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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.

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

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Cover Image: The Very Long Baseline Array (VLBA) is the world's largest, full-time astronomical instrument, consisting of a series of 10 radio antennas spread out across North America from Hawaii to the Virgin Islands. Each antenna is 82 feet (25 meters) in diameter, weighs 240 tons, and is nearly as tall as a ten story building. The antennas, controlled by the Array Operations Center in Socorro, New Mexico, function together as one instrument with very high resolution and sensitivity. The data from each antenna is recorded onto magnetic tapes and sent by mail to the astronomers doing the observations. The VLBA was dedicated in 1993 and is used by astronomers around the world. Cover image courtesy of: NASA/GSFC and ORBIMAGE, NRAO/AUI

Atacama Large Millimeter Array (ALMA)

ALMA Project Progress Report

Two of the three unfilled key positions in the Joint ALMA Observatory (JAO) offices have been filled.

Tony Beasley has accepted AUI/NRAO's offer to become ALMA Project Manager in the JAO. It is anticipated that he will begin serving in this position in September in Chile. Prior to this, he will be participating in ALMA meetings, the first of which was the ALMA Science Workshop held in May at the University of Maryland. Tony has been Project Manager for CARMA at Caltech; before taking that position he held the Assistant Directorship for Program Development in Charlottesville, and before that, the Deputy Assistant Directorship for VLA/VLBA computing.

Rick Murowinski has accepted AUI/NRAO's offer to become ALMA Project Engineer in the JAO. He began his duties on May 18, 2004. Rick comes to ALMA from The Astronomy Technology Research Group (Victoria), where he has been Deputy Leader of the group and working on ground- and space-based instrumentation for large telescopes, Gemini and JWST among others. Rick's research interests are in solid state detector physics. The move to ALMA brings his career in a full circle from its start at Algonquin Radio Telescope and then working on SIS mixers at Chalmer's Institute of Technology (Goteberg). Rick will take up duties for JAO while initially remaining based in Victoria. Once the new Chilean offices are ready this fall, he'll move to Santiago.

The project continues to search for a candidate to fill the position of Project Scientist, to be in charge of commissioning and science verification of ALMA.

The interface between the Executives and the JAO has been clarified by a Management Plan defining implementation of the management structure outlined in the Bilateral Agreement. Project management has been developing a Project Management Control System (PMCS) to define an integrated project schedule and to track costs and performance. The PMCS will be implemented over the course of the remainder of the year.

At the end of May, testing of the prototype antennas at the ALMA Test Facility on the VLA site concluded. Radiometric tests of the Alcatel/EIE antenna concluded the suite of tests; a report on the performance of that antenna and the Vertex/RSI antenna was delivered to the project by the Antenna Evaluation Group. Even as the final tests were occurring on the prototype antenna, a joint technical evaluation group was evaluating bids for construction of the production antennas. The report

This picture is of the ALMA camp - the living quarters are on the far right. Dining and office space are behind that. The first project employees moved in on June 1, 2004. On the far left in the distance is the contractor camp. This picture is taken from above the camp, looking over the salt lake to the north end of which San Pedro is located. Photo by Jim and Debra Shepherd.

of this group will be delivered to the project in June, followed by evaluation of the commercial portion of the bid. It is expected that a contract for the production antennas will be let in September.

Visitors to the ALMA Camp (see photo on previous page) at the site of the Operations Support Facility (OSF) will find several temporary offices and sleeping facilities now, along with a splendid outdoor grill area as ALMA staff take up residency. The road from the OSF to the Array Operations Site (AOS) is in an advanced stage of completion. A request for bids for the initial phase of construction of the AOS Technical Building has been issued; excavation is expected to commence in the fall. Office space for ALMA in Santiago has been secured and will be ready for occupancy this fall.

The first of several moves from Arizona occurred in June with the arrival of the Tucson Receiver Group in Charlottesville. During the next several months an ALMA Integration Center will take shape in the NRAO Technology Center in preparation for the production of the major ALMA systems.

Since mid-March, all ALMA receiver cartridges have undergone preliminary design reviews; no substantial problems were found. Assembly of the first complete ALMA Front End, comprising all four cartridges in the dewar, is scheduled to begin in January 2005. A major improvement to the baseline correlator design is a tunable filter bank card, replacing the original single filter card. This increases the correlator flexibility, notably the resolution in the widest bandwidth is increased by a factor of 32. Details of the plan to implement this improved filter bank are in their final stages. Integration of the elements of the ALMA system has begun, providing the first opportunity to perform tests of substantial portions of ALMA hardware and software. Following lab integration, the prototype hardware will be installed at the ATF for testing on the prototype antennas.

An ALMA Operations Plan has been drafted to provide a view of the future operations phase of ALMA. The Chair of the Operations Planning Group has been Darrel Emerson, working with his counterpart at ESO David Silva, and representatives of all ALMA teams. The Operations Plan is reaching maturity, with details of budget and personnel and deployment of those personnel included in the upcoming version. One element of the Plan is the local ALMA center, the ALMA Regional Center (ARC). In North America, the ARC will be embedded in a more fully functional center, the North American ALMA Science Center (NAASC). While the ARC provides the bare essentials — proposal handling, observing file generation and distribution of data to the user — the NAASC adds to these the level of support services users find at other NRAO facilities.

Paul Vanden Bout was appointed the first Head of the NAASC and will participate in more fully defining the facility during the coming months. During May, an ALMA Science Workshop was held at the University of Maryland to familiarize future users with use of the instrument, and to provide definition for the interaction between ALMA and its users centered in the NAASC. This is the first of a series of workshops designed to familiarize future users with ALMA.

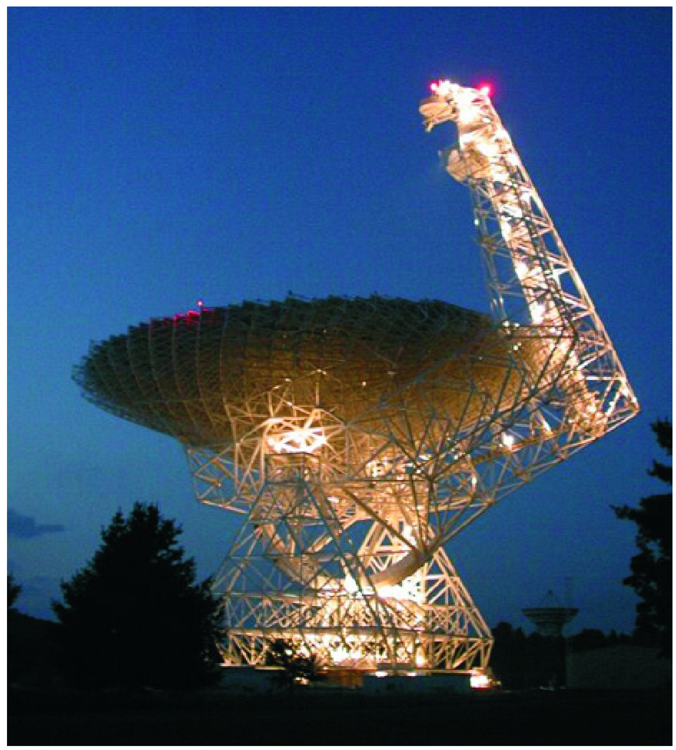
At the workshop, astronomers discussed their scientific expectations from ALMA, led by overviews from A. Blain (Caltech), N. Evans (Univ. of TX.), M. Meixner (STScI) and M. Gurwell (CfA). Blain noted that the high resolution available from ALMA enables its images to avoid confusion from overlapping sources and resolve their internal structure; ALMA provides in less than an hour spatially and spectroscopically resolved images of the most interesting galaxies found. Evans described ALMA's contributions to star formation studies, from the revelation of the detailed structure of star-forming clouds in other galaxies to the use of absorption against circumstellar disks to reveal motions leading to star formation on fine scales. Meixner noted that ALMA's high resolution and sensitivity in the submillimeter range would lead to detection of photospheric emission from a host of normal stars, and detail the complex spatio-kinematic structure of the envelopes of evolved stars. Gurwell highlighted ALMA's high imaging dynamic range, enabling it to image planetary phenomena as diverse as volcanic plume evolution on Io, vertical thermal structure and winds in the atmospheres of Mars and Venus, or the gas streaming from disintegrating cometary nuclei to inform our knowledge of primoridal solar system chemistry. During breakout sessions, the focus turned to specific examples of ALMA projects as described in the Design Reference Science Plan (see *www.alma.nrao.edu/science*). Returning to the plenary session, representatives of North American radio facilities described their instrumental plans for the ALMA era. Discussion of support needed to extract the best science from the huge ALMA data output (up to 5 TB/day of data) extended late into the night. The next day, summaries were presented as the workshop closed. Members of the ALMA North American Science Advisory Committee (see *http://www.cv.nrao.edu/naasc/admin.shtml*) held a face-to-face meeting to synthesize the results of the workshop for inclusion in a written report.

H. A. Wootten

Green Bank

The Green Bank Telescope

The first half of 2004 has seen a significant number of high quality scientific results from the GBT. Since the beginning of the year, a substantial number of papers have been submitted, including about nine ApJ Letters published or in press. Highlights include papers on the binary double pulsar, high velocity clouds about M31, studies of the fine structure constant, detections of high redshift molecular lines, and detections of new interstellar molecules. Nearly all of the major observing capabilities are working completely and reliably, and observers are clearly utilizing them to good effect.



The Robert C. Byrd Green Bank Telescope at night.

From January through April of this year, ~62 percent of total telescope time (on a 24-hour-day basis) was scheduled for science. Fractions will be somewhat lower during the summer months while structural inspections, painting, and other engineering activities are underway, but will rise again in the fall. From mid-September through mid-May, the GBT is dynamically scheduled to match projects with weather requirements.

With the increase in observing time and available capabilities, the backlog of proposals from previous calls is being steadily reduced. The low frequency (<10 GHz) backlog is now effectively eliminated. Nearly 1000 hours of approved time still remains in the queue for higher frequencies, but should be eliminated this coming fall and winter. At the recent June 1, 2004 deadline (for Trimester 04C), 700 hours of low frequency and 200 hours of high frequency time were requested. These numbers should increase again at the October call.

This summer our inspection contractor, Modjeski & Masters, is undertaking the second installment of GBT structural inspections begun last summer. Last summer, critical members in the tipping structure were inspected; this summer half the reflector backup structure and all the alidade structure will be inspected. No inspections are scheduled for 2005, although inspections are planned on a periodic basis for future years. Structural painting will also resume this summer, and will be an annual activity for several years. As reported in previous newsletters, some defects were found last summer in the elevation shaft assembly welds. Following extensive investigation and inspection, these defects were determined to be shrinkage cracks from the original welding and do not appear to be the result of fatigue. Several of these defects were ground out and rewelded, and others will be monitored for any changes. Provided that no significant changes in the shaft weldments are noted, this does not appear to be a serious problem.

The NRAO staff and our engineering consultant, SG&H, continue to study the behavior of the azimuth track and to develop plans for long-term repairs or modifications. Finite element models have been successful in describing the dynamical properties of the wear plate and base plate assembly, and accounting for the probable fretting wear mechanism. The mechanism for wear plate fatigue is still under study. In the meantime, the maintenance staff has found effective means to manage the problems, albeit with effort and expense. Little or no observing time is presently being lost to the track. It is unlikely that major modification work will be scheduled to occur before 2006 unless the present performance or behavior of the track should change.

