NRAO Newsletter

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12 Meter Telescope To Close End of July 2000

It was announced on February 22 that the NRAO will close the 12 Meter Telescope at the end of the current observing season, July 2000. The following is the text of the press release that accompanied that announcement.

National Radio Astronomy Observatory Announces Closure of Millimeter-Wave Telescope

The National Radio Astronomy Observatory (NRAO) will close down its millimeter-wavelength telescope on Kitt Peak, Arizona, in July 2000, Director Paul Vanden Bout announced today. The closure will affect the activities of 24 NRAO employees. The Arizona telescope, known as the 12 Meter Telescope because of the diameter of its dish antenna, is the only millimeter-wavelength instrument in the US that is operated full-time as a national facility, open to all scientists.

The action was made necessary by the current and anticipated budget for the Observatory, Vanden Bout said. “We are forced to reduce the scope of our activities,” Vanden Bout said.

The NRAO also operates the Very Large Array and Very Long Baseline Array from its facilities in New Mexico and is completing construction of the Green Bank Telescope in West Virginia.

The 12 Meter Telescope is used to observe electromagnetic radiation with wavelengths of a few millimeters down to one millimeter, a region that lies between what is traditionally considered radio waves and infrared radiation. The NRAO is currently participating in an international partnership to develop the Atacama Large Millimeter Array (ALMA), an array of 64 antennas to observe at millimeter wavelengths from a 16,500-foot-high location in northern Chile.

“We understood that ALMA eventually would replace the 12 Meter Telescope, but we had hoped to continue operating the 12 Meter until ALMA began interim operations, probably sometime in 2005. That is not possible, and we are forced to close the 12 Meter this year,” Vanden Bout said. More than 150 scientists use the 12 Meter Telescope for their research every year.

The NRAO’s Tucson-based employees have been notified of the Observatory’s decision. Some of the NRAO employees in Tucson already are working on the ALMA project. Over the next few months, the NRAO will seek to transfer 12 Meter staff to the ALMA project or to other positions within the Observatory, where that is possible. Where necessary, the Observatory will assist staff members in finding other employment, Vanden Bout said.

“In the next few weeks, the Observatory will complete plans for disposing of the 12 Meter Telescope and its associated equipment. In addition, the NRAO will consult with the operators of other millimeter-wavelength telescopes in an attempt to ensure that astronomers whose research depends upon such observations can obtain observing time elsewhere. We want to mitigate the effect of this closure upon the scientific community as much as possible,” Vanden Bout said.

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The 12 Meter Telescope has a long and distinguished history of scientific achievement. Built in 1967, it was first known as the 36 Foot Telescope. It was responsible for the birth of millimeter-wavelength molecular astronomy, a field of research in which scientists seek to detect the characteristic “fingerprints” of molecules in space. Dozens of the different molecular species comprising the tenuous material between the stars were first detected by the 36 Foot Telescope. The most significant of these molecular discoveries was carbon monoxide, whose spectral lines are the primary signpost of the formation of new stars in galaxies.

In 1984, the telescope was refurbished with a new reflecting surface and support structure. At that time, it was re-christened the 12 Meter Telescope. It continued to make landmark studies of the composition of the interstellar gas clouds and of star formation. In addition, the research program was expanded to include studies of celestial objects such as comets, evolved stars, and external galaxies. Throughout its history, the NRAO Tucson staff has continued to improve the technical capabilities of the 12 Meter Telescope, making it a more useful tool for a wider range of scientific studies.

“When ALMA becomes operational, it will produce dramatic advancements in astronomy, and we look forward to those discoveries. However, the success of ALMA will be built in large part on a foundation of millimeter-wavelength expertise and achievement that came from the 12 Meter Telescope and the dedicated people who worked on it for many years. We are sorry that the 12 Meter has to be closed now, but its place in astronomical history is secure and all those who built, maintained, operated, and observed with it can be proud of their accomplishments,” Vanden Bout said.

Since the time of the announcement there have been discussions between the NRAO and the NSF concerning the eventual disposition of the 12 Meter, which is NSF property (see accompanying article, “What Will Become of the 12 Meter?”). A list of present and past users of the 12 Meter has been contacted and polled concerning their scientific requirements to assemble information that could be of use in determining the disposition of the 12 Meter and/or its instrumentation. The twelve staff members whose employment will be terminated at the end of July have been notified; twelve staff members have been transferred to the ALMA Project or, in one case, to Green Bank operations.

P. A. Vanden Bout

What Will Become of The 12 Meter?

It may be possible that some organization other than the NRAO would like to operate the 12 Meter. The NRAO is ready to advise prospective 12 Meter operators regarding the telescope. Interested parties should contact J. Desmond, Associate Director for Administration [*jdesmond@nrao.edu*, 804-296-0315] for information on costs of elements of operation. Information on the performance of the telescope and its instrumentation, and other operational considerations can be obtained from D. Emerson, Assistant Director for Arizona Operations [*demerson@nrao.edu*, 520-882-8250].

The 12 Meter facility is owned by the National Science Foundation. All questions concerning the disposition of the 12 Meter and its associated instrumentation should be directed to R. Dickman, Radio Facilities Unit Coordinator, NSF Division of Astronomical Sciences [*rdickman@nsf.gov*, 703-306-1822].

P. A. Vanden Bout

Polarimetry with the Millimeter Autocorrelator

The millimeter autocorrelator (MAC) is both an autocorrelator and a cross-correlator, although it has until recently been used only for standard autocorrelation spectrometry. In early March 2000, software was provided that allowed several of the possible modes (bandwidth/quadrant combinations) to be used for cross-correlation for the first time. By cross-correlating the independent linear signals from each polarization channel of the dual-linear polarized receivers at the 12 Meter, the MAC produces the four Stokes parameters necessary to derive the polarization characteristics of radio sources. Considerable modification of the standard 8-channel IF systems, and the LO systems (to provide phase-coherent LO to each receiver channel) was made. Also required is a correlated noise tube, whose phase is measured in terms of linearly polarized continuum radio sources, and which was demonstrated to track the phase of the IF and cross-correlator electronics. In this manner it was determined that, while the phase of the system wanders considerably over time, it can be accurately tracked, and the effects of the phase variations accurately removed. The polarimeter was used to measure the Zeeman effect of the CN molecule at 113 GHz in several star-forming molecular clouds, and hence to derive the magnetic fields in them. Such fields are believed to be important in supporting molecular clouds against rapid collapse and to control the final stages of the star-forming process. The polarimetry method should be applicable to the ALMA array, where even higher precision should be possible owing to the greater mechanical stability of the ALMA telescopes.

B. E. Turner and C.E. Heiles
J. G. Mangum for the Tucson Staff

Optical Guiding at the 12 Meter Telescope

An experiment designed to test the potential for optical guiding with the 12 Meter pointing system was successfully completed in February 2000. This "proof of concept" experiment involved tracking a star by commanding the telescope control system with updated azimuth and elevation pointing offsets based on measurements from our optical pointing system. By updating the telescope tracking information based on optical measurements of the position of the star every five seconds, the accuracy to which the telescope tracked the position of the star was kept to $\lesssim$1". Further refinement of this technique will proceed as part of the ALMA optical pointing system being developed by the Tucson group.

T. W. Folkers and J. G. Mangum

ALMA

In the past quarter the most visible milestone of the Design and Development (D&D) phase of the ALMA Project was successfully completed: AUI signed a contract for the US ALMA prototype antenna. The 12-meter diameter antenna prototype will be provided by Vertex Antenna Systems, LLC. This company is a recent merger of the parent company, Vertex Communications, with TIW and the antenna design team that was formerly part of Krupp. Divisions now part of Vertex Antenna Systems were responsible for the design and fabrication of other millimeter/submillimeter telescopes now in use for astronomy, including the IRAM antennas, the BIMA antennas, the Heinrich Hertz Telescope, and the Kosma Telescope. The experience of Vertex was one of the important criteria in the selection process.

A second ALMA prototype antenna is being procured by the European side of the ALMA Project. The Europeans have contracted with European Industrial Engineering (EIE), an Italian firm, for their antenna prototype. The technical specifications for both the US and the European prototype antennas are identical. In particular, the surface accuracy requirement for both antennas is 20 microns RSS under the environmental conditions that prevail on the Chajnantor site, and the pointing requirement is 0."6 under the same conditions. The two engineering designs, of course, will be different. The purpose of this dual procurement is to assure technical and cost competition in the antenna procurement process through the prototyping phase.

The delivery schedule for the two prototype antennas is 21 months, which means they will arrive in November 2001. Both antennas will be delivered to the ALMA Project at the VLA site. Once accepted, they will be competitively evaluated by a joint US-European team over the course of the next 16-24 months. This evaluation will take the form of both single-dish tests and interferometric tests. The interferometer comprised of the two antenna prototypes will also be used to evaluate prototype ALMA instrument modules, e.g., for the receiving system, the IF distribution, the optical fiber communication network, and it will be used as a real-world test of the ALMA software system. When the Chilean site development is sufficiently mature the prototype antennas will be disassembled and shipped to Chile.

A second major milestone of the Design and Development phase of the ALMA Project is delivery to the ALMA Coordinating Committee (ACC) of a statement of the scope and cost of the US-European ALMA Project. Here the task is (1) to define the science requirements for ALMA; (2) to define the technical system that will meet those requirements; and (3) to estimate the costs of constructing those technical systems. Discussions on all of these issues culminated this spring with a joint ALMA System review designed to produce the *technical baseline* ALMA instrument, and with a joint meeting of the ALMA Science Advisory Committee establishing the *science baseline* requirements. With these two inputs the cost estimate will be completed and delivered to the ACC at the April 2000 committee meeting.

