National Radio Astronomy Observatory
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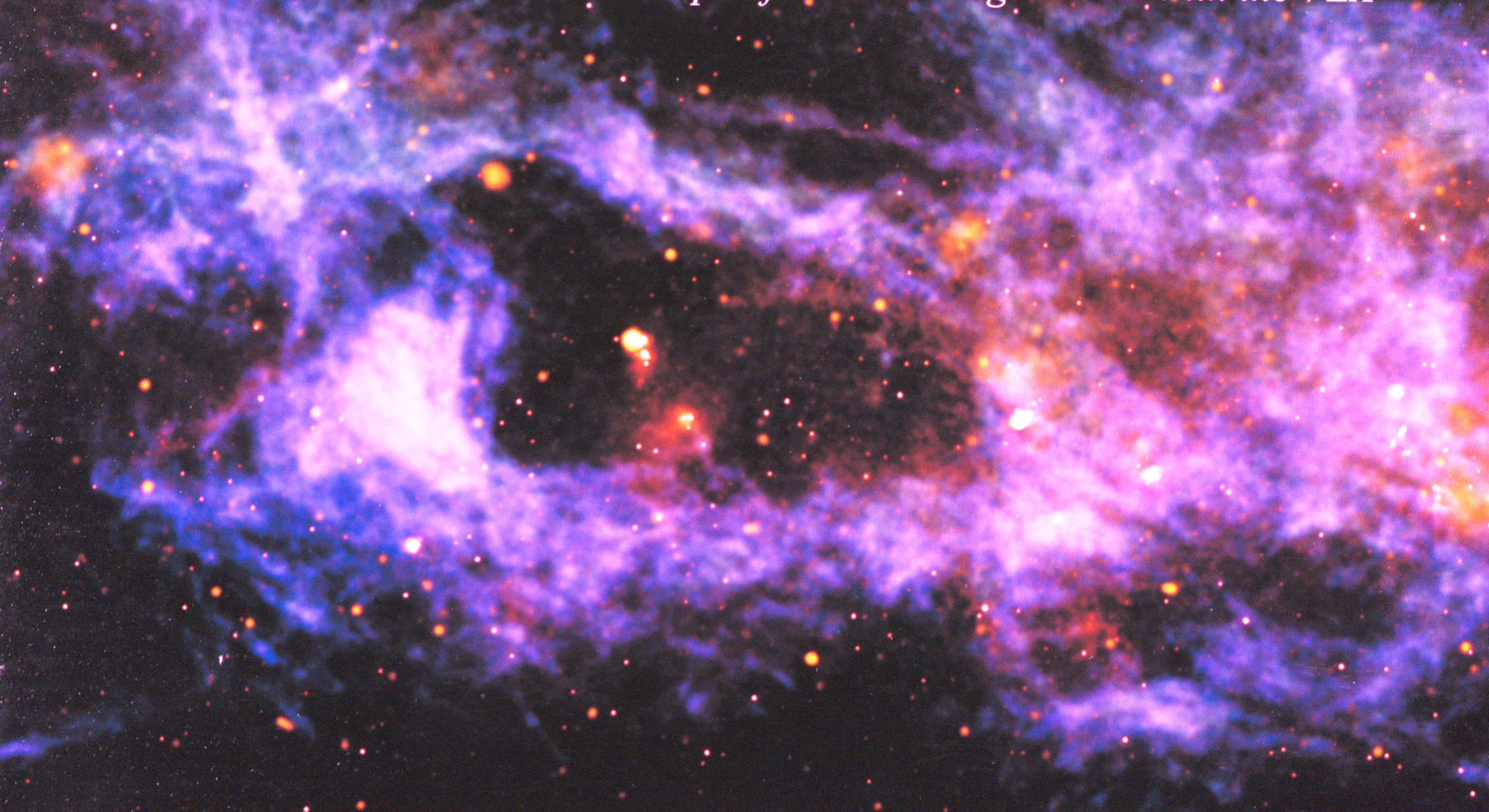
Issue 111

VLA Reveals "Smoking Gun" for How Multiple-Star Systems Form

ALMA Achieves Major Milestone with Antenna-Link Success

Extended Circumstellar Envelope of RS Cnc Imaged in HI with the VLA



Also in this Issue:

Weighing the Central Star of NGC 7027

Expanded Coverage in L-Band Now Available on EVLA Antennas

VLBI with the VLA Including EVLA Antennas

VLBA 22 GHz Receiver Upgrade

VLA Archive Pipeline

GBT Instrumentation Update

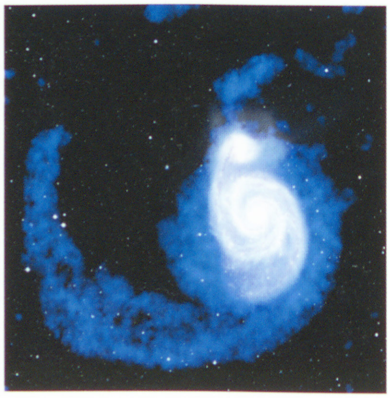
Sister Cities: San Pedro de Atacama, Chile, and Magdalena, New Mexico

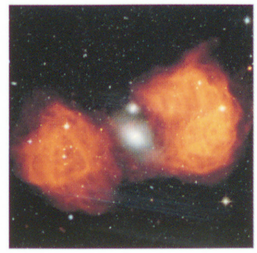
A Web-based Course in Radio Astronomy

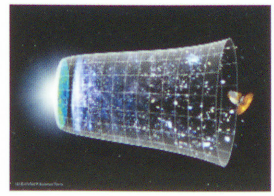
TABLE OF CONTENTS

Cover: What appears to be the hole of an elongated smoke ring in this image really is an enormous, nearly empty, bubble blown into the dusty, gas disk of our Milky Way Galaxy. NRAO/AUI Image Contest 2006 - First Place Award: Composition by J. English (Manitoba), J. M. Stil and A. R. Taylor (Calgary). Investigators: J. M. Stil, A. R. Taylor, J. M. Dickey, D. W. Kavars, P. G. Martin, T. A. Rothwell, A. I. Boothroyd, Felix J. Lockman, and N. M. McClure-Griffiths.

NRAO 50th Anniversary







List of Speakers
Don Backer
Amy Barger
Barry Barish
Roger Blandford
Jim Braatz
Rich Bradley
Paul Butler
John Carlstrom
Jim Condon
Jim Cordes
Ger de Bruyn
Frank Drake
Heino Falcke
Henry Ferguson
Ed Fomalont
Martha Haynes
Dave Heeschen
George Helou
Craig Hogan
Garth Illingworth
Nissim Kanekar
Michael Kramer
Shri Kulkarni
Fred K.Y. Lo
Avi Loeb
Jim Moran
Ue-Li Pen
Scott Ransom
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Patrick Thaddeus
Paul Vanden Bout
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Eli Waxman
Robert Wilson

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- Origin of Cosmic Structure & Galaxy Evolution
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June 18-21, 2007, Omni Charlottesville Hotel

www.nrao.edu/50 early registration deadline - April 15, 2007

NRAO 50 YEARS

Registration to attend the NRAO 50th Anniversary Science Symposium is now underway. The response thus far has been significant, and it is inspiring to see the names of colleagues from the past and present planning to attend. Note that the early registration deadline is April 15. To register and obtain more information, please visit the symposium's website at *http://www.nrao.edu/50*.

Science

The Extended Circumstellar Envelope of RS Cnc Imaged in HI with the VLA

For stars of low to intermediate mass ($0.8 \lesssim M_* \lesssim 6 M_\odot$), evolution onto the asymptotic giant branch (AGB) marks the final chapter in their lives as thermonuclear burning stars. This stage is characterized by an enormous increase in luminosity (up to several thousand $L_\odot$) and significant mass-loss ($\sim 10^{-8}$ to $10^{-4} M_\odot$ yr^{-1}) through cool, low-velocity ($\sim$10 km s^{-1}) winds. Over the course of roughly a million years, the material ejected from the atmospheres of such stars creates extensive circumstellar envelopes, up to a parsec or more in diameter. Following the AGB phase, the star will slowly contract to form a white dwarf, which may briefly ionize the surrounding circumstellar debris to form a planetary nebula.

Mass-loss during the AGB phase is one of the primary means through which enriched material is recycled back into the interstellar medium (ISM). Because the resulting circumstellar envelopes are so extensive, this process also plays a role in shaping the structure of the ISM on parsec scales. Furthermore, for AGB stars in binary systems, the geometry of the circumstellar ejecta may be crucial to the evolution of Type Ia supernovae. Overall, knowledge of the mass-loss histories of evolved stars is key to understanding the complete life-cycle of our Galaxy.

Traditionally, the circumstellar envelopes of AGB stars have been studied primarily through trace molecular species (e.g., CO; dust grains; SiO, H_2O, OH masers). However, by far the most abundant species in circumstellar envelopes is hydrogen. Atmospheric models predict that for the coolest giants ($T_{\rm eff} \lesssim 2500$K), hydrogen shed from the stellar atmosphere will be predominantly molecular, while in warmer stars ($T_{\rm eff} > 2500$K), it will be mainly atomic (Glassgold & Huggins 1983). Nonetheless, even for cooler stars, circumstellar HI may be formed as a result of the dissociation of H_2 by chromospheric emission, shocks, a hot companion, or the interstellar radiation field. As the circumstellar envelope expands, additional atomic material may also be swept up from the ambient ISM. This suggests that in the majority of AGB stars, at least some fraction of the circumstellar envelope should be atomic hydrogen, and therefore be traceable via the HI 21-cm line. Because HI is not destroyed by the interstellar radiation field, it has the potential to trace circumstellar envelopes to much larger distances from the star than molecules, thereby sampling a significantly larger fraction of the stellar mass-loss history.

The main drawback of using HI as a probe of circumstellar envelopes is that even for the nearest AGB stars, its signal is expected to be quite weak, and often is confused with strong interstellar emission along the line-of-sight. For this reason, early searches for HI in circumstellar envelopes were largely unsuccessful, and yielded only one detection of a bona fide AGB star (*o* Ceti; Bowers & Knapp 1988). However, this situation has changed dramatically during the past few years. Indeed, a team using the Nançay Radio Telescope in France has recently reported HI detections of roughly two dozen AGB and related stars (Le Bertre & Gérard 2001, 2004; Gérard & Le Bertre 2003, 2006; Gardan et al. 2006).

Motivated by the Nançay results, we have recently begun an HI imaging survey of AGB stars with the VLA (Matthews & Reid 2007). The VLA is complementary to single-dish telescopes for the study of HI in circumstellar environments, since it provides key information on the geometry of the HI gas and its distribution relative to the star. In addition, as an interferometer, the VLA is an effective filter of large-scale interstellar contamination.

Using the VLA in its smallest (D) configuration, we have detected HI at velocities consistent with the circumstellar envelopes of four out of five AGB stars observed to date (see Matthews & Reid 2007 for details). Three of these stars were already suspected to have circumstellar HI based on Nançay observations. Perhaps our most intriguing detection so far is that of

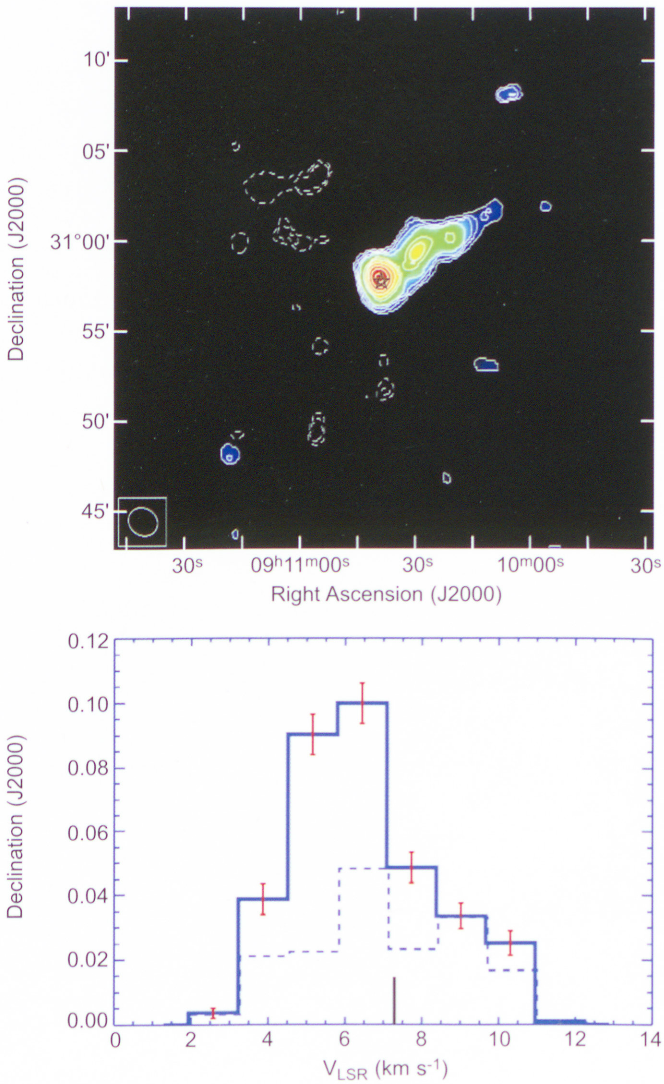

Figure 1a. (top panel): HI total intensity map of a 30'×30' region around the semi-regular variable RS Cnc obtained with the VLA. The spatial resolution is 102"×90" and the contour levels are (-16, -8, 8, 16, 24... 86)×1.25 Jy beam^{-1} m s^{-1}. A star symbol marks the star's optical position. Figure 1b. (bottom panel): Integrated HI spectrum of RS Cnc based on the VLA data. The dashed line shows the contribution from the more extended emission component to the northwest, and the thick line shows the total emission. The black vertical bar indicates the stellar systemic velocity derived from CO observations.

the S-type semi-regular variable RS Cnc (Figure 1). This star is located at a distance of 122 pc and has a spectral type of MIII8 and an effective temperature $T_{\rm eff}$=3110 K.