The NRAO staff and our university collaborators continue to make good progress on GBT development projects. The new 26-40 GHz (Ka-band) pseudo-correlation receiver was completed in April and has undergone first engineering evaluations on the telescope. Only a limited set of test observations has been undertaken, but performance looks good. This receiver will undergo full astronomical commissioning in the fall and early winter when high transparency weather returns. The Caltech Continuum Backend, a fast switching, large bandwidth backend designed for use with the 26-40 GHz receiver, underwent a recent project review and appears on track for delivery this fall. Work on this project is being shared by Caltech and the NRAO. The Penn Array camera project, a collaborative effort of UPenn, NASA-Goddard, NIST, U. Cardiff, and NRAO to construct a 64-pixel, 3 mm bolometer array for the GBT is also progressing well. The full cryogenics system is assembled and functioning well and the optics tower has been installed recently. Delivery of the Penn Camera is expected in 2005. The Precision Telescope Control System project to deliver 3 mm telescope capability for the GBT is progressing very well and is described in a companion article. The software group has recently delivered a number of capabilities to observers including a single dish FITS (SDFITS) data export format, binary data files for the CLASS data reduction system, and progress toward an IDL data reduction capability. Finally, work toward a new configuration and observing interface to the GBT is proceeding very well, and is scheduled for beta release in mid-summer.

P. R. Jewell

Latest Results from the GBT Precision Telescope Control System Project

The goal of the GBT Precision Telescope Control System (PTCS) project is to allow the GBT to work effectively at frequencies up to 115 GHz (wavelengths down to 3 mm). It is now just a little over a year since our Conceptual Design Review, and we have already made excellent progress, culminating in the delivery of usable Q-band (43 GHz, 7 mm) performance in the spring of this year. After an initial period of instrumentation development during summer 2003, during the fall we developed and released significantly improved strategies for pointing and focus corrections. More recently, we have started the detailed characterization of the antenna efficiency and surface accuracy. Each of these activities is briefly described below.

Pointing/Focus

It was well known from the original GBT design studies that thermal gradients in the antenna would be one of the largest so-called "non-repeatable" sources of pointing and focus error. Thermal gradients may introduce up to ~30 arcseconds of pointing error under the most extreme conditions. This affects the blind pointing both directly, and also indirectly, by introducing systematic errors into traditional (gravity only) pointing models developed using conventional techniques. Changes in the thermal gradients may introduce drifts in offset pointing over the required tracking timescales of one-half to one hour. Finally, thermal gradients may cause tens of millimeters of radial focus error, an effect not explicitly anticipated during early GBT operation. All of these effects meant that in the spring of 2003, although the GBT was capable of 26 GHz operation, observations required frequent offset pointing and focus checks.

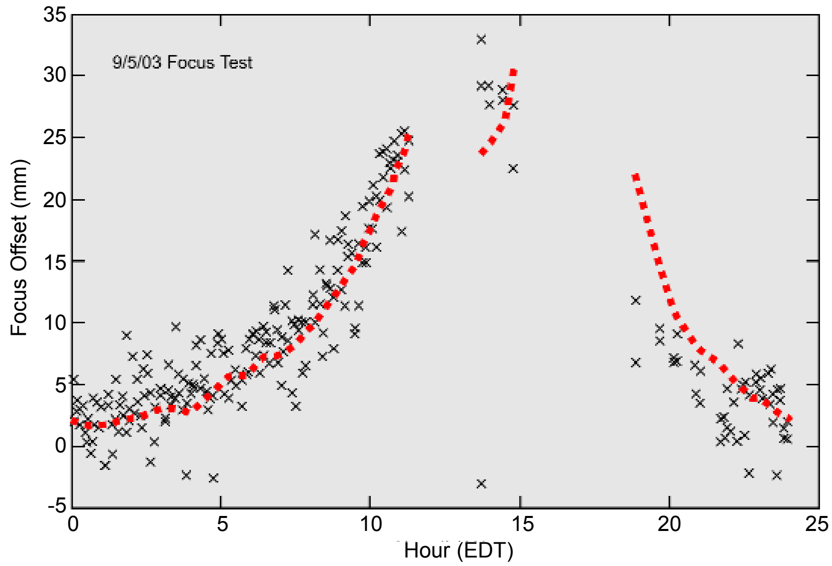


Figure 1. A test of the focus thermal model. Black crosses are the measured positions, red dots the prediction of the model. X-axis is local time in hours, Y-axis focus offset in mm.

The performance of the antenna has now been substantially improved, to the level required for Q-band operation, by the development of an elegant but operationally simple mechanism for correcting in real time for the effects of thermal gradients in the antenna. During the summer of 2003, we installed a system of ~20 precision temperature sensors on the antenna subreflector, feedarm, primary backup structure and alidade. These have an absolute accuracy of 0.15 deg C, and are read out over RS232/Ethernet at a 1 Hz rate. During the fall, we performed a number of pointing runs, where azimuth, elevation and radial focus offsets were measured astronomically, while temperature data was simultaneously logged. Through physical intuition, insight and discovery via numerical experimentation, we chose a series of "features," or linear combinations of temperature sensors, to characterize deformations of the substructures of the GBT. For example, the difference between the subreflector and mean temperature of the primary backup structure represents the difference in material thermal expansion coefficient between the primary (steel) and subreflector (aluminum). We then performed linear regressions between these features and the astronomically measured data. These regressions simultaneously estimate the feature coefficients and the traditional gravity pointing terms, so that we end up with both a thermally-neutral gravity model, and the thermal corrections to the gravity model. The models were then tested by applying them to additional, independent datasets. An example for focus is shown in Figure 1. This shows the results of repeated focus measurements on a source, 0117+8928, within one degree of the north celestial pole, and hence effectively stationary in azimuth and elevation. All of the focus variations are therefore due to thermal gradients. The data span a 24 hour period, with some daytime measurements rejected due to high wind. The measured data are shown as black crosses, while the predictions of the model are the red dots. As can be seen, the model does an excellent job of removing the large (~30 mm) diurnal variation in focus. Similar results are obtained for azimuth and elevation pointing error.

This scheme has now been implemented within the GBT monitor and control system, with the model being evaluated in real-time, and corrections to pointing and focus applied automatically every 10 seconds. Using this correction system, we routinely achieve 68th percentile focus residuals of < 3 mm, and pointing residuals of ~3" or better in each axis under benign conditions. The model is now being extended to account for other

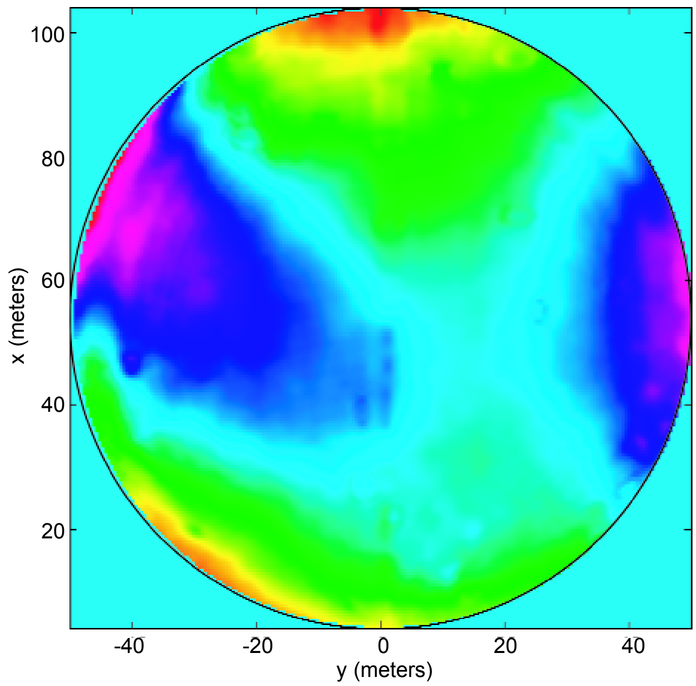


Figure 2. A false-color image of a phase-coherent 12 GHz holography map showing the total wavefront error. The peak to peak range is −1.3mm (blue) to +1.3mm (yellow); the rms error is ~400 microns. 1.3mm, the rms error ~400 microns.

effects, in particular wind, and we are confident that there are further improvements to be gained.

Surface Measurements

In line with our intermediate priorities to deliver Q-band operation for this past winter, the bulk of the PTCS efforts to date have been devoted to pointing improvements. However, we have also made some surface accuracy and efficiency measurements. We have used two independent methods to measure surface deformations. First, we have used traditional phase-coherent holography, performed at 12 GHz using a geo-stationary satellite at an elevation angle of about 42 degrees, near the rigging angle. Secondly, we have used the phase-retrieval technique (also known as the "out-of-focus" beam map, or OOF technique) developed and implemented by the Radio Astronomy Group at the University of Cambridge, UK. In this approach, only the power pattern of the antenna is measured, usually at two or more different focus settings. The phase of the signal in the aperture is later recovered by numerical processing. Usually, this technique is used with artificial sources, but the Cambridge group have extended this to provide measurement of surface errors with moderate spatial resolution, by observing astronomical sources using existing astronomical receivers. We have tested this technique at 12, 22, and 43 GHz, using astronomical methanol, water, and SiO maser sources. The two techniques are complementary: phase-coherent holography provides higher resolution, but our system is currently restricted to 12 GHz and a single elevation; the OOF technique provides lower spatial resolution, but can be performed over a range of elevations, and at higher frequencies.

The results of a 150 × 150 point phase-coherent holography map (~0.7 m resolution on the dish) is shown in Figure 2. The corresponding OOF maps show good agreement. Details at the individual panel level (especially a few stuck actuators) are easily visible in the holography amplitude and phase plots. However, the rms surface error in these maps, ~ 400 microns, is entirely dominated by the large-scale error, which is well represented by a series of Zernike polynomials.

We have measured a 43 GHz gain-elevation curve for the GBT, without any attempt to correct for residual thermal or gravitational distortions. The efficiency peaks at around 0.43 at 52 degrees elevation, and falls off symmetrically at higher and lower elevations. The absolute efficiency scale is somewhat uncertain due to uncertainties in the receiver calibration. However, the measured value of 0.43 gives a Ruze equivalent surface error of 390 microns, in good agreement with the holography measurements.

Since measuring this gain-elevation curve, we have performed tests of the surface corrections predicted by the holography measurements, by performing back-to-back measurements on 3C286 and 3C279, with and without the corrections applied. Unfortunately, attempts to determine absolute efficiencies using these measurements were prevented by the uncertainties in the receiver calibration, and the poor weather conditions at the time of the observations. However, in all cases, the peak gain was improved (by ~20 - 30 percent), the beam FWHM became closer to the theoretical value, and sidelobes were significantly reduced. We are therefore confident that we can use holographic measurements to substantially improve the surface accuracy of the antenna.

Future Work

The PTCS project has fallen naturally into a six-month cycle, with instrumentation development work proceeding primarily in the summer, and extensive commissioning work performed mainly during the winter high-frequency observing season. We are currently upgrading the temperature sensors, and installing inclinometers and accelerometers. We are planning a series of experiments using infrared thermography of the primary surface in conjunction with OOF beam maps to attempt to isolate (and correct for) thermal gradient figure error, and simultaneously refine the FEM model of gravitational distortions, much the same as was done in our pointing corrections. Our goal is to deliver prototype 86 GHz operation in the Spring of 2005, with full 115 GHz operation to be delivered a year later.

