NRAO Newsletter

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Green Bank

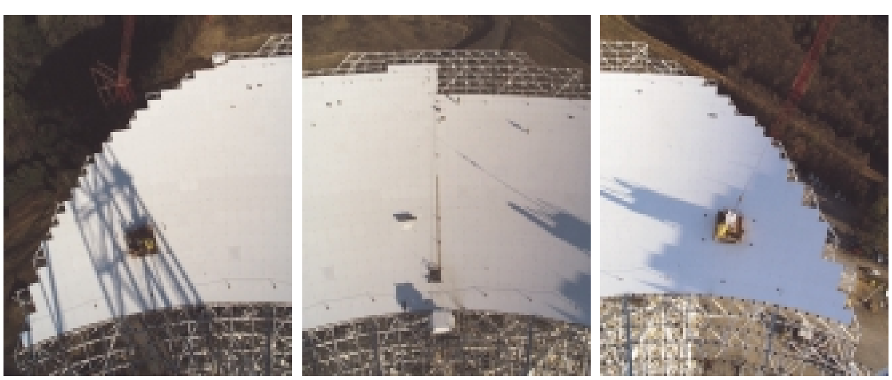
The Green Bank Telescope

Antenna Structure

As reported in the previous NRAO newsletter, the antenna structure was essentially completed with the installation of the tip of the upper feed arm in July. The alignment of all 16 azimuth wheels was completed in mid-November, and 23 of the 30 elevation gear segments have been rough aligned. The S70 derrick that was used to lift heavy portions of the antenna structure has been disassembled and removed from the site. After a break over the holidays, the construction crew will resume its work by checking the servo system, testing surface actuator cables, laying panels, and setting panel corners.

Surface Panels

As of November 19, 1902 of the 2004 surface panels have been manufactured by RSI. Of these, 1868 have passed surface accuracy requirements and 1747 have passed paint inspection. At the time of this writing, 1740 panels have been delivered to the GBT site, and 1465 of these have been installed on the structure. The panels are visible in the accompanying photographs. An NRAO panel setting tool was used to precisely align the corners of some panels during a two-week trial period in late November.



The surface panels for the GBT are supported by motor-driven actuators. To date, 2146 of the 2209 actuators have been aligned to conform with the design paraboloid. Of the aligned actuators, 2017 have been welded in place.

NRAO Systems for the GBT

An end-to-end test of GBT software was successfully carried out on December 1. During the test, an all sky pointing observation was simulated with an antenna simulator. The software evaluated during the test included the telescope monitor and control software, the operator/engineer graphical user interface (GUI), the observer's GUI, and the commissioning tools in AIPS++. The hardware used during the test included the Ku-band receiver, IF electronics, and the digital continuum receiver. Only a few minor problems were encountered during the test. Staff astronomers and telescope operators will continue to run these tests to familiarize themselves with the software and to identify any additional problems.

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NRAO Systems for the GBT (continued)

All GBT equipment in use at the 140 Foot Telescope was removed after the telescope was retired on July 22. The spectral processor, VLBA data acquisition rack, and the SAO maser were installed in their permanent locations in the new addition to the Jansky Laboratory. The C, X, Ku, and K-band receivers were moved to the electronics laboratory to prepare them for installation on the GBT.

On October 15, five of the 12 ground laser rangefinders were used to measure distances to a retroreflector on the GBT feedarm. The measurements detected the structural oscillation modes that were predicted by a dynamic analysis of the structure. The frequencies of the oscillations were verified by an independent measurement with accelerometers.

M. M. McKinnon

An Old Friend Retires

On July 22, 1999 the 140 Foot Telescope in Green Bank, WV was retired from service. Many observers and NRAO employees have fond memories of it over the more than 34 years that it has been with the Observatory. All of us have learned to live with its personality and idiosyncratic behavior. And even though it has suffered physical setbacks over the years it has always bounced back and has had a very distinguished career with many accomplishments.

It all began in 1955 when design studies of the 140 Foot started. The decision to build was made in March of 1956, bids were solicited for fabrication and construction in August of 1957 and actual construction began about a year later in 1958. There was a pause in the construction schedule in 1961 when the shaft, yoke and some auxiliary components were redesigned. Construction restarted in early 1962. The design, size and weight of the 140 Foot presented several challenges and some interesting "moments" during assembly over the next few years (M.M. Small, "The New 140 Foot Radio Telescope," *Sky & Telescope*, Vol 30, No 5, November 1965). Major construction was completed in the spring of 1965 and shortly after in May, first observations (lunar occultations at 234 to 405 MHz) were conducted by S. Von Hoerner. The long and prosperous career officially began at its dedication on October 13, 1965.

Although the 140 Foot construction had its problems and challenges, it was in contrast to, and not an indication of the success that it would achieve over the next 34 years. In July 1965 the first unambiguous detection of radio recombination lines was made with the 140 Foot by P. Mezger and B. Hoglund. In 1969 the first organic polyatomic molecule (H_2CO) was detected in absorption in the interstellar medium by L. Snyder, D. Buhl, B. Zuckerman and P. Palmer. The first long-chain molecule (HC_3N) in the interstellar medium was detected by B. Turner in emission a few months later. About half of all known molecules today which have transitions at centimeter wavelengths were detected using the 140 Foot.

Other notable achievements using the 140 Foot include the first detection of Zeeman splitting of the 21 cm line of hydrogen in space in 1968 by G. Verschuur, the first detection of H I absorption arising from within another galaxy in 1970 by M. Roberts, pioneering very long baseline interferometry observations in March 1967, and the first transcontinental and transatlantic VLBI observations in 1967 and 1968 respectively.

Other 140 Foot observations made significant contributions to cosmology, the study of pulsars, SETI observations and many other different fields of astrophysics. All of these many contributions were recognized at the thirtieth anniversary celebration held on September 30, 1995.

We are sorry to see the 140 Foot retire but we know that it has made a rich contribution to NRAO and to astronomy during its distinguished life. Following the last observations the process to mothball it began and was completed about the middle of October. This state of hibernation allows it to return to service, just as some retired NRAO employees have done after retiring! If funding is found over the next year we will certainly welcome it back. It is a tribute to

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Old Friend Retires (cont.)

NRAO and all the employees and the astronomers who have used the telescope that the 140 Foot has had such a successful career in radio astronomy. In its retirement it will stand as a reminder to us all of its glorious past. It is entirely fitting that its larger and more imposing successor, the GBT, will tower over it. This is a memorable symbol of the past and future of radio astronomy!

R. C. Bignell

Frank Drake Returns to Green Bank

Frank Drake was one of the very first members of the NRAO Scientific Staff along with Dave Heeschen and John Findlay. He lived in Green Bank for five years in the late 1950s and early 1960s, overseeing development of instruments, conducting experiments with the first radio telescopes, and working to establish NRAO as a institution with scientific credibility. He also did Project Ozma, the first deliberate search for radio emissions from extraterrestrial intelligence. On October 27, 1999, Drake, now at the University of California, Santa Cruz, and President of the SETI Institute, returned to Green Bank to receive this year's Jansky Lectureship Award, to give a talk about progress in the search for extraterrestrial intelligence, and to meet with old friends and colleagues.

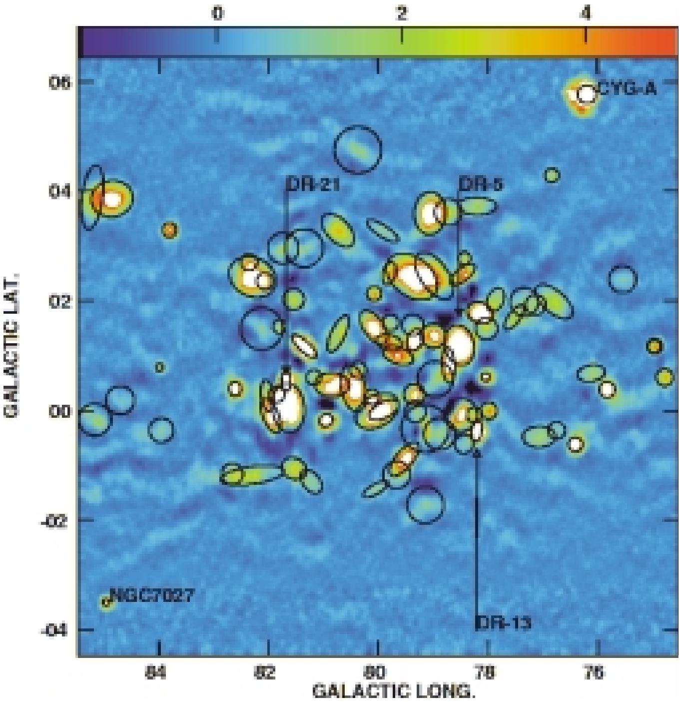
Planning for Project Ozma was begun in 1959, at a time when the only telescope at NRAO was the recently-completed Howard E. Tatel 85 Foot. Drake reasoned that the 85 Foot Telescope would be able to detect radio signals from the strongest transmitters then in existence on Earth out to a distance of several parsecs. He began a modest project to build a 21 cm receiver for this experiment but made sure that it could be used for other research so that the marginal cost of the Project could be kept very low. In the autumn of 1959 Otto Struve, then the new Director of NRAO, discussed the upcoming experiment in a lecture at MIT and it made the national news. The November 1959 NRAO Monthly Summary of Activities noted that Dr. Drake's projected search for coherent signals from life on other planets has received much recent publicity. "Dr. Drake has been planning this program for several years, and work on the equipment – which will also be used for another, more conventional program – was begun last spring. The recent publicity has gotten somewhat out of hand. The odds against success in this initial attempt are obviously extremely high. However, it is well worth trying with presently available equipment." Struve himself wrote several articles in which he defended the value of this type of research at the NRAO.