The VLA has revealed circumstellar HI surrounding RS Cnc comprising a compact, slightly elongated region centered on the star (with mean diameter ~82" or 0.05 pc), together with a more extended emission component, reaching 6' (0.2 pc) to the northwest (Figure 1a). The latter component is comparable in extent to the dust emission previously detected by IRAS. Both the compact and extended HI components toward RS Cnc peak within ~0.5 km s^{-1} of the stellar systemic velocity (Figure 1b).

The existence of two distinct emission components toward RS Cnc implies that its mass-loss has occurred during multiple episodes and that a portion of this mass-loss was highly asymmetric. These findings contrast with traditional spherically symmetric outflow models where the mass-loss remains constant with time. We measure similar HI fluxes for both components, implying a total HI mass of $M_{\rm HI}\approx 1.5\times 10^{-3}\,M_{\odot}$—comparable to the mass of Jupiter! This amount of HI is likely too large to have been formed through the dissociation of H_2 by the interstellar radiation field, implying this material was shed directly from the star in atomic form. The total HI mass could be somewhat higher if there is an additional large-scale component to which the VLA is insensitive (see Gerard & Le Bertre 2003). Our data also provide a new estimate for the recent mass-loss rate for RS Cnc of the $\approx 1.7\times 10^{-7}$ $M_{\odot}$ yr^{-1}.

The detection of HI in the circumstellar envelopes of AGB stars such as RS Cnc with the VLA underscores the potential of the VLA and EVLA for furthering our understanding of the late stages of stellar evolution. With the complementary imaging studies of the molecular components of circumstellar envelopes that will become available from ALMA, radio observations will continue to play a critical role in our understanding of stellar mass-loss and its role in shaping the Galaxy.

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VLA Reveals "Smoking Gun" for How Multiple-Star Systems Form

Understanding how stars form has a broad impact across many areas of contemporary astrophysics, from the formation and evolution of galaxies to the creation of planetary systems. The VLA has played an important role in studies of star formation, providing, for example, images at the highest angular resolution currently available for bipolar ionized jets from young stellar objects. And with its ability to penetrate the thick dust envelopes surrounding nascent stars, the VLA can pinpoint the location of the driving source of larger-scale bipolar molecular outflows.

Thanks to a large body of observations spanning radio to X-ray wavelengths complemented by theoretical studies, we now have a solid framework for explaining the formation of single low-mass stars like the Sun (e.g., Shu et al. 1987). Such stars form within dense condensations in giant molecular clouds: these condensations collapse from inside out by virtue of their own gravity, seeding at their centers a nascent star (i.e., protostar). Infalling material from the rotating condensation does not directly fall onto the protostar, but first collects in a rotating disk around the protostar. As this material is transported inward along the disk a portion is diverted into a bipolar outflow, which carries away excess angular momentum thereby allowing the remaining material to accrete onto the protostar. Over time material in the condensation is depleted (in part blown away by the bipolar outflow), leaving a newly-born star with a remnant circumstellar disk that may form planets.

The process outlined above, however, is not the main pathway by which most low-mass stars form. About two-thirds of low-mass stars are members of binary or multiple systems. Yet, we only have a rudimentary framework for how such systems might form, reflecting the difficulties faced in observing binary/multiple protostellar systems. The average separation of binary systems or hierarchical multiple systems on both the pre-main-sequence and main-sequence is ~40 AU (Duquennoy & Mayor 1991; Mathieu 1994). This translates to an angular separation of ~0.3" even at the nearest active star-forming regions (e.g., the Taurus-Auriga molecular cloud) at ~140 pc. Furthermore, the circumstellar disks of individual protostellar components are expected to be truncated by mutual gravitational interactions to no larger than about one-third the orbital separation (Artymowicz & Lubow 1994; Pichardo et al. 2005). Hence resolving these disks requires angular resolutions higher than ~0.1". The only telescope currently capable of penetrating the thick dust envelopes surrounding protostellar systems and studying their individual components at the required angular resolutions and sensitivity is the VLA.

In 2001, we observed the protostellar system L1551 IRS5 with the VLA, utilizing also the Pie Town antenna of the VLBA, to achieve an angular resolution of ~0.4" (Lim & Takakuwa 2006). This optically-invisible object was first discovered in 1976 during a near-IR survey of the L1551 cloud (Strom et al. 1976), which is part of a network of molecular clouds at a distance of ~140 pc in the constellation Taurus.

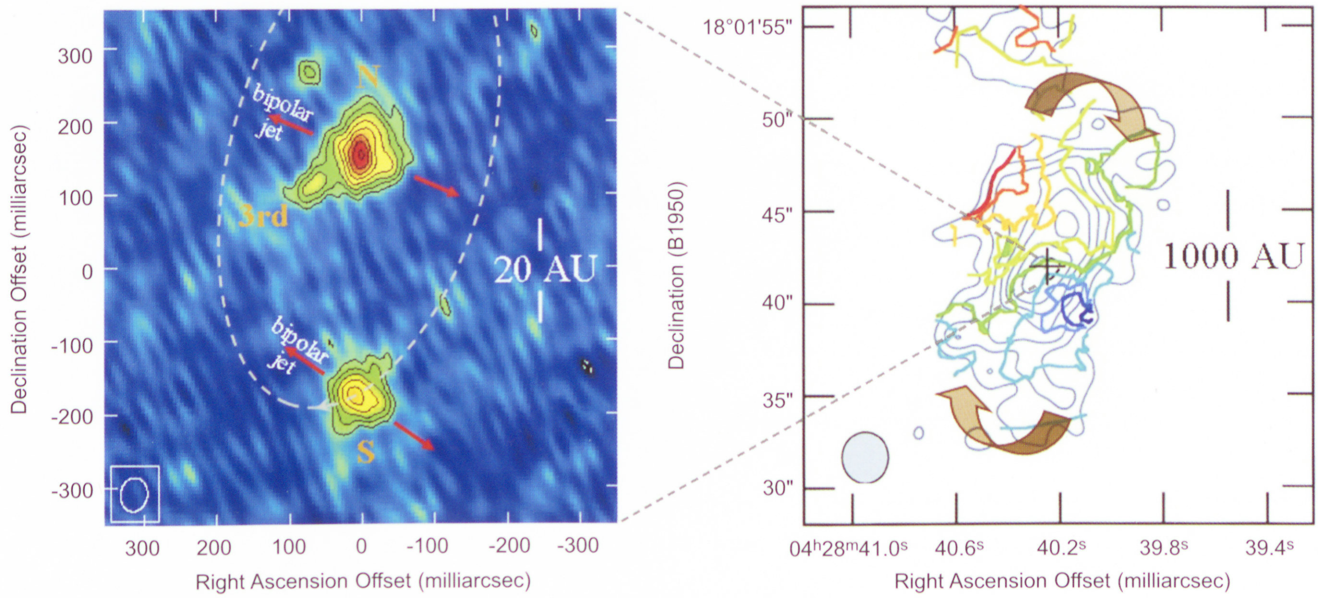

Figure 1. (Left panel) Our VLA 7-mm image of the multiple protostellar system L1551 IRS5 with arrows indicating the directions of bipolar ionized jets from the N and S components imaged on large scales at 3.6 cm (Rodriguez et al. 2003a). The dashed lines indicate the inclined circular coplanar orbit of the S component, with arrow indicating clockwise orbital motion. The synthesized beam is shown at the lower left corner, and a scale size of 20 AU is indicated. (Right panel) Nobeyama Millimeter Array image of the much larger surrounding molecular pseudodisk with grey contours showing the integrated $C^{18}O$ intensity. Colors indicate the intensity-weighted mean $C^{18}O$ velocity (from Momose et al. 1998). The arrows indicate the clockwise rotational motion of the pseudodisk. The synthesized beam is shown at the lower left corner, and a scale size of 1000 AU is indicated. Note the accurate alignment of the N and S circumstellar disks with each other as well as the surrounding pseudodisk, and the matching clockwise orbital motion of the N and S protostellar components with the clockwise rotational motion of the pseudodisk.

L1551 IRS5 has since become one of the most intensively studied of all protostellar systems.

In 1980, the first recognized bipolar molecular outflow was discovered associated with L1551 IRS5 (Snell et al. 1980); such outflows are now known to be ubiquitous around protostars. In 1985, using the VLA, a pair of 2 cm sources oriented approximately north-south was found associated with L1551 IRS5 (Bieging & Cohen 1985); these sources have since been shown to comprise a pair of closely-aligned bipolar ionized jets (Rodriguez et al. 2003a), which are parallel to the larger scale bipolar molecular outflow. In 1997, again using the VLA, a pair of compact 7 mm sources attributed to circumstellar dust disks were detected at the centers of these jets (Rodriguez et al. 1998). At that time, only about half of the antennas of the VLA were equipped with receivers operating at 7 mm. Our observation at 7 mm in 2001 used the entire complement of the VLA, which together with the Pie Town VLBA antenna provided a factor of ~2 higher sensitivity and angular resolution compared with that previously achieved.

The image of L1551 IRS5 made from our observations is shown in Figure 1 (left panel). This image has an angular resolution of $0.037" \times 0.046"$, corresponding to a spatial resolution of 5.2×6.4 AU. As can be seen, we detected the two known components oriented north-south separated by 46.3 ± 0.5 AU. These components are labeled and hereafter referred to as the northern, N, and southern, S, components. In addition, we discovered for the first time a previously unknown third component to the south-east of the N component separated by just 11.4 ± 1.2 AU.

Both the N and S components exhibit a cross-shaped structure. In each case, one arm of the cross is accurately aligned with the axis of a bipolar ionized jet (as indicated in Figure 1) associated with that component, and thus delineates the base of that jet. The N and S jets are unresolved along their minor axes, placing an upper limit of 6.4 AU and 6.2 AU, respectively, for their widths. These jets must therefore be driven within a radial distance of just 3.1–3.2 AU from their central protostars, placing the most stringent such constraint yet available for outflow-driving models. The other arm of each cross, closely orthogonal to its associated bipolar jet, delineates dust emission from an inclined circumstellar disk. Both disks have sizes of just 18 AU, about an order of magnitude smaller than the disks observed around single low-mass protostars. We showed that the disk sizes are somewhat smaller than the upper limit imposed by theoretical models for gravitationally-truncated disks (Pritchard et al. 2005).

The major axes of both the N and S circumstellar disks lie at a position angle of ~160°. Both these disks are resolved along their minor axes, indcating for both an inclination of ~60° to the plane of the sky. The N and S circumstellar disks are therefore accurately aligned with each other. We have combined our measurements with those collected at 2 cm for proper motion studies (Rodriguez et al. 2003b) and also the previous measurement at 7 mm (Rodriguez et al. 1998) to more accurately determine the relative proper motions of the N and S components. These measurements, now spanning a period of 16 years, confirm that the S component is moving to the south-east with respect to the N component. We find that the direction of motion is consistent with the S component describing a circular coplanar orbit (i.e., with an orbital plane parallel to the plane of the circumstellar disks) in the clockwise direction about the northern component with an orbital period of ~380 years. The inferred total mass for the N and S components is ~0.9 $M_\odot$, with each component likely having similar masses.

L1551 IRS5 is known to be surrounded by a molecular pseudodisk, which also is shown in Figure 1 (right panel). This pseudodisk exhibits clockwise rotation, has its major axis at a position angle of ~162°, and is inclined by ~64° to the plane of the sky (Momose et al. 1998). Thus, the N and S circumstellar disks are accurately aligned not just with each other but also the surrounding pseudodisk. Furthermore, the orbital motion of the N and S components is in the same direction as the rotational motion of this pseudodisk. These attributes constitute a "smoking gun" for the formation of the N and S protostars as a consequence of fragmentation in the inner region of their parent pseudodisk, currently the leading model proposed for the formation of binary/multiple systems.

The way in which the third component formed is less clear. Its circumstellar disk, which has a size of ~9 AU, is not aligned with the N and S circumstellar disks, nor the surrounding pseudodisk. Theoretical studies suggest that gravitational forces can tilt the circumstellar disk of a protostar in the presence of more massive protostellar companions with larger disks. On the other hand, the third component may have been captured. Future measurements of its orbital motion can help distinguish between these two possibilites.

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S. Takakuwa (NAOJ)

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Weighing the Central Star of NGC 7027

Planetary nebulae are unusual objects. They come from low mass, faint stars yet are among the brightest radio-emitting objects in a galaxy. They are gaseous nebulae with typical diameters of 0.1 pc and form during the transformation of an evolved star to a white dwarf. During this transition, between 20 and 80 percent of the mass of the star is ejected in a slow but catastrophic wind. Eventually, the star begins to evolve down the white dwarf cooling track, while the expanding nebula will merge with the interstellar medium. This evolution, from the ejection of the nebula to its fading and disappearance, lasts only between 10^3 and 10^5 yr: it is the fastest (non-explosive) phase of stellar evolution, and one where measurable evolution may be expected within human time scales.

