NRAO Newsletter

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IN GENERAL

Proposal Submitted for Expanded VLA

The year 2000 will see 20 years of operation of the Very Large Array. More than 10,000 VLA observing projects, by over 2,200 scientists, from hundreds of institutions, have produced a prodigious legacy of new knowledge, manifested in over 4,000 journal articles that cover virtually every area of professional astronomy. More than 200 published PhD dissertations include data taken with the VLA.

The VLA has been outstandingly productive because, at its inception, it represented a major step in observing capability, and that capability has since been enhanced. Most of that enhancement has been in the area of image processing software. For example, the VLA was originally intended to produce 100 x 100 pixel images, with a dynamic range of 100, in a 12-hour integration. Today, 16384 x 16384 pixel images, with a dynamic range of 10,000, can be routinely produced in the same time (or perhaps less). There have been hardware improvements as well, but much of the VLA hardware remains as built and is, by present standards, obsolete. The scientific requirements of the new millennium cannot be met by the present VLA.

Working with the user community, the NRAO has been planning for an expansion of the VLA. Those plans call for a ten-fold increase in nearly every performance specification. This can be achieved at an expense less than the inflation-adjusted cost of the present VLA.

We can have the power of ten VLAs for the price of the one we have today.

The Astronomy and Astrophysics Survey Committee has recognized how powerful the Expanded Very Large Array (EVLA) will be in many areas – studying magnetic fields, imaging objects obscured by dust, responding rapidly to

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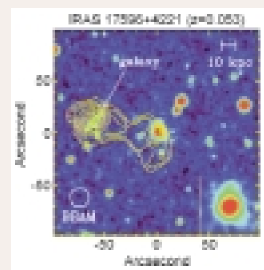
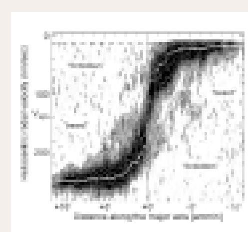
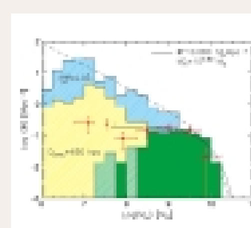
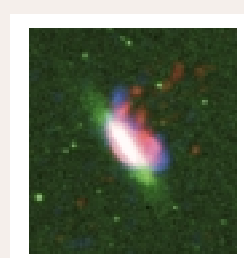




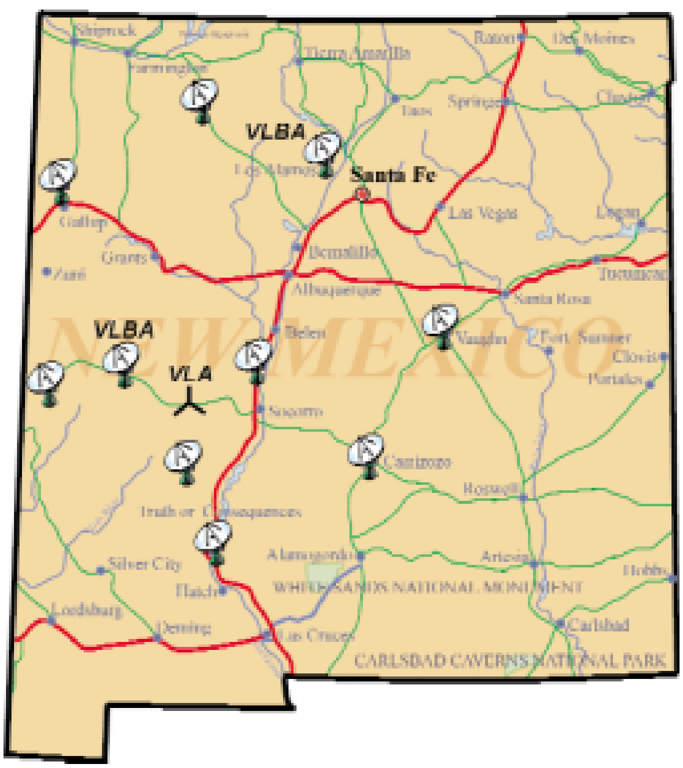




transient objects, and tracking the formation and evolution of objects on all scales from stars to galaxies – and has ranked the EVLA very highly in its recent report, *Astronomy and Astrophysics in the New Millennium.*

On May 18, a proposal for Phase 1 of the EVLA was submitted by Associated Universities, Inc., to the National Science Foundation. It requests $49.9 million to be spent over nine years to expand the capabilities of the electronics of the VLA, by providing a new correlator, local oscillator and intermediate frequency systems (including fiber optics), new and improved receivers, and antenna modifications needed to implement the new electronics. Mexico is contributing to this first phase of the expansion through a $2 million grant from CONACyT to the group of L. Rodriguez at Universidad Nacional Autónoma de Mexico (UNAM). We are also negotiating with Canada over its participation, which would contribute about $10 million. It is likely that both foreign partners would contribute to the correlator system, and that the correlator would be built by the group at the Dominion Radio Astrophysical Observatory. These foreign contributions are additional to the NSF funds requested.

Phase 2 of the VLA Expansion Project will add eight antennas at sites in New Mexico to provide baselines intermediate to those of the VLA and the VLBA (see figure below). This will give the VLA ten times its present angular resolution, thus completing the ten-fold improvement in the instrument's performance specifications. A proposal will be submitted to the NSF at a later date for Phase 2.



Until the Phase 1 proposal has been reviewed and funded, the Observatory will be working to complete elements that have already begun with Major Research Instrumentation and internal funds: 43 GHz receivers, for which the matching funds came from the Max-Planck-Institut für Radioastronomie and from an earlier grant to L. Rodriguez at UNAM, and 22 GHz receivers. The VLA real-time operating system will be rebuilt, as planned, but it will be designed to serve the EVLA as well. An EVLA advisory committee drawn from the user community will be appointed this summer. D. Sramek will continue to serve as Project Engineer and R. Perley as Project Scientist.

P. A. Vanden Bout

Scientific Requirements for the EVLA On-Line Computing System

We are now in the first stages of designing a new real-time computer system for the VLA. This will replace the rapidly aging ModComp computers and serve as the control system for the EVLA.

Many NRAO staff have recently put in a great deal of effort to produce the Scientific Requirements for the EVLA real-time computing and software. These are publicly available on the web at *http://www.aoc.nrao.edu/doc/vla/upgrade/asg/pub/.* We welcome and encourage suggestions from all VLA users. We ask that users external to NRAO review the requirements document and return comments to J. Benson or F. Owen.

These scientific requirements pertain only to the real-time control system, not the EVLA as a whole. As the final hardware architecture of the EVLA has not yet been determined, we have had to estimate some of the EVLA's capabilities. We welcome any comments about the scientific requirements of the EVLA as a whole.

J. M. Benson, F. N. Owen

Report from the World Radiocommunication Conference

Radio astronomers and other scientists who use the radio spectrum in a passive (receive only) mode secured regulatory access to substantial portions of the millimeter-wave spectrum at the World Radiocommunication Conference (WRC-00), which met for four weeks in Istanbul, Turkey, in May. The World Radiocommunication Conference is the forum where countries come together to decide on the shared use of the radio frequency spectrum, to allow the deployment or growth of all types of radiocommunication services. Held every two to three years, it's a crucial event: at stake is the future of both new and existing services, as the meeting painstakingly partitions the radio frequency spectrum for use by a growing number of radio-based applications. These include personal communications services, satellite systems such as satellite broadcasting or GPS, and amateur radio, as well as those that are related to science: radio astronomy, earth exploration, and deep space research. The decisions of the Conference are incorporated into revisions of the Radio Regulations, the set of rules and regulations governing radio services worldwide, and eventually form an international treaty that binds all governments.

WRC-00 added substantial spectrum to the existing allocations for radio astronomy in the range between 71 and 275 GHz (the highest frequency internationally allocated for specific purposes). The new allocations represent the culmination of more than three years of careful planning and coordination between U.S., Australian, European, and Japanese radio astronomers working on spectrum issues. As a result of this cooperation, the proposals presented on this issue by three of the major regional telecommunications groupings – the Interamerican Conference on Telecommunications (CITEL), the European Conference on Post and Telecommunications (CEPT), and the Asia-Pacific Telecommunications Conference (APT) – were nearly identical, and discussions related to this agenda item at the Conference could be kept at a minimum.

Radio astronomers first managed to call attention to the need for additional allocations for passive radio services at the 1997 Conference, which established the agenda for WRC-00. The current allocations in this part of the spectrum date back to the 1979 World Administrative Radio Conference (WARC-79). At that time, millimeter-wave radio astronomy was just beginning, and its science requirements were not well known. For example, many interesting molecular spectral lines that originate in the interstellar medium have been discovered since then. Many of the recently discovered spectral lines are not covered currently by radio astronomy allocations, but many of them will be under the newly approved Allocation Table. The increase in spectrum allocated to radio astronomy was facilitated by the fact that commercial technologies at frequencies above about 50 GHz are not yet fully developed and, when they are, radio astronomers expect to be able to share with most terrestrial radio services. This is because high-frequency radio waves, unlike those below a few tens of gigahertz, are absorbed by the atmosphere over relatively short distances. As a consequence, radio observatories, which as a rule are located at high and dry places and far from urban centers, need to be protected from man-made emissions only within relatively small areas. The situation is more difficult with satellite emissions, particularly with space-to-Earth transmissions. Sensitive radio astronomy receivers are blinded by these emissions, just like an optical telescope is when illuminated by a searchlight. To avoid this problem, WRC-00 relocated most satellite downlinks within the 71 to 275 GHz range to parts of the spectrum that are not needed for scientific observations. Once again, this process was aided by the fact that no satellite yet operates at these high frequencies.

