# NRAO Newsletter

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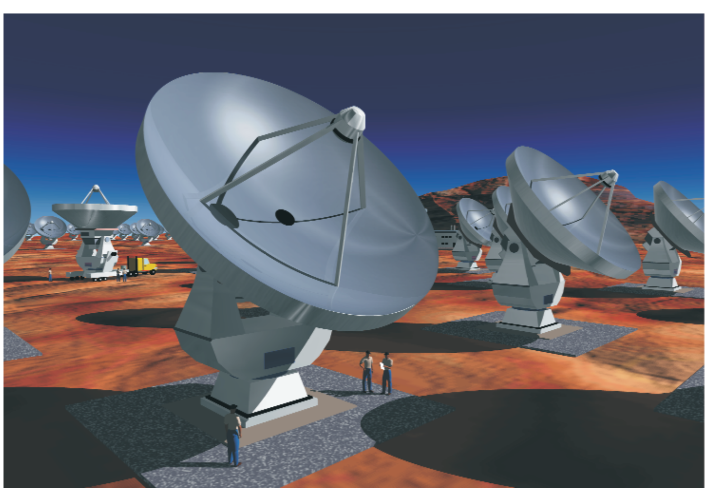
## ALMA

The summer months have seen a great deal of activity and significant progress in the ALMA Project. Authorization for construction of the array was granted by the National Science Board and the ESO Council, an interim Joint ALMA Office (JAO) has been established and is functioning effectively, having already produced a revised Project Plan. Nearly final drafts of the "defining" documents for the ALMA project partnership are being reviewed by the ALMA partners, and negotiations with the government of Chile for AUI and ESO to build and operate ALMA on Chajnantor are nearing completion. This year the phrase "lazy days of summer" certainly did not apply to ALMA!

The real watershed events for the project were the approvals from NSF and ESO. In July, the ESO Council voted unanimously to include in the ESO Long Range Plan funding for construction and operation of a new observatory, ALMA, to be done in equal partnership with North America. Construction funding for ALMA begins in calendar year 2003 in the ESO plan. A month later, in August, the U.S. National Science Board voted to authorize the NSF to spend the funds needed for all nine years of ALMA construction. The NSB authorization was made specifically for the U.S. commitment to ALMA as an international partnership. Barring unforseen events, these approvals should provide us with considerable confidence that ALMA will become a reality. Now our task is to assure that ALMA achieves the ambitious scientific and technical goals that have been set for it.

The ALMA Coordinating Committee (ACC) has been refining the articles of the "Bilateral ALMA Agreement" which is the foundation document for the project. The agreement sets up the ALMA Board as the governing body for the project and defines an advisory committee structure, and establishes the Joint ALMA Office as the central project management to assure that the tasks assigned to the European and North American Executive are carried out as planned. It also defines the composition and reporting structure of the JAO and defines the responsibilities of the partners and the benefits that will accrue to the partners. The process of drafting the Bilateral ALMA Agreement has led the ACC to deal with some challenging issues, and to assess many competing options. The process is complicated because ALMA, as an international research partnership of equals, has no close parallel to draw on, and the organizational structure had to be thought through from scratch. Fortunately, the process has gone well, and we expect the Agreement to be ready for signature by the end of this year.



*ESO artist concept of ALMA.*

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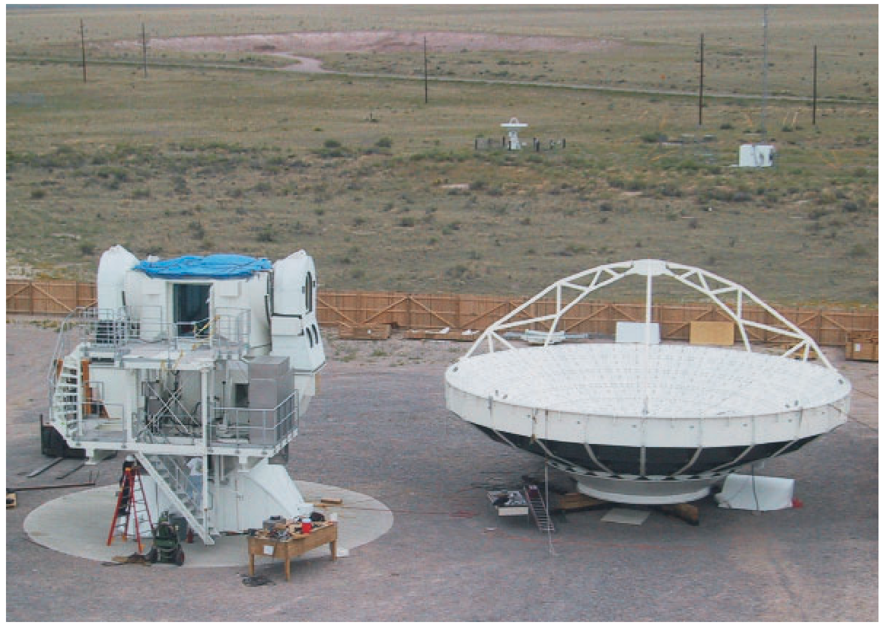
As noted in the July NRAO Newsletter, an interim JAO was established by the ACC as a way of continuing the project momentum until the time that the Agreement was signed and a permanent JAO could be put in place. The interim JAO, with Paul Vanden Bout as Director, Massimo Tarenghi as Project Manager, and Stephane Guilloteau as Project Scientist, has completed the Project Plan with the intention of submitting it to the ACC for approval in the fourth quarter of this year. The Project Plan includes the project Work Breakdown Structure (WBS), a division of tasks between the two Executives and a "value" for each task, a schedule of deliverables, and the management plan for the project. Meanwhile, recruitment for the permanent JAO staff is actively progressing.



*Major components of the Vertex RSI antenna assembled at the ATF as of August 28, 2002.*

The ACC, through its Chile Negotiating Team, has met several times over the past three months with officials of the Republic of Chile in an attempt to reach agreement on the legal structure of ALMA operations in Chile and to establish an appropriate legal instrument that will permit AUI and ESO to make use of specific pieces of land for ALMA, for the ALMA Operations Support Facility, and for the road connecting these two. All of the land is owned and administered by the Republic of Chile. The government of Chile, the Chilean astronomical community, and local officials in the vicinity of the Chajnantor site have all been extremely supportive of the ALMA project. They appreciate the potential of the project and have worked closely with us to see that ALMA is executed in such a way that its benefits are made available to them and their constituencies so as to be in harmony with their existing interests. Again, the entire process is expected to converge and the appropriate documents to be signed by the end of this year.

In summary, the ALMA Project is organized, its scope and goals are defined, and it has appropriate funding commitments. It is a time of great expectation. Stay tuned.

*R. L. Brown*

## Antenna Erection Continues at the ALMA Test Facility

Assembly of the VertexRSI antenna continues to make solid progress at the ALMA Test Facility (ATF) located on the VLA site. In the photograph above, the two major antenna structures can be seen erected at the ATF site. The pedestal, yoke and receiver cabin can are mounted on the concrete antenna foundation. The structure on the right is the carbon-fiber reinforced plastic (CFRP) backup structure (BUS) with feed legs that are mounted on a 6 meter diameter invar cone. Over the next month both parts will be integrated into a full antenna. Progress has been delayed due to the late delivery of the reflector panels.

The first set of machined aluminum panels is expected to arrive on-site in early September. Over several weeks, the 264 panels will be installed on the BUS, aligned, and set to better than 100 microns rms. Once this process is completed, the lightning protection will be installed along with the BUS insulation and cladding. The BUS reflector structure will then be installed on top of the receiver cabin.

The mount and receiver cabin structure are in the process of being outfitted with electrical and mechanical furnishings. The power distribution, UPS and servo cabinet are installed with other electrical furnishing in progress. The main components of the HVAC system have been installed. The mount insulation and cladding are installed on the pedestal cone and yoke arms. Over the next several weeks the complete mount insulation and cladding will be installed. VertexRSI will ship the Antenna Control Unit (AUC) and Pointing Computer (PTC) to the ALMA computing division for preliminary evaluation and testing before it is installed on the antenna.

ALMA equipment will be installed on the antenna in conjunction with VertexRSI in order to recover some of the schedule delays. This will include the optical pointing telescope, cabling, equipment racks, high pressure helium lines and the helium compressor for the cooled front ends along with other testing planned by the Antenna Evaluation Group.

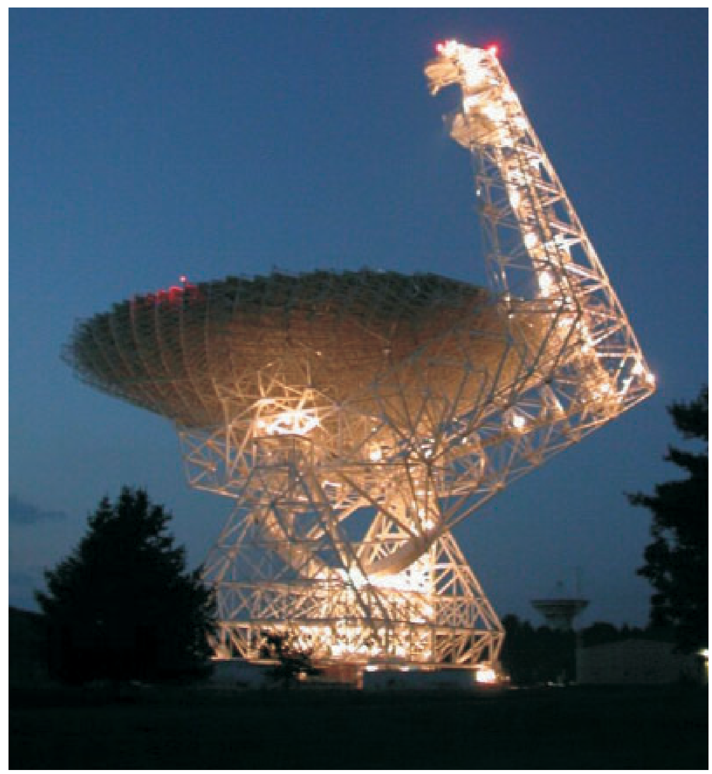
The VLA site staff, working with ALMA staff, have been instrumental in providing support for the ATF. Rigging and crane support is being provided throughout the erection of the antennas. Routine safety visits along with weekly meetings with the contractor have helped to ensure a safe work environment for all involved. RFI and EMI emissions by the ATF site and Contractor have been carefully controlled and monitored in order to preserve good observing conditions at the VLA site.

In October, the antenna should be ready for commissioning and acceptance testing. Once ALMA accepts the antenna from VertexRSI, it will undergo final outfitting with ALMA hardware, the holography system, the radiometry receiver system and other metrology systems. The Antenna Evaluation Group, an international team of scientists and engineers, will then begin assessing the performance of the antenna to verify that it meets all of ALMA's requirements.

*J. S. Kingsley*

# GREEN BANK

## The Green Bank Telescope



The transition from commissioning to regular operations continues at the GBT. Over the past few months, the staff has focused on system refinements and program checkouts, in parallel with scientific observations. During the summer, about 30 percent of total time went to scheduled observing programs, and the remainder was divided between commissioning activities and maintenance. We expect the fraction of time for observations to increase throughout the autumn and that the GBT will be approaching full operational status by the end of the year.