The Project Ozma observations were made in the spring and summer of 1960, and although no detections resulted, the experiment started an area of research which has grown with time and has certainly touched the imagination of the public. While at Green Bank, Drake also penned his famous equation which gives the number of currently-detectable civilizations in the Galaxy as a function of a number of variables. Much of the original equipment used in Project Ozma is still on hand and it will become part of an exhibit in the new Astronomy Education Center now under development in Green Bank.

During his recent visit to Green Bank Drake was reunited with three NRAO employees, all now retired, who were telescope operators during Project Ozma. Fred Crews, former head of the Telescope Services Division, George Grove, who for many years ran VLBI experiments at the 140 Foot Telescope, and Bob Viers, who was supervisor of the 300 Foot Telescope, all joined Drake for dinner before his lecture, and stayed on in the Residence Hall Lounge for several hours afterward swapping stories about life in Green Bank in the days before catalog shopping, cable TV, good highways, and the Internet. Other employees from that era, including Bob Vance and Sidney Smith, were also on hand.

Drake's Jansky Lecture was very well attended and drew a number of area residents, some of whom brought their children. Drake began his talk by noting that it was quite appropriate that he speak of SETI at Green Bank since it all started here more than 40 years ago. He went on to describe the motivation behind the search, recent topics in exobiology, and progress in technology and technique that might make the search more fruitful. The lecture was covered by local and regional press, and an account of it is available from the *Pocahontas Times* web site at: *www.pocahontastimes.com* in their November 11, 1999, issue.

F. J. Lockman



Galactic Plane at 8.35 and 14.35 GHz

The Galactic Plane (GP) is being monitored for bright transient sources at 8.35 and 14.35 GHz using the NRAO/NASA Green Bank Earth Station to survey the sky simultaneously at these frequencies. The GP surveys are intended to detect short lived radio sources. The Galactic Plane "A" survey (GPA) is the first in a series of surveys intended to discover variable and transient radio sources, by making rapid and repeated observations of large regions of the galactic plane. This survey is made simultaneously in the region bounded by $|b| < 5°$ and $-15° < \ell < 255°$. The GPA survey is motivated, in part, by previous sensitive surveys made at NRAO Green Bank with the 300 Foot Telescope to study properties of compact radio sources in the galactic plane at 5 GHz, including the survey of Gregory and Taylor (1981, Ap.J., 248:596). The Gregory and Taylor survey discovered a number of variable sources including GT0236+610, a galactic X-ray binary system. The GPA survey FITS format images are available online at *http://www.gb.nrao.edu/~glangsto/GPA* . The flux density calibration of the GPA survey is based on observations of sources in the Cygnus region. The 8.35 GHz image of this region is shown in the figure above.

G. I. Langston and A. H. Minter

Green Bank Computing

We have purchased a dedicated projector with improved resolution and brightness to use with computer-based presentations in the Green Bank auditorium. All visitors are welcome to bring their laptop computers and use this display.

One note of caution: Since Green Bank has a unique RFI environment, we have not installed any Category 5 (Cat5) equipment, also known as unshielded twisted pair (UTP), 10BaseT, or 100BaseT. All of our computer connections to the Ethernet use AUI, BNC (coaxial or 10Base2), or fiber (10BaseF) ST or SC connectors.

If you have a laptop, or are thinking of acquiring one, it may one day be brought to Green Bank. Most laptops, by default, only provide UTP connectors. If possible, you might consider getting an adaptor card that is compatible with our unusual network. One common PCMCIA connector, that we use widely, provides a BNC connector as an option at no additional cost. We will have a PCMCIA card and its associated software driver available to install in laptops temporarily.

Catching the Wave Public Education Program

In Fall 1998, the NRAO received a grant from NSF Informal Science Program! Over the next three years, our project, called Catching the Wave, will result in interactive exhibits, and programs for K-12 students and the general public. We are excited to have the opportunity to enhance the public's experience while visiting the NRAO in Green Bank.

Catching the Wave, the theme for the new exhibition, will contain interactive exhibits organized around five central questions: What are Radio Waves?, How do we Detect Radio Waves?, What can Radio Astronomy tell us about the Universe?, What is going on at the Telescopes now?, and What is the Role of Technology in Science? For a look at some of our exhibit ideas go to the web site: *http://www.gb.nrao.edu/~sheather/excerp.html*. Keep in mind that these exhibit concepts are subject to change and many new exhibit ideas have been discussed with our exhibit designer, John Moser of Moser Productions. We expect to prototype at least part of the Catching the Wave exhibition during the 2000 tour season, with fabrication and installation to occur in 2001.

In addition to providing an entertaining learning experience for the public, Catching the Wave programs will focus on K-12 students in West Virginia, and surrounding states. We will develop programs – field trip experiences – that meet national science education standards and state-based science learning goals. Science-specific problem-solving scenerios are being created in which small groups of students investigate questions much as the professionals at the Observatory would. For example, one group of students might assume the role of an NRAO interference technician, discovering sources of RFI at the Observatory and reporting their results to other students. This approach is in sharp contrast with that offered at the typical science museum where students bounce from one exhibit to the next, learning virtually nothing.

In concert with Catching the Wave, we are in the process of designing a new science education center. The new facility will include an exhibit hall, auditorium and classrooms, and a rooftop optical observatory.

S. A. Heatherly

ALMA

ALMA Project

In the past three months, the U.S. side of the ALMA Project has made substantial progress in making the transition from the U.S.-only Millimeter Array Project to the joint U.S.-European ALMA Project. Briefly, what is involved here is forming a common project from what previously had been two separate projects. This means (1) forming a common Project team; (2) forming an agreed common Project scope; (3) establishing an agreed common Project schedule; and (4) establishing an agreed Project cost and assignment of responsibilities.

The joint Project Team is being formed by consolidating the management and oversight people and committees for each major Project task. In the joint Project there are nine major tasks, or "level-1 work breakdown structure" elements. For each of these tasks the respective U.S. Division Heads and their counterpart European Team Leaders have been meeting to establish mechanisms for working together. In many cases, advisory committees have been set up that are made up of individuals from both European and U.S. institutions. For example, an ALMA Science Advisory Committee (ASAC) has been established and is functioning to provide advice to the Project management. Membership of all the joint committees can be found on the ALMA web pages (which are now mirrored in Europe). In the Design and Development Phase (referred to as Phase 1), through December 2001, the Project Management is provided by the ALMA Executive Committee, two representatives from the U.S. and two from Europe.

The scope of the joint Project, for Phase 1 and for Phase 2 (construction) is being established in different ways. In Phase 1, the principle technical deliverables, or output products, are antenna prototypes and an agreed system block diagram completed in detail for the final ALMA array. In an attempt to keep competition in the process leading to procurement of the production quantity of antennas needed for ALMA, and to secure for ALMA an antenna of the highest technical performance, the ALMA Project in Phase 1 will contract for two prototype 12 m diameter antennas. One prototype is being procured by the European side and another prototype is being procured from a different manufacturer by the U.S. side. The technical specifications for the two prototype antennas are identical in all respects. The two antennas will be delivered in 2001 to the VLA site where they will be competitively evaluated in both single dish and interferometric tests. Out of this process a single antenna design, either the U.S. prototype or the European prototype, will be selected for ALMA. It is expected that the contract for the production run of antennas will specify that the contractor support half the fabrication effort on each side of the Atlantic. Meanwhile, the second major deliverable of Phase 1, the ALMA system specification, is also well underway. Drafts of the block diagrams both for the test interferometer (the interferometer created from the two prototype antennas) and for the final ALMA array are being circulated for comment and revision within the Project. A critical design review of the test interferometer system, and a preliminary design review for the final ALMA system, will be held this spring.

The Project schedule will result from an assessment of two competing forces. On one side, the desire of all Project participants to maximize the buying power of their respective financial commitments means that for those Project tasks that involve contract work,– for example, the antenna procurement,– doing these phases of the project quickly is desirable. (Contractors regard the future as a risk; the customer pays for that risk). On the other side, for much in-house effort the maximum cost efficiency is often set by the capabilities of existing staff or existing facilities so that special facilities don't have to be built for the needs of ALMA construction and then discarded or underused. This usually means that a stretched-out schedule is desirable. However, with the resources available to the joint Project in Europe as well as in the U.S., it may be feasible to bring these two optimum timescales into harmony. This is the goal of the effort now in progress.

The Project cost and assignment of responsibilities for delivering hardware to ALMA is being developed by the ALMA Executive Committee. The planning is being done based on the costing developed for the MMA U.S. Reference Project that was delivered to the NSF in July 1999 and audited by the NSF at that time. A draft of the ALMA cost, schedule and scope is due to be delivered to the ALMA Coordinating Committee at the end of March 2000.

Finally, we are very pleased to welcome to the U.S. side of the ALMA Project the new Project Manager, Marcus Rafal. Marc comes to us from the Space Telescope Science Institute and will provide experienced management leadership in the next, very demanding, stages of the ALMA Project.