Further details of the PTCS project are available at: *http://wiki.gb.nrao.edu/bin/view/PTCS/WebHome.*

Acknowledgements

The work described here would not have been possible without the full support of the PTCS project team. Current team members include: Joe Brandt, Jeff Cromer, Ray Creager, Paul Marganian, Melinda Mello, J.D. Nelson, Jason Ray and John Shelton. We gratefully acknowledge assistance with the surface measurements from Claire Chandler, Ron Maddalena, Fred Schwab, Bojan Nikolic, Richard Hills, and John Richer. We would also like to acknowledge the previous NRAO staff members, the construction contractors Lockheed-Martin and its predecessors, and others who have delivered us such a delightful antenna to work with.

R. M. Prestage, K. T. Constantikes, D. S. Balser, J. J. Condon

The Green Bank Telescope Joins 7-mm VLBI Community

One of the key intermediate goals for the Green Bank Telescope, and the GBT Precision Telescope Control System Project, was to deliver usable Q-band (43GHz, 7mm) telescope performance by the Winter of 2003/04. This capability was achieved in December 2003. In conjunction with use of the active surface, the crucial new development was the implementation of automated real-time corrections to pointing and focus, to compensate for the effects of thermal gradients in the antenna structure (see accompanying article). This correction system has been in production use, to great effect, since February 2004.

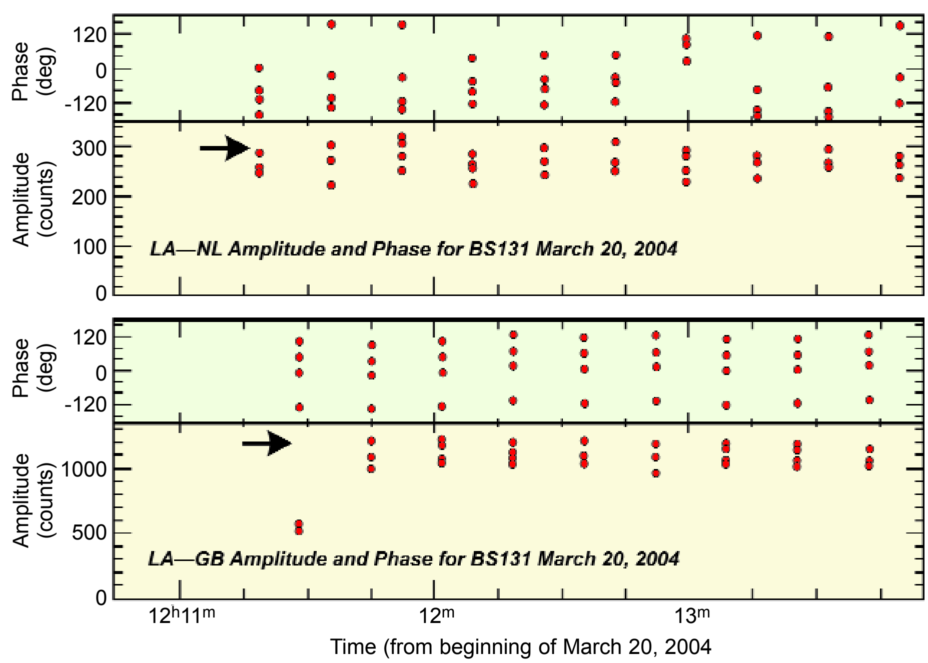


Figure 1. Amplitude and phase plots for the calibration source NRAO530 for the Los Alamos to North Liberty (top) and Los Alamos to Green Bank (bottom) baselines.

The first class of science to make use of this new capability has been 7 mm VLBI, with observations performed in March and April 2004. Mapping of Sgr A* was the object of project BS131 (Shen et al), and the M84 jet was observed in project bw070 (Walker et al). Sgr A* will again be studied by Bower et al. in May.

Under good weather conditions (clear skies and winds below 5 mph) the telescope performance is very good, as shown in the accompanying correlator plot. This figure shows results for the calibration source NRAO530 in project BS131. The upper two panels show the results from the LA-NL baseline (Los Alamos to North Liberty), and the large arrow shows the typical correlated amplitude is about 300 counts. The lower two panels show the results from LA-GB (Los Alamos to the GBT), and the corresponding amplitude is about 1200 counts. Since the geometric area of the GBT is 16 times that of a VLBA antenna and the fringe amplitude is proportional to the geometric mean of the collecting areas, we conclude that the GBT aperture efficiency equals that of the NL VLBA antenna, about 40 percent. This is quite consistent with our independent direct measurements.

The inclusion of the GBT in VLBI observations provides many advantages. One is the immediate increase in sensitivity noted above. Another is that the inclusion of a large antenna such as the GBT improves the ability to use self calibration. Finally, inclusion of the GBT can significantly improve the UV coverage, either directly by providing additional baselines, or indirectly by allowing the self-calibration of other antennas which contribute N-S resolution.

In summary, the addition of the GBT to the VLBI network will make possible observations of unprecedented high sensitivity, and we look forward to the delivery of many exciting new science results.

R. M. Prestage, F. D. Ghigo

GBT Student Support Program: Announcement of Awards

Three awards were made in April as part of the GBT Student Support Program. This program is designed to support GBT research by graduate or undergraduate students at U.S. universities, thereby strengthening the proactive role of the Observatory in training new generations of telescope users.

The April awards were in conjunction with approved observing proposals submitted at the February deadline. Awards were made for the following students:

- P. Kondratko (Harvard U) in the amount of $35,000 for the proposal entitled *"Anchoring the Extragalactic Distance Scale"*.

- M. Krco (Cornell U) in the amount of $33,000 for the proposal entitled *"GBT Observations of Narrow HI Absorption as a Probe of Molecular Cloud Evolution"*.

- P. Demorest (UC Berkeley) in the amount of $17,000 for the proposal entitled *"Precision Timing of Binary and Millisecond Pulsars"*.

New applications to the program may be submitted along with new GBT observing proposals at any proposal deadline. For full details, restrictions, and procedures, select "GBT Student Support Program" from the GBT astronomers page. For a cumulative record of past awards under this program, select "GBT Student Support Status" from the GBT astronomers page.

J. M. Dickey (U Minn)
J. E. Hibbard, P. R. Jewell, F .J. Lockman,
J. M. Wrobel (NRAO)

Socorro

VLA Configuration Schedule; VLA/VLBA Proposals

Configuration	Starting Date	Ending Date	Proposal Deadline
D	18 Jun 2004	30 Aug 2004	2 Feb 2004
A(+PT)	17 Sep 2004	10 Jan 2005	1 Jun 2004
BnA	21 Jan 2005	14 Feb 2005	1 Oct 2004
B	18 Feb 2005	23 May 2005	1 Oct 2004
CnB	03 Jun 2005	20 Jun 2005	1 Feb 2005
C	24 Jun 2005	19 Sep 2005	1 Feb 2005
DnC	30 Sep 2005	17 Oct 2005	1 Jun 2005
D	21 Oct 2005	03 Jan 2006	1 Jun 2005
A(+PT?)	20 Jan 2006	01 May 2006	3 Oct 2005

GENERAL: Please use the most recent proposal cover-sheets, which can be retrieved 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. Fax submissions will not be accepted. Finally, VLA/VLBA referee reports are now distributed to proposers by email only, so please provide current email addresses for all proposal authors via the most recent LaTeX proposal coversheets.

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 (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 L-band (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 2004, the A configuration daytime will involve RAs between 11h and 20h. In 2005, the B configuration daytime will involve RAs between 21h and 04h. Current and past VLA schedules may be found at *http://www.vla.nrao.edu/astro/prop/schedules/old/*. EVLA construction will continue to impact VLA observers; please see the web page at *http://www.aoc.nrao.edu/evla/archive/transition/impact.html*.

Approximate VLA Configuration Schedule

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

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 currently amounts to only about one quarter of observing time. Adverse weather increases the scheduling prospects for dynamics requesting frequencies below about 10 GHz. When the VLA-Pie Town link is in use during the VLA's A configuration, we will try to substitute a single VLA antenna for Pie Town in a concurrent VLBA dynamic program. Therefore, scheduling prospects will be enhanced for VLBA dynamic programs that can accommodate such a swap. 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 DSN, is the responsibility of the proposer.

J. M. Wrobel, B.G. Clark
schedsoc@nrao.edu

VLBI Global Network Call for Proposals

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

Date	Proposals Due
21 Oct to 11 Nov 2004	01 Jun 2004
Feb/Mar 2005	01 Oct 2004

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. 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 EVN correlator at JIVE 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 EVN correlator at JIVE 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 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 Global proposals that include requests for NRAO resources, send proposals to *propsoc@nrao.edu.* Please ensure that the Postscript files sent to the latter address request US standard letter paper. Proposals may also be sent by paper mail, as described at the web address given. Finally, VLA/VLBA referee reports are now distributed to proposers by email only, so please provide current email addresses for all proposal authors via the most recent LaTeX proposal coversheet.

J. M. Wrobel, B. G. Clark
schedsoc@nrao.edu

Correlator Station Positions

The station locations used on the VLBA correlator were updated on May 12, 2004. The new coordinates are based on the 2004b solution from the Goddard Space Flight Center and are a significant improvement over the coordinates, and especially the rates, that have been in use for several years. The 2004b solution should closely match the International Terrestrial

Reference Frame (ITRF) and should be appropriate for use with the International Celestial Reference Frame (ICRF) source coordinates and the Earth Orientation Parameters (EOP) from the USNO that are used on the correlator. For the first time, we are now using a consistent set of reference frames.

The VLA positions in the geodetic frame have been recalculated to match the new VLBI coordinates. The VLA uses a unique coordinate frame that is shifted and rotated with respect to the ITRF. VLA positions are measured with baselines run on the VLA. Two positions are available in both the VLA frame and in 2004b — VLA station N8 and Pie Town (used by the VLA in Pie Town link observations). The new positions for the VLA antennas are based on shifting the VLA frame so that N8 is at its position from the 2004b solution, and rotating the frame in the XY plane by an empirical number, very close to the VLA center longitude, so that the Pie Town VLA and 2004b positions match as closely as possible.

The changes in the VLBA positions were typically less than 10 mm in each coordinate in the positions at the reference date of 1997.0. But the rates used previously were based on only a small time span of data and are significantly different in the new solution. These are the rates due to tectonic motion and have values of typically a few cm per year. For correlation, the reference positions are adjusted by the rates multiplied by the time offset from the reference date. The adjusted positions are different by up to 30 mm in each coordinate (typically 10 to 20 mm). What ultimately matters is the baseline coordinates which are the differences between the antenna coordinates. The magnitude of the vector differences between the old baselines and those from 2004b are between 4 and 34 mm with 20 mm being typical.

The accuracy of phases derived using phase referencing should be improved by the baseline changes divided by the wavelength and scaled down by the ratio of the source/calibrator separation divided by a radian. For example, a 20 mm baseline change for a 1.3 cm wavelength observation with a 2 degree target/calibrator separation would have phases improved by about 20 degrees.