Early science observations with the GBT continue to yield significant new results. The benefits afforded by the unblocked aperture, high surface brightness sensitivity, and comparatively high angular resolution are leading to new discoveries in Galactic structure from HI observations. Pulsar projects, VLBI, and planetary radar observations in conjunction with Arecibo and Goldstone are proving highly productive. Projects involving OH megamasers and high redshift HI are also underway.

Initial commissioning tests revealed a number of areas needing refinements or further development, including software systems, Spectrometer mode implementation and checkout, radio frequency interference suppression, and spectral baseline investigations. The staff has made progress in all these areas over the summer. The software group identified a number of areas in which performance enhancements were needed, conducted root cause analyses for each of these, then set development priorities. The group has improved performance in local oscillator control and Spectrometer functionality. They have also designed a mechanism to simplify configuration of the telescope prior to an observation. The first release phase for the new functionality is expected in late September. The GBT Spectrometer has a very large number of modes that required testing. Most modes are now operational and have had initial engineering verification. They are now undergoing astronomical checkout. Initial observations with the GBT in the lower frequency ranges (1.5 GHz and below) revealed considerable RFI. A significant amount of this RFI was traced to systems on the GBT itself or other sources on site. A concerted effort is underway to identify and eliminate this RFI, and improvements are now evident. The most substantial program has been to filter the cables from the feedarm servo system. This project should be completed by the end of September. Improvements in the shielding of the GBT control and equipment rooms in the Jansky Lab are also underway. Spectral baseline curvature has been found in several of the receivers in initial observations. A systematic program to identify the source of the baseline shapes is also underway.

The GBT's azimuth track continues to present problems. As has been chronicled in past NRAO Newsletters, there has been a succession of difficulties with the track from the outset of operations. Some of these problems have been resolved, and some are on-going. Around the beginning of this year, indications appeared of deterioration of the grout that supports the steel track on top of the concrete ringwall. In March, a slight tilting of the azimuth wheels was detected as they passed over the joints between track segments. During the summer, this problem was traced to fretting wear on the interior, mating surfaces of the upper wear plates and lower base plates of the track. This is a significant problem that will progress in severity, and thus requires a remedy. The GBT antenna engineers are actively investigating various approaches to these problems including installation of robust anti-fretting and shimming materials, strengthening the joints by welding the base plates, and longer-term remedies that might include complete replacement of track. We are planning a major review meeting in late September in which the problems and their proposed solutions will be presented to a group of structural and materials experts. The present problems have not had a significant impact on observing time so far, but that is an issue of concern in the future. We will keep the community informed about the track status through this Newsletter and other forums.

The GBT is now on the regular trimester proposal system used for all NRAO facilities. At the last proposal deadline (June 1), 66 proposals were received and 35 were selected for scheduling. Because observations are still sharing time with commissioning, the proposal queue is building up faster than it is being discharged. For this reason, the October 1 deadline will be a limited call, with priority given to target of opportunity observations. Each PI with a program in the queue has been recently informed of its status. We expect the queue to approach an equilibrium by early 2003. The new student support program was inaugurated in the late summer and is described in the accompanying article by Wrobel and Jewell.

Throughout the early autumn, commissioning priority will be given to checking out observing programs by the commissioning staff, and then to scheduling those programs for their full allotment of observing time. In October, the 1.3 cm receiver will be re-installed, and tests and observing programs will continue. In December, we plan to begin commissioning the 7 mm (Q-Band) receiver that covers the 40-50 GHz band. Based on the success with the active surface last spring, we believe that open-loop operation of the active surface will yield acceptable performance at 7 mm. Further improvements will be made as the precision control system matures.

GBT development projects are continuing to progress. A project meeting for the Penn Array bolometer camera was held in July. All three partners in the development consortium, UPenn, NASA-Goddard, and NRAO are making good progress on their components. We have two instrumentation collaborations with groups at Caltech, one for development of the pulsar fast dump system used with the GBT Spectrometer and spigot card, and the other for digital continuum backends to be used with the 1.3 cm and 3 mm receivers. A preliminary design review for the digital continuum backend project is scheduled for September 6. Further discussions concerning the interface between the spigot card and fast dump system will also be held in September. The 1.3 cm and 3 mm receiver projects being built by NRAO are also in the construction phase and are progressing well.

*P. R. Jewell*

## GBT Student Support Program: Announcement of Awards

The NRAO has inaugurated a new program to support GBT research by students, both graduate and undergraduate, at U.S. universities. The program covers student stipends, computer hardware purchases, and student travel to meetings to present GBT results. Applications to the program are tied to GBT observing proposals. The GBT Student Support Committee met August 27 to evaluate the support applications received as described in the July NRAO Newsletter.

Factors considered by the committee included, but were not limited to, the science ranking of the related observing proposal(s); a work assignment that clearly outlined the student's contributions to the GBT research; the importance of the work to the student's professional development (e.g., whether or not the GBT research would be included in the student's dissertation); and a responsible request for funds, in light of the number of hours allocated to the observing proposal(s) and the availability of other funds to support the proposed research. The committee approved the following awards, totaling approximately $217,000.

| Student | University | GBT Observing Advisor | Proposal Code |
|---|---|---|---|
| J. Carbone | Hofstra U. | D. Lubowich | 02B-010 |
| A. Celi | Hofstra U. | D. Lubowich | 02B-010 |
| Y. Chen | U. of Mass. | M. Yun | 02A-035 |
| C. Garland | U. of Florida | J. Williams | 02C-024 |
| J. Hewitt | Northwestern U. | F. Yusef-Zadeh | 02B-005,02B-006 |
| B. Jacoby | Caltech | S. Kulkarni | 01A-069,01A-071,02B-021 |
| D. Kavars | U. of Minnesota | J. Dickey | 01A-011 |
| P. Kondratko | Harvard U. | L. Greenhill | 02A-065,02C-045,02C-048 |
| C. Law | Northwestern U. | F. Yusef-Zadeh | 02B-006,02C-019 |
| M. Modjaz | Harvard U. | J. Moran | 02C-062 |
| T. Robishaw | U. of California | C. Heiles | 02A-053 |
| M. Sewilo | U. of Wisconsin | E. Churchwell | 02A-018 |

New applications to the program may be submitted along with new GBT observing proposals at any proposal deadline. For full details, restrictions, and procedures, please visit *http://www.gb.nrao.edu*, then select “student support program”. Questions on the program may be directed to Joan Wrobel (*jwrobel@nrao.edu*, phone 505-835-7392) in her role as GBT Student Support Coordinator.

*J. M. Wrobel*
*P. R. Jewell*

## GBT HI Galaxy Survey Data Available on the Web

Data from the GBT background task HI survey of galaxies are beginning to appear on the web at *http://www.gb.nrao.edu/~rfisher/GalaxySurvey/galaxy_survey.html*.

The objects for which spectra have been reduced are marked with an asterisk in the “Line Profile Index.” Click on the lines for those objects to see the data.

A little over half of the galaxies in the combined list of approximately 490 objects suggested have had at least one successful observation with the GBT. About two thirds of the data taken so far have been reduced and posted on the web. More data will appear as time permits.

As you might imagine, there have been a number of kinks to iron out of the telescope in its commissioning phases, and we are still working on some of them. The FFT spectrometer that has been used for this survey has a couple of flux density calibration issues that we are still working on. What is currently known about the calibration is described on the “Calibration” web page, but the calibration process is still in an iterative stage. You will see in the early data quite a lot of self-generated RFI. In many cases this has not affected the HI measurements very much, but it looks pretty rough. In cases where a measurement has been severely compromised by RFI, the objects have been returned to the observing list. Later data look better as we improve the electronics filtering and shielding.

*J. R. Fisher*

## Green Bank Astronomy Education and Visitor Center Project

The new Education and Visitor Center building in Green Bank is taking shape. As seen in the accompanying photo, the exterior construction is nearing completion. Work on the interior is also advancing, including installation of the electrical and HVAC systems, and some interior drywall. Exterior earthwork, parking lot construction, and landscaping will commence soon. Construction work should be completed by the end of the year. A grand opening is anticipated in the spring. A separate contract for development of exhibits for the center is also progressing well and will be completed this fall.

The Astronomy Education and Visitor Center will have approximately 20,000 square feet of finished space, including a large exhibit hall, 150-seat auditorium, and a classroom wing with a large computer room and two classrooms. Food service and gift shop areas are also included. The center will fulfill the dual role of a visitor center for the general public and an astronomy education center for K-16 students. Significant programs are planned for both aspects of the center.

*P. R. Jewell, S. A.Heatherly, M. Holstine*

*Construction progress of the Green Bank Education and Visitor Center.*

# SOCORRO

## VLA Configuration Schedule; VLA / VLBA Proposals

| Configuration | Starting Date | Ending Date | Proposal Deadline |
|---|---|---|---|
| C | 11 Oct 2002 | 06 Jan 2003 | 3 Jun 2002 |
| DnC | 17 Jan 2003 | 03 Feb 2003 | 1 Oct 2002 |
| D | 07 Feb 2003 | 12 May 2003 | 1 Oct 2002 |
| A(+PT) | 30 May 2003 | 08 Sep 2003 | 3 Feb 2003 |
| BnA | 19 Sep 2003 | 06 Oct 2003 | 2 Jun 2003 |
| B | 10 Oct 2003 | 05 Jan 2004 | 2 Jun 2003 |

GENERAL: Please use the most recent proposal coversheets, which can be retrieved at *http://www.nrao.edu/administration/directors_office/tel-vla.shtml* for the VLA and at *http://www.nrao.edu/administration/directors_office/vlba-gvlbi.shtml* for the VLBA. Proposals in Adobe Postscript format may be sent to *propsoc@nrao.edu*. Please ensure that the Postscript files request U.S. standard letter paper. Proposals also may be sent by paper mail, as described at the web addresses given above. FAX submissions will not be accepted. Only black-and-white reproductions of proposal figures will be forwarded to VLA/VLBA referees. Finally, VLA/VLBA referee reports are now distributed to proposers by email only, so please provide current email addresses for all proposal authors. For VLA proposals, email addresses can be transmitted in the most recent proposal coversheet. For VLBA proposals, email addresses can either be included in the proposal itself or else emailed separately to *lappel@nrao.edu*.

VLA: The maximum antenna separations for the four VLA configurations are A-36 km, B-11 km, C-3 km, and D-1 km. The BnA, CnB, and DnC configurations are the hybrid configurations with the long north arm, which produce a circular beam for sources south of about -15 degrees declination and for sources north of about 80 degrees declination. Some types of VLA observations are significantly more difficult in daytime than at night. These include observations at 90 cm (solar and other interference; disturbed ionosphere, especially at dawn), deep 20 cm observations (solar interference), line observations at 18 and 21 cm (solar interference), polarization measurements at L band (uncertainty in ionospheric rotation measure), and observations at 2 cm and shorter wavelengths in B and A configurations (tropospheric phase variations, especially in summer). Proposers should defer such observations for a configuration cycle to avoid such problems. In 2003, the D configuration daytime will involve RAs between $19^h$ and $05^h$.