Scientists also managed to add a note to the radio regulations, indicating their interest in the spectrum up to at least 1000 GHz – well over the highest frequency currently allocated to the various radio services. Other issues of interest to radio astronomers at WRC-00 included regulatory protection from space-to-Earth satellite transmissions in the neighborhood of radio astronomy bands at 5, 15, and 42.5 GHz. WRC-00 indicated that more studies are required on how satellites and radio astronomers may share the spectrum in the vicinity of these bands.

T. E. Gergely, Program Manager,
Electromagnetic Spectrum Management
National Science Foundation

Appointment of Associate Director for Data Management

I am pleased to announce the appointment of Tim Cornwell as NRAO Associate Director for Data Management, effective May 1, 2000.

Tim will be responsible for the development of an Observatory Data Management Plan, in consultation with the user community, scientific staff, and NRAO management. He will also be responsible for executing the Plan, which will encompass all aspects of scientific data management at the NRAO.

The organizational structure for data management will be similar to that for business administration. The site directors and project heads will continue to have day-to-day responsibility for the computing personnel who now report to them. However, they will now be responsible to Tim for the data management activities performed by their employees. Some centralized functions, for example, AIPS++, communications, security, and Observatory-wide computing purchasing, will be directly supervised by Tim. The Computing Council will be an advisory body to the Associate Director for Data Management.

P. A. Vanden Bout

Data Management at NRAO

NRAO is putting together a plan to improve data management at the Observatory. The aim is to make it easier for observers to access NRAO telescopes and to present the data from the telescopes in a more "user-friendly" form, making our services comparable to those offered for large instruments such as the HST and VLT. To improve accessibility, we plan to streamline and consolidate proposal handling and telescope scheduling across the Observatory telescopes. To improve data

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products, we will do the initial calibration and, where appropriate, initial imaging of observations, thus ensuring that some scientific results can be obtained directly without observers always having to do these processes manually themselves. We plan to store these results in an Observatory-wide archive, for on-line retrieval.

We hope that by widening the services we offer to users of our telescopes and data, we will increase the number of users. This would benefit existing telescopes such as the VLA and VLBA and also help attract scientists to the GBT, EVLA, and ALMA. As well, NRAO (and radio astronomy in general) needs to make such an initiative to participate in the National Virtual Observatory (a planned resource where astronomy data archives from all spectral regions can be accessed at a single on-line location), which was mentioned favorably in the decadal review.

While this plan is focused on NRAO, we are discussing the possibility of extending it to other U.S.-based astronomical facilities. More details of the planning process will be published in subsequent newsletters. Meanwhile, if you wish to know more, please contact me directly.

T. J. Cornwell

AIPS++ News

On March 16, 2000, the Jodrell Bank Observatory officially rejoined the AIPS++ consortium as a partner. Jodrell Bank was one of the original founding partners in the consortium but withdrew in 1995. We are very pleased to welcome JBO/MERLIN back and look forward to working together.

In early May, we issued the second release, version 1.3, of AIPS++. This completes a six-month development cycle that started after the first release, version 1.2, in October 1999. Our goal in this cycle has been towards scientific completeness. Version 1.3 has numerous changes in most parts of the package, but particularly in calibration and imaging of synthesis data, image manipulation, and viewing. In addition, many new tools, such as a general-purpose fitter, have been provided. A fuller description of the changes is found in the release notes for version 1.3. We have now started on the development of version 1.4 which we intend to release in October 2000. Our goal in version 1.4 is to complete the provision of reduction capabilities for both connected-element interferometers and single-dish radio telescopes, with special emphasis being paid to improving the usability of these parts of the package for processing of VLA data.

In January 2000, we hosted a meeting in Socorro on “Pipeline Reduction in AIPS++.” This was a small informal workshop on the development of pipelined calibration and imaging systems for radio telescopes. Representatives of both consortium and non-consortium telescopes attended, and gave presentations on the experience of, and needs for, pipelines. We achieved a highly satisfactory degree of convergence of views during this short workshop, and we are now coordinating work on pipelines at the various consortium sites. It is clear that the tool-based approach used in AIPS++ is highly suited to the development of pipelines tuned to the needs of different telescopes and scientific questions.

If you would like a CD-ROM containing version 1.3, please send e-mail to *aips2-request@nrao.edu*. The currently supported architectures are Linux (Redhat 6.*, and SuSE 6.2+) and Solaris (2.5, 2.6).

T. J. Cornwell

Observatory-Wide Computing Developments

Security

With the continuing threat of computer attacks such as the recent well-publicized “ILoveYou” virus, we are emphasizing to all our users the importance of caution with respect to files received as electronic mail attachments. If you need to send an attachment to a colleague at the NRAO, please make sure they are expecting it. Conversely, if you receive an attachment that you did not expect, verify with the sender that it was intentional before opening or reading it.

We remind all members of our user community that, as part of the process of implementing our Computing Security Policy, certain services will be restricted to specified systems at each site. To access these, please use the following aliases:

Service Alias

www - main NRAO pages *www.nrao.edu*
www - 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 network “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.

If you have any questions, comments, or concerns about NRAO computing security, please contact Ruth Milner, Computing Security Manager (*rmilner@nrao.edu*, 505-835-7282).

Networking

Videoconferencing at the NRAO is now used for nearly all inter-site meetings. ISDN support, which will allow external organizations to participate if they have the right equipment, has been installed and is now being tested.

NRAO Socorro, which is located on the campus of the New Mexico Institute of Mining and Technology (NMIMT), will soon benefit from an NSF grant awarded to NMIMT and the University of New Mexico to fund a connection to the Abilene (a.k.a. Internet2) network. Installation is expected to occur over the next few months. The connection from NMIMT to Albuquerque, which the AOC and VLA share, will be upgraded to T3 (45Mbps), roughly fifteen times the current bandwidth. From Albuquerque, Abilene traffic will be transmitted over a 155 Mbps link. General internet access bandwidth, which is likewise shared with other organizations in Albuquerque, will also be increased, though by a much smaller factor. Network access to the AOC, and to a lesser extent the VLA as well, will thus be significantly improved, particularly from institutions which are themselves connected to Abilene or vBNS.

Organization

On May 1, 2000, Observatory-wide Computing was reorganized to renew the NRAO's focus on Data Management issues. See earlier article in this issue, "Data Management at NRAO."

M. R. Milner

GREEN BANK

The Green Bank Telescope

The past quarter has been a very significant one for the GBT. The antenna is now structurally complete and all surface panels have been installed, and we have achieved a number of other important milestones.

One major task, now completed, was to test the actuator cables. The active surface system has 2,209 12-conductor cables that run from each actuator to the central actuator control room. With the COMSAT workers on the actuator end, and a team of NRAO workers in the actuator control room using NRAO-built test gear, each of these cables has now been tested. Some of the cables failed their initial resistance tests because moisture had accumulated in the connectors, despite the protective wrapping that enclosed them. These are being dried and will be retested later.

The Q-Band (40-50 GHz) Receiver, which is the highest frequency GBT receiver built so far, has recently been completed. The receiver consists of four dual-polarization beams (eight receivers), and will ultimately have a chopping tertiary for beam switching. Lab tests of the receiver are giving TRx values of 40-45 K across the band. This receiver has been a collaborative project of the Green Bank and CDL groups and was built in about a year.

We have also finished setting the corners of the surface panels. There are 2,004 surface panels. Below each panel corner is an actuator, which adjusts the four panels whose corners meet at that position. This scheme requires that the four adjacent panel corners be aligned quite precisely. To do this, NRAO staff developed a special tool with electronic readouts and a portable computer interface, and assisted COMSAT personnel with its use. A setting team could routinely measure and adjust a set of panel corners every 12 minutes, and up to three setting teams were at work at any one time.

The laser metrology system utilizes small corner cube retroreflectors that are placed at each set of panel corners. In order to accurately indicate the location of the surface panels, the position of the optical reflection center must be measured with respect to the retroreflector mount. A calibration system was developed by the GBT Metrology Group and the measurements were carried out by the Operations Group. This calibration was a necessary step before the retroreflectors could be mounted on the dish and used with the metrology system.

Setting surface-panel corners on the GBT.

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On April 28, the Metrology Group conducted a complete set of point-to-point measurements using the 12 laser rangefinders mounted on the ground around the periphery of the GBT. In the point-to-point measurements, the laser rangefinders measure the distances to each other to develop a "phase-closure" relationship: this ensures that the metrology system can make self-consistent measurements to the required accuracy. The results of the measurements were very encouraging and indicated that the system is progressing well toward the required 100 micron measurement accuracy.