The cost estimate, confirmed by the ACC, is an important input to deliberations that will be held in the US (at NSF) and in Europe (by the European Coordinating Committee) pursuant to a decision by the two sides to commit to construction and operation of ALMA. Neither side can proceed to construction until these negotiations are concluded. For this reason, the funding for ALMA at the NRAO for the year 2001 could not, as we had hoped, include construction funds. The NSF chose to extend Design and Development for an additional year. The ALMA Project Manager, Marc Rafal, and his staff are in the process of establishing the tasks and goals for that fourth year effort. The anticipated cessation of operation of the NRAO 12 Meter Telescope on Kitt Peak in July of this year has meant that many experienced and talented people in Tucson could be offered positions working on ALMA tasks. Such transfers will complete ALMA staffing for the Design and Development phase. The Project will now concentrate on securing the resources to assure that this entire team can work effectively and productively.

R. L. Brown

ALMA Activities in Tucson

Presently, personnel located at the NRAO millimeter-wave laboratory in Tucson assigned to the ALMA Project are playing key roles in many design and development phase tasks. In particular, the antenna engineering team, the array systems engineering group, engineering for the evaluation receivers and array photonic applications, and the individuals responsible for the US side of site development and site testing, are all resident in the Tucson laboratory. It has been expected that as these tasks grew in the

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construction phase of the ALMA Project, operating staff from the NRAO 12 Meter Telescope would be transferred into the open ALMA positions, leading ultimately to the phase-out of the 12 Meter. However, the closure of that telescope in mid-2000 has accelerated some important aspects of this planning.

The cessation of 12 Meter operations this summer will impact the ALMA Project in two ways: first, the ALMA share of administrative and facilities costs in Tucson will increase without the 12 Meter. Second, several of the operations staff already scheduled for transfer to ALMA will be transferred earlier than previously expected. Acceleration of this transfer has been approved and all of the affected people have been notified of their new assignments. Cost impacts aside, we are fortunate to have the services of these people on ALMA earlier than expected which should allow us to make progress on some ALMA tasks more quickly than otherwise would have been the case.

In light of the increased costs, we felt it was prudent to initiate a review of the options for carrying out the long term ALMA tasks slated for the Tucson laboratory. The options considered ranged from keeping all of the tasks in Tucson, to transferring some or all of the tasks, staff, and facilities to other NRAO locations. Factors considered included the estimated cost and schedule impacts on both short term and long term activities as well as the impact of any move on the Tucson personnel.

I am pleased to announce that the first portion of this review is now complete. Assuming approval of construction funding, it is our intent to continue ALMA activities in Tucson as planned at least through completion of prototype receiver development and the design and fabrication of the necessary automatic test equipment required for characterization of the completed receiver assemblies. These tasks are expected to extend through 2004. Over the next year we will develop, in concert with our European ALMA colleagues, detailed plans for receiver production and testing in order to make decisions concerning the nature and scope of ALMA activities in Tucson beyond 2004.

I am optimistic that the NSF will favorably review the ALMA plans for construction in FY2002, and I look forward to working with all the ALMA staff in the US to build this important new window on the universe.

M. D. Rafal

Joint Project Tests ALMA Prototype Software on 12 Meter

An ALMA joint demonstration project between the European Southern Observatory (ESO) and the NRAO was carried out to integrate ESO software and existing NRAO software to control the motion of the NRAO 12 Meter Telescope. The integrated software is intended as a prototype for the future ALMA telescope control software. Production ESO software from the VLT provided the operator interface and coordinate transformation software, while Pat Wallace's TPOINT provided the pointing model software. The project was carried out during the months of September through November, 1999, in Socorro, NM, by Robert Karban (ESO) and Ron Heald (NRAO).

On the 26th to 28th of November, the project had its highlight: the final test with the 12 Meter Telescope at the NRAO site in Tucson, AZ. Since the test period lasted only 72 hours, it was essential to prepare, plan, and test the software thoroughly and systematically. To accomplish this, some standard practices of ESO Software Engineering were applied. ESO configuration management, systematic regression testing, build procedures, development environment, test preparation, and documentation procedures were used. Using these methods, we were able to manage efforts among the various persons in the project locally, as well as to provide remote support from ESO. The project was successfully completed.

For the test results and more details on the project see: *http://www.alma.nrao.edu/development/computing/news.*

We would like to thank Bob Freund and the other members of the Tucson operations staff who provided excellent system support during these three days at the 12 Meter.

R. Heald (NRAO) and R. Karban (ESO)

GREEN BANK

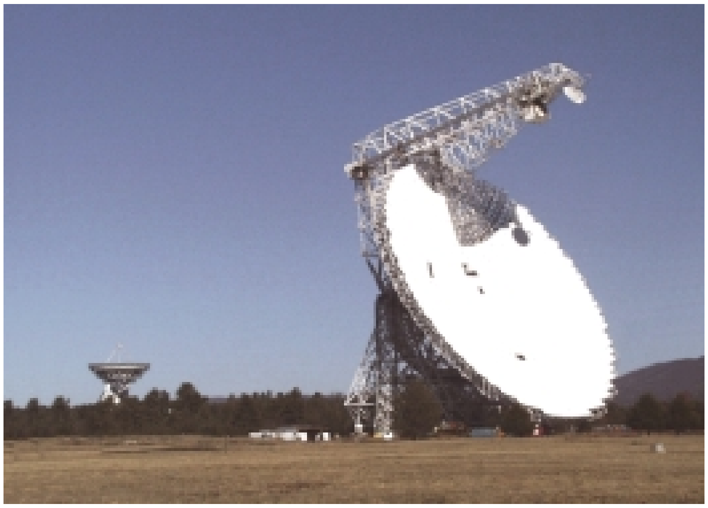
Editor's Note: The following article gives the status of GBT construction as of March 20, 2000. As we go to press, all surface panels have now been installed on the telescope.

The Green Bank Telescope

Antenna

As shown in the accompanying photographs, the GBT was tipped to five degrees elevation for the first time on February 28. The tip in elevation followed the alignment of the 30 gear segments that make up the elevation bull gear.

The photographs also indicate the current status of surface panel installation. Of the 2004 panels that make up the primary reflecting surface, 1938 have been installed on the telescope. The panel manufacturer, Radiation Systems, Inc., has completed the fabrication, measurement, and painting of all GBT surface panels. All of the panels have been delivered to the GBT construction site, and all of the 2209 surface actuators that support the panels have been aligned and welded in place. The setting of panel corners will resume after all panels have been installed on the telescope.



The testing of the actuator control cables on the telescope began on January 18. Approximately 1364 of the 2209 actuator cables have been tested. Despite the installation of protective coverings over the cable connectors, water has accumulated in about a third of the connectors, causing these cables to fail their insulation resistance test. Cables with wet connectors are hung out to dry after they are tested instead of being permanently attached to an actuator. These cables will be retested to insure that their insulation resistance is acceptable.

NRAO Systems for the GBT

A two-element, 100-meter baseline, 12 GHz interferometer was placed into operation the week of March 6 to measure atmospheric phase stability. The measurements will be used to study anomalous refraction, which can adversely affect telescope pointing at high frequencies. The interferometer is a replica of the device used for ALMA site monitoring. This project was a cooperative effort between NRAO Tucson and Green Bank.

A calibration procedure for the surface retroreflectors was developed, and 1437 of the 2209 retroreflectors have been calibrated. The mount that supports a retroreflector actually suspends the retroreflector below the telescope surface. The calibration procedure is needed to determine the normal distance between the telescope surface (the face of the mount) and the retroreflector's reflecting point. These normal distances must be subtracted from the rangefinders' measurements of the surface to give the true distance to the surface.

The assembly of the four-beam, dual-polarization Q-band receiver is nearly complete. The Green Bank machine shop fabricated the receiver's four feed horns, and the Central Development Laboratory delivered the receiver's eight low noise amplifiers. The initial cool-down and testing of the receiver will begin in April.

The feed horns for low frequency receivers on the GBT are fabricated by alternately stacking aluminum hoops and rings. After the hoops and rings are welded together, the exterior of the resulting structure is reinforced with fiberglass. The fiberglass reinforcement of the feeds for the S-band, 800 MHz, and 1070 MHz receivers was completed over the last quarter. All feeds requiring fiberglass reinforcement are now complete.

M. M. McKinnon

Prospective Science with the Green Bank Telescope

As GBT construction nears completion, a review of the major scientific areas that it can address may be useful to prospective observers. The NRAO staff prepared the compilation that follows, which emphasizes areas in which the GBT will make unique contributions. An expanded version of this prospectus appears in a new NRAO brochure: "The Green Bank Telescope: From Proto-Galaxies to Pulsars." The brochure is available from the Site Director's Office, Green Bank, upon request.

GBT Design Features and Capabilities

The GBT is designed for precision, sensitivity, and versatility. It can operate over a wavelength range of 3 meters (100 MHz) to 3 millimeters (100 GHz). The unblocked aperture improves sensitivity through lower blockage and system noise, reduces standing waves that can limit many spectroscopy projects, and improves image fidelity through lower sidelobe response. The active surface and metrology system will help the antenna achieve its best possible efficiency at a given frequency and maintain that efficiency over a wide range of tracking angles. Up to nine receivers can be mounted at a time, and the receiver selection system allows any of those receivers to be positioned and activated within minutes. The new GBT Spectrometer has an order of magnitude more resolution and bandwidth than previous instruments and will facilitate detailed atomic and molecular line studies. These design and performance features will make the GBT a unique scientific facility for addressing a wide range of astrophysical problems.