Changing the coordinates used on the correlator will affect any long term astrometric monitoring projects. The geodesy groups use only total delays to avoid worries about such correlator changes. Other groups for whom this might be important should have some mechanism to adjust all of their data to common models. Note that, thanks to the tectonic motions, processing with the same coordinates all the time is not a viable option — the antennas really are moving.

For details of the 2004b solution visit the website: *http://gemini.gsfc.nasa.gov/solutions/2004b/*. For EOP from Bulletin-A as used by the correlator see *http://maia.usno.navy.mil/bulletin-a.html*.

R. C. Walker

VLA/VLBA Observing for University Classes or Summer Programs

Instructors of university classes in observational astronomy or advisors of summer student programs may request small amounts of observing time on the VLA or VLBA. A typical allotment per class or program would be two VLA hours and/or four VLBA hours.

To apply for this time, the instructor or advisor should send a short request of one or two paragraphs to *schedsoc@nrao.edu*. This request should include a description of the class or program, the range of dates when the class or program will meet, the most desirable date for the observing time, plus statements that at least ten classroom hours will be devoted to the observing project and that sufficient computing resources will be available to the students.

Most requests will come from experienced VLA/VLBA observers known at the NRAO. However, sometimes requests come from instructors or advisors with no prior VLA/VLBA observing experience; in such cases, we recommend that the instructor or advisor first gain some experience by, for example, attending a synthesis imaging summer school and/or collaborating with an experienced colleague.

The time allotted for student observing will be coordinated with the time allotted to normal observing, whether under regular proposals or under rapid-response-science proposals. Student time will therefore be scheduled at LSTs where normal observing has the least demand on the instrument. About 2 to 6 weeks in advance, the instructor or advisor will be emailed about which particular time slot has been allocated. Before the actual observing, the instructor or advisor should reply stating what will be observed in the allotted time. Data acquired during student time will have no proprietary period.

We request a short report on the outcome of the observing project, either written jointly by the students or the best of the project reports tendered by the students as part of their classwork. This report, preferably in postscript or PDF format, should be sent to *schedsoc@nrao.edu*. Reports on student observing time that was scheduled after June 1, 2004, will be posted at *http://www.aoc.nrao.edu/~schedsoc/*.

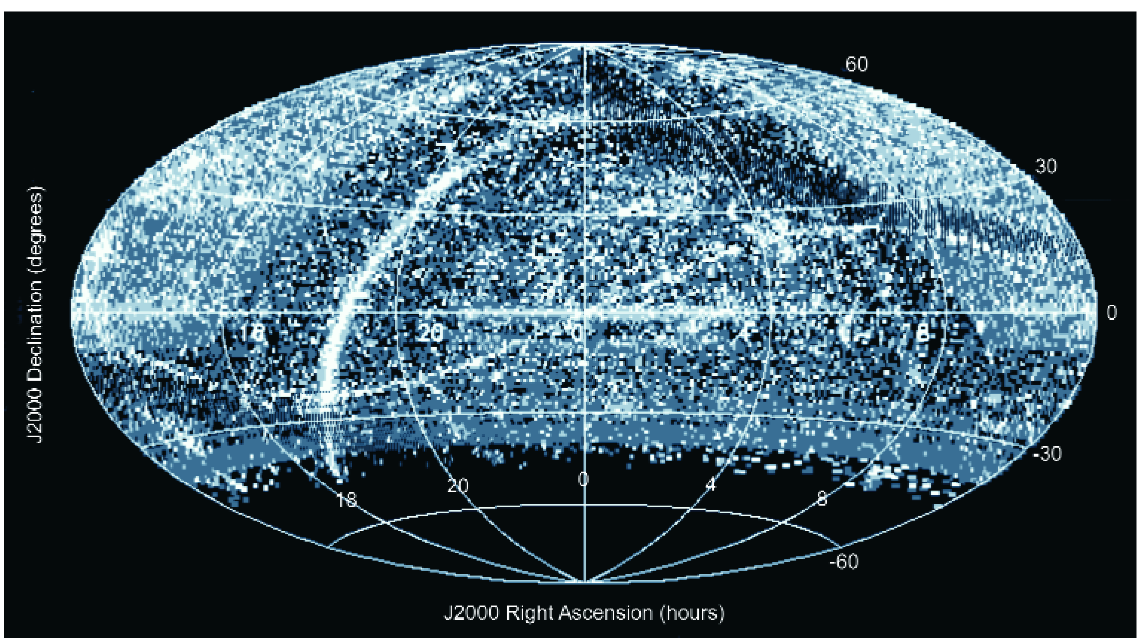
J. M. Wrobel, B. G. Clark
schedsoc@nrao.edu

The Status of the NRAO Data Archive

The NRAO Data Archive has been operational for seven months and allows everyone on-line access to all VLA data and some VLBA data (*http://e2e.aoc.nrao.edu/archive*). Thus far over 350 users from 175 institutions have downloaded over 7800 telescope data files. The download data rate is about 100 Gbytes per month. Data files over one year old are in the public domain (see URL below for details) and accounted for 3/4 of the file downloads. The data files reside on a hard disk array and provide the archive users with fast access and downloads via FTP.

Currently the archive contains all VLA data going back to 1976, raw VLBA data going back to June 2002, and some calibrated VLBA data going back to December 2002. Efforts to expand the VLBA archive back to 1992 are underway. There is a small amount of GBT data available now from 2002 and 2003. We intend to begin archiving raw GBT data and making it available within the third quarter of 2004.

In the figure below, the coverage of VLA data in the archive is shown. The total integration time of the



The coverage of VLA data in the archive is shown. The total integration time of the VLA per square degree is plotted from under 300 seconds (black) to over 10000 seconds (white). Every square degree on the sky above -40 degrees declination has been observed by the VLA and is in the Data Archive.

VLA per square degree is plotted from under 300 seconds (black) to over 10000 seconds (white). Every square degree on the sky above -40 degrees declination has been observed by the VLA and is in the Data Archive.

A new NRAO-wide data archive policy has been written and may be found at *http://www.nrao.edu/administration/directors_office/dataarchive.shtml*. The new policy shortens the proprietary period from 18 months to 12 months. This is in line with proprietary periods at other major observatories.

The development of the NRAO Archive is proceeding in phases. The first phase is essentially complete, that is, we now provide users with access to all VLA data and tools to identify and download the data that they're interested in. The next phase is to make the archive scientifically more useful to a wider range of astronomers, especially non-radio astronomers. To that end, a group in Socorro is discussing several issues: improvements to the user interface, more descriptive display tables and automated data reduction pipelines that will produce calibrated data and useful images.

We would like to encourage people to use the archive, experiment with it, and send comments and suggestions to either *jbenson@nrao.edu* or *dfrail@nrao.edu*. The web page at *http://e2e.aoc.nrao.edu/archive/archivefuture.html* contains an outline of what we think is important to develop in the near future.

J. M. Benson, D. A. Frail, G. B. Taylor

VLA and VLBA Large Proposal Results

The Large Proposal Review Committee for the VLA and VLBA met in late April to consider large proposals submitted at the deadline of February 2, 2004. This Committee is made up entirely of scientists from outside the NRAO, who consider the broad scientific impact of large observing proposals in their deliberations. At their April meeting, the Committee evaluated four large VLA proposals and one large VLBA proposal. They were advised of the proposals' logistical impact on other VLA and VLBA observing by the Assistant Director for Socorro Operations, but otherwise acted independently in arriving at their recommendations. In the end, it is the intent of the NRAO to implement all the recommendations of the Committee.

The single submitted VLBA proposal was accepted for all its requested time. Of the four VLA proposals, one was accepted for all its requested time, one was accepted for part of its requested time, and two were rejected.

The table below gives the amount of time requested and allocated for the large proposals, with the VLA proposals broken down by configurations:

Configuration	No. Proposals	Hr. Requested	Hr. Allocated
A	2	640	240
B	1	400	0
C	3	524	24
D	0	0	0
Hybrid arrays	0	0	0
All	1	495	~240
ALL VLA	4	2059	~504
VLBA	1	336	336

Below, we list the proposal codes, investigators, and proposal titles for which observing time was granted via the review process:

- AK583, Kulkarni et al., *"Cosmic Explosions."* 20 hours of VLA time allocated per month, beginning after the successful completion of scientific checkout for the Swift satellite.

- AS801, Schinnerer et al., *"The COSMOS Deep 1.4 GHz Imaging Survey: Probing Cosmic Evolution in the Radio Domain."* 240 hours of VLA A configuration and 24 hours of VLA C configuration allocated.

- BL123, M. Lister et al., *"The MOJAVE Program: Monitoring of Jets in AGN with VLBA Experiments."* 14 VLBA sessions of 24 hours each, allocated at monthly intervals.

Note also that the upcoming VLA configuration cycle, from approximately September 2004 through January 2006, has time reserved for previously allocated large proposals. These include 120 hours in C configuration for AK563, 121 hours in BnA configuration and 212 hours in B configuration for AP452, 89 hours in B configuration for AW605, and 40 hours in B or BnA configuration for AH810. For identification of these proposals and more information, see the Large Proposal web page cited below.

As a reminder to prospective proposers, VLBA large proposals may be submitted at any of the standard NRAO deadlines. The next deadline for VLA large proposals will be June 1, 2005. Potential proposers should be aware that this VLA deadline will cover the configuration cycle from January 2006 through May 2007, during full production mode and outfitting of the EVLA at a rate of 4-6 antennas per year. Therefore, one might expect the total amount of observing time, and the number of available antennas, to be reduced somewhat. More detailed predictions will be made available as the June 2005 deadline draws nearer.

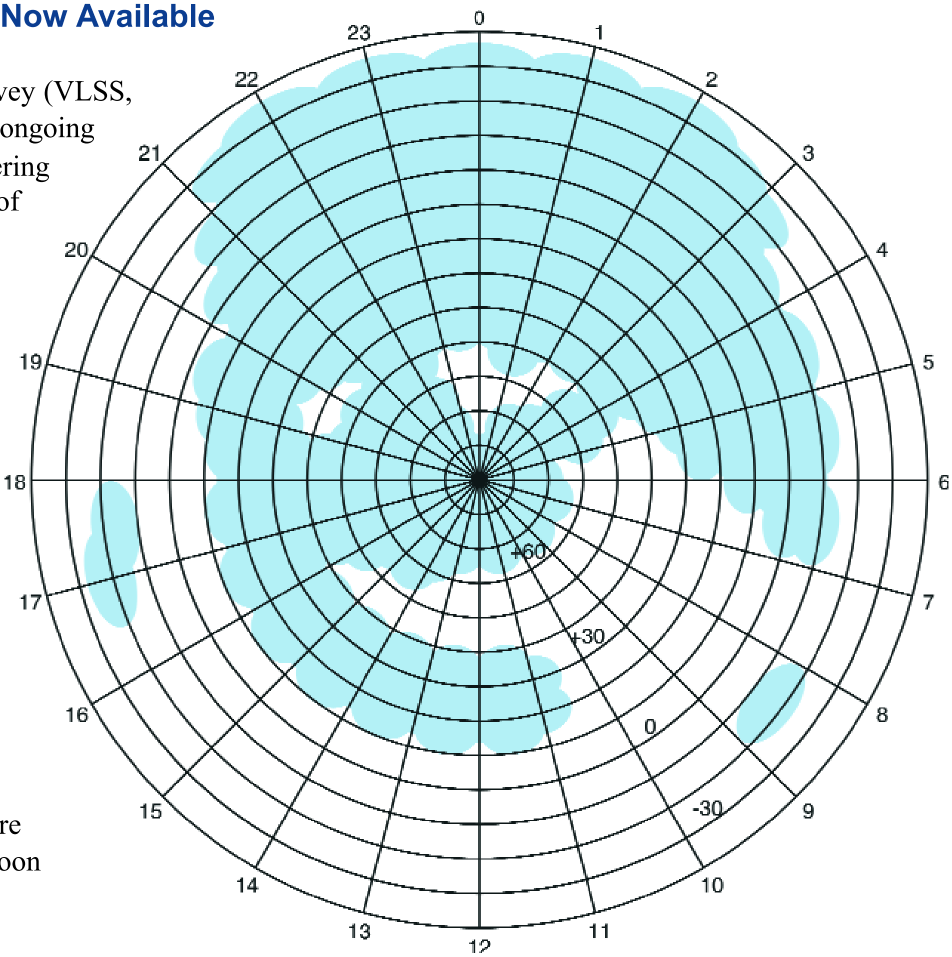
Additional information about the large proposal process, and links to results from previously scheduled large proposals, may be found at *http://www.vla.nrao.edu/astro/prop/largeprop/*.

