NATIONAL RADIO ASTRONOMY OBSERVATORY

October 2004

Newsletter

Issue 101

ALMA Progress Update

VLBA Detects a New Radio Source Inside Supernova 1986J

GBT Discovers Two New Interstellar Molecules

VLA Observes Galactic Transient Sources

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The NRAO Graphics Department will be happy to assist you in the production of images for your article as well as for your research papers. Contact Patricia Smiley (*psmiley@nrao.edu*) with your request.

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

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Assistant Editor: Sheila Marks; Layout and Design: Patricia Smiley

Cover Image: The Very Large Array Telescope is a collection of 27 radio antennas located at the NRAO site in Socorro, New Mexico. Image courtesy of: NRAO/AUI Photographer: Kristal Armendariz

Atacama Large Millimeter Array (ALMA)

ALMA Project Progress Report

Proposals for the Atacama Large Millimeter Array (ALMA) production antenna procurement were received April 1, 2004. Review of the proposals submitted to AUI / NRAO is being conducted among three committees: the Joint Technical Evaluation Team (JTET), the Business Evaluation Committee (BEC), and the Contract Selection Committee (CSC). The JTET is composed of personnel from NRAO and ESO and is conducting a technical review of all proposals. The BEC is conducting business due diligence and reviewing the business and management aspects of the proposals submitted to AUI / NRAO. Finally, the CSC will receive the reports of the JTET and BEC, open the financial offers, and make a recommendation to the AUI President and the NRAO Director. A technical Working Group has been established jointly by the NRAO Contract Selection Committee (CSC) and ESO Contract Awards Committee (CAC) to evaluate a small number of remaining technical issues with each of the proposed antennas. The group is chaired by Dave Woody and includes North American and European experts. Final negotiations and contract award are anticipated in October 2004 following National Science Foundation and ALMA Board approval.

The Japan Negotiating Team, a committee of the ALMA Board, and representatives of the Japanese National Institutes of Natural Science (NINS) have reached a draft agreement with ESO and the National Science Foundation concerning the construction of the Enhanced ALMA.

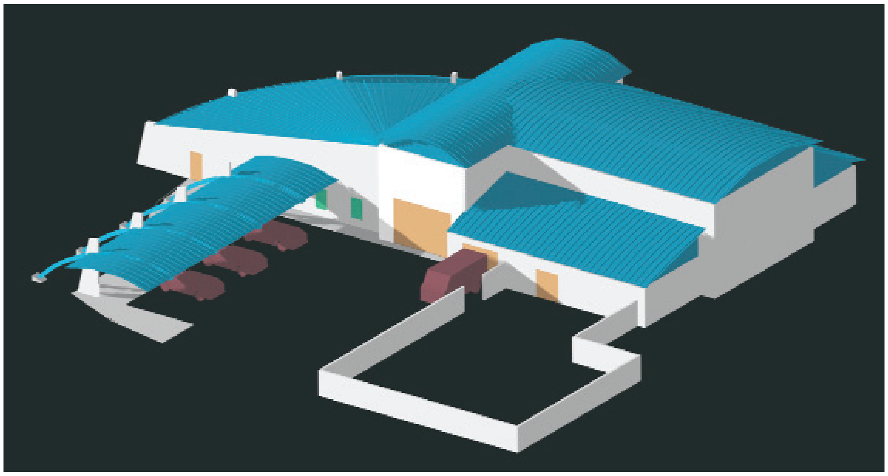
While the search continues for an ALMA Project Manager, NRAO Director K.Y. Lo has assumed the role of Interim North American ALMA Project Manager. Dr. Lo will remain in this position until a new Project Manager has been hired and arrives in Charlottesville.

A contractor has been selected for the initial construction of the ALMA Array Operations Site (AOS) technical building. The foundation package includes the necessary excavation and the construction of the building foundation. Work will start as soon as NSF approval is received for the contract. A contract has also been negotiated for the outfitting of the temporary ALMA office in Santiago, Chile and will be executed after NSF approval is received. The office will house the JAO and Executive staff located in Santiago.

During the last week of September, two key ALMA meetings took place in Charlottesville: the ALMA Science Advisory Committee (ASAC) and a meeting of all ALMA IPT leads and their deputies. The IPT meeting focused on completing the Integrated Project Schedule.

A successful review of the Local Oscillator (LO) was held in early September in Tucson. The review focused on the programmatic status of the LO and insured that all required steps are in place to complete the pre-production prototypes.

M. D. Rafal



Artist's concept of the ALMA Array Operations Site (AOS) technical building.

ALMA Town Meeting

There will be an ALMA Town Meeting at the 205th AAS meeting, which is being held January 9-13, 2005 in San Diego. The ALMA Town Meeting is scheduled for Tuesday, January 11, from 1:00 - 2:00 p.m., and is principally aimed at informing the North American astronomical community about the scientific capabilities and current status of the ALMA Project.

There has been much progress in the construction of ALMA, in Chile, North America, and Europe. Japan is poised to join the ALMA Project as a third partner. The meeting will cover progress on all these fronts. Equally important, there will be a presentation of the North American ALMA Science Center (NAASC, *http://www.cv.nrao.edu/naasc/*), which is being organized in Charlottesville, Virginia. This center will be the main communication hub between North American astronomers and the Joint ALMA Observatory. Following the presentation, there will be a discussion session where we will solicit comments from the user community, with a focus on the science user services to be provided by the NAASC. If you will be at the AAS Meeting, please plan to attend this Town Meeting.

The tentative agenda for the Meeting is as follows:

- Introduction - K. Y. Lo, Director of NRAO
- ALMA Science Examples - M. Yun, U. Mass
- Project description, status - M. Tarenghi, ALMA Director
- North American ALMA Science Center - A. Wootten, NA ALMA Project Scientist
- Discussion (15 mins) - A. Wootten, Moderator

P. A. Vanden Bout

Director's Office

This is an exciting and challenging time at the National Radio Astronomy Observatory (NRAO). Through the Atacama Large Millimeter Array (ALMA) and Expanded Very Large Array (EVLA) projects, the NRAO is involved in designing and building new centimeter, millimeter, and sub-millimeter wavelength research facilities which will open scientific frontiers. Observatory personnel also continue to meet the challenge of developing new capabilities and operations modes for our existing facilities, improving the scientific productivity of the Robert C. Byrd Green Bank Telescope (GBT), the Very Large Array (VLA), and the Very Long Baseline Array (VLBA).

Important transitions are taking place throughout our community to enable this era of progress. Associated Universities, Inc., (AUI) is the not-for-profit science management corporation that operates the NRAO under a Cooperative Agreement with the National Science Foundation. After the October 21 – 22, 2004 meeting of the AUI Board of Trustees, Dr. Riccardo Giacconi will step down as President of AUI. On behalf of everyone at the Observatory, I want thank Dr. Giacconi for his leadership and support of the NRAO, its mission, and its people. Dr. Giacconi led AUI and the NRAO through major organizational improvements and changes in the scope of the Observatory's mission, including the completion of the GBT and the initiation of the construction phase of the ALMA and EVLA projects. Dr. Giacconi's legacy is a remarkable tribute to the strength of his scientific vision and leadership. Dr. Giacconi will remain active

Dr. Riccardo Giacconi

in the astronomy community, becoming a University Professor at Johns Hopkins University, where he expects to continue his long research career.


Dr. Ethan Schreier

Immediately after the October AUI Board of Trustees meeting, Dr. Ethan Schreier will begin his term as AUI President. Dr. Schreier is a distinguished scientist and manager with a broad range of experience. He has held senior positions at the Einstein X-ray Observatory, the Hubble Space Telescope, and at AUI, where he has most recently been Executive Vice President. I look forward to working closely with Ethan in his new role. I am confident that his term as AUI President will also be one of great accomplishment.

Another important transition is taking place in the NRAO Director's Office: Jim Condon has agreed to serve as Interim Deputy Director for six months beginning September 1, 2004. Jim Condon takes over from Dave Hogg, who stepped down from this position at the end of August.

Dave Hogg has been an outstanding Deputy Director, and we will miss him in that position. The good news is that Dave has kindly agreed to continue to consult with the Director's Office after August, even as he spends more time doing research. I know that everyone will join me in thanking Dave for his more than forty years of dedication to the Observatory's well-being, and for his valuable service as Deputy Director over the past 14 months.

Jim Condon received tenure as a member of the NRAO scientific staff in 1981. He is an outstanding scientist, with a distinguished and internationally-recognized research record who knows the Observatory very well. Most recently, in his role as Project Scientist for the GBT Precision Telescope Control System, Jim has been a key contributor. Jim's intellect, experience, and judgment will undoubtedly be of great value to the Director's Office.

Fostering closer ties between the NRAO and the astronomical community is a high priority. The enhanced 2005 Jansky Fellowship Program provides outstanding research opportunities for young astronomers, on par with those available through the Hubble and Chandra Fellowship Programs. Jansky Fellowships can be held at all NRAO sites, and appointments may also be held at U.S. universities (see article on page 12).

In consultation with its user community, the NRAO has initiated a program to support astronomical research at the GBT by graduate and undergraduate students at U.S. universities. This program offers substantial financial support and strengthens the proactive role of the Observatory in training new generations of telescope users. The Observatory has seen excellent community response to this GBT program and hopes to soon initiate a similar program for the VLA and VLBA.

Through the enhanced NRAO Visitors Program, the Observatory encourages Ph.D. scientists and engineers in radio astronomy and related fields to visit its facilities. The terms of a visit are negotiable, ranging in duration from weeks to months. The purpose of a visit can be interaction with NRAO staff, summer research, or a sabbatical.

The NRAO sees the challenges of the present as necessary and welcome steps toward the scientific opportunities of the future. The Observatory's people are proud of what they have accomplished and confident of their ability to design, operate, and maintain the facilities demanded by the extraordinary scientific enterprise that is modern astronomy.

K. Y. Lo

Socorro

Pie Town Link, EVLA, and VLA/VLBA Impact During A Configuration

EVLA prototyping and the beginning of EVLA production during the current A configuration will lead to the VLA having only 25 operational antennas for considerable periods, rather than its normal complement of 27. The "empty" stations during A configuration generally will be AW5 and AE3, chosen in an effort to minimize the effect of missing (u,v) coverage, as well as to provide enough short spacings for calibration and enough long spacings for the high-resolution science.

Approximately 270 hours of VLA+Pie Town link observing have been approved for the current A configuration. This is the first epoch when we have good winter weather combined with the Pie Town link and the new high-frequency VLA receivers (completed 43 GHz systems plus lower-noise 22 GHz systems). In addition, it is unclear how many more times we will offer the present Pie Town link, since its limited bandwidth will make it less important as we transition toward EVLA operations. Therefore, we are making it a priority to achieve the best science possible in the current Pie Town link session, particularly at the highest frequency VLA bands.