R. L. Brown

Science with the Atacama Large Millimeter Array

Two hundred astronomers from around the world attended the "Science with the Atacama Large Millimeter Array" conference in Washington, D.C. on October 7 and 8, 1999. Associated Universities, Inc. (AUI) sponsored the event. The venue was the Carnegie Institution of Washington.

A reception on Capitol Hill, sponsored by AUI in honor of this first ALMA science meeting, kicked off the events. Several members of Congress and their staffers met astronomers at the catered affair, which featured remarks by Rep. Vernon Ehlers (R-Michigan), a physicist and member of the House Science Committee. He urged astronomers to keep Congress informed of the importance and progress of ALMA.

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Science with the ALMA (continued)

The conference itself commenced with incoming AAS President Anneila Sargent (Caltech) delivering the keynote address. Over the following two days, astronomers gave presentations in four topical areas: ALMA's capabilities in studying galaxies from near the time of their formation to the present; the detection and study of planets and disks around nearby stars; the study of star formation; and the study of the origin, distribution, and evolution of the elements and their isotopes. A poster session was also held. The Science with ALMA conference proceedings, edited by Al Wootten, will appear in the *Publications of the Astronomical Society of the Pacific*. Abstracts of invited talks and poster sessions can be found on-line at: *http://www.alma.nrao.edu/library/alma99/index.html.*

To familiarize the media with the ALMA project, a press briefing was held on October 7. The briefing, moderated by AUI President Riccardo Giacconi, featured remarks by Sargent, Alan Boss (DTM), David Spergel (Princeton), Robert Eisenstein (NSF Assistant Director for Mathematics & Physical Sciences), Catherine Cesarky (ESO Director General), and Keiichi Kodaira (NOAJ Director General). The reception, meeting and press conference were to introduce ALMA as an international collaboration hosted by Chile whose partners include the US (NSF, through AUI), and Europe (ESO, CNRS (France), MPG (Germany), NFRA (Netherlands), FNR (Sweden) and PPARC (UK). Negotiations continue with prospective partners including Japan, Canada and Spain.

R. A. Johnson

New Committee - ALMA Science Advisory Committee

The Atacama Large Millimeter Array (ALMA) project has formed a new committee, the ALMA Science Advisory Committee (ASAC) to provide scientific advice to the project and outreach to the wider community. We also intend to provide information to the community through the web site:

http://www.alma.nrao.edu/committees/sac/sac.html

In addition, we are all willing to give colloquia on the ALMA project. A list of the committee members can be found at the previously mentioned web site.

Please give your comments or ask questions directly to individual committee members.

N. J. Evans, II
Chairman, ASAC

ALMA Photonics Development in Tucson

During the past few months the effort on the Photonic LO system has continued. We have demonstrated a round trip correction system over a fiber length of 25 km. For this system we use a high-stability, long-coherence-length laser as an optical interferometer coupled to a servo system that continuously adjusts the fiber length to keep it constant to a fraction of the 1.5 micron fringe spacing.

We have recently used this system, in conjunction with a second laser, to demonstrate the transmission of a phase stable reference frequency over this length of fiber. The second laser is offset in frequency from the high stability laser and the resultant beat note is phase locked to a microwave reference. The correction signal resulting from the phase comparison is applied to the second laser and the two optical frequencies are then transmitted over the 25 km length of fiber. At the far end of the fiber the two frequencies are combined (mixed) in a photo-detector and the phase of the resultant beat note is compared with the phase of the transmitted beat frequency. The spectral purity of the difference frequency is independent of the difference frequency and experiment shows that both the correction system and the spectral purity of the difference frequency are adequate for the ALMA application.

Our experiments to date have been confined to readily available commercial components and in particular to photo-detectors that are specified only to frequencies up to 60 GHz. We have recently tested a commercial photo-detector at frequencies up to 120 GHz, however, and have found the device to give appreciable power at these higher frequencies. This has led to a change in the ALMA baseline design in which the reference frequency to the 64 antennas will be photonically generated at frequencies up to around 120 GHz and distributed using the correction system described above. This decision will make the installation of an all photonic LO system far easier in the future. Work on the high frequency photo-detectors needed for the all photonic system is being carried out by our ALMA partners in Germany, possibly England, and also in Japan, a potential future partner.

Meanwhile, we are continuing to develop the photonic calibration system in which a signal is injected directly into the receiver and may be used for calibration of the instrumentation of the entire interferometer. At the end of September 1999, a Preliminary Design Review (PDR) for the Photonic LO was held in Tucson. Various outside experts formed part of the Evaluating Committee and the recommendations included increasing the effort on the calibration system, investigating more fully the efforts of other groups in this area of technology, and proceeding with the concept of the photonic reference system. The photonic effort on the ALMA project has generated considerable interest in the blossoming fiber optic community and the Tucson Group was invited to present a paper giving the latest results at the annual international Microwave Photonics meeting in Melbourne, Australia in November 1999.

J. M. Payne

VLA

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
B	29 Oct 1999	14 Feb 2000	1 Jun 1999
CnB	25 Feb 2000	13 Mar 2000	1 Oct 1999
C	17 Mar 2000	19 Jun 2000	1 Oct 1999
DnC	30 Jun 2000	17 Jul 2000	1 Feb 2000
D	21 Jul 2000	02 Oct 2000	1 Feb 2000
A	13 Oct 2000	08 Jan 2001	1 Jun 2000
Bna	19 Jan 2001	05 Feb 2001	1 Oct 2000

The maximum antenna separations for the four VLA configurations are: A-36 km, B-11 km, C-3 km, D-1 km. The BnA, CnB, and DnC configurations are the hybrid configurations with the long north arm, which produce a round beam for southern sources (south of about -15 degree declination) and extreme northern sources (north of about 80 degree declination).

Approximately Long-Term Schedule

	Q1	Q2	Q3	Q4
2000	C	C	D	A
2001	B	B,C	C	D
2002	A	A,B	B	C
2003	D	D,A	A,B	B
2004	C	D	D,A	A,B

Observers should note that some types of observations are significantly more difficult in daytime than at night. These include observations at 327 MHz (solar and other interference; disturbed ionosphere, especially at dawn), line observations at 18 and 21cm (solar interference), polarization measurements at L band (uncertainty in Ionospheric rotation measure), and observations at 2cm and shorter wavelengths in B and A configurations (trophospheric phase variations, especially in summer). They should defer such observations for a configuration cycle to avoid such problems. In 2000, the D configuration daytime will be about 10h RA and the A configuration daytime will be about 18h RA.

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. The VLBA spends about half of available observing time in coordinated observations with other networks, with the scheduling dictated by those networks. In decreasing order of the time devoted to the observations, these are HALCA space VLBI, Combined Millimeter VLBI Array, Global astronomical VLBI with the EVN, and geodetic arrays coordinated by GSFC.

Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the European VLBI network is a global proposal, and must be sent to the EVN scheduler as well as to the NRAO. VLBA proposals requesting only one EVN antenna, or requesting unaffiliated antennas, are handled on a bilateral basis; the proposal should be sent both to 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.

B.G. Clark

Recent Developments on the VLA - Pie Town Link

Since the publication of NRAO Newsletter No. 81, three new developments have occurred in the implementation of the VLA-Pie Town (PT) optical-fiber link. On November 22, 1999, fringes were detected for the first time using all four VLA IF bands. The data were analyzed to confirm that both AC and BD IF pairs had the same noise characteristics. In the November-December period, software and hardware were implemented to allow the VLA on-line system to refer to PT as antenna 29, rather than “borrowing” an identity from another VLA antenna. This step is an important one for routine operations, since it allows on-line system files to simultaneously include information for all VLA antennas and PT. With this improvement, the VLA operator’s on-line displays also can access monitor and control data from PT as antenna 29.

On December 14, 1999, some aspects of the new software were tested, and performed as expected. Also at that time, tests of the link hardware with the two-way digital (monitor and control) and one-way analog (IF) signals all on a single fiber were made. The hardware performed nearly flawlessly. Several successful tests also have been made of a switch that causes the PT noise diode to operate at the VLA's 19.2 Hz rate rather than the VLBA’s standard 80 Hz

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Recent Developments on the VLA - Pie Town Link (continued)

rate, thus enabling calibration of PT in the same manner as a normal VLA antenna.

Progress continues to be made in implementing the VLA -PT fiber-optic link as an operational system, and the facility is on schedule for user access in the next A configuration (fourth quarter of 2000).

M.J. Claussen and J.S. Ulvestad

Q and K-Band Receiver Status

Six new Q-band receivers operating between 40 and 50 GHz will be installed by the end of January 2000 at the VLA, bringing the total to 19 antennas with Q-band capabilities. The system temperature of a Q-band receiver system (excluding atmosphere) ranges from 40 to 80 K. Depending upon weather, the atmosphere can typically add between 30 and 100 K to the total system temperature. Antenna surfaces with new Q-band receivers are being readjusted using data from K-band holography scans. Additional improvements to the surface accuracy will be made using Q-band holography data when the Array is in a more compact configuration. During this same period, the K-band (22-24 GHz) system has undergone significant improvements. A total of 12 new K-band receivers will be installed by the end of January 2000. The typical system temperature of a new receiver is 35 K compared to 100 - 150 K for the older systems. The atmosphere can add between 20 and 50 K to the system temperature.