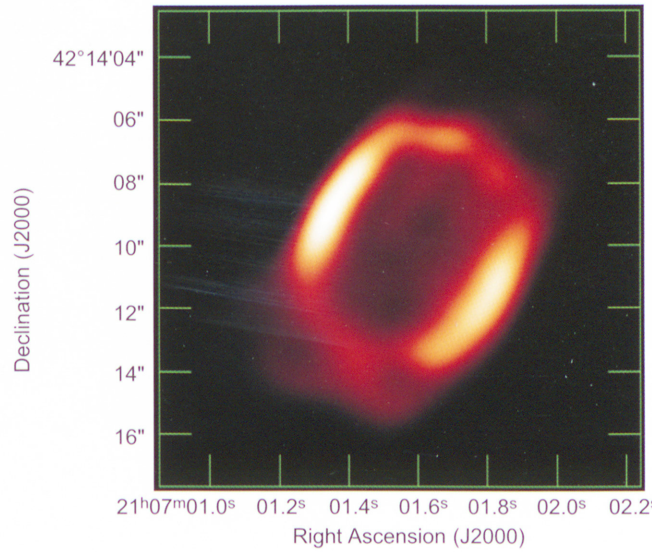

Figure 1. NGC 7027 at 7mm wavelength and 0.8" resolution.

The planetary nebula NGC 7027 has the highest flux density of any planetary nebula—mainly because of its youth and proximity. It has a compact (10"), dense (10^5 cm^{-3}) ionized nebula, embedded within a much larger molecular envelope. The radio flux is as high as 6 Jy, which combined with its small angular diameter, has made NGC 7027 one of the standard radio flux density sources. NGC 7027 has been observed regularly at the VLA, starting in the early 1980's. The expansion of the nebula was measured directly at this time to be 4.7 milliarcseconds per year (Masson 1986). An image of the nebula at 7mm wavelength and 0.8 arcsecond resolution is shown in Figure 1.

NGC 7027 has been included in a long-term VLA project—which started in 1983—to monitor all objects used as primary flux calibrators in order to improve our knowledge of the calibration scale. An unexpected result from this long-term monitoring program has been to detect the fast evolution of NGC 7027, allowing an accurate estimate of the mass of the central star—one of the most accurate masses ever measured for a single, non-pulsating star.

The radio spectrum shows two distinct regions. At wavelengths longer than ~5 cm, the radio flux is self-absorbed within the nebula. In this optically thick region, the radio flux is proportional to the projected surface area of the nebula. At shorter wavelengths, all the radio emission generated in the nebula escapes: here the radio flux is proportional to the number of ionizations per second, i.e. the number of ionizing photons per second emitted by the central star.

The radio monitoring shows a notable *increase* over time of the flux in the optically thick region. This is illustrated in the left panel of Figure 2 for a wavelength of 20 cm. At the same time, at optically-thin wavelengths the flux is *decreasing* as seen in the right panel for a wavelength of 2 cm. The physics behind these contrasting behaviors provides an unexpected clue to stellar evolution.

At short wavelengths, the observations show a clear and unexpected fading of the nebula. The optically thin radio flux arises from free-free interaction between electrons and charged nuclei (mainly hydrogen). To good accuracy, it is proportional to the ionization rate. The thick molecular envelope indicates that NGC 7027 is opaque to ionizing photons in all directions. Thus, the number of ionizations measures the number of ionizing photons emitted by the star.

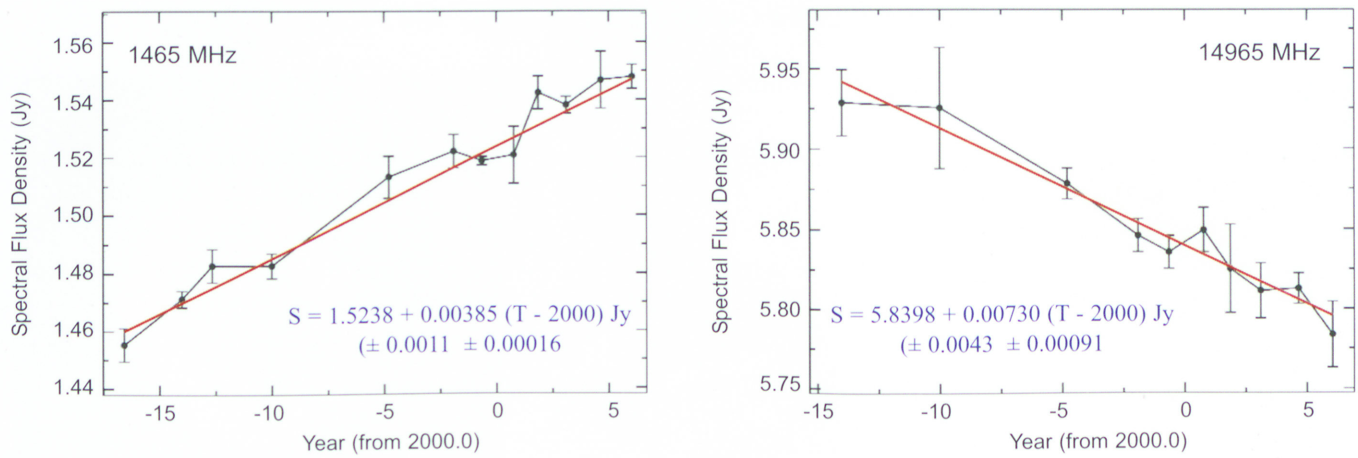

Figure 2. (left) NGC 7027 radio flux evolution at 20 cm (optically thick regime) and (right) at 2 cm (optically thin regime).

We find a decline in the optically-thin radio flux of -0.15 percent yr^{-1}. This decline shows the evolution of the central star. The star is known to be hot ($T_{eff} \approx$ 160,000 K). The number of ionizing photons is dropping for two reasons. Firstly, the star is located at the tip of the white dwarf cooling track: it may have just begun its decrease in luminosity. Second, and in apparent contrast to this, the star is still increasing in temperature, giving a decrease in the number of ionizing photons as the energy per photon increases. We find a change in temperature of 85 K yr^{-1}, and a change in luminosity of 0.10 percent yr^{-1}, where we relate these two quantities using the evolutionary models from Thomas Blöcker.

The same models predict that the speed of evolution is a very strong function of mass of the star. A good fit of the fading of the nebula is found if the mass of the star is $M = 0.636 \pm 0.009\, M_{\odot}$. The quoted uncertainty is based on observables only: allowing for uncertainties in the theoretical predictions will increase the errors to ~0.02 $M_{\odot}$. Few stellar mases have been measured to such accuracy.

The original mass of the star was around 3 $M_{\odot}$: the difference with the current mass shows the effect of the catastrophic mass loss which ended about 1000 yr ago. We predict that the current evolution will proceed at an approximately linear rate for the next ~500 yr, at which point a very sudden luminosity drop will occur. The precise time when this occurs is very sensitive to mass, and once determined will allow us (or future generations) to further improve the mass accuracy. The timing depends on the current temperature of the star and on its mass.

Monitoring of NGC 7027 has given a clear picture of its expansion and evolution. Seeing real-time evolution is rare in astronomy: although everything in astronomy evolves, whether stars, galaxies or the Universe, this evolution normally occurs at an indiscernable rate.

The models predict that the observed evolution will continue at an approximately linear rate. Eventually, the star will reach a peak temperature, after which it will begin to cool down and also will fade much more rapidly. We predict that this will happen within 100–1000 yr. Whether it will still be the VLA which will detect this event can be debated—but for astronomers with some patience, there is a future in radio astronomy.

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R. Perley (NRAO),
P. van Hoof (Royal Observatory of Belgium)

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Atacama Large Millimeter/submillimeter Array

ALMA Achieves Field Interferometry

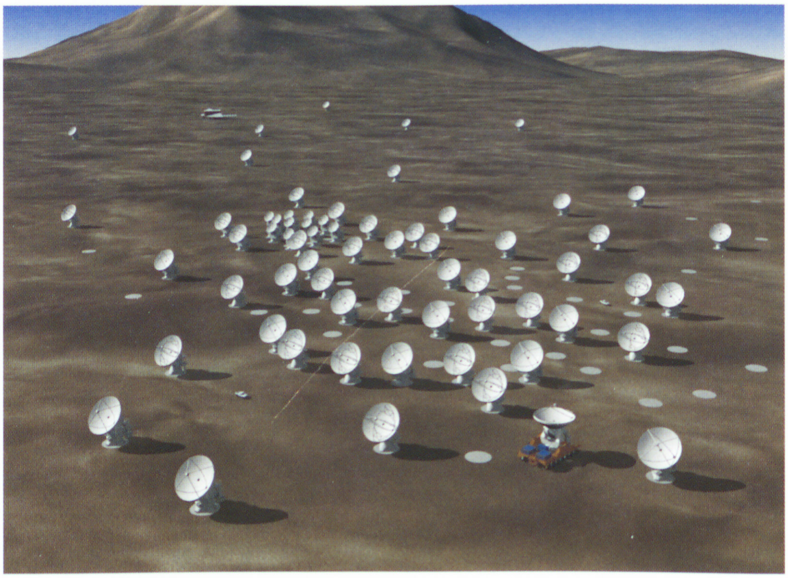


Figure 1. An artist's concept of the ALMA array, including the Atacama Compact Array at left center. Image courtesy ESO.

The ALMA prototype system was tested for the last many months in the NRAO Array Operations Center (AOC) labs in Socorro. During the fall and winter of 2007, this system has been integrated into the two prototype antennas and their associated hardware at the Antenna Test Facility (ATF) near the VLA. The ALMA holography system was thoroughly tested on the VertexRSI antenna and after a final acceptance test will be shipped to the Operations Support Facility (OSF) in Chile for use on the first production antennas, which will arrive at the OSF soon. The results of the holography measurements were confirmed with photogrammetry; the system is believed ready for the production antennas. Pointing of the two prototype antennas has proceeded through optical pointing (the Optical Pointing Telescopes will also be shipped to Chile soon) to radiometric pointing, which is proceeding. The throughput of the prototype system has been demonstrated by detection of the transmitter signal at 3 mm from the holography tower. The final step in the process will be interferometric detection of astronomical sources (see next article). A team of Chilean ALMA employees has been deployed in Socorro, Charlottesville, and Garching to train for their tasks in assembling ALMA and verifying its performance on the Chajnantor site.

A review of prototype system integration (PSI) was held at the NRAO AOC in Socorro on January 24 and at the ATF on January 25. The purpose of the meeting was to plan and coordinate the integration, testing, and commissioning activities to be done at the ATF in 2007 and Q1 2008. At the meeting, the work on elements of the prototype system in the AOC labs was discussed and methodologies for assessing system performance in the less controlled field environment were considered.

The receivers currently installed are special purpose receivers built to evaluate the prototype antennas. The ALMA receivers, populated with cartridges for all four bands (3 mm, 1.3 mm, 0.8 mm and 0.65 mm) from

Figure 2. The prototype ALMA antennas (VertexRSI, foreground; AEC, background) stand ready for prototype system integration near the Very Large Array in New Mexico.

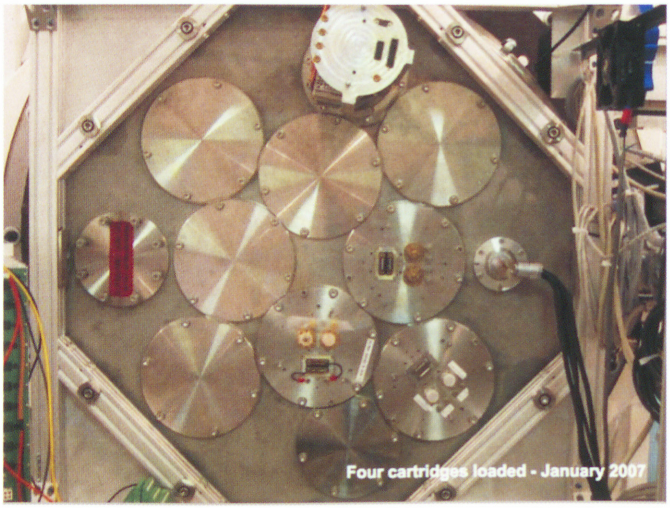


Figure 3. The ALMA dewar under test in the NTC Front End Integration Facility in Charlottesville. The four first receiver band cartridges are inserted.

Europe and North America, are being tested at the Front End Integration Center located in Charlottesville at the NRAO Technology Center (NTC). The testing has been proceeding very well; all cartridges are meeting their noise temperature specification handily, and in fact showing considerably better than specified performance. Once tested, the ALMA front end assembly will be shipped to the ATF for integration into the prototype system; after this step it will go to the OSF for installation on the first ALMA production antennas later this year. Subsequent front end assemblies move directly to Chile for installation in the steadily arriving production antennas. The bilateral ALMA correlator, one quadrant of which has been running at the NTC for many months, will be upgraded to include tunable filter banks and then moved to Chile for installation in the 5000 m Array Operations Site (AOS) Technical Building later this year. Construction of the second quadrant is in an advanced stage at the NTC. A new version of the prototype correlator now installed at the ATF, enhanced with the tunable filter banks, will replace the current prototype at the ATF in the fall.

At the AOS Technical Building, whose construction will be complete by arrival of this *Newsletter*, the installation of ALMA equipment (notably the correlator) will proceed. At the 2900 m OSF, construction of ALMA infrastructure continues at full bore. The building in which the first production antennas will be assembled, the VertexRSI Site Erection Facility, is in an advanced stage of construction (see Figure 4) alongside its sister facilities where the first Japanese production antenna will be assembled later this year, followed by the first European production antenna next year. Activities at the OSF will be centered in the OSF Technical Building, now under roof and proceeding toward 2008 completion.

At the Joint ALMA Office in Santiago, hiring continues for the positions that will carry out assembly of the array and operate its infrastructure. The current building cannot contain the projected level of personnel, and a process has been initiated to construct a permanent ALMA headquarters on the grounds of the ESO facility at Vitacura. In the fall, Richard Hills will join the JAO as Project Scientist, (in the interim A. Wootten fills this post). Alison Peck will join ALMA in Santiago in April as Deputy Project Scientist. Hills and Peck will be joined by a number of commissioning scientists as the array moves toward its commissioning and science verification stages.

