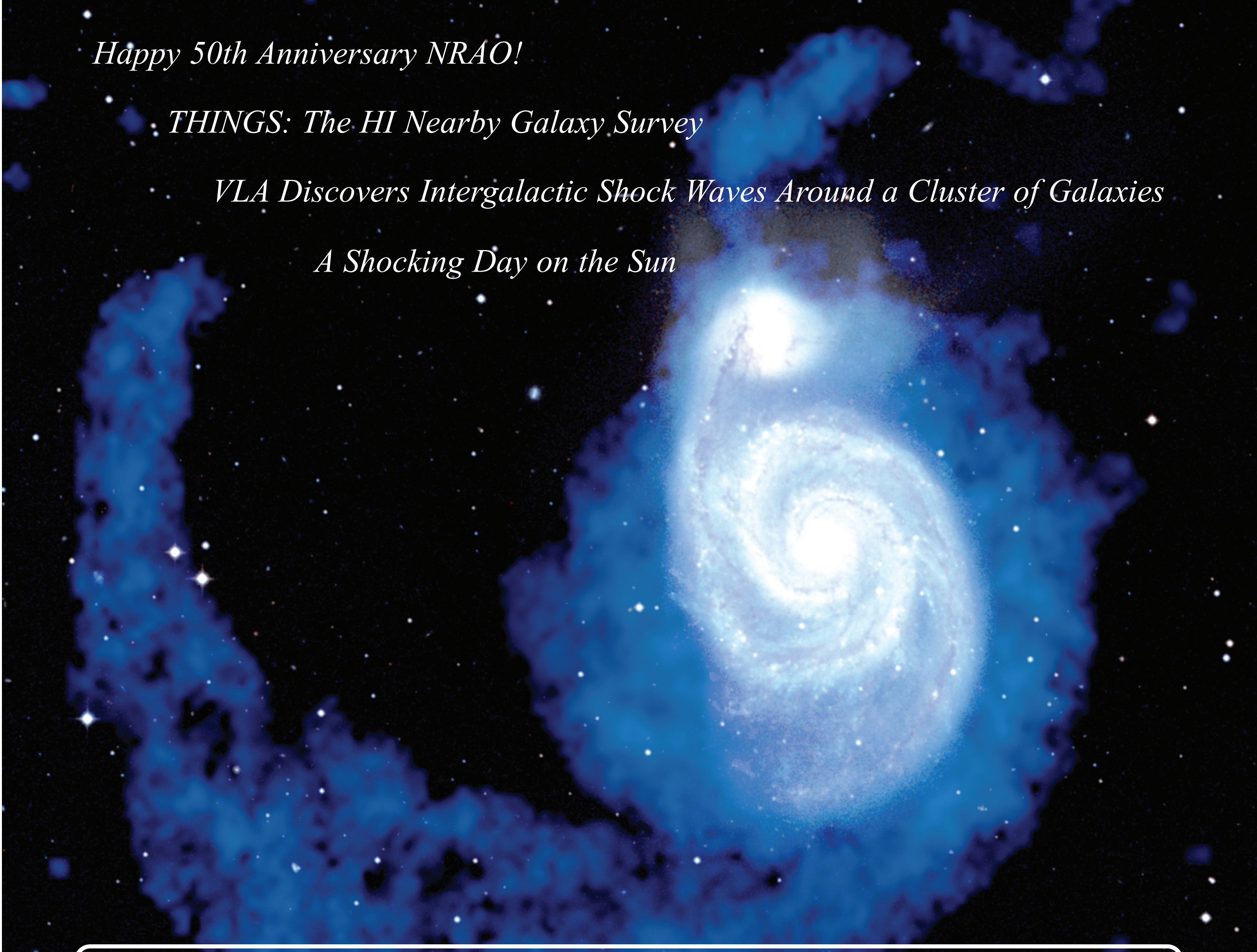
NATIONAL RADIO ASTRONOMY OBSERVATORY

Newsletter

January 2007

Issue 110



Happy 50th Anniversary NRAO!

THINGS: The HI Nearby Galaxy Survey

VLA Discovers Intergalactic Shock Waves Around a Cluster of Galaxies

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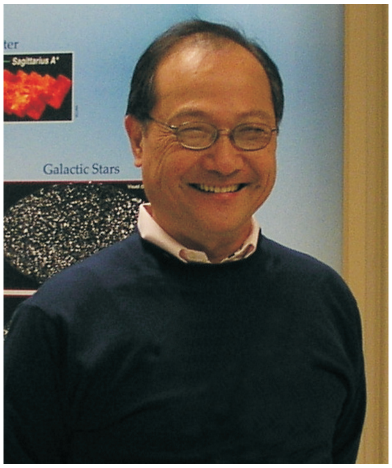
Cover: The long tidal tail of Hydrogen gas shown in this image was shaken loose by the dance of M51, the Whirlpool galaxy with its companion, NGC 5195. Investigators: A.H. Rots, J.M. van der Hulst, P.E. Seiden, R.C. Kennicutt, P.C. Crane, A. Bosma, L. Athanassoula, and D.M. Elmegreen. Image composition by J. M. Uson.



Fred K. Y. Lo, Director

Happy New Year!

As we look forward to 2007 and beyond, we are happy to note that the prospect for exciting new research enabled by the NRAO continues to look bright. The science capability and impact of the Green Bank Telescope (GBT) is increasing steadily, and the GBT's recent discoveries include the fastest millisecond pulsar, multiple molecules, and a water giga-maser associated with a high redshift quasar. The remarkable Very Long Baseline Array (VLBA) astrometric accuracy of a few micro-arcseconds is being applied to an increasing number of important scientific problems, such as the proper motion of M33, the determination of sub-parsec accuracy distances to pre-main sequence stars, and direct distance measurement to a mega-maser beyond 100 Mpc. The Very Large Array (VLA) continues as the world's premier imaging radio telescope, recently revealing intergalactic shocks that arise from the formation of a galaxy cluster; the Expanded VLA (EVLA) project is proceeding well and will soon improve the array's sensitivity by ten-fold. To facilitate significant science objectives, the NRAO will continue to devote up to 50 percent of the observing time on all its telescopes to Key and Legacy projects requiring more than 200 hours.

Two major new facilities, the EVLA and the Atacama Large Millimeter/submillimeter Array (ALMA), will be available for early science in 2009 and 2010, respectively. Around 2012, together with other flagship observatories that will come on-line across the electromagnetic spectrum, the NRAO telescope suite will constitute a set of powerful research facilities that the astronomy community will employ to explore the Universe and open new frontiers.

To fulfill its mission of enabling cutting-edge research in the study of the Universe using radio astronomy techniques, attracting and training future scientists and engineers, and stimulating public interest in science, the NRAO has undertaken an extensive strategic planning process. This process is especially timely now that the Senior Review committee report (*http://www.nsf.gov/mps/ast/seniorreview/sr-report.pdf*) has been released. This report notes the NRAO's excellent record of managing its world-class observatories and recommends that radio astronomy leadership remain centered at the NRAO, given its scale. The report emphasizes that the VLBA is the premier scientific instrument for Very Long Baseline Interferometry and is poised to produce its strongest scientific contributions. It further notes that the angular resolution of the VLBA is not likely to be superseded even by the Square Kilometre Array (SKA) and, thus, the VLBA provides a unique capability. The GBT is identified by the Senior Review report as a part of the base program in U.S. astronomy, a "new and highly promising telescope" that has already made significant scientific discoveries.

The report does recommend some reductions and changes at the NRAO. Specifically, the report recommends that: VLBA operations make a transition to a significant reliance on international funding by 2011 or risk closure; GBT operations cost be reduced; and scientific staff cost be reduced. In developing its strategic plan for the next decade and beyond, the NRAO will coherently address many issues, including the Senior Review recommendations.

For the NRAO to continue delivering scientifically effective and cutting-edge facilities for the astronomical community, as in the case of helping to realize the SKA, an excellent scientific staff is essential. Not only does the scientific staff serve in key management and operations roles, they also provide a good fraction of the scientific and technical innovation needed to develop next generation facilities. The NRAO is developing a strategic staffing plan that is optimized for cost and effectiveness, and addresses the natural turnover that will occur in the scientific staff in the next few years.

In the end, it is the science enabled by the NRAO that justifies its operations. Over the past few years, the NRAO has been continuously making changes across the Observatory to increase its science impact and improve its cost effectiveness. These changes will continue into the future so that the NRAO will remain a flagship observatory at radio wavelengths for the U.S. and international astronomy communities for decades to come.

Happy 50th Anniversary NRAO!

From a serendipitous discovery by Jansky to strategically focused research on cosmic evolution, radio astronomy has become an indispensable tool for astronomers to explore the Universe. Over the last 50 years, the National Radio Astronomy Observatory has continually provided cutting edge telescopes and instrumentation to the astronomical community and enabled a vast range of discoveries.

To commemorate the 50th anniversary of its founding on November 17, 1956 and the ground breaking at Green Bank on October 16, 1957, the NRAO will host a scientific symposium June 18–21, 2007 at the Omni Charlottesville Hotel entitled *Frontiers of Astrophysics: A Celebration of NRAO's 50th Anniversary*. Besides celebrating 50 years of contributions to astronomy by the NRAO, the symposium will bring together experts in areas of the highest interest in astrophysics, present the latest research in these areas from across the electromagnetic spectrum, and inform the design of future radio instrumentation that will address key science questions.

To obtain more information, please visit the symposium's website at *http://www.nrao.edu/50*.

Looking forward, the NRAO is in an excellent position to continue its proud tradition of helping the astronomy community use our forefront facilities and to have an outstanding scientific impact on all areas of astronomy and astrophysics. Equally important is the radio astronomy expertise embodied in the NRAO which is an invaluable resource for the astronomy community to realize new experiments and next generation telescope facilities.

We look forward to the next 50+ years!

