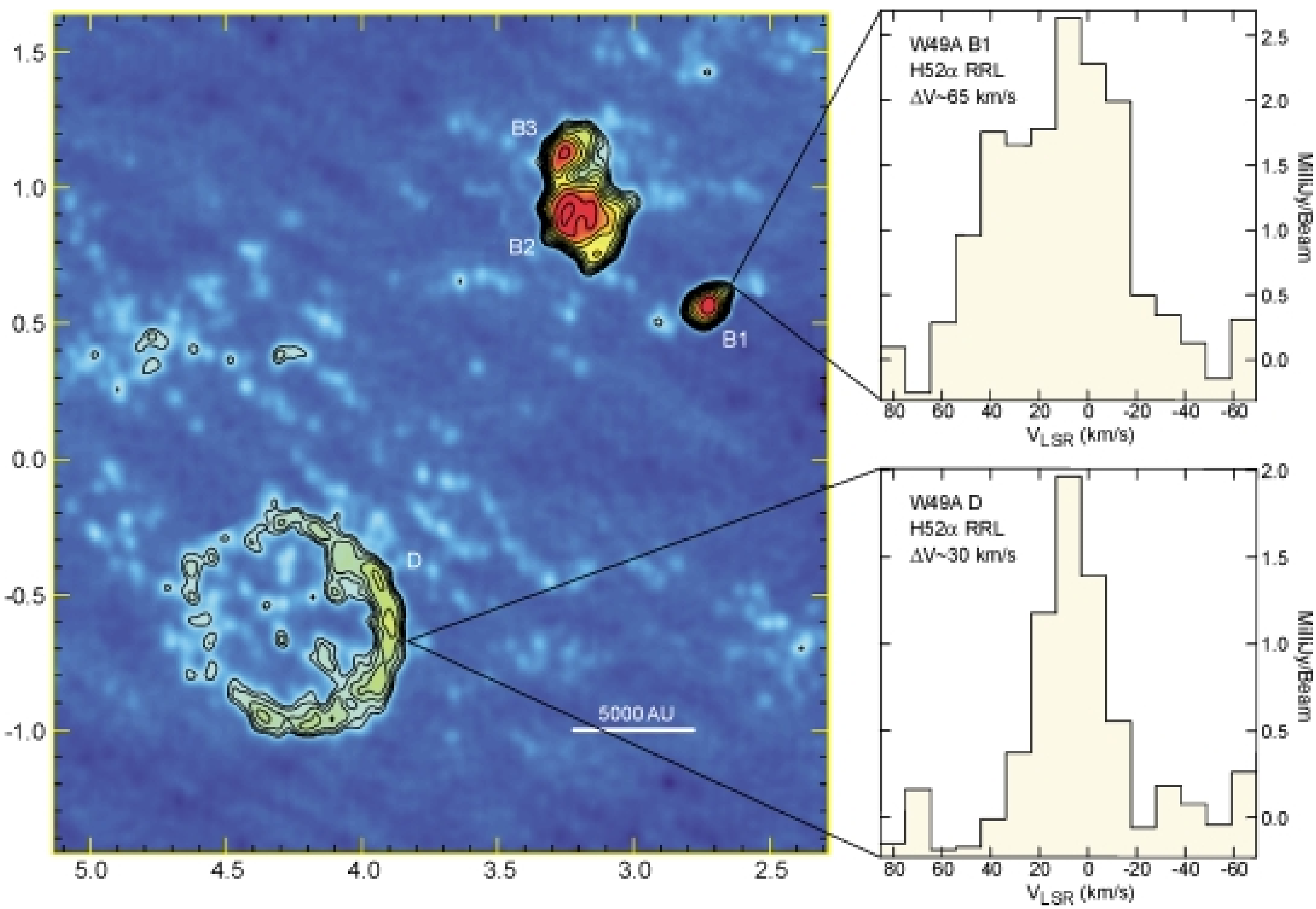


Figure 3. The W49A B and D regions as imaged at 7 mm with the VLA. Insets show the integrated H52α radio recombination line flux toward sources B1 and D. A combination of imaging spectroscopy and multi-frequency observations to determine continuum spectral indices can effectively identify the youngest of the UC HII regions in a massive star forming cluster.

We have recently obtained ultra-high-resolution observations of both the millimeter continuum and the H52α spectral line (Wilner et al. 2001; De Pree et al. 2000) in W49A. These observations and others have indicated the existence of a new subclass of sources within the UC H II region category. De Pree et al. (1996) and Jaffe & Martin-Pintado (2000) have identified a number of sources that have very broad radio recombination lines ($\Delta V > 50$ km s^{-1}), and continuum spectral indices ($S_\upsilon \sim \upsilon^\alpha$, $0.6 < \alpha < 1.0$) that rise monotonically. These spectral indices rise up to the highest frequencies detected (1 mm in the case of some of the regions in W49A), and their values indicate that the rise is not due to the presence of dust, which would cause the index to increase much more steeply. At 7 mm, the recombination lines are not significantly biased by opacity or pressure effects and can provide accurate velocities and linewidths for comparison with molecular line data.

Jaffe & Martin-Pintado (2000) have called these sources broad line recombination objects (BLROs). It is possible that BRLOs represent the earliest stage of the evolution of UC H II regions, and might be transitional objects that link hot cores to UC H II regions. We hope to extend our high frequency line and continuum work in the coming year to the massive star-forming region W51. Rising spectral indices (indicative of ionized winds), shell-like and bipolar morphologies, molecular outflows and broad radio recombination lines all point, perhaps, to the presence of accretion disks early in the massive star formation process. Molecular line observations made with the Atacama Large Millimeter Array (ALMA), once operational, will be able to detect the presence of such disks.