The Early Universe

The GBT's sensitivity at millimeter wavelengths will make it a powerful tool for observing highly redshifted dust and spectral lines from the earliest epochs of galaxy formation. At present, only a few galaxies with redshifts as high as z~2-4

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have been detected in their dust continuum and CO line emission, and only because they are amplified by intervening gravitational lenses. It is likely that many unlensed systems can be detected with the GBT. The GBT's frequency coverage is ideal for studying the most abundant molecular species in high-redshift galaxies. The strongest CO line emission for z~2-4 is expected to occur in the 3 mm band, where the GBT will have unprecedented sensitivity. For both spectral line and continuum observations of high-redshift objects, noise levels that require tens of hours to achieve with existing instruments can be reached in a few minutes with the GBT. With this sensitivity advance, the GBT may be the first instrument capable of studying the earliest stages of galaxy formation in the redshift ranges z~5-15.

Atmospheric transmission in the 3 mm band is excellent in Green Bank for as much as 30 percent of the year. Calculations show that a new-generation 3 mm bolometer camera placed on the GBT would have extraordinary sensitivity to continuum emission from redshifted dust. There are plans to obtain such a camera for the GBT. The GBT will also be ideal for cosmological studies at 1 cm (30 GHz).

Pulsars

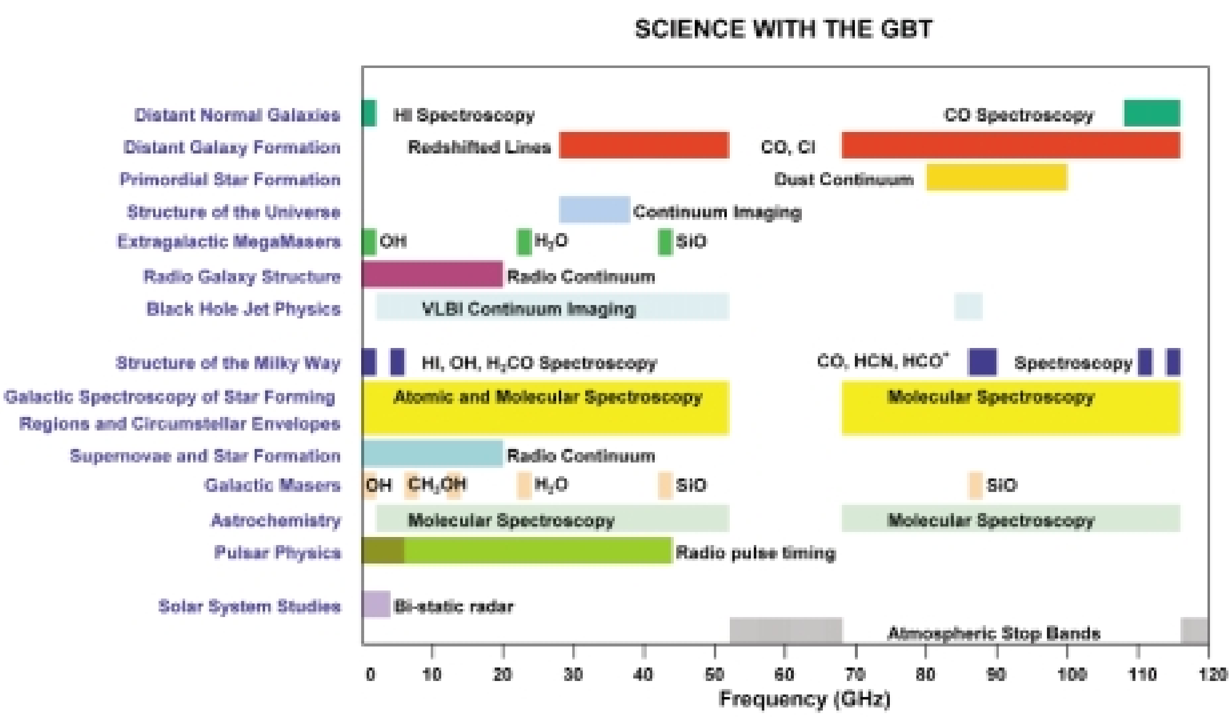
The GBT will provide a major advance in pulsar observing. Sensitive searches for radio pulses (100 MHz to ~43 GHz) from magnetars, Geminga, and other "radio quiet" (X-ray loud) pulsars, should be fruitful. The GBT will also be unique in its sensitivity to pulsars in the Galactic Center region and in southern globular clusters. Both interstellar scattering and the dispersion caused by free electrons in the interstellar medium broaden the distinctive pulses of pulsars at low frequencies, making them difficult to detect. The sensitivity of the GBT will allow single pulse observations to be extended to higher frequencies (e.g., 5 GHz) where the effects of pulse broadening are not as pronounced.

Very Long Baseline Interferometry

Many of the most interesting astrophysical problems requiring ultra-high angular resolution, such as probes of active galactic nuclei, also require extremely high sensitivity. For certain projects, the addition of the GBT will improve the VLBA's imaging sensitivity by up to an order of magnitude. The GBT and VLA will form a very high sensitivity, east-west baseline for inclusion in the VLBA and the European VLBI Network (EVN). In particular, the GBT adds sensitivity to the longest baselines of the VLBA and EVN. The added sensitivity the GBT provides makes possible many important projects that were impossible before, including radar studies of small solar system objects, water masers in distant galaxies, and early detection and imaging of gamma-ray burst sources.

Radio and Millimeter-wave Imaging

The GBT will offer new capabilities for high-fidelity imaging on large angular scales. At its Gregorian focus, the GBT has a large field of view that can accommodate future focal plane array receivers and detectors, including large-format bolometer cameras. The GBT Spectrometer and the Monitor and Control System can support fast-sampling, on-the-fly observing from single or multiple receiver inputs and wide bandwidth spectroscopic imaging. With these facilities, the GBT will map the structure of our Galaxy and nearby external galaxies with high dynamic range, at high frequencies, and over large angular areas. Surveys of large areas for radio population studies and frequent patrols of large areas to identify source variability will also be possible.



The range of astrophysical topics that the GBT will address over its operational frequency range.

H I and Atomic Spectroscopy

With the GBT, measurement of highly accurate and absolutely calibrated Galactic 21 cm H I can be done quickly and routinely. This will be of benefit to those who need to correct for Galactic interstellar absorption in observations of extragalactic objects in the UV and soft X-ray, for studies of the soft X-ray background, and for comparisons of 21cm H I spectra with spectra of other species. The low sidelobes of the antenna will make possible the study of faint H I in the Galactic halo and studies of the energetics of the ISM, which depend on very accurate measurement of the wings of Galactic H I profiles. The GBT's good instrumental polarization characteristics will allow Galactic magnetic fields to be mapped using observations of H I Zeeman splitting.

The unblocked aperture of the GBT will be ideal for studies of wide, weak lines such as the hyperfine transitions of $^3He^+$, an important light element for constraining stellar evolution models and Big Bang nucleosynthesis. Radio recombination lines of hydrogen, helium, and carbon along with the continuum emission will probe the physical properties of ionized gas in H II regions and planetary nebulae. With the wide-band spectrometer, the GBT can observe many radio recombination lines simultaneously while also providing good measurements of the continuum.

Star Formation

Broad frequency coverage, high sensitivity, and high angular resolution make the GBT an ideal tool for studies of the dense cold dust disks surrounding protostars and young stellar objects. Several molecular species have Zeeman effects as strong as that of the H atom, but for reasons of chemistry, probe gas at densities associated with star formation. With the GBT, the classical question of the role of magnetic fields in star formation could be addressed for the first time. NH_3 at 23 GHz is one of the best molecules to study the density and temperature structure of prestellar cores and young protostars, and the GBT will offer significant new capabilities in this area. In the 40-50 GHz band, molecules such as SiO can be used to study jets and shocks in the outflows from young stars, while CS will reveal the density structure of even the coldest prestellar cores. Continuum observations in this band and at higher frequencies will allow a much deeper census of young stars embedded in dense cores than is possible now.

In the 3 mm band the GBT will offer extraordinary sensitivity both for line and continuum observations. A variety of molecular tracers can be used in this band to study and characterize the earliest phases of young low-mass star formation. Because this band contains many ground state transitions of simple, abundant molecules, the GBT can detect fainter and colder gas than can be achieved in the submillimeter waves. In the 3 mm band the GBT has about the same angular resolution as current large submillimeter telescopes. By using optically thin, low excitation molecules one can map the velocity field in the outer layers of cool accretion disks. By combining optically thick and thin molecular tracers one can see infall and accretion in protostellar objects that are so young that they have not yet formed a stellar core.

Astrochemistry and Astrophysical Molecular Spectroscopy

The frequency coverage and agility of the GBT and the capabilities of the spectrometer for wide bandwidth spectral line imaging will make the GBT a powerful new instrument for studies of the chemistry in interstellar and circumstellar clouds. At its lower operating frequencies, the GBT can provide unique data on heavy molecules, including those of biological significance. In its high frequency range, the GBT can observe the many species in the rich, 3 mm spectral window. The spectroscopic capabilities of the GBT should be ideal for detecting new interstellar molecular species.

Solar System Studies

The large collecting area and high sensitivity of the GBT will make it a prime instrument for the study of solar system objects. Used as the receiving system in bistatic radar experiments with the powerful Arecibo and JPL/Goldstone transmitters, the GBT will be able to image planetary surfaces, near-Earth asteroids, and comets. Such radar images have angular resolution orders of magnitude finer than other ground-based imaging techniques, and are thus uniquely able to characterize an asteroid's shape and surface texture. Used in conjunction with the VLA or other large telescopes, the GBT will contribute sensitive baselines in very high resolution interferometry experiments to map objects close to the Earth and more distant planetary surfaces. The GBT will also be an excellent tool for spectral observations of comets and planetary atmospheres. In addition to typical molecular species such as HCN, OH, and CO, heavier molecules that are rarer and hence more difficult to detect will be an important target of study for the GBT.