K. Y. Lo, C. L. Carilli, L. M. Clark

SCIENCE

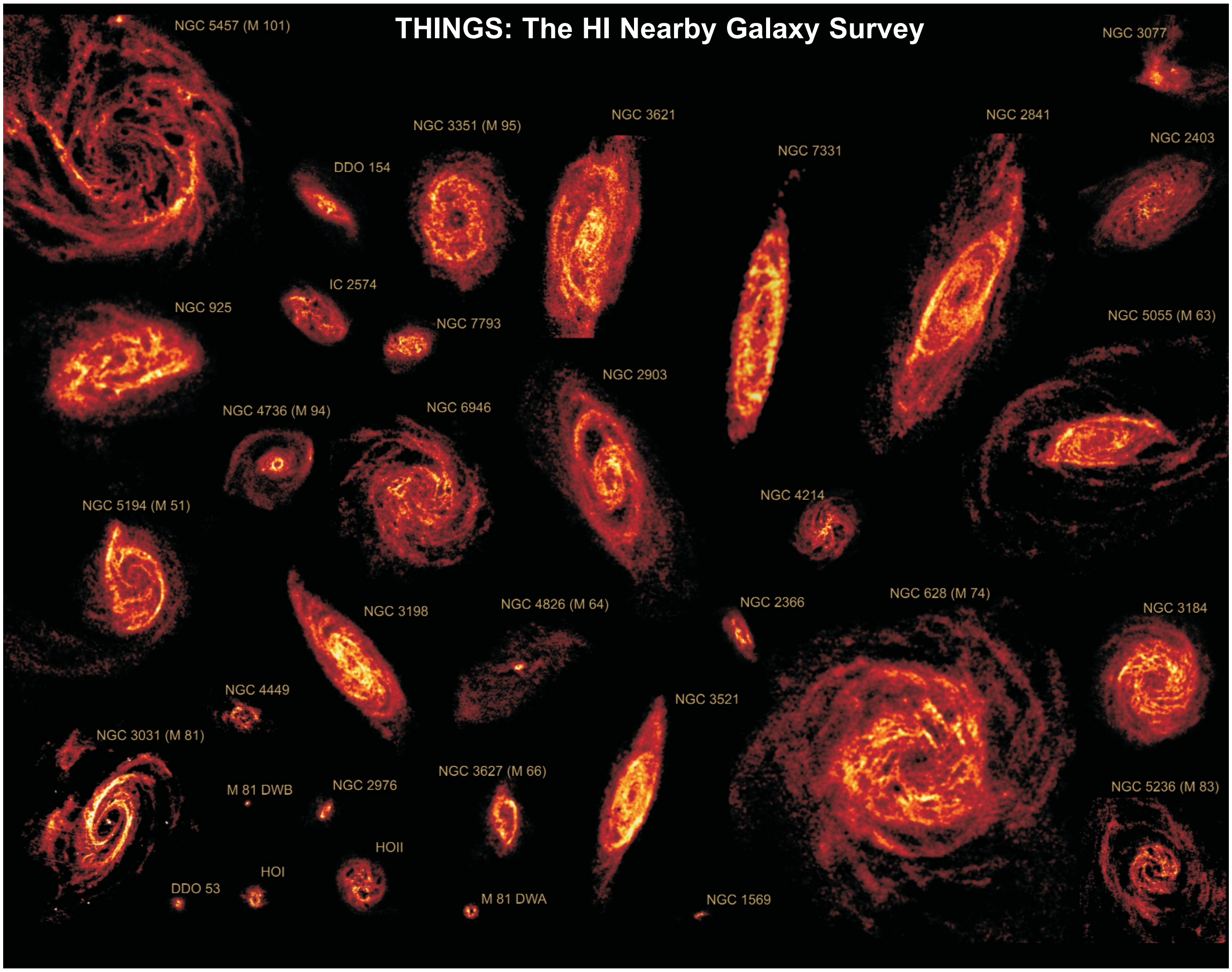


Figure 1. A composite of the atomic hydrogen surface density maps of all THINGS galaxies. All images are shown with the correct relative scale so that their HI morphologies can be compared directly (see http://www.nrao.edu/imagegallery/php/level3.php?id=562).

Studies of the atomic interstellar medium (ISM) by means of observations of the 21 cm line of atomic hydrogen (HI) are instrumental for understanding processes leading to star formation, the dynamics and structure of the ISM, and the (dark) matter distribution, thereby touching on major issues related to galaxy evolution. Right from the start, the NRAO VLA has played a key role in these studies. Early VLA HI observations of galaxies were predominantly made with the fairly compact C and D configurations, leading to images of 15–45" resolution. In the early 90's, facilitated by the installation of lower noise L-Band receivers, it became feasible to make observations in the B configuration, which led to the publication of higher resolution maps at 6" resolution of several sources. The success of these studies encouraged us to propose *The HI Nearby Galaxy Survey (THINGS)* which is the largest program ever undertaken at the VLA dedicated to 21 cm HI observations of the highest quality (6" angular and ≤ 5 km s^{-1} velocity resolution)

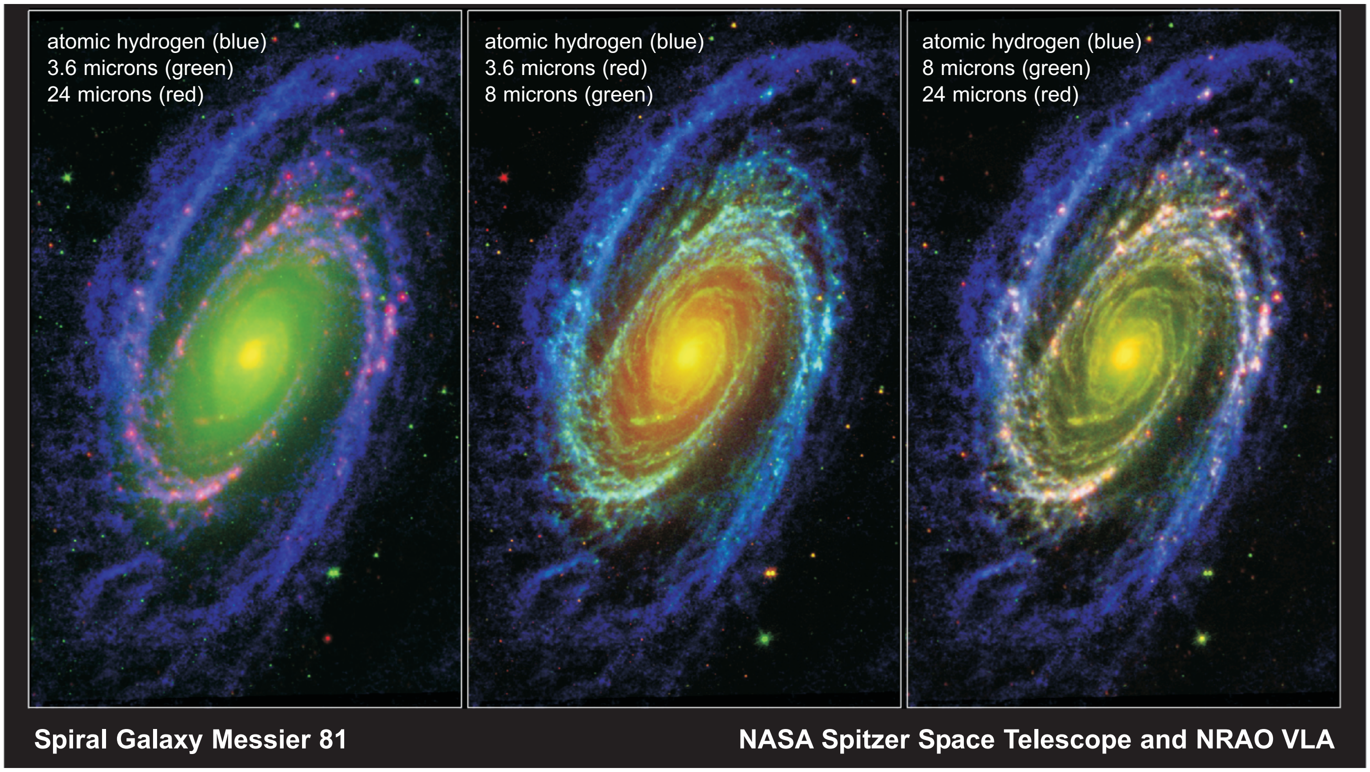


Figure 2. The spiral galaxy M81—the panels show different overlays of Spitzer near- and mid- infrared images taken from SINGS (PI: R. Kennicutt) and the HI map from THINGS.

of a sample of 34 nearby galaxies (at distances $3 < D < 10$ Mpc), covering as wide a range as possible of star formation rate, total mass, absolute luminosity, evolutionary stage, and metallicity.

In Figure 1 we show a composite of the atomic hydrogen surface density maps of all THINGS galaxies. All images are shown at the correct relative scale so that their HI morphologies can be compared directly. The angular resolution corresponds to linear sizes of 100 – 300 pc (depending on the distance of each target). The technical objective of THINGS was to obtain a homogeneous set of HI data cubes of a sample of galaxies that span a wide range in galaxy properties, at the practical limit of what can be achieved with the VLA. The scientific goal of THINGS is to address the key questions mentioned above. For that it is vital that ancillary data are available. Most THINGS galaxies feature in SINGS, the *Spitzer* Infrared Nearby Galaxies Survey and the GALEX Nearby Galaxy Survey (NGS). In fact, high quality observations from the X-ray through the radio are available at comparable resolution for each galaxy.

It is obvious from Figure 1 that there is a stunning variety of morphology, from the dwarf galaxies shown towards the bottom left, to the more massive and bigger spiral galaxies. In many cases, the HI distribution is dominated by shells and bubbles. A preliminary analysis reveals that HI shells in dwarf galaxies can reach sizes exceeding those seen in much larger and more massive spirals. To first order this result may be explained by the fact that the mechanism responsible for creating these structures, most likely the combined action of multiple supernova explosions of rapidly evolving stars in a (super) star cluster, is the same in dwarfs as in spirals. However, the gravitational potential in a dwarf galaxy is substantially lower than in a spiral galaxy, which implies that the scale height of their ISM is larger, allowing for HI shells to grow to larger dimensions before they break out of the HI disk. We are currently making an inventory of HI shells in each of our target galaxies with the aim to compare the properties of the shells across galaxy type, and their relation to sites of recent and current star formation, in order to discriminate between the various competing descriptions which exist of the structure of the ISM in galaxies.

The high velocity and spatial resolution of the data enable us to study their kinematics in considerable detail. We use this to constrain the distribution of dark matter within the THINGS galaxies. The resolution of the maps is high enough that HI emission can be traced all the way to the center of the galaxies, which is critical to investigate the shape of the dark matter density distribution at small radii. Of particular interest are the rotation curves of dwarf and late-type galaxies. These galaxies are thought to be dominated by dark matter, and their rotation curves should reflect the dynamics of their dark matter halos. A preliminary analysis suggests that at least the dwarfs whose dynamics are dominated by rotation have a core-like dark matter distribution. The major advantage of having two-dimensional, high-resolution velocity fields available is that we can explicitly model and correct for non-circular motions. We are currently working on analysing the magnitude and nature of the non-circular motions as a function of dominance of the baryons, stellar mass, etc., which will eventually lead to a much improved description of importance and distribution of dark matter in the THINGS galaxies.