A new web site is being developed to summarize the most recent Q and K-band upgrades and provide a detailed status of the system. The current web address is *http://www.aoc.nrao.edu/~dshepher/highfreq.shtml*. Observers with K and Q-band time are encouraged to look at this site to determine which receivers are on-line and whether they are operational at the time of their observations.

D.S. Shepherd

VLA / VLBA Calibrators

Starting in September of 1999, we began a VLA polarization monitoring program for ~10 compact calibrators, widely distributed in Right Ascension, primarily to enable better calibration of the VLBA. Each source is observed about once a month and reduced semi-automatically. Flux densities and polarization angles are tied to observations of 3C48, 3C138, or 3C286. Currently, calibration is available at C, X, K and Q bands. The results are described in the VLA/VLBA Calibration Page at the URL *http://www.aoc.nrao.edu/~smyers/calibration/*.

S.T. Myers & G.B. Taylor

New Mexico Computing Developments

As elsewhere, activities in the computer division in the last three months have concentrated on completing our preparations for Y2K. NRAO-NM has finished its OS upgrades and Y2K patching. All Linux machines have been upgraded to Redhat 6.0, and all Suns except for a few special cases have been upgraded to Solaris 2.6. The special case Suns now run a patched version of Solaris 2.5.1. All of the non-Y2K compliant PC motherboards have been replaced.

After the first few weeks of January we intend to install several new hardware items around the building. We will place a new high capacity black-and-white printer in the new West Wing addition. We will also install a new poster format color printer, which most likely will be placed in the public room AOC-260. A Windows-NT/Redhat Linux PC will be placed in AOC-260 also; this machine will be available for general public use and will have a CD-R(W) writer installed. This will offer users an alternative to tapes as a data backup and transportation medium for modestly sized datasets. Finally, we will replace two DAT drives on public machines by newer drives which accept the DDS3 format. This will be a welcome addition to the sole public DDS3 drive we have available, and will allow us to offer DDS3 access to each AOC corridor with public workstations.

G. A. van Moorsel

New Staff in Scientific Services

The Scientific Services Division in Socorro has added three new staff members, replacing a number of people who have left NRAO or moved on to other duties in the last three years. Two are already on board. They are Steve Myers, who came from the University of Pennsylvania, and Debra Shepherd, from the Caltech Millimeter Array. The third new scientist is Claire Chandler, who will arrive in February, from Cambridge University. Shepherd and Chandler both do the bulk of their research in star formation in our own Galaxy, while Myers' primary interests are cosmology and gravitational lenses.

Aside from their own research, both Chandler and Shepherd will be working primarily in the area of support and testing for the new 7mm and 1.3cm systems on the VLA. Together with Chris Carilli, just returned from sabbatical, this group represents a substantially increased effort in the area of high-frequency VLA performance. In addition to helping bring new receivers into service, they will be working on the use of the Atmospheric Phase Interferometer to make observing decisions, water-vapor radiometry for improved tropospheric phase calibration, and plans for dynamic scheduling of the VLA based on the atmospheric monitoring. These efforts, in the long run, will fold into the planning and implementation of the proposed VLA Expansion.

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New Staff in Scientific Services (continued)

Myers has begun working on the improvement of polarization calibration of the VLBA and has joined the team addressing multiple issues associated with 3mm observing on the VLBA. This team also includes Vivek Dhawan and Jon Romney from the current scientific staff in Socorro. Over the next year, we expect to have new 3mm systems on at least two more VLBA antennas, bringing the total to six, and to achieve more reliable and improved performance of the existing systems.

We welcome the new staff members, and look forward to their scientific achievements and contributions to NRAO telescopes in the coming years.

J.S. Ulvestad

VLA Twentieth Anniversary

The VLA will be 20 years old in 2000, and plans to celebrate this occasion are underway! Festivities at the site will be on the afternoon of May 24, 2000, at the end of the conference on “Gas and Galaxy Evolution.” The conference is being held in honor of the VLA’s anniversary.

This celebration will be a tribute to the VLA and individuals who made the VLA a reality. Activities will include a barbecue and tours of the site.

M. T. Romero

Synthesis Imaging Summer School in 2000

The Seventh Summer School in Synthesis Imaging will take place from June 20 (Tuesday) through June 27 (Tuesday) of 2000. The summer school will be hosted by NRAO and New Mexico Tech and held in the Workman center on the Tech campus in Socorro, New Mexico. In addition to lectures covering all aspects of radio interferometry, data reduction tutorials on June 23 at the Array Operations Center (AOC) will allow attendees to get “hands-on” experience with data calibration and imaging for both VLA and VLBA data. There will also be an afternoon program on June 24 dedicated to teaching AIPS++.

The timeline for the school is reproduced below. Further information, including the complete program, can be found at *http://www.aoc.nrao.edu/~gtaylor/synth2000.html.* Electronic registration through this web page is encouraged.

Important Dates for Synthesis Imaging Summer School 2000:

01 February 2000	Early Registration closes
14 February 2000	Second Announcement to registered participants
15 May 2000	Payment deadline for early registration
26 May 2000	Last day allowed for registration
31 May 2000	Third and Final mailing to registered participants
01 June 2000	Deadline for Motel Reservations
20 June 2000	First Day of School
23 June 2000	Data reduction tutorial at AOC
25 June 2000	VLA tour
27 June 2000	Last Day of School

G.B. Taylor, J.M. Wrobel & C. Carilli

VLBA / VLBI

VLBI 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
10 Feb to 02 Mar 2000	6cm, 18cm, 3.6cm, 1.3cm	01 Oct 1999
25 May to 15 Jun 2000	6cm, 18cm, other?	01 Feb 2000
06 Sep to 27 Sep 2000	6cm, 18cm, other?	01 Feb 2000
08 Nov to 25 Nov 2000	6cm, 18cm, other?	01 Jun 2000

It is recommended that proposers use a standard cover sheet for their VLBI proposals. Fill-in-the-blank TEX files are available by anonymous FTP from *ftp.cv.nrao.edu*, directory proposal or via the VLBA home page on the World Wide Web (*http://www.aoc.nrao.edu/vlba/html/VLBA.html*). Printed forms, for filling in by typewriter, are available on request from Lori Appel, AOC, Socorro.

Any proposal requesting NRAO antennas and antennas from two or more institutions in the Euorpean VLBI network constitutes a Global Proposal. Global proposals MUST reach BOTH Network’s Schedulers on or before the proposal deadline date; allow sufficient time for mailing. In general, FAX submissions of global proposals will not be accepted. The Socorro correlator will be used for some EVN-only observations unsuitable for the Bonn correlator until such time that they can be processed with the JIVE correlator. Other proposals, not in EVN sessions, requesting use of the Socorro correlator must be sent to NRAO even if they do not request the use of NRAO antennas; proposals for the use of the Bonn correlator must be sent to the MPIfR if they do not request the use of any EVN antennas. For Global Proposals, or those to the EVN alone, send proposals to:

R. Schwartz
Max Planck Institut fur Radioastronomie
Auf dem Hugel 69
D 53121 Bonn, Germany

(continued page 10)

VLBI Network Call for Proposals (continued)

For proposals to the VLBA, or Global Network proposals, send proposals to:

Director
National Radio Astronomy Observatory
520 Edgemont Road
Charlottesville, VA 22903-2475
USA

Proposals may also be submitted electronically, in Adobe Postscript format, to *proposevn@hp.mpifr-bonn.mpg.de* or *propsoc@nrao.edu* respectively. Care should be taken to ensure that the Postscript files request the proper paper size.

B. G. Clark

CALC Release 9.1 Installed on the VLBA Correlator

As part of the on-line software upgrade on the VLBA Correlator, effective 07 Dec 1999, a new version of the CALC Interferometry Model program has been installed. The new CALC, Version 9.1, replaces CALC Version 8.1, which was installed in March 1995. The most important feature of CALC 9.1 that affects us is the introduction of the IERS Conventions (1996) Nutation Model. This reduces the nutation model error from about 40 milliarcseconds to within 1 milliarcsecond. The improved nutation values typically shift the residual delays by 2 or 3 nanoseconds. CALC 9.1 also contains a large number of other upgrades and changes. These generally affect the correlator interferometer model at the picosecond and smaller level. A detailed description of the CALC 9.1 release is available upon request directed to *jbenson@nrao.edu*.

J. M. Benson

12 Meter

On-The-Fly Analysis at NRAO Tucson

In order for us to provide assistance with the analysis of on-the-fly data, visiting observers can make arrangements to use the NRAO Tucson downtown computing services for their OTF analysis. Observers who might benefit particularly from the use of the NRAO-Tucson computing system are those with limited OTF analysis experience, or those whose home computing resources are strained in handling the quantity and processing needs of OTF data. In particular, on-site assistance from the 12 Meter scientific staff in the analysis of OTF data may prove helpful. If you are interested in visiting NRAO-Tucson to analyze 12 Meter OTF data, contact Jeff Mangum (*jmangum@nrao.edu*, 520-882-8250, x113).

J. G. Mangum

Note to 12 Meter Observers

In order to make the best use of the 12 Meter Telescope, prospective and scheduled observers are strongly encouraged to contact the Friend of the Telescope, Jeff Mangum, for advice regarding their proposed experiments. This is of particular importance for observers conducting 1 mm Array and on-the-fly experiments given the complexity of these observing modes. Send questions via email to *jmangum@nrao.edu* or call 520-882-8250, x113.