The ALMA Board approved an updated version of the ALMA Operations Plan (AOP). The AOP was reviewed at ESO during January. Members of a National Science

Figure 4. The VertexRSI antenna site erection facility building rises on the OSF grounds. Antennas will be assembled in this large facility which is nearly eight stories tall.

Figure 5. Comet McNaught, seen here in the sky above the Array Operations Site to the left of the Technical Building, put on a spectacular show for the committee reviewing the ALMA Operations Plan on 2007 January 23. Photo H. Heyer (ESO).

Foundation panel charged with reviewing the proposal visited the ALMA site during January. The panel met under auspices of the ALMA Board and the National Science Foundation in Arlington, Virginia on February 27–28 to conclude their report.

President George W. Bush presented the funding request for fiscal year 2008 to U.S. Congress in February. Funding requested in FY 2008 from the Major Research Equipment and Facilities Construction account for ALMA reflects the new baseline configuration and cost as approved by the National Science Board.

Transitions

Prof. Richard Hills has been appointed as the ALMA Project Scientist, and Dr. Alison Peck as the Deputy Project Scientist. Richard Hills is Professor of Radio Astronomy, and a member of the Astrophysics Group, in the Physics Department of Cambridge University, UK. His work is well known in the field of millimeter and sub-millimeter-wave astronomy. Prof. Hills is recognized as an expert in radio astronomical instrumentation, telescopes, and interferometry. Dr. Alison Peck is a staff member of the Sub-Millimeter Array (SMA) at the Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA. Dr. Peck is responsible for all science and observer scheduling at the SMA telescope on the summit of Mauna Kea, HI. As such, her responsibilities range from designing and implementing a system of dynamic scheduling, optimizing data taking and reduction procedures, to outreach activities. We look forward to their leadership in, among other matters, the science commissioning and science verification of ALMA.

Mark Holdaway has left NRAO to pursue his business interests. I want to thank him for the wisdom and advice he has so generously provided over the years. Although he may be retiring, he will always be the *Wizard of ALMA* to those of us in the Science IPT. We wish him every success with his business and hope, of course, that it is so successful he might still find time to provide us with advice on occasion.

Al Wootten

ALMA Achieves Major Milestone with Antenna-Link Success

The Atacama Large Millimeter/submillimeter Array (ALMA), an international telescope project, reached a major milestone on March 2, when two ALMA prototype antennas were first linked together as an integrated system to observe an astronomical object.

The milestone achievement, technically termed "First Fringes," came at the Antenna Test Facility (ATF) on the grounds of the National Radio Astronomy Observatory's (NRAO) Very Large Array (VLA) radio telescope in New Mexico.

Radio waves emitted by the planet Saturn were collected by the two ALMA antennas, then processed by new,

Antenna Test Facility, New Mexico: VertexRSI antenna, left; AEC antenna, right. Credit: Drew Medlin, NRAO/AUI/NSF

state-of-the-art electronics to turn the two antennas into an interferometer.

The successful Saturn observation began at 7:13 p.m., U.S. Mountain Time Friday (0213 UTC Saturday). The planet's radio emissions at a frequency of 104 GHz were tracked by the ALMA system for more than an hour.

"Our congratulations go to the dedicated team of scientists, engineers, and technicians who produced this groundbreaking achievement for ALMA. Much hard work and many long hours went into this effort, and we appreciate it all. This team should be very proud today," said NRAO Director Fred K.Y. Lo. "With this milestone behind us, we now can proceed with increased confidence toward completing ALMA," he added.

ALMA, now under construction at an elevation of 16,500 feet in the Atacama Desert of northern Chile, will provide astronomers with the world's most advanced tool for exploring the Universe at millimeter and submillimeter wavelengths. Astronomers will use ALMA's transformational capability to study the first stars and galaxies that formed in the early Universe, to learn long-sought details about how stars are formed, and to trace the motion of gas and dust as it whirls toward the surface of newly-formed stars and planets.

"This was fantastic work. Using our two prototype antennas to observe Saturn was the first complete, end-to-end test of the advanced systems we are building for ALMA," said Adrian Russell, North American Project Manager for ALMA. "ALMA is an extraordinary international endeavor, and the collaboration of partners from around the world is vital to the success of the project," Russell added.

"The success of this test is fundamental proof that the hardware and software now under development for ALMA will work to produce a truly revolutionary astronomical tool," said Massimo Tarenghi, ALMA Director.

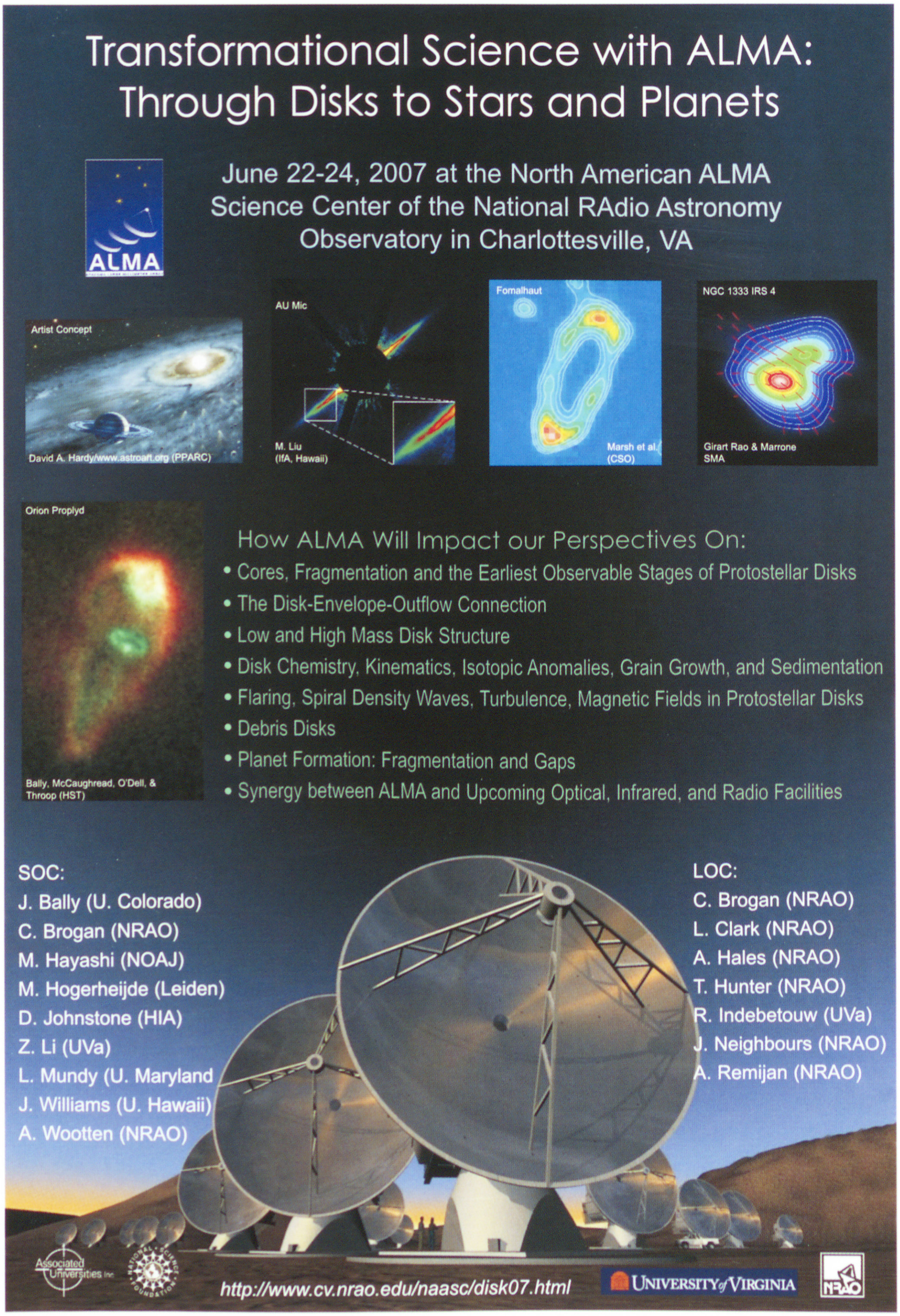
"This achievement results from the integration of many state-of-the-art components from Europe and North America and bodes well for the success of ALMA in Chile," said Catherine Cesarsky, ESO's Director General.

In addition to the leading-edge electronic and electro-optical hardware and custom software that proved itself by producing ALMA's first fringes, the system's antennas are among the most advanced in the world. The stringent requirements for the antennas included extremely precise surfaces, highly accurate pointing, and the ability to operate reliably in the harsh, high-altitude environment of the ALMA site.

The Antenna Test Facility includes prototype antennas built by VertexRSI in the U.S. and by the AEC Consortium (ALCATEL Space of France and European Industrial Engineering of Italy). These antennas were evaluated individually at the ATF. Both prototypes were fitted with electronic equipment for receiving, digitizing and transmitting signals back to a central facility. At the ATF, a small-scale prototype version of ALMA's correlator has been installed. The full-scale ALMA correlator is being built at the National Radio Astronomy Observatory's Technology Center in Charlottesville, Virginia, and will be installed at the high-altitude site in Chile when completed. ALMA also will include Japanese antennas built by Mitsubishi.The complete press release, photos, and graphics are available on-line at *http://www.nrao.edu/pr/2007/almafringes*.

Dave Finley

Second NAASC ALMA Science Workshop



The second NAASC ALMA science workshop (poster above) will generate extensive discussion and new ideas regarding how ALMA may be used to transform the subjects of protostellar and protoplanetary disks through presentations on the current state of our understanding, predictive theories, as well as simulations. Pre-registration and abstract submission are now complete, and we have had a very positive response—with more than 120 pre-registrants. Full registration opens April 2, and will be on a first-come-first served basis due to the size of our venue which can accommodate ~75 participants.

Crystal Brogan

The North American ALMA Science Center (NAASC)

A major external review of the ALMA Operations Plan was held on February 27, 28, and March 1, 2007 near National Science Foundation (NSF) headquarters in Arlington, VA. This review involved both an international panel with North American, European, and Japanese representation, to review the global ALMA operations plan, plus a North American-specific panel that reviewed both the global plan plus the NAASC proposal, as submitted to the NSF in October 2006. The international panel was chaired by the IRAM director, Pierre Cox, and the North American panel was chaired by the Gemini South director Jean-Rene Roy. Both panels heard a series of presentations on the operations plan from the international operations team, including members of the NRAO staff, with ample time for direct questioning of the operations team.

The panels presented their main findings at the end of the review. Overall, the response was extremely positive, and both panels were very impressed by the plan, concluding that no ground-based observatory has ever had such a detailed operations plan in place prior to full operations. They found the staffing levels and schedule were well considered and adequate, and they felt that the operations plan has an excellent chance of success. Both panels also emphasized the need for adequate staffing during early operations, to ensure support of users at a time when the observatory will be at a critical juncture in terms of rapidly increasing capabilities, and increasing demand from the user community.

This review represents the primary pre-operations milestone for the operations team, and successful completion can be considered a major affirmation of the hard work of the operations working group and the NRAO staff involved with operations planning.

While most of the time of the NAASC staff was spent preparing for the operations review, staff were also deeply involved in software testing. Testing was done of the ALMA pipeline, and the CASA-PY post-processing software, including the CASA user interface.

The spectral line database (Splatalogue) was released to the public at *http://www.splatalogue.net* on February 1, 2007. To date, over 400 species have been resolved and new data are planned to be included starting in July with the help of Frank Lovas (NIST). Work has also begun to incorporate the Splatalogue into the ALMA observing and proposal tool.

Chris Carilli

Expanded Very Large Array

Current Status of the EVLA Project

Ten antennas are in various stages of retrofit to the EVLA design. Eight EVLA antennas (13, 14, 16, 17, 18, 23, 24, and 26) are used routinely in observations and account for over 19 percent of VLA antenna-hours devoted to astronomical observations. The outfitting of antenna 21 with electronics is well underway. The mechanical overhaul of Antenna 19 began in late February.

Substantial progress was made toward the goal of retiring the old Modcomp-based VLA Control System. The hardware and software for the visibility pipeline were completed, providing a path by which the output of the VLA correlator is now available to the EVLA Monitor and Control (M&C) System. The state of the interim version of the Data Capture and Format software was also advanced to the point where it is now possible to capture the output of the visibility pipeline and form a partial archive record containing visibility data and some, but not all, of the needed meta data. This partial archive record was successfully input to AIPS, demonstrating the complete data path from antennas, through the correlator, to the post-processing software for the EVLA M&C System. Another crucial milestone was achieved with the demonstration of the EVLA M&C System's ability to control the VLA correlator. The VLA correlator was successfully operated in both continuum and spectral line modes by the EVLA M&C System.

Ten antennas are in various stages of retrofit to the EVLA design. (Photographer: Colleen Gino)

A critical design review of the EVLA Transition M&C System was held on December 5–6, 2006. A transition system is needed to satisfy the project requirement that the VLA must continue to operate while the EVLA is being built. This means the transition system must be able to control EVLA and VLA antennas, the VLA correlator, and the prototype WIDAR correlator. The review committee found that the requirements for the transition system are complete and that the architecture selected for the system design will satisfy those requirements. The committee's primary recommendations were to improve the design for network security, improve the design for system alerts, update the design of the virtual correlator interface (which has already been done), and make the use of the network protocol (UDP) for data transmission robust to packet loss.