Another main topic of ongoing research is a detailed comparison of the HI data to observations at different wavelengths. As an example, we show the spiral galaxy M 81 in Figure 2. The panels show different overlays of Spitzer near- and mid- infrared images and the HI map from THINGS. There is stunning agreement between the 8 micron emission (mostly dominated by PAH) detected by Spitzer and the VLA HI map. The 24 micron emission (hot dust powered by star formation) beautifully follows the spiral arms out to large radii. We are currently extending this kind of work and are combining all information available (including the UV images from GALEX) to study the star formation thresholds (the HI column density above which star formation can start) as a function of Hubble type in our sample galaxies.

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E. Brinks (University of Hertfordshire),
W. J. G. de Blok (Mt. Stromlo Observatory),
F. Bigiel (Max Planck Institute for Astronomy),
R. Kennicutt (Cambridge University),
M. Thornley (Bucknell University)

VLA Discovers Intergalactic Shock Waves Around a Cluster of Galaxies

The distribution of galaxies in the Universe is marked by vast cosmic voids embraced by a network of galaxy filaments and massive galaxy clusters containing up to thousands of galaxies. This inhomogeneous matter distribution emerged from an extremely smooth initial state created by the Big Bang, with relative density fluctuations of only 10^{-5}. This remarkable smoothness was first directly revealed by the work of the COBE (Cosmic Background Explorer) team, work that was awarded the 2006 Nobel Prize in physics. Over billions of years, the initially tiny density variations grew drastically through gravitational attraction of neighboring matter.

Larger and larger structures still form today as a result of the violent merging of galaxies and clusters of galaxies. In addition, there is a continuous accretion flow of gas falling onto galaxy clusters out of the dilute intergalactic medium. Astronomers presently think that a significant fraction (possibly up to 30 percent) of the matter present in the Universe could be in this thin, diffuse medium heated to temperatures of 10^5 K to 10^7 K by intergalactic shocks. The direct detection of this gas is an active field of research, but this is not an easy task. One of the possible methods to detect such matter is the observation of peripheral

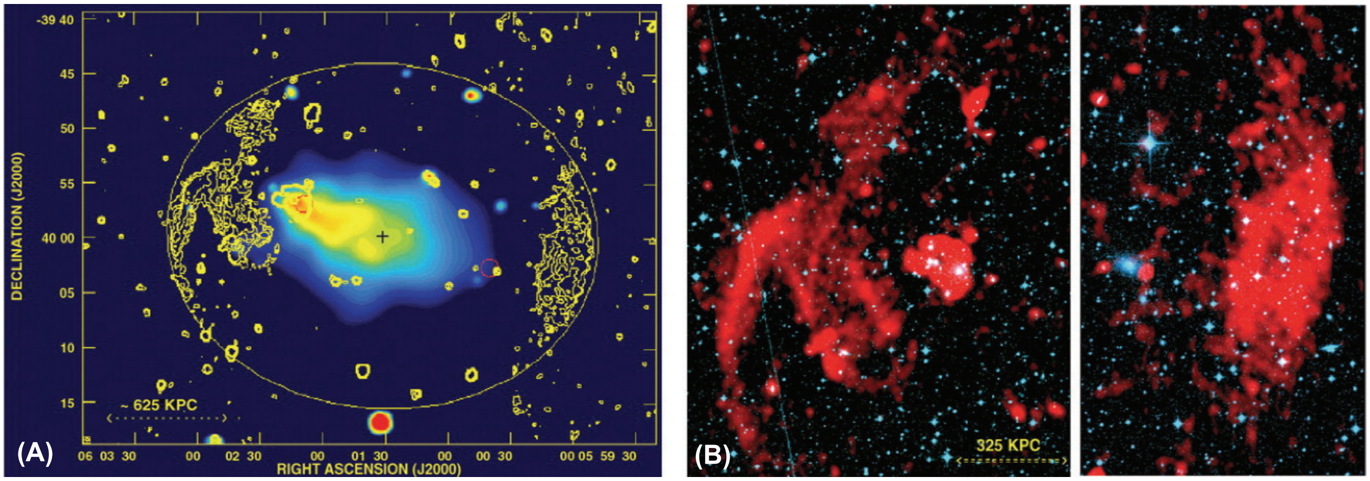

Figure 1. (A) A composite map of radio and x-ray emissions from the galaxy cluster Abell 3376. VLA observed 1.4 GHz radio emission is shown by yellow contours (0.12, 0.24, 0.48, and 1 mJy per beam; 20 arcsec FWHM beam). The yellow ellipse shows an elliptical fit to the peripheral radio structures, and the "+" marks the center of the ellipse. The central color image depicts the thermal X-ray emission detected by the ROSAT PSPC (Position Sensitive Proportional Counter) instrument (12-ks exposure; 0.14- to 2.0-keV band). The red circles mark the positions of the two brightest cluster galaxies; the brightest elliptical galaxy on the lower right and the second brightest elliptical galaxy associated with the bent-jet radio source MRC 0600-399 near the X-ray peak. (B) Composite images: The VLA 1.4 GHz radio maps (in red) for the eastern (left) and the western (right) radio structures are shown overlayed on the red band Digitized Sky Survey image (in blue).

regions in clusters of galaxies at radio wavelengths, where the strongest shocks occur.

Using data from two of the world's largest and most sensitive telescopes—the Very Large Array (VLA) in radio, and the XMM-Newton in X-ray wavelengths—we have discovered giant, ringlike structures around a cluster of galaxies, known as Abell 3376 [Bagchi et al. (2006)]. Based on its redshift of 0.046, Abell 3376 is located some 600 million light years from Earth. These huge, newly-discovered ring segments, some six million light years across (about 2 Mpc), were revealed in a deep VLA radio observation at the wavelength of 20 cm (Figure 1). These structures probably mark the sites of cosmological shock waves, caused by energetic collisions, mergers, and movement of gas and smaller galaxy groups in this cluster under construction. The discovery provides tantalizing new information about how such galaxy clusters are assembled, about magnetic fields in the vast spaces between galaxy clusters, and also about the origin of the highest-energy cosmic rays. Cosmic rays are extremely energetic protons or nuclei with energies up to 10^{20} eV, but their origin is still unknown, and they have puzzled scientists for decades [Cronin (1999)].

The X-ray observations of Abell 3376 obtained with the ROSAT and XMM-Newton satellites show that the cluster has a spectacular "bullet" or "cometary" structure, elongated along the principal axis of the radio emission (Figure 2). As in all galaxy clusters, this X-ray emission is attributed to a very hot diffuse gas (with a temperature of $\sim 6 \times 10^7$ K). The temperature map of this hot gas (Figure 2) reveals the existence of alternatively hotter and cooler zones. This suggests that a small cluster is crossing a large one, creating shock waves which are heating the gas in some regions. The movement of the small cluster is probably along the direction of the "wake" visible on the X-ray image, and this direction is perpendicular to that of the large scale shocks, which led to the formation of gigantic arcs of radio emission at the location of shock fronts.

But what produces the radio waves emitted from the giant ring structures? Gas falling into the gravitational wells of galaxy clusters can reach velocities of up to a few thousand kilometers per second. When it collides with the hot and ionized gas at a temperature of 10^7 to 10^8 K within clusters, large-scale "accretion" shock