We have made a general decision to optimize Pie Town link science by not giving an operational VLA antenna to the simultaneous VLBA program while we are operating the Pie Town link. Instead, we will allocate the first EVLA test antenna, antenna 13, once it is operational in VLBA modes. We do not expect antenna 13 to be available before about the middle of October, perhaps later; it will not have receivers at the VLBA bands of 2.3, 5, and 15 GHz. Calibration of antenna 13 will be more challenging than for the VLBA antennas; the calibration data that we supply will be the true gain tables for antenna 13, plus system temperature values "shadowed" (copied) from Los Alamos.

VLBA Pie Town antenna and VLA Pie Town Link.

Since the VLBA largely is scheduled dynamically, the scientific impact of implementing the above decision should not be large. We have accepted the normal amount of high-priority VLBA science for the current observing trimester. It is likely that a few high-priority observations requiring all ten VLBA antennas will occur a few months later than they would have otherwise. For high-priority, multi-epoch observations, we will make every effort to schedule their epochs at times that are not affected by the loss of Pie Town to the VLA. Some medium- or low-priority VLBA programs actually will have an improved chance of being scheduled between September and January, particularly if the PIs require only 8 or 9 antennas in the constraints specification within their schedule files.

Finally, to minimize impact on the standard VLA A configuration, we plan to schedule very few VLBA+Y1 (VLBA plus a single VLA antenna) programs during the September-January time frame. Thus, there should be few cases where the VLA is scheduled with a maximum complement of 24 antennas. Of course, our typical down-time of about four percent of scheduled antenna-hours means that some VLA observers will be missing an additional antenna for some periods.

J. S. Ulvestad

VLA Observations of Galactic Transient Sources

We have for several years maintained a program of VLA monitoring of Galactic transient sources, focusing primarily on those sources undergoing X-ray outbursts as seen by various all-sky monitors. Currently, information on any initial detections or interesting upper limits is broadcast to the community through Astronomical Telegrams (*http://www.astronomerstelegram.org/*) or through IAU Circulars. With recent improvements in the NRAO archive system, advances in the NRAO's ability to respond rapidly to multi-wavelength triggers (*Rapid Reponse Science*, see *NRAO Newsletter 96*) and a slow but steady increase in the undersigned authors' ability to generate useful web pages, these VLA monitoring data will now be made more generally available. First, the raw data are instantly available for public access through the NRAO archive, under proposal name AR545. Second, the most recent results may be found on the web page: *http://www.aoc.nrao.edu/~mrupen/XRT/current.shtml.*

The goal is to provide individual web pages with multi-wavelength light curves for all sources. At the moment only a few are on-line (see links from the web address above), but we are working on automatic scripts to generate the rest and hope to have those available within the next month or two. As in the past, we will also send the observed flux densities, noise estimates, and other processed data for recent or ongoing outbursts to any interested parties (e-mail: *mrupen@nrao.edu*).

M. P. Rupen, A. J. Mioduszewski, V. Dhawan

Project-Based Scientific Staff Organization

I am pleased to announce the formation of a project-based scientific staff organization for activities in support of the VLA, VLBA, and EVLA. This organization is intended to create focal points for activities in support of particular projects, as well as providing an improved mechanism for scientists in various job categories to contribute to development and support activities for these telescopes. In general, telescope users and prospective observers should contact the EVLA, VLA, or VLBA project scientists with questions about telescope capabilities and technical details. The User Programs Scientist should be contacted regarding visits to the AOC, assistance in preparing observing scripts, and the assignment of contacts for data-reduction visits to Socorro.

Rick Perley will continue his current role as EVLA Project Scientist, which includes a specific responsibility for testing the performance of new capabilities being installed as part of the EVLA Project. In addition, the following appointments were effective Monday, July 12, 2004, for terms until the end of September 2006.

VLA Project Scientist - Frazer Owen - responsible for scientific activities related to ongoing VLA operations as well as the transition between VLA and EVLA.

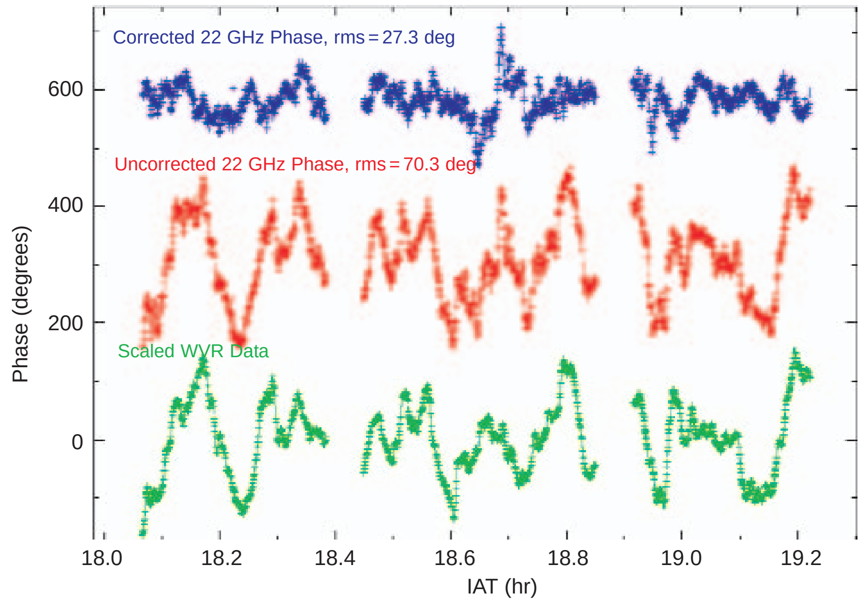
VLBA Project Scientist - Greg Taylor - responsible for scientific activities related to ongoing VLBA operations as well as improvements to the VLBA. During Greg's leave of absence from September 2004 through May 2005, Craig Walker will be Acting VLBA Project Scientist.

User Programs Scientist - Mark Claussen - responsible for user support and outreach programs (e.g., student programs, New Mexico Symposium, astronomer web pages, and visiting observers).

J. S. Ulvestad

Water-Vapor Radiometry Tests at the VLA

The dominant source of phase fluctuations for the VLA at high frequencies (greater than 5 GHz) are fluctuations in the water vapor content of the troposphere. These fluctuations can decorrelate the signal from an astronomical source to the extent that the source may not be detected or imaged unless it is strong enough for self-calibration techniques to work on timescales shorter than that of the fluctuations. In order to be able to image weak sources under marginal observing conditions a means of correcting for the phase fluctuations introduced by the troposphere must be developed. One method currently being explored at many of the millimeter-wave observatories around the world uses the fact that the atmospheric water vapor is also a source of continuum and line emission. Fluctuations in the water vapor produce concomitant fluctuations in the sky emission, and measurements of these fluctuations via radiometry can then be used to derive corrections for the astronomical phase.



At the VLA we have been investigating such phase correction techniques by measuring fluctuations in the 22 GHz water-vapor line using a three-channel system attached to the existing K-band receivers on antennas 26 and 28. Key to these experiments is the need for a very stable detection system, to ensure that the fluctuations are indeed originating in the atmosphere and not in some other element of the receiver. To this end all the electronics of the water-vapor radiometer (WVR) are mounted on a temperature-stabilized plate that replaces the standard IF plate of the K-band receiver. In this way, we achieve a gain stability of 1 part in 20,000, on timescales up to 1000 seconds.

Tests of the WVR system at the VLA comprise observations of a strong astronomical source with a short integration time, while simultaneously saving WVR data using the VLA Monitor and Control system. Test data have been obtained during a 1-year period from February 2003 to January 2004 under various weather conditions and for different baseline lengths, at the default VLA continuum frequencies for X, U, K, and Q bands (8, 15, 22, and 43 GHz respectively). We find that applying a correction derived from the WVR outputs always improves the rms phase of the VLA data, and that this is the case at all four frequencies tested.

The best correlation between the measured phase and the WVR output occurs for clear skies. The correlation is poor when the tropospheric phase stability is very good, since the phase fluctuations are instead limited by the stability of the VLA electronics (namely, phase noise introduced by the switching of the last delay bit for each antenna). The correlation is highly variable on days with clouds, where the output from the WVR is contaminated by the emission from liquid water. The figure shows an example of the WVR results for a baseline length of 2.5 km, sky cover 50-75 percent with forming cumulus, and an observing frequency of 22 GHz. The middle (red) trace shows the uncorrected phase, the bottom (green) trace is the output from the WVR after being scaled to phase, and the top trace (blue) shows the phase after being corrected using the WVR output.

The success of the WVR tests to date has led to a revised design for the WVRs, to be implemented for the EVLA if funding permits. Further details of the results shown here, and the revised WVR design, are available in EVLA Memos 73 and 74.

C. J. Chandler, W. F. Brisken, B. J. Butler, R. H. Hayward, B. E. Willoughby

VLA Configuration Schedule; VLA/VLBA Proposals

Configuration	Starting Date	Ending Date	Proposal Deadline
A(+PT)	17 Sep 2004	10 Jan 2005	1 Jun 2004
BnA	21 Jan 2005	14 Feb 2005	1 Oct 2004
B	18 Feb 2005	23 May 2005	1 Oct 2004
CnB	03 Jun 2005	20 Jun 2005	1 Feb 2005
C	24 Jun 2005	19 Sep 2005	1 Feb 2005
DnC	30 Sep 2005	17 Oct 2005	1 Jun 2005
A-D (Large Proposals)	20 Jun 2006	02 Apr 2007	1 Jun 2005
D	21 Oct 2005	03 Jan 2006	1 Jun 2005
A(+PT?)	20 Jan 2006	01 May 2006	3 Oct 2005
BnA	12 May 2006	29 May 2006	1 Feb 2006
B	02 Jun 2006	05 Sep 2006	1 Feb 2006

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 US standard letter paper. Proposals may also be sent by paper mail, as described at the web addresses given above. FAX submissions will not be accepted. Finally, VLA/VLBA referee reports are now distributed to proposers by email only, so please provide current email addresses for all proposal authors via the most recent LaTeX proposal coversheets.