The work described in this article has been carried out with the collaboration of Miller Goss (NRAO), Jack Welch (Berkeley), and David Wilner (CfA). Portions of this research have been supported by Small Research Grants from the American Astronomical Society.

References:

Cesaroni, R., Hofner, P., Walmsley, C. M., Churchwell, E., 1998, A&A, 331, 709

Conti, P. & Blum, R., 2001, to appear in ASP Conference Series, The Earliest Phases of Massive Star Birth, University of Colorado at Boulder 6-8 August 2001, P. A. Crowther, ed.

De Pree, C.G., 1996, PhD Thesis, UNC Chapel Hill

De Pree, C. G., Mehringer, D. M., Goss, W. M., 1997, ApJ, 482, 307

De Pree, C. G., Wilner, D. J., Goss, W. M., Welch, W. J., McGrath, E. 2000, ApJ, 540, 308

Jaffe, D. T., & Martin-Pintado, J. 1999, ApJ, 520, 162

Mac Low, M.-M., van Buren, D., Wood, D. O. S., & Churchwell, E. 1991, ApJ, 369, 395

Osterbrock, D. 1989, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei, University Science Books, Mill Valley, CA

Shepherd, D. S. & Churchwell, E., 1996, ApJ, 472, 225

Wilner, D. J., De Pree, C. G., Welch, W. J., Goss, W. M., 2001, ApJ, 550L, 81

Chris De Pree
Agnes Scott College

The NRAO Graphics Department will be happy to assist you in the production of images for your article as well as for your research papers. Contact Patricia Smiley *(psmiley@nrao.edu)* with your request.

Editor: Barry Turner *(bturner@nrao.edu)*
Science Editor: Juan Uson *(juson@nrao.edu)*
Assistant Editor: Sheila Marks
Layout and Design: Patricia Smiley

If you have an interesting new result obtained using NRAO telescopes that could be featured in this section of the NRAO Newsletter, *please contact Juan Uson at* juson@nrao.edu. *We particularly encourage Ph.D. students to describe their thesis work.*

NRAO Contact Information

To obtain more information on the NRAO, visit the NRAO homepage at: *http://www.nrao.edu*

To contact any NRAO site:

Headquarters
Director's, Human Resources, and Business Offices
Atacama Large Millimeter Array
(434) 296-0211

Green Bank Site
Green Bank Telescope
(304) 456-2011

Array Operations Center
Very Large Array
Very Long Baseline Array
(505) 835-7000

Tucson Site
(520) 882-8250

NRAO Results

For more information on recent results with NRAO telescopes, visit the following web addresses:

NRAO Press Releases: *http://www.aoc.nrao.edu/pr/pr.html*
NRAO Preprints: *http://www.nrao.edu/library/nrao_preprints.shtml*
"What's New at the VLA?": *http://www.aoc.nrao.edu/vla/html/VLAnews.shtml*

NRAO Products

NRAO provides web access to the results from a number of radio surveys, including the following:

VLA NVSS Survey (VLA D-array 20 cm continuum): *http://www.cv.nrao.edu/nvss/*
VLA FIRST Survey (VLA B-array 20 cm continuum): *http://www.cv.nrao.edu/first/*
Galactic Plane "A" Survey: *http://www.gb.nrao.edu/~glangsto/GPA/*

In addition, the NRAO maintains an archive of all observations. These may be queried via the web:

VLA database archive: *http://www.aoc.nrao.edu/vla/vladb/VLADB.html*
VLBA cumulative list of observed sources: *http://www.aoc.nrao.edu/ftp/cumvlbaobs.txt*

Observing Information

VLA: *http://www.aoc.nrao.edu/vla/html/vlahome/astronomer.html*
VLBA: *http://www.aoc.nrao.edu/vlba/html/vlbahome/observer.html*

Information on proposal templates, instructions, and deadlines can be found at:
http://www.nrao.edu/administration/directors_office/

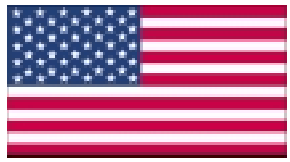
Publicizing NRAO Results

If you have a new result obtained using an NRAO telescope, and you think it might be of interest to a wider audience, please write a 2-3 sentence description of the result and e-mail it to one or more of the people below. Your information could result in a press release, an article in this *Newsletter*, and/or inclusion of your image in the NRAO image database.

Press release contacts: Dave Finley, Public Information Officer (*dfinley@nrao.edu*)
Charles Blue, Public Information Officer (*cblue@nrao.edu*)
Newsletter contact: Juan Uson, *Newsletter* Science Editor (*juson@nrao.edu*)
Image database contact: Patricia Smiley, Information Services Coordinator (*psmiley@nrao.edu*)

NRAO Preprint Policy

It is NRAO policy to pay a portion of the page charges for articles reporting original observations made with NRAO instruments or utilizing NRAO archival data. For more information and for details of the policy and requirements, please see: *http://www.nrao.edu/library/page_charges/shtml.*



EDITOR NRAO NEWSLETTER
NATIONAL RADIO ASTRONOMY OBSERVATORY
520 EDGEMONT ROAD
CHARLOTTESVILLE, VA 22903-2475

NON-PROFIT ORG.
U.S. POSTAGE PAID
CHARLOTTESVILLE, VA
PERMIT #071

ADDRESS CORRECTION REQUESTED

TO:

DATED MATERIAL - DO NOT DELAY