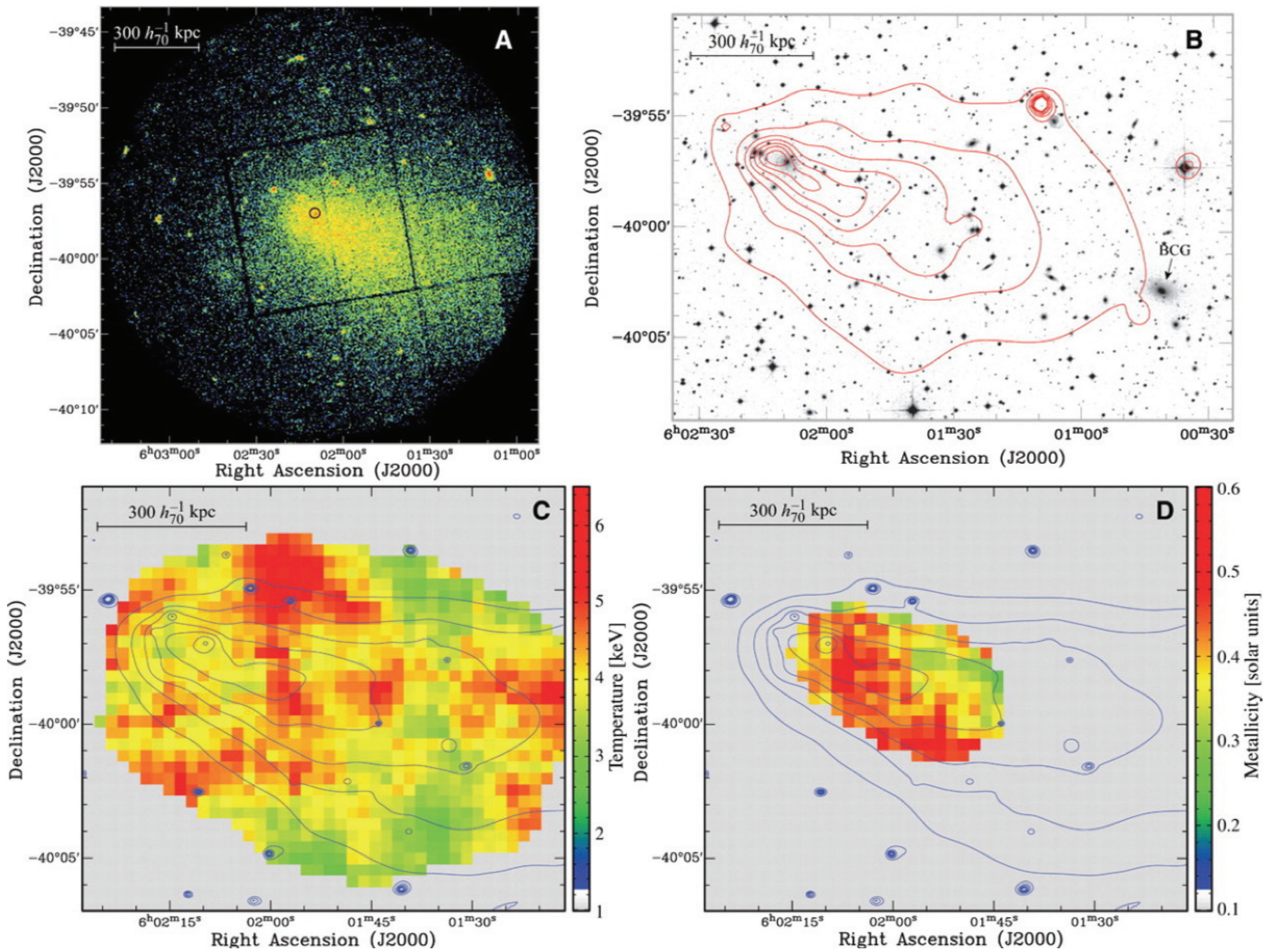

Figure 2. (A) XMM-Newton MOS1 and MOS2 (MOS = Metal Oxide Semiconductor) telescope composite photon image in the 0.3 to 8.0 keV band. The black circle shows the position of the second-brightest galaxy on the X-ray peak. (B) Red band Digitized Sky Survey optical image with ROSAT smoothed X-ray intensity iso-contours superposed (0.2 to 2.0 keV). The brightest cluster galaxy is indicated with an arrow. (C) Temperature map (color scale in keV units) derived from XMM data. Noticeably, there are several alternating cold and hot regions, their temperatures varying from ~2 to ~6 keV. The superposed X-ray intensity contours are from an adaptively smoothed XMM image. (D) Metallicity map (color scale in solar units) derived from XMM data. It shows a strong metallicity variation along the X-ray intensity elongation axis. Contours are the same as in the previous panel.

waves form that heat the infalling gas to similar temperatures [Pfrommer et al., (2006)]. Magnetic fields in the gas may permit a small fraction of the thermal gas particles to scatter back into the upstream region of the shock wave and to undergo the energizing shock compression again and again. This so-called diffusive shock acceleration process produces nonthermal particles with an energy spectrum easily extending into ultrarelativistic energies (close to speed of light), where particle energies exceed their rest mass energies by large factors. Although the number of these relativistic particles is small compared with the thermal ones, they can account for a substantial fraction of the dissipated shock energy. The highly energetic electrons can be “kicked” by the shock waves to very high energies. These electrons would gyrate across the magnetic field lines and emit the feeble radio waves picked up by the highly sensitive VLA radio antennas. This so-called synchrotron radiation is also observed in particle accelerators on Earth, as well as in the expanding supernova shock fronts.

We propose that the pair of giant radio structures in galaxy Abell 3376 may be emission from the accretion shock of the cluster. This dual radio morphology may be caused by the stronger matter flow onto the cluster along an embedding galaxy filament. If this interpretation is correct, it would be a remarkable finding, because it would imply the presence of magnetic fields in the infalling gas, whereas magnetic fields have so far only been detected within galaxy clusters. Furthermore, we would have the first observational identification of an accretion shock wave. Accretion shock waves are very interesting because they may be the link to the origin of the still mysterious ultra-high-energy cosmic rays [Kang, Rachen, and Biermann (1997)], which are protons with energies up to 10^{20} eV. Although most of the energy of the cosmic structure formation is dissipated in the centers of galaxy clusters, the shock waves in the outskirts and especially the accretion shocks have much higher Mach numbers and therefore should be more efficient particle accelerators, as can be seen in Figure 1. The highest energy electrons from such shocks can scatter photons of the cosmic microwave background into gamma-ray bands and thereby contribute to the observed and still unresolved gamma-ray background [Loeb & Waxman (2000); Miniati (2002)]. As a result, the giant radio rings in Abell 3376 mark locations to be monitored in the future for all kinds of high-energy radiation.

There is another plausible explanation for the double arcs, however. In the late stage of a violent merger of similarly sized galaxy clusters, an outgoing pair of shock waves emerges. These shock waves steepen as they run into the more dilute gas of the cluster outskirts, similar to tsunami waves propagating into shallower water. A resulting pair of radio relics was indeed observed in a morphologically similar merging cluster, Abell 3667 [Rottgering, et al., (1997)] and is well reproduced by numerical simulations [Roettiger, Burns & Stone (1999)]. Possibly, the radio structures in Abell 3376 are also of this type.

In any case, it is exciting that the giant radio arcs in Abell 3376 provide us with direct insight into the fluid dynamics of cosmic structure formation. This important and surprising observation gives a foretaste of the radio glow of the cosmic large-scale structure [Waxman & Loeb (2000)] which one hopes to discern with the next generation radio telescopes such as the Low Frequency Array (LOFAR), the Long Wavelength Array (LWA), and the Square Kilometre Array (SKA).

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S. Paul (Universitat Wurzburg, Germany)

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A Shocking Day on the Sun

The Sun's atmosphere is a turbulent place, full of movement, waves, and disturbances at very different height levels. It is also the physical setting in which many phenomena, later found to be widespread in astrophysics, were first identified, including accelerated particle beams and shock waves. Solar radio astronomy was responsible for these discoveries in the years after World War II, when radar scientists turned their wartime expertise to the skies and found numerous bright radio bursts coming from the Sun. The nature of these bursts could be identified by observing the changes in their frequency characteristics as a function of time, in what we call a "dynamic spectrum".

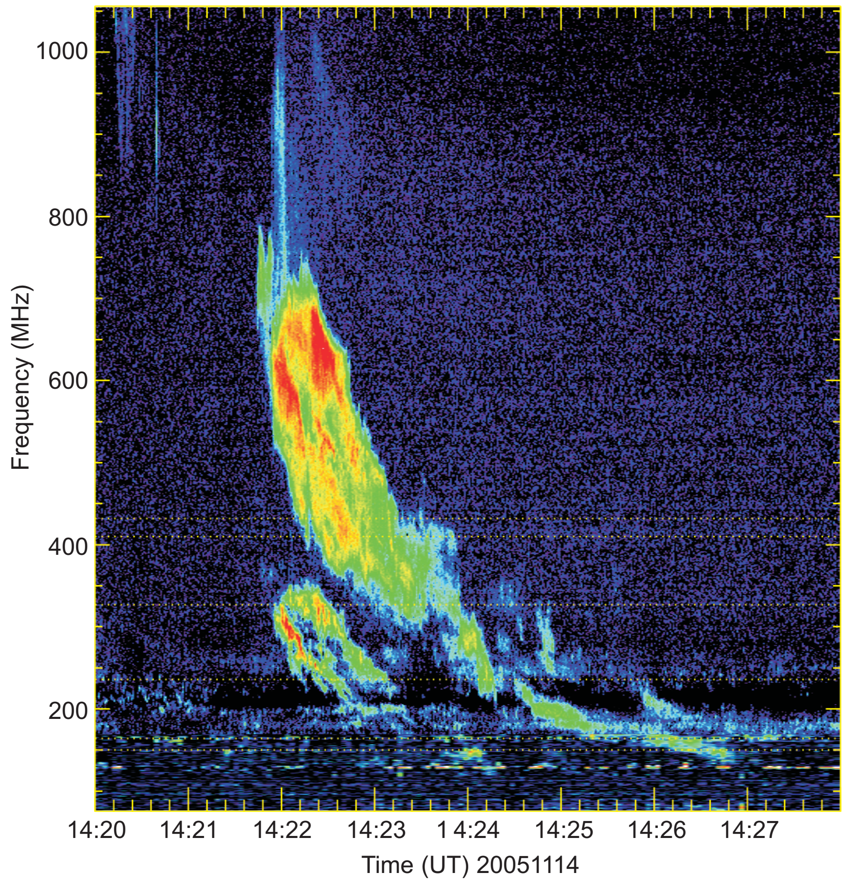


Figure 1. The dynamic spectrum of the radio burst, merging the data from the Green Bank Solar Radio Burst Spectrometer (GBSRBS) from 170 to 1070 MHz with the RSTN San Vito spectral data from 75 to 170 MHz, both at one second time resolution. The dashed horizontal lines show the observing frequencies of the Nançay Radio Heliograph in France.

Among the brightest and most dramatic of the solar radio events are the so-called "Type II" bursts. These are relatively narrow-band features that usually start at frequencies of order ~100 MHz or below, and then drift to even lower frequencies. They often occur in fundamental-harmonic pairs, drifting down to near the ionospheric cutoff (ν_c ~10 MHz) over about ten minutes. The emission mechanism has been confidently identified as plasma emission, i.e., conversion of electrostatic Langmuir waves at the electron plasma frequency ($\nu_p \propto \sqrt{n}$, where n is the ambient electron number density in the solar atmosphere) into propagating electromagnetic waves at the plasma frequency and its harmonic. The downwards drift in frequency represents the outwards motion of a disturbance in the solar atmosphere at heights of order 1 $R_\odot$ above the surface. Using atmospheric density models the typical speed of these disturbances was estimated to be in the range 500–2000 km s^{-1}. Since the relevant local signal speed is the magnetohydrodynamic Alfvén speed, known to be about 500 km s^{-1} at these heights, these disturbances were identified as shocks, driven by an as yet unidentified disturbance.

For a gap of many years in the 1980s and 1990s it was not possible for scientists to work with dynamic spectra of such events at western hemisphere times. With increased interest in solar phenomena resulting from a desire to predict conditions in the solar wind at the Earth, funding from the National Science Foundation has been used to construct a system (the Solar Radio Burst Spectrometer, or SRBS) to acquire spectra of solar radio bursts all the way from 10 to 1000 MHz, taking advantage of the radio-quiet zone around

Green Bank to cut down on interference features. The low-frequency system, observing below 70 MHz, was described in the January 2005 *Newsletter*. The high-frequency system, from 200 to 1000 MHz, has been operating with a feed on the 45 foot dish at Green Bank since mid-2005.