Several items remain to be done in the weeks to come. The contractor will be commissioning all antenna servo systems and completing many small, miscellaneous jobs. NRAO staff will be outfitting the actuator control room, installing fiber optic cable to the receiver room, and rerouting the road around the outside of the laser metrology monuments. We expect that the contractor's work will be completed by late summer. After the NRAO accepts the antenna from the contractor, we will begin equipment outfitting and commissioning.

M. M. McKinnon, P. R. Jewell

GBT Dedication Ceremony Set

The Green Bank Telescope will be dedicated on August 25, 2000, at the GBT site. The ceremony will recognize the contributions of the hundreds of people who have worked on the project and will set the stage for the GBT's scientific operation. The formal ceremony will begin at 1:00 p.m., with Senator Robert C. Byrd as the keynote speaker. The ceremony will be open to the public and members of the astronomical community are particularly invited to attend.

P. R. Jewell

Interferometer Upgrade Uses GBT "YGOR" System

The operations of the Green Bank 85 Foot Telescopes have been moved to the new Jansky Lab control building. Placing the equipment in one of the new shielded control rooms eliminates concerns about RFI that might affect the GBT, and consolidates all telescope control in the same building.

The old control computer for the Green Bank Interferometer (GBI), a DDP-116, had been in continuous service since 1967, and had become increasingly difficult to maintain. At the time of the move to the new control building we replaced it with a VME chassis containing an MV167 computer, interfaces to the delay and gain control (designed by John Ford), and an A/D for data acquisition. The interferometer is now running under the GBT "YGOR" software system, designed to control, monitor, and coordinate the many hardware and software systems on the GBT.

Telescope 85-3, which operates independently of the other 85 Foot Telescopes and does continuous monitoring of pulsars for D. Backer's group at Berkeley, is now also running under the new YGOR-based software and VME hardware. The operators use a new "CLEO" control screen, similar to the operators' screens designed for the GBT by R. Maddalena and students.

The upgrade of the two-element GBI is still in progress but we expect it to be finished in June.

Since 1996, the GBI has been mainly used to monitor variable Galactic sources – X-ray binaries such as Sco X-1, Cyg X-3, and SS433, and "microquasar" sources such as GRO 1655-40 and GRS 1915+105 – and to follow up X-ray transient events. Daily and more frequent monitoring of some of these objects has given radio observations that can be compared with X-ray and gamma-ray observations from the Compton Gamma Ray Observatory and other satellite observatories.

Over the last four years, the GBI has been funded largely by NASA, with contributions from NRAO, NRL, and USNO. The control system upgrade was funded with the last of the NASA money. New sources of funding will need to be found to keep the GBI running past this year.

F. D. Ghigo

New Public Education Center at Green Bank

For more than a decade, the Green Bank Observatory has had a vigorous public education and outreach program. Tens of thousands of tourists visit the site each year and we run programs for regional students, Chautauqua short courses for college professors, and weekend star parties for boy scouts. Since 1987 we have run a series of professional development institutes, now well-known nationwide, which have given hands-on research experience to more than 750 K-12 science teachers: evaluations have shown that they have enhanced the science education of about 100,000 K-12 students. These and many other activities are carried out under the direction of our Education Officer, Sue Ann Heatherly.

But as these efforts have expanded, the limits of the Green Bank site to accommodate them have become more and more apparent. The building in which the education programs are run was not originally designed for this purpose, and there are often problems with traffic flow and lack of space. Several years ago it became clear that if the Observatory were to increase its education and outreach activities at Green Bank, it would need a separate facility designed expressly for these purposes.

Work on such a facility, a new Green Bank Astronomy Visitor and Education Center, is now under way. The building will house an orientation center for tourists, an auditorium, and a science store. At its heart will be a 4,000-square-foot exhibit space containing interactive displays which will teach about science and astronomy in general, and radio astronomy in particular. There will be a special focus on the GBT, showing real-time displays of incoming data and telescope control information, and highlighting its recent discoveries. There will also be classrooms and dedicated labs for use by student groups. The new building will allow us to operate the tour program year-round, drawing visitors from the nearby ski resort, and will make Green Bank the target of field trips for school districts throughout the region and the state.

An architectural firm has just been selected to design the new building, and it is now considering issues such as the specific location and relationship to other site facilities. It is expected that the new center will have its own entrance and parking lots so that visitor traffic will be separated from site traffic. At the same time, the building will be located in the center of the Observatory so that it will be convenient for NRAO staff who will participate in many of the programs. The current schedule calls for design work to be completed later this year, construction to start in 2001, and the project to be finished by the end of 2002.

F. J. Lockman

ALMA

Three recent meetings of the various components of the ALMA partnership have helped sharpen the project focus. The ALMA Science Advisory Committee (ASAC) has prioritized the scope of the project given the expected funding from the U.S. and European partners; the ALMA Coordinating Committee (ACC) has reviewed the cost, setting in train the process for the partners to commit to that level of funding; and the Joint Receiver Design Group (JRDG) has agreed on a firm concept for the *front-end subsystem* (formerly called “the receiver”).

Over the past six months a concerted effort has gone into developing an auditable cost estimate for the 64 antenna ALMA array. The requirement that the cost be *audited* means that the estimate has to be made *bottom-up*: that is, the cost of constructing all elements of the array, including materials costs, contract effort (where appropriate), staff effort and contingency is tabulated separately for each subsystem or module and then summed to produce the final cost estimate. Clearly such a bottom-up estimate cannot be done reliably until the technical description of each subsystem and module in the array is defined. By March 2000 the ALMA system engineering groups on both sides of the Atlantic had agreed on the ALMA instrumentation block diagram: this is called the *technical baseline* of the project. The two management groups then worked together to cost that baseline. Particular attention had to be paid to the allocation of costs to staff effort. The goal is to make the cost of that effort independent of where the work is actually done, and so the effort had to be fully burdened with benefits costs, indirect charges (i.e., institutional support services), and adequate allowance for vacations, sick leave, and travel.

An equally important input to the costing process is scientific priority. Meetings by the ASAC over the last few months have helped to establish not only requirements for the technical baseline, but also to prioritize capabilities of the array. Combining the highest priority scientific requirements, the cost of the technical baseline and the cost limits sought by the partners, we have defined the scope of ALMA as 64 12-meter antennas with four initial frequency bands (3 mm, 1 mm, 0.85 mm, and 0.45 mm). The cost estimate includes sufficient contingency to allow for technical and schedule risk associated with producing all the array subsystems. As that risk is retired (e.g., firm contracts are placed) the contingency made available will be used to add to the array receivers for the lower priority frequency bands.

The resulting cost estimate of $552 million (year 2000 dollars) was reviewed by the ACC in April. Both the U.S. and the European sides agreed to seek approval from their member institutions or government(s) to support an equal partnership at this cost level. In seeking such approval two questions arise immediately: (1) What is the legal structure of the ALMA observatory and how does my government or institution relate to it?, and (2) How will the construction tasks be divided between the two partners, U.S. and Europe? The ACC has assigned responsibility for answering these questions to two committees: an ad hoc Working Group for the first, and the ALMA Executive Committee for the second.

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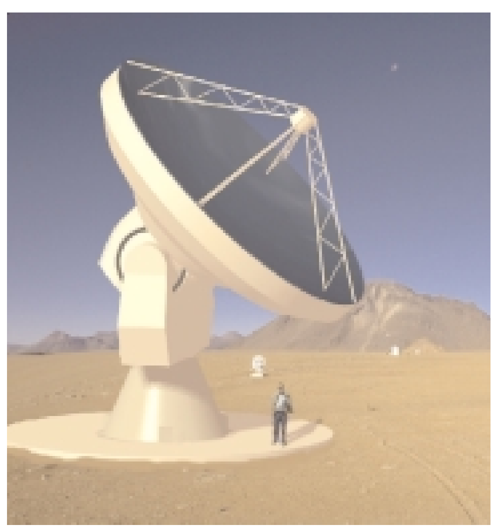


ALMA Prototype Antenna *Engineering concept: Vertex Antenna Systems, LLC*

On the technical side of the project, design of the front-end subsystem has proven to be a particularly challenging task. The designs of all the major modules of the front-end interact with each other. This means that the overall design has to be done with the active involvement of many groups. In particular, the groups doing the design of the frequency inserts (now called *cartridges*), the Rutherford Appleton Laboratory group doing the cryogenic design, and the IRAM group responsible for the optics design, all have to work together at the same pace. Fortunately the JRDG, meeting frequently, has been able to successfully choreograph this work, and we now have a design for the entire front-end subsystem that is nearly ready for its preliminary design review. The JRDG co-chairmen, Wolfgang Wild and John Payne, deserve a lot of credit for bringing it all together.

Technical progress continues at a rapid pace in all areas. For example, the preliminary design review (PDR) of the two prototype antennas will occur in June. This is a major milestone for both. The PDR will focus on the technical approach each contractor is implementing to reach the ALMA performance specifications. The overall progress of the project will be tracked on ALMA's web pages (*http://www.alma.nrao.edu*).

Finally, we are pleased and encouraged to see the strong endorsement given by the decade review committee for expeditious construction of ALMA. As things are progressing now, we will have a good running start on that construction as FY2002 begins.