VLA: The maximum antenna separations for the four VLA configurations are A-36 km, B-11 km, C-3 km, and D-1 km. The BnA, CnB, and DnC configurations are the hybrid configurations with the long north arm, which produce a circular beam for sources south of about -15 degree declination and for sources north of about 80 degree declination. Some types of VLA observations are significantly more difficult in daytime than at night. These include observations at 90 cm (solar and other interference; disturbed ionosphere, especially at dawn), deep 20 cm observations (solar interference), line observations at 18 and 21 cm (solar interference), polarization measurements at L band (uncertainty in ionospheric rotation measure), and observations at 2 cm and shorter wavelengths in B and A configurations (tropospheric phase variations, especially in summer). Proposers should defer such observations for a configuration cycle to avoid such problems. In 2005, the B configuration daytime will involve RAs between 21^h and 04^h. Current and past VLA schedules may be found at *http://www.vla.nrao.edu/astro/prop/schedules/old/*. EVLA construction will continue to impact VLA observers; please see the web page at *http://www.aoc.nrao.edu/evla/archive/transition/impact.html*.

Approximate VLA Configuration Schedule

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

VLBA: Time will be allocated for the VLBA on intervals approximately corresponding to the VLA configurations, from those proposals in hand at the corresponding VLA proposal deadline. VLBA proposals requesting antennas beyond the 10-element VLBA must justify, quantitatively, the benefits of the additional antennas. Any proposal requesting a non-VLBA antenna is ineligible for dynamic scheduling, and fixed-date scheduling of the VLBA currently amounts to only about one quarter of observing time. Adverse weather increases the scheduling prospects for dynamics requesting frequencies below about 10 GHz. When the VLA-Pie Town link is in use during the VLA's A configuration in 2004, we will try to substitute EVLA antenna 13 for Pie Town in a concurrent VLBA dynamic program (see the *Newsletter* item by Jim Ulvestad on *Pie Town Link, EVLA, and VLA/VLBA Impact*). 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 to be sent only to the NRAO. Note the possibility to propose for the High Sensitivity Array, discussed further in a separate article. Any proposal requesting the 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.

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VLBI Global Network Call for Proposals

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

Date	Proposals Due
17 Feb to Mar 2005	01 Oct 2004
02 Jun to 20 Jun 2005	01 Feb 2005
20 Oct to Nov 2005	01 Jun 2005

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

Please use the most recent proposal coversheet, which can be retrieved at *http://www.nrao.edu/administration/directors_office/vlba-gvlbi.shtml*. Proposals may be submitted electronically in Adobe Postscript format. For Global proposals, those to the EVN alone, or those requiring the Bonn correlator, send proposals to *proposevn@hp.mpifr-bonn.mpg.de*. For Global proposals that include requests for NRAO resources, send proposals to *propsoc@nrao.edu*. Please ensure that the Postscript files sent to the latter address request U.S. 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 via the most recent LaTeX proposal coversheet.

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High Sensitivity Array Results and Future Deadlines

The June 1, 2004 proposal deadline was the first at which proposals were solicited for the VLBI High Sensitivity Array (HSA), in which the VLBA is combined with a collection of large apertures, including VLA, GBT, Arecibo (Ar), and Effelsberg (Eb). Consult *NRAO Newsletter No. 99* for the call for proposals, and see *http://www.nrao.edu/HSA* for further information and a new sensitivity plot.

At the first deadline, a total of 22 proposals were received which requested the VLBA and at least two of the larger apertures, with a total of 290 hours of time requested. The usual refereeing process was followed by NRAO and Effelsberg (Arecibo made use of the NRAO referee reports), and technical evaluations also were made by representatives of the participating observatories. Representatives of all participating telescopes took part in the final time allocation, based on the referee grades and comments, constrained by the maximum time available. Out of the 22 proposals submitted, nine were granted some observing time, though not all approved proposals were given all the time requested. The total number of hours requested and allocated was as follows:

	VLBA	VLA	GBT	Eb	Ar
Requested	290	284	290	143	65
Allocated	74	68	74	55	23

The proposals accepted for some or all of their requested time are the following:

BB190 - Bietenholz - Supernova 2001em: *Does it Have a GRB Jet?*
- 12 hr VLBA+VLA+GBT; 5 hr Eb; 2.5 hr Ar

BB191 - Barvainis - *Are Radio-Quiet Quasars Superluminal?*
- 10 hr VLBA+VLA+GBT+Eb+Ar

BB196 - Bartel - *Resolving the Pulsar/Black-hole Nebula in the Center of SN 1986J's Shell*
- 12 hr VLBA+VLA+GBT+Eb

BD103 - Desmurs - *High Dynamic Range Map of SiO Maser Emission in IRC+10011*
- 6 hr VLBA+VLA+GBT+Eb

BG150 - Giovannini - *Jet and Counter-jet Emission in Markarian 501*
- 8 hr VLBA+VLA+GBT+Eb

BG155 - Greenhill - *Mapping the Accretion Disk in the IC2560 AGN and implications for H_0*
- 8 hr VLBA+VLA+GBT

BH128 - Hough - *Deep Imaging of Faint Nuclei in 3CR FR-II Quasars and Radio Galaxies*
- 8 hr VLBA+VLA+GBT+Eb+Ar

BJ054 - Jackson - *Detection of a Third Image in CLASS B1030+074*
- 4 hr VLBA+VLA+GBT; 2.5 hr Ar

BP116 - Piner - *Using the HSA to Measure High Brightness Temperatures*
- 6 hr VLBA+GBT+Eb

We plan to continue the HSA proposal opportunity at future deadlines, namely October 1, 2004, February 1, 2005, and June 1, 2005. As for the first deadline, a maximum of 100 hours of HSA observing time will be granted to the most highly ranked proposals at each deadline. Proposers should be aware of a few limitations not expressed specifically in the first call:

(1) The NASA Deep Space Network (DSN) was not included in the announcement of the HSA; proposals requesting HSA+DSN presently are not being accepted, due to the virtual impossibility of scheduling all the large telescopes involved.

(2) Proposals for "Known Transient Phenomena" generally will not be accepted, due to the difficulties in arranging allocations on all the tightly scheduled large telescopes on short notice. (Note that this proposal category is defined only for the NRAO telescopes, in any case.) Only extremely valuable and scientifically unique Targets of Opportunity might be considered by the large telescopes, on a case-by-case basis outside the normal HSA proposal mechanism.

(3) Few or no proposals that involve 43 GHz observations will be accepted at the February 1, 2005, deadline because of the low probability of having acceptable weather during the northern summer.

J. S. Ulvestad, B. G. Clark, J. M. Wrobel, R. Bignell (NRAO)
C. Salter (Arecibo Observatory) A. Kraus (MPIfR)

Taylor / Lonsdale VLBI Report Available

The Taylor/Lonsdale report on *Mapping the Future of VLBI Science in the U.S.* has been submitted to the National Science Foundation's Division of Astronomical Sciences. The report is now available to the community at the following URLs: *http://www.nrao.edu/VLBIfuture/* and *http://web.haystack.mit.edu/vlbi/vlbi.html*.

G.B. Taylor (NRAO), C.J. Lonsdale (MIT Haystack Obs.)

Green Bank

The Green Bank Telescope

Fall photo of the Green Bank Telescope.

The summer season at the Green Bank Telescope is used primarily for observations below 10 GHz. This summer has been particular productive for low-frequency pulsar observations and for development of pulsar instrumentation. Good progress was made in refinements of the Pulsar Spigot mode of the GBT Spectrometer. This mode allows bandwidths of up to 800 MHz at data dump rates of a few microseconds. This new capability provides a significant increase in sensitivity and has already produced some important pulsar results. The implementation of the Spigot Mode has been a joint effort of NRAO and D. Kaplan of Caltech. In addition, university groups have installed two new pulsar backends at the GBT, the Caltech-Green Bank-Swinburne Recorder-II (CGSR2) and the Green Bank Astronomical Signal Processor (GASP). These back-ends both had successful astronomical tests over the summer. The combination of the GBT and these new modes and backends are providing very powerful pulsar observing capabilities.

We will soon be entering the fall and winter observing season, during which both high- and low-frequency observing will be scheduled. The new Ka-Band (26-40 GHz) receiver will be installed in early October for further commissioning. We anticipate that this receiver will be available for astronomy by February 2005. The Q-Band receiver will be reinstalled in early November. After some further tests in November and December, it should be available for use by mid-January. Work on both the Caltech Continuum Backend and the Penn Array bolometer camera are proceeding well and both should be available for tests this winter.

A review of GBT software development was held on August 30-31, 2004 by the Observatory's e2e coordination group. GBT software and development staff gave twelve presentations on software science drivers, priorities and resource allocations, current projects, and longer-term initiatives. The review panel was co-chaired by W. Cotton and D. Tody. Other panel participants included E. Fomalont, G. Hunt, T. Morgan, S. Ransom, J. Mangum, J. Benson, D. Frail, A. Farris, B. Clarke, and K. Sowinski. The GBT staff described its plans for an IDL package for interactive reduction of basic single-dish data, and longer-term plans for a Python and compiled-language package with an initial focus on single-dish imaging needs. The *Ease of Use* initiative that will provide observers with flexible, powerful, and efficient tools for configuring and executing observations on the telescope was also described. Short-term plans include the development of a script language based around the concept of scheduling blocks. This will form the foundation of longer-term initiatives that include queue-based, dynamic scheduling. Software work to support monitor and control and instrument development projects was also discussed. Common approaches to software development at the GBT, EVLA, and ALMA were discussed at length and will be implemented as possible. There was a solid consensus that the review had been very useful, and initial feedback from the panel was positive.

Structural inspections of the GBT were conducted again this summer by the firm of Modjeski and Masters. During the summer of 2003, critical members of the tipping structure were inspected. This summer, the alidade and half the backup structure were inspected. The inspections went very smoothly and have been completed. The structure was found to be in very good condition, in general. The only defects found were in a few of the original welds, and these will be repaired within the next few weeks.

The trial retrofit of the azimuth track has performed well. Earlier concerns about possible defects indicated by ultrasonic testing were traced to the testing method. As a further confirmation, we removed the trial bridging wear plate in June after one year of use and subjected it to a destructive metallurgical examination; no defects were found. The trial retrofit has also performed well in other respects. It also appears likely that this geometry, coupled with the use of bronze-teflon-molybdenum runners, will successfully mitigate the fretting wear problem in the original design. NRAO staff, together with consulting engineers at Simpson, Gumpertz, and Heger, are now focusing on the cause of the wear-plate end cracks. Possibilities include material properties, stresses from the structural geometry, and spreading of the material under the wheel loads. Once this is resolved to our satisfaction, we can proceed with a track retrofit.