Software development for Science Support Systems continues to progress. A new graphical user interface tool was developed to manage catalogs of sources, including calibrator catalogs. This tool is also used for the management of user catalogs and for the selection of sources to be included in observation setups (via the Observation Preparation Tool). Work has begun on the Observation Scheduling Tool (OST), the software that will be used to schedule observations on the EVLA. The OST design is fully fleshed out, and an initial implementation (based on the knowledge already gained from having a prototype in place for the VLA) is done. The OST will support current-style dynamic scheduling (with VLA OBSERVE files) and new-style dynamic scheduling (using Scheduling Blocks), and also has built in a number of metrics to gauge performance. The current VLA archive access web system was updated to allow automatic access to proprietary data for those projects that have used the Proposal Submission Tool (PST) for proposal submission. This is the first step toward a real "end-to-end" system where things are mostly automated.

Testing of modules and other system hardware continue in an effort to better understand the jumps and drifts in visibility phase that are being seen in the antenna hardware system. Laboratory tests have been underway for several months, and test results have already led to some changes in the hardware. These changes mostly involve RF interconnect and thermal issues. System tests using the modified hardware in the antennas were conducted in January 2007. These tests were designed to enable us to evaluate the performance of the changes that have been made and to narrow down the problems to specific parts of the system. The newest version of the round trip phase hardware was also tested at the same time. The tests indicate that the phase drifts are likely due to thermal effects in the down converter modules. Additional laboratory tests are underway to identify and eliminate the source of the thermal problems in the down converter.

A significant milestone for the WIDAR correlator was achieved in January 2007 when the correlator chip passed all 30 predefined, full speed (256 MHz) tests on its test board. The test results suggest that the chip is functioning as designed. Additional speed margin tests must be completed before full production of the chips can proceed.

The delivery, assembly, and startup of the -48V power plant for the WIDAR correlator should be complete by the end of April 2007.

The design of the 3-bit, 4 Gsps sampler was shown to meet its performance specification, but it is now being re-examined because of the availability of the Rockwell digitizer chip. Rockwell requires NRAO to pay all non-recoverable engineering costs, making the cost of the design exceed our initial budget estimate. Other sources and designs are being investigated, including a digitizer chip used by the ALMA project and a digitizer chip that may be commercially available from Tektronics.

The 4-8 GHz receiver originally slated for Antenna 26 is currently being used for the first cooled tests of the new wideband 4-8 GHz OMT prototype. Initial tests are promising, but the receiver temperature has several resonances in the passband which are being investigated. Due to delivery issues with the narrowband polarizer and low noise amplifiers, the interim 4–8 GHz receivers for Antennas 23 and 17 were delayed. We are now modifying the 4.5–5.0 GHz circular polarizers salvaged from the old VLA C-Band receivers as a temporary stopgap until the new 4–8 GHz polarizer enters mass production.

Due to fabrication issues with the 40–50 GHz MMIC post-amplifiers, the delivery of the 40–50 GHz receivers for Antenna 26, 23 and 17 were delayed.

The final design of the front end control module (F317) was completed. The F317 is the module that allows the EVLA M&C System to control multiple receivers in an antenna. Four F317s were produced in December 2006. After they were tested and shown to meet specification, the F317s were installed in antennas. All parts and boards for the F317s have been received to complete the construction of the remaining 70 modules.

The design of the card cage and its six associated circuit boards was finalized. The card cage resides on a receiver and facilitates communication between the receiver and F317. A comprehensive bill of materials for the card cages was made, and the final production order was placed.

All intermediate frequency (IF) modules and local oscillator (LO) modules, with the exception of the 4P IF converter module and the round trip phase module, are in full production. The 4P converters have been redesigned and now meet specifications. The baseband converter is still lacking the gain-slope equalizer filters. The latest design of the gain-slope equalizer meets specification, and it will start to be incorporated into existing modules in the fall of 2007. Despite problems with early prototypes, the current version of the frequency synthesizers appears to be working well. Global phase jumps on the array have been traced to the Central LO Reference Generator (L350). The phase jumps are still under investigation. Temperature gradients within the L350 module have been discovered, and the effect of the gradients on phase stability is also under investigation.

The temperature sensors and firmware in the DC power supplies have now been completed and tested for the P301 and P302 DC/DC converter modules for the antennas. This design is now ready for production. The newly functional temperature sensors in the modules will improve system protection and help to monitor thermal conditions during phase stability testing.

Mark M. McKinnon

Expanded Frequency Coverage in L-Band Now Available on EVLA Antennas

The VLA's frequency coverage in L-Band (20 cm) has long been limited by a bandpass filter to the range 1200 to 1740 MHz. The high frequency end was chosen to block strong RFI, primarily a Forest Service microwave link at 1785 MHz (this signal mixes with the 3200 MHz LO and, via a 2nd order harmonic, creates a spurious image at 1415 MHz!). The EVLA antennas are designed to handle high man-made input powers, and as such have no band limiting filters. Indeed, recent tests on the eight operating EVLA antennas from 1740 to 2000 MHz show good sensitivity and polarization throughout this range. The antenna System Equivalent Flux Density (SEFD; see the last paragraph in the VLBA 22 GHz receiver upgrade article in this *Newsletter*) for most of the EVLA antennas is near 350 Jy all the way from 1200 to 2000 MHz. There are no strong interfering signals within the 1700–2000 MHz frequency band. Subsequent inquiries to the Forest Service have revealed that the 1785 MHz link, and all their link frequencies in NM and AZ operating near 2 GHz, have been discontinued.

Access to frequencies below 1200 MHz remains limited by a waveguide cutoff arising within the Orthogonal Mode Transducer (OMT). A prototype EVLA OMT, which will provide good sensitivity below 1200 MHz, has now been installed on EVLA Antenna 14 and shows good performance from single-antenna tests. Those interested in the details should refer to EVLA Memo #109. Two more prototype OMTs have been ordered, which will permit test interferometer observations by the end of the year. The key issue of whether useful astronomy can be performed in the very adverse RFI environment below 1150 MHz, primarily due to the aeronautical DME (Distance Measuring Equipment) emissions, remains open. It is unlikely the full suite of L-Band OMTs will be purchased until more information on this key question can be obtained. A decision may be deferred until tests utilizing the prototype WIDAR correlator, which will permit rapid blanking in the time/frequency plane, can be made.

Rick Perley

EVLA Developments Require Modern Versions of AIPS

As part of the modernization of the VLA, the Modcomp computers will finally be replaced with modern Linux machines by the end of June 2007. This has necessitated a conversion of the control software from Modcomp-specific codes (written in assembly language, FORTRAN, and a little C) to a more general code written primarily in Java and C. The portion of this software that will continue to write out the data in the old format, for some period of time at least, is called IDCAF (Interim Data Capture and Formatting), and has been developed by Walter Brisken. Eventually, IDCAF will be replaced by software which exports the data in a binary "Science Data Model" format. While the data written by IDCAF are essentially in the old format written by the Modcomps, there are a few differences. Most of these are in parameters that AIPS task FILLM ignored anyway, but one option in the old format, which was never implemented, will now be used. That option is to write the data in correlation units rather than in uncalibrated deci-Jy. The AIPS task FILLM has been modified to detect this option and to scale data in correlation units by the nominal sensitivity so that the output of FILLM will be the same as it always has been. This modification was made in the 31DEC06 version of AIPS. Users of older versions of AIPS will need to update their version to 31DEC06 or 31DEC07 (the current development version) in order to read VLA data written after June of this year.

The 31DEC06 version of AIPS also contains changes to FILLM, PRTAN, and a few other tasks to label new EVLA antennas with station names of the form 'EVLA:ann' while stations with older antennas are named 'VLA:ann', where a is W, E, or N and nn is the station number. The 31DEC07 version also contains a correction to FILLM to recognize the Master Pad as a legitimate EVLA station and new verbs which will allow users to select only VLA or EVLA antennas. Thus, in 31DEC07 only, ANTENNAS = VLA; BASELINE = EVLA will select only baselines between old VLA antennas and new EVLA antennas.

E. Greisen and W. Brisken

VLBI with the VLA Including EVLA Antennas

Transitioning VLA antennas to EVLA antennas is proceeding rapidly. As this is written there are eight EVLA antennas in the array. Since there are so many EVLA antennas, including them with the phased array has become important for sensitivity. It is now recommended that all EVLA antennas be used in the phased VLA. It must be noted however, that the EVLA antennas are somewhat less reliable than the VLA, and users should be sure to phase up often during a phased-array experiment, and to inspect their data carefully during data reduction. It takes a minimum of 30 seconds to phase up, so phasing scans should be 30 seconds plus the amount of time it takes to detect the source for VLBI purposes. At this time the EVLA antennas have fewer frequency bands available compared to VLA antennas. All are available at L, X and K-Band, while there are some missing at C and Q-Band (although this may be rectified by the time this *Newsletter* is published). P- and 4-Bands remain unavailable. A summary of the impact of the EVLA antennas on observing can be found at *http://www.aoc.nrao.edu/evla/archive/transition/impact.html.* Please also check the "EVLA returns" web page for instructions on how to include EVLA antennas in your observations effectively, at *http://www.vla.nrao.edu/astro/guides/evlareturn/*.

Transitioning VLA antennas to EVLA antennas is proceeding rapidly. (Photographer: Colleen Gino)

Note that at the end of June the Modcomp computers that currently run the VLA will be turned off, and the VLA and EVLA antennas will be controlled from a new online system. While it is likely that VLB observing modes using the (E)VLA antennas will be available, they are not guaranteed.

Amy Mioduszewski

Socorro

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
DnC	26 Jan 2007	12 Feb 2007	2 Oct 2006
D	16 Feb 2007	14 May 2007	2 Oct 2006
A	01 Jun 2007	10 Sep 2007	1 Feb 2007
BnA	21 Sep 2007	08 Oct 2007	1 Jun 2007*
B	12 Oct 2007	14 Jan 2008	1 Jun 2007*

Note: This deadline also applies to Large Proposals as described elsewhere in this Newsletter.*

VLA Proposals

Use of the web-based NRAO Proposal Submission Tool is required for all VLA proposal submissions; please see *http://www.vla.nrao.edu/astro/prop/vlapst/*. 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). In 2007, the B configuration daytime will involve RAs between 13^h and 20^h. Proposers and observers should be mindful of the impact of EVLA construction, as described at *http://www.aoc.nrao.edu/evla/archive/transition/impact.html*. They should also consult the "EVLA returns" page for instructions on how to include EVLA antennas successfully in their observations, at *http://www.vla.nrao.edu/astro/guides/evlareturn/*.

VLA Scheduling

VLA scheduling takes two forms, fixed date and dynamic. Some approved proposals will be scheduled on fixed dates. Other approved proposals will be accepted for insertion into the VLA dynamic scheduling queue. A guide to VLA dynamic scheduling is available at *http://www.aoc.nrao.edu/~schedsoc/dynvla.shtml*. Current and past VLA schedules may be found at *http://www.vla.nrao.edu/astro/prop/schedules/old/*.

VLBA and HSA Proposals

Please use the most recent proposal cover sheet, which can be retrieved at *http://www.nrao.edu/administration/directors_office/ vlba-gvlbi.shtml*. 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 may also be sent by paper mail, as described at the web address given above. VLA/VLBA referee reports are distributed to proposers by email only, so please provide current email addresses for all proposal authors. Time will be allocated for the VLBA on intervals approximately corresponding to the VLA configurations (see previous page), from those proposals in hand at the corresponding VLA proposal deadline.

VLBA proposals requesting antennas beyond the ten-element VLBA must justify, quantitatively, the benefits of the additional antennas. VLBA proposals requesting the High Sensitivity Array (HSA) described at *http://www.nrao.edu/HSA/* need to be sent only to the NRAO. VLBA proposals requesting the GBT, the VLA, or Arecibo need to be sent only to the NRAO. VLBA proposals requesting only one antenna affiliated with the European VLBI Network (EVN), 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, is the responsibility of the proposer. Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the EVN is a Global VLBI proposal (see next page).

VLBA and HSA Scheduling

VLBA scheduling takes two forms, dynamic and fixed date. Some approved proposals will be accepted for insertion into the VLBA dynamic scheduling queue; for such proposals, information about proposal priorities, plus the preparation and submission of observe files, may be found at *http://www.aoc.nrao.edu/~schedsoc/dynamic-memo.shtml*. A list of dynamic programs which are currently in the queue or were recently observed may be found at *http://www.vlba.nrao.edu/astro/schedules/*. Other approved proposals will be scheduled on fixed dates. Any proposal requesting a non-VLBA antenna is ineligible for dynamic scheduling. For example, HSA scheduling occurs only on fixed dates. Current and past VLBA schedules may be found at *http://www.vlba.nrao.edu/astro/schedules/*.

J. M. Wrobel and B. G. Clark
schedsoc@nrao.edu

Global VLBI Proposals

Proposals for Global VLBI Network observing at centimeter wavelengths are handled by the NRAO. There are three Global sessions per year, with up to three weeks allowed per session. Plans for these sessions are posted at *http://www.obs.u-bordeaux1.fr/vlbi/EVN/call.html*. Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the EVN is a Global proposal. The preferred path for Global proposal submission is through the NorthStar proposal tool. It has not yet been decided whether the LaTeX proposal form will continue to be supported (the community will be informed by email well before the next proposal deadline). Global VLBI scheduling occurs only on fixed dates.

J. M. Wrobel and B. G. Clark
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Modcomp Retirement and Observing Mode Availability

Since its inception, the VLA has been operated by a set of Modcomp computers. These are computers which control all aspects of observing at the VLA, from ingestion and interpretation of the astronomer-created OBSERVE files, to controlling the antennas and correlator, to writing the data to tape and disk. The Modcomps also support a large number of peripheral operations tasks, including the monitoring of the array, manual control when necessary, and access to and analysis of historical monitor data.