R. L. Brown

12 METER

12 Meter Telescope to Cease Operation

After nearly 32 years of service to the astronomical community, the 12 Meter Telescope will cease operation as a national millimeter-wave astronomy facility at 17:00 LST (21:08 MST) on Tuesday, July 25, 2000. The remaining NRAO Tucson staff will work exclusively on the ALMA project, focusing on systems, receiver, antenna, site, imaging, and calibration development.

J. G. Mangum

VLA

Q-band (43 GHz) and K-band (22 GHz) at the Very Large Array

The improvement to the VLA at high frequencies is continuing in 2000 with the installation of new receivers at 43 GHz and upgraded receivers at 22 GHz, at the rate of about one per month. (For the latest system status, and details of system performance, see: *http://www.aoc.nrao.edu/~dshepher/highfreq.shtml*.) As of May 20, 19 of the VLA's antennas were equipped with 43 GHz receivers, with system temperatures between 70 and 100 K. Thirteen of the antennas have 22 GHz receivers with system temperatures between 40 to 50 K; the remaining 17 antennas have system temperatures between 100 to 130 K at 22 GHz. We expect to have 43 GHz receivers installed on all 27 antennas by March 2001. The 22 GHz receiver upgrade is scheduled to end by December 2000, at which time 16 antennas will have lower noise receivers. We are currently seeking funds to complete the 22 GHz upgrade. Meanwhile, we are exploring methods for proper data weighting to optimize signal-to-noise (see *http://www.aoc.nrao.edu/~dshepher/K.reduction.shtml*).

In parallel with receiver installation, the antenna performance parameters are being improved through: (i) surface adjustments based on interferometric holographic measurements, and (ii) an upgrade to the encoder electronics to improve short-term (30 min) pointing accuracy. We hope that by the end of 2000 we will have all antennas performing with a nominal aperture efficiency between 30 percent and 40 percent at 43 GHz, and a pointing accuracy (after reference pointing on 30 min timescales) of $10''$ or better.

The atmospheric phase interferometer is being used for decision-making in contingency scheduling for a number of 43 GHz projects that require good phase stability, and for which a parallel program at lower frequency can be found in the same LST range (see *http://www.aoc.nrao.edu/doc/vla/html/PhaseMonitor/phasemon.html*). Two of the new 22 GHz receivers have had three-channel water vapor radiometers incorporated into the receivers, to allow us to study techniques for real-time radiometric phase correction. The two-element interferometer is being used to test the stability of this system, and to determine optimum operating parameters.

C. L. Carilli, D. S. Shepherd, C. J. Chandler

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
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	07 May 2001	1 Oct 2000
CnB	18 May 2001	04 Jun 2001	1 Feb 2001
C	08 Jun 2001	04 Sep 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 degree declination) and extreme northern sources (north of about 80 degree 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 daytime than at nighttime. 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).

To avoid problems, such observations should be deferred for a configuration cycle. In 2001, the B configuration daytime will be about 00^h RA and the C configuration daytime will be about 08^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: these are HALCA space VLBI, the Combined Millimeter VLBI Array, Global astronomical VLBI with the EVN, and geodetic arrays coordinated by GSFC. The scheduling of coordinated observations is dictated by these networks.

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

Summary of Large VLA Proposals in 2000-2001

A panel of non-NRAO astronomers convened in late February to consider observing proposals requesting large amounts of VLA time. After a great deal of hard effort in evaluating the relative merits of work in highly diverse areas of astronomy, the panel laid out a program for the VLA to make substantial progress on large proposals. However, it also recommended substantially less time than the proposers requested. The panel's recommendations were approved by NRAO management at the end of March.

Overall, the panel recommended that about 10 to 20 percent of VLA time should go to large proposals, with no more than 50 percent of the observing time at any LST range for any configuration.

VLA time was recommended by the panel for the following projects:

• AK 509, by Shri Kulkarni, Dale Frail, and collaborators, "Radio afterglows from gamma ray bursts." This is to be scheduled at about 30 hours per month, for an entire configuration cycle, with time scattered through the month

(continued page 10)

so that the team can conveniently attempt to observe new bursts within a few days of the time of the burst. They will also be permitted a limited number of preemptions, for important bursts, with time for the displaced observer to be made up at the end of each configuration.

• AT 245, by Russ Taylor, John Dickey, and collaborators, "A global, high resolution HI survey of the Milky Way." This has been given 260 hours in the D configuration beginning in July, 2000, to cover the plane of the Milky Way from 18 degrees longitude to 67 degrees.

• AB 950, by Bob Becker, Richard White, and David Helfand, "Continuation of the FIRST survey." This has been given 200 hours, centered at 12h LST, in B configuration in both 2001 and 2002.

• AS 687, by Tom Soifer and collaborators, "A deep radio survey of the SIRTF First-look Survey." This has been given 120 hours, centered at 17h LST, in B configuration in both 2001 and 2002.

• AG 592, by Jacqueline van Gorkom and collaborators, "HI survey of clusters in the local universe." This has been given 200 hours in C configuration in 2001 and 160 hours in C configuration in 2002, mostly at night in both cases.

• A proposal, AP 397, by Rick Perley, Jim Condon, and collaborators, "A 4 meter all-sky survey." This survey requested B configuration. Because of both the considerable pressure on this configuration and unsettled issues related to this project, the committee recommended that only exploratory observations (totaling 70 hours) be conducted, in BnA and B configurations in 2001.

These proposals total about 1,330 hours over the next 16 month configuration cycle: this is 11 percent of 16 months or 14 percent of usable observing time.

It is likely that another committee to review large proposals will be convened in June or July 2001.

B. G. Clark

New Mexico Computing Developments

We have continued to increase the number of Linux PCs at the AOC, recently buying five high-end and eight low-end systems. The high-end systems will replace slower machines currently on scientists' desks. The machines freed up, as well as the new low-end systems, will initially be used by our thirteen summer students, and then passed to other users. Purchases such as this are designed to eliminate our dependency on older, obsolete systems.

Our new poster-size color laser printer is now available for general use. To print to this machine you still need some assistance from computer division staff, but we expect this to diminish as we become more familiar with its operation. During the first months, this machine has proved to be very popular with users.

Thanks to a sizable equipment purchase, we were able to start turning our last non-switched subnet into a switched one. This subnet serves our PCs running various flavors of Windows. For the machines connected to this switch, throughput and response time have improved dramatically. All our Unix workstations have been on switched subnets for some time.

G. A. van Moorsel

JObserve

JObserve, the Java-based successor of Observe, has been tested over the last six months by NRAO staff. It allows VLA Observe files to be prepared using a graphical user interface, making it independent of keypad mapping details. It should be portable to a wide variety of architectures.

The next in-house release of observe is scheduled for early June. We expect to release another version of JObserve, for release outside NRAO, in the first half of July. This version will incorporate fixes to problems found in the June release and also will support VLA observing with the Pie Town antenna. For information on the July release, please contact Stephan Witz (*switz@nrao.edu*) or visit *http://observe.nrao.edu/.*

G. A. van Moorsel

"Barry Clark at 60" Symposium Proceedings Available

The volume of proceedings from the 1998 Socorro symposium honoring Barry Clark is now available. Entitled *Radio Interferometry: The Saga and the Science* (editors Finley and Goss), the 334-page book traces the history of radio interferometry through historical reminiscences by many of the pioneers of the technique, and reviews the scientific contributions of the instruments Barry Clark helped develop.

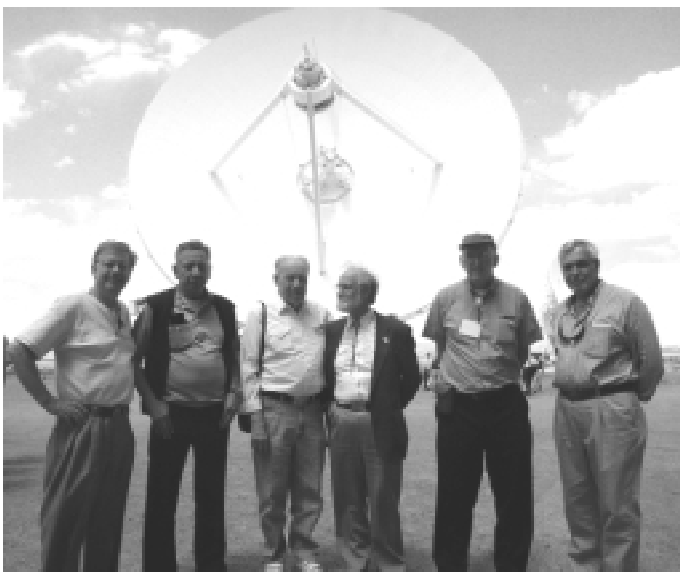
The book contains a wealth of historical information, an outline of the scientific achievements of the Very Large Array and the Very Long Baseline Array, and a look ahead to the future of radio interferometry. It includes sections on: *HI and the Interstellar Medium*; *Development of the Very Large Array*; *Impact of the Very Large Array*; *Development of the Very Long Baseline Array*; *Impact of the Very Long Baseline Array*; and *The Future of Radio Interferometry*.

The book is available for $25 plus shipping from Lori Appel in Socorro (*lappel@nrao.edu*). All orders must be prepaid. For more information, see: *http://www.nrao.edu/pr/barrybook.html*.