J. S. Ulvestad

In General

New VLSS Data Release Now Available

The VLA Low-frequency Sky Survey (VLSS, formerly known as 4MASS), is an ongoing effort to map an area of 3π sr covering the entire sky above a declination of -30 degrees, at a frequency of 74 MHz (400 cm) see April 2004 *Newsletter* for discussion of the science. The survey has 80" resolution and an average detection limit of 0.5 Jy/beam (5σ). These observations are possible due to the new 74 MHz system on the VLA as well as various new data reduction algorithms which can now handle the challenges of RFI and ionospheric distortions at this low frequency. The VLSS is being conducted as a service to the astronomical community and all data products are being made publicly available as soon as they are reduced and verified.



The blue regions indicate the current sky coverage of the VLSS. Maps and source catalogs of any area in this region are now available at the VLSS website (http://lwa.nrl.navy.mil/VLSS).

The first major data release for the VLSS is now publicly available at the VLSS website (*http:// lwa.nrl.navy.mil/ VLSS*), which is also linked from the NRAO homepage. Previously only data from regions observed during test observations were available, comprising under 10 percent of the total survey region. The new release includes maps and catalogs for all observations conducted so far, totaling roughly 50 percent of the eventual survey region. The images are available as a set of $14°\times14°$ images distributed on a grid such that adjacent images overlap by at least 2 degrees. Images can also be obtained through a postage stamp server. A source catalog containing all ~ 32, 000 objects detected at the 5σ level is available in its entirety or through our searchable catalog browser.

Our next round of observations will take place in early 2005, and we expect to have that data reduced, verified, and released publicly toward the end of that year. At that point the survey will be roughly 90 percent complete, with only regions in the far south (below -10 degrees) and various high noise fields (due mainly to an over-active ionosphere) remaining to be observed (or re-observed).

The scientific goals of this survey are multiple. Samples of sources with steep spectral indices at low frequencies can be used to detect pulsars, high redshift radio galaxies, and cluster halos and relics. Using these low frequency data it is also possible to study absorption effects in supernova remnants, normal galaxies, and in HII regions in the Galactic plane. Another main goal of this survey is to make a low frequency counterpart to the NVSS, which will be available for public use by all astronomers. Finally we will produce a low frequency sky model which can be used to plan and calibrate more sensitive 74 MHz VLA experiments, as well as providing an initial calibration grid for planned radio telescopes such as the SKA and LOFAR.

Wendy Lane and Aaron Cohen,
(Naval Research Laboratory)

Survey done in collaboration with Rick Perley,
Bill Cotton, Jim Condon (NRAO),
Namir Kassim, Joseph Lazio (NRL),
and Bill Erickson (UMD)

Green Bank Conference on the Discovery of Sag A*

A small workshop commemorating the 30th anniversary of the discovery of SgrA*, the radio source associated with the supermassive black hole at the center of our Galaxy, was held in Green Bank, WV, on March 25th and 26th. There were 60 participants from a variety of international and national institutes and many of the NRAO scientific staff. The program consisted of a day and a half of scientific talks, a banquet, and a ceremony and dedication of a plaque on the 45 Foot Telescope by the original discoverers. A reception for all participants and Green Bank staff followed at the Green Bank Science Center.

The discovery of the compact radio source at the center of the Milky Way was made by Bruce Ballick and Bob Brown in February 1974. They had originally been searching for compact regions of star formation in the vicinity of the Galactic Center. The placement of the 45 Foot Telescope near Huntersville, W V as the 35 km outstation for the NRAO Green Bank radio link interferometer (consisting of three 85 Foot antennas at Green Bank), was crucial for resolving out the extended confusion from SgrA West and providing spatial resolutions of 0.3" (at 3.7 cm) and 0.7" (at 11 cm) and detecting the very compact radio source, SgrA*.

An opening review talk on massive objects at the centers of galaxies was given by Roger Blanford (Caltech), followed by a series of historical talks given by the original observers, Bruce Ballick (U Washington) and Bob Brown (NAIC), and the Green Bank site director at that time, Dave Hogg (NRAO). A number of fascinating letters from Ballick to Brown were shown which provided additional insight into the details of the discovery (also summarized recently by Goss, Brown & Lo, 2003, Astron. Nachr. S1, 1). Roy Booth (OSO), K.Y. Lo (NRAO) and Ron Ekers (ATNF) also presented accounts of early work on the size and structure of SgrA* based on some of the first

Bob Brown (left) and Bruce Balick (right) at the 45 Foot Telescope, which provided the crucial baseline for their discovery of SgrA.*

aperture synthesis studies at Jodrell Bank, Owens Valley Radio Observatory, and the VLA.

Following the historical talks on SgrA*, a series of talks on recent results were presented. Don Backer (UC Berkeley) gave an overview of interstellar scattering properties toward SgrA*, and Geoff Bower (UC Berkeley) and Zhi-Qiang Shen (Shanghai Observatory) reported on VLBA closure phase techniques used to constrain the size of this compact source. Results on the linear and circular polarization of SgrA* were given by Geoff Bower (UC Berkeley). Variability of SgrA* on a number of timescales is now confirmed across the spectrum from radio — Zhao (CfA), Bower (UC Berkeley), Herrnstein (AMNH)) to near-IR — Ghez (UCLA), Genzel (MPIfA), Schoedel (Cologne) to X-rays — Baganoff (MIT). Progress reports by Ramesh Narayan (CfA), Sera Markoff (MIT), Eliot Quataert (UC Berkeley) and Fulvio Melia (U Arizona) followed, describing the various models to explain the spectrum, polarization and variability of SgrA*. Perspectives on the current state and characteristics of the modeling were given by Heino Falcke (MPIfA). The stellar and intersetllar environment surrounding SgrA* was discussed in a series of talks on Friday morning. The scientific talks concluded at noon with a thoughtful review by Mark Morris (UCLA).

Following the scientific program, a dedication ceremony was held at the 45 Foot antenna, where NRAO Director Fred Lo presented Bruce Ballick and Bob Brown with commemorative framed posters (see picture). A plaque on the 45-foot antenna and an informational adjacent sign for visitors were unveiled. An informal scientific session was held on Friday evening to discuss prospects for future millimeter and sub-millimeter VLBI observations of SgrA*. The next generation of telescopes will provide an excellent opportunity for imaging on the scale of the event horizon, allowing for detailed tests of accretion models and general relativity.
The scientific program, PDF and PPT versions of the talks, and photographs are available on the web at: *http://www.aoc.nrao.edu/~gcnews/GCconfs/SgrAstar30/index.html*.

Cornelia Lang
(U. Iowa)

From the Spectrum Manager

The NRAO made three FCC filings in recent months, on matters ranging from Ku-band satellite uplinks on ships — we requested exclusion zones around the Mauna Kea and St. Croix VLBA stations — to redefining the meaning of RFI (the "interference temperature" metric) and allowing use of higher power unlicensed devices in remote areas (so-called "cognitive radio" technology). In another initiative occasioned by FCC activity (some might call it hyper-activity) the Observatory is in the process of contacting all the local power operators supplying the NRAO antennas to assess their plans for deployment of Broadband Over Power Lines, aka BPL. This new service, which the FCC has decided to allow under very slightly modified Part 15 rules governing unlicensed devices, holds great peril for the passive and services, amateur radio, and emergency communications. The question now, though, is not whether but when large-scale deployment will begin.

Although some of the most important issues are still at L-band and below — the 1720 MHz OH line now finds itself squarely in the middle of a large swath of spectrum re-aligned for cell phone use; Iridium is petitioning to expand its ~1620 MHz frequency allocation downward; and BPL will increasingly make its way onto the scene — K-band and mm-wave spectrum are increasingly under pressure. The FCC has already approved the use of 24 GHz short-range radar on cars; your next one may have more microwave transceivers than airbags. The FCC has also approved guidelines for unlicensed use of so-called ultrawideband (UWB) devices, one example of which is to use the entire 3-10.6 GHz spectrum to send HDTV from one end of your house to the other. And point-to-point 76 GHz microwave links will soon be available free on a first-come-first-served basis at a national website.
The Observatory has instituted an email discussion group on RFI matters, to which all interested passive users of the spectrum are invited to subscribe online at: *http://listmgr.cv.nrao.edu/mailman/listinfo/RFIWatch.*

The NRAO now also hosts, quarterly (approximately), a free-to-call-in national telecon during which we have free-ranging discussion of RFI- and spectrum management-related issues. The next will be held in early September: interested parties should subscribe to RFIWatch or send to *hliszt@nrao.edu* a request to be notified.

H. S. Liszt
Scientist and Spectrum Manager

Color Figures in Proposals

We are pleased to announce a formal policy in which the NRAO will once again accept color figures as part of the proposals for VLA, VLBA, and GBT. Due to limitations in our ability to duplicate all our proposals in color, or to select out specific pages to be printed in color, we are adopting the following rules for such submission.

(1) The electronic proposal should include a legible grey-scale version of the color figure. The NRAO will only distribute black-and-white versions of proposals to the referees on paper.

(2) If the proposer wishes a color version of the figure to be available to the referees, he/she should add to the figure caption language such as *"Color version of this figure is available on line at NRAO."*

(3) Proposers should inform the relevant NRAO personnel of the existence of a color figure, and deposit that figure with NRAO. For the GBT, this may be done by including the figure as a separate attachment using the Proposal Submission Tool. For the VLA and VLBA, proposers should wait until they get an acknowledgment that includes the code assigned to the proposal. Then, they should log in to NRAO via anonymous ftp, change to directory pub/incoming/Proposals/colorfigs, and deposit the figure. They should use the naming convention "XXnnnn-Fign.ps" where "XXnnnn" is the proposal code, such as AB1023 or BN043. The "n" in "Fign" should be replaced by the Figure number.

(4) Color figures will be made available to the referees via a private URL, so that they may view the figures when reviewing a proposal.

We wish to remind proposers that this procedure places some extra burden on the referees, by asking them to download the appropriate color figures from the web. However, all options that involve paper distribution of the color figures from the NRAO are administrative nightmares in an era of electronic proposals. Since it is an additional task for the referees, we cannot guarantee that the color figures actually will be accessed. Therefore, we suggest that proposers use color figures sparingly, and only if they are essential to the scientific justification; an over-reliance on unnecessary color figures is unlikely to endear a proposer to the referees!