P. R. Jewell

GBT Student Support Program: Announcement of Award

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

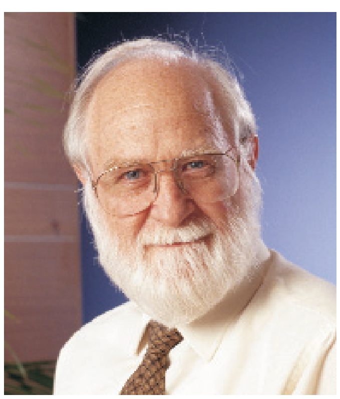
The August award was to Casey Law (Northwestern U) in the amount of $35,000 for the proposal entitled "*A Study of the Galactic Center Lobe.*"

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

K.E. Johnson (U Wisconsin), D.J. Nice (Princeton U), J.E. Hibbard, P.R. Jewell, F.J. Lockman, J.M. Wrobel (NRAO)

In General

Ronald D. Ekers Selected for the 2004 Jansky Lectureship



Associated Universities, Inc. (AUI) and the National Radio Astronomy Observatory (NRAO) are pleased to announce that the thirty-ninth annual Karl G. Jansky Lecture will be given by Dr. Ronald D. Ekers, an Australian Federation Fellow and past Director of CSIRO's Australia Telescope National Facility. Professor Ekers also is President of the International Astronomical Union, the world's professional body for promoting astronomy through international cooperation. The lecture is entitled *Paths to Discovery*. Ekers is being honored for his long series of accomplishments in radio astronomy, especially in the study of radio galaxies. He has been an innovator in the development of new techniques and instrumentation for radio astronomy.

The Jansky Lectureship is awarded each year by the Trustees of Associated Universities, Inc. to recognize outstanding contributions to the advancement of astronomy. The lectureship is named after Karl G. Jansky, the AT&T Bell Labs engineer who in 1932 first discovered natural radio waves emanating from space.

Ekers' interests include extragalactic astronomy, especially cosmology, and galactic nuclei, radio astronomical techniques, and image-formation theory. In addition to his work in Australia, he has worked in the United States, the United Kingdom, and the Netherlands. He was Assistant Director at the NRAO in charge of the Very Large Array from 1980 to 1987 and Director of the CSIRO's Australia Telescope National Facility from 1988 to 2003, where he is credited with building it into one of the world's top radio observatories. Ekers is best known for his extensive work in imaging the radio emission and in identifying optical counterparts of extragalactic radio sources. Ekers' deep insight and understanding of a broad spectrum of contemporary astrophysical problems has been the driving force behind his development of innovative interactive techniques for the analysis of radio interferometric data, and his crucial contributions to the design, development, and effective operation of radio telescopes including the Westerbork Synthesis Array in the Netherlands, the Very Large Array in New Mexico, and the Australia Telescope. He was elected a Fellow of the Australian Academy of Science and a Foreign Member of the Royal Dutch Academy of Science in 1993, and a Foreign Member of the American Philosophical Society in 2003. He was awarded the Astronomical Society of Australia's Robert Ellery Lectureship in 1997 and awarded Australia's Centenary Medal in 2003. Ekers will deliver the Jansky Lecture according to the following schedule:

Socorro, New Mexico, on Wednesday, Nov. 10th at 8:00 p.m. in the Macey Center at New Mexico Tech

Green Bank, West Virginia, on Monday, Nov. 15th at 7:30 p.m. in the Science Center auditorium

Charlottesville, Virginia, on Wednesday, Nov. 17th at 7:30 p.m. in Gilmer Hall at the University of Virginia

Historical information on the Jansky Lectureship can be found at *http://www.nrao.edu/jansky/janskyprize.shtml*.

For media queries, please see *http://www.nrao.edu/news/media_contacts.shtml.*

L. T. Shapiro

Jansky Fellowship Program

August 2004 marks the beginning of the new traveling Jansky fellowship program, in which some of the research fellows will be located at external institutions, in addition to those located at the NRAO facilities. The new program was announced last year, and the reception from the community was excellent, with more than 60 applicants covering a broad range in research interests. The distribution of requested host institutions was broad, and yet there was no lack of quality applicants for the NRAO sites. Also, for the first time the selection committee included scientists from outside the NRAO. The committee members were: C. Carilli, W. M. Goss (NRAO), J. Carlstrom (Chicago), J. Hewitt (MIT), J. Stocke (Colorado), and S. Vogel (Maryland). We would like to thank the committee members for their efforts and for providing outstanding guidance in this critical first year of the program.

The new traveling Jansky Fellows for 2004 are:

A. Baker is going to the University of Maryland to work with Andy Harris on mm studies of high-redshift star-forming galaxies. Andrew is coming from MPE, where he has been a postdoctoral fellow. He received his Ph.D. from Caltech.

T. Cheung is going to MIT to work with Claude Canizares on X-ray/radio observations of AGN/jets. He's coming from Brandeis University, where he recently received his Ph.D.

N. Miller is going to Johns Hopkins to work with Tim Heckman on radio observations of star-forming galaxies at intermediate and high redshift. Neil has been at GSFC as a postdoctoral fellow, and he did his thesis work at New Mexico State.

Also, Shami Chatterjee will be moving to the CfA as a traveling Jansky Fellow in September 2004, to work with B. Gaensler on pulsars and Galactic radio astronomy, after spending a year in Socorro as a resident Jansky Fellow.

The above are in addition to the three new Jansky Fellows coming to the NRAO, Socorro.

V. Fish works on Galactic star-forming regions using VLBI observations. Vincent is coming from Harvard, where he recently completed his Ph.D.

N. Kanekar works on radio QSO absorption-line systems and many other things. Nissim is coming from the Kapteyn Institute, where he was a postdoctoral fellow. He received his Ph.D. in Pune, India.

J.-P. Macquart is one of the leading researchers on intraday variable radio sources. J.-P. is also coming from the Kapteyn Institute, where he was a postdoctoral fellow, and he received his Ph.D. from Sydney University. J.-P. plans to move to Caltech to work with S. Kulkarni midway through his Jansky Fellowship.

A full listing of the NRAO postdoctoral fellows can be found on the NRAO home page. The NRAO will continue the expanded Jansky program for 2005/2006. Details on the program and the application procedure can be found at: *http://www.nrao.edu/administration/directors_office/jansky-postdocs.shtml*.

C. L. Carilli, W. M. Goss

Opportunities for Undergraduate Students, Graduating Seniors, and Graduate Students

Applications are now being accepted for the **2005 NRAO Summer Student Research Assistantships**. Each NRAO summer student conducts research under the supervision of an NRAO staff member at one of the NRAO sites, on a project in the supervisor's area of expertise. The project may involve any aspect of astronomy, including original research, instrumentation, telescope design, or astronomical software development. Examples of past summer student research projects are available on the Summer Student website at *http://www.nrao.edu/students/NRAOstudents_summer.shtml*.

Supervisors choose their own student candidates from all applications received, and the site to which a summer student is assigned depends on the location of the NRAO supervisor who chose them. Students are encouraged to review the web pages of NRAO staff for an idea of the types of research being conducted at the Observatory. On their application, students may request to work with a specific staff member or to work on a specific scientific topic or to work at a specific site.

The program runs 10-12 weeks over the summer, from early June through early August. At the end of the summer, participants present their research results in a student seminar and submit written reports. These projects often result in publications in scientific journals. Financial support is available for students to present their summer research at a meeting of the American Astronomical Society, generally at the winter meeting following their appointment.

Besides their research, students take part in other activities, including a number of social events and excursions, as well as an extensive summer lecture series which covers various aspects of radio astronomy and astronomical research. Students also collaborate on their own observational projects using the VLA, VLBA, and/or GBT.

There are three types of Summer Student programs available at the NRAO:

The **NRAO Research Experiences for Undergraduates (REU)** program is for *undergraduates* who are citizens or permanent residents of the United States or its possessions and is funded by the National Science Foundation (NSF)'s Research Experiences for Undergraduates (REU) program.

The **NRAO Undergraduate Summer Student Research Assistantship** program is for *undergraduate students or graduating seniors* who are citizens or permanent residents of the United States or its possessions or who are eligible for a Curriculum Practical Training (CPT) from an accredited U.S. Undergraduate Program. This program primarily supports students or research projects that do not meet the REU guidelines, such as graduating seniors, some foreign undergraduate students, or projects involving pure engineering or computer programming.

The **NRAO Graduate Summer Student Research Assistantship** program is for first- or second-year *graduate students* who are citizens or permanent residents of the United States or its possessions or who are eligible for a Curriculum Practical Training (CPT) from an accredited U.S. Graduate Program.

The stipends for the 2005 Summer Student Program are $460 per week for undergraduates and $490 per week for graduating seniors and graduate students. These stipends include an allowance for housing, since housing is not provided.

Students who are interested in Astronomy and have a background in Astronomy, Physics, Engineering, Computer Science, and/or Math are preferred. The same application form and application process are used for all three programs and may be accessed at *http://www.nrao.edu/students/summer-students.shtml*. Required application materials include an on-line application form (including a statement of interest), official transcripts, and three letters of recommendation. The deadline for receipt of application materials is Monday, January 24, 2005.

F. J. Lockman
NRAO Summer Student Coordinator

Conclusion of 2004 NRAO Summer Student Research Programs

August brought to a close the 45th year of the NRAO Summer Student program. The student participants included undergraduate students, graduating seniors, and graduate students supported by various NRAO student programs (see accompanying article and *http://www.nrao.edu/students/*). The 25 student projects were detailed in the previous issue of the NRAO newsletter, and on-line summaries of this work are available at *http://www.nrao.edu/students/archive/projects.php*.

J. Hibbard

Doing Dishes and Radio Astronomy for Teachers

In June the NRAO-Socorro held a four-day pilot class for teachers called "Doing Dishes: Observational Radio Astronomy for Science Education." Funded by a NASA IDEAS grant, the purpose of the class was to design a 2-week curriculum in observational radio astronomy to be offered through New Mexico Tech's Master of Science Teaching program. Eight teachers were selected through an application process. Those chosen represented grade levels four through twelve and six school districts throughout the state. Mark Claussen, Lisa Young, and Dan Klinglesmith provided the background of the program, giving lectures and technical observing assistance as teachers learned to use the Small Radio Telescope (SRT) at the VLA Visitor Center and the 2-element instructional interferometer and optical instruments at the Etscorn Observatory on the New Mexico Tech campus.

In July, with the help of the teachers' suggestions and valuable input, the Radio Astronomy for Teachers class was expanded to two weeks and ten teachers. The curriculum included a full-day tour of the VLA, a movie night with "The Dish," and hands-on activities. The teachers learned to use the radio telescopes, set up their own experiments, analyzed the results, and presented their findings on Friday. They were also required to include a spin-off lesson plan that addressed inquiry learning and National Science Standards. Results of their work can be seen on the web at *http://www.aoc.nrao.edu/epo/teachers/RAFT/*.

The class will be taught every two years, alternating with a class in optical astronomy.