The GBT and the Family of NRAO Instruments

The GBT will work in concert with the other major NRAO instruments – the VLA, VLBA, and in the future, ALMA – to provide a powerful and comprehensive capability for studies at radio and millimeter wavelengths. Whereas the interferometers will be unique in their ability to image small structures, the GBT will be most adept at imaging larger fields to set the astrophysical context, while providing comparable detection sensitivity to interesting compact objects. The GBT's ability to use incoherent detectors such as bolometers and to take advantage of the rapid technological advances in bolometer cameras will be particularly important for continuum imaging on large scales. The GBT also forms a critical bridge in frequency coverage between the VLA at centimeter wavelengths and ALMA at millimeter wavelengths. Observing techniques and strategies of the GBT will build upon the pioneering work of the NRAO

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12 Meter. The enormous collecting area of the GBT will be of great advantage to many VLBA projects requiring the highest sensitivities.

P. R. Jewell

Green Bank Computing News

The major new piece of equipment installed in the last few months is a Hewlett-Packard printer capable of printing D, E, and A0 formats. It has already revolutionized the preparation of poster papers for scientific and technical conferences. It is also used for engineering drawings by the drafting and technical staff.

Because of lack of manpower, we had fallen behind on upgrades to the Unix operating systems. We embarked on a program to address this aggressively. With two exceptions, all Suns now operate Solaris 2.6 and all PCs running Linux have been upgraded to RedHat 6.0. One of the exceptions is the machine at the 140 Foot Telescope, fahd, which will be left at Solaris 2.5 in the near term in case we need to resuscitate the telescope. The other (arcturus) will remain at 2.5.1 until it is clear that we have successfully migrated all third party software. AIPS and AIPS++ users are encouraged to run on the Sun Ultra60 (presently known as arcturus2), which has many times (10x) the performance of the other Sun machines.

To provide a more uniform environment for our Windows users, we embarked on a program to upgrade all of the Windows 95 computers to Windows NT. This is now essentially complete.

Despite the fact that Green Bank has very clean and reliable power, it still suffers occasional interruptions. We now have all of the servers (Unix and Windows NT) and the essential computers to operate the GBT on modern uninterruptible power supplies.

G. C. Hunt

VLA

Changes to Policy for the Review of Large VLA Proposals

A little over three years ago, the NRAO adopted a policy for the review of proposals for large amounts of observing time. That policy was recommended by the Large Proposals Committee, chaired by A. Bridle. Since then, proposals requesting more than 300 hours of observing time on the VLA have been subjected to the “skeptical review” defined by the Committee. (A higher threshold of 1000 hours applies to the single dishes; no large proposal has yet been received for any telescope other than the VLA.) A skeptical review panel was convened recently to review a number of large VLA proposals. The panel has made several recommendations, all of which are being adopted by the Observatory as policy for the future:

- Large proposals to the VLA and VLBA will be reviewed once per full configuration cycle, roughly once every 16 months. The deadline for such proposals will be announced. Proposals for special targets of opportunity are welcome at any time. These announcements and deadlines should not be interpreted as a commitment by the Observatory to schedule large projects as a routine part of every review cycle.

- Large proposals will be categorized as either a “survey” or a “large project” and will receive particularly close scrutiny with respect to their impact on the standard “small projects” that constitute the bulk of VLA and VLBA observing. Authors of large proposals should bear this categorization in mind when writing the justification for their proposal.

- Large proposals are allowed to exceed the page limit imposed on standard VLA and VLBA proposals. This allows for a request justification commensurate with the time requested and for an appeal to be made to the broader range of astronomical interest and expertise present in the skeptical review panels.

- Surveys should necessarily yield data products that are of use to the general astronomical community, such data being made public as soon as possible, both raw data and refined data products. Principal investigators will be required to produce a brief intermediate report for projects that go beyond one configuration cycle as well as a final report and final set of data products, all of which will be made public.

- Overall, no more than 10-20 percent of the VLA or VLBA observing time will be made available to large projects, with a limit of 50 percent of the observing time at any LST range for any configuration.

- Large proposals will be refereed by the standard set of VLA or VLBA referees before being sent to the skeptical review panel.

- The skeptical review panel will be responsible for both making recommendations regarding the scheduling of large proposals for observing time and monitoring the progress of successful proposals.

- The policy stated here applies to the VLA and VLBA. Rules of procedure beyond those stated in the report of the Bridle Committee will be generated for the GBT when it becomes necessary.

- The results of skeptical reviews will be announced and publicized in the *NRAO Newsletter* and on the NRAO web site, as will results from large projects underway.

P. A. Vanden Bout

Call for Proposals to Use the VLA-Pie Town Link

The project to connect the Pie Town VLBA antenna (PT) to the VLA in real time is making satisfactory progress; thus we will be able to provide this system as a user facility during the VLA A configuration session beginning in October 2000. The NRAO proposal deadline for this configuration is June 1, 2000. We invite proposals for the A configuration to request the VLA-PT link if scientifically appropriate.

The major importance of the link for scientific observations is the factor of two improvement in angular resolution for sources with declinations north of about +40 degrees, while maintaining the full sensitivity of the VLA. At lower declinations, the angular resolution is improved, but the full factor of two improvement in all directions is generally not realized. Of course, single snapshots will achieve enhanced resolution in only one dimension.

When the PT link is in operation, observers will lose two VLA antennas, one whose back-end electronics is used for PT, and a second that must replace PT in the VLBA. Scheduling of observations using the link will be done with JObserve, the Java-based scheduling program that will be released to the general community well before October 2000. We are still developing techniques to correct for the offsets between the PT and VLA maser clocks; it may be that additional calibration and data analysis steps (e.g., fringe-fitting) will be required to make best use of the VLA-PT link.

Since PT is an important resource that must be shared with the VLBA, users proposing to use the VLA-PT link must make a strong scientific justification for the inclusion of PT. Item 11 of the VLA proposal cover sheet has been modified to contain a box that must be checked to request the PT link; we also suggest the use of item 21, "Special hardware, software, or operating requirements," to request use of the link. Proposers should obtain the most recent VLA proposal cover sheet from *http://www.nrao.edu/administration/directors_office/tel-vla.shtml*.

We strongly recommend that users who are allocated time to use the VLA-PT link should send a member of their observing team to the VLA and schedule a visit to the AOC after their observations. This will provide first-hand experience in the behavior of the link, up-to-date information on the latest recommended calibration techniques, and direct NRAO user support.

Users and other interested parties can be kept up-to-date on the status of the VLA-PT link by pointing their web browser to:
http://www.aoc.nrao.edu/vla/html/PieTown/PieTown.html.

We expect to provide a general proposers' and users' guide at the above web address by May 1, 2000, well in advance of the proposal deadline. Questions and comments also can be directed to the undersigned at *mclausse@nrao.edu* or *julvesta@nrao.edu*.

M. J. Claussen and J. S. Ulvestad

Synthesis Imaging Summer School 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, NM. 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 also will 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.nrao.edu/~gtaylor/synth2000.html*. Registration for the summer school may close early if we reach our capacity of 150 students. If we go over 150, there will be a waiting list.

Important Dates for Synthesis Imaging Summer School 2000:

1 Feb 2000	Early registration closes
14 Feb 2000	2nd announcement to registered participants
15 May 2000	Payment deadline for early registration
26 May 2000	Last day allowed for registration
31 May 2000	3rd and final mailing to registered participants
1 June 2000	Deadline for motel reservations
20 June 2000	1st day of School
23 June 2000	Data reduction tutorial at AOC
24 June 2000	AIPS++ lectures and tutorial
25 June 2000	VLA tour
27 June 2000	Last day of School

G. B. Taylor, J. M. Wrobel, and C. L.Carilli

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
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	20 Oct 2000	08 Jan 2001	1 Jun 2000
BnA	19 Jan 2001	05 Feb 2001	1 Oct 2000
B	09 Feb 2001	01 May 2001	1 Oct 2000
CnB	12 May 2001	30 May 2001	1 Feb 2001

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 degrees declination) and extreme northern sources (north of about 80 degrees declination).

Approximate 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 day than at night. These include observations at 327 MHz (solar and other interference; disturbed ionosphere, especially at dawn), 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). They should defer such observations for a configuration cycle to avoid such problems. In 2000, the A configuration daytime will be about 17^h RA and in 2001, the B configuration daytime will be about 00^h 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 Goddard Space Flight Center.

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

New Mexico Computing Developments

The AOC and VLA site computer systems have withstood the Y2K transition well. All our important services had been moved to new servers with Y2K-compliant operating systems. Even so, our old servers did not die completely in 2000; at this time they are still limping along, but will be shut down for good shortly. Computer Division support staff was on hand on January 1, 2000, but could go home within a few hours when it became apparent that all important systems were running well.

Several new hardware items have been installed. First tests of the new poster-size color laser printer were successful and we expect to make this printer available for general use soon. A new high volume laser printer was installed in the west wing, allowing better printing access to staff in this new wing. We are gradually upgrading our tape drives on public machines; each of the three corridors with public workstations now has access to one DDS-3 DAT drive; we plan to further improve the tape situation of both DATs and Exabytes during the remainder of this year.