**Approximate Long-Term VLA Schedule**

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

VLBA: Time will be allocated for the VLBA on intervals approximately corresponding to the VLA configurations, from those proposals in hand at the corresponding VLA proposal deadline. VLBA proposals requesting antennas beyond the 10-element VLBA must justify, quantitatively, the benefits of the additional antennas. Any proposal requesting a non-VLBA antenna is ineligible for dynamic scheduling, and fixed date scheduling of the VLBA currently amounts to only about one quarter of observing time. Adverse weather increases the scheduling prospects for dynamics requesting frequencies below about 10 GHz. As of 1 August, the VLBA dynamic queue contained about twice as many segments requiring LSTs inside the range 15h to 18h than outside this range. Therefore, scheduling prospects are enhanced for dynamics requesting time from 18h to 15h, in segments as long as 20 hours or as short as 2-3 hours. See *http://www.aoc.nrao.edu/vlba/schedules/this_dir.html* for a list of dynamic programs that are currently in the queue or were recently observed. VLBA proposals requesting the GBT, the VLA, and/or Arecibo need be sent only to the NRAO. Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the European VLBI Network (EVN) is a Global proposal, and must reach BOTH the EVN scheduler and the NRAO on or before the proposal deadline. VLBA proposals requesting only one EVN antenna, or requesting unaffiliated antennas, are handled on a bilateral basis; the proposal should be sent both to the NRAO and to the operating institution of the other antenna requested.

Coordination of observations with non-NRAO antennas, other than members of the EVN and the DSN, is the responsibility of the proposer.

*B. G. Clark, J. M. Wrobel*

## VLBI Global Network Call for Proposals

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

| Date | Bands | Proposals Due |
|---|---|---|
| 06 Feb to 27 Feb 2003 | 18/21 cm, 6 cm, 5 cm ... | 01 Oct 2002 |
| 22 May to 12 Jun 2003 | 18/21 cm, 6 cm, ... | 03 Feb 2003 |
| 06 Nov to 27 Nov 2003 | TBD | 02 Jun 2003 |

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

Please use the most recent proposal coversheet, which can be retrieved at *http://www.nrao.edu/administration/directors_office/vlba-gvlbi.shtml*. Proposals may be submitted electronically in Adobe Postscript format. For Global proposals, those to the EVN alone, or those requiring the Bonn correlator, send proposals to *proposevn@hp.mpifr-bonn.mpg.de*. For proposals to the VLBA or Global proposals, send proposals to *propsoc@nrao.edu*. Please ensure that the Postscript files sent to the latter address request US standard letter paper. Proposals may also be sent by paper mail, as described at the web address given. Only black-and-white reproductions of proposal figures will be forwarded to VLA/VLBA referees. Finally, VLA/VLBA referee reports are now distributed to proposers by email only, so please provide current email addresses for all proposal authors, either by including them in the proposal itself or by emailing them separately to *lappel@nrao.edu*.

*B. G. Clark, J. M. Wrobel*

## VLA/VLBA Proposal Cover Sheets

Prospective VLA and VLBA proposers are reminded that they should fill out the cover sheets completely, particularly including the information regarding the individual sources. An increasing number of proposers have been providing source tables separate from those specified on the cover sheets, without supplying all the information asked for (e.g., required rms and source strength). Even if the sources are too numerous for all to be listed, a single entry giving the typical source and observing parameters still should be made. These parameters are needed to properly assess the technical and observing requirements of proposals; incomplete information may result in a proposal being rejected because the requirements cannot be evaluated.

*J. S. Ulvestad*

## Schedsoc@nrao.edu

The duties of the VLA/VLBA Scheduling Officer now are being shared between Barry Clark and Joan Wrobel. To ensure that communications you have with the scheduler are read by the appropriate person, send email to *schedsoc@nrao.edu* instead of to Clark or Wrobel directly.

*B. G. Clark, J. M. Wrobel*

## 2002 Synthesis Imaging Summer School

The Eighth Summer School in Synthesis Imaging took place June 18 through June 25 of 2002 in Socorro, New Mexico, on the campus of the New Mexico Institute of Mining and Technology (NMIMT). The school was attended by 149 participants from 15 countries, making this the largest school to date (the 2000 school had 148 participants). A little over one third of the participants (57/149) came from outside the U.S., including 9 from Mexico, 4 from Japan, and 4 from Canada. China, Korea, Australia and Brazil also were represented, but the largest group (besides U.S.) was 19 from the U.K. Most of the participants were graduate students in astronomy, but there also were postdocs, faculty, staff and a good number of NRAO summer students.

A full week of lectures on aperture synthesis theory and techniques were given, primarily by the NRAO staff, but also by staff from the Naval Research Laboratory (NRL), Caltech, and the Harvard-Smithsonian CfA. The lectures were all given in Powerpoint and can be found in various electronic formats at the school web page (*http://www.aoc.nrao.edu/~gtaylor/synth02/synth02.html*). Practical tutorials demonstrating data collection, calibration and imaging of both VLA and VLBA data were given at the Array Operation Center on Friday, June 21. These tutorials occupied more than 55 workstations and kept 28 members of the scientific staff (just about everybody) and three volunteers from NRL (Joe Lazio, Aaron Cohen and Wendy Lane) busy on that Friday. The VLA tour on Sunday, June 23, was another high point of the school, featuring an antenna climb and a "behind the scenes" tour with the engineers who keep the VLA working. Pictures from the school can be found at the school web page mentioned above.

As in the past, the 2002 school benefitted from generous support from Associated Universities Incorporated (AUI) and NMIMT. New in 2002, travel support for U.S. and Mexican citizens was provided by special awards from NSF and CONACYT. I would like to thank all our sponsors and all the lecturers and volunteers who made this school a success.

*G. B. Taylor*

## NRAO-NM Computing Division

Early in 2002, a decrease in available office space at the AOC forced us to reduce the number of public machines from 12 to 10. At the same time, we upgraded 8 of the 10 remaining machines to very fast dual-processor PCs running the Linux operating system. As a result, in spite of the reduction in number, the total processing power for visitors sharply increased.

We kept our two fastest Sun workstations for visitors who require the Solaris operating system. Now, after more than 6 months' experience with the new situation, it appears demand for the Suns is very low; often visitors are assigned a Sun because all Linux PCs are taken; we are not aware of any visitor explicitly requesting a Sun.

We therefore plan to replace the two remaining Suns by Linux PCs similar to the eight already in use. Comments on this planned change should be directed at *gvanmoor@nrao.edu*.

*G. A. van Moorsel*

## 1612 MHz Filters to Mitigate Iridium Interference

At the VLA over the past year, NRAO has been installing a filter in the 20 cm receivers in order to mitigate strong radio frequency interference (RFI) from the Iridium constellation of satellites. The RFI from Iridium spans the frequency range from about 1619 to 1626 MHz. However, some sideband emission has been noted as low as 1616 MHz. Observations of the OH line at 1612.2 MHz can be affected by Iridium emission because the interference from the satellite resonates with the calibration noise tube cycle. The resonance and sideband RFI at best renders the calibration of the data very difficult, if not impossible, and at worst, makes the data completely useless for imaging.

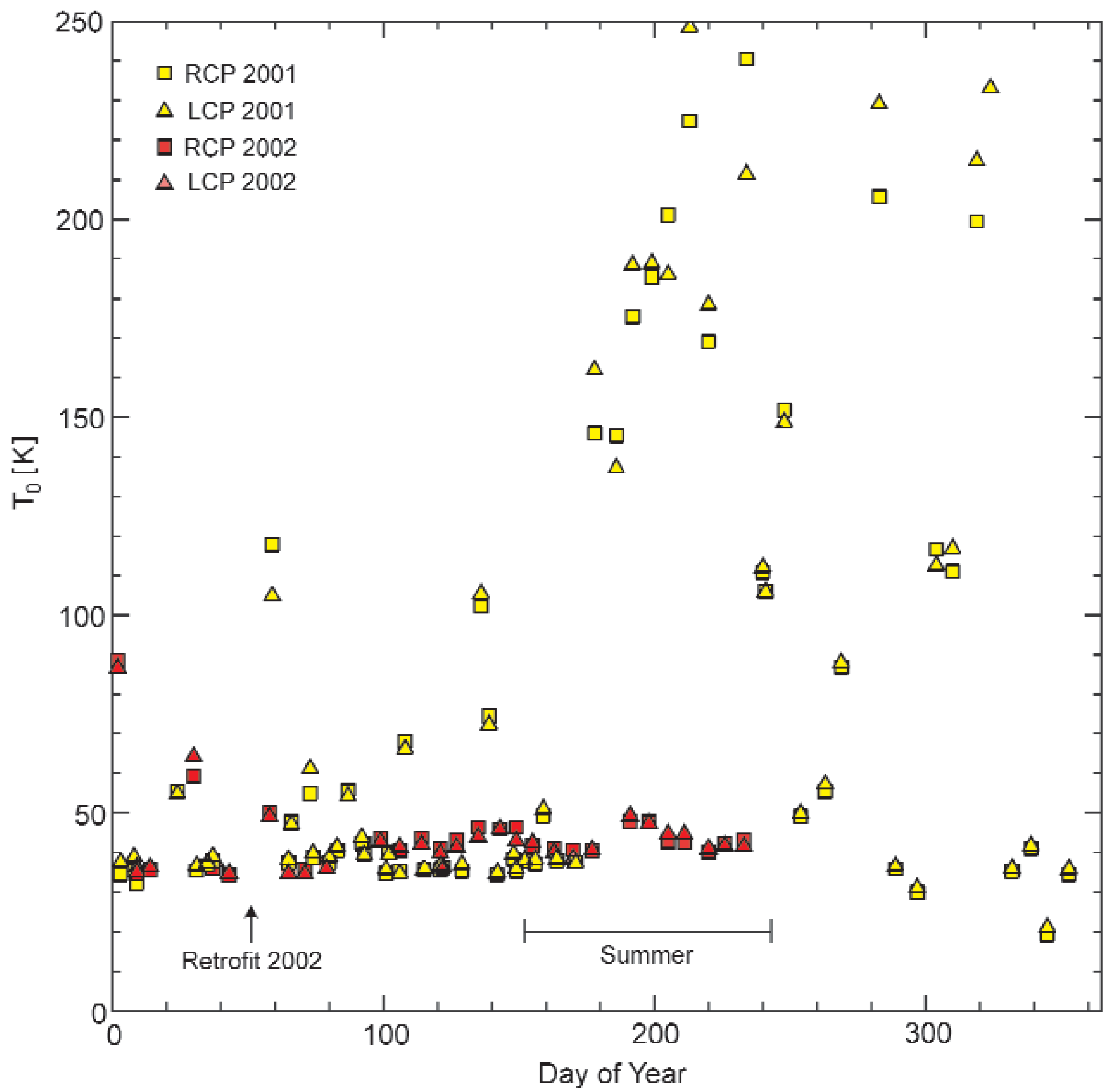
The bandpass filters that we are installing are 3 MHz wide and centered at 1611.9 MHz. This frequency range will allow observations of Galactic OH at the 1612.2 MHz line. Installation of the filters in the VLA antennas is proceeding apace, and we currently have filters installed in twenty antennas. Testing of the filters and associated hardware also is proceeding, and we expect imaging tests to continue throughout the autumn. Filters should be installed on all 28 antennas by the end of November 2002. We expect that this filter system will be available to users by the beginning of the A configuration in the spring of 2003 (the proposal deadline for this A configuration is February 3, 2003). Users considering observing the 1612.2 MHz transition of OH should contact the undersigned (*mclausse@nrao.edu*) for further information.