Solar Type II radio bursts are predominantly low-frequency phenomena, so we were not expecting to observe many of them with the SRBS high-frequency system, particularly during solar minimum. It was therefore with some surprise that we looked at the data from November 15 last year and saw the event shown in Figure 1: a classic Type II burst with fundamental and harmonic bands, both split as is often the case, but starting at the remarkably high frequency of 760 MHz (in the harmonic band). This is almost an order of magnitude higher frequency than a typical Type II. Since the frequency goes as $\sqrt{n}$, this corresponds to seeing the Type II start at a density 100 times normal. Since the Alfvén speed is $\propto B/\sqrt{n}$, where B is the magnetic field strength, the onset of emission at much higher densities implies lower than normal magnetic fields in the atmosphere at the corresponding densities. A search of the literature reveals that only a few of the thousands of cataloged Type IIs have been observed at such a high frequency, so we set out to investigate the properties of this event in more detail.

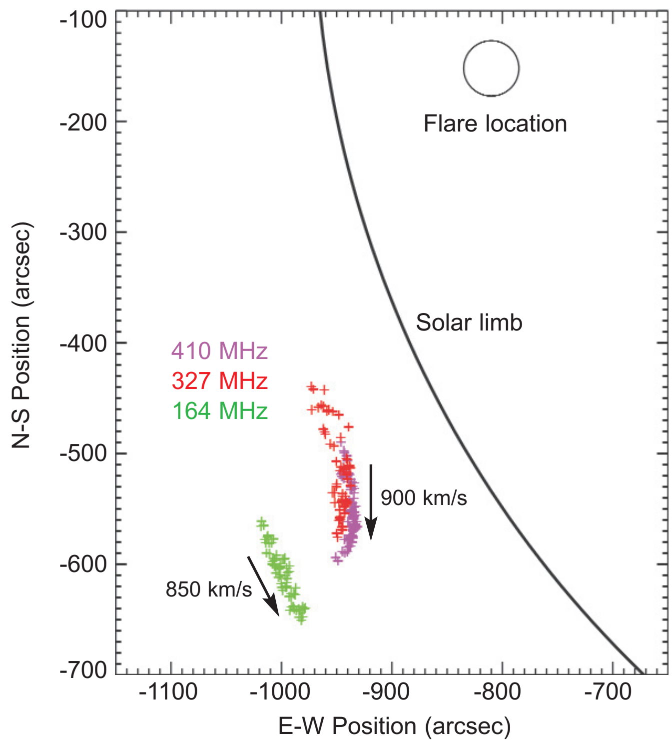


Figure 2. Motion of the Type II radio burst obtained by fitting source positions in images at frequencies of 410, 327 and 169 MHz. The arrows indicate the direction of motion and the fitted speeds are shown. At 410 and 169 MHz all positions belong to the harmonic branch, with the 169 MHz measurements coming at a much later time (see Figure 1); at 327 MHz there is a mixture of harmonic and fundamental emission. The flare location is marked in the upper right corner of the plot.

We were in luck in that the event occurred during the very narrow time range when the Sun can be observed simultaneously in the early morning at Green Bank and the late afternoon at the Nançay Radioheliograph (NRH) in France, which makes images of the Sun at several fixed frequencies between 150 and 432 MHz. Actual measurements of motion of Type II radio bursts on the sky are quite rare, partly because at a fixed frequency emission comes from a fixed electron density level, and partly because at the low frequencies where Type II bursts most commonly occur the spatial resolution of imaging observations is generally poor. In the case of this event, we can map the radio emission at all the observing frequencies of the NRH. We find the radio source to be quite small, and showing very clear motion (Figure 2), with the emission spatially coincident at all frequencies above 200 MHz and displaced slightly outwards at lower frequencies.

The position measurements show motion at a constant velocity of order 900 km s^{-1} at all frequencies, which is consistent with what has been inferred for Type II bursts from coronal density models and frequency drift rates. However, those inferences assume that the Type II burst moves outwards along a radial density gradient, whereas the NRH images clearly show the Type II burst to be moving tangentially, parallel to the Sun's limb, and displaced laterally a long way from the location of the corresponding solar flare. Such large lateral displacements of the Type II location from the flare location have been seen in other cases as well. The height of the radio emission when it commences at

380 MHz in the fundamental branch is indeed much larger than typical atmospheric models suggest for the corresponding density. Furthermore, coronagraph observations of the event show no sign of a coronal mass ejection, one of the leading candidates for the driver of Type II shocks. Instead, the small size of the radio source and the lack of offsets between the location at different frequencies from 200 to 432 MHz, corresponding to a density range of a factor of 4, suggest an alternative picture of a driver that may have been a small dense blob of plasma propagating laterally at a speed well above the Alfvén speed of the surrounding atmosphere.

This event is particularly valuable for understanding the properties of Type II bursts because the radio spectrum is essentially uncontaminated by any other kind of radio emission, and it occurs at high frequencies where relatively high spatial resolution imaging can be achieved. This event provides one of the most convincing measurements of motion in the plane of the sky yet achieved for this class of solar radio burst, but it adds to the mysteries surrounding these dramatic bursts in other ways.

S. White (University of Maryland), C. Mercier (Paris Observatory), T. Bastian and R. Bradley (NRAO)

Atacama Large Millimeter/submillimeter Array

Second NAASC ALMA Science Workshop:
Transformational Science with ALMA: Through Disks to Stars and Planets

On June 22–24, 2007, the North American ALMA Science Center at NRAO and the University of Virginia will sponsor a workshop in Charlottesville, Virginia on protostellar disks. The focus of the meeting will be to discuss how ALMA will impact our understanding in several key areas of disk formation and evolution including:

- Cores, Fragmentation and the Earliest Observable Stages of Protostellar Disks
- The Disk-Envelope-Outflow Connection
- Low and High Mass Disk Structure
- Disk Chemistry, Kinematics, Isotopic Anomalies, Grain Growth, and Sedimentation
- Flaring, Spiral Density Waves, Turbulence, Magnetic Fields in Protostellar Disks
- Debris Disks
- Planet Formation: Fragmentation and Gaps
- Synergy between ALMA and Upcoming Optical, Infrared, and Radio Facilities

The members of the Scientific Organizing Committee are John Bally (University of Colorado), Crystal Brogan (Chair, NRAO), Masa Hayashi (NAOJ), Michiel Hogerheijde (Leiden University), Doug Johnstone (HIA), Zhi-Yun Li (University of Virginia), Lee Mundy (University of Maryland), Jonathan Williams (University of Hawaii), and Al Wootten (NRAO). The first announcement and other information are available at *http://www.cv.nrao.edu/naasc/disk07.html*. It is our hope that the meeting 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. In order to solicit talks on the most cutting-edge research, we will be requesting proposals for specific presentation topics in the near future. Students and post-docs are especially encouraged to attend. Please bookmark our meeting page, and visit often for updates. Pre-registration is now available and we will be open for abstract submission soon!

Crystal Brogan

The North American ALMA Science Center (NAASC)

The proposal for funding North American ALMA operations and the North American ALMA Science Center was submitted to the NSF on October 31, 2006. Prior to submission, intensive reviews were held, including an internal review by key NRAO operations staff and Canadian representatives, and an external review by the ALMA North American Science Advisory Committee. The global ALMA operations plan was also submitted on November 3 to the ALMA Board for review. A summary of the plan was presented to the Board in Madrid in November. The next quarter will see extensive external reviews of the operations plan and the NSF proposal.

The NAASC staff are participating in extensive software testing in Socorro and Charlottesville, including tests of the ALMA pipeline and the CASA-PY reduction software. The NAASC was well represented at the Madrid ALMA science meeting, *Science with ALMA: A New Era for Astrophysics*, with a number of talks and posters being presented on recent scientific research by the staff. The second NAASC science workshop entitled *Transformational Science with ALMA: Through Disks to Stars and Planets*, to be held in June, 2007 in Charlottesville, is accepting pre-registrants (see associated *Newsletter* article). Lastly, a concerted effort has been made to establish a spectral line working group whose primary purpose is to provide ALMA a complete database of molecular and recombination lines.

This database can be used by all astronomers interested in spectral line astrophysics and, in particular, astrochemistry. This effort is being led by Anthony Remijan (see associated *Newsletter* article) and includes members from all the interested international institutions, including JPL, Herschel, Illinois, NIST, Manchester, Koln, and others.

ALMA commissioning is imminent, and early science soon after. The NAASC staff are available for presentations on ALMA capabilities, status, and science at North American institutions. Please contact the undersigned if you are interested in a visit by a NAASC staff member.

Chris Carilli
ccarilli@nrao.edu

ALMA's Lab Testing Moves to the Field

As the physical plant in Chile grows in preparation for the arrival of the first antennas in 2007, the electronics has moved from laboratory testing to field testing. The components of ALMA have been extensively tested in the laboratory, first in Tucson and more recently at the Array Operations Center (AOC) in Socorro. The controlled conditions of the lab provided engineers and scientists with an opportunity to test the timing, phase and amplitude stability, robustness, and other qualities of the backend electronics. With the lab goals achieved, the elements of the backend are in the process of being moved to the two remaining prototype antennas at the Antenna Test Facility (ATF) near the VLA. There they will be integrated with remaining components of the prototype ALMA system to provide preliminary astronomical data on its performance.

Holography using the system that will be used during Q2 2007 in Chile at the Operations Support Facility (OSF) is in its final stages at the ATF. This system has been installed on the Vertex antenna. The holography system tests a complete system as it will be installed in Chile, including data collection in an ALMA format, storage in an ALMA archive, and retrieval from the archive for analysis. Holography images of the antenna surface will be compared with photogrammetric measurements for verification.