J. S. Ulvestad, P. R. Jewell

2004 Summer Student Class

By the time this newsletter hits the stands, the 2004 summer student class should have reported to their assigned NRAO sites. The 2004 class consists of 24 students: 14 undergraduate students supported by the National Science Foundations "Research Experience for Undergraduates" (REU) program; two undergraduate students or graduating seniors supported by the NRAO Undergraduate Summer Student program; and eight graduate students supported by the NRAO Graduate Summer Student program. Eleven students are assigned to Socorro, eight to Charlottesville, and five to Green Bank. These 24 students were chosen from 146 applications.

During their 10-12 week summer internship, the students will work with an NRAO advisor on a project in the advisor's area of expertise. Besides their summer research projects, the students will attend a lecture series and go on field trips to other observatories. Students assigned to Socorro will collaborate on a VLA and VLBA observational project and attend the Synthesis Imaging Summer School. Students assigned to Green Bank or Charlottesville will have the opportunity to work on a GBT observational project.

The accompanying table lists the names and schools of all 2004 summer students, together with their NRAO advisor, site, and project title. More detailed descriptions of the student projects are available at *http://www.nrao.edu/students/NRAOstudents_projects04.shtml*. Details on these and all NRAO student programs are available at *http://www.nrao.edu/students/*.

J. Hibbard

2004 NRAO Summer Students					
Participant	**School**	**Project**	**Advisor**	**Site**	**Program**
Patrick Cameron	California Institute of Technology	Radio Observations of Gamma-ray Burst Afterglows	Dale Frail	SOC	NRAO GRP
Jana Grcevich	University of Wisconsin-Madison	High Resolution Imaging of Formaldehyde Emission Towards Pre-protostellar Cores	Yancy Shirley	SOC	NSF REU
Nicole Gugliucci	Lycoming College	The Evolution of Radio Galaxies	Greg Taylor	SOC	NSF REU
Kelley Hess	Cornell University	Radio Sources in the Andromeda Galaxy	Lorant Sjouwerman	SOC	NSF REU
Bradley Isom	University of Nebraska-Lincoln	A Test Spectrometer for the Green Bank Electronics Division	John Ford	GB	NSF REU
Sarah Jaeggli	University of Arizona	Broadband Digital Spectrograph for the GB/SRBS	Rich Bradley	CV	NSF REU
Carlos Kelly	University of Alaska, Fairbanks	Software Development for the ALMA Correlator	Jim Pisano	CV	NRAO GRP
John Kelly	University of Virginia	VLA Observations of the Chandra Deep Field South	Ken Kellermann	CV	NRAO GRP
Mariana Lazarova	Sweet Briar College	Turbulent Characteristics of Galactic HI	Tony Minter	GB	NRAO uGRP
Marsha Logan	Benedict College	Research Opportunities in Solar Radiophysics	Tim Bastian	CV	NRAO GRP
Chun Ly	University of Arizona	Investigating the Structure of Radio Jets	Craig Walker	SOC	NRAO GRP
Ann Martin	University at Buffalo	The Life of Young Radio Jets Near Black Holes	Yuri Kovalev	GB	NSF REU
Danielle Miller	James Madison University	Data Reduction Involving Higher-Dimensional	Nicole Radziwill	GB	NSF REU

2004 NRAO Summer Students (continued)

Participant	School	Project	Advisor	Site	Program
Rebecca Percy	Villanova University	Automated 600 - 720 GHz Receiver Measurements	Eric Bryerton	CV	NSF REU
Lin Qiu	University of Wisconsin-Madison	Automation Hardware Development for ALMA Receiver Evaluation	John Effland	CV	NRAO uGRP
Lynnae Quick	North Carolina Agricultural and Technical University	Radio Observations of Brown Dwarfs	Rachel Osten	CV	NSF REU
Urvashi Rao Venkata	University of California, San Diego	A New Deconvolution Algorithm	Tim Cornwell	SOC	NRAO GRP
Kirstin Schillemat	Clarkson University	The Jets of the Microquasar SS433	Vivek Dhawan	SOC	NSF REU
Sarah Scoles	Agnes Scott College	A Search for Explosive Radio Transients in the VLA Data Archive	Glen Langston	GB	NSF REU
Anandkumar Shetiya	New Mexico Tech	Optimization of Scale Sensitive Deconvolution Algorithms	Sanjay Bhatnagar	SOC	NRAO GRP
Christine Simpson	Wellesley College	Water Masers in the FU Orionis Object Z Canis Majoris	Mark Claussen	SOC	NSF REU
David Stewart	Virginia Tech	Prototype Design of a New Orthomode Transition Based on the Active Balun Technique	Shing-Kuo Pan	CV	NRAO GRP
Adrienne Stilp	University of Wisconsin-Madison	Observations of the Sunyaev-Zeldovich Effect in Clusters of Galaxies with the Cosmic Background Image	Steve Myers	SOC	NSF REU
Ben Zeiger	Willamette University	Time Evolution in the Supernova Remnant STB 80	Shami Chatterjee	SOC	NSF REU

A Change in Editor for the Newsletter

It is exactly 23 years ago this month that the first issue of the NRAO Newsletter appeared, having been founded by Mort Roberts, then Director, with myself appointed as Editor. In June 1981, there was only one other astronomical newsletter (ESO's *Messenger*) and none other that could be nicknamed the Yellow Peril (the color of the NRAO Newsletter was intended to be gold). Over time, we graduated from single-column to double-column, from matte to glossy, and greeted the new millennium (January 2000) with full color. The subject matter had evolved from a narrow emphasis on purely technical matters to the present inclusion of science, for which John Hibbard, Juan Uson, and Jim Condon have served as associate editors for science. They have provided a wealth of stimulating science featuring the results of NRAO facilities, and including images of technically superb quality. Our subscription list grew from about 400 to 1247 at present. The current budget for four issues per year is ~$15,000.

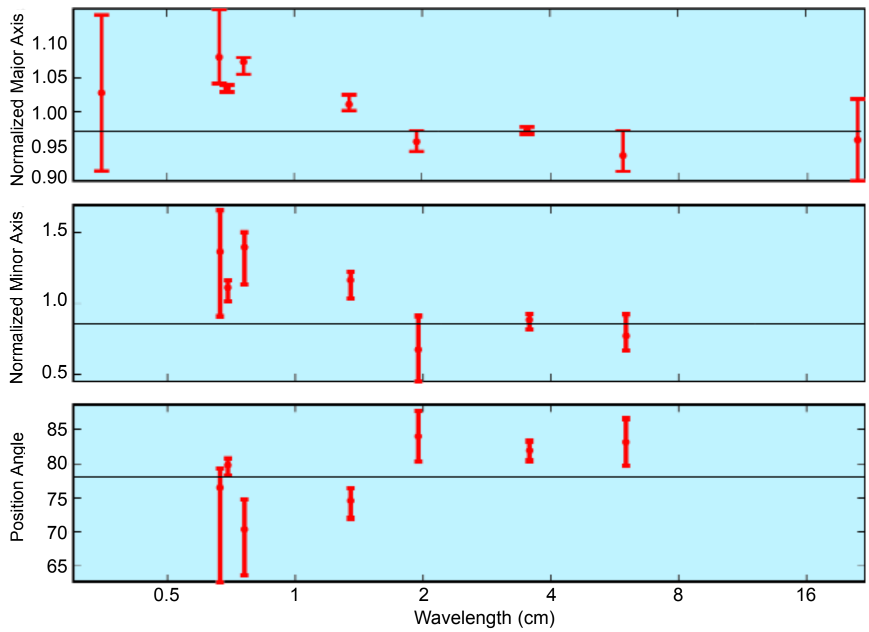
After nearly a quarter century, it comes time to modernize once again, this time with the Editor. The present issue is the 100th, which seems to be a good number for me to bow out with. After nearly a quarter century, it is time to pass the editor's job to someone new. Thus, beginning with the October 1 issue, Mark Adams, recently hired as the Assistant to the Director, will begin his tenure as editor. I'd like to express my great appreciation for the many people who have made the Newsletter possible. These include those who contributed articles over the years (in some cases a great many), and those who helped with the production of the Newsletter. The list is long, but in addition to the Science editors, I would like to single out Sheila Marks and Patricia Smiley. Pat has been with the Newsletter since 1981 and her graphic arts skills have been indispensable. It has been a pleasure to work with all.

Barry Turner, Editor

New Results

Detection of the Intrinsic Size of the Galactic-Center Black Hole Radio Source, Sagittarius A*

This year is the 30th anniversary of the discovery of Sagittarius A* (Sgr A*), the compact radio source associated with the massive black hole at the center of the Milky Way. Since that time, Sgr A* has been the target of numerous observations at radio, infrared, and X-ray wavelengths and much has been learned. The proper motions of stars in the Galactic Center, for instance, have demonstrated conclusively that the mass of the object is 4 million times the mass of the Sun (Ghez et al. 2004).



Major-axis size, minor-axis size, and position angle (deg) of Sgr A as a function of wavelength normalized by a λ^2 scattering law (solid line). The deviation in the short wavelength sizes from the scattering law are the indication of the presence of the intrinsic source. We include a 3.5 mm measurement of the major axis, also made with closure-amplitude techniques (Doeleman et al. 2001).*

In spite of this progress, much is still unknown about Sgr A*. In particular, we have yet to achieve the most basic of results: an image of the source itself. This problem has remained thorny because of the presence of turbulent interstellar plasma along the line of sight from the Earth to the Galactic Center. This turbulent plasma scatters the radio waves produced by the source. The resultant image is an ellipse with a size that scales quadratically with wavelength. From 20 cm to 0.7 mm wavelength, the apparent size of Sgr A* decreases from 0.5 arcsec to less than 1 milli-arcsec. Since the effects of scattering weaken substantially with decreasing wavelength, observations have been pushed to short wavelengths. A combination of the effects of water vapor in the atmosphere and poor antenna performance make calibration challenging in this regime, leading to uncertainty over the quality of the image.

We have recently used a non-standard technique, closure amplitude analysis, to study new and archival observations of Sgr A* obtained with the Very Long Baseline Array (Bower et al. 2004). Our technique is robust against many of the problems of short-wavelength observing. Essentially, closure amplitude analysis forms a quantity that is independent of amplitude calibration. The result is less precise but more accurate than what is found with traditional calibration. We compensate for the lack of precision by using a large number of experiments, 19 in total, to achieve a more accurate and more precise result.

The VLBA data span 6 cm to 0.7 cm wavelength. Combining the VLBA data at 2 cm and longer wavelengths with archival Very Large Array data at 20 cm, we are able to make a highly accurate calibration of the scattering law. We difference our measured size from the expectation of the scattering law to obtain a measurement of the intrinsic size of the source at 1.3 cm and 0.7 cm wavelength (see figure). The intrinsic size is 24 ± 2 Schwarzschild radii at 0.7 cm, where one Schwarzschild radius is the size of the event horizon of a four million solar mass black hole. This is the highest-resolution observation of any black hole system in units of the event horizon. We can use the size and the upper limit to proper motion of the black hole (Reid et al. 2003) to derive a lower limit to the mass density of the black hole: 40,000 solar masses per cubic astronomical unit (1 AU = 150 million km).