J. G. Mangum

12mnews Email List Server

In order to improve our ability to disseminate information regarding new features, changes, and other notes of interest to the 12 Meter Telescope user community, we maintain an email list server called "12mnews." Notes sent to 12mnews subscribers will contain short articles which will usually contain links to web page documents containing further information. We anticipate that 12mnews notices will be distributed every couple of months.

We invite all 12 Meter Telescope users to subscribe to this list server. To subscribe to 12mnews, send the following in the body (not the subject line) of an email message to *Majordomo@majordomo.cv.nrao.edu*:

subscribe 12mnews

This will subscribe the account from which you send the message to the 12mnews list. If you wish to subscribe another address instead (such as a local redistribution list), you can use a command of the form:

subscribe 12mnews
other-address@your_site.your_net

If you have questions or comments about 12mnews, please let me know.

J. G. Mangum

In General

Announcement

I am pleased to announce the appointment of Marc D. Rafal as NRAO Assistant Director and ALMA (U.S.) Project Manager, effective 7 February 2000. He comes to the NRAO from the Space Telescope Science Institute, where he was the Deputy Instrument Manager for the new Wide Field Camera (WFC3) being built for the Hubble Space Telescope. On behalf of the Observatory staff I would like to welcome him to the NRAO and the ALMA Project. We all look forward to working with him.

This appointment adds new strength to the management team of the ALMA Project, a project that has grown substantially in size and complexity since it began. By broadening the management team, Marc's appointment will allow current managers to concentrate on specific Project areas needing their expertise. In this regard, Bob Brown will become NRAO Deputy Director, effective February 7, 2000. His primary responsibility will be ALMA international relations. Peter Napier will assist Marc in engineering and construction planning while continuing to carry his responsibilities as Head of the Antenna Division.

P.A. Vanden Bout

NRAO Program Advisory Committee

A new standing NRAO committee has recently been appointed to advise the Observatory on its long range plan and on new initiatives. The members of the committee are: D. Backer (U.C., Berkeley), E. Churchwell (U. Wis.), J. Cordes (Cornell), N. Evans, chair (U. Texas), L. Mundy (U. Maryland), T. Phillips (Caltech), M. Reid (CfA), P. Schloerb (U. Mass.), and J. Turner (UCLA). The Committee met December 2-3 to review the Program Plan for 2000 and to discuss Observatory priorities. It also reviewed a draft of the VLA Expansion proposal and plans for utilizing the GBT at high frequencies. First thoughts on an integrated data management system for NRAO telescopes were also discussed.

P. A. Vanden Bout

Commemorative Stamp to Feature VLA

The U.S. Postal Service has announced a souvenir sheet of six commemorative stamps, "Space Achievement and Exploration," to be issued next year. One of the stamps will feature the Very Large Array. The other observatories in the set are: Hubble Space Telescope, Keck Observatory, Cerro Tololo Observatory, Mt. Wilson Observatory, and Arecibo Observatory. The 60¢ stamps cover the first class international rate for the first ½ ounce. The set was developed with assistance from the National Air and Space Museum. The first day of issue will be July 10 at the World Stamp Expo 2000 in Anaheim, California. The issuance of these commemorative stamps is the successful culmination of the efforts of many individuals over many years to have ground-based astronomical telescopes recognized in a U.S. stamp series.

P. A. Vanden Bout

Gas and Galaxy Evolution: A Conference In Honor of the 20th Anniversary of the VLA 21-24 May 2000, Socorro, NM

In celebration of 20 years of VLA observations, NRAO and New Mexico Tech are co-sponsoring a conference on the role of gas in galaxy evolution. We particularly encourage graduate students and recent Ph.Ds to attend. The initial response has been very encouraging, with more than 150 astronomers expressing interest following the first announcement in October.

Important upcoming dates include:

01 Mar 00	Early registration closes Deadline for requests for student travel support
14 Apr 00	Deadline for submission of abstracts
07 May 00	Deadline for (blocked) hotel registrations
20 May 00	Reception
21 May 00	First day of meeting
24 May 00	Last day of meeting; VLA 20th birthday celebration
15 Jul 00	Manuscripts due at NRAO

The second mailing was sent out in December, with subsequent mailings expected in February and April of 2000. Up-to-date information about the conference, including the mailings and the registration form, may be found on the conference Web site, at *http://www.nrao.edu/vla2000/*. Please direct any other enquiries to *vla2000@nrao.edu*. Conference attendance is limited by the auditorium to about 160 people, so it is important to register early. We look forward to seeing you!

M. Rupen, on behalf of the Scientific and Local Organizing Committees

Observatory-Wide Computing Developments

Security

During the past few months, the Computing Council and a group of NRAO staff developed a formal policy on computer and network security which went into effect on November 10, 1999. The primary goal of the policy is to improve the security of our computing environment without compromising services that are fundamental to our role as a user facility. Changes will be phased in during the first half of 2000.

The main impact on our user community will be the implementation of restrictions on some kinds of access. For example, unencrypted connections to the NRAO such as telnet, rlogin, and ftp from non-NRAO locations will be

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Observatory-Wide Computing Developments (cont.)

limited to a small number of designated systems at Charlottesville, Green Bank, Socorro, Tucson, and the 12 Meter Telescope. In addition, services which are known not to be required outside of the NRAO will be blocked, to minimize potential intrusion paths. Virtually all of the break-ins at the NRAO during the past year involved a few such services; most are now blocked at all NRAO sites. We will also implement new measures to detect intrusion attempts.

Since computer security affects and involves all of us, we are also increasing efforts to educate not only computing staff, but also our computer users, including visitors to NRAO, on this subject. Summaries of recommended or required security practices will be available soon in visitor information packets and on Web pages accessible from NRAO computers.

If you have any questions, comments, or concerns about the new NRAO Computing Security Policy, or wish to obtain a copy, please contact Ruth Milner, Computing Security Manager (*rmilner@nrao.edu*, or call 505-835-7282). Inquiries regarding security incidents affecting the NRAO should also go to Ruth.

To reduce the risks associated with remote access, we continue to recommend, and may eventually require, the use of the secure shell ("ssh") package to replace the more common "telnet," "rlogin," and "rsh" connections between the NRAO and your home system. ssh encrypts the transmitted data, including your password, and thus hides account information from "*sniffer*" programs. ssh is supported at all NRAO sites. Software to make ssh connections is available for UNIX and Windows, in both free and commercial versions. We urge all NRAO users to install ssh on the computers that they will use to connect to our systems.

Videoconferencing

Preparations continue for installation of videoconferencing capability, which is funded by a special grant from the NSF. All four major NRAO sites are now benefiting from significant increases in the networking bandwidth between them. Most of the necessary equipment was delivered in mid-December. Systems will be installed first in Charlottesville and Green Bank for testing, and then in Socorro and Tucson. The facilities should be available for general use in the spring of 2000.

For those of you with videoconferencing capability, the NRAO equipment will use H.323 protocol, with a gateway to H.320 (ISDN). Because we are using common standards, we expect our facilities to interoperate well with most popular videoconferencing equipment. More details will be forthcoming when the installations are closer to being operational.

M. R. Milner

2000 Summer Research Program

NRAO will host a summer research program for a limited number of well-qualified undergraduate and graduate students. Observatory staff members will mentor selected students on a research program of current interest; examples from last year's program may be found at *http://www.cv.nrao.edu/~awootten/reu99.html*. Topics include the origins of planets, stars and galaxies, astrochemistry and observational cosmology. Students will gain first-hand experience gathering data from NRAO's radio telescopes, reducing the data, and analyzing, presenting and publishing the results.

Students who have not graduated before summer 2000 will be eligible to participate in the NRAO Research Experiences for Undergraduates (REU) program, funded by the National Science Foundation. Participation in this program is restricted to citizens or permanent residents of the United States.

The 2000 Research Experiences for Undergraduates at NRAO will accept applications until January 20, 2000; notice of decisions will be sent by March 1, 2000. Forms are available from Department Heads, on the web (URL *http://www.cv.nrao.edu/html/headquarters/summer-students.html*) or by writing to:

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

H. A. Wootten

New Results

Starting with this issue of the NRAO Newsletter, we will include short articles describing recent scientific results achieved using NRAO telescopes. Below are the first three such articles.

If you have a recent scientific result that you would like to report in these pages, please email a short description of your result to John Hibbard (jhibbard@nrao.edu).

What We Have Learned From Radio Afterglow of GRBs

Background

Gamma Ray Bursts (GRBs) have been in the news continuously over the past two years. Their extraordinary luminosity, rapid release of energy and the possibility that they may allow us to look at a Universe so young that even quasars had not yet formed, are some of the reasons why astronomers are fascinated by GRBs. The lay public appears to be fascinated by their exotic nature, their brilliance and the suggestion that GRBs may be the birth cries of newly formed (and perhaps spinning) black holes.

GRBs were discovered in 1967 with satellites launched to monitor compliance with outer space test nuclear treaties. The wavelength of a typical GRB photon is 0.1 Å or smaller–too small to use imaging telescopes based on specular reflection. As a result GRBs could not be located to the precision needed (arcseconds) to identify counterparts at other (radio, optical) wavelengths. The Burst and Transient Spectrometer Experiment (BATSE) aboard the Compton Gamma-Ray Observatory (CGRO) sharpened the mystery of GRBs by demonstrating that bulk of the GRBs are isotropic and have a distribution of fluxes suggesting that the GRB population is bounded. These constraints are consistent with a model in which GRBs are located at cosmological distances.