Meanwhile, at the NRAO Technology Center (NTC) in Charlottesville, cartridges for ALMA Bands 3 (3 mm), 6 (1.3 mm) and 7 (.85 mm) have been installed in the dewar with all their associated electronics. The Band 9 cartridge will be installed shortly to comprise the first ALMA Front End incorporating all receiver elements. After a period of testing at the North American Front End Integration Center at the NTC, this first Front End will be integrated into the prototype

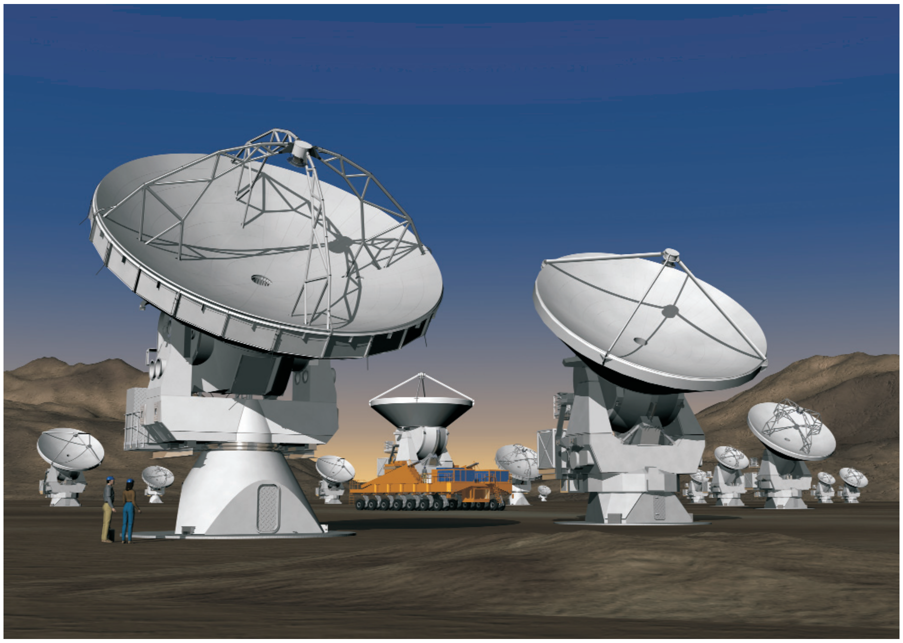


Figure 1. Artist's concept of the ALMA Array as it might appear near the end of construction. Illustrated is the VertexRSI antenna (left foreground, the ALMA antenna trannsporter (center mid-distance), the AEM antenna (right foreground), and the Melco ACA antenna (right background) © ESO.

designed for the ALMA system and the SMA system in which is was deployed. A better match has been achieved and measurements continue on Mauna Kea.

Preparations proceed for the arrival of the elements of ALMA in Chile, and for their Assembly, Integration, Verification (AIV), Commissioning, and Operation. Many of the AIV staff have been hired and have commenced training at various ALMA sites around the world. As ALMA's focus shifts to Chilean operations over the next years, the staff will outgrow the current offices in Santiago. A Call for Tender for a more permanent Santiago home for ALMA, to be located adjacent to ESO, is being prepared. Several key Operations posts are being filled: the Head of Administration and Head of Science Operations are already working on planning a smooth transition from construction to operations over the next few years. The training of the next generation of scientists and engineers also continues; about 138 attended a school on interferometry in December held at the Universidad Católica in Santiago. As the current round of schools featuring use of ALMA closes with the winter school in Tokyo in January, nearly 600 young astronomers will have been introduced to the ALMA system and its promise of transformational science.

Much of the ALMA equipment arrives at the OSF where it receives its first level of testing and integration. The heart of this activity is in the OSF Technical Building (OSF TB), well under construction now on the site and the focus of a fixed webcam, linked to www.alma.info. The antennas first arrive at the individual contractor's Site Erection Facilities (SEF). Construction of the first of these, for the Vertex antenna, is well under way—27 containers of construction materials arrived in December from Texas and are being installed.

system at the ATF in New Mexico. After testing there it will be shipped to the OSF in Chile for integration into the first production antenna for testing on the sky. Also at the NTC, work continues on the second quadrant of the ALMA correlator, which will be populated with tunable filter bank (TFB) cards produced in France to increase the flexibility of the correlator. The first quadrant, running at the NTC for many months, will be retrofitted with TFBs. During early 2007 work will begin on moving the correlator to the Technical Building at the Array Operations Site, its permanent home.

A Workshop on Water Vapor Radiometry (WVR) was held in October at Wettzell, Germany to exchange and compare information among the astronomical, meteorological and geodetic communities. R. Hills presented interim results from the prototype ALMA WVRs, deployed at the Smithsonian Millimeter Array on Mauna Kea. The correction is meeting the ALMA specifications under good conditions. However the comparison between observed interferometer phase and that inferred from the WVRs was limited in good conditions by a mismatch between the radiometer

Figure 2. Work on the building for the VertexRSI Site Erection Facility has begun in prepration for receiving the first production antenna in early 2007. The ALMA camp is in the right background, in front of Licancabur.

While the OSF TB proceeds toward first quarter 2008 completion, AIV activities will be conducted from a temporary building at the OSF, which was completed in November. One of the first activities testing the production antennas will be holography; the tower for the holography transmitter is also nearing completion. The very active construction on the site now involves over 300 people. This number will grow as ALMA grows, so expansion of the already full camps currently on the site is being pursued.

Final outfitting of the 16,570 foot elevation Array Operations Site Technical Building (AOS TB) is well under way, with the installation of the HVAC (heating, ventilating and air conditioning) systems just completed. By the time this article appears, the building will be completely enclosed, powered by a temporary generator, and connected to the OSF via an interim link. Nearby, the design of the road and fiber network at the AOS is nearing final stages, including the design of the outermost antenna station network. Just north of the AOS, preparations are being finalized for installation of the stations for the central stations of the array, its most compact configuration.

Al Wootten

Transitions

At its November meeting, the ALMA Board welcomed several new members to the ALMA Science Advisory Committee (ASAC), while thanking several members for their service during the past three years. Jean Turner (UCLA) and Christine Wilson (McMaster University) have provided the ALMA Board advice for many years; both have chaired the Committee. Joining the ASAC will be Jacqueline van Gorkom (Columbia) and Douglas Johnstone (HIA).

Todd Hunter arrived in Charlottesville from the Smithsonian Submillimeter Array at the Center for Astrophysics. At NRAO he will work on both the Green Bank Telescope and ALMA. Robert Reid arrived as an ALMA postdoc in Charlottesville from the Dominion Radio Astrophysical Observatory (DRAO) in Penticton. Antonio Hales joined the Charlottesville ALMA group from University College London, where he recently completed his dissertation on the circumstellar environments of stars with infrared excesses.

ALMA is operated by the Executives through the Joint ALMA Observatory in Santiago. Key staff positions recently filled include the Head of Administration, Mr. Russell Smeback, who will join the Santiago staff in December, and the Head of Science Operations. At ESO, Thomas Wilson has left the position of European Project Scientist to join the Office of the Director General; Robert Laing is filling the post of European Project Scientist during the interim.

Al Wootten

ALMA Working Group on Spectral Line Frequencies and The Molecular Spectroscopy Database (Splatalogue)

The next generation of powerful radio and millimeter/submillimeter observatories (e.g. EVLA, ALMA, and Herschel) will require extensive resources to help identify the thousands of spectral line transitions that will undoubtedly be present toward numerous astronomical objects including high and low mass star forming regions, protoplanetary nebulae and comets. The abundance of spectral line features at millimeter/submillimeter wavelengths present toward high mass star forming regions is already apparent with recent work done with the CSO and APEX toward Orion. Thus, in order to provide the astronomical community with the tools needed to conduct research in spectral line astrophysics, the ALMA Working Group on Spectral Line Frequencies (AWGSLF) was convened on Thursday, July 27, 2006. The AWGSLF mission statement is:

"The ALMA Working Group on Spectral Line Frequencies is dedicated to generating a collated and rationalized database of spectral line frequencies, transitions, and line strengths from radio to infrared wavelengths that can be freely accessed and used by the entire astronomical community interested in spectral line astrophysics."

To that end, the charter members and present chairs of the AWGSLF, Anthony J. Remijan of NRAO, Charlottesville and Andrew J. Markwick-Kemper of the University of Manchester have developed the Molecular Spectroscopy Database (Splatalogue). Splatalogue is an attempt to collate, rationalize, and extend existing spectroscopic resources for use by the astronomical community. The Jet Propulsion Laboratory (JPL) database, the Cologne Database of Molecular Spectroscopy (CDMS) and the Lovas/National Institute of Standards and Technology (NIST) database provide an enormous amount of data—collecting the data in all three online databases together generates over 3.5 million transition data entries across almost 700 molecular species. As part of the ALMA

	Frequency	Uncertainty	LineList	E_L	Transition	
1	43.42376	0.05	JPL	0	1-0	ALMA BAND 1
2	43.42376	0.05	CDMS	0	1-0	ALMA BAND 1
3	43.42386	0.022	Lovas/NIST		1-0	ALMA BAND 1
4	86.84696	0.05	JPL	1.4485	2-1	ALMA BAND 2
5	86.84696	0.05	CDMS	1.4485	2-1	ALMA BAND 2
6	86.84701	0.045	Lovas/NIST		2-1	ALMA BAND 2
7	130.26862	0.05	JPL	4.3454	3-2	ALMA BAND 4
8	130.26862	0.05	CDMS	4.3454	3-2	ALMA BAND 4
9	130.26872	0.067	Lovas/NIST		3-2	ALMA BAND 4
10	130.26872	0.067	Lovas/NIST		3-2	ALMA BAND 4
11	173.68828	0.09	Lovas/NIST		4-3	ALMA BAND 5
12	173.68831	0.08	JPL	8.6907	4-3	ALMA BAND 5
13	173.68831	0.08	CDMS	8.6907	4-3	ALMA BAND 5
14	217.10498	0.011	Lovas/NIST		5-4	ALMA BAND 6
15	217.10498	0.08	JPL	14.4843	5-4	ALMA BAND 6
16	217.10498	0.08	CDMS	14.4843	5-4	ALMA BAND 6
17	260.51801	0.08	JPL	21.7261	6-5	ALMA BAND 6
18	260.51801	0.08	CDMS	21.7261	6-5	ALMA BAND 6
19	260.51807	0.014	Lovas/NIST		6-5	ALMA BAND 6
20	303.92682	0.0173	CDMS	30.4161	7-6	ALMA BAND 7
21	303.92688	0.016	Lovas/NIST		7-6	ALMA BAND 7
22	303.92697	0.1	JPL	30.4161	7-6	ALMA BAND 7
23	347.33057	0.02	CDMS	40.554	8-7	ALMA BAND 7
24	347.33063	0.3475	JPL	40.554	8-7	ALMA BAND 7
25	347.33066	0.018	Lovas/NIST		8-7	ALMA BAND 7
26	390.72845	0.877	JPL	52.1397	9-8	ALMA BAND 8
27	390.72861	0.0238	CDMS	52.1397	9-8	ALMA BAND 8
28	434.11954	1.8253	JPL	65.173	10-9	ALMA BAND 8
29	434.12018	0.0293	CDMS	65.173	10-9	ALMA BAND 8
30	434.12030	0.023	Lovas/NIST		10-9	ALMA BAND 8
31	477.50308	3.3717	JPL	79.6536	11-10	ALMA BAND 8
32	477.50458	0.0368	CDMS	79.6537	11-10	ALMA BAND 8
33	477.50473	0.025	Lovas/NIST		11-10	ALMA BAND 8
34	520.87817	5.7395	JPL	95.5814	12-11	
35	520.88110	0.0468	CDMS	95.5815	12-11	
36	564.24396	9.1991	JPL	112.956	13-12	
37	564.24902	0.0593	CDMS	112.956	13-12	
38	607.59943	14.072	JPL	131.777	14-13	ALMA BAND 9
39	607.60760	0.0745	CDMS	131.778	14-13	ALMA BAND 9
40	607.60779	0.03	Lovas/NIST		14-13	ALMA BAND 9
41	650.94360	20.7352	JPL	152.044	15-14	ALMA BAND 9
42	650.95612	0.0927	CDMS	152.045	15-14	ALMA BAND 9
43	650.95636	0.035	Lovas/NIST		15-14	ALMA BAND 9
44	694.27545	29.6253	JPL	173.758	16-15	ALMA BAND 9
45	694.29388	0.1139	CDMS	173.759	16-15	ALMA BAND 9
46	694.29419	0.034	Lovas/NIST		16-15	ALMA BAND 9
47	737.59387	41.2428	JPL	196.916	17-16	
48	737.62018	0.1384	CDMS	196.918	17-16	
49	780.89777	56.1565	JPL	221.52	18-17	
50	780.93433	0.1663	CDMS	221.522	18-17	
51	824.18591	75.0074	JPL	247.568	19-18	ALMA BAND 10
52	824.23553	0.1978	CDMS	247.571	19-18	ALMA BAND 10
53	867.45709	98.5132	JPL	275.06	20-19	ALMA BAND 10
54	867.52307	0.2331	CDMS	275.065	20-19	ALMA BAND 10
55	910.71002	127.473	JPL	303.995	21-20	ALMA BAND 10
56	910.79633	0.2723	CDMS	304.002	21-20	ALMA BAND 10