*M. J. Claussen*

## VLA 22 GHz Receiver Leakage Repairs

For some time, the new VLA 22 GHz (K-band) receivers have been contaminated by water during wet weather, with resulting system temperatures 50-200 K greater than normal. This can affect data for periods from several days to several weeks depending on the length of time it takes for the receiver feed and window to dry completely. Several attempts were made to seal the feedhorns from moisture contamination without removing them from the antennas. This approach didn't yield acceptable results and it was decided that each new K-band receiver had to be removed, retrofitted, retested and then reinstalled. The feed upgrade included sealing of the feedhorns with O-rings and RTV sealant, and adding insulating foam below the dewar window to prevent condensation. A passive desiccant system, which had been installed previously, along with a dry nitrogen purge of the horn will help to prevent new moisture problems in the feedhorns. More stringent use of the feed heaters has also been implemented to minimize the effect of condensation on the outer GoreTex cover. The retrofits are now completed and appear to have been successful as demonstrated in the figure below which shows a comparison of the system temperature $T_o$ due to all sources except the atmosphere, for antenna 19 during year 2001 and 2002.

*Y. M. Pihlstroem*




*This figure demonstrates the success of the retrofitted K-band receivers at the VLA.*

## Future Directions in High Resolution Astronomy: A Celebration of the 10th Anniversary of the VLBA

In August 2003, the VLBA will mark the tenth anniversary of its opening ceremony. In commemoration of this event, we are planning an international scientific meeting, to be held June 8 - 12, 2003, in Socorro, NM, on the contributions of the VLBA, and VLBI in general, to astronomical and other scientific disciplines, and on the future of high resolution observations in astronomy. The meeting will be sponsored by NRAO and New Mexico Tech. Because of its proximity in time to the IAU General Assembly, we have not sought IAU sponsorship.

Our overall goal is to review the exciting progress of VLBI science and technology, and where the future lies. We will survey the current state of scientific progress in the broad scope of astronomical, astrophysical, and geophysical fields to which VLBI observations have contributed. We also wish to discuss future frontiers for VLBI, and for other high resolution telescopes operating across the electromagnetic spectrum. Finally, we will consider the technological developments that will be necessary to support these future directions.

The meeting will include invited reviews, and contributed talks and posters, on the major scientific topics listed below. The organizers hope to emphasize both invited and contributed talks from younger members of the community. Anyone interested in participating is encouraged to pre-register at the meeting website.

### Meeting Overview and Timeline

**SCIENTIFIC TOPICS**

- AGN jets
- Supermassive black holes, accretion disks, and $H_2O$ masers
- OH megamasers, starbursts and normal galaxies
- Microquasars and compact stellar systems
- Supernovae and pulsars
- Masers: star formation and evolved stars
- Interstellar medium & propagation effects
- Gravitational lenses
- Astrometry & geodesy
- Extragalactic distance scale
- Future VLBI instrumentation
- High angular resolution telescopes across the EM spectrum
- Future science at high angular resolution

**SCIENTIFIC ORGANIZING COMMITTEE**

J. Attridge (Haystack Obs.)
J. Cordes (Cornell Univ.)
P. Diamond (Jodrell Bank Obs.)
J. Eilek (New Mexico Tech)
A. Fey (USNO)
D. Gabuzda (Univ. College Cork)
M. Garrett (JIVE)
L. Greenhill (Harvard-Smithsonian CfA)
H. Hirabayashi (ISAS)
K-Y. Lo (NRAO)
A. Marscher (Boston Univ.)
K. Menten (MPIfR)
M. Reid (Chair) (Harvard-Smithsonian CfA)
J. Romney (NRAO)
A. Whitney (Haystack Obs.)

**IMPORTANT DATES**

| | |
|---|---|
| 09 August 2002 | First Announcement |
| 14 February 2003 | Second Announcement |
| 14 March 2003 | Abstract deadline for contributed talks and posters |
| 15 April 2003 | Payment deadline for early registration |
| 16 May 2003 | Deadline for motel reservations |
| 23 May 2003 | Third and final mailing to registered participants |
| 08 June 2003 | VLBA/VLA tours |
| 09 June 2003 | First day of scientific sessions |
| 12 June 2003 | Last day of conference |

**WEBSITE**

The meeting website can be found at URL: *http://www.aoc.nrao.edu/events/VLBA10th/*. Pre-registration now is available at the site.

Mark Reid - SOC Chair, Harvard-Smithsonian CfA
Jon Romney - LOC Chair, National Radio Astronomy Observatory
Jim Ulvestad - National Radio Astronomy Observatory
Jean Eilek - New Mexico Tech

*J. D. Romney*

# IN GENERAL

## Data Management: NRAO's Web Services

As reported in the last NRAO Newsletter ("Web Server Configuration Workshop"), NRAO has obtained four identical servers to satisfy our web service needs. These systems are now fully deployed at each of the major sites (Charlottesville, Green Bank, Socorro, and Tucson). Furthermore, the mirroring system that duplicates the content of the main NRAO web site (*www.nrao.edu*) is also operational and stable.

We have now turned on the "round robin" feature of the Domain Name Service (DNS) so that when you try to resolve the name www.nrao.edu, you will get not one but three IP addresses. These represent the Charlottesville, Socorro, and Tucson web servers; whichever one comes first will be the one you get when you point your web browser at *www.nrao.edu*. If one or even two of these are for some reason unreachable or not responding (things we hope are very unlikely!), the remaining system(s) will still respond. The browsers we tested all ignored any systems that were down (deliberately, for the tests) and always served content from the remaining live servers.

As well as serving www.nrao.edu, all four servers are providing at least one additional "virtual host" by serving content for the local site, e.g., *www.aoc.nrao.edu*. NRAO's primary web services are now essentially all running the Apache web server on X86/Linux systems.

Finally, the Green Bank local site *www.gb.nrao.edu* is also being mirrored, using the technology developed at the Web "ConfigFest" Workshop in Charlottesville during June this year. A complete copy of the master is routinely copied (incrementally) to the Socorro server, and *www.gb.nrao.edu* is now also round-robin, resolving either to the Green Bank or AOC servers. This should help mitigate bandwidth contention on the currently overloaded Charlottesville-Green Bank network connection (currently all Internet traffic to Green Bank is routed through Charlottesville).

*P. P. Murphy*

## 2002 NRAO Summer Student Research Programs

The NRAO Summer Student Research Assistantship (*http://www.nrao.edu/eduction/students/*) program has ended its 43rd year in 2002 with the 25 students heading for their colleges from the four NRAO sites, having accomplished their research projects. The 15 undergraduate students were supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) Program, and the other ten students (graduating seniors, foreign and graduate students) were supported by the NRAO Graduate Summer Research Program. Applications for both programs for next summer will be accepted soon, as described in the accompanying articles. As examples of the sorts of research undertaken by the students and their advisers at the four NRAO sites, we give a short summary of the research accomplished by the students at *http://www.nrao.edu/education/students/NRAOstudents_projects02.shtml*

### NRAO Research Experiences for Undergraduates (REU) Program

Information and application forms will soon be mailed soliciting applications for the NRAO REU Program next summer. This program is for undergraduates who are U.S. citizens enrolled at a U.S. undergraduate institution. It is funded by the NSF REU Program (AST division). Students spend 10-12 weeks over the summer working closely with an NRAO mentor on a research project. Students with a background in Astronomy, Physics, Engineering, Computer Science, and/or Math are preferred. Goto *http://www.nrao.edu/education/students/summer-students.shtml* for an application form and a more detailed job description. Site specific information and links to previously conducted research projects are available at the NRAO Summer Student website at *http://www.nrao.edu/eduction/ students/NRAOstudents_summer.shtml*.

The deadline for receipt of application materials will be January 24, 2003; notice of decisions will be sent by March 1, 2003. Forms are available from Department Heads, or on the web at: *http://www.nrao.edu/education/students/summer-students.shtml*. Information may also be obtained by writing to:

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

### NRAO Graduate Summer Research Program

Information and application forms will soon be mailed soliciting applications for the NRAO Graduate Summer Research Program next summer. This program is for graduating seniors or first and second year graduate students enrolled in accredited Graduate Programs. Students spends 10-12 weeks over the summer working closely with an NRAO mentor on a research project. Students with a background in Astronomy, Physics, Engineering, Computer Science, and/or Math are preferred. Go to *http://www.nrao.edu/education/students/summer-students.shtml* for an application and a more detailed job description. Site specific information and links to previously conducted research projects are available at the NRAO Summer Student website *http://www.nrao.edu/education/students/NRAOstudents_summer.shtml*.

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

*H. A. Wootten*

## Image Gallery Live

The new "image gallery" is now live and public. It can be found at the old image gallery button on the NRAO home page or at *http://www.nrao.edu/imagegallery*. In creating this image gallery, up to this point, generally only images that already existed somewhere with the NRAO public domain were used. They were copied to the site and classified according to the category scheme devised for the new "image gallery." The images include links to related websites, journal references, press releases and technical data whenever possible. This new gallery design uses a MySQL database and PHP-based active content web technology to provide more advanced searching and selection. Each image also has links to NED and SIMBAD databases to easily obtain coordinates and other information.

However, the intent is to grow the image gallery with new images. Your radio images or combined radio/other wavelength images are wanted for the gallery. A submission instrument at *http://www.nrao.edu/imagegallery/php/ext_sub.php*, has been developed whereby you can readily provide such images. The process is designed to be as painless as possible, but help is available if needed. If you are aware of specific historical images or other specific images that would be appropriate for the gallery, please provide us with that information.

*L.T. Shapiro*

# NEW RESULTS

## What are the Cores of Low Luminosity Radio Galaxies?

It is arguably through the study of nearby low luminosity radio galaxies that we have the best opportunity to gain an understanding of the conditions in a galaxy which lead to the formation of a radio active nucleus and the physics of extragalactic radio jets, since it is only at low redshifts that we currently have the resolution to probe structures on physically interesting scales. The jets in radio loud elliptical galaxies provide unique diagnostics of the black hole and 'accretion' disk properties that cannot be obtained through studies of normal galaxies; they allow the determination of the instantaneous jet axis (through VLBA mapping) and the time history of that axis (through the extent and shape of the jets), which can be used to constrain the lifetime of the activity and the stability of the BH/accretion disk axis on timescales from ~$10^3$ to $10^7$ years.