A concentrated effort is under way to update the Socorro-based computer web pages; most of these have been completely rewritten. We plan to bring these new web pages online some time in the spring.

G. A. van Moorsel

VLBI / VLBA

Space VLBI Groups at NRAO Receive NASA Group Awards

The Space VLBI groups at Green Bank and Socorro have received NASA Group Achievement Awards for their work in supporting the VSOP international space VLBI mission. The VSOP mission is an international collaboration led by the Japanese space agency ISAS, which launched the mission's HALCA spacecraft in 1997. NASA has provided development and ongoing operations funding for NRAO's support of the mission. All NRAO involvement in the VSOP mission has been on a peer-reviewed basis, with NRAO participating in the reviews.

Space VLBI missions extend the interferometer baselines beyond the diameter of the Earth and allow extremely high angular resolutions. The VSOP mission is the first in what is hoped to be a series of Space VLBI missions that may include RadioAstron, VSOP2, and ARISE.

The NRAO Green Bank group operates one of the four ground tracking stations for Space VLBI communications. These provide a maser-referenced frequency standard to HALCA. HALCA samples the astronomical signals and transmits the data back to the stations on a wideband downlink. The tracking stations record the data on VLBI tapes and ship them to one of several correlators involved in the mission.

The NRAO Space VLBI Project in Socorro provides co-observation by the VLBA and other NRAO telescopes, correlation of VSOP observations, and scientific and user support at the AOC. During the mission's first two years of scientific operation, it was assigned up to 30 percent of the VLBA's scheduled observing time. About 75 percent of the mission's General Observing Time results have come through the VLBA correlator.

The NRAO groups were notified of the award by Joel Smith, Manager of the JPL Space VLBI Project. Smith stated that the awards were issued "for the rousing success that the international Space VLBI mission VSOP has become through the collective effort of all the elements of the US Space VLBI team. The success of the NASA-sponsored parts of this amazingly complicated mission was made possible because of your team, and the incredible effort made by each of the team members."

The Observatory and each member of the two groups received a citation from NASA that reads, "In recognition of exemplary achievement in generation of astrophysical images with unprecedented angular resolution through support of the Japanese mission Very Long Baseline Interferometry Space Observatory Programme (VSOP)."

The Green Bank Earth Station program was formed by Larry D'Addario and has included Martin Barkley, Carl Bignell, Dave Burgess, William Campbell, Pete Chestnut, Ray Escoffier, Mike Fowler, Dave Gordon, Don Gordon, Ron Gordon, Tim Glaser, Wes Grammer, Kevin Gumm, Glen Langston, Ed Meinfielder, Anthony Minter, George Moellenbrock, Sasha Nabakov, Dan Pedtke, Pat Schaffner, William Shillue, Dick Thompson, Doug Varney, and Ann Wester.

The NRAO Space VLBI Project in Socorro is led by Jon Romney. Those receiving citations were John Benson, Steve Blachman, Chuck Broadwell, Barry Clark, Mark Claussen, Ketan Desai, Chris Flatters, Ed Fomalont, Joe Greenberg, Andy Hale, Craig Lewis, Amy Mioduszewski, George Peck, Peggy Perley, Jim Ulvestad, Ron Weimer, and Joan Wrobel.

P. R. Jewell and J. D. Romney

Space VLBI

After a lengthy recovery from a partial reaction-wheel failure, the VSOP mission's HALCA spacecraft was able to resume observations on March 8. At present, pointing of HALCA's 8-m VLBI antenna is restricted to a cap of angular radius 15 degrees centered on the anti-solar vector. Fortunately, three very important targets for VSOP, 3C273, 3C274, and 3C279, could be observed in this region during the second half of March. The VLBA and VLA again formed most of the ground telescope array in these observations. HALCA's first post-recovery fringes were detected at the VLBA correlator on March 29. It is hoped that the region of sky accessible to HALCA can be expanded in a few months.

J. D. Romney

Update on VLBA Dynamic Scheduling

In February of 1999, NRAO initiated a policy of "dynamic" scheduling, ushering in a new era for scheduling observations with the VLBA. Currently, the scheduler allocates approximately 40 percent of any given month to fixed observations. Another 20 percent is devoted to maintenance and testing. The remaining 40 percent of time is deliberately left unscheduled and designated for projects to be scheduled dynamically. Observers of approved, refereed projects provide the operations staff with the details of their observations via a "key" file, for no particular date, centered on a particular local sidereal time for the Pie Town, NM, station. Other information, such as a list of critical stations/baselines, is also specified by the observer at this time. VLBA operations then schedules these projects on the fly, taking into consideration up-to-date information on the health of each station, weather, and other priorities.

Since the inception of dynamic scheduling, more than 130 astronomical projects have been accommodated in this way. It is hoped that this method of scheduling the VLBA will improve data quality for observations that require optimal weather conditions at the 10 VLBA stations, which are located in such diverse places as Saint Croix in the Virgin Islands, the continental US, and the top of Mauna Kea in Hawaii. Another advantage of this method is that the observing of unpredictable events, such as gamma-ray bursters, has been greatly facilitated. So far, dynamic scheduling has allowed operations staff to increase the amount of time spent on astronomical observations each month from 50 percent to 60 percent. It is anticipated that

(continued page 12)

once we have refined the tools needed and learned from our experiences with this mode, this percentage will increase further.

M. P. Perley

VLBI Network Call For Proposals

Proposals for VLBI Global Network observing are handled by the NRAO. There usually are 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
25 May to 15 Jun 2000	6 cm, 18 cm, other?	01 Feb 2000
06 Sep to 27 Sep 2000	6 cm, 18 cm, 90 cm, other?	01 Feb 2000
08 Nov to 25 Nov 2000	6 cm, 18 cm, other?	01 Jun 2000

It is recommended that proposers use a standard cover-sheet for their VLBI proposals. Fill-in-the-blanks TeX files are available by anonymous ftp from *ftp.cv.nrao.edu*, directory proposal, or via the VLBA home page on the web. 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 European VLBI network constitutes a Global proposal. Global proposals *must* reach *both* Network 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 even 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 für Radioastronomie
Auf den Hugel 69
D 53121 Bonn
Germany

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

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

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

IN GENERAL

Observatory-Wide Computing Developments

Security

We are continuing to make progress in our efforts to improve computer security at NRAO facilities as we implement the new Computer Security Policy. Key network services offered by each site have been identified; all other access will be blocked from outside of the NRAO. Certain services are being restricted to specified systems at each site. To access these, please use the following:

Service	Name
World-Wide Web	
Main NRAO page	www.nrao.edu
Site pages	www.<site>.nrao.edu
ftp	ftp.<site>.nrao.edu
telnet, rlogin	login.<site>.nrao.edu

where <site> is one of cv, gb, aoc, or tuc. These names should be used both from outside of the NRAO and within our own networks.

For the time being, access using ssh/slogin will continue to be largely unrestricted. To reduce the risks associated with remote access, we 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.

A steadily growing amount of information on computer security, including the text of the Computer Security Policy, is available on NRAO's internal web pages, which are accessible to visitors using any NRAO computer. These resources will continue to be expanded in the future.

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*, 505-835-7282). Inquiries regarding security incidents affecting the NRAO should also go to Ruth.

Windows 2000 at the NRAO

Microsoft has recently released Windows 2000, an operating system with the potential to improve our Windows environments and to simplify PC administration. Windows 2000 does, however, contain features that can introduce serious incompatibilities with existing systems on our networks.

Many large organizations, especially those with mixed Windows and Unix networks, face the same problem and are electing to postpone Windows 2000 deployment until industry-wide solutions have appeared and been tested, and support staff have been properly trained. The NRAO has also decided to take this approach.

Before any Windows 2000 systems can be installed on our existing networks, NRAO support staff will need time to test the new features in a trial environment and then to determine the best configuration for Windows 2000 networking across the NRAO. Until this training and evaluation program is complete, there will be a moratorium on the deployment of Windows 2000 on computers which connect to the NRAO networks. During this period, only those systems participating in the test environment may use the new operating system.

If you will be visiting the NRAO and plan to bring a laptop computer which runs Windows 2000, please contact the PC support staff at the relevant NRAO site to find out whether you will be able to connect it to the test network there. Note that it will probably be late summer before a test environment has been set up.

Videoconferencing

All four major NRAO sites are now using videoconferencing. Additional configuration and testing is still needed for ISDN support, which is required in most cases to permit participation from locations outside of the NRAO. Details will be provided in the next issue of the *NRAO Newsletter*.

Hello Year 2000, Goodbye “Millennium Bug”

Thanks to the efforts of many staff members, the NRAO’s computer systems and software survived the transition from 1999 to 2000, including the leap day, with only a few minor glitches. Communications, Fiscal computing, and telescope observing all proceeded normally. The VLBA successfully observed on New Year’s Eve through midnight UT and the VLA through both midnight UT and midnight local time. No NRAO site reported problems with outside providers such as electricity, water, financial services, or transportation.

M. R. Milner

Charlottesville Computing

Linux

The new Linux system (“Vulcan”), mentioned in the October 1999 *Newsletter,* was delivered and has been deployed. It is likely the least expensive public workstation NRAO has purchased to date (about US $7,000), and while it may not be the most powerful, its price/performance ratio is second to none. The system is a 550 MHz Pentium III Xeon with 768 megabytes of memory, 62 gigabytes of user disk space and a 21-inch monitor. It delivers about 21.6 AIPSMarks. Visitors to Charlottesville may avail themselves of this system, now located in the Edgemont Road AIPS Cage; a sign-up sheet is available, and advance booking is possible by contacting Jim Condon (*jcondon@nrao.edu*).