R. J. Harrison

Proceedings of Summer School in Spectrum Management for Radio Astronomy

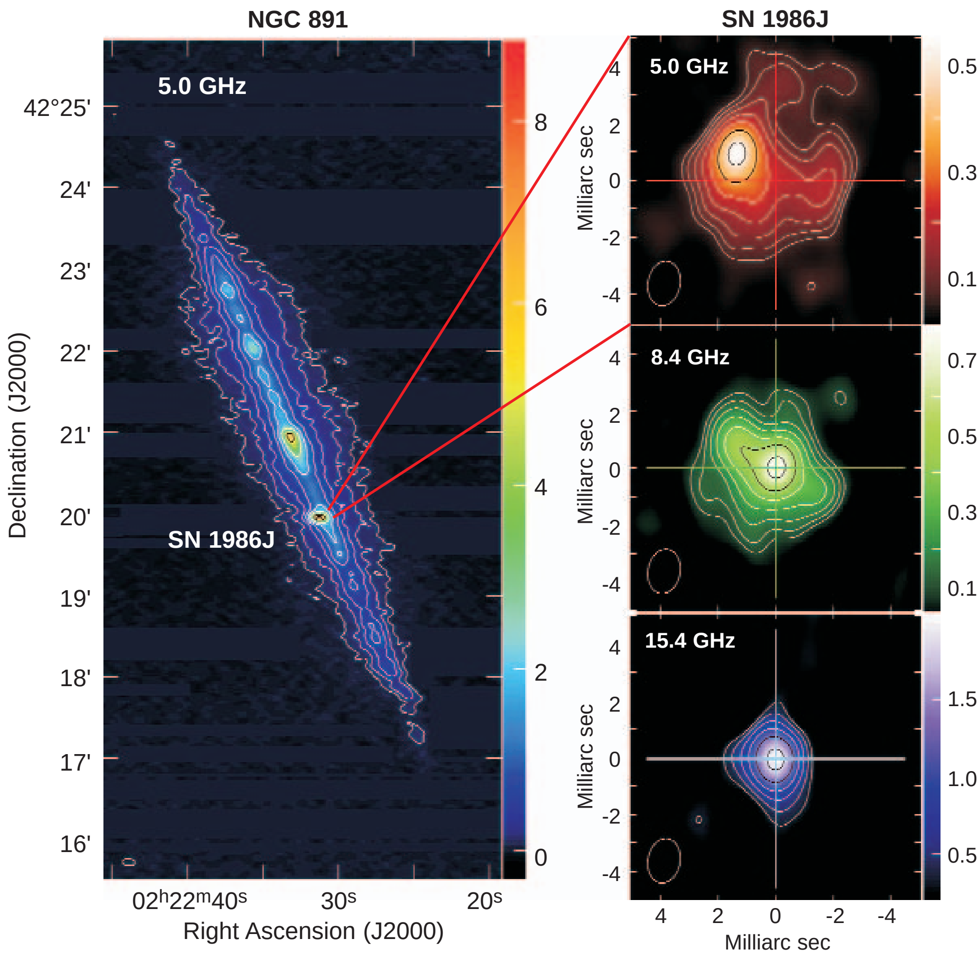
This very successful summer school was held back in 2002, but the Proceedings from it are now available. These Proceedings, edited by Murray Lewis (NAIC) and Darrel Emerson (NRAO), give a good introduction to *Spectrum Management for Radio Astronomy* as well as providing a useful reference for those already active in the field. The Proceedings can be downloaded in PDF form from *http://www.iucaf.org/ sschool/procs/*, where you can also find a Table of Contents. If you wish to have a copy in printed form (~250 pages), please contact Pat Smiley (*psmiley@nrao.edu*).

D. Emerson

New Results

First Signs of a Stellar Corpse: the Compact Core of Supernova 1986J

The VLBA, together with the VLA, GBT, and Effelsberg telescopes, has discovered a new radio source inside supernova 1986J which is most likely a compact remnant powered by the black hole or neutron star produced by the supernova. This would be by far the youngest black hole or neutron star yet detected.*



The galaxy NGC 891 and SN 1986J. The left panels shows a VLA image. The right panel shows VLBI images of SN 1986J at three frequencies, taken between November 2002 and June 2003. The large cross indicates the common origin of the coordinate system determined by phase-referencing. The central remnant appears at this origin.

Supernova 1986J was the explosion at the end of the life of a massive star in the nearby galaxy NGC 891. During their lifetimes, stars are powered by fusion, and the energy released by this process provides the pressure which keeps stars from collapsing under their own weight. Very massive stars burn their fuel all the way from hydrogen to iron; but when iron itself is fused, the reaction absorbs rather than releases energy, and the energy source abruptly turns off. In the resulting implosion the stellar core collapses upon itself, reaching higher and higher densities. Protons and electrons fuse to form neutrons, which release copious numbers of neutrinos and create a much harder equation-of-state. For some stars these twin avenues of resistance suffice to reverse the ongoing collapse, and the resulting shock wave moves out through the stellar envelope, leaving behind a neutron star. For more massive stars, even these pressure sources do not suffice, and the collapse compresses the central material beyond hope of resistance, forming a black hole. Even in this case not all of the mass falls into the center. The angular momentum of the infalling material ensures the creation of a central accretion disk, in which the angular momentum is traded between

There have been claims of optical pulsations associated with supernova 1987A in the Large Magellenic Cloud. However, these claims are controversial or their validity is not clear. See Middleditch et al. (2000) for the observational case so far.

different mass elements. Some of the mass can then fall into the growing black hole; the rest however is flung outwards at very high speeds, in the form of relativistic jets. These jets can be powerful enough to reverse the implosion and again create strong outgoing shock waves.

These shock waves, whether produced by neutron-star bounces or black-hole jets, move at tens of thousands of kilometers per second through several solar masses of material. The resulting supernovae can outshine entire galaxies.VLBI imaging can directly resolve these outgoing shocks (e.g., Bietenholz, Bartel, & Rupen 2003; Marcaide et al. 1997). The presence of pulsars near the centers of older supernova remnants (e.g., Roberts et al. 2003) confirms the association between these shock waves and the creation of neutron stars. One outstanding puzzle however has been the lack of any direct evidence for a neutron star or black hole created in a *recent* supernova. At least some young pulsars, like that in the Crab Nebula, produce nebulae which emit very strongly across the electromagnetic spectrum; yet none has been associated with any of the many hundreds of supernovae observed over the past several decades. Nor have the light curves of these supernovae compellingly suggested any extra energy source from a central remnant.

We may finally have detected such a central remnant in the peculiar supernova 1986J. This supernova was the first to be discovered at radio (rather than optical) wavelengths (Rupen et al. 1987) and is among the brightest and most persistent radio supernovae known. As such it has been the subject of ongoing radio monitoring (e.g., Weiler, Panagia, & Sramek 1990; Bietenholz, Bartel, & Rupen 2002 [BBR02]) as well as VLBI imaging (e.g., Bartel et. al 1991, BBR02). Initially it seemed to follow the typical pattern for core-collapse supernovae, with the radio source having a steep spectrum and slowly declining in flux. The VLBI images showed a ragged edge-brightened shell morphology. Recently these characteristics changed. A strong high-frequency (15-43 GHz) component appeared in the radio light curves (BBR02). Subsequent phase-referenced VLBI observatons succeeded in mapping this component and locating it within the shell. The resulting images are shown in Figure 1 (Bietenholz, Bartel, & Rupen 2004). At 5 GHz we see a distorted shell; at 8 GHz, a central component begins to appear; while at 15 GHz the shell is gone and only the central component is left.

What is this central remnant? It lies at the center of the radio shell and is unresolved in these observations, setting a limit to the angular size of 0.8 milliarcsec, or 8000 AU at the distance of NGC 891 (10 Mpc). The high brightness temperature (over 20 million K) implies that this must be synchrotron rather than thermal emission. The inverted radio spectrum (higher flux at higher frequencies) suggests that it is small enough to be absorbed at lower frequencies or that it has a very unusual intrinsically inverted spectrum. Further, it was not present in 8 GHz observations in 1988, in agreement with the radio light curves. Taken together this argues for a different physical mechanism than the expanding shock front and suggests that we are seeing a central remnant associated with the neutron star or black hole created in the supernova. For comparison, the source in SN 1986J is ~200 times stronger than the nebula powered by the Crab pulsar at 15 GHz, which may be expected given its much younger age (~18 vs. 950 years old). The central component in SN 1986J may thus represent the first association of a black hole or neutron star with an observed, modern supernova. This black hole or neutron star would then be by far the youngest yet known.

M.F. Bietenholz, N. Bartel, & M.P. Rupen

References:

Bartel, N., Rupen, M. P., Shapiro, I. I., Preston, R. A., & Rius, A. 1991 Nature 350, 212

Bietenholz, M.F., Bartel, N., & Rupen, M.P. 2002, ApJ, 581, 1132 [BBR02]

Bietenholz, M.F., Bartel, N., & Rupen, M.P. 2003, ApJ, 597, 374

Bietenholz, M.F., Bartel, N., & Rupen, M.P. 2004, Science, 304, 1947

Marcaide, J.M. et al. 1997, ApJL, 486, 31

Middleditch, J. et al. 2000, NewA, 5, 243

Roberts, M.S.E. et al., 2003, ApJ, 588, 992

Weiler, K.W., Panagia, N., & Sramek, R.A. 1990, ApJ, 364, 611

Exploring the Origins of Black Holes and Neutron Stars

It is believed that relativistic stars (neutron stars and black holes) are fossils of the most massive stars. There are several theoretical models on the properties of the stellar progenitors and the physics involved in their collapse. However, it has been difficult to obtain observational constraints to these theories. For instance, the mass limit above which stars end as black holes, and under what conditions black holes form in energetic supernova explosions, are both subjects of debate.