It is currently believed that essentially all galaxies harbor a massive black hole in their nuclei (e.g., Gebhardt et al. 2000). If this is true, then it becomes hard to understand why we do not see the luminosity released by the inevitable accretion of the galaxy ISM onto the black hole in ALL galaxies. It has been suggested that at low mass accretion rate, the accretion disk becomes a very inefficient radiator (e.g., Fabian & Rees 1995). Such inefficient disks have been called ion tori (e.g., Rees et al. 1982) or advection dominated accretion flows (ADAFs) (e.g., Narayan & Yi 1995). Inefficient accretion disks may apply not only to apparently inactive galaxies, but also to low luminosity radio galaxies. Unlike the more powerful Fanaroff & Riley class II (FRII) radio galaxies, FRI galaxies lack bright quasi-isotropic optical-UV continua and broad line regions. Furthermore, they exhibit ratios of optical to radio luminosities that are much lower than those found in their more powerful counterparts (e.g., Baum, Zirbel & O'Dea 1995). A large difference in accretion rate and radiative efficiency between FRI and FRIIs would explain the difference in the optical and IR properties of these galaxies and would allow

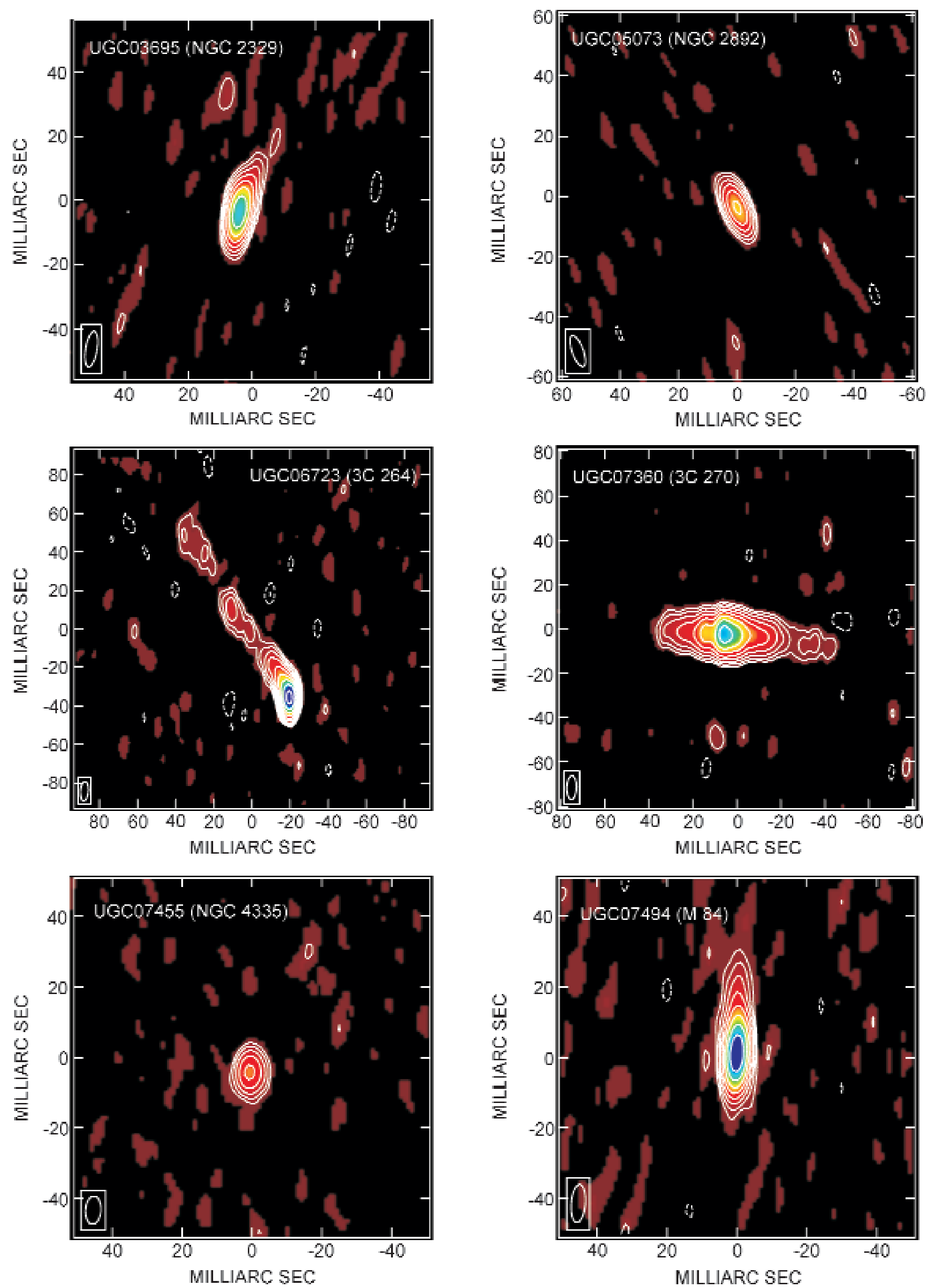



*Figure 1. VLBA images of Stokes I emission at 1.67 GHz from six FRI radio galaxies. The lowest contour levels correspond to three times the noise levels and contours are spaced at 3 × [-3, -2, -1, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512]. All images are self-calibrated. (From Xu et al. 2000).*

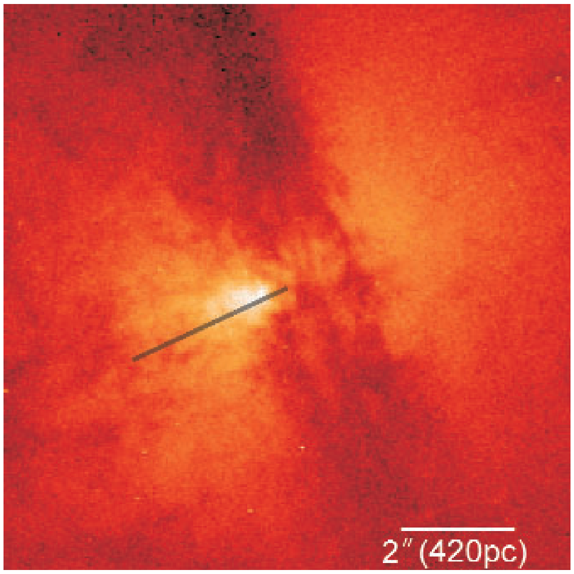
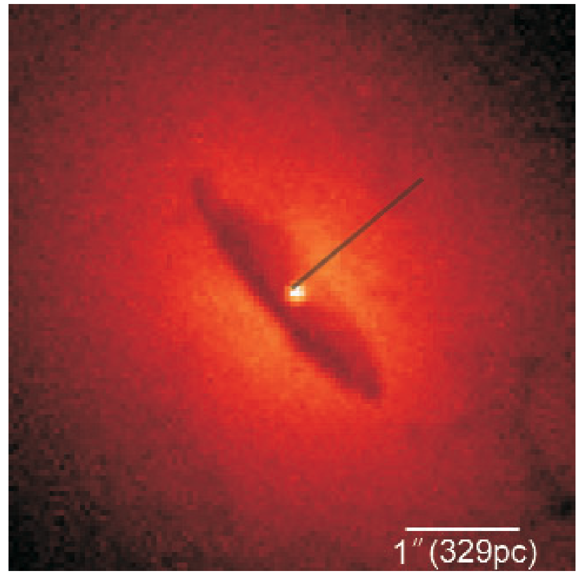



*Figure 2. (a) V-band (F555W) WFPC2 image of the center of one UGC FRI sample galaxy. North is up and East is to the left. NGC3801 [distance 47 $(h_{70})^{-1}$ Mpc] has a kpc-scale dust lane along its major axis (clearly visible in this image) and dusty filaments along its minor axis. The radio jet axis (indicated by the black line) is projected perpendicular to the dust lane.*




*(b) V-band (F555W) WFPC2 image of the center of one UGC FRI sample galaxy. North is up and East is to the left. NGC315 [distance 73 $(h_{70})^{-1}$ Mpc] contains an optical core of unresolved continuum emission surrounded by a dust disk [diameter 860 $(h_{70})^{-1}$ pc] which is aligned with the host major axis. The radio jet axis (indicated by the black line) is projected perpendicular to the dust disk.*

for an evolutionary connection between the two classes of source—i.e., with FRIIs evolving into FRIs as their accretion rate drops and the nature of the disk changes. The existence of these disks would also provide a new unification between active and non-active galaxies in which the dominant parameter is accretion rate.

A project is in progress to study a complete sample of the nearest low luminosity radio galaxies (the UGC FRI sample) at the highest possible resolutions, spanning as large a wavelength range as possible. A systematic series of observations to study this sample is now underway, using HST, ROSAT, Chandra, the VLA, VLBA, and IR telescopes.

In order to understand the role of relativistic motion in jet energy transport and constrain the orientations of the axes of the central engines and their obscuring circumnuclear regions, we undertook Very Long Baseline Array (VLBA) observations of our sample (Xu et al. 2000). We detect parsec-scale radio emission in all 17 sources observed with the VLBA. Five VLBA sources show only radio cores, ten sources show core-jet structures, and two sources show twin-jet structures. We find that the VLBA images are core-dominated, while the VLBA scale jets, if detected, contribute only a small fraction (mostly $<20\%$) of the total VLBA radio flux densities (Figure 1). We also find that (1) all VLBA jets are aligned with VLA jets; (2) the jet-to-counterjet sidedness ratio measured with the VLBA is generally larger than that measured with the VLA; (3) the VLBA jets fade with distance from the AGN core as luminosity per unit length $L_{jet} \sim r^{-2}$; (4) the observations suggest self-similarity in the structures of the knots. Results (1) and (2) are consistent with Doppler boosting effects on the parsec scales and deceleration of the jets between scales of tens of parsecs and kiloparsecs. We also find that a distribution of bulk Lorentz factors centered near $\Gamma = 5$ can reproduce our VLBA detection statistics for core, core-jet, and twin-jet sources. We considered three hypotheses to explain our result that the jets fade on the tens-of-parsecs scale. (1) If the fading is due to a decrease of the Doppler boosting as the jet decelerates, it would predict very different behavior for the one-sided and two-sided jets, contrary to observations. Also, in most cases we would expect the jets to brighten, not fade, owing to compression of the jet fluid as the jet decelerates. (2) Synchrotron losses in a magnetic field about an order of magnitude higher than our estimated equipartition values would produce dimming on the appropriate size scales but with a slope to the brightness evolution that is inconsistent with the observed value. (3) Expansion losses in an adiabatically expanding jet, with constant velocity and opening angle, are roughly consistent with the observations, provided the magnetic field structure in the jets is perpendicular to the jet axis. We will test this with VLBA polarimetry to determine the magnetic field structure and higher resolution and higher dynamic range observations to determine and follow the jet expansion. Our results imply that the jets do not decelerate on the tens of parsecs scale but must decelerate on larger scales; i.e., the deceleration zone is still to be observed.

The UGC FR-I sample was observed with WFPC2 on board HST with the V (F555W) and I (F814W) broad-band filters and with narrow-band filters centered on H$\alpha$ + [NII]. The HST WFPC2 reduction pipeline facilitated most of the broad-band data reduction. For the narrow-band image an 'off-band' image was created in order to subtract continuum emission from the 'on-band' narrow-band image thus isolating the H$\alpha$+[NII] emission. The off-band image was constructed using both V and I images to minimize the effect of differences in dust opacity between filters.

Two features stand out in the nuclei of the FRI galaxies. First, central dust distributions with widely differing morphologies (Figure 2) and typical scales of a kiloparsec or less were detected in 19 of the 21 early-type galaxies. Second, the broad-band and emission-line flux shows a distinct compact peak in many of the UGC FRI nuclei. Gaussian fitting to the emission peaks confirmed that this 'core' emission component is unresolved at HST scales (FWHM PSF ~ 0.1″) implying that it originates from a region with a size of a few tens of parsec or smaller. The superb spatial resolution of HST allows the measurement of the optical nuclear fluxes which constitute typically less than 0.1% of the optical broad-band flux of the stellar host (as opposed to, for example, quasars which outshine their hosts).