D. G. Finley

Gas & Galaxy Evolution Conference

NRAO and New Mexico Tech sponsored and hosted an international meeting on Gas and Galaxy Evolution in Socorro on May 21-24, 2000, celebrating the 20th anniversary of the VLA. The meeting was a great success, with more than 180 participants from 91 institutions in 16 different countries. Topics ranged from high-velocity clouds and “normal” and interacting galaxies to large-scale structure and the implications of Lyman-alpha absorption systems. Apart from listening to more than 70 talks and trying to read more than 80 posters, we held a debate on high-velocity clouds (more observations needed!) and viewed the fabulous Weirdo Wall, devoted to galaxies with strange and unexpected distributions of neutral hydrogen. The conference finished up with everyone going out to the VLA site for a southwestern barbeque and a tour of the VLA. Many thanks to all those whose hard work made this possible, especially Terry Romero, Skip Lagoyda, James Robnett, Tracy Clarke, and Dave Westpfahl!



Two original members of the VLA start-up, Jack Lancaster and Ron Ekers (center), are pictured with Paul Vanden Bout and Jack Campbell (left), Miller Goss and Dick Sramek (right).

The proceedings will be published by the PASP; manuscripts are due at NRAO by **September 1, 2000**. Instructions to authors and other details may be found on the conference web site: *http://www.nrao.edu/vla2000*. If you have any photographs from the meeting, please get in touch with Michael Rupen (*mrupen@nrao.edu*). I’m putting together a bunch of scanned photos on the web, some of which will no doubt wind up in the conference book.

M. P. Rupen

VLBA / VLBI

VLBA 3 mm Upgrade

The VLBA antennas, LO and recording systems, and correlator were designed to support a 3 mm observing band, with an optimal location reserved for 3 mm receivers on the antenna feed ring. Several efforts toward realizing this capability are now under way or will start in the near future. At this wavelength, many of the VLBA subsystems which produce such high-quality data at longer wavelengths have to operate much closer to their design limits. Enhancements will be necessary in many areas to make routine 3 mm observing feasible. We have formed an umbrella VLBA 3 mm Upgrade development group to coordinate, and provide scientific input to, the efforts in these areas by the electronics, engineering services, and operations divisions. This article provides an overview of the developments involved. Future articles will provide further details on specific developments.

Receivers

Four 3 mm (W-band) receivers, covering the 80-90 GHz range, were installed on VLBA antennas between 1996 and 1999, and operated in sessions of the Coordinated Millimeter VLBI Array (CMVA). These systems must now be regarded as prototypes. Each is unique, and there are no spares. They have been difficult to maintain in an operational state, but have thereby called attention to areas requiring redesign. It was possible to field three of the four for the CMVA session in April. We intended to leave these three receivers in place after the April session and this has been possible, with only one minor repair needed to date.

With funds from the Max-Planck-Institut für Radioastronomie in Bonn, Germany, we have begun construction of four additional receivers, with a wider frequency coverage (80-96 GHz). This expansion makes the 3 mm systems more similar in percentage bandwidth to the other VLBA receivers: it will increase the number of methanol maser transitions which can be observed and the redshift range over which CO can be observed in absorption. A new design, incorporating many improvements, is nearly finished. Parts are on order to complete two new systems by the end of 2000, and some parts have been ordered for the next two systems also: these are scheduled for completion by the end of 2001. We hope to eventually complete a ninth receiver, and to retrofit the four original systems.

Antenna Measurements and Adjustments

After considering several alternatives, we have selected a local (i.e., non-VLBI) holography system as the best approach, given the current funding and staffing constraints. This system will observe a 12 GHz geostationary communications satellite beacon and use a special feed optically coincident with the 3 mm feed location. We can

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reposition the holography feed diametrically opposite the 3 mm position on the feed ring, to allow separation of the figures of the main- and sub-reflector. We plan to build the system at very low cost, using as much as possible of each VLBA station's equipment. The few additional components will be chosen and designed to allow the entire system to be moved between the VLBA stations. Many of these parts are already on order.

At least some subreflectors are likely to need machining or other surface adjustments, and in the next quarter we will look at techniques for mechanical measurement and machining.

Pointing Techniques

Several specialized techniques to provide the accurate pointing required in the 3 mm observing band are currently operational or expected to become so in the near future. Reference pointing has been available for some time. Inclusion of the azimuth track profile in the pointing equation, and improved control of the focus/rotation mount rotational positioning, are now both ready for operational testing.

This summer we will start to characterize suspected errors in the azimuth and elevation encoders. If these are similar to the known encoder errors in the VLA antennas, the same fix currently being implemented on the VLA will be tried on the VLBA antenna encoders.

Wideband Recording Capabilities

With low correlated flux at the highest spatial resolution, and relatively high receiver and sky temperatures, sensitivity is at a premium in the 3 mm band. Continuum sensitivity will be enhanced by completion of the VLBA recording system's long-planned 512 Mbps, dual-recorder capability. Recent tests using the four VLBA stations currently outfitted were completely successful at recording and correlation in one of the three possible modes. A recent test of three sets of new formatter modules is awaiting analysis. The 512 Mbps capability should be available on the VLBA by early 2001. Policies regarding its use will be announced later.

The VLBA recorder group recently reached a milestone, completing its report on hardware requirements for the 1 Gbps recording upgrade study funded by NASA. The final report, which will include software requirements and operational considerations, is planned for late summer.

Further information on any of these developments may be obtained by contacting J. D. Romney, V. Dhawan or R. C. Walker.

J. D. Romney

New VLBA Documentation

Two new scientific memos have been produced to help VLBA users. "A Step-by-Step Recipe for VLBA Data Calibration in AIPS," by Jim Ulvestad, provides a simple supplement to the more comprehensive description included in the AIPS Cookbook. It leads the users through a step-by-step procedure for straightforward VLBA observations, including continuum strong-source or phase-referenced observations as well as simple spectral-line observations. The recipe described in the document has been tested by several experienced and novice users, and has been revised many times. The second document, "Strategies for Phase Referencing with the VLBA," by Wrobel, Walker, Benson, and Beasley, describes strategies for the proposal, observation, and correlation stages. Simple data-reduction is described in the recipe for data calibration.

Both of these documents are available on the VLBA web site, in the Scientific Memos series at *http://www.aoc.nrao.edu/vlba/html/MEMOS/scimemos.html*. If you have questions or comments, or would like further information about these two memos, contact Jim Ulvestad (for calibration) or Joan Wrobel (for phase-referencing).

J. S. Ulvestad, J. M. Wrobel

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
13 Sep to 04 Oct 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 coversheet 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 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 Networks Schedulers on or before the proposal deadline date: allow sufficient time for mailing. Faxed submissions of Global proposals will not usually be accepted.

EVN-only observations unsuitable for the Bonn correlator will be processed by the Socorro correlator until such time as they can be processed with the

JIVE correlator. Other proposals (not in EVN sessions) that request the use of the Socorro correlator must be sent to NRAO, even if they do not request the use of NRAO antennas. Similarly, proposals that request the use of the 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 dem 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

NEW RESULTS

Editor's Note:

On May 21-24 of this year, NRAO and New Mexico Tech sponsored a conference on "Gas & Galaxy Evolution: A conference in Honor of the 20th Anniversary of the VLA." The following four science articles describe some of the exciting results which were presented at that meeting.

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

HI Imaging of Low-z QSO Host Galaxies

What *is* the nature of QSO host galaxies? Since their discovery in the early 1960s, the continual improvement of ground-based optical-imaging technology has permitted the detection of "fuzz" at ever improving clarity around an increasing number of QSOs at progressively higher redshifts. (At the same time, the optical luminosity required by bright galactic nuclei to qualify as QSOs – rather than *just* AGNs – has also gone up!) These observations reveal that a fraction of QSOs reside in morphologically peculiar galaxies, at least some of which can be seen to be interacting with other galaxies. Such tidal interactions are among the mechanisms most favored by theoretical models for driving gas from the interstellar medium into the galactic center, thus providing fuel for the central supermassive black hole.

The Hubble Space Telescope, freed from the blurring effects of the Earth's atmosphere, has been used to image a small sample of QSOs at moderately low redshifts ($0.1 \lesssim z \lesssim 0.5$) with greatly improved clarity (Bahcall et al. 1997; Boyce et al. 1998). These observations reveal that some, but not all, QSOs lie in interacting systems (6/34). The remainder, by contrast, appear to be morphologically normal, although a large fraction (21/34) appear to have companion galaxies lying close in projection to the QSOs (within $\lesssim 25$ kpc, but with no redshift measurements). Overall, these observations suggest that QSOs reside in a broad range of environments, from apparently undisturbed host galaxies lying in relative isolation to strongly disturbed host galaxies lying in violently interacting systems.

Are optical images of QSO host galaxies deceptive? Observations in the 21 cm line of atomic hydrogen (HI) gas can reveal disturbances in galaxies not easily detectable or at all visible in optical starlight. An outstanding example is the M81 group of galaxies: by contrast with optical images, which reveal no apparent interactions between group members, the HI image taken by Yun et al. (1994) shows dramatic evidence for extensive tidal interactions in the form of streamers connecting three prominent members of the group. To study the gas distribution and kinematics in QSO host galaxies, we are conducting an ongoing program to image in HI all 23 QSOs in the catalog of Veron-Cetty & Veron (1998) with redshifts $z < 0.07$ visible from the VLA (i.e., with $\delta > -40$ deg). Only one of the QSOs in our sample is radio loud, reflecting the much greater fraction of radio-quiet QSOs in an optically-selected sample.