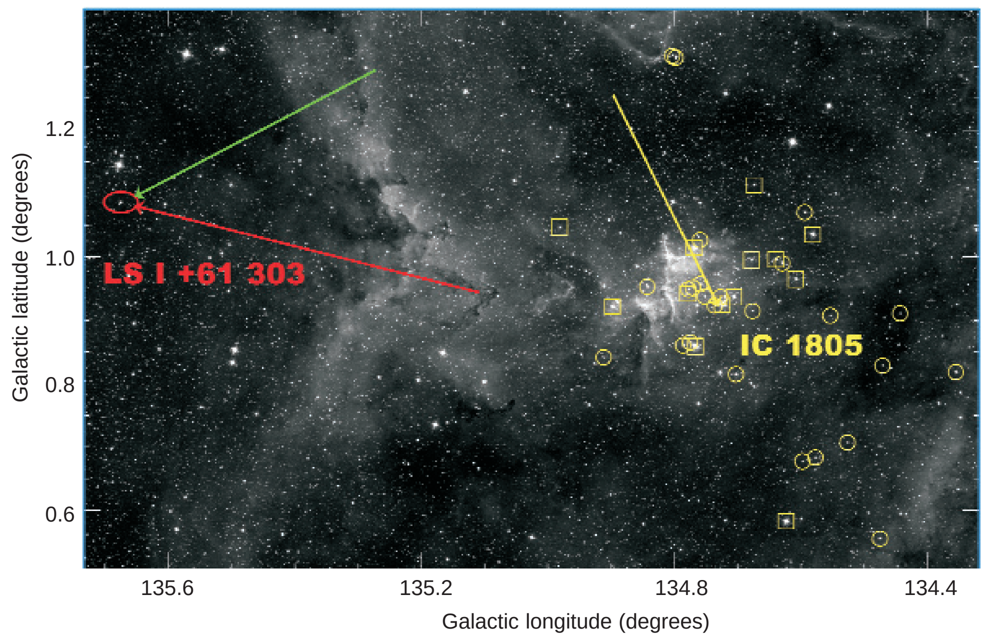


Figure 1. The X-ray binary LS I +61° 303 (circled in red) was shot out from its birth place in a complex of massive stars (yellow) in this visible-light image. The green arrow indicates the microquasar's motion on the sky and the yellow arrow indicates the star cluster's motion. The red arrow indicates the microquasar's motion relative to (away from) the star cluster.

The kinematics of X-ray binaries in our Galaxy can provide clues to help answer these types of questions. When a neutron star or black hole interacts with a mass-donor star, the distance, proper motion, radial velocity, and therefore the space velocity of the binary in three dimensions can be determined. Observations with the Very Long Baseline Array (VLBA) had shown that X-ray binaries produce optically thick compact jets of sizes ≤100 AU (e.g., Dhawan et al. 2000). Subsequent VLBA astrometry of the compact jet of the microquasar XTE J1118+480 in the Galactic halo allowed us to determine its proper motion with unprecedented precision (Mirabel, Dhawan, Mignani, et al. 2001).

Those first results encouraged us to start the analysis and integration of multiwavelength data bases on X-ray binaries that are in the public domain. VLBA astrometric measurements of X-ray binaries by Bradshaw et al. (1999), Lestrade et al. (1999), and others were integrated with optical data from diverse sources to derive the space velocities and gain insight on the birth places and mechanisms of formation of the compact objects in the following X-ray binaries: LS 5039 (Ribó et al. 2002), GRO J1655 – 40 (Mirabel et al. 2002), Cygnus X-1 (Mirabel & Rodrigues 2003a), Scorpius X-1 (Mirabel & Rodrigues 2003b) and LS I +61° 303 (Mirabel et al. 2004). The low-mass black hole GRO J1655 – 40 was found to be moving with a large runaway velocity, which is consistent with a delayed formation in a hypernova explosion (Israelian et al. 1999).

Recently, we found that LS I +61° 303 is running away from its birth place in a young complex of massive stars (Figure 1). The supernova explosion that formed the compact object of ≤ 2 $M_\odot$ ($M_\odot$ is the mass of the Sun) blew away about 2 $M_\odot$ shooting out the binary with a linear momentum of 430 $M_\odot$ km s^{-1}, which is comparable with the linear momentum found in solitary neutron stars and millisecond pulsars (Mirabel, Rodrigues, & Liu 2004). The orbital parameters of the binary combined with its runaway speed imply that the natal supernova was asymmetric. If the progenitor of the compact object was formed only four or five million years ago as one of the most massive stars present in the cluster IC 1805, the star would have been 60 or more times as massive as the Sun and would have expelled some 90 percent of its initial mass before the supernova explosion.

On the contrary, Cygnus X-1 moves along with its parent association of massive stars and was not kicked out from it (Figure 2). The upper limit for a runaway linear momentum of Cygnus X-1 indicates that the black hole of ~10 $M_\odot$ did not receive a trigger as energetic as that imparted to the compact object in LS I + 61° 303. Therefore, the black hole in Cygnus X-1 was formed in situ, and if the massive star formation in the parent association was coeval, the progenitor would have been 40 or more times as massive as the Sun.

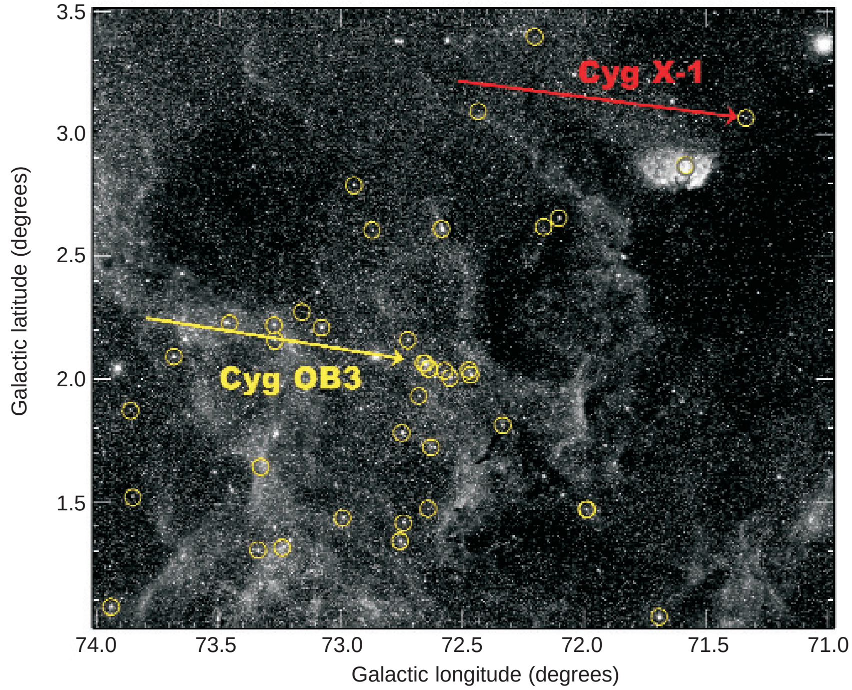


Figure 2. Motions of Cygnus X-1 (red arrow) and the association of massive stars Cygnus OB3 (yellow arrow) are shown in this visible-light image. Contrary to LS I +61° 303, Cygnus X-1 was not kicked out from its birth place. The upper limit for a runaway linear momentum suggests that the black hole in Cygnus X-1 was formed in the dark from a progenitor that would have been 40 or more times as massive as the Sun.

Although the number statistics are still low, these preliminary results are consistent with evolutionary models for binary massive stars (Balberg & Shapiro 2001; Fryer et al. 2002), where neutron stars and low-mass black holes form in energetic supernova explosions, whereas the black holes with the larger masses form in underluminous supernovae or even in complete darkness. The development of astrometric facilities at radio (VLBI) and other wavelengths will help us to understand both the evolution of stars before they explode as supernovae and the physics of the supernova explosions themselves.

I. Félix Mirabel
CEA-Saclay-France & CONICET-Argentina

References:

Balberg, S. & Shapiro, S.L. 2001, ApJ, 556, 944
Bradshaw, C. F., Fomalont, E. B. & Geldzahler, B. J. 1999, ApJ, 512, L121
Dhawan, V., Mirabel, I. F. & Rodríguez, L. F. 2000, ApJ, 543, 373
Fryer, C.L., Heger, A., Langer, N., & Wellstein, S. 2002, ApJ, 578, 335
Israelian, G., Rebolo, R., Basri, G. et al. 1999, Nature, 401, 142
Lestrade, J. F., Preston, R.A., Jones, D.L. et al. 1999, A&A, 344, 1014
Mirabel, I.F., Dhawan, V. Mignani, R.P. et al. 2001, Nature 413, 139
Mirabel, I.F., Mignani, R., Rodrigues, I. et al. 2002, A&A, 395, 595
Mirabel, I.F. & Rodrigues, I. 2003a, Science 300, 1119
Mirabel, I.F. & Rodrigues, I. 2003b, A&A, 398, L25
Mirabel, I.F., Rodrigues, I. & Liu, Q.Z. 2004, A&A, 422, L29
Ribó, M., Paredes, J.M., Romero, G.E. et al. 2002, A&A, 384, 954

GBT Discovery of Two New Interstellar Molecules: Propenal & Propanal

Using the Robert C. Byrd Green Bank Telescope, we discovered two new interstellar molecules (Figure 1) —propenal (CH_2CHCHO) and propanal (CH_3CH_2CHO)— toward the giant molecular cloud Sgr B2(N) (Hollis et al. 2004). We detected two transitions of the 8-atom molecule propenal and six transitions of the 10-atom molecule propanal. Propanal is now one of the largest organic molecules known in the interstellar medium and its detection helps to constrain the formation mechanism of these large molecular species.

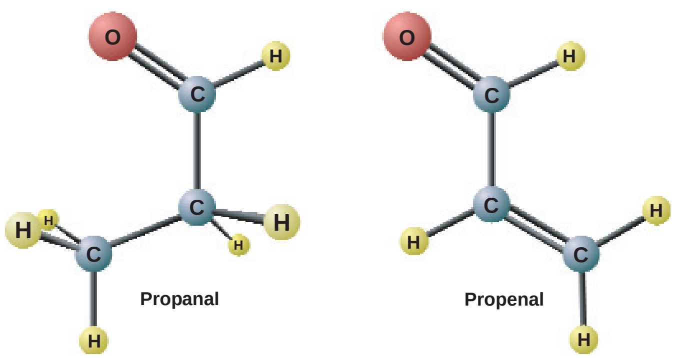


Figure 1. Diagrams of the 10-atom molecule propanal and the 8-atom molecule propenal.