Through the years, there have been several generations of Modcomps at the VLA, with the most recent being the Classic 9250 Series, installed at the VLA in 2001. These computers are no longer being produced by Modcomp, and they are getting ready to stop even supporting them through maintenance contracts. Since they are rather old now, they have become somewhat fragile, and difficult to maintain. For this reason, we have had a plan for some time to replace the Modcomp computers with standard desktop workstations. This plan pre-dated the EVLA project, and in its early phases involved a straight replacement of the Modcomp functionality. However, with the knowledge that we would require a new monitor and control system for the EVLA, we have now combined these two needs, and the Modcomp replacement for the VLA is now the EVLA computer and software system, with intermediate "translators" from EVLA control software system language to VLA antenna and correlator hardware language.

We have been progressing well enough along this path that we now are able to commit to stopping all maintenance of the Modcomps at the end of June 2007. At that time, the Modcomp computers will be turned off, and taken completely out of the VLA control system. Although we will at that time guarantee support for the most common VLA observing modes, there are some for which we cannot guarantee such support. These include:

- Solar
- Planets
- Multiple subarrays
- VLB (both single dish and phased array)
- Holography

Of these, all but Solar observing will probably be supported, but we cannot guarantee it.

Bryan Butler

VLBA 22 GHz Receiver Upgrade

When the VLBA was built, it was outfitted with state-of-the-art receivers of the time. At many frequencies, the receiver temperatures are low enough that significant sensitivity increases from upgrades would be unlikely, although bandwidths could be increased. But the technology for the higher frequencies has improved significantly in the nearly two decades since the VLBA designs were made. A collaborative project with the Max Planck Institut für Radioastronomie is now in progress to improve the sensitivity at 1.3 cm wavelength (22 GHz) by replacing the old GAsFET amplifiers in the existing receivers with units based on the modern WMAP design using InP devices built at the NRAO Central Development Laboratory. These are the same amplifiers that are used in the new EVLA receivers. The polarizers are not being replaced, so the tuning range will remain approximately as it was before. The goal of the project was to improve the overall sensitivity of the VLBA at 1.3 cm by about 30 percent. All of the receivers will be upgraded during 2007. For much of the year, there will be fewer than ten VLBA antennas with 1.3 cm receivers, but every few weeks, there will be a period when that band can be scheduled at all sites.

The project began with the modification of the spare 1.3 cm receiver. That modified receiver was installed on the VLBA antenna at Pie Town on February 6, 2007. Initial results are very encouraging. Hot/cold load tests done immediately after installation give a receiver temperature of around 13 K and a system temperature, including sky, optics, and spillover, of around 42 K. The System Equivalent Flux Density (SEFD) determined later in pointing/gain observations is around 400 Jy. Pie Town is now significantly more sensitive at 1.3 cm than any of the other antennas in the array, including those few that, over the last few years, had received more modern amplifiers. Typical SEFDs for the original receivers are 800-1000 Jy so, if all of the modified receivers work as well as the one at Pie Town, the sensitivity of the array will be more than doubled, significantly exceeding the project goal. To put the new receivers in perspective, the typical SEFDs for mid-range receivers between 1.4 and 8.6 GHz, where the atmosphere is much less of an issue, are around 300 Jy.

The SEFD (Jy) is the system temperature (K) divided by the gain (K/Jy). It is a good measure of overall sensitivity (the lower the number the better the sensitivity) and has the added benefit that it is independent of the assumed cal temperature, which divides out in the ratio. Users of the new Pie Town receiver will likely see higher reported system temperatures than that given above, but the reported gain is also unphysically high. These indicate that the cal temperature in use is too high, which is likely the result of a ripple in the cal temperatures with frequency that is under study.

Craig Walker

VLBA Data Path Upgrade to 4 Gbps

We have initiated upgrades to the VLBA data path to enhance substantially the instrument's continuum sensitivity. The overall goal is operation at 4 Gbps throughput by 2011, and we anticipate that some observations with the highest scientific priority could be carried out in the 1-4 Gbps range within 12 to 18 months. The upgrades encompass the entire data path downstream from the IFs; the 4 Gbps target corresponds to 2-bit sampling of the entire 500-MHz bandwidth from each of the two IFs normally used. Development efforts are focused in three separate, relatively independent areas, with several options still under consideration in each case. Only the option(s) presently considered to be most promising can be described within the scope of this article.

The VLBA's existing baseband converters and samplers can be replaced by a single sampler/filter module, using modern FPGA technology to sample the entire IF bandpass and digitally filter the sample stream into distinct channels ("baseband channels" in current VLBA jargon). Preliminary specifications include two separate, program-selectable operating modes: a maximum of 16 tunable channels, with maximum bandwidth of 256 MHz each, and output sample precision up to 8 bits; and a polyphase filterbank with up to 32 channels spanning the entire passband of each IF. Each mode is subject to an overall maximum throughput of 8 Gbps. (The overdesign relative to the 4 Gbps goal is partly to allow for future expansion of the upstream equipment, and partly to accommodate the geodetic requirements described below.) The module would include output interfaces for several formats, including VSI (for Mark 5), 1G and/or 10G ethernet (for e-VLBI and potential new recording systems), and OC-192 (for the Pie Town-VLA link).

After considering several alternatives, we believe the best option for realizing this unit is a further development of the Digital Backend (DBE) for which Haystack Observatory has already completed a preliminary version in collaboration with the Casper group at UC Berkeley. The NRAO and Haystack identified the extension of that system, to include several crucial requirements for both the VLBA and for geodetic VLBI, as an extremely promising opportunity for collaborative development. The extended DBE would use a new, higher-capacity FPGA, and would exploit the design expertise developed at NRAO for the EVLA project, where quite similar equipment has already been implemented.

A new wideband recording system will be essential for full exploitation of the DBE's 4 Gbps output capacity, but appropriate options are not readily discernible at present. Compatibility with the existing pool of disk recording media, which represents a major investment by the VLBA and by nearly all other VLBI facilities globally, is a crucial requirement. Among current disk-based systems, Mark 5B+ can record a 2 Gbps input stream, but its throughput is limited by a 1 Gbps playback rate through the VSI interface. If necessary, two such systems in parallel would allow 4 Gbps operation for at least a fraction of the time. However, recent trilateral discussions among Haystack Observatory, NRAO, and Conduant Corporation, manufacturer of the Mark 5 series of recording systems, gave grounds for some optimism that a compatible recording system with full 4 Gbps throughput may be available before 2011.

Finally, replacement of the existing VLBA correlator is the third major development area. Here there are two quite different primary options. The WIDAR correlator currently being built at DRAO for the EVLA will have a 32-station configuration, and the excess capacity not required for the 27-element EVLA would be sufficient to process the 10-station VLBA at up to 16 Gbps. The signal-processing boards can accommodate VSI interfaces for input directly from Mark 5 recordings. This approach would require negligible additional hardware investment, but would require some software effort, potentially substantial in scope, to extend the resource-allocation subsystem to support VLBA correlation, and to do so without constraining the EVLA's capabilities. In addition to its cost, this software development is also a concern because it probably could not begin until the correlator is largely functional for EVLA-only operation.

Another attractive correlator option is a software-based system. Software correlation provides an extremely flexible trade-off among basic parameters including the number of stations and polarization states, bandwidth, spectral resolution, integration time, pulsar gating, and specialized non-standard modes, with almost no constraints beyond the available processing power. This flexibility in turn allows correlation resources to be allocated fairly, on the basis of scientific priority, in parallel with the allocation of observing time. Processing capacity can be upgraded incrementally, and matched if desired to simultaneous increases in recording capacity. A software correlator could be put into service relatively quickly, begin to support a fraction of the VLBA's correlation load, and make available a variety of capabilities beyond the limits of the existing correlator. However, the cost of the computing infrastructure necessary to support VLBA correlation at various levels is not well known at present.

Several software correlators have already been written, most of them designed to run on computing clusters in order to exploit the parallelism inherent in the application. Some such systems are in routine use, although generally on smaller arrays, and at much lower fractional observing time, than the VLBA. In a still-incomplete survey, it appears that the DiFX software correlator developed at Swinburne University would be an excellent match to the VLBA's requirements. We are developing a rudimentary processing capability to start benchmarking it as a first step toward the solid cost estimate required to decide between the two correlator options discussed here.

A new "VLBA Sensitivity Upgrade Memo" series has been launched to document developments in all three of the above areas, as well as the 22-GHz LNA upgrade described in a separate article by Craig Walker. These memos are accessible via the NRAO website.

Jonathan Romney

End to End Operations

The VLA Archive Pipeline

The VLA archive contains information about tens of thousands of radio sources at many frequencies and resolutions. It is a gold mine of information. However, the archive contains only the unprocessed visibility data, and very few images or calibrated visibilities are available. To make the VLA products accessible to all astronomers, we began a pilot project two years ago to determine the feasibility of automatic calibration and imaging of VLA archive data. The processing script was based on the AIPS interferometric package and consisted of three parts. The first part searches the VLA archive over a specified period and determines which of the observations can be calibrated and imaged in a straightforward manner. The main part of the processing is a modified version of the VLARUN procedure in AIPS that automatically calibrates and images raw VLA data. In the last part the data products are formatted and saved in a uniform matter. The scripts were made as automatic as possible.

The pilot project processed archival 5 and 8 GHz continuum data obtained during winter 1999/2000 by the VLA in B configuration. In this pilot, 239 data sets were calibrated and imaged, resulting in a total of 672 images. Less than 25 percent of the data sets selected turned out 'uncalibratable' for a variety of reasons and are not included in the above totals. The quality of each image depended on the observing strategy set by the observer, and local weather and hardware conditions, but all were scientifically useful. Further calibration and editing by astronomers (or additional pipeline processing) to obtain the highest quality images can proceed directly from the pipeline products when desired.

Since August 2006, we have improved the pipeline capabilities by extending the processing to all VLA configurations for continuum observations above a frequency of 1.2 GHz. As of February 1, 2007 more than 15,000 images of 3500 radio sources have been produced. The images and calibrated data will be made available through an upgraded NRAO archive interface in summer 2007. Processing of the historical VLA archive will continue until all of the projects for which images can be automatically generated are available.

L. Sjouwerman, J. Benson, J. Crossley, E. Fomalont and N. Radziwill

Green Bank

Trimester 07C Call for Proposals

The deadline for the 07C (October 2007 through January 2008) call for proposals will be June 1, 2007. At this time, we anticipate accepting proposals for all GBT facility instrumentation; including the Ka-Band and Q-Band receivers. During this trimester we will endeavor to discharge the backlog of accepted Ka-Band proposals. The proposal selection meeting will be held in August, so we will have the flexibility to accommodate any changes (forward or backward) in the track refurbishment schedule at that time.

Richard Prestage

GBT Instrumentation Update

Dual Band 350/800 MHz Capability at the GBT: The Prime Focus Receiver 1 at the GBT covers 290-920 MHz, but the range is divided into four bands. A manual feed change taking several hours is required to switch between the bands. In practice this means that observations can be difficult to schedule, and any experiment requiring rapid changes between bands is currently impossible.

We have recently investigated the possibility of constructing a dual-band feed for the GBT to allow simultaneous observations at 350 and 800 MHz. The concept analyzed involved two stacked short-backfire antennas allowing simultaneous use of both bands. This antenna configuration, however, exhibited significant loss of efficiency compared to existing feeds, compromising the sensitivity of the GBT to an unacceptable level. We therefore now plan to consider alternative concepts. One possible approach is to allow rapid, remote changes between the two bands, perhaps by mounting feeds side-by-side on the receiver box. The concept will be analyzed to determine if the relatively small prime focus field-of-view and available space allows a practical implementation with acceptable performance. This approach would not allow simultaneous observations, but could give considerably more flexibility in scheduling at little or no loss in sensitivity. The detailed design study is required to determine whether this approach is actually viable in practice.

R. D. Norrod, S. Srikanth, G. Anderson

Update on the Q- and Ka-Band Receivers: We have good news for those who have proposed to use the Ka (26–40 GHz) and Q-Band (40–50 GHz) receivers. The January *Newsletter* contained a preliminary summary of the fall commissioning results. Since that article was written we have had a fair amount of success in using both receivers with the GBT spectrometer in its 800 MHz mode.

For Q-Band, we have astronomically verified that the receiver has a useful frequency coverage of 38.2 to 49.8 GHz. Under 8 mm of precipitable water, which is just slightly better than our winter average of 9 mm, system temperatures (Tsys) vary from 60 to 75 K at 40 GHz to 150 K at 49 GHz, the substantial rise being due mostly to the change in atmospheric emission from oxygen across the band. Outside of this range, Tsys increases drastically. Thus, the receiver meets its design goals for system temperature and frequency limits.

We also have a CO(1-0) detection toward Q0957+561B at a redshift of $z = 1.41$ (Figure 1). The data are for 3.3 hours of standard NOD observations. The weather was again slightly better than average (8 mm of precipitable water). The data show a 6σ detection, near perfect baselines, and noise that is within 10 percent of its theoretical value. The line intensity, width, and center are consistent with that expected from Krips et al. (2005, A&A 431, 879). Since January, the receiver has been in routine use by our observers.