Printing

A new printing system, recently installed on all Unix systems in Charlottesville, has provided us with several benefits. Chief among these is a faster print server – a cast-off Pentium 90 now running a stripped-down and secured version of Linux. Another noticeable benefit is more reliable printing.

The new print server uses CUPS, the Common Unix Printing System, as the basis for its operations. This is a modern system that on the Unix clients provides drop-in replacements for both lpr and lp commands, as well as the other ancillary commands such as lpq, lpstat, etc. It offers a large number of options and supports a wide variety of printers.

However, the real beauty of this system will become evident as it is deployed elsewhere. At least one other NRAO site is planning on installing a similar print server. This will make inter-site printing essentially trivial, as one can specify which print server one wants to use on the printing command line, e.g., “lpr -Pps1@printserver.example.edu.” This should provide a useful service for visitors whose home institutions have installed CUPS. As the software is freely available from *www.cups.org*, we will not be surprised if it is widely adopted by others in the future.

Security

As part of the ongoing implementation of NRAO’s Security Policy, we have started to perform internal scans on our networks to reveal, isolate, and correct potential problems or vulnerabilities. At the time of writing, most Charlottesville systems have been scanned. With the cooperation of staff at the other sites, we will be extending this scanning to all of NRAO. This has already helped us to remove several unneeded services, close or alter certain ports, etc. and will ultimately lead to NRAO being able to offer a more secure, reliable service to staff and visitors.

In addition, all new Unix accounts created in Charlottesville will automatically be set up for maximal ease of use with the Secure shell. Technically, this means we will pre-generate a public/private set of ssh keys for each new account, with a null passphrase (unless a non-empty passphrase is requested). This will make use of slogin, ssh, and scp commands much easier and useful to most users,

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and more attractive than their traditional counterparts (rlogin, rsh, rcp).

Finally, a new facility has been made available to NRAO Charlottesville staff and guests to permit secure shell logins from any java-capable web browser. Pointing your browser at *http://www.cv.nrao.edu/mt/* will bring up a java applet which is a secure shell client program. It can only connect to our web server in Charlottesville. This has already proven to be very popular and convenient with our staff while on travel, as the regular secure shell (ssh, SecureCRT, or variants) is not always available at remote locations.

Miscellaneous

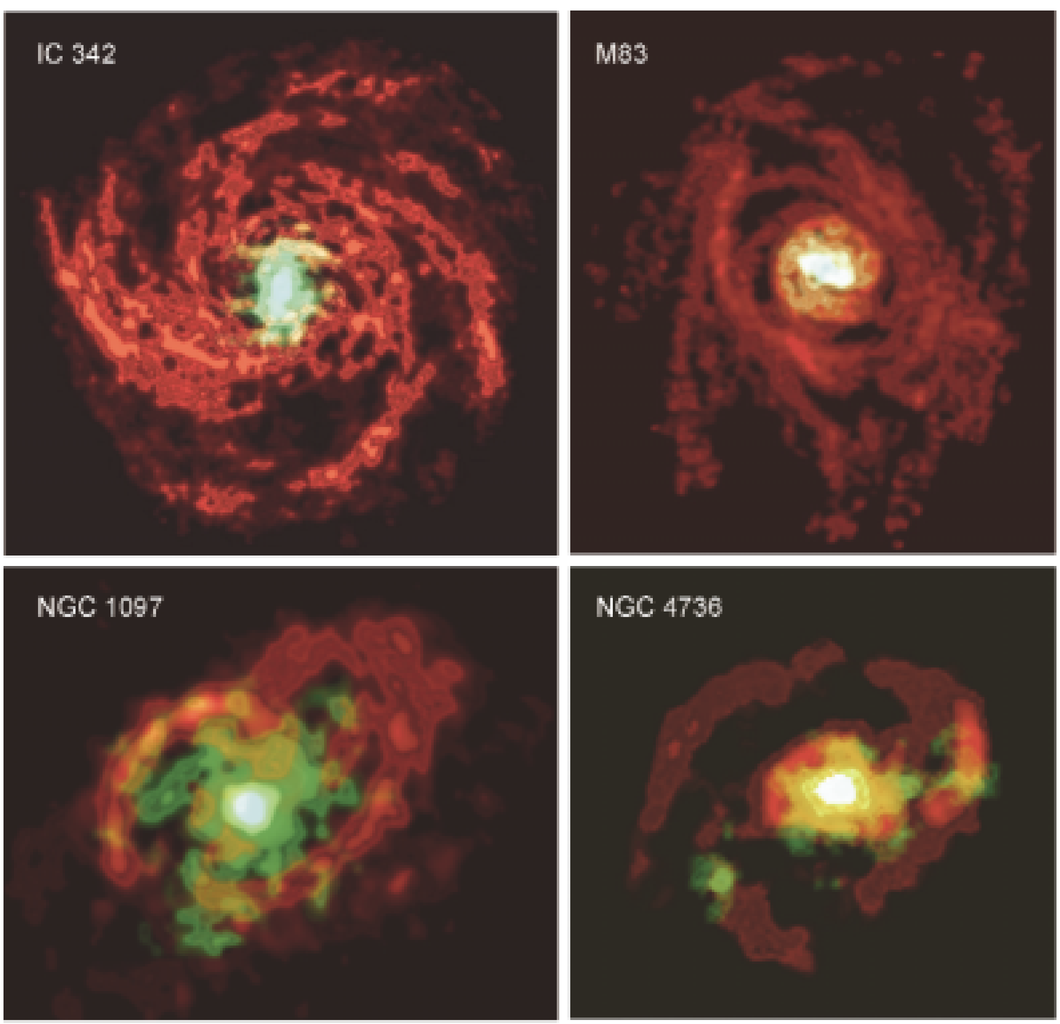
We are investiging use of a web-based "groupware" style product called BSCW ("Basic Support for Cooperative Work"), to help eliminate many of the traditional problems faced by the various groups of users that we support (both within and outside the Observatory). This software is already in use at the Max-Planck Institut für Radioastronomie in Bonn, Germany, and has proven to be very useful for collaborative work, sharing documents, etc. It is expected that this software will significantly help our staff work with colleagues at other institutions. As with CUPS, this software is also free of charge to qualifying academic institutions.

A repository for NRAO-wide Open Source software packages has been made available by Charlottesville Computing. This is currently being populated with a variety of packages that have already been installed in Charlottesville and in which administrators at other sites have expressed interest. Plans are under way to make this repository available transparently via NFS at all NRAO sites.

P. Murphy

NEW RESULTS

Mapping Molecular Gas in Spiral Galaxies with the NRAO 12 Meter Telescope



Distribution of CO and H I in four of our sample galaxies. The CO data (reproduced in green) was obtained using the NRAO 12 Meter Telescope, and has a resolution of 55" and column density sensitivity of $N_{H2} = 3 \times 10^{20}$ cm^{-2}. The H I maps (reproduced in red) are from VLA C+D or C-array observations, taken from the following sources: IC 342: Crosthwaite, Turner & Ho, 2000, AJ, in press; M83: Ondrechen & van der Hulst (from the VLA archive, 1983); NGC 1097: Ondrechen, van der Hulst & Hummel,1989, ApJ, 342, 39; NGC 4736: Braun, 1995, A&AS, 114, 409.

A first step in understanding how the global patterns of star formation in galaxies arise is to locate the fuel for the star formation, the molecular gas. Because H_2 in cold molecular clouds cannot be observed directly we observe the "tracer," CO, and derive the corresponding H_2 mass indirectly via an empirically determined "conversion factor." While many nearby, gas-rich spiral galaxies have been mapped to some extent in CO, very few have extensive, deep, fully sampled maps of the entire CO disk. With the NRAO 12 Meter and its sophisticated "on-the-fly" observing mode, it is possible to efficiently and reliably map cold, extended CO emission over very large areas.

As part of a dissertation study, several spiral galaxies were selected for a short survey of CO and H I content. The goal of the project is to observe the neutral gas distribution in an illustrative, heterogeneous sample of spiral galaxies, ranging from big to small, starburst to quiescent, actively interacting to isolated. Galaxies were selected based on previous CO detections, large angular size, and low inclination. Their distances range from 2 to 17 Mpc. We have used the 12 Meter to map the full optical extent of each galaxy in CO, covering regions from 10' x 10' to 15' x 15'. H I data was taken from the literature or (with permission) from the VLA archive. We reproduce the CO and H I images of four galaxies from our sample here: IC 342, M 83, NGC 1097 and NGC 4736. These figures emphasize the relative CO/H I distribution and trace nearly equivalent column densities in both H_2 and H I ($N_{H2} \sim N_{H\,I} \geq 3 \times 10^{20}$ cm^{-2}).

These figures clearly show the transition from predominantly atomic gas (red) at large radii to predominantly molecular gas (green; CO/H I overlap in yellow) in the inner regions. This general radial structure has been known for some time (Morris & Lo 1978, ApJ, 223; Young & Scoville 1982, ApJ, 258). However the detailed structure of the CO has not previously been studied. While not emphasized in these figures, our maps show that there is extensive inter-arm molecular gas.

The radial extent of the CO disk as compared to the H I disk can vary enormously. In IC 342 and M83, both barred, late-type spirals, the CO disk covers only a small fraction of the H I disk, while in NGC 1097 and NGC 4736, the radial extent of the CO is almost comparable to the H I. Interestingly, these last two galaxies comprise the most recently interactive and strongly barred (NGC 1097) and the most quiescent and ringed (NGC 4736) of our galaxy sample. We see no evidence for CO/H I anti-correlations on small scales. Instead, spiral arms change smoothly from CO arms in the inner disks to H I arms in the outer disks. Finally, a comparison with star formation tracers such as 20 cm radio continuum or 100 μm FIR, indicates that large concentrations of gas or regions of relatively low Toomre Q do not guarantee star formation. Some other process must participate.