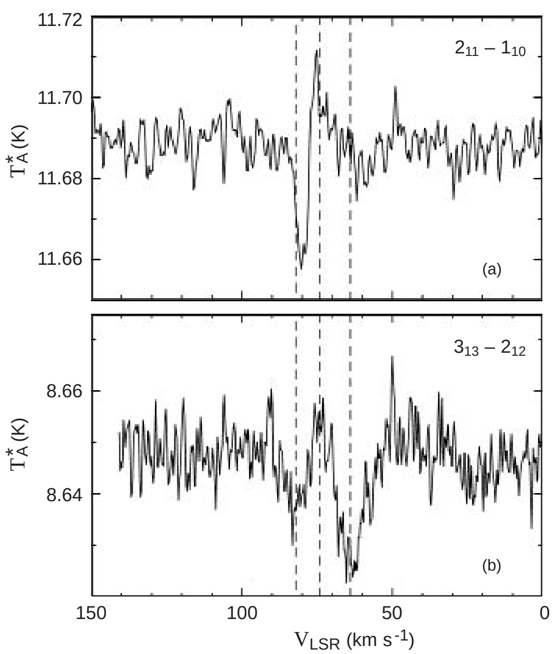
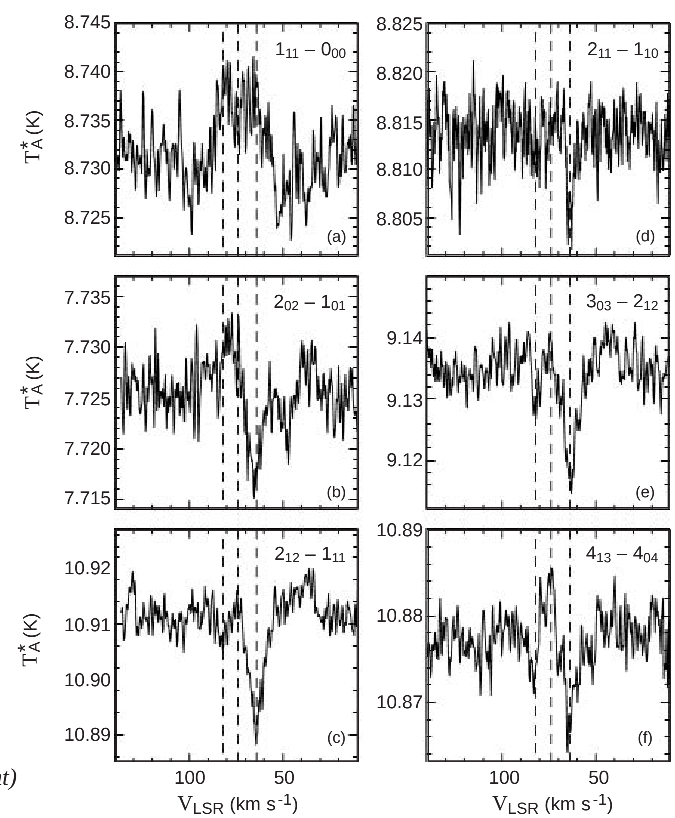


Figure 2a (above) CH_2CHCHO Propenal spectra and Figure 2b (right) CH_3CH_2CHO Propanal spectra. Both toward Sgr B2(N).

The observations of propenal and propanal were made in February 25 - April 17, 2004. Figures 2a and 2b show the spectra of propenal and propanal, respectively. In almost all cases, we see a strong absorption component near the LSR velocity of +64 km s^{-1}. However, also seen are a weaker absorption component at +82 km s^{-1} and a self-absorbed component at +74 km s^{-1}. The spectra show all these features that are presumably due to differences in the competing effects of emission and absorption for any given transition.

Not only were these observations significant because they were the first detections of new species using the GBT, but the observations also gave insight into their formation. Many complex molecules seen in the direction of Sgr B2(N) are shown by interferometry to be largely confined to the Large Molecule Heimat (LMH) region, which is a hot molecular core about 5" in diameter. Such molecules include methyl formate, acetic acid, ethyl cyanide, acetone, formic acid, vinyl cyanide and methyl cyanide. However, aldehydes including



formaldehyde, formamide, acetaldehyde, glycolaldehyde, propynal, propenal, and propanal are detected with single-dish telescopes or interferometers having large synthesized beams indicating that these molecules have significant spatial scales on the order of arcminutes. Thus, an efficient formation mechanism must be taking place to form these molecules and then to distribute them into the cold gas phase.

One of the simplest possible formation mechanisms to build larger molecular species is successive hydrogen addition to a molecule either on a grain surface or in grain mantles. This formation mechanism has been tested by laboratory experiments with interstellar ice analogs (Hudson & Moore 1999). The detection of interstellar propenal and propanal, along with the known interstellar species propynal, all toward the same source, may imply the following hydrogen-addition formation sequence:

$$\underset{\text{(Propynal)}}{HC_2CHO} + 2H \rightarrow \underset{\text{(Propenal)}}{CH_2CHCHO} + 2H \rightarrow \underset{\text{(Propanal)}}{CH_3CH_2CHO}$$

Finally, in addition to constraining formation models, the detection of these two new aldehydes in the interstellar medium has wider-reaching implications concerning prebiotic organic chemistry. For example, one type of laboratory synthesis that forms amino acids, called Strecker synthesis, requires the presence of ammonia (NH_3), hydrogen cyanide (HCN), and aldehydes (-CHO). Thus, our observations are not only helping to constrain interstellar astrochemistry but are beginning to investigate the question of whether some part of the prebiotic organic chemistry that happened on the early Earth could have taken place in interstellar space.

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References:

Hollis, J.M., Jewell, P.R., Lovas, F.J., Remijan, A., & Møllendal, H. 2004, ApJ, 610, L21
Hudson, R.L., & Moore, M.H. 1999, Icarus, 140, 451

Probing the Births of Super Star Clusters

Super star clusters (SSCs) are among the most extreme star-formation environments known. These clusters are incredibly massive and dense, with each harboring on the order of a million stars within a radius of only a few parsecs. Many SSCs have properties that are consistent with being adolescent versions of the ancient globular clusters which are ubiquitous in massive galaxies at the current epoch. Moreover, because thousands of massive stars are formed nearly simultaneously in SSCs, they have a violently disruptive effect on their surrounding interstellar medium when the combined stellar winds and supernovae get underway.

During their earliest evolutionary stages, SSCs are shrouded in their natal material, rendering standard optical (and near-infrared) stellar and nebular diagnostics unusable. Nevertheless, if we want to understand the physical conditions that are capable of creating these incredible clusters, we must observe them while they are forming—necessitating radio observations at long wavelengths.

Several investigations at radio and thermal-infrared wavelengths have now revealed a population of extremely young SSCs (Johnson & Kobulnicky 2003, and references therein). At radio wavelengths, these natal clusters manifest themselves as compact optically thick free-free sources, with turnover frequencies $\gtrsim$5 GHz (Figure 1). To produce a spectral turnover at such a high frequency, extremely dense (over 10,000 electrons per cubic cm)) ionized gas is required.

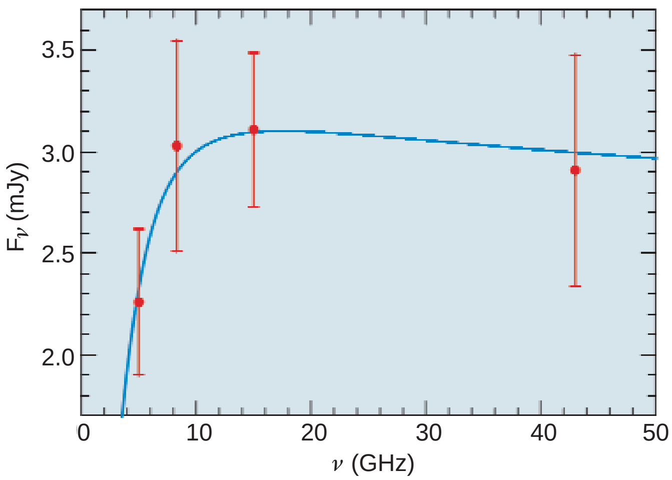

Figure 1. The radio spectrum of the most luminous natal super star cluster in the starburst galaxy Henize 2-10 along with a model fit (Johnson & Kobulnicky 2003). All observations are from the VLA.

This spectrum is remarkably similar to (although vastly scaled-up from) those of individual high-mass protostars in the Milky Way, the so-called "ultra compact HII regions" (e.g., Wood & Churchwell 1989). This similarity suggests that the early stages of SSC evolution may parallel those of individual massive stars. Therefore, observations of individual ultracompact HII regions in the Galaxy are critical to interpreting observations of natal clusters.

Based on existing knowledge of ultracompact HII regions, the simplest physical model for natal SSCs is the following: Newly born massive stars ionize the dense material in their immediate vicinity, creating an extremely dense HII region. The HII region is in turn surrounded by a dust cocoon whose inner boundary is presumably near the sublimation temperature. Sparse clusters are likely to contain spatially discrete HII regions and cocoons, but the existence of individual cocoons becomes less tenable in the extreme stellar densities of the cores of massive SSCs.

Observations have provided estimates for some of the physical properties of natal clusters, including their size, electron density, pressure, stellar mass, HII mass, dust mass, and age. For example, recent VLA observations of the starburst galaxy Henize 2-10 at 7 mm wavelength (see Figure 1) have enabled us to place relatively tight constraints on the radii and densities of the previously detected natal SSCs in this galaxy (Kobulnicky & Johnson 1999; Johnson & Kobulnicky 2003). In this case, the dense HII regions surrounding the natal clusters have radii ~ 2–4 pc and average electron densities of ~$10^3 - 10^4$ cm^{-3} (with peak values of ~$10^5 - 10^6$ cm^{-3}). The pressures implied by these densities are $P/k_B \sim 10^7 - 10^{10}$ cm^{-3} K, several orders of magnitude higher than typical pressures in the interstellar medium of our Galaxy. Such pressures may seem commonplace to those who work on star

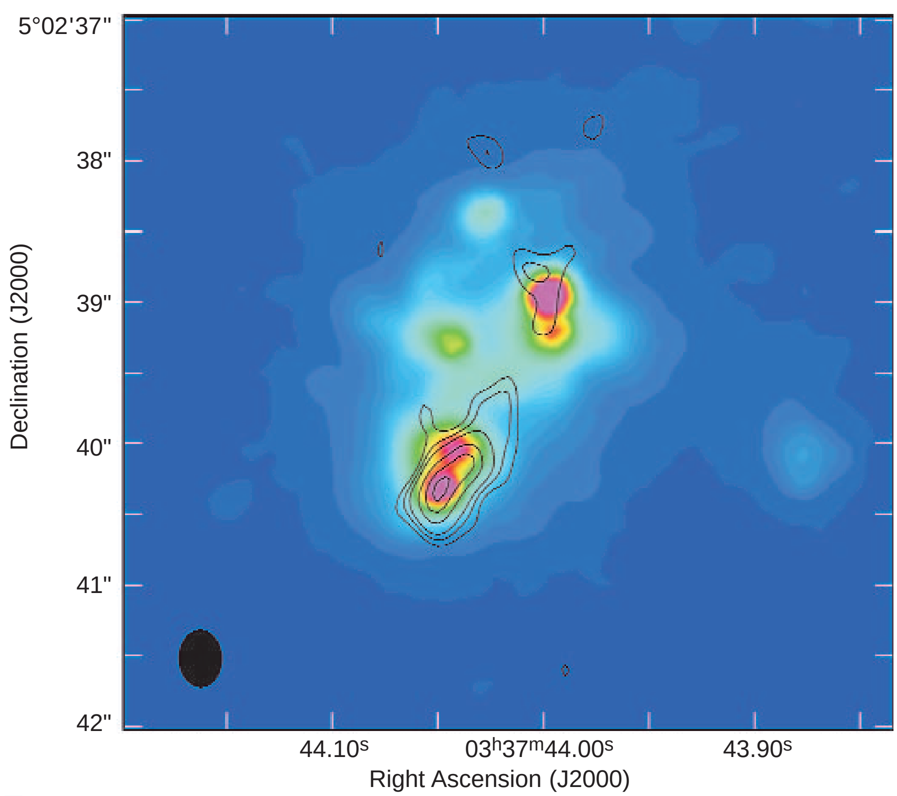

Figure 2. The starburst galaxy SBS 0335−052. VLA 1.3 cm contours are overlaid on an HST I-band image. The luminous radio source is a natal super star cluster that has an ionizing luminosity equivalent to that of ~10,000 O7-type stars (Johnson & Plante, in prep.).

formation in the Milky Way, but one has to bear in mind the large volumes over which these pressures are sustained for SSC formation.