Table 1. Here we query the splatalogue to show the lines of SiO v=0 which lie in the ALMA receiver bands.

and EVLA scientific plans, one of the main goals of telescope operations is that each new instrument be easy to use by a “novice” observer. Thus, a molecular spectroscopy database needs to be available that is as descriptive as possible in the way it represents molecular, atomic, and recombination line transitions.

Currently, the databases that are used for this search, the JPL and CDMS databases, do not describe transitions in the most user-friendly way, and where the catalogs overlap, these descriptions are not in general consistent and have to be compared and resolved to be made so. Furthermore, the Lovas/NIST database tabulates only observed interstellar transitions, but it does provide the user with a much better representation of molecular transitions by using a full description.

One of the main goals of the Splatalogue is to update the procedure by which a user searches for spectral lines—the Splatalogue will contain at least one example of every detected line. The linelists on which the Splatalogue builds are primarily ordered by species, then by frequency. The Splatalogue is different—it is ordered by species, then by transition, which is more sensible. In this way, every observation, calculation or measurement of a transition can be easily cross-referenced against that table. So you can ask for e.g. CH_3CN 4(3)-3(3) and see all the entries for that species/transition, be they observation, measurement, or calculation. Furthermore, it is the goal of the members of the AWGSLF to provide the astronomical community a prioritized list of frequencies for the most common molecules and their transitions based on what the AWGSLF believes to the most accurate measurement of that transition as well as to assist the observer in deciding which molecular species and transitions are astronomically relevant.

From a querying point-of-view, the Splatalogue has two major modes of operation—one user-friendly, the other application-friendly. The former is a PHP based web interface, an example of which is shown in Table 1. The latter returns results of IVOA-compliant queries in VO-table XML. Clearly there is scope for other data formats as well.

Service is also designed to be fully extensible. The interface between the Splatalogue and the ALMA Archive is key, but extension from within the astronomical spectroscopy community itself will also be possible and encouraged. We are collaborating with the ALMA Archive group to ensure that the Splatalogue and the Archive can communicate and share spectral line data with as much flexibility as possible. We envision updating the Archive with new spectral line data by using the timestamp field of Splatalogue (which shows when a given entry was created) in conjunction with the time of the last update the Archive received.

Currently, meetings are taking place between the members of the AWGSLF. The minutes of each meeting and the current progress taking place in the AWGSLF and with Splatalogue can be found at *http://wikio.nrao.edu/bin/view/ALMA/ALMAWorkingGroupSpectralLineFrequencies*.

Finally, the initial public release of Splatalogue is planned for December 31, 2006 and it will exist at *http://www.splatalogue.net*. Furthermore, it is the intention of the members of the AWGSLF, NRAO, and ALMA to continue work on updating and maintaining the Splatalogue as new astronomical and laboratory data become available. In general, a new species or a re-measured species will be added no later than one week upon receipt of the new data from the laboratory community and after the public release. Overall the agreement by almost all the laboratory spectroscopists contacted in North America to work on updating the Splatalogue is very encouraging and we anticipate worldwide cooperation for this effort.

For further information about Splatalogue or the AWGSLF, please contact Anthony Remijan: *aremijan@nrao.edu* or Andrew Markwick-Kemper: *andrewjmk@gmail.com.*

Anthony J. Remijan

Expanded Very Large Array

Current Project Status

Eight antennas are in various stages of retrofit to the EVLA design. Five EVLA antennas (13, 14, 16, 18, and 24) are now used in routine VLA observations. These antennas account for over 13 percent of VLA antenna-hours devoted to astronomical observations. Antenna 26 is undergoing tests and is expected to contribute to routine array observations by the end of November 2006. Electronics outfitting on Antenna 23 is nearly complete, and it should return to operations in December 2006. The mechanical overhaul of Antenna 17 is well underway. Outfitting the antenna with electronics will commence when its mechanical overhaul is complete in December 2006.

The prototype of an EVLA design for the 3-bit, 4 GHz sampler was completed. The EVLA design is based on the commercially available Rockwell RAD-006 digitizer chip. The sampler circuit board was built and tested. Laboratory tests show that the sampler meets project specifications.

The delivery of the WIDAR correlator has been delayed because of errors in the fabrication of its printed circuit boards. Fortunately, the fabrication errors have been corrected, and no further delays due to the fabrication process are expected. The baseline board, which carries the correlator chips, is now being tested at the DRAO in Penticton, British Columbia. Prototypes of the correlator's fanout board, station board, and common backplane are scheduled to be delivered to the DRAO in early to mid December 2006. On-the-sky tests of the prototype correlator are scheduled for February 2008, and the full board installation and testing of the final correlator at the VLA site is scheduled to begin in March 2009.

Figure 1. EVLA 1–2 GHz feed horns.

A correlator face-to-face meeting was held in Socorro on October 31 – November 1, 2006. The meeting allowed EVLA project personnel to meet with their Canadian colleagues to discuss and resolve correlator-related issues. Topics discussed at the meeting included correlator board testing, software needed for on-the-sky tests of the prototype correlator, format of correlator output data, correlator installation plans, and the monitor and control system for the correlator's electrical power.

The fire protection system for the correlator shielded room consists of an FM200 gas suppressant system and a conventional water sprinkler system as a backup. The FM200 system was accepted from the contractor in October 2006, and it was placed in operation, with the exception that the FM200 storage tanks will remain electrically disconnected from the system until the correlator arrives. The NRAO safety department is coordinating training sessions with the FM200 contractor to train NRAO personnel on the operation and maintenance of the system. The water sprinkler system is complete and operational.

Fabrication of the feed horns for EVLA receivers continues at a brisk pace. The assembly of all 4–8 GHz feed horns is complete. A vendor is fabricating the 26–40 GHz feed horns, and the delivery of the components for these horns is expected to be complete in November 2006. Project plans call for twenty 1–2 GHz feed horns to be complete by September 2007, and 16 of these have been fabricated to date (Figure 1).

The prototype EVLA 1–2 GHz receiver with its new wideband orthomode transducer (OMT) was installed on Antenna 14 in late October 2006. On-antenna tests of the receiver are underway. Fabrication drawings for the OMT were completed, and bids for OMT production will be solicited.

The design for the 1–2 GHz OMT was scaled for use at 4–8 GHz. Two prototype 4–8 GHz OMTs have been fabricated and are undergoing RF tests in the laboratory.

The mechanical design of the 26–40 GHz receiver was completed. A three dimensional drawing of the receiver was used to optimize component placement with the goal of minimizing insertion loss in the signal path (Figure 2). Fabrication drawings of receiver components were submitted to the VLA machine shop, and the assembly of a prototype receiver will begin in December 2006.

Antenna testing identified signal isolation problems in the baseband downconverter. The problems were resolved by adding an isolation amplifier and installing board covers with RF-absorbing material in the IF section of the module. The downconverter modules will be complete with the installation of gain-slope equalizing filters, which are currently under development at the NRAO Central Development Laboratory.

Occasional, unpredictable phase jumps have been reported on VLA-EVLA baselines. The jumps occur most at frequency changes, but have been observed in the middle of scans as well (see the web page on using retrofitted EVLA antennas with the EVLA at *http://www.vla.nrao.edu/astro/guides/evlareturn/*). The source of the phase jumps is unknown, but may be due to a subtle interface issue between EVLA and VLA hardware or software systems. Additional antenna tests are being conducted to determine the source of the phase jumps.

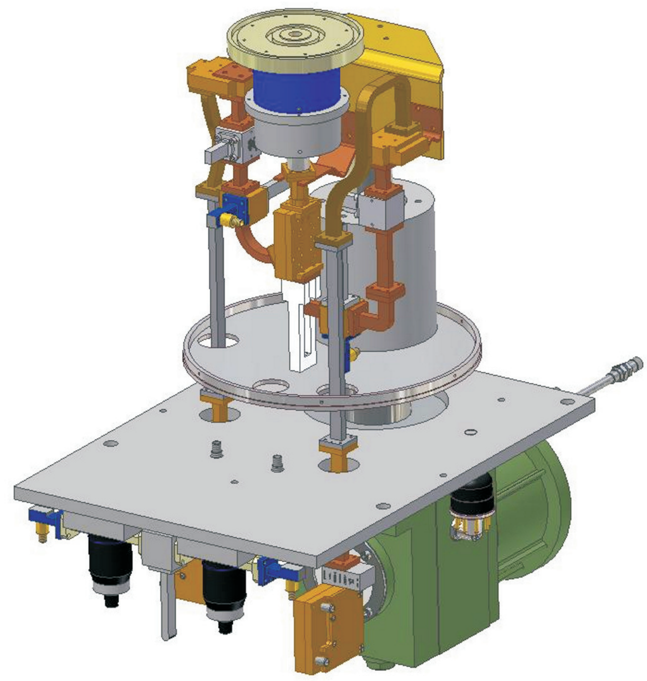


Figure 2. Mechanical design of the 26–40 GHz receiver.