Credit for the recent breakthrough in this field belongs to the Italian-Dutch satellite BeppoSAX. Launched in 1996 this satellite was a veritable armada carrying a wide field camera (WFC), a shadow camera which imaged 3 percent of the sky at hard X-rays, a standard GRB detector, two sets of X-ray imaging cameras, and a high energy rocking detector. It was this unusual combination that enabled SAX to localize GRBs with sufficient precision for observations at optical and radio wavelengths. GRBs caught in the WFC view were rapidly followed up with the imaging cameras and the phenomenon of afterglow – long lived emission at lower energies – was discovered. The X-ray afterglow is detectable for several days after the burst. All of the much-publicized advances have come from detailed studies of the afterglow.

Our own work in this field began in 1993, inspired by an influential paper by two theorists from Princeton (Bodan Paczynski and James Rhoads). Their paper came at an opportune time for us. We had just finished a very successful program of identifying and studying of soft gamma-ray repeaters (SGRs) using the VLA and Palomar, and thus we began a similar multi-wavelength program to search for the long-lived afterglow emission from GRBs.

In 1996, we realized the importance of SAX for the VLA experiment, namely a tighter and rapid localization, and we formed a collaboration with the SAX team. In May 1997, our dream was finally realized with the detection of radio afterglow from GRB 970508. This was the same burst for which our Keck observations of intergalactic absorption lines demonstrated, for the first time, that GRBs are at cosmological distances.

GRB work at the VLA: post-SAX

An often unappreciated fact is that radio afterglow are discovered as often as optical afterglow. More importantly, the radio emission from afterglow provides complementary and often unique information, and persists much longer than the emission at shorter wavelengths (Figure 1). To date we have discovered 12 radio afterglow. Eleven have come from our VLA program while the other has been discovered by our sister GRB program at the Australia Telescope Compact Array (ATCA).

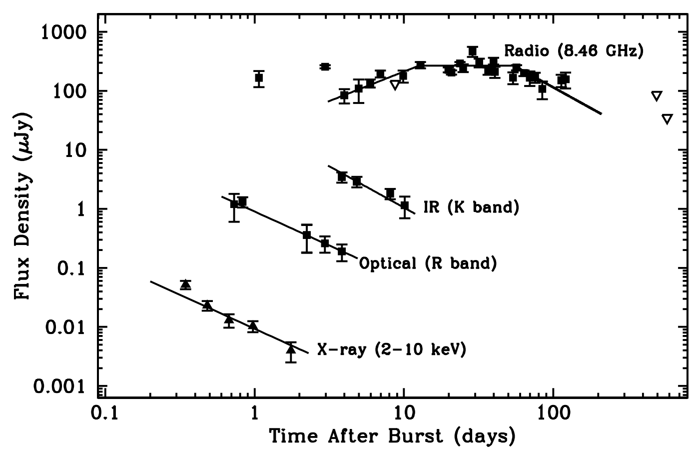

Figure 1: *Broad-band light curves of GRB 980329, from the X-ray to the radio. The solid line represents a model of a spherical blast wave propagating into the circumburst medium.*

Some of the principal discoveries of these programs are:

The demonstration of relativistic expansion of GRB afterglow. From basic theoretical arguments of compactness and large energy release we expect the afterglow to expand at relativistic speeds. VLA observations show that the radio flux of GRB 970508 underwent deep and chromatic scintillation – the hallmarks of diffractive scintillation. It is well known that only very compact sources (a few microarcseonds or smaller) suffer from diffractive scintillation. Thus, following the suggestion of J. Goodman, we attributed the variations due to the compact size of the afterglow. The inferred expansion speed two weeks after the burst is superluminal.

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What We Have Learned From Radio Afterglow of GRBs (continued)

Diffractive scintillation is squelched and replaced by gentler and broad-band scintillation as the source expands beyond a few microarcseconds; this is the so-called refractive scintillation. At the present time and in the foreseeable future only radio observations have the ability to measure the sizes of afterglow.

Discovery of Dusty Host Galaxies. In almost all cases, as the afterglow has faded, we have been able to identify a faint galaxy, presumed to be the host of the GRB. While X-ray afterglow has been identified for all GRBs, optical afterglow is seen for only two-thirds of the bursts. For GRB 980329 we identified a bright radio afterglow and later identified a highly reddened optical/IR afterglow (Figure 1). We now believe that the "missing" optical transients are due to GRBs located in dusty regions. This was the first strong suggestion linking GRBs to dusty star-forming regions.

Explosion Calorimetry. Strong relativistic motions (with Lorentz factors Γ>>1) give us a limited view of the source, namely solid angles less than Γ^{-2}. This has limited our ability to compute the true energy release in a burst. We can compute the maximum release by assuming that the burst is spherical. Fortunately, the radio emission peaks weeks to months after the burst and in one case it appears that the expansion has become non-relativistic by the time of peak emission at 1.4 GHz. Without the confusion from large Γ we are able to estimate the total energy release using formalism developed for the Crab nebula. We find the surprising result that in one particular case (GRB 970508) the energy release is less than that of a SN! Several more examples are needed to be sure of this rather important

Progenitors. It is generally believed that GRBs are associated with the birth of spinning black holes, and that the energy from this spin is an important and integral part of the GRB phenomenon. Such a black hole is believed to emerge from the coalescence of binary neutron stars (e.g. PSR 1913+16) or as the end product of certain types of (rotating) massive stars. The discovery of GRB 980329 (and additional such radio-bright and optically-dim GRBs) links GRBs with dusty regions. In one case, GRB 980703, it appears that we are seeing free-free absorption due to a foreground HII region. Finally, the good coincidence of GRBs with host galaxies strongly suggests that GRBs do not come from halos of galaxies, the preferred location of binary neutron stars. Thus, we can state that at least the *long duration* GRBs – the sort that SAX has so far localized – are associated with massive stars.

Physics of Fireballs and Circumburst Medium. Radio observations provide several diagnostics of the physics of fireballs and constrain the circumburst medium. The broad-band spectrum in the range 1-30 GHz is an excellent diagnostic of the ambient density. A high density results in a higher synchrotron self-absorption frequency. If GRBs emerge from massive stars then the circumburst medium would be dense thanks to copious mass loss from the progenitor. The evidence for such a medium is mixed. In some cases, we see good evidence for such a wind-shaped circumburst medium (Figure 1). Further progress in this important area is possible but requires us to measure the broad band spectrum (1-30 GHz) within the first week of the burst.

As the relativistic ejecta sweeps up the ambient gas, a shock propagates through the ejecta – the so-called reverse shock. This reverse shock will produce a short-lived emission and the famous ROTSE 9th magnitude prompt emission (from GRB 990123) is attributed to this reverse shock. Less appreciated is the fact that short-lived radio emission was seen from this GRB as the electrons cooled. Unlike the ROTSE optical emission the radio emission is stretched not over 1000 s but over 10^5 s. The traditional advantages of radio – the immunity to day-night, lunar and weather cycles – have enabled us to identify four examples of emission from reverse shocks. In contrast, the optical experiments (ROTSE, LOTIS) have identified only one such example.

The Future

This article highlights the special contributions from the radio to GRB astronomy. Where do we go from here? Here is our view of the future. To start with, there are some indications of diversity in the GRB population. As shown by the giant outburst of 1998 August 27th, SGRs can, at times, mimic GRBs. Furthermore, GRB 980425 has been identified with a nearby (40 Mpc) radio bright supernova, SN 1998bw. Finally, we know nothing about the genesis of the short duration GRBs. In January 2000 the High Energy Transient Explorer-II (HETE-II) will be launched. HETE-II will localize 30 GRBs per year of which about five are expected to be the mysterious short duration bursts. It may well be that with a larger population of well-studied GRBs, we will discover new classes of GRBs. There are also tantalizing hints from the SAX sample that there may exist a hitherto unknown population of X-ray rich bursts. HETE-II is well suited for the detection of these events, dubbed "X-ray flashers."

GRBs may allow us to probe the high-redshift universe. The gamma-ray emission and the radio afterglow are unaffected by extinction. Therefore, if GRBs do trace massive stars they provide a unique probe of star-formation history of the Universe. The brightness of GRBs and their afterglow allows their use as probes of the IGM and star formation beyond the redshift range possible with quasars *(z>5).*

S. R. Kulkarni (Caltech)
D. A. Frail (NRAO)

The NGC 4258 Water Maser and Calibration of the Extragalactic Distance Scale

NGC 4258 has long been known to be an unusual spiral galaxy. It was one of the original 12 galaxies with highly excited nuclear emission lines described by Seyfert in 1943. In the 1960s, it was found to display secondary, nonstellar, spiral arms extending many kiloparsecs from the nucleus. In the 1980s, water maser emission from the nucleus was discovered by a Caltech group, who postulated that it was associated with a molecular torus in the AGN. About six years later a group at NRO observed the galaxy and discovered high-velocity spectral features bracketing the previously known emission at the systemic velocity, offset by about 1000 km/s. This reinforced speculation that the maser emission arose in a rapidly rotating torus, but without spatial information other explanations were viable. Before discovery of the high-velocity emission the U.S. VLBI Network and the Effelsberg 100 m telescope had observed the systemic emission. Combined with the new high-velocity spectrum, the first VLBI map pointed to the presence of a thin rotating disk and large central mass. However, it was the map made with the VLBA during its shakedown in April 1994 that so beautifully showed Keplerian rotation. This captured the attention of the community. The result was published in *Nature* and presented at press conferences at the AAS in Tucson in January 1995 and at the Ministry of Education in Japan.