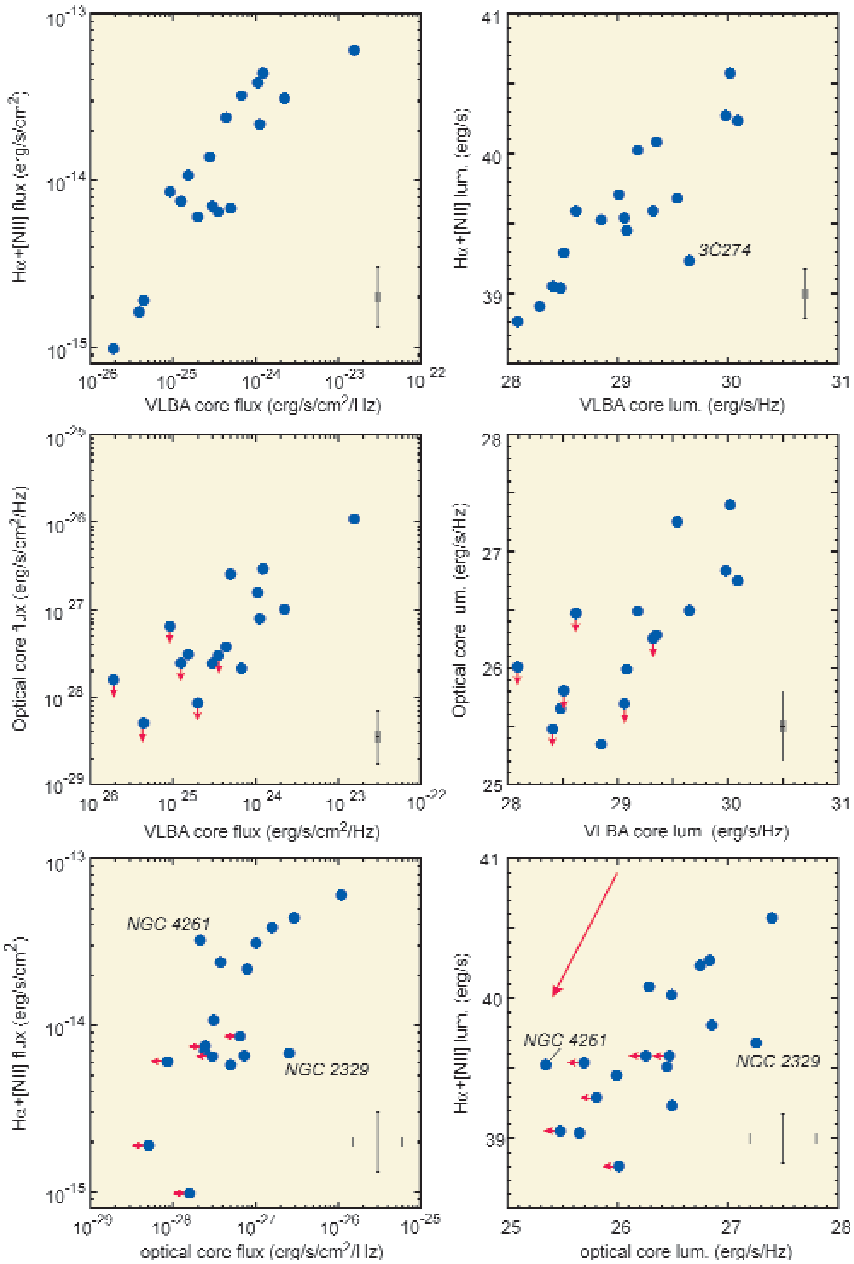



*Figure 3. The VLBA radio core, WFPC2 optical core, and core H$\alpha$ emission in the UGC FR I nuclei plotted versus each other. The left column contains flux-flux plots, the right column contains luminosity-luminosity plots. Arrows indicate upper limits. The correlation between each pair of quantities is significant at more than the 99% level according to a generalized Kendall tau test The error bars in the lower right corner of each plot indicate the typical error for each quantity. The large arrow in the lower right plot indicates the displacement of a data point if it were observed through a dust screen with a V-band opacity A(V)=3. (From Verdoes Kleijn et al. 2002).*

The broad band spectral energy distribution of the central engine can be used to constrain the properties of the nuclear accretion disk, e.g., its geometry, structure, and accretion rate. We carried out an analysis of the relationship between the 0.01″ scale radio and 0.1″ scale optical continuum and H$\alpha$ core emission of our complete sample using our HST imaging data in order to address these questions (Verdoes Kleijn et al. 2002). We confirm the linear correlation between optical and radio core emission in low luminosity radio galaxies seen by Chiaberge, Capetti & Celotti (1999). Additionally, we find that both core emissions also correlate with the core H$\alpha$ emission (Figure 3). The mutual correlations are unlikely to be caused by obscuration from the ubiquitous central dust. We favor a jet origin for both the radio and optical core emission because (i) optical and radio core emission are tightly correlated, (ii) the spectral indices from radio to optical are similar to those for extended optical jets, and (iii) we know that on the parsec scale and larger the radio emission is produced in a jet. However, a significant contribution from a second component, such as accretion disk/flow/wind, to the radio and optical emission below the 0.1″ scale for the optical and the 0.001″ scale for the radio emission may well be present.

The correlation of the optical and radio core emission with the isotropic H$\alpha$ emission constrains the core bulk Lorentz factor assuming a relativistic jet origin for the radio and optical emission. For a continuous jet, bulk Lorentz factors 2–5 are inferred, somewhat smaller than the bulk Lorentz factors required by the BL Lac-FRI unification schemes. If the core emission is dominated by a jet component, this discrepancy could be reconciled by a two-layer jet with a fast moving spine surrounded by a slower outer layer (e.g., Sol, Pelletier, & Asseo 1989; Laing & Bridle 2002). If the radio and optical core emission are indeed inner jet synchrotron emission, then their strong correlation with H$\alpha$ core emission implies either a direct link between jet luminosity and gas excitation power even on these very small scales, possibly via jet-gas interactions, or a close relation between AGN photo-ionizing power and jet radiative (and possibly kinetic) power (e.g., Baum & Heckman 1989). Lastly, we find that radio, optical and H$\alpha$ core luminosities of elliptical LINER-type AGNs with and without kiloparsec-scale radio jets appear to have similar relations. The results suggest (i) the engines in the two types producing the cores might be similar and (ii) the core radio emission in ellipticals without large-scale radio jets may be produced by small-scale jets. The clue to what distinguishes sources with and without large-scale radio jets has yet to be identified.

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## VLA Observations of the "Integral Sign" Galaxy

The "Integral Sign" galaxy (UGC 3697) is a nearby Sd spiral that exhibits a dramatic "S"- shaped warp in its stellar disk (Figure 1). Although a mild degree of bending or twisting is observed in the outer gas disks of the majority of spiral galaxies, warping of the stellar disk is typically less pronounced, and warps of the amplitude seen in UGC 3697 are rare. This implies UGC 3697 may be in a rather unstable and short-lived dynamical state. UGC 3697 is further intriguing in that in spite of its significant distortion, its stellar disk appears remarkably thin. Moreover, unlike most spiral galaxies viewed edge-on, it shows no obvious dust lane and no hint of a spheroid component. In these ways, the appearance of UGC 3697 is reminiscent of the flattest and dynamically coldest Sd galaxies—the so-called "superthins" (Goad & Roberts 1981).

Superthins appear to be among the least evolved disk galaxies in the local universe. They typically exhibit quiescent, gas-rich disks with low metallicities and minimal signs of dynamical heating (e.g., Bergvall & Rönnback 1995; Matthews et al. 1999). They also appear to be highly dark-matter dominated. An example of a prototypical superthin spiral is UGC 7321 (Matthews et al. 1999). As summarized in Table 1, UGC 7321 and UGC 3697 share a number of similar global physical properties, including their sizes, neutral hydrogen contents, scale heights, and peak rotational velocities. However, UGC 3697 has a blue luminosity ~5 times higher than UGC 7321 and a far-infrared luminosity 23 times greater. Combined, these traits strongly suggest that UGC 3697 may have once been a quiescent superthin that has only recently begun a transformation as the result of a tidal interaction or minor merger. Indeed, UGC 3697 is part of a small galaxy group that includes the peculiar ellip-

Table 1.

| | UGC 3697 | UGC 7321 |
|---|---|---|
| $D$ (Mpc) | 18 | 10 |
| $V_{rot}$ (km s$^{-1}$) | 95 | 104 |
| $A_{25}$ (kpc) | 17.0 | 16.1 |
| $h_z$ (pc) | 131 | 145 |
| $M_{HI}$ ($\times 10^9 M_\odot$) | 1.4 | 1.1 |
| $L_B$ ($\times 10^9 L_\odot$) | 3.5 | 1.0 |
| $L_{FIR}$ ($\times 10^9 L_\odot$) | 1.8 | 0.079 |

tical UGC 3714, as well as several dwarf galaxies. Catching a superthin in the act of being perturbed is of considerable interest, as it can show how these seemingly fragile disks respond to environmental influences.

*Figure 1. Optical B+R composite image of the "Integral Sign" galaxy, UGC 3697, obtained with the 3.5-m WIYN telescope at Kitt Peak, AZ. The field shown is ~3.5' across.*

In order to further explore the environment of UGC 3697 and assess how it has affected the neutral gas (HI) distribution and kinematics of this galaxy, we have observed UGC 3697 in the HI 21-cm line using the VLA in its CS configuration. We obtained a total of 12 hours of on-source data, reaching a $3\sigma$ limiting column density of $\sim 2 \times 10^{19}$ cm$^{-2}$ per channel with a velocity resolution of 5.2 km s$^{-1}$ and a spatial resolution of $\sim 19''$.

As seen in the total HI intensity image in Figure 2, our VLA observations reveal a pronounced gaseous warp in UGC 3697. Overall, the HI distribution traces the shape of the stellar warp, but it also exhibits additional twists and extensions. On the eastern side of the galaxy, we find gas concentrated along the midplane as well as a wide swath of more diffuse emission sweeping below the plane. In our optical image in Figure 1, this region is faintly delineated by a very blue population of stars.

One surprise revealed by our VLA data is that unlike in normal edge-on spirals, the brightest HI concentration in UGC 3697 is not found near the central regions of the galaxy, but rather along its western edge, where we detect a bright, extended blob of emission in the galaxy midplane. A network of long, curved filaments of gas, ~3–7 kpc in extent, also protrude from the northern edge of the disk near this location. Neither these filaments nor the bright midplane clump have any obvious optical counterpart.

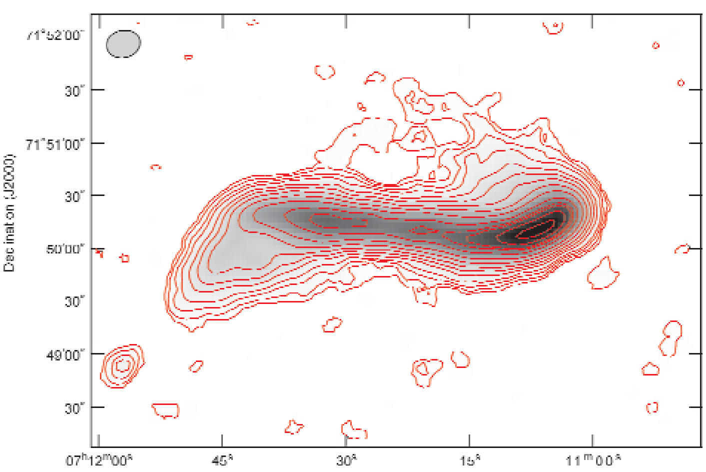


*Figure 2. Contour and greyscale representations of the HI intensity distribution in UGC 3697. A previously uncatalogued dwarf companion is also visible in the lower left. The contour levels are 0.37, 0.93, 1.9, 3.0, 5.2, 7.5, 10, 15, 21, 30, 37, 41, 49, 56, & 71 × $10^{20}$ cm$^{-2}$ at a FWHM resolution of 19"×16" (1.7×1.4 kpc). The greyscale range is 0 - 5.6 × $10^{21}$cm$^{-2}$.*

In Figure 3 we show the HI velocity field for UGC 3697 and its environs. Not surprisingly, the velocity field of UGC 3697 itself appears highly distorted owing to the strong warping of the disk. These data also confirm the presence of several gas-rich neighbors, only one of which was a previously catalogued member of the UGC 3697 group (UGC 3714). Although it is the brightest visual companion of UGC 3697, UGC 3714 is only a weak HI source and exhibits little rotation. In contrast, the brightest two HI companions in Figure 3 appear only as extremely faint smudges on the Digitized Sky Survey. We also have detected a previously uncatalogued dwarf very close to the eastern tip of the disk of UGC 3697. A rotational signature in this dwarf is evident from our data, and in Figure 1 we see a faint optical counterpart $\sim 10''$ across, with $L_B \sim 8.5 \times 10^6$ $L_{\odot}$.