The Ka-Band system is our first correlation receiver and requires observing techniques and a calibration algorithm that are different from any of our other receivers. In the fall, we were somewhat pessimistic about the spectral-line performance of the receiver since all our attempts to commission it had resulted in

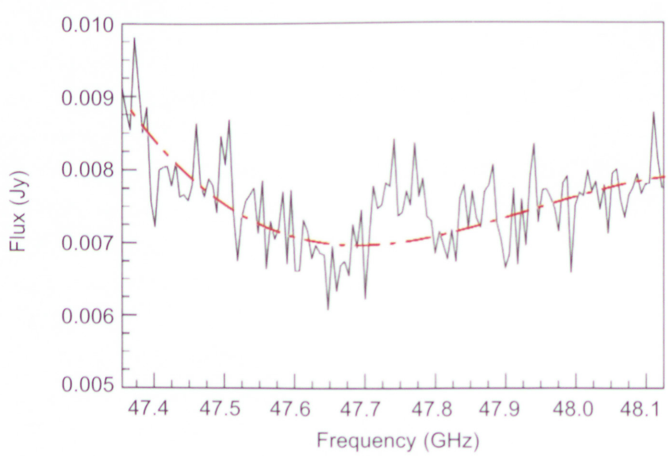

Figure 1. Detection of CO(1-0) toward Q0957+561B at a redshift of z= 1.41 in an 800 MHz bandpass using the Q-Band receiver. The data have been smoothed to 30 km/s but we have not removed any baseline.

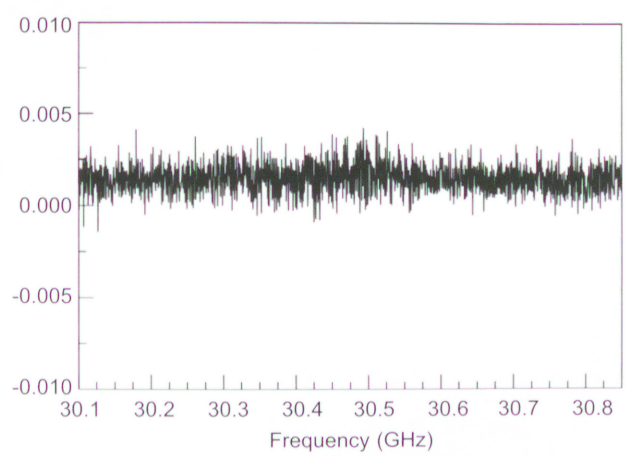

Figure 2. Four hour observation of the north celestial pole using the Ka-Band receiver. We have not removed any baselines. Resolution is 3.9 km s^{-1}.

significant baseline shapes. In contrast, the continuum performance of the receiver, using the Caltech Continuum Backend (CCB), was determined to be superb. Until we could prove the receiver was useful for wide-line spectroscopy, we deemed it safe to only schedule narrow-line spectroscopy and continuum CCB observations during the first trimester of 2007.

Undaunted, we explored other algorithms and observing techniques and we now believe we have something that works. The new technique breaks from our original attempts at treating the spectral-line observations in a way similar to that used for CCB observations. Rather, the new algorithm treats the receiver as a hybrid of a beam-switched and a total-power receiver. By the time this article goes to press, we will have finished a memo describing our Ka-Band tests and the suggested observing techniques and calibration algorithms.

Unfortunately, our attempts of performing an astronomical verification at Ka-Band have been frustrated by either high winds or low temperatures. Figure 2 illustrates the receiver's performance using four hours of data taken toward the north celestial pole (NCP). We observed the NCP since it was too windy that night for accurate pointing at Ka-Band. Nevertheless, with regard to baseline shapes, these data should closely mimic observations performed under similar weather with 6 mm of precipitable water. Conditions such as these or better occur about 33 percent of the time during the high-frequency observing season. The baselines are remarkable and the noise is very close to theoretical.

We have also determined that Tsys values are around 45–75 K between 27 and 34 GHz and rise steeply above 34 GHz. We are also seeing large magnitude ripples in Tsys above 34 GHz. At this time, we do not have a good explanation for why the frequency range of the receiver is less than expected.

Before the summer track shutdown, we plan to attempt a demonstration observation toward a redshifted galaxy. If that demonstration goes well, we will be scheduling our backlog of Ka-Band projects in fall 2007.

In addition to these astronomical tests, laboratory investigations this winter have improved our understanding of the origins of the short-period baseline instabilities that were significantly improved last summer. The results indicate the possibility of further stability improvements. We will pursue these in conjunction with the planned effort to improve the Ka-Band receiver—Zpectrometer performance during the summer of 2007.

R. J. Maddalena, C. Figura (Wartburg College), D. J. Pisano, R. Norrod, and J. Wagg

Green Bank Telescope Azimuth Track Project

Close-up of weld joint between two base plates

Preparations for the remediation of the azimuth track are proceeding well, and starting to accelerate! Green Bank has received two shipments of wear plates. The first shipments of base plates are expected the week of March 12. Efforts on site are ramping up, with attention being given to the miscellaneous modifications that need to be made to accommodate the new track design. The field contractor, General Dynamics SATCOM, is perfecting grout installation tasks and plate alignment tasks. We are on schedule to perform all of this work in May–July, with August set aside for contingency and antenna re-commissioning.

B. Anderson and D. Egan

Education and Public Outreach

Sister Cities: San Pedro de Atacama, Chile, and Magdalena, New Mexico

In the back row, Gabriela Rodriguez, Sandra Berna and Myriam Rivera pose with fifth grade teacher Jim Sauer and his class. Mr. Sauer is will visit San Pedro next summer.

Associated Universities, Inc. (AUI) and the NRAO have recently initiated a Sister Cities program, linking San Pedro de Atacama, Chile, and Magdalena, New Mexico in the U.S. This educational and cultural exchange program establishes formal links and a mutually beneficial relationship between these towns, particularly for science and language teachers and their students.

In September 2006, Mayor Jim Wolfe and the Village Council of Magdalena, New Mexico, officially proclaimed San Pedro de Atacama, Chile, its Sister City; and in December 2006, San Pedro Alcaldesa Sandra Berna proclaimed the same of Magdalena in a ceremony that included the U.S. Ambassador to Chile, Craig Kelly.

Magdalena and San Pedro de Atacama share cultural similarities: the majority of their populations are of native or Spanish ancestry, and they derive the bulk of their income from agriculture and tourism. Magdalena and San Pedro de Atacama are small communities of comparable population, located in relatively undeveloped regions of high-elevation desert near major (NRAO!) international radio astronomy research facilities. The Very Large Array / Expanded Very Large Array is just 40 kilometers west of Magdalena; the Atacama Large Millimeter/Submillimeter Array (ALMA) is only 40 kilometers east of San Pedro de Atacama. Both villages have a single high school that serves a large geographic area.

Though it is a small town, San Pedro is the center of one of the main tourist areas in northern Chile and sees 100,000 visitors per year from around the world. English language skills are a priority for San Pedro students working in the tourism industry. Through email and distance conferencing, Magdalena and San Pedro students can work on these skills together while teaching each other about their respective cultures. Magdalena students will have the opportunity to practice their Spanish language skills and broaden their view of the world by comparing their way of life with that of their counterparts in San Pedro. The teachers in both

Myriam Rivera, Sandra Berna, and Gabriela Rodriguez (left to right) on the pedestal of the VertexRSI prototye ALMA antenna with their tour guide, Clint Janes (ALMA Back End IPT Lead).

schools will trade expertise and methodology in the areas of physics and astronomy instruction.

This Sister Cities program's inaugural participants arrived in Magdalena on Monday, January 29: San Pedro High School Principal Myriam Rivera, tourism teacher Gabriela Rodriguez, and Mayor Sandra Berna. The Magdalena Village Council held a community ceremony to welcome their Chilean guests. The teachers and mayor were treated to a tour of the school facilities and a range of activities. They enjoyed a high school basketball game, New Mexico's version of chile rellenos, prepared by the high school Spanish class, and numerous classroom activities. Field trips included the Bosque del Apache wildlife refuge (with Magdalena second graders), the Alamo Navajo Reservation school and health center, a ranch and hunting guide, art galleries and shops, dinners hosted by Magdalena teachers, and an in-depth tour of the VLA and the prototype antennas at the ALMA Test Facility. The Chilean guests sampled many of the foods available in Magdalena, including enchiladas for dinner, Navajo tacos for lunch, and biscuits and gravy for breakfast! They also presented a community program about life in San Pedro de Atacama and gathered student email addresses to initiate a penpal program between San Pedro and Magdalena students. The Internet will allow for future classroom connectivity and sharing, especially in the language classes.

In June 2007, second grade teacher Sandra Montoya and middle school math teacher Joleen Welborn will travel from Magdalena to San Pedro de Atacama under the auspices of the AUI/NRAO Sister Cities program. They will be accompanied by fifth grade teacher Jim Sauer, whose travel will be funded by the Magdalena School Board. This first visit to Chile will aid in cementing the solid relationships that have been established between these communities and school systems.

R. Harrison and E. Hardy

The NRAO at the Joint Meeting of the American Astronomical Society (AAS) and the American Association of Physics Teachers (AAPT)

Seattle, Washington hosted a joint meeting of the American Astronomical Society (AAS) and the American Association of Physics Teachers (AAPT) from Saturday, January 6 through Wednesday, January 10, 2007 with approximately 3,200 persons in attendance.

The Observatory's recently re-designed exhibits debuted at this meeting (see photo). The central exhibit of the re-designed set provides an overview of the NRAO research facilities and project suite: the Atacama Large Millimeter/submillimeter Array (ALMA), Expanded Very Large Array (EVLA), Green Bank Telescope (GBT), Very Large Array (VLA), and Very Long Baseline Array (VLBA). The Observatory's two major projects—ALMA and EVLA—are featured in exhibits that are placed on either side of the overview. All three exhibits can be deployed as a unit, as they were for this AAS / AAPT meeting, or the individual exhibits can be separately transported and deployed. The ALMA exhibit, e.g., will be featured at one or more engineering job fairs in the coming year.

EPO distributed two new NRAO press releases in conjunction with this AAS / AAPT meeting. The first of these releases describes the recent research results of Laurent Loinard (UNAM), Amy Mioduszewski (NRAO), Rosa Torres (UNAM), and Luis Rodriguez (UNAM). This team's high-precision VLBA distance measurements are providing new insights into key star-forming regions in our Galaxy. A second NRAO press release described the work of Joan Wrobel (NRAO) and Luis Ho (Carnegie Institute). These astronomers combined the power of all the operational NRAO telescopes to peer deep into the heart of the galaxy

The re-designed NRAO exhibit set. The central exhibit provides an overview of the entire NRAO facilities and project suite. The separate EVLA and ALMA exhibits are to the left and right, respectively, of the central exhibit. Each of the exhibits is ten feet in length and eight feet tall.

NGC 4395, discovering the strongest evidence yet that matter is being ejected by a medium-sized black hole.

Numerous AAS / AAPT meeting attendees visited our exhibits in Seattle to seek information about radio astronomy and the NRAO, converse with Observatory staff about science, and pick up the available materials. The popular 2007 NRAO Calendar published each of the prize-winning images from the just concluded second annual AUI/NRAO Image Contest, as well as visually compelling astronomical images created by NRAO scientists Juan Uson, Crystal Brogan, and John Hibbard, last year's First Prize image by Aeree Chung, and the poster for the NRAO 50th anniversary science symposium. Other materials prepared by NRAO EPO and scientific staff and distributed at this AAS / AAPT meeting included revised ALMA and EVLA brochures, updates on the GBT and the VLBA, two high-quality color posters, and a new Observatory-wide brochure. The two posters were especially popular with educators. The first of these featured a radio-optical composite created by EPO Scientist Juan Uson; the second showed the most recent Image Contest First Prize image, a striking VLA—MSX composite created by Jayanne English (University of Manitoba).

EPO personnel Dave Finley, Sue Ann Heatherly, and Mark Adams staffed and managed the NRAO exhibits.

Members of the Observatory's scientific staff and management team assisted EPO, including Director Fred K.Y. Lo, Site Directors Richard Prestage and Jim Ulvestad, and scientists Bill Cotton, Ed Fomalont, Jay Lockman, Al Wootten, and others. AUI President Ethan Schreier and Vice President Pat Donahoe also spent time at the NRAO exhibit meeting talking with AAS and AAPT members.

An hour-long NRAO Town Hall meeting was held on Monday, January 8, and was attended by 135 AAS/AAPT members. Director Fred K.Y. Lo provided an NRAO overview and an ALMA update; New Mexico Site Director Jim Ulvestad updated the community on EVLA/VLA/VLBA science and status; and GBT Scientist Jay Lockman spoke about recent GBT science and status. NRAO Public Information Officer Dave Finley made a brief presentation, encouraging the community to consider working with the NRAO to publicize their research results. A half-hour question and answer session followed.

We enjoyed seeing and talking with the AAS and AAPT membership at this meeting and look forward to seeing our colleagues again at the May 27–31, 2007 AAS meeting in Honolulu, Hawaii.

Mark Adams

In General

Results of the October 2006 Large Proposal Call

In January 2007 the Large Proposal Review Committee met to review all 25 proposals submitted during the October 2006 call for Large Proposals. A Large Proposal is defined as one which requires at least 200 hours of observing time on one or more NRAO telescopes (GBT, VLBA and VLA). In the steady state, the NRAO expects to increase the fraction of allocated observing time for large projects to 25–50 percent of the total scientific observing time. This decision was reached after receiving community input from a Legacy Science workshop in May 2006 and from the Users Committee.

The Large Proposal Review Committee was selected from external members of the astronomical community, and consists of multi-wavelength observers and theorists with broad expertise. They received technical reports and the regular referee reports for each proposal, as well as some general description of the scheduling constraints (construction, weather, etc) for each telescope.

The NRAO staff had no involvement in the deliberations of this committee. The committee provided NRAO with a rank-ordered list of ten proposals that they concluded met the high standards required for the substantial commitment of time for a Large Proposal. As this amounted to about 20 percent of total telescope time for all NRAO telescopes for the next year, NRAO agreed to allocate time to all ten of these programs.