We have so far analyzed data for 12 objects, and have detected HI from seven QSO host galaxies (for an earlier study of three of the objects, see Lim & Ho 1999). Examples of our results for five of the objects are illustrated in the accompanying figure, which shows the integrated

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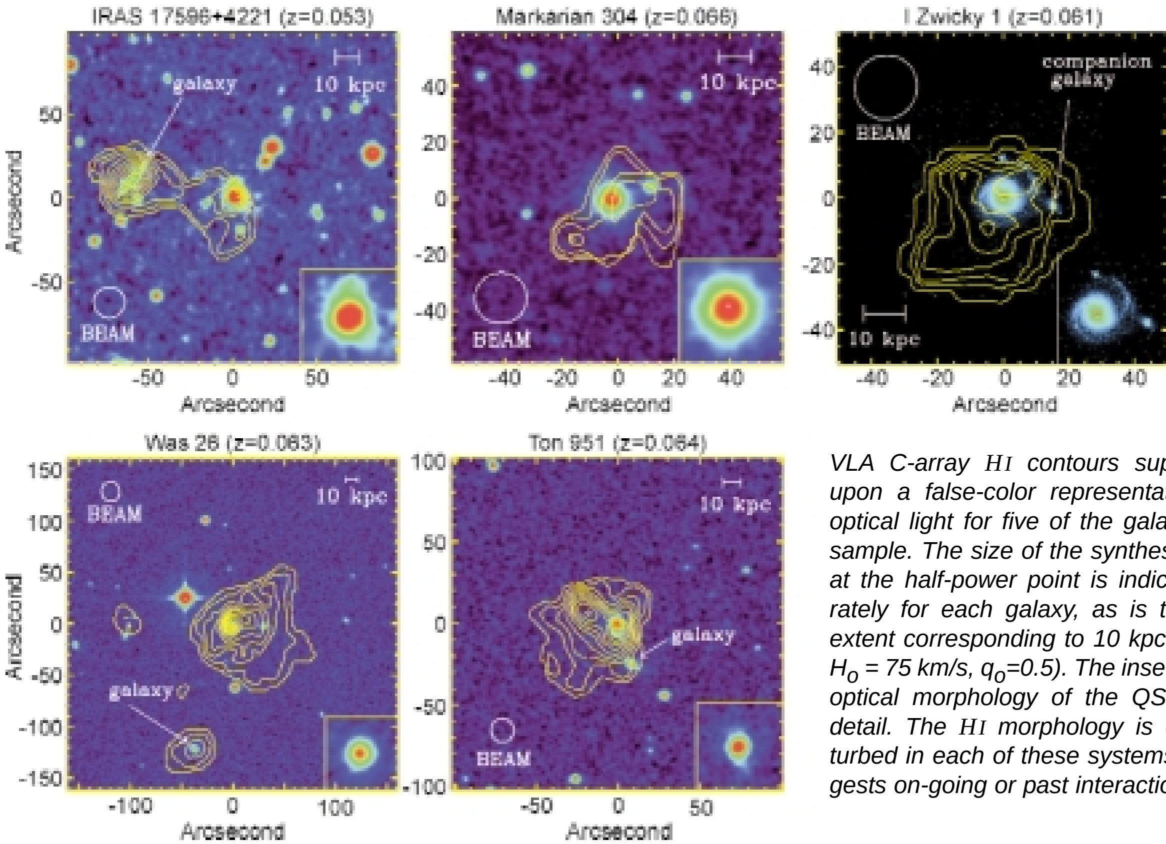

VLA C-array HI contours superimposed upon a false-color representation of the optical light for five of the galaxies in our sample. The size of the synthesized beam at the half-power point is indicated separately for each galaxy, as is the angular extent corresponding to 10 kpc (assuming H_o = 75 km/s, q_o=0.5). The inset shows the optical morphology of the QSO in more detail. The HI morphology is clearly disturbed in each of these systems, and suggests on-going or past interactions.

HI emission in contours superposed on false-color optical images. In all cases our HI images reveal dramatic evidence for large-scale disturbances in the gas distribution, and sometimes also the gas kinematics (not shown), even when no such disturbances are readily, if at all, apparent in the optical. The interacting companion galaxy responsible for the tidal disturbances can be unambiguously identified in some of our HI images, although in other cases observations at higher angular resolutions are required to definitively confirm the culprit involved (but which is likely to be the optical galaxy indicated in the images). There is only one example of a featureless spheroidal host galaxy which has no apparent interacting companion galaxies seen either in the optical or in HI (Mrk 304). The tidal morphology of the HI shown (see figure) suggests that this is likely to be a merger remnant. In one case (not shown), we detect only the companion galaxy of the QSO in HI, and it shows HI tidal features.

The HI gas masses of the detected QSO host galaxies range from about 10^9 $M_\odot$ to 10^{10} $M_\odot$, whereas those not detected have HI gas masses less than about 10^9 $M_\odot$. These gas masses are not dissimilar to the range exhibited by ordinary field galaxies; e.g., our Galaxy has an HI gas mass of 3-5x10^9 $M_\odot$. Thus, QSO host galaxies at low redshifts do not appear to be particularly HI gas-rich; indeed, our HI images reveal that QSOs need not necessarily reside in the more HI gas-rich of two interacting galaxies. These results suggest that the nature of the interaction, and not just the nature of the QSO host galaxy, is an important factor in determining which galaxy in an interacting pair hosts a QSO; i.e., presumably the galaxy in which copious gas is forced into the center to fuel the central supermassive black hole. Among the HI-detected objects (8/12), the projected separation between the QSO and its (optically identified) interacting companion galaxy ranges from 10-100 kpc, with only one example of a complete merger. These results are not consistent with the picture in which QSOs are born during the late phase of an interaction when the two interacting galaxies have largely merged (Sander et al. 1988), at least not for many of the optically-selected QSOs in our sample. Rather, these QSOs appear to reside in a broad range of interacting environments.

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P. T. P. Ho, Smithsonian Astrophysical Observatory, USA
C. Hua-Ting, National Taiwan University, Taiwan
W. Shyang, National Taiwan University, Taiwan
L. Wen-Shuo, National Taiwan University, Taiwan

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The HI Halo of the Spiral Galaxy NGC 2403

Halo components of both ionized and neutral gas extending to large distances (several kpc) from the plane of the disk have been observed in edge-on galaxies (c.f. Hoopes et al. 1999, Swaters et al. 1997). Vertical motions, sometimes associated with superbubbles in the disk, have been observed in face-on galaxies (e.g., Kamphuis et al. 1991). These observations indicate in- and outflows of gas in spiral galaxies, which are either part of the "internal" disk-halo circulation or the result of interactions and exchange with the environment.

To date, these studies of the disk-halo connection have been carried out in galaxies with extreme inclinations – edge-on or nearly face-on – with the obvious limitation that the former only give information on the vertical gas distribution, while the latter only on the vertical velocity component. However, both types of information are obtainable in a galaxy of intermediate inclination, and, in principle, in such a galaxy the 3-D gas distribution and kinematics can be studied.

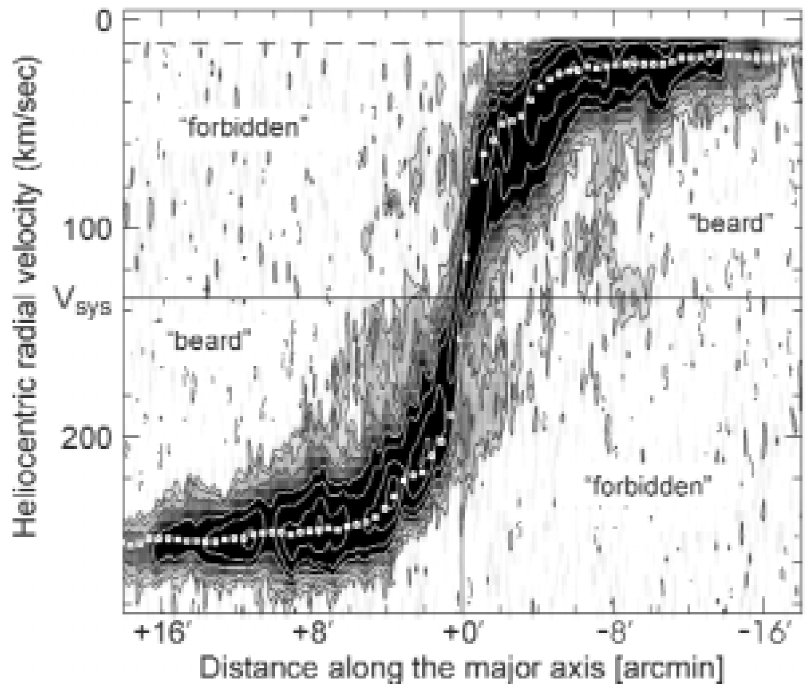

Figure 1: Position-velocity diagram along the major axis of NGC 2403, showing the extended "beard" towards the systemic velocity, and apparent counter-rotating gas in the "forbidden" quadrants of this diagram.