What can these new data tell us about the evolutionary history of UGC 3697? One hypothesis for the origin of galactic warps is that they are triggered by tidal interaction. Since a fairly massive object is required to trigger a warp purely via tidal effects, the most likely culprit would appear to be UGC 3714, at a projected distance of 39 kpc from UGC 3697. Assuming a typical internal group velocity, it is feasible that UGC 3697 and UGC 3714 may have had a close encounter $\sim 10^8$ yr ago. This timescale is roughly consistent with the ages of the HII regions of UGC 3697 inferred by Márquez & del Olmo (1991). However, a problem with this scenario is that the disk of UGC 3697 lacks the signatures of dynamical heating (thickening) expected from such an event (e.g., Reshetnikov & Combes 1997). Moreover, to the limiting sensitivity of our present data, UGC 3697 does not show any gaseous bridges or arcs linking it with UGC 3714 or any of its other neighbors.

Several pieces of evidence in our new VLA data suggest a new, alternate possibility for the origin of the warp of UGC 3697. Examination of our individual HI channel maps reveals that the bright blob of gas seen along the midplane in Figure 2 does not follow the same ordered rotation as the underlying disk—i.e., its mean radial velocity deviates from the adjacent material. The total amount of gas in this "anomalous" component is $\sim 2 \times 10^8$ $M_\odot$. This is comparable to the HI mass of a typical dwarf irregular galaxy, suggesting that a dwarf may have recently either plummeted into the disk of UGC 3697, or been stripped of the bulk of its gas during a close fly-by. Such an event would be expected to trigger inflows of gas toward the central regions of the galaxy (Hernquist & Mihos 1995) and may account for the enhanced 21-cm radio continuum emission we detect within the central kpc of UGC 3697. The faint dwarf seen near the eastern edge of UGC 3697 could be the stripped core of this intruder.

Independent of the origin of the strong warping of the disk of UGC 3697, the question remains what will be the ultimate fate of this system. If a $\sim 10^8$ $M_\odot$ satellite has indeed been accreted, the late stages of this process are expected to excite vertical instabilities in the disk (Sellwood et al. 1998), hence the "superthin" disk of UGC 3697 may soon begin to buckle and thicken. The outcome could be a transformation into something resembling typical Magellanic spirals, which have substantially thicker disks and less regular and symmetric structure, but often very similar masses, sizes, HI contents, and luminosities to UGC 3697. Since galaxy interactions and mergers were far more common in the past, our results hint that other superthin disks residing in rich environments may have already been similarly transformed, helping to account for the puzzle of the diverse array of disk morphologies seen within a similar range of physical parameter space at the end of the Hubble sequence—from quiescent superthins to star-bursting Magellanic systems.

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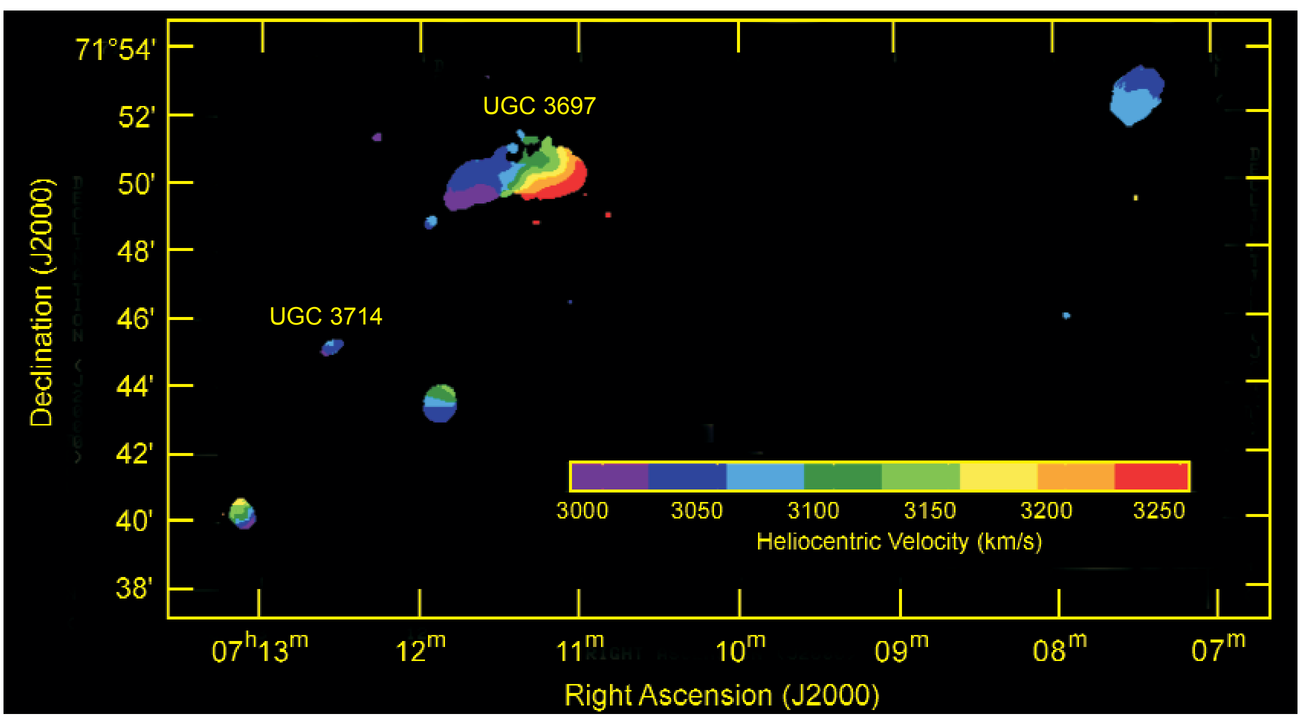


*Figure 3. HI velocity fields of UGC 3697 and several neighboring members of the UGC 3697 group.*

## A New Diagnostic for Galaxy Collisions

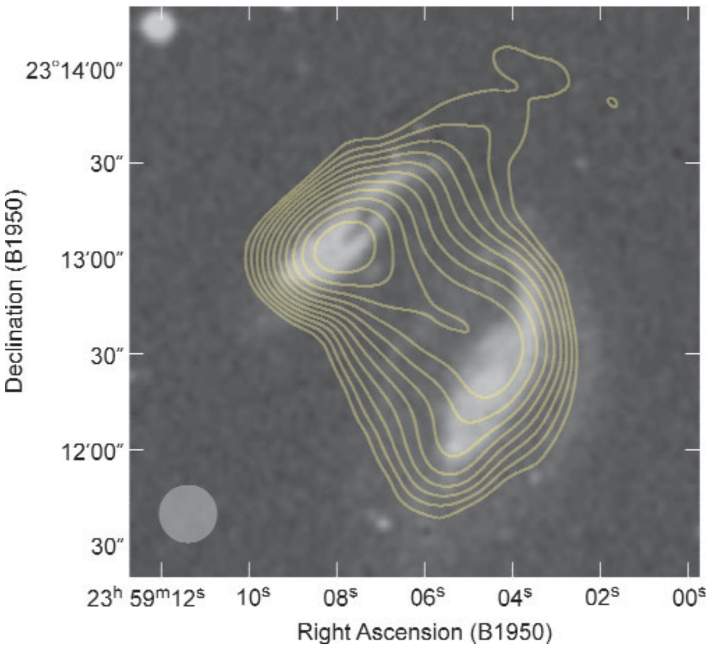


*Figure 1. As UGC 12914 (lower right) and UGC 12915 (upper left) separate following their face-on collision, they are joined by a bridge of radio continuum emission whose contours look like stretching bands of taffy.*

Collisions play an important role in the assembly and evolution of galaxies, triggering starbursts, and fueling active galactic nuclei. The most conspicuous diagnostics of recent collisions are tidal tails and bridges of stars which respond to gravitational forces but do not actually collide with anything. Gravitational *N*-body simulations can reproduce the observed stellar distributions, retrace the dynamical history of the interactions, and constrain the masses of (collisionless) dark halos. Interstellar HI provides an independent diagnostic of galaxy collisions, responding to both gravity and fluid forces—gas clouds really can collide, conserving momentum but not energy, and be stripped from their parent disks by ram pressure. Since most galaxies have HI disks that initially extend well beyond the disks of stars, even distant encounters can disturb the HI detectably, and true collisions often feature very long and spectacular HI tails. To the extent that the HI gas can be approximated by a smooth fluid, its behavior can be simulated by smoothed particle hydrodynamic (SPH) codes (Mihos & Hernquist 1996).

Disk galaxies also contain molecular clouds, ionized gas, magnetic fields, and relativistic electrons. Normally, the radio emission from a disk galaxy does not extend significantly above or below the disk, and the strong continuum bridge between the disks of UGC 12914 and UGC 12915 (Figure 1) was the first to be discovered (Condon et al. 1993). They were dubbed the "Taffy" galaxies after the appearance of the radio contours stretching between them. Bright synchrotron emission implies the presence of both strong magnetic fields and numerous relativistic electrons in the space between the galaxies. How did they get there? Disc magnetic fields are anchored by ionized gas in giant molecular clouds (GMCs). GMCs are exceptionally dense lumps in the interstellar medium and, like stars, they are not stripped from their parent disks by ram pressure during a direct collision. Magnetic field lines linking GMCs in each disk are grabbed by ionized gas in the other as the disks interpenetrate, and the fields are stretched across the gap between the disks as they separate after the collision. Disk cosmic rays are constrained to travel along those field lines and fill the widening gap, where they emit synchrotron radiation, a new diagnostic for galaxy collisions. So long as magnetic flux is conserved, the field strength in the bridge joining the post-collision disks will remain comparable with the initial field strength in the disk, which is $B \approx 5-10\ \mu G$ in normal spiral galaxies. As the bridge lengthens and its volume $V$ increases following the collision, its total magnetic energy $B^2 V/(8\pi)$ increases at the rate of $\sim 10^{41}$ erg $s^{-1}$. The power source is kinetic energy extracted as the magnetic field tries unsuccessfully to pull the separating galaxies back together.