The early VLBA observations showed in detail that the masers trace a thin, slightly warped, nearly edge-on disk rotating around what is, in all likelihood, a supermassive black hole (fig. 1). The line-of-sight velocities of the high-velocity features follow a Keplerian rotation curve to high accuracy, while the velocities of the systemic maser features change linearly along the disk plane, which is consistent with their lying within a narrow range of radius.

(continued page 16)

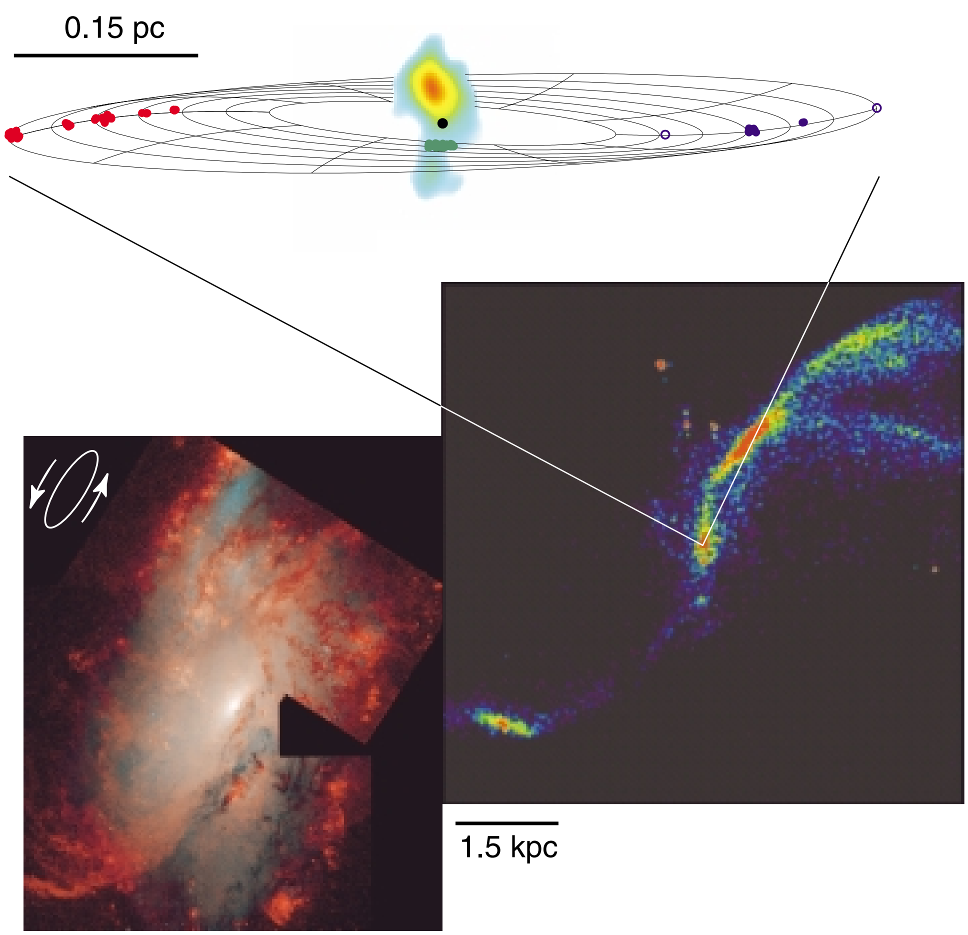

Figure 1—(bottom) Ground-based Halpha+[NII] (red) and HST continuum F547M+F791W (blue/green) images of NGC 4258. (middle) VLA image at 20 cm highlighting nonstellar, so-called anomalous arms, which are substantially displaced from the galaxy's spiral stellar arms. The arms may stem from interaction of a precessing jet with the galactic disk. The innermost, north-south emission is aligned with the spin axis of the accretion disk and the jet axis observed on VLBI angular scales. (Images to appear in ApJ, Cecil et al.). Parts of the stellar and anomalous arms are also visible in the ground-based Halpha+[NII] image. (top) Original (c. 1994) VLBI map of the maser distribution (dots) superposed on a fitted disk model. The open blue dots indicate the innermost and outermost radii at which blueshifted emission has been observed in more recent observations. The central engine lies at the fitted geometric center of the disk (black spot). Color contours denote the continuum (jet) emission at 1.3 cm. The masers, engine, and jet are registered at the level of about 2% of the disk inner radius.

The NGC 4258 Water Maser and Calibration of the Extragalactic Distance Scale (continued)

In general, the maser features lie where the orbital velocity is parallel or perpendicular to the line of sight, i.e., where the amplification gain paths are longest because the line-of-sight component of the orbital velocity varies most slowly.

With collaborators from NAOJ and NRAO, we extended the initial imaging study with a multi-epoch proper motion study because the measured orbital velocity corresponds to tens of microarcseconds per year, easily measurable with the VLBI. The intrinsic scientific value of proper motions lies in the fact that in the context of the disk model they permit the measurement of distance. These estimates may be based on relatively simple geometric considerations, assuming circular orbits. The distribution of masers on the sky gives the inclination of the disk. The rotation curve of the high-velocity masers gives the orbital velocity as a function of radius (in angular units) and the "mass function" (central mass divided by distance). The mean angular radius of the systemic masers is obtained from the mass function and the observed gradient in Doppler velocity across the near face of the disk. Combined with the rotation curve, the mean angular radius indicates the mean orbital velocity of the systemic masers. The ratio of this orbital velocity and the mean proper motion is the distance.

While measurement of proper motions requires several years and great effort, the tracking of accelerations is technically easier and permits an independent measurement of distance. As far back as the mid 1980s, even before the disk structure was known, the line peaks among the systemic emission were known to display a secular velocity drift of about 10 km/s per year. The drift is the bulk centripetal acceleration of disk material on the near side of the disk, where the acceleration is nearly parallel to the line of sight. (The acceleration of high-velocity material is nearly perpendicular to the line of sight and is proportionately smaller; our group has measured it to be a few tenths of 1 km/s per year.) As in a proper motion analysis, one infers an angular radius and orbital velocity, but now these are combined with the measured acceleration to obtain a distance. Unlike in a proper motion analysis, one must map the maser only once (in principle), and then track emission features as they drift through the spectrum.

At first brush, it seems that the measurement of a distance using acceleration data is preferable. Single-dish spectroscopy is relatively easy to perform and the velocity drift is large enough to be easily detected (i.e., many linewidths per year), while the proper motion in one year is about 5% to 10% of an interferometer beam. However, model accelerations are more sensitive than proper motions to uncertainties in estimated radius. In addition, there are two operational complications. First, the spectrum of NGC 4258 is a blend of many individual features that cannot be formally decomposed. One substitutes the tracking of spectral peaks for the tracking of physical clumps and assumes that there is no ambiguity. Second, the spectrum changes significantly over months, which dictates frequent observation. In the end, both proper motion and acceleration techniques are complementary; the tracking of spectral features simplifies the identification of spatially discrete clumps, given that the systemic emission is partially blended in both position and velocity.

In 1994 we inferred a crude geometric distance of 5.4±1.3 Mpc using the US Network VLBI observations of the systemic masers, the high-velocity spectrum, and an acceleration measurement obtained from Effelsberg data for 1984 to 1986. Once the high-velocity and systemic masers were mapped together and the disk structure fully traced, we substantially refined the distance estimate, obtaining 6.4±0.9 Mpc. This distance was limited, nonetheless because the gas clumps studied in the 1980s were not the ones mapped in 1994. They had long since been swept across the line of sight and were no longer beaming emission toward us. A "proper" analysis awaited results of the multi-epoch VLBI study begun in 1994. Now, simultaneous measurement of both accelerations and proper motions over three years point to a distance of 7.2±0.3 Mpc (4%), which appeared in *Nature* in August 1999. The uncertainty includes both statistical and systemic components, but it relies on the assumption that the orbits are circular.

The conventional wisdom concerning accretion disks has been that because of viscosity particle orbits become circular in a relatively short time. Though recent theoretical work has challenged this wisdom, we may use the VLBI data to constrain the disk eccentricity to be less than a tenth. The limit follows from two measurements. First, the red and blue rotation curves are symmetric to a high degree. Second, we have imaged a compact, bipolar jet associated with the central engine, and we find that it coincides with the estimated geometric center of the maser disk to a high degree. (We achieved precise registration of the jet with respect to the maser emission and disk center by employing an old but powerful technique wherein the maser signal is used as a phase reference for the continuum signal.) If we consider the maximum possible eccentricity (0.1) and a distribution of possible orientations for the semi-major axis, then the uncertainty in distance is 0.5 Mpc (7%). Further modeling of the data may provide a tighter limit on eccentricity and reduce this already small uncertainty.

The great value of the VLBI distance estimate is clear in light of a distance estimate of 8.1+0.8 Mpc derived from a set of 15 Cepheid variables by HST observers (*Nature*, November 1999). The error is composed of a statistical uncertainty of 0.4 Mpc and a systematic uncertainty of 0.7 Mpc that is tied to calibrations and data reduction techniques shared with the Hubble Key Project. The largest component of this systematic uncertainty arises from the estimate by the Key Project team of the distance to the Large Magellanic Clouds (LMC), 50±4 kpc. A reduction

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The NGC 4258 Water Maser and Calibration of the Extragalactic Distance Scale (continued)

in the assumed distance of the LMC to 44.6 kpc would reconcile the maser and Cepheid scales. This distance would also better agree with the LMC distance estimates obtained from observations of the detached binary Hv2274 and from the relatively new "red clump star" technique (41.0 – 45.7 kpc).