The intrinsic size decreases strongly with decreasing wavelength. If the power-law that we observe continues to even shorter wavelengths, then the source will become comparable to the event horizon scale around a wavelength of 1.3 mm. On this scale, the image will be severely distorted by propagation effects in the strong gravity of the black hole (Falcke, Melia, & Agol 2000). Radiation traveling close to the black hole will be gravitationally lensed and appear in a ring with an inner radius of five Schwarzschild radii. Detection of this ring will be the tightest constraint ever placed on the mass density of a black hole. Details of the image may reveal information about the spin of the black hole. Plans are underway to conduct the next-generation experiment to observe this effect. The experiment will rely on an ad hoc network of millimeter and submillimeter wavelength telescopes including the Atacama Large Millimeter Array in Chile. While technically very challenging, this exciting experiment will provide us ultimately with the closest look at physics in the strong gravity of a black hole.

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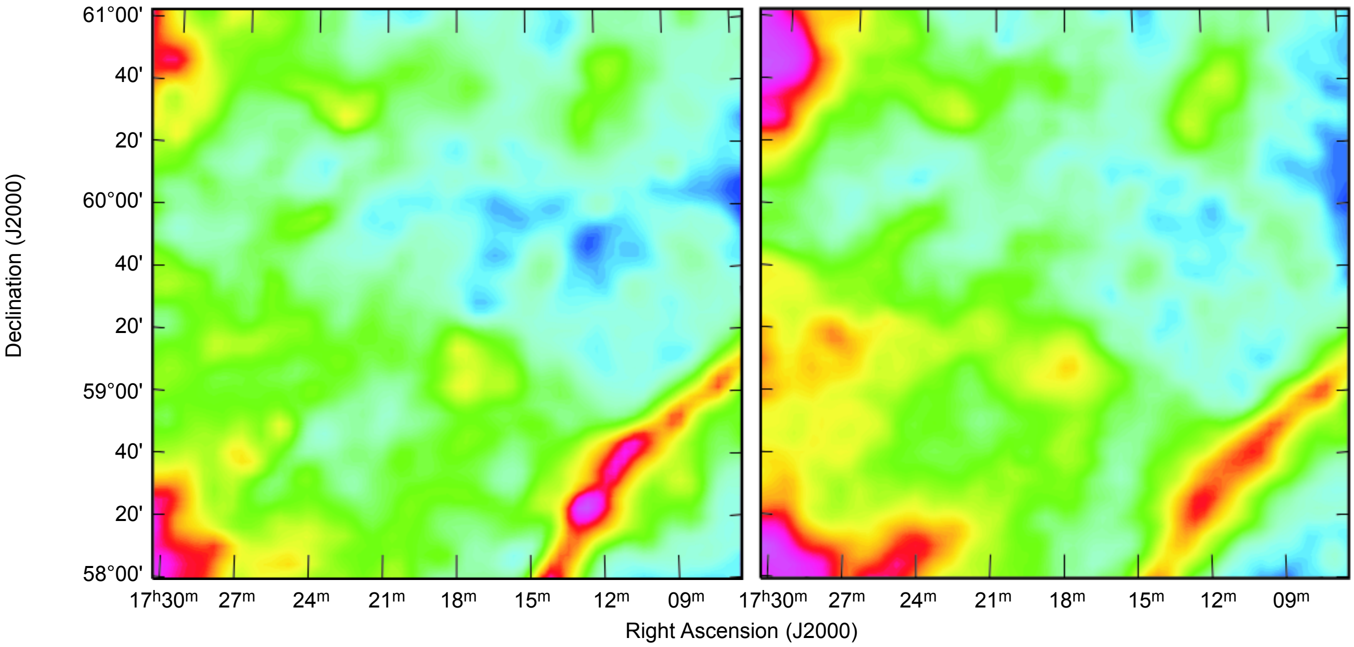
Comparing Dust and Gas In Interstellar Space

Between every astronomer and the extragalactic universe stands the interstellar medium of our own Galaxy, the Milky Way, which can obscure, confuse, and impede attempts to peer through it. This is a special problem at wavelengths most affected by emission or absorption since there is no direction from Earth to extragalactic space which is completely free of interstellar gas and dust.

The Spitzer Space Telescope (formerly called SIRTF) is the last of NASA's four "Great Observatories." It was launched into an Earth-trailing solar orbit in August 2003 to obtain images and spectra in at infrared wavelengths between 3 and 180 microns. Its earliest science mission is the "First-Look" Survey (FLS) covering an area of about five square degrees — a deep view of the extragalactic sky in the far-infrared at sensitivities about 100 times better than surveys with previous satellites. Because emission from "foreground" Galactic dust can be bright at longer infrared wavelengths, it is important to understand this Galactic contamination in the FLS field.

One of the best tracers of interstellar dust is interstellar gas. At high Galactic latitudes, where there is little molecular gas, the best tracer is the 21 cm line of neutral atomic hydrogen (HI). The total amount of gas is approximately proportional to the total amount of dust, and the line observations can be used to distinguish gas in clouds with different velocities.

The Robert C. Byrd Green Bank Telescope (GBT) has a significant advantage for measuring 21 cm emission at high Galactic latitudes, where the emission is always extended and often quite weak. Most radio telescopes have feeds, subreflectors, and support legs partially blocking their main mirrors, and they scatter "stray" HI radiation from unwanted directions into the feeds. These structures are offset on the asymmetric GBT so the aperture is unblocked and the amount of stray radiation confusing the desired signal is reduced.



Interstellar gas is an excellent tracer of dust in the FLS area. The left panel is a false-color image of infrared-emitting dust, and the right panel shows the HI column density after the high-velocity emission has been subtracted. Colors ranging from dark blue to red indicate increasing column density.

However, there is still some stray radiation from forward spillover around the subreflector which we attempted to subtract to make an accurate image of the spectra and sky distribution of HI in the FLS field with 9.2 arcmin resolution. The HI spectra show emission from a number of interstellar components: a high-velocity cloud, several intermediate-velocity clouds, a widespread broad-line source, and several local, cool clouds.

How do the dust and gas images compare? The left panel of the figure is the best image showing the total amount of dust derived from infrared data by Schlegel, Finkbeiner, and Davis (1998). Not all HI is associated with infrared-emitting dust. In particular, high-velocity clouds have never been detected in the infrared, most likely because these distant clouds have almost primordial chemical compositions. They contain hydrogen and helium gas but are nearly devoid of the heavier elements (carbon, oxygen, silicon, iron, etc.) produced in stars and needed to form dust. Our HI map of the FLS field, excluding emission from high-velocity clouds ($V_{LSR} < -100$ km/s), is shown in the right panel of the figure. The detailed similarity of these HI gas and dust images is striking. A quantitative analysis shows that the dust-to-HI gas ratio does vary somewhat across the FLS field and among spectral components. For the brighter components this suggests the presence of molecular hydrogen in addition to atomic hydrogen. For others the variations imply an interesting variation in physical conditions across a cloud. It is clear that these HI data are providing new information about the interstellar medium itself as well as estimates of the Galactic foreground contamination.

The GBT data were obtained as a service to the astronomical community and have been released via the web (*http://www.cv.nrao.edu/fls_gbt*) for anyone to use and analyze.

F. J. Lockman and J. J. Condon

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Detailed Radio Images Seen Through a Gravitational Lens

Radio surveys have been extremely successful at identifying gravitational lens systems, the most notable being CLASS (the Cosmic Lens All-Sky Survey) which discovered a total of 22 lens systems using data from the VLA, MERLIN, and the VLBA. Lens systems result when the radio rays from a distant source pass, en route to the earth, close to a large mass concentration such as a galaxy or galaxy cluster. Gravity causes the rays to be deflected and can, under certain conditions, produce multiple images of the background source. The positions and brightnesses of the various images can be used to measure important properties of the galaxy doing the lensing, such as its total mass and mass distribution. Very Long Baseline Interferometer (VLBI) observations can often provide the most useful constraints on the lens model as the high resolution can separate the lensed images (which are usually unresolved by smaller arrays) into additional components if the source contains substructure.

A good example of where VLBI observations have revealed subcomponents in previously unresolved lens images is the source CLASS B0128+437 (Biggs et al. 2004). This was known to consist of four lensed images from MERLIN observations, but follow-up observations with the VLBA at 5 GHz resolved the images into a jet having a length of ~30 milli-arcsec and dominated by three knots of emission in the brightest image A (see Figure 1). This image shows the MERLIN map (center inset) indicating the positions of the four images plus VLBA maps of each image. B0128+437 is not a terribly bright source (CLASS sources have total flux densities as low as 30 mJy), and the brightest VLBI subcomponent has a total flux of only 4 mJy. However, the signal-to-noise ratio is sufficient (off-source rms noise = 50 microJy/beam) that we can determine the positions and sizes of each subcomponent by fitting elliptical Gaussians to the data.

This source has also been studied at other frequencies (2.3 and 8.4 GHz) with the VLBA observing in conjunction with the 100-m Effelsberg telescope in Germany. These data have allowed us to measure the brightness variation with frequency of the subcomponents. Since gravitational lenses are achromatic, we can use this frequency dependence to

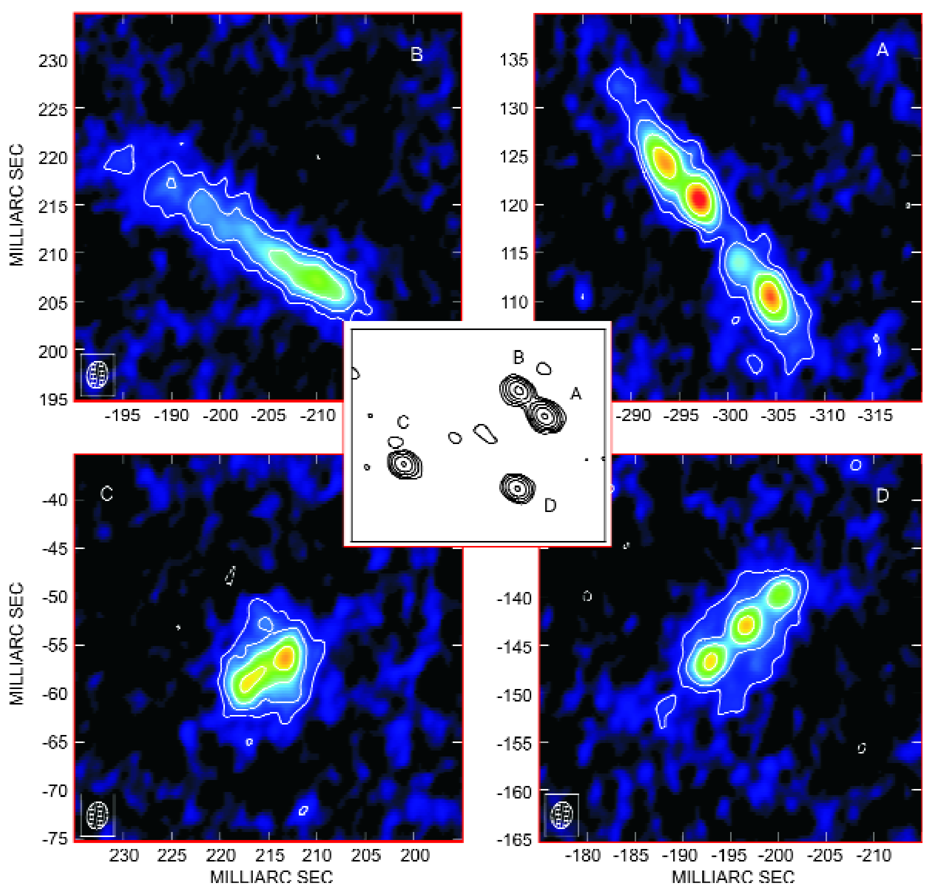

Figure 1. The four images A, B, C, and D as seen by MERLIN (center inset) and resolved by the VLBA (outer panels).