To learn more about the Taffy galaxies, we made high-resolution multifrequency continuum, polarization, and HI VLA images of them (Condon et al. 1993). Figure 2 shows the gory aftermath of the head-on galaxy collision with the DSS optical image in green, the 1.4 GHz radio continuum brightness in red, and the HI 21 cm line brightness in blue. The stellar disks of UGC 12914 and UGC 12915 appear white because they are bright in all three bands. The column density of HI is actually highest between the galaxies, indicating that most of the disk HI was stripped when the disks passed through each other.

The total masses of the individual galaxies were estimated from the widths of their rotation curves. The HI radial velocities of UGC 12914 (4360 km $s^{-1}$) and UGC 12915 (4390 km $s^{-1}$) happen to differ by only 30 km $s^{-1}$, a value much smaller than their total three-dimensional velocities, so their orbital plane must lie nearly in the sky. Since the orbits of colliding galaxies in isolated pairs are probably almost parabolic, their speeds in the center-of-mass frame can be determined from their linear separation and masses. UGC 12914 and UGC 12915 are moving apart at about 600 km $s^{-1}$, and the dynamical time since the collision is $\tau \approx 3.4 \times 10^7 (h_{70})^{-1}$ [$h_{70} \equiv H_0 / 70\ km\ s^{-1}\ Mpc^{-1}$].

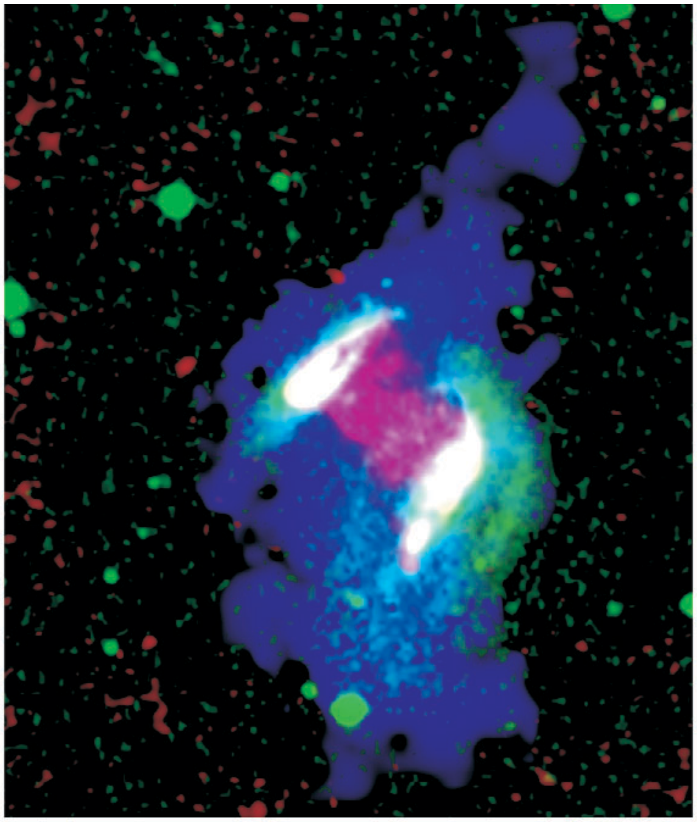

*Figure 2: Aftermath of a collision: the UGC 12914/5 system in visible light (green), HI line (blue), and 1.4 GHz continuum emission (red).*

Spectral steepening of the continuum bridge provides an independent estimate of its age, and hence the time elapsed since the collision. Neither the diffusion nor the convection speeds for relativistic electrons approach 600 km s$^{-1}$, so electrons in the middle of the bridge have not been replenished by recent supernova remnants and are now "older" than disk electrons by about the collision age. The bridge spectrum steepens to $\alpha$(1.49 GHz, 4.86 GHz) $\approx 1.3$ near the center, about $\Delta\alpha = 0.5$ higher than the disk spectral index. Using the bridge surface brightness ($\approx 10$ K at 1.49 GHz) plus its width [$\approx 10\ (h_{70})^{-1}$ kpc] as an estimate of its thickness gives the equipartition field strength [$B \approx 7\,(h_{70})^{2/7}\ \mu$G]. This field strength is consistent with flux conservation following field stripping from normal spiral disks. The synchrotron lifetime of electrons with critical frequency 1.49 GHz in the equipartition field is $\tau_s \approx 7 \times 10^7\,(h_{70})^{-3/7}$ yr. Their inverse-Compton lifetime is about a factor of three lower because the optical plus far-infrared radiation energy density in the bridge is about a factor of three higher than the magnetic energy density, so the observed spectral steepening indicates that the collision occurred about $2 \times 10^7$ yr ago, within the uncertainties equal to the dynamical age.

Normal spiral galaxies obey the tight far-infrared (FIR) / radio flux correlation. The logarithmic parameter $q$ is normally used to specify the FIR/radio ratio; its average is $\langle q \rangle \approx 2.3$ and $q < 2.0$ usually indicates the presence of a radio-loud AGN. The UGC 12914/5 system is uniquely radio-loud among non-Seyfert galaxies in the IRAS Bright Galaxy Sample; it has $q = 1.94$. All of its "excess" radio emission can be attributed to the bridge; the disks alone are normal. Perhaps the relativistic electrons now trapped in the bridge would have escaped silently into intergalactic space had the collision not occurred; that is, normal galaxies may not be good calorimeters for relativistic electrons. Analyzing the cosmic "crash test" provided by the UGC 12914/5 system yields a new insight into normal galaxies.

The unique properties of the "Taffy" system (e.g., steep-spectrum radio bridge, low FIR/radio ratio) can be interpreted as the typical aftermath of a direct collision between two originally normal disk galaxies. However, so long as the "Taffy" system remained unique, the concern remained that its unique properties were caused by initially unusual galaxies and not by the collision as modeled. It is notoriously easy to construct models consistent with limited astronomical data. However, if our interpretation is right, it does make a prediction: most other "Taffy" systems should be similar. Testing it requires the discovery of a new "Taffy" system having similar properties consistent with our analysis of UGC 12914/5.

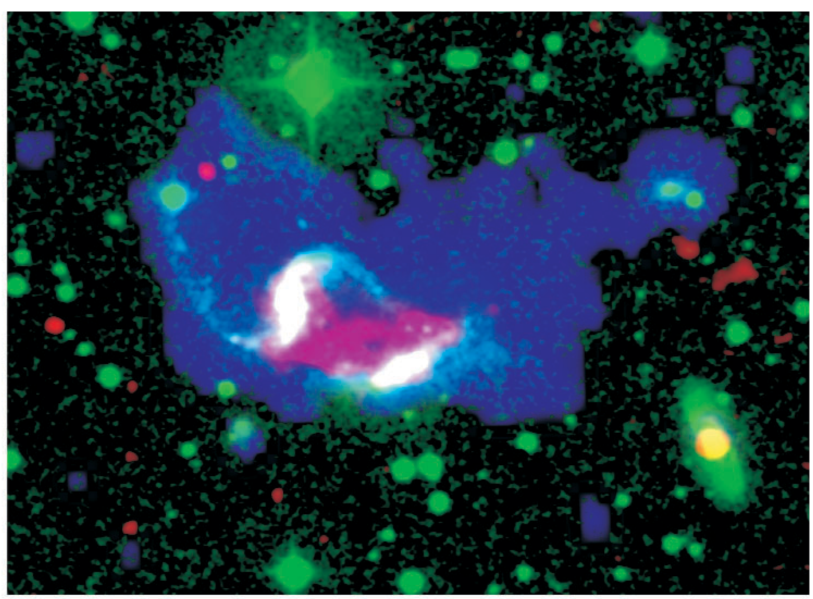

*Figure 3: The second "Taffy" system UGC 813/6 is similar to the original (see Figure 2), so both are probably typical examples of interpenetrating collisions by initially normal disk galaxies.*

That opportunity finally arose when the second "Taffy" pair UGC 813 and UGC 816 was recognized among $2 \times 10^3$ bright UGC galaxies detected by the NVSS. The rarity of these systems is not surprising. A very close collision is required for molecular disks to overlap and interpenetrate. The post-collision galaxies must now be well separated and oriented so that the bridge is clearly visible between them. Finally, synchrotron and inverse-Compton losses probably make the continuum bridges fade below detectability at cm wavelengths after $\approx 10^8$ yr. Although the NVSS image (45″ FWHM resolution) shows only a single peak midway between these galaxies, their nuclei are 51″ apart, so they are formally resolved and we inferred the existence of a continuum bridge from the lack of a central minimum. The unusually low FIR/radio flux ratio $q = 1.86$ of the UGC 813/6 system also supported the "Taffy" hypothesis. To confirm the continuum bridge and compare UGC 813/6 with UGC 12914/5, we recently made high-resolution multifrequency continuum, polarization, and HI VLA images of UGC 813/6 (Condon, Helou & Jarrett 2002).

UGC 813/6 in Figure 3 certainly does look a lot like UGC 12914/5 in Figure 2. There are some differences, however. The projected separation between UGC 813 and UGC 816 is nearly twice as large [$\approx 19(h_{70})^{-1}$ kpc], suggesting a longer time has elapsed since their collision. The two disks are not quite parallel, and the HI column density does not peak midway between the galaxies. Their oblique collision probably didn't strip as much HI from the disks, and the bridge HI has had a longer time to fall back onto the disks. The velocities of UGC 813 (5070 km s$^{-1}$) and UGC 816 (5370 km s$^{-1}$) differ by 300 km s$^{-1}$ so their orbital plane does not lie close to the sky plane.

The HI disk profiles of UGC 813 and UGC 816 are too distorted for a direct mass measurement. We estimated their total mass as 50 times their total HI mass and used the ratio of their 2.2$\mu$m luminosities as a proxy for mass ratio to conclude that UGC 816 is about 1.2 times as massive as UGC 813. Since the projected separation of UGC 813 from UGC 816 is much larger than the largest pericentric distance of any collision capable of stripping magnetic fields from their molecular disks, we made the approximation that UGC 813 and UGC 816 are now separating almost radially. Then the transverse component of their separation velocity is $v_\perp \approx 400$ km s$^{-1}$ and the dynamical time since the collision is $\tau \approx 4 \times 10^7$ yr.

The continuum spectral index of UGC 813/6 ranges from $\alpha \approx 0.8$ in the disks to $\alpha \approx 1.3$ in the center of the bridge. The equipartition magnetic field strength is $B \approx 6-10\,\mu$G. Synchrotron and inverse-Compton losses are comparable in the region between UGC 813 and UGC 816, and the spectral steepening suggests that the bridge is about $5 \times 10^7$ yr old, again in good agreement with the dynamical age.

The similarity of UGC 12914/5 and UGC 813/6 suggests that they are typical of the "Taffy" phenomenon and the unusual properties of these systems can be used as diagnostics for better understanding both normal spiral galaxies and collisions. Unfortunately, these collisions are difficult to model numerically for two reasons: (1) SPH codes treating the interstellar medium as a smooth fluid can model some phenomena in a lumpy medium on scales larger than the mean free path of individual lumps, but not the "Taffy" phenomenon which depends completely on the inhomogeneity of the colliding disks. (2) Current models for gas dynamics do not include magnetic fields. The "Taffy" fields are strong enough to affect both the thermodynamics and the bulk dynamics of the bridge gas. In conclusion, we note that improved models capable of treating inhomogeneous magnetic media will be more important than the discovery of additional "Taffy" galaxies or improved observations of the two known pairs, and we hope that some theoretician will take up this challenge.

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*B. T. Soifer, Caltech*

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