The suggested rescaling would raise the Hubble constant, as determined by the Hubble Key Project, by 12% and would affect all other measurements of extragalactic distance that depend on Cepheid calibration of Standard Candles. Future surveys of AGN may uncover much more distant maser-host galaxies that would make possible new and direct estimates of cosmological constants, whose values are probably less well known than is sometimes claimed. However, NGC 4258 will be a hard act to follow. It is especially valuable because it displays high-velocity blue and red emission, systemic emission, and detectable accelerations and proper motions.

The identification of maser-host galaxies among AGN has been slow because the typical detection rate is 5%, maser emission is weak, and most spectrometers are relatively narrowband. Furthermore, no other maser source has had as great an impact as NGC 4258 in part because no other maser displays as high velocity emission. However, wideband spectrometer-receiver combinations will soon be available at the GBT, Effelsberg, and some DSN 70 m antennas. This new instrumentation should permit detection of many new masers, which will feed follow-up studies that could combine the VLBA, upgraded and phased VLA, Effelsberg, GBT, DSN, and perhaps VSOP-2 or ARISE to form a (super)global array with at least five times the sensitivity and at least twice the angular resolution of our first VLBA observation of NGC 4258 in 1994. The prospects for future maser studies are bright, and their effect on calibration of extragalactic distances has probably only just begun to be felt.

L. J. Greenhill & J. M. Moran
Harvard-Smithsonian Center for Astrophysics

The Orbital Variation of Mars' Climate

In only the past few decades of human history have we developed an appreciation of the complex physical processes that contribute to the overall balance and habitability of our home world. With this growing awareness, we are slowly recognizing the precariousness of the life supporting conditions provided by the chemistry and climate of the Earth atmosphere. Natural variations lead to large fluctuations in average climate conditions, producing events as ancient as the glaciations of prehistory and as recent as the mini ice age of the 1600s. In addition to these poorly understood natural variations, we must also be concerned about the effects of our own industrial activities, which have led to recent environmental phenomena such as the polar ozone holes and global warming. Even more recently, we have begun to consider the potential range of atmospheric and surface conditions that exist or may exist on planets within our solar system (notably Mars and Venus) and beyond. As it turns out, these conditions are extremely diverse, and display variations in space and time that are also much more extreme than we are used to from our terrestrial experience. This article describes a new view of Mars climate, which exhibits a distinctive orbital variation in its atmospheric structure that has no observed parallel with our own atmosphere.

Spectral Line observations of Mars atmospheric CO from the NRAO 12 Meter Telescope on Kitt Peak have supported a long-term program to measure the temperature variations with altitude in the atmosphere since the late 1980s. These ground-based temperature retrievals span a larger altitude range (0-70 km) than obtained from Mars spacecraft missions during the 1970s (the Mariner 9 orbiter in 1971-72 and the Viking lander/orbiter missions of 1976-1978). They also greatly extend the seasonal and interannual coverages provided by these 1970s spacecraft missions, a virtue that has proven especially valuable in distinguishing annual (orbital) versus interannual variations of the global Mars atmosphere. Over the past 20 years, models of Mars' climate have been strongly influenced by the dusty, warm atmospheric conditions associated with the 1971 and 1977 major global dust storms observed during the Mariner 9 and Viking missions. In such models, the Mars atmosphere is characterized by background dusty and warm conditions throughout its elliptical orbit (eccentricity=0.09). Global atmospheric heating from solar absorption interacts dynamically with the intense Hadley circulations of the northern and southern solstices. Large increases in dust loading, which may grow to global dust storms in some years, occur during the perihelion portion of the Mars orbit, but atmospheric water vapor is typically sub-saturated and ice cloud formation restricted in occurrence throughout the Mars year. Water ice clouds with a diverse range of morphologies were observed by Viking and Mariner 9, but have not been considered to influence the dynamical/radiative balance of the global Mars atmosphere.

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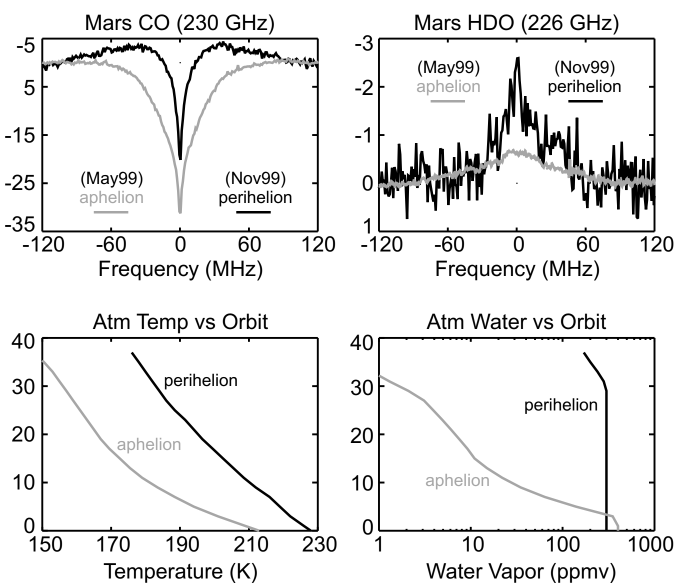
The Orbital Variation of Mars' Climate (continued)

However, Kitt Peak millimeter observations of atmospheric temperature (from CO spectra) and water (from HDO spectra) profiles over five consecutive Mars years between 1989 and 1999 have revealed a much more profound orbital variation of the global Mars atmosphere than indicated by the dusty Viking model. In particular, the Mars atmosphere exhibits a distinctive cold and cloudy climate for minimum solar heating conditions around aphelion. Figure 1 compares Kitt Peak millimeter CO (230 GHz) and HDO (226 GHz) spectra, and their respective temperature and water vapor profile determinations, of global atmospheric conditions at Mars' aphelion (gray lines) and perihelion (black lines) in 1999. The entire Mars atmosphere is 20-25 K colder in the aphelion versus perihelion half of the Mars year, leading to drastically different global water vapor saturation conditions. Clancy et al. (1996) identified a previously unrecognized equatorial cloud belt in HST imaging around Mars' aphelion



in 1991, 1993, and 1995, which is associated with the low altitudes (<10 km) of global water saturation in this distinctive aphelion climate. The dichotomy of aphelion and perihelion atmospheric behavior for Mars suggest that ice growth on dust aerosols leads to nonlinear feedback among atmospheric water vapor, temperature, cloud and dust distributions within the Mars atmosphere. As a result, this process may contribute to hemispheric and interannual variations of dust and cloud aerosol distributions, incorporation of dust and water in the seasonal caps, and atmospheric photochemistry (Clancy et al. 1996; Clancy and Nair, 1996; Clancy and Sandor, 1998).

More recently, Kitt Peak CO millimeter observations have served as a monitor of perihelion dust storm heating (and hence expansion) of the global Mars atmosphere during The 1997-98 aerobraking operations of the Mars Global Surveyor (MGS) spacecraft. The MGS spacecraft arrived in a highly elliptical orbit around Mars in early September of 1997, with a design to use atmospheric drag at the periapsis of this orbit (at 110-120 km altitudes) as a means of circularizing the orbit towards its final mapping configuration. This aerobraking technique saves substantial mission costs in terms of the fuel carried into Mars orbit (specifically in terms of the required launch vehicle). However, the season in which this aerobraking took place was characterized by explosive dust storm activity on Mars, which can drive equally rapid increases in upper atmospheric densities (by >100-200%, through atmospheric heating from dust solar absorption). Without sufficient observational warning in the context of lower atmospheric behavior, such large and abrupt upper atmospheric density increases would imperil aerobraking operations and the safety of the MGS spacecraft (Keating et al., 1997). The contemporaneous Kitt Peak millimeter and MGS temperature profiling in 1997-99 also provided the first opportunity to "calibrate" the millimeter technique to established planetary IR methods of atmospheric temperature sounding. Excellent agreement in Mars' atmospheric temperatures is determined between the contemporaneous Kitt Peak millimeter and MGS IR temperature retrievals. Furthermore, both of these sets of measurements prove to be 10-20K colder than the Viking models for the 1999 aphelion season on Mars (Clancy et al., 1999).

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R. T. Clancy
Space Science Institute

NRAO Contact Information

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

To contact any NRAO site:

Headquarters
Director's, Personnel, and Business Offices
Atacama Large Millimeter Array
(804) 296-0211

Array Operations Center
Very Large Array
Very Long Baseline Array
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Green Bank Telescope
(304) 456-2011

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Galactic Plane "A" Survey: *http://www.gb.nrao.edu/~glangsto/GPA*

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VLBA cumulative list of observed sources: *http://www.aoc.nrao.edu/ftp/cumvlbaobs.txt*

Observing Information:

VLA: *http://www.aoc.nrao.edu/vla/html/VLAusing.shtml*
VLBA: *http://www.aoc.nrao.edu/vlba/html/observing.html*
12M: *http://www.tuc.nrao.edu/obsinfo.html*

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