The late-type spiral galaxy NGC 2403, with an inclination of about 60 degrees, appears to be an ideal case for such a study. This galaxy hosts very rich HII regions and HI observations show a disk exceptionally filled with holes and expanding supershells. At larger scales, the HI data (Schaap et al. 2000) show kinematical features which indicate the presence of halo gas rotating more slowly than the gas in the disk.

Recently, we have obtained deeper HI observations of NGC 2403 with the VLA (48 hrs integration, C array) that reveal new, unexpected features. These data show, much more clearly than the data of Schaap et al. 2000, that the velocity profiles have systematic and very extended tails towards the systemic velocity (the so-called "beard"; see Figure 1), confirming the HI halo. Furthermore, they show new features in the "forbidden" quadrants of position-velocity diagrams, which indicate peculiar, but well-organized, non-circular motions.

We have calculated a series of full 3-D models in order to investigate the nature of this HI gas. From these models it is clear that a single thick disk, an outer flare or a line-of-sight warp can be excluded by the data and that a two-component structure is needed. One model that gives a good description of the kinematics of the beard is one with an extended HI halo in which the gas has slower rotation and where there are large-scale inward radial motions of about 20 km/s (Figure 2). Such small radial inflow does not

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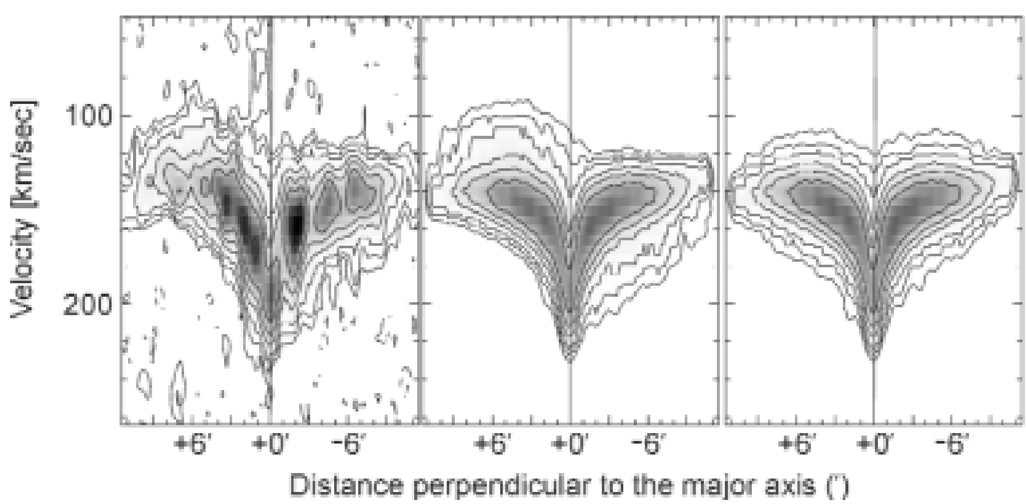

Figure 2: (left:) Position velocity map parallel to the minor axis, taken slightly offset to the west from the center of NGC 2403. The faint gas shows a marked asymmetry in the kinematics that is well modeled by an extended HI halo that rotates somewhat slower and that shows large-scale radial inward motions (center panel). The counter-rotating gas is not explained by such a model. For comparison, a standard circularly rotating disk, with no radial motions, is shown in the right panel.

explain, however, the peculiar, forbidden velocities in the inner parts, which may imply vertical motions of more than 100 km/s, or that the kinematical center of gas at large distances from the plane is somewhat shifted, causing apparent counter rotation.

The large-scale pattern shown by the anomalous HI (including the "forbidden" HI) seems to point to one phenomenon and one common origin. There is an evident analogy with some of the HVCs observed in our galaxy. Possibilities are: 1) a galactic fountain: the HI traces the final phase of the inflow of the fountain. 2) a general inflow and accretion of extragalactic gas, or 3) a mis-aligned halo: the observed pattern can also be reproduced by a misalignment of the rotation axes of the halo and of the disk. This might be related to the observed outer warp in NGC 2403.

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R. Sancisi, Astronomical Observatory of Bologna, and Kapteyn Institute, Groningen
G. van Moorsel, NRAO, Socorro

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A VLA Blind HI Survey of the Ursa Major Cluster

Motivation

The slope of the HI mass function (HIMF) at the low mass end is a much debated topic. It is related to the distribution of primordial density fluctuations and it constrains galaxy formation scenarios. If a large undiscovered population of HI rich dwarf galaxies does exist, it may contain a non-negligible fraction of the baryon content of the universe and provide fuel for the star formation process in more massive disk galaxies through their capture, infall and accretion. Furthermore, the slope of the HIMF ties in directly with the recently launched hypothesis that the High Velocity Clouds (HVCs), apparently associated with the Milky Way, might actually be of an intergalactic nature, being the primordial remnants of the formation of the Local Group (Blitz et al. 1999).

Despite its importance, the slope of the HIMF at the low-mass end has not been measured with any accuracy down to HI masses of 10^7 $M_\odot$. In general, the statistics in the 10^7 - 10^8 $M_\odot$ mass range is too poor, with typically one or two galaxies in the lowest HI mass bin. The Arecibo HI Strip Survey (AHISS) of Zwaan et al. (1997) indicates a slope in the range 1.1-1.3 with two galaxies in the last mass bin. From a deep Arecibo Slice Survey combined with AHISS data, Schneider et al. (1998) claimed a sharp steepening of the HIMF below 10^8 $M_\odot$, again with only two galaxies in the last mass bin. At recent meetings in Guanajuato and Socorro, a slope of 1.3 was reported from the Australian HIPASS survey by Staveley-Smith, and a slope as steep as 1.7 was suggested by Schneider et al., from the new Arecibo Dual-Beam Survey (ADBS). It should be noted that the volume corrections of all these blind HI surveys are severly hampered by uncertain corrections for the large scale structure in the universe. These corrections should account for the fact that we are located in a local overdensity and that dwarf galaxies are more easily detected nearby than in the distant universe, introducing a bias toward a steeper slope.

The sensitivity of the VLA in its D configuration in combination with the overdensity of the nearby spiral rich Ursa Major cluster can provide sufficient detections per HI mass-bin down to 10^7 $M_\odot$ to reliably measure the slope of the HI mass function at the low-mass end. Furthermore, all galaxies in the UMa volume are at the same distance, eliminating the effects of large scale structure along the depth of the survey. The VLA would also be sensitive enough to detect the UMa equivalent of the Local Group population of intergalactic HVCs with typical HI masses of a few times 10^7 $M_\odot$, as initially suggested by Blitz et al. (1999).

The Ursa Major Cluster

The Ursa Major cluster is a gravitationally bound overdensity located in the supergalactic plane at a distance of 18 Mpc. However, it contains no ellipticals, just a dozen S0's and has a velocity dispersion of only 150 km/s (Tully et al. 1996). Its morphological mix is similar to lower density field regions. If the slope of the HIMF would indeed be as steep as 1.7, there would be about 2900 HI objects in the Ursa Major volume, based on the high-mass end of the HIMF of the 80 known cluster members.

The VLA blind HI survey

In collaboration with Martin Zwaan, Brent Tully and Neil Trentham, it was decided to design a VLA blind HI survey of the Ursa Major cluster and image all the VLA fields in the R-band with the CFHT wide-field camera. The optical campaign was aimed at measuring the faint end of the Luminosity Function (LF) and will provide optical morphologies and luminosities of the HI detected dwarfs. In return, the HI detections provide redshifts for the optically selected cluster candidates.

A cross-pattern of 22x32 pointings was observed, with pointing centers separated by a primary beam FWHM (Figure 1). The low velocity dispersion of the cluster allows for a 3.125 MHz bandwidth to cover the entire velocity range with 10 km/s resolution after Hanning smoothing. The rms noise of 0.79 mJy/beam corresponds to a minimum detectable HI mass of $5x10^6$ $M_\odot$ at 6-sigma. The data were flagged and calibrated in AIPS, mosaiced and cleaned in MIRIAD and further analyzed in GIPSY. Within the imaged areas about 16 percent of the cluster volume was sampled. Currently, the full North-South and half of the East-West strip has been processed.

Results

In total 32 galaxies were found by applying a 6-sigma clip on the channel maps, and all of them have an optical counterpart in the CFHT images. Only 13 new dwarfs were discovered. The volume corrected HIMF in UMa is plotted in Figure 2, where the last mass bin includes four galaxies. The low-mass end of the mass function is flat, and highly inconsistent with a slope of 1.7, as shown by the dashed line. The green histogram shows the previously known optically selected, non-volume corrected UMa HIMF, to which the VLA HIMF was normalized at the high mass end. In accordance with the HIMF, the LF is also flat down to an absolute R-band magnitude of -11. The blue histogram shows the expected distribution of HI masses of the population of Local Group HVCs, under the assumptions that they are indeed of an intergalactic nature and virialized with a dark matter fraction of 95 percent, and that UMa has the same space density of HVCs as the Local Group, for which a volume of 15 Mpc^3 was adopted. The yellow histogram shows the expected distribution of HI masses of the recently identified population of compact HVCs (Braun and Burton, 1999) in the case that they are located in the Local Group at a common distance of 650 kpc (again assuming a similar space density as in the Local Group).