These preliminary results form the basis of Pat Crosthwaite's dissertation, which is currently in progress. Initial publications: Crosthwaite, Turner & Ho 2000, AJ in press; Crosthwaite et al. 2000, submitted. See also: *http://www.astro.ucla.edu/~lucian/papers.html.*

L. P. Crosthwaite and J. L. Turner
Division of Astronomy and Astrophysics, UCLA

Giant Radio Plumes of Luminous IR Galaxies

One of the important unanswered questions concerning the luminous infrared galaxy phenomenon is whether the large luminosity observed is powered by a starburst or by an AGN. Determining the nature of the power source is not a trivial task since the luminosity arises from the heavily obscured nuclear regions. Clear evidence for an AGN, either hard X-ray emission or a VLBI source with high surface brightness (>10^7 K), has been detected in some cases, but proving that these active nuclei produce the bulk of the luminosity is a more demanding task.

An interesting and unexpected new clue has been revealed in our VLA 21 cm imaging survey of a distance limited sample of IR luminous galaxies (distance < 100 Mpc, $L_{IR} \geq 3 \times 10^{11} L_\odot$; Hibbard & Yun 1996 and in preparation). The 1.4 GHz radio continuum observations reveal 100 kpc-scale giant radio plumes in three (Mrk 231, Mrk 273, NGC 6240) out of the nine galaxies in our sample (Figure 1, Figure 2a; see Yun et al. 2000). These edge-brightened features are also visible in the NVSS images, and their high degree of polarization suggests a coherent magnetic structure (Figure 2b).

The radio plumes are between 75 and 230 kpc long, comparable to the length of jets/lobes in powerful radio galaxies and much larger than either the radio jets found in Seyfert galaxies or the emission line nebulae associated with galactic superwinds (≤ 50 kpc; Heckman et al. 1990). The radio plumes are well aligned with the rotation axis of the nuclear molecular gas complexes (Bryant & Scoville 1996, Bryant 1997, Downes & Solomon 1998), suggesting that they are directly related to the ongoing luminous activity in the central kpc regions.

The derived radio luminosities between 10 MHz and 100 GHz are about 2×10^{40} ergs s^{-1}. In comparison, the radio luminosities of nuclear superwinds, Seyfert radio bubbles, and jets/lobes in radio galaxies are typically 10^{37-38}, 10^{38-39}, and 10^{40-45} ergs s^{-1}, respectively (Baum et al. 1993, Zirbel & Baum 1995, Colbert et al. 1996). Therefore, the observed luminosities are most consistent with an AGN origin. However, the plume luminosities are only a small fraction of either the bolometric (IR) or the superwind kinetic luminosity ($L_{plume}/L_{IR} \sim 10^{-5}$, $L_{plume}/L_{kin} \sim 10^{-2}$; see Heckman

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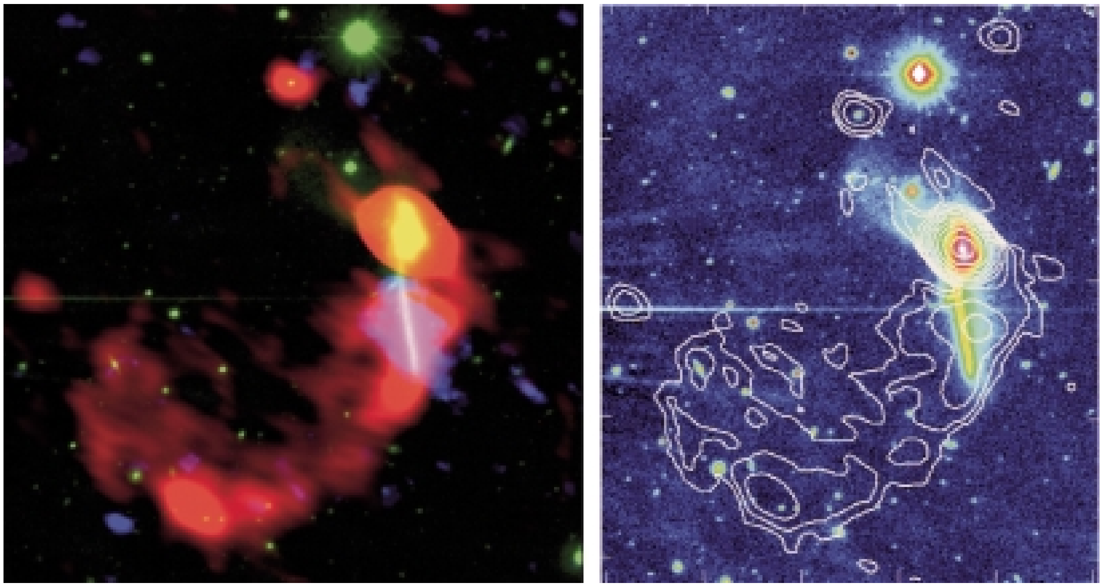


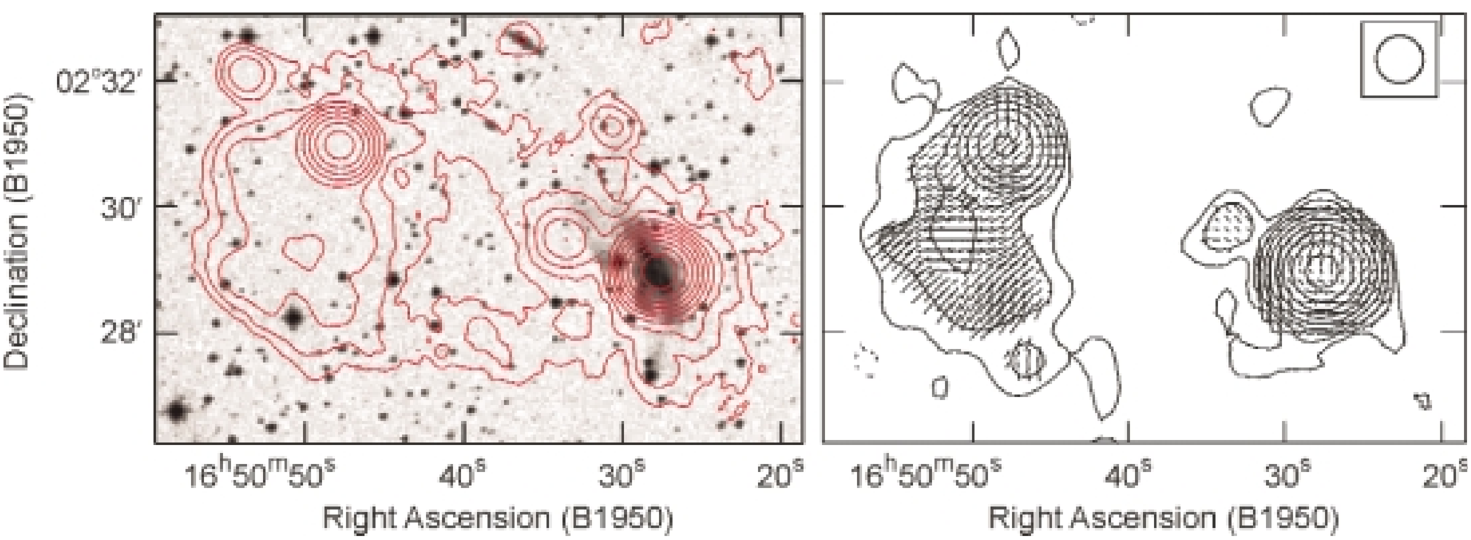
Left: False color RGB image of Mrk 273, with the starlight shown in green, 21cm H I line emission in blue, and 1.4 GHz radio continuum emission in red. Right: optical image of Mrk 273 in spectral colors, with contours of the 1.4 GHz emission superimposed.

et. al. 1990 and references therein), and it is hard to exclude a possible superwind origin. The advantage of an AGN/jet model is that the energy flux can be channeled, resulting in much smaller energy and momentum loss and thus enabling the particles to reach a greater distance in a given amount of time.

The minimum energy magnetic field derived for the radio plumes is about 1 μG with a corresponding total energy of about 10^{57} ergs (see Miley 1980). If there is equipartition between magnetic field and relativistic particles, then the particle density in the radio plumes is about 10^{-6} cm^{-3}. In comparison, the internal magnetic field and total energy stored in the radio lobes of Cygnus A is about 50-300 μG and >10^{59} erg, and n=10^{-4} cm^{-3} (Carilli et al. 1998). A highly ordered magnetic field aligned along the outer envelope, as inferred from the high polarization, suggests an expanding bubble-like structure plowing into the external medium.

All three galaxies with giant radio plumes clearly host powerful AGN (hard X-ray or radio VLBI sources) while other luminous IR galaxies without any evidence for an AGN (e.g., Arp 220) do not show such plumes. These giant plumes have not been detected until now because of their unexpectedly large size and low brightness, but they may be ubiquitous at a fainter level, and we are currently pursuing more sensitive observations to address if they are unique signposts of galaxies hosting a powerful AGN.

M. S. Yun
NRAO - Socorro



Giant radio plumes detected in NGC 6240 at 1.4 GHz with the VLA contoured in red upon a greyscale representation of the optical image from the DSS (left panel). These edge-brightened structures are also seen in the NVSS images (right panel), which reveal a high degree of polarization. It is possible that these extended radio features are projected foreground or background objects, but the faint continuous emission connecting back to the optical galaxy as well as their alignment with the optical and X-ray emission lobes and the spin axis of the nuclear molecular gas disk are strong evidence tying them to the activity in NGC 6240.