The table below shows these ten accepted programs. They span a wide range of science from interstellar chemistry, star formation, planet searches, gravitational waves, AGN and galaxy evolution, and precision cosmology. There are also a significant number of collaborative projects with other radio facilities, and several multi-wavelength efforts (GLAST, HST, Chandra, etc). For more details on each of these projects including data products and data release dates go to *http://www.vla.nrao.edu/astro/prop/largeprop/*.

Dale A. Frail

Principal Investigator	Proposal	Telescope(s)
Demorest (UC,Berkeley)	Detecting nHz Gravitational Radiation Using a Pulsar Timing Array	GBT
Braatz (NRAO)	The Megamaser Cosmology Project	GBT + VLA + VLBA
Miller (JHU/NRAO)	Deep 1.4GHz VLA Observations of the Extended Chandra Deep Field South	VLA
Lister (Purdue U.)	The VLBA 2cm MOJAVE/GLAST Program	VLBA
Marscher (U. Boston)	Probing Blazers Through Multiwaveband Variability of Flux, Polarization, and Structure	VLBA
Ott (ATNF)	VLA and HST: Star Formation History and ISM Feedback in Nearby Galaxies	VLA
Hunter (Lowell Obs.)	The LITTLE THINGS Survey	VLA
Hollis (Goddard)	A GBT Legacy Survey of Prebiotic Molecules Toward SgrB2(N-LMH) and TMC-1	GBT
Crutcher (U. Illinois)	A Definitive Test of Star Formation Theory	GBT
Bower (UC, Berkeley)	RIPL: Radio Interferometric Planet Search	GBT + VLA + VLBA

The June 2007 Call for Large Proposals

The NRAO encourages the submission of proposals which require significant amounts of telescope time when justified by the potential scientific payoff. We define a Large Proposal as one which requires at least 200 hours of observing time on one or more of the NRAO telescopes. Large Proposals will be further constrained to a maximum of 50 percent of the available observing time in any LST range during any trimester (configuration for the VLA). The results for the most recent October 2006 Large Proposal call are described elsewhere in the *Newsletter*.

The next call for Large Proposals will be for the June 2007 proposal deadline. This call will apply for only VLA proposals requiring the C and D array configuration. The GBT and the VLBA will not be part of this call. For more information about policy and process, including plots of the relative proposal pressure for past C and D array configurations, please go to *http://www.nrao.edu/administration/directors_office/largeprop.shtml.*

In the longer term it is our intention to move to a unified proposal call for all NRAO telescopes (and configurations), and to synchronize with the NSF funding cycle. We tentatively have set the date for the next Large Proposal call to be the June 2008 deadline.

Dale A. Frail

A Web-based Course in Radio Astronomy

Essential Radio Astronomy (ERA) is a one-semester course intended for astronomy graduate students and advanced undergraduates with backgrounds in astronomy, physics, or engineering. The goal of ERA is fostering the community of researchers using radio astronomy by attracting and training the most talented university students. Therefore we are making ERA available via the web at no cost—see *http://www.cv.nrao.edu/course/astr534/ERA.shtml.*

ERA greatly simplifies the task of teaching radio astronomy at the university level. Although ERA is web-based, the text consists of full sentences and paragraphs, not just lecture notes or Powerpoint bullets; and all equations are legibly rendered in TeX. ERA also includes ten sets of problems and a final exam, with solutions. We developed ERA in 2000, 2002, and 2006 for the University of Virginia radio-astronomy course ASTR 534. ERA allowed us to use a computer and projector to display the web pages in class, nearly eliminating the need to write equations and drawings on a blackboard. Prior to each class we handed out printed versions of these pages so the students could follow the lectures without the distraction of copying everything into their notebooks. (Printable copies of the lectures and supplementary materials are available from the course web site as .pdf files.) ERA is also suitable for individual or directed-study courses that do not involve lectures.

To reach the widest possible student audience, we made ERA sufficiently complete and self-contained that its only prerequisites are basic calculus physics courses covering elementary classical mechanics, macroscopic thermodynamics (e.g., the first and second laws of thermodynamics), electromagnetism, and quantum mechanics (quantization of energy and angular momentum). Courses in electromagnetism using vector calculus, special relativity, statistical thermodynamics, advanced quantum mechanics, or astronomy are not required. Although ERA can be used alone, we recommend the textbook Tools of Radio Astronomy (4th Edition) by K. Rohlfs & T. L. Wilson as a reference for advanced students interested in "the tools that a radio astronomer needs to pursue his/her trade."

Instructors or students interested in using ERA are welcome to contact us with questions, suggestions, corrections, etc. ERA currently includes only the most essential material that can be covered in one semester. We anticipate adding new material in the future and invite contributions from experts.

J. J. Condon and S. M. Ransom
jcondon@nrao.edu sransom@nrao.edu

James A. Firmani

Human Resources Manager Appointed

The Observatory's new Human Resources Manager, James A. Firmani, joined the NRAO senior management team on February 26, 2007. Jim Firmani was Director of Human Resources for the CNA Corporation, a Federally Funded Research and Development Center in northern Virginia, for almost eight years. He held managerial positions in Human Resources and Compensation Services for the Columbia Energy Group for 20 years. Jim's background includes a BS in Accounting, an MBA in Manpower Management, and certifications as a Society of Human Resources Professional (SPHR), Certified Compensation Professional (CCP), Certified Benefits Professional (CBP), Certified Relocation Professional (CRP), and Global Remuneration Professional (GRP). He has also attended continuing education programs at the Wharton School, UCLA Anderson School of Management, and the Center for Management Research.

Fred K. Y. Lo

2007 Grote Reber Gold Medal to be Awarded to Govind Swarup

The 2007 Grote Reber Medal for lifetime, innovative achievement in radio astronomy is to be awarded to Professor Govind Swarup of the Tata Institute of Fundamental Research (TIFR) in India.

Govind Swarup is being honored for his many contributions to astronomy, for his development of new techniques for radio astronomy, and for leading the development of radio astronomy in India for nearly half a century. Following a brief period at the Harvard radio astronomy station at Fort Davis, Texas, Swarup went to Stanford where he received his Ph.D. in 1961 working with Ron Bracewell. He returned to India in 1963 to begin a research program in radio astronomy at the TIFR where he led the construction of the Ooty radio telescope which has been used since 1970 to study the angular structure of radio galaxies and quasars, the solar wind, Galactic radio sources, the interstellar medium, pulsars, and cosmology.

Prof. Govind Swarup

More recently, Swarup was the driving force behind the Giant Metrewave Radio Telescope (GMRT) which consists of thirty 45 m dishes spread over distances of up to 25 km and is the most powerful radio telescope in the world operating at decimeter wavelengths.

The 2007 Reber Medal will be presented to Prof. Swarup by the President of the Royal Society, Sir Martin Rees, on October 4 at a ceremony at Jodrell Bank. The Reber Medal was established by the Trustees of the Grote Reber Foundation to honor the achievements of Grote Reber and is administered by the Queen Victoria Museum in Launceston, Tasmania in cooperation with NRAO, the University of Tasmania, and the CSIRO Australia Telescope National Facility. Nominations for the 2008 Medal may be sent to Martin George, Queen Victoria Museum, Wellington St, Launceston, Tasmania 7250, Australia or by e-mail to: *martin@qvmag.tas.gov.au* to be received no later than November 15, 2007.

Ken Kellermann

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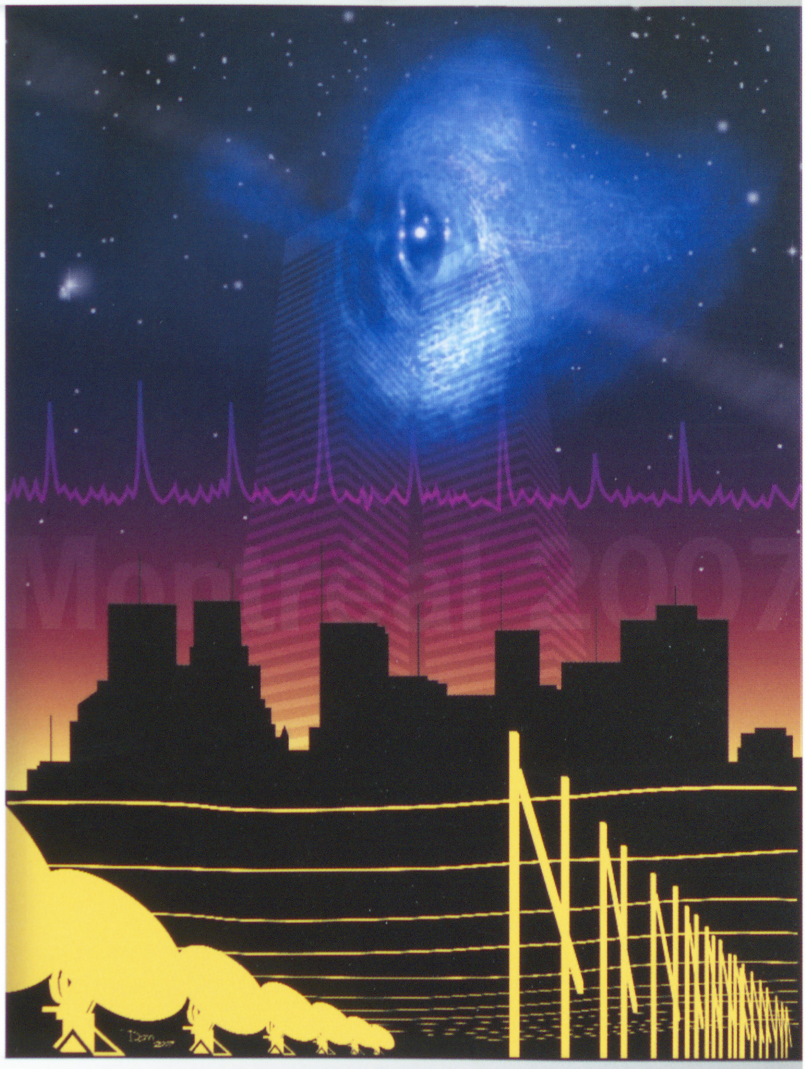

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Keynote Public Lecture: Prof. S. Jocelyn Bell Burnell, CBE, FRS, FRAS
Conference Opening: Prof. Antony Hewish, FRS, Nobel Laureate
Conference Summary: Prof. Joseph H. Taylor, Nobel Laureate

NRAO Library News

The National Radio Astronomy Observatory Library recently posted updated page charge requirements on the Library Web Page *http://www.nrao.edu/ library/.* The major changes include:

- providing original observation Proposal Number(s) when NRAO instruments are used at the time of page charge requests;
- expansion of page charge coverage for papers utilizing NRAO instrument archival data.

Please see: *http://www.nrao.edu/library /pagecharges.shtml* for more information.

For questions, please contact the Observatory Librarian or telephone 434-296-0254.

Marsha J. Bishop

Further Information

Visit the NRAO web site at: *http://www.nrao.edu*

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NRAO Results

For more information on recent scientific research with NRAO telescopes:

NRAO Press Releases: *http://www.nrao.edu/pr*
Discoveries with the GBT: *http://www.gb.nrao.edu/epo/GBT/data.html*
VLA Observation Highlights: *http://www.vla.nrao.edu/genpub/current_obs/*

NRAO Data and Products

NRAO Data Archive System: *http://e2e.nrao.edu/archive/*
VLA NVSS Survey (VLA D-array 20 cm continuum): *http://www.cv.nrao.edu/nvss/*
VLA FIRST Survey (VLA B-array 20 cm continuum): *http://www.cv.nrao.edu/first/*
Galactic Plane "A" Survey: *http://www.gb.nrao.edu/~glangsto/GPA/*
Green Bank Solar Radio Burst Spectrometer (SRBS): *http://www.nrao.edu/astrores/gbsrbs/*
Essential Radio Astronomy (web-based radio astronomy course):
http://www.cv.nrao.edu/course/astr534/ERA.shtml

Observing Information

VLA: *http://www.vla.nrao.edu/astro*
VLBA: *http://www.aoc.nrao.edu/vlba/html/vlbahome/observer.html*
GBT: *http://www.gb.nrao.edu/astronomers.shtml*
Information on proposal templates, instructions, and deadlines can be found at:
http://www.nrao.edu/administration/directors_office/

Publicizing NRAO Results

If you have a new research result obtained using an NRAO telescope that might be of interest to a wider audience, please write a 2-3 sentence description of the result and email it to one or more of the persons listed below. Your information could result in a press release, an article in this Newsletter, and/or inclusion of your image in the NRAO Image Gallery.

Press release contact: Dave Finley, Public Information Officer (*dfinley@nrao.edu*)
Newsletter contact: Mark Adams, Editor (*mtadams@nrao.edu*)
Image Gallery contact: Patricia Smiley, Information Services Coordinator (*psmiley@nrao.edu*)

NRAO Page Charge Policy

It is NRAO policy to pay a portion of the page charges for articles reporting original observations made with NRAO instruments or utilizing NRAO archival data. For more information and for details of the policy requirements, please see: *http://www.nrao.edu/library/page_charges.shtml*.

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 research result obtained using NRAO telescopes that could be featured in the NRAO *Newsletter*, please contact Tim Bastian at *tbastian@nrao.edu*. We particularly encourage Ph.D. students to describe their thesis work.

Editor: Mark T. Adams (*mtadams@nrao.edu*); Science Editor: Tim Bastian (*tbastian@nrao.edu*); Assistant Editor: Sheila Marks; Layout and Design: Patricia Smiley

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