Another fascinating galaxy in which to study natal SSCs is the ultra-low-metallicity galaxy SBS 0335 – 052. With a metallicity only 1/40 that of the Sun, this galaxy has the second lowest metallicity known (Melnick, Heydari-Malayeri, & Leisy 1992) and is perhaps the best analog of a "primordial'' starburst in the local universe. This galaxy provides us with the opportunity to study what effect extremely low metallicity in the early universe may have had on globular cluster formation and assess whether SSCs forming now are indeed the precursors to globular clusters. New high-resolution radio images of this galaxy indicate a powerful thermal source (Figure 2; Johnson & Plante, in prep.), and thermal-infrared observations suggest that the nascent cluster lies behind $A_V > 15 - 30$ magnitudes of extinction (Plante & Sauvage 2002). These radio and infrared observations require an ionizing luminosity equivalent to ~10,000 O7 type stars within a radius < 10 pc, making it one of the most incredible star forming sites anywhere in the local universe.

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References:

Johnson, K. E. & Kobulnicky, H. A. 2003, ApJ, 597, 923
Kobulnicky, H. A. & Johnson, K. E. 1999, ApJ, 527, 154
Plante, S. & Sauvage, M. 2002, AJ, 124, 1995
Melnick, J., Heydari-Malayeri, M., & Leisy, P. 1992, A&A, 338, 43
Wood, D. O. & Churchwell, E. 1989, ApJS, 69, 831

The Double Pulsar System J0737-3039: How A Modulates B

The two pulsars ("A" and "B") in the double-pulsar binary system J0737-3039 have periods of 23 milliseconds and 2.8 seconds and are in a 2.4-hour mildly eccentric orbit which we view nearly edge-on (Burgay et al. 2003, Lyne et al. 2004). The system has already provided unprecedented opportunities for studying relativistic gravity and relativistic plasma physics and for probing pulsar magnetospheres. Exploratory-time GBT observations in December 2003 and January 2004 have allowed detailed studies of the pulsars' velocities (Ransom et al. 2004), their polarization and morphological properties (Demorest et al. 2004, Ramachandran et al. 2004), and the A pulsar's eclipse (Kaspi et al. 2004).

The flux density of the 2.8-second pulsar B varies significantly around the orbit. The B pulsar is very strong, with single pulses detectable, when it is "in front" of A and is quite weak at other orbital phases. These variations suggest that the emission of B is strongly influenced by the radiation from A. This is not surprising, given that the rate of spin-down energy loss from A is 3600 times greater than that from B. Our analysis of data taken with the remarkably sensitive combination of the GBT 820 MHz receiver and the SPIGOT card has revealed the first direct observational evidence for such an interaction between the two pulsars. In Figure 1, we present a sequence of single pulses from B at one of the two orbital phases when single pulses are detectable. A striking effect, easily seen in this plot, is a drifting phenomenon occurring in the leading part of the pulse. These drifting features are not observed in the other orbital phase range at which single pulses from B are detectable.

How do we explain these features? At first sight, they are very similar to the drifting subpulses that have been detected from a number of "normal" radio pulsars. However, further investigation reveals that the separation of features within a given B pulse is exactly 23 milliseconds, equal to the period of the A pulsar. Furthermore, the spacing of the drifting features in time is 5.10 B periods, corresponding to a fluctuation frequency of 0.196 cycles per period of B. This frequency is exactly equal to the beat frequency between the periods of the two pulsars.

Using the intrinsic periods of the two pulsars and their orbital elements, we can accurately predict the frequency of A's pulsed radiation as seen by B. In Figure 2, we show an expanded view of the single pulses from Figure 1 with the predicted phases at B of a signal with A's periodicity. It is clear that the drifting pattern closely follows the predicted variation in phase. This, and the fact that the separation of successive features within a given pulse is equal to the period of A, show that these features are due to the direct influence of a signal with A's periodicity on the B pulse emission mechanism. This may be due to the magnetic component of A's radiation field modulating the magnetic field of B, "wiggling" its beam and taking it in and out of our line of sight.

Why do we only see this drifting phenomenon at certain orbital phases? This can be understood given the geometry of the system. The energy and momentum from A's electromagnetic radiation distort B's magnetosphere into a cometary shape. When B is between us

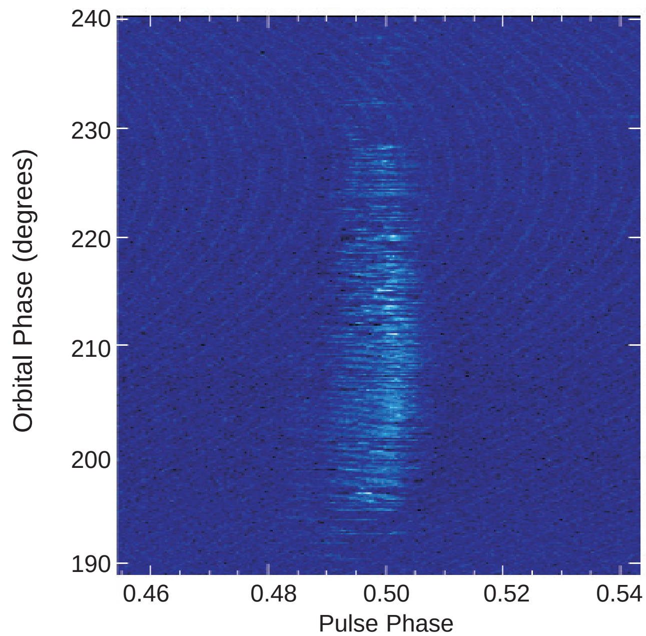

Figure 1. Single pulses of B at 820 MHz for orbital phases 190 - 240 degrees on MJD52997. There are 403 B pulses included in this plot, with only 10 percent of the pulse period of B shown. Drifting features are present through most of these data, but are particularly obvious in the leading part of the pulse between orbital phases 195 and 210 degrees. Single pulses from both components of A may also be seen in the background, most clearly at orbital phases around 225 degrees, where differential Doppler shifts from the orbital motion result in harmonically related apparent pulse periods.

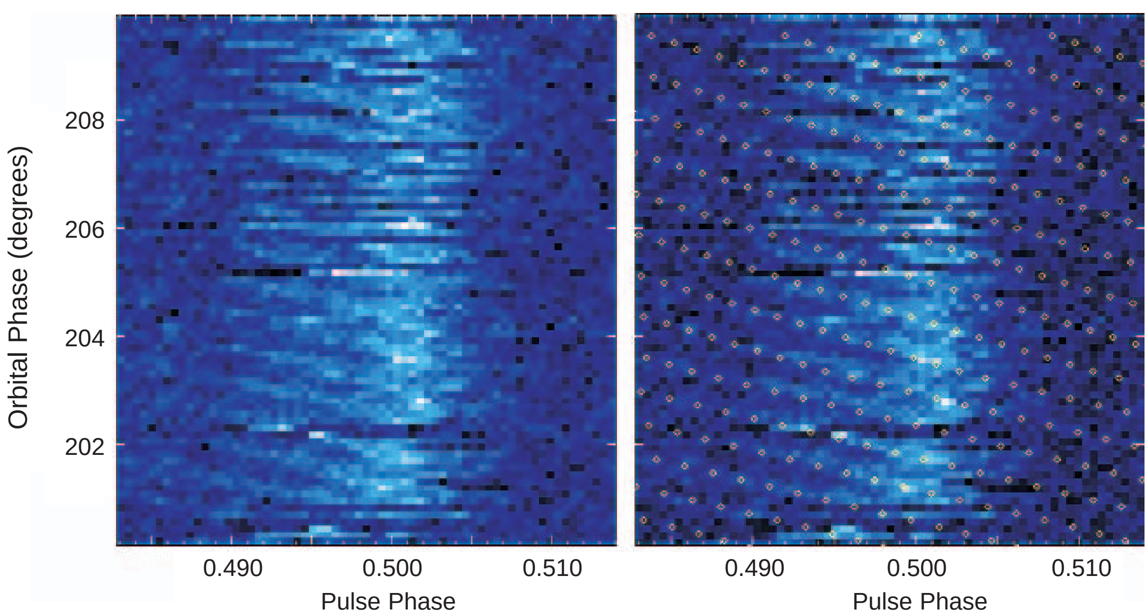

Figure 2. (Left) An expanded view of Figure 1 from orbital phases 200 to 210 degrees. (Right) Yellow dots denote the arrival at the center of B of emission from an arbitrary rotational phase of A.

and A, the B pulses propagate through the cometary tail and are relatively undisturbed. However, for the orbital phase range plotted in Figure 1, the radiation from A is more transverse to the field lines in the emission and propagation zones, allowing the modulation process to be effective.

In summary, our analysis, reported in McLaughlin et al. (2004), has revealed the first direct evidence for an interaction between A and B. Further studies of this phenomenon will be extremely important for understanding not only the unique emission processes in this system, but pulsar radio emission in general. Furthermore, detailed studies of this drifting behavior may enable us to significantly improve our knowledge of the geometry of and physics responsible for B's emission beam.

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References:

Burgay, M. et al. 2003, Nature, 426, 531
Demorest, P. et al. 2004, ApJ, in press (astro-ph/0402025)
Kaspi, V. M. et al. 2004, ApJ, in press (astro-ph/0401614)
Lyne, A. G. et al. 2004, Science, 303, 1153
McLaughlin, M. A. et al. 2004, ApJ, in press (astro-ph/0407265)
Ramachandran, R. et al. 2004, ApJ, in press (astro-ph/0404392)
Ransom, S. M. et al. 2004, ApJ, 609, L71