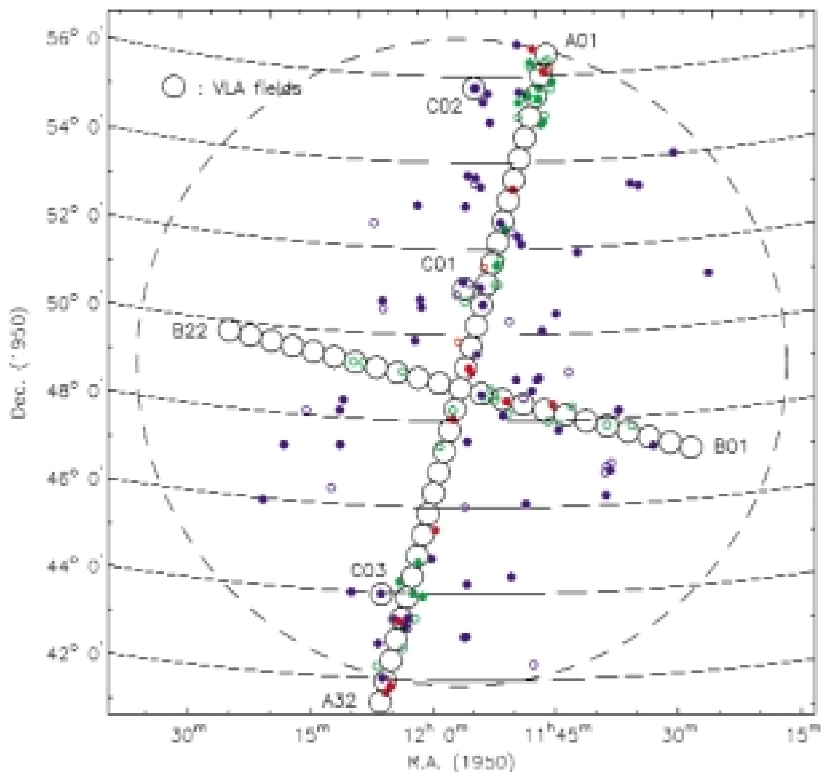

Figure 1: Layout of the VLA pointings on the sky. The dashed circle indicates the defined area of the UMa cluster. Blue symbols: Previously known cluster members (open: intrinsically fainter than the SMC). Red symbols: Newly discovered HI dwarfs (open: just outside predefined cluster volume). Green symbols: Optically selected cluster member candidates (open: likely background objects).

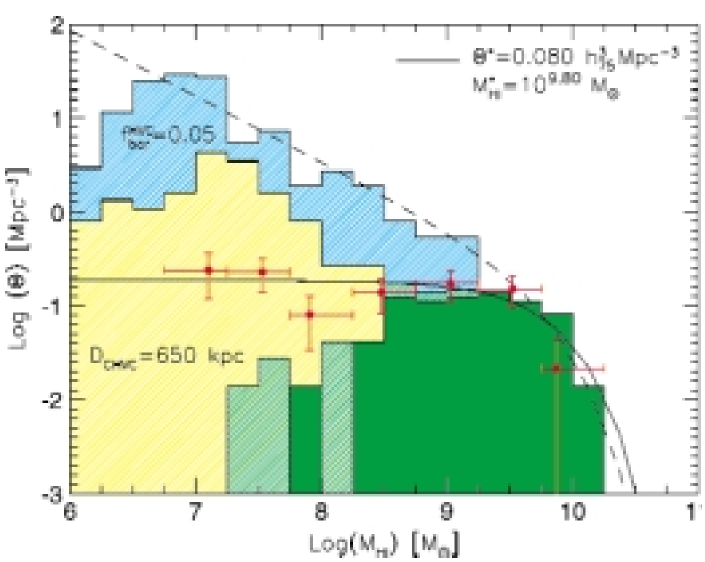

Figure 2: The newly measured HI mass function in UMa is plotted with red symbols. The horizontal errorbars show the bin widths while the vertical errorbars indicate the Poisson noise. The flat HIMF rules out a significant population of intergalactic High Velocity Clouds in UMa.

In conclusion, the HI mass function in the Ursa Major cluster is flat down to HI masses of 10^7 $M_\odot$. No free-floating HI clouds were detected, nor were extragalactic analogs of the hypothesized Local Group intergalactic High Velocity Clouds.

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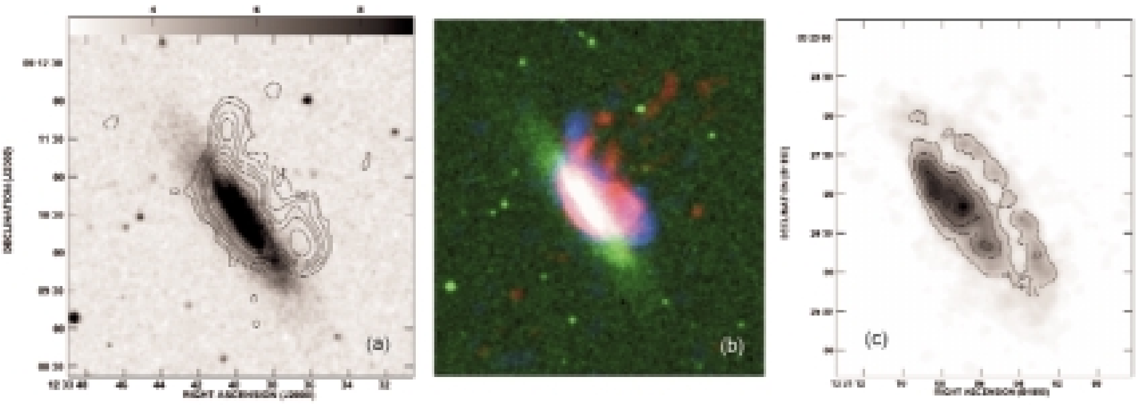
Ram Pressure Stripping of the Virgo cluster spiral NGC 4522: Model Prediction versus Observations

Since Gunn and Gott (1972) introduced the concept of ram pressure stripping, which can affect galaxies moving inside an intracluster medium, this mechanism has been invoked to explain the observed HI deficiency of spiral galaxies in clusters (Chamaraux et al. 1980, Giovanelli & Haynes 1985). Nevertheless, it has not yet been unambiguously shown that ram pressure stripping is responsible

(continued page 18)

Figure 1



for the HI distribution and kinematics of any particular spiral galaxy. The possibility of a tidal interaction producing the distortion has never been completely ruled out. The best place to study the gas removal due to ram pressure is the Virgo cluster as it is the closest cluster which can be observed in great detail. Most of the spiral galaxies seem to have entered the cluster only recently (within several Gyr, Tully & Shaya 1984). About half of them are HI deficient (Giovanelli & Haynes 1985), and their HI disk sizes are considerably reduced (van Gorkom & Kotanyi 1985, Warmels 1988, Cayatte et al. 1990, 1994).

Kenney & Koopmann (1999) made optical broadband and Hα images of the Virgo cluster spiral galaxy NGC 4522 which is located at a distance of ~1 Mpc from the Virgo cluster center. These authors find a considerable part of the Hα emission arising from extraplanar H II regions, whereas the stellar disk is not disturbed. They suggest that the atomic gas of NGC 4522 is being stripped by the gas pressure of the hot intracluster medium.

Recent VLA maps in HI and radio continuum from the CS configuration confirm active stripping of gas in NGC 4522 (Kenney, van Gorkom, & Vollmer, 2000, in prep). The HI emission is shown contoured upon an optical map in Figure 1a. One third of the total HI emission lies above the plane of the stellar disk, with distances as large as $1'$=5 kpc above the disk. Figure 1b shows a color coded image of stars in white and green, the HI emission in blue, and the radio continuum emission in red. Extensive radio continuum emission lies in filaments which are as long as 15 kpc, and clearly suggest relative motion of the galaxy through the intracluster medium. The radio continuum emission lies inside the HI emission, suggesting a hot low density core in the wake of the galaxy.

Some features of the HI and Hα observations can be understood with the help of N-body simulations of a gas-rich spiral galaxy falling into the Virgo cluster (Vollmer et al. 2000). In order to take into account the clumpiness of the interstellar medium (ISM), we use a sticky particle model in which each particle represents a cloud complex with an assigned mass-dependent radius. The viscosity of the clumpy ISM is due to inelastic collisions between the particles. The effect of ram pressure is modeled as an additional acceleration applied to the particles located at the front side of the galaxy motion.

In Figure 1c we show the predicted HI distribution of a spiral galaxy which passed through the cluster core ~650 Myr ago, viewed at the same inclination and position angle as NGC 4522. At that moment, the gas, which has not been accelerated to the escape velocity during the stripping process, falls back onto the galaxy, i.e., it is in the phase of re-accretion. The re-accreting gas hits the ISM in the disk, forming an expanding gas ring. The model HI distribution is similar to the observed HI emission distribution. In particular, the secondary HI peak in the extraplanar emission suggests an edge-on ring. A preliminary comparison of the model velocity field with the observed one is very encouraging. According to the simulations, NGC 4522 may have passed through the dense core of the cluster Virgo ~600 Myr ago.

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