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First Results of the VSOP Continuum Survey Presented at the VSOP Symposium

On January 19-21, 2000, the VLBI Space Observatory Programme (VSOP) at the Japanese Institute of Space and Astronautical Science (ISAS) in Sagamihara hosted "The VSOP Symposium: High Energy Astrophysical Phenomena Revealed by Space-VLBI." A variety of interesting results from VSOP, the first-ever dedicated space-VLBI mission, were presented, including the first statistical results from the VSOP Continuum Survey. The VSOP Continuum Survey is an impressive international collaboration led by scientists in Japan (it is the only mission-led project) and involves the contributions and cooperation of observatories and institutions on every habitable continent, including the NRAO's Green Bank Earth Station which is used to track the VSOP satellite (HALCA) and the VLBA Array and Correlator. This article summarizes the VSOP Continuum Survey and the first results presented at the VSOP Symposium. More information about the VSOP mission, the VSOP Symposium, and the VSOP Survey may be obtained at *http://www.vsop.isas.ac.jp*.

The majority of VSOP observing time is given to peer-reviewed General Observing Time (GOT) proposals which are solicited from the astronomical community. The GOT projects are typically high-quality imaging studies (sometimes multi-epoch) using large ground arrays whose limited time contributions were negotiated prior to the mission. However, with a detection threshold of ~0.1 Jy at 5 GHz, many more sources than have been proposed for GOT observations are detectable. Therefore, the VSOP Continuum Survey was initiated to complement the GOT observations with a systematic study of a large sample of sources at 5 GHz. When complete, the VSOP Continuum Survey will be suitable for statistical active galactic nuclei (AGN) and cosmology studies as well as future space-VLBI mission planning.

The VSOP Continuum Survey sample consists of the ~402 extragalactic sources with a total flux density (at epochs between 1985-1996) at 5 GHz $S_\nu > 1$ Jy with spectral index $\alpha > -0.5$ ($S_\nu \sim \nu^\alpha$) and galactic latitude $|b| > 10^o$. All sources with $S_\nu > 5$ Jy are included regardless of spectral index or galactic latitude. All members of this sample with declination $\delta > -43^o$ (357 sources) were observed in a 5 GHz VLBA snapshot survey (Fomalont et al. 2000, in preparation) in order to determine the correlated flux density on the longest practical earth baselines. To ensure a high probability of detection on HALCA baselines approaching three earth diameters in length, only those 289 sources with correlated flux densities exceeding ~0.3 Jy on the VLBA's MK-SC baseline (or with $\delta < -43^o$ and thus lacking the long-baseline ground measurement) were included in the target list for actual observing with HALCA.

A typical Survey experiment consists of a single-orbit (~6 hours) observation using HALCA and 2-4 ground radio telescopes. Ground radio telescope time contributions were negotiated independently of the GOT contributions and obtained from Arecibo (NAIC, Puerto Rico) Ceduna and Hobart (University of Tasmania, Australia), the Green Bank 140 Foot (NRAO, US), Hartebeesthoek (HartRAO, South Africa), Kalyazin (Lebedev Institute, Russia), Kashima (CRL, Japan), Mopra (ATNF, Australia), Noto (CNR, Italy), Sheshan (Shanghai University, China), Torun (Copernicus University, Poland), and Usuda (ISAS, Japan). To optimize the overall efficiency of the VSOP mission, sources observed for GOT experiments are not observed independently by the Survey; instead, a suitable dataset is extracted (with PI permission) from the GOT for use in the statistical results of the Survey. Via extractions, the following observatories have contributed indirectly to the VSOP Survey: ATCA (ATNF, Australia), Effelsberg (MPIfR, Germany), Jodrell MKII (University of Manchester, UK), and the VLBA (NRAO, US). Most Survey observations are correlated at either the S2 Correlator in Penticton (Canada) or at the VSOP Correlator in Mitaka (Japan). GOT extractions come from all three VSOP mission correlators, including the VLBA Correlator in Socorro (US). As of April 1, 2000, 195 (67 percent) of the 289 target sources have been observed.

Data reduction for the VSOP Survey is being undertaken by a group of astronomers located in Australia, Canada, Europe, Japan, and the United States. A prior calibration and fringe-fitting are performed in AIPS, and rudimentary imaging (to improve the calibration) and modelfitting are performed in DIFMAP. As of April 1, 2000, 67 observations have been fully reduced.

For the purposes of a statistical analysis, the visibility amplitudes for each source have been divided into 50 Mλ bins from 0 to 500 Mλ (the longest practical earth baseline is less than 200 Mλ). Note that the 0-50 Mλ flux densities used in this analysis represent the flux density on the shortest available VLBI baselines and not the total, zero-baseline, flux density, which is often considerably larger in

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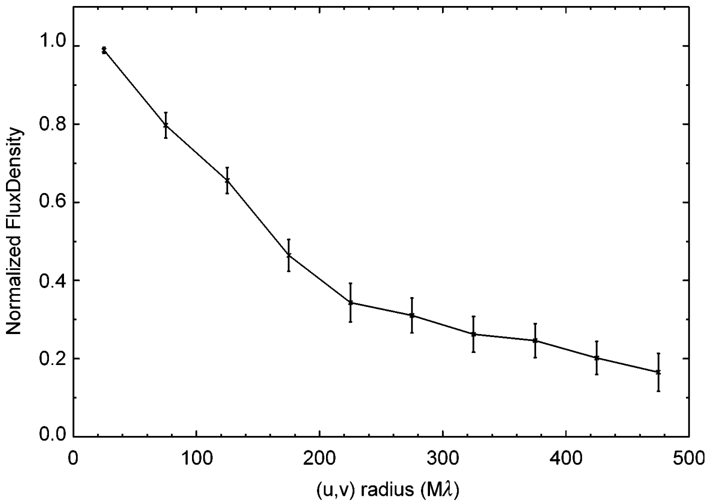

Figure 1. The weighted mean of the normalized flux density distribution for the survey sources analyzed so far.

sources with significant extended structure. The average visibility function (normalized to the 0-50 Mλ bin) for the currently reduced sample is shown in Figure 1. At 200-250 Mλ, the visibility functions clearly flatten significantly, indicating a less-resolved component tends to dominate on the space-VLBI scale at 5 GHz. Nearly all sources are resolved (i.e., have some extended structure) at this resolution to some degree, with BL Lac objects tending to be more compact than quasars.

A principle goal of the VSOP Survey is to determine the peak brightness temperatures for studies of Doppler beaming in AGN. Brightness temperatures may be derived from the elliptical Gaussian modelfits performed in DIFMAP. However, the DIFMAP algorithm does not provide error estimates and often has difficulty converging to a two-dimensional finite component on a point source. This problem is exacerbated by the elliptical and limited (u,v)-coverage available for most Survey observations, especially when the source structure is complicated. To be considered a robust size measurement, model components must be 50 percent larger (in both dimensions) than the limit imposed by the data's signal-to-noise ratio for an isolated component; otherwise, the limiting size is adopted and only a lower limit to the brightness temperature may be derived. Figures 2a and 2b show the observers' frame and source frame (at the emitted frequency) brightness temperature (or limit) distributions for the sources analyzed so far. Approximately 30 percent of these sources have brightness temperatures in excess of 10^{12} K, and among the 59 sources with available redshifts, 51 percent have source-frame brightness temperatures greater than 10^{12} K.

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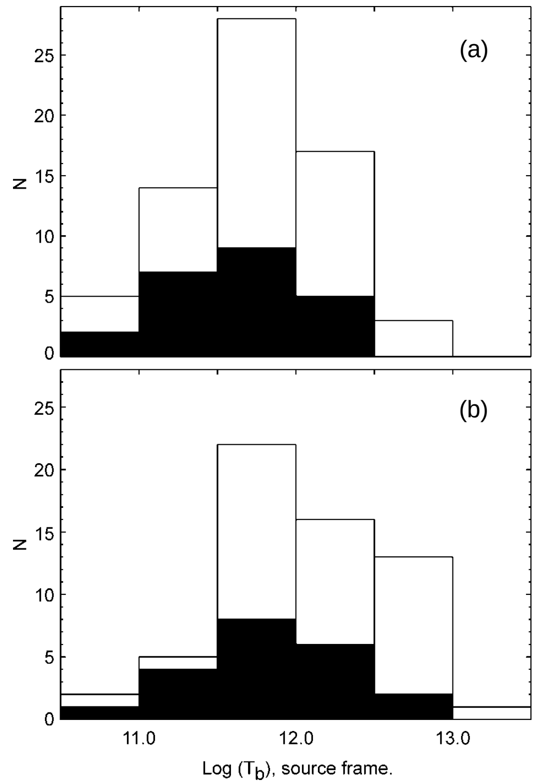

Figure 2. (a) Brightness Temperature distribution in the observer's frame. The filled blocks represent sources where robust component size measurements were available; unfilled blocks represent sources where only an upper limit on size (and therefore a lower limit on brightness temperature) is possible.

(b) Brightness Temperature distribution in the source frame at the emitted frequency. The filled blocks represent sources where robust component size measurements were available; unfilled blocks represent sources where only an upper limit on size (and therefore a lower limit on brightness temperature) is possible.

Editor's Note:

If you have a recent, exciting result obtained with an NRAO telescope that could be featured in this section of the* NRAO Newsletter, *please contact John Hibbard, at* jhibbard@nrao.edu. *We are particularly interested in highlighting ongoing thesis projects.

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

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

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

Observing Information:

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

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