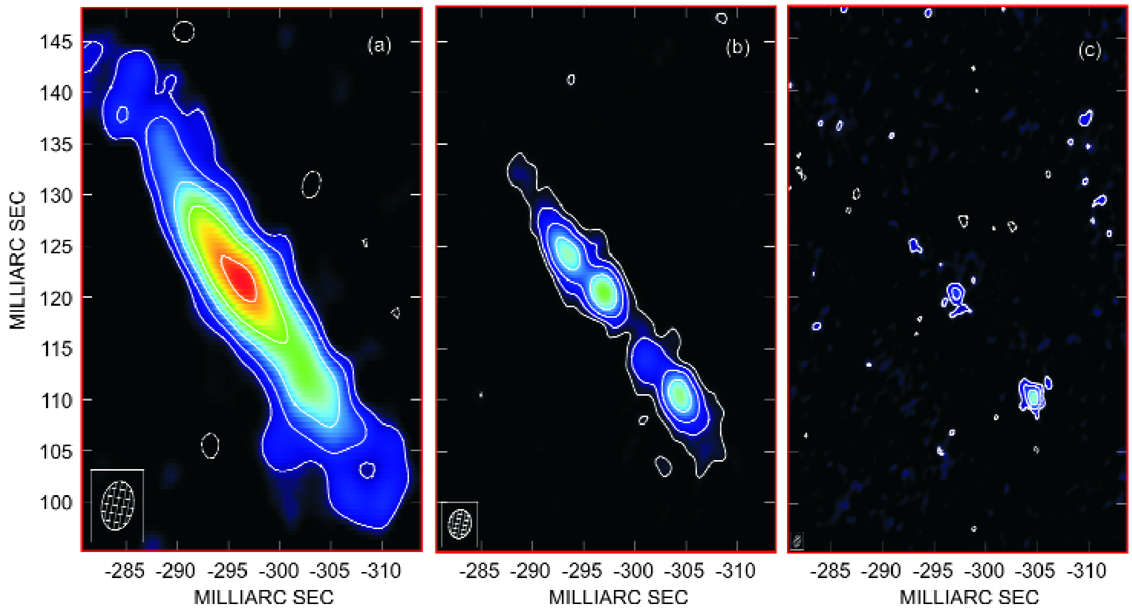

Figure 2. Component A at 2.3 GHz (left), 5 GHz (middle), and 8.4 GHz (right).

determine which subcomponent in each image corresponds to the same source component. Figure 2 shows image A at 2.3, 5 and 8.4 GHz (from left to right). A comparison between the two highest frequencies demonstrates that the brightness of the southernmost component is less variable with frequency than the others.

We have attempted to find a mass model which satisfies the multitude of image constraints that have been provided by the VLBI imaging. Prior to this a simple model had been constructed using the MERLIN data alone, but since practically nothing is known about the lensing galaxy (Hubble Space Telescope observations show it to be extremely faint, I = 24 mag), it was not possible to compare the model galaxy parameters with observations. The extra constraints provided by the VLBI data, however, rule out such simple models for the lensing galaxy as these are unable to reproduce the observed subcomponent positions. More complicated models are therefore required and an important factor in the success of this will be the acquisition of improved optical/infrared HST imaging with which important model constraints (such as the position of the lensing galaxy) can be obtained.

Whereas it requires detailed modeling to reveal the discrepancy between the observed and modeled image positions, immediately apparent from the VLBI map is the difference between image B and the other three. Whilst three subcomponents can be seen in images A, C and D (the three subcomponents in C are revealed in maps of higher resolution), image B (figure 1) shows no apparent signs of any significant substructure. This image does have the appearance of a straight jet, but the subcomponents appear to be missing. This is caused, we believe, by the radio radiation producing this image being distorted as it travels through the interstellar medium of the lensing galaxy. The result is that the subcomponents are smeared and can no longer be differentiated. VLBI studies of other lens systems suggest that this phenomenon is quite common in the lens population.

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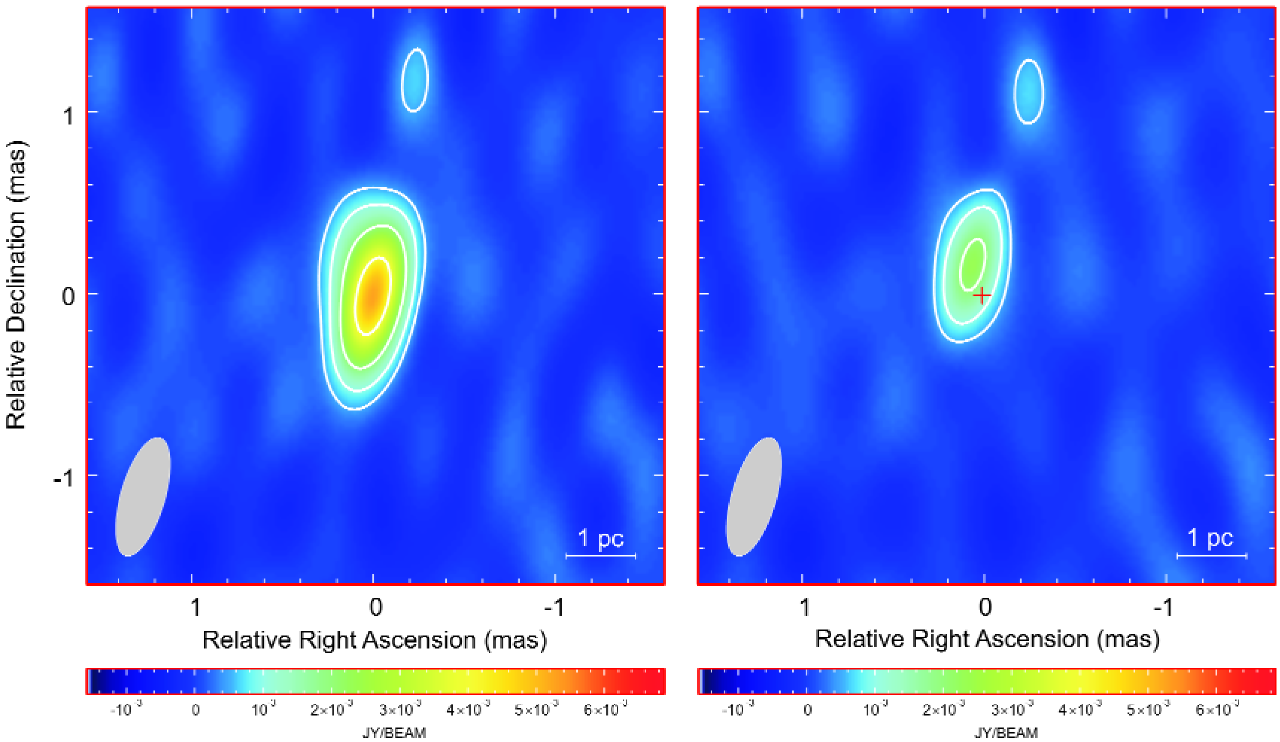
Resolving the Afterglow of a Gamma-ray Burst



Left: Image of GRB 030329 at 15 GHz taken with an array consisting of the VLBA, VLA, GBT, and Effelsberg telescopes. The resolution is 0.25 × 0.67 mas. Contours start at 0.6 mJy/beam and increase by factors of 2. The extension to the northeast is a ~ 20σ detection of a jet component. Right: The same image with a point source of 4 mJy at the position of the main afterglow component subtracted. The jet component has a flux density of 1.8 mJy.

Gamma-ray Bursts (GRBs) herald the most powerful explosions in the Universe and produce afterglows that can be detected for months to years at radio wavelengths before they fade away. Very Long Baseline Interferometer (VLBI) observations of the nearby ($z = 0.1685$) gamma-ray burst GRB 030329 allowed us, for the first time, to resolve a GRB afterglow (Taylor et al. 2004). The size of the afterglow was found to be ~0.07 mas (0.2 pc) 25 days after the burst, and 0.17 mas (0.5 pc) 83 days after the burst, indicating an average apparent expansion rate of 3-5 times the speed of light. This apparent superluminal expansion is consistent with expectations of the standard fireball model (Granot & Loeb 2003, and references therein). Based on energetics and breaks in the light curves, typical GRBs appear to be collimated into cones of angle ~0.1 radians (Berger, Kulkarni, & Frail 2003), which we must be within to see the gamma-rays. To get an apparent superluminal expansion of 5*c* requires Lorentz factors of ~7 and bulk motions close to the speed of light. The energy release estimated from the measured expansion of GRB 030329 is 2×10^{50} ergs assuming expansion into a circumburst medium with a constant density of 1 cm^{-3}.

Much more difficult to explain in GRB 030329 was the emergence of an additional compact component at a distance of 0.28 ± 0.05 mas (0.80 pc) from the main component (Figure 1). Assuming that it was ejected at the time of the explosive event marked by the GRB itself, an apparent velocity of 19*c* would have been required to reach its observed position 52 days after the burst. This is the first such "shrapnel" from a GRB explosion to be observed. If such high-speed components turn out to be commonplace, then this fact will have profound implications for the fireball models.

We measure the projected proper motion of GRB 030329 in the sky to be < 0.3 mas in the 80 days following the burst. In the relativistic fireball model a shift in the flux centroid is expected due to the spreading of the jet ejecta (Sari 1999). For a jet viewed off the main axis the shift can be substantial. However, since gamma rays were detected from GRB 030329 it is likely that we are viewing the jet largely on axis. The predicted displacement in this case is expected to be small (0.02 mas), and well below our measured limit over 80 days of 0.10 ± 0.14 mas.

In the competing "cannonball" model, the afterglow originates from the superluminal motion of plasmoids ejected during a supernova explosion with $\Gamma_0 \sim 1000$ (Dado, Dar, and De Rújula 2003). Dar & De Rújula (2003) predicted a displacement of 2 mas over the 80 days of our VLBI experiment assuming plasmoids propagating in a constant-density medium. This model can be ruled out based on the VLBI limit of < 0.3 mas on the proper motion. A further problem for the cannonball model is that the compact plasmoids will scintillate strongly at all times, whereas in GRB 030329 there are only moderate variations seen in the radio light curves, consistent with weak interstellar scintillation. Berger et al. (2003) derive a model-dependent size of 0.020 mas at 15 days after the burst, consistent with the growth rate directly imaged by the VLBA starting 25 days after the burst.

The VLBI campaign to obtain these results made use of many of the largest radio telescopes on Earth including the VLBA, phased VLA, Green Bank, Effelsberg, Arecibo, and phased Westerbork telescopes. By correlating the signals from all these telescopes a low noise of 30 microJy/beam was achieved in just 138 minutes on the fading GRB, 83 days after the burst. The resultant high signal-to-noise observation yielded the most secure measurement of the angular size of the afterglow.

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