The monitor and control (M&C) group achieved a significant milestone in September 2006 by installing a new controller for the VLA correlator. The controller allows the EVLA M&C system to control the VLA correlator. The milestone represents a significant step in the transition from the VLA M&C system to the EVLA M&C system.

The *Critical Design Review* for the EVLA M&C transition system was held on December 5–6, 2006.

The hardware board for what is termed the "visibility pipe" is being wire-wrapped. The visibility pipe is the means by which data from the VLA correlator will be distributed within the EVLA M&C system. Software development for the visibility pipe has started, and testing should begin in December 2006.

Hardware was acquired to support the ESO/ALMA Next Generation Archive System (NGAS). It was installed at the Array Operations Center (AOC) in Socorro, and will be used within the VLA/VLBA/GBT archive storage and access system as a test of how NGAS will be applicable for the EVLA.

A third release of the VLA/GBT Proposal Submission Tool (PST) was made in time for the October 2, 2006 proposal deadline. For the first time, the VLA and GBT were supported within a single online tool (the PST), marking the beginning of a new era in which the NRAO has common, Observatory-wide software tools. The VLA/GBT PST is the prototype for the EVLA PST. The only changes necessary for the EVLA PST will be the definition of hardware setups, which require only relatively modest additions to the current code.

Internal releases of the Observation Preparation Tool (OPT) continue to be made. The OPT will replace the functionality of the present OBSERVE and JObserve programs, and permit straightforward dynamic scheduling for the EVLA. The OPT now uses the Source, Scan, and Scheduling Block models. Testing of the OPT with the AOC scientific staff began in earnest, allowing very early input on the functionality and the look-and-feel of the tool.

A charter was developed for a Science Advisory Group for the EVLA (SAGE), and members are being recruited. The group will advise the NRAO Director and the VLA/VLBA Assistant Director on science priorities for the EVLA including the definition and implementation of first scientific user observing modes, the definition and implementation of "first science" programs with the EVLA, and the priority ranking of any possible descope options for the project. Where appropriate, SAGE members may participate in the initial development and testing of scientific user capabilities on the EVLA. The SAGE is expected to be a conduit between the NRAO and the North American and international science community for the dissemination of information pertaining to the status and progress of EVLA scientific developments and user capabilities.

Mark McKinnon

Observing with EVLA Antennas

As reported in the previous issue of this Newsletter, EVLA antennas are now included in astronomical observations by default. As of this writing (late November 2006), five antennas are included (13, 14, 16, 18, and 24), with a sixth (26) to follow at the end of November 2006, and a seventh (23) in December 2006. There continue to be a number of caveats of which observers need to be aware:

1. We occasionally see phase jumps between VLA and EVLA antennas. While we are working hard at solving this problem, we advise all observers to calibrate more frequently (at least once every 20 minutes) and at every change in frequency.

2. Online Doppler tracking is incompatible between the VLA and EVLA antennas. Spectral line observers should check the "evlareturn" web page (URL below) for information on how to observe in fixed frequency mode.

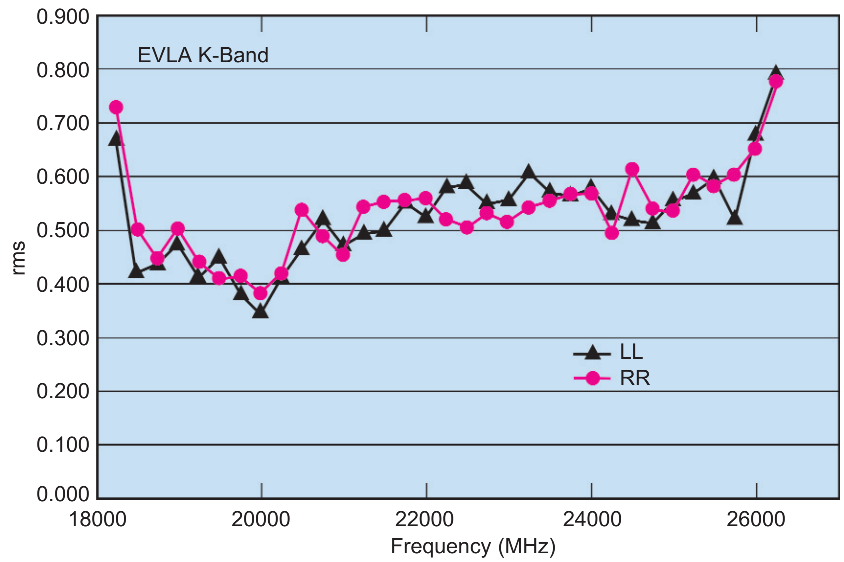
3. Round-trip phase correction does not yet work for EVLA antennas. This affects only very few astrometric-type observations.

4. Not all receiver systems are available on the EVLA antennas. We are actively working on adding 4 and P-Band capabilities; one antenna already has P-Band working, and we expect all EVLA antennas will allow 4 and P-Band observing by late spring 2007. There are no plans to outfit EVLA antennas with U-Band receivers until late in the project.

The latest information is available at *http://www.vla.nrao.edu/astro/guides/evlareturn/*.

R. A. Perley and G. A. van Moorsel

New EVLA K-Band Receivers



The rms (in arbitrary units) of the data as function of frequency.

New EVLA K-Band receivers are now available on six antennas. These receivers are usable over a much wider range of frequencies than their predecessors. EVLA observations have been made at frequencies spanning the full new EVLA K-Band range from 18 to 26 GHz, with a 250 MHz increment, alternating between an empty field and a nearby strong calibrator. The graph shows the rms (in arbitrary units) of the data as function of frequency. The apparent slope in the central part is due to a combination of increasing system temperature as a function of frequency, decreasing aperture efficiency, and the (unknown) spectral index of the calibrator used. All five antennas equipped with the new K-Band receivers were included; since these measurements were made a sixth antenna has also been outfitted with a new K-Band receiver. We are currently refining these tests and will report further in a future issue.

Gustaaf van Moorsel

End to End Operations

Update on the CASA System

Common Astronomy Software Applications (CASA) is a software system for the reduction, display, and analysis of radio-astronomical data. The present CASA effort builds upon the libraries developed by the AIPS++ consortium, and we are now providing a completely revised user interface using a Python/iPython interface (*http://www.python.org/; http://ipython.scipy.org/moin/About*). The software development is focused on new functionality needed for the ALMA and EVLA telescopes.

CASA is currently in Alpha release in which the basic Python interface and user syntax are being developed. During this stage, it is undergoing testing by scientists internal to the ALMA/EVLA projects and also by the ALMA Pipeline subsystem (approximately ten astronomers) for algorithmic development. We expect that the core functionality will be implemented after tests and usage by the ALMA/EVLA projects in December 2006 and March 2007.

We will then produce a Beta release in the third quarter of 2007, and we plan to expand the pool of scientists using CASA for research, drawn primarily from the ALMA and EVLA projects but also including external researchers. In addition to improving the user interface and efficiency of CASA, we will concentrate on the development and testing of the algorithms which will be needed by EVLA and ALMA. This will require close cooperation between the computer scientists and astronomers. We anticipate a full public release in 2008. Those wishing to participate in testing prior to the public release should contact the ALMA/EVLA Computing Project Scientists (ALMA: Debra Shepherd *dshepher@nrao.edu*; EVLA: Michael Rupen *mrupen@nrao.edu*).

In the second quarter of 2007, an ALMA/EVLA data simulator, built upon the CASA interface and functionality, will provide data to determine the expected image quality and to test the more advanced algorithms needed by ALMA and EVLA.

The CASA web page (*http://casa.nrao.edu*) can be viewed for updated plans and other information about the system.

Joe McMullin

Transition to the Virtual Observatory (VO) Facility

Since 2001, staff from many astronomical facilities have worked together to develop the concepts, form standards and protocols, and build prototype scientific applications that take advantage of data from diverse collections.

As the Virtual Observatory (VO) demonstration project comes to an end in 2007, it will be necessary to provide an operational mechanism to support the standards, protocols and tools that have been developed. To make the VO a truly useful scientific resource with wide appeal, researchers must be able to access VO services that have been rigorously tested, reviewed, and documented. This will be the focus of the new VO facility, which will emerge over the next year and (much like the VO project) be widely distributed through the University community and astronomical facilities. The NRAO's data archive system currently employs technologies developed by the VO, such as Simple Image Access Protocol (SIAP), and continues to explore others to enhance access to data and images from NRAO telescopes. As a result, the NRAO will remain committed to supporting the VO as it transitions from a project to full operations.

N. M. Radziwill and R. Hanisch

Green Bank

Green Bank Telescope Azimuth Track Project

Components are in production for the remediation of the azimuth track next summer. Project team members from Green Bank have made several visits to inspect base plates being rolled at Mittal Steel's Coatesville, PA mill. Material properties of the plates greatly exceed the NRAO's minimum specifications. Over half of the plates have now arrived at Continental Field System's Savannah, GA shop for machining, and to be welded together in pairs before shipment to Green Bank.

FEMCO Machine Company in Punxsutawney, PA is machining the threaded connectors that will be used to fasten the base plates and wear plates together, as well as providing the nuts. Almost half of the connectors have been machined, and all of the nuts have been produced.

Seven splice plates were also manufactured by FEMCO and delivered to the site. Forty-one of the existing plates will be refurbished and reinstalled next summer.

Wear plates are in production at Oliver Steel Company, and by the time of the publication of this newsletter should be ready for inspection by the project team and by Gadsden Tool Company, which will perform the final machining.

The Green Bank project team is also working with the field service companies—Continental Field Systems and General Dynamics/Vertex RSI—to orchestrate the outage work for next summer and develop an integrated schedule. The goal is to perform all of this work in May–July, with August set aside for contingency and antenna re-commissioning.

B. Anderson and D. Egan

Azimuth Track Team member Dennis Egan (in yellow hard hat) inspecting the first set of the new GBT track base plates at Mittal Steel in Coatesville, PA..

Limited 07B Trimester Observing Call after Summer 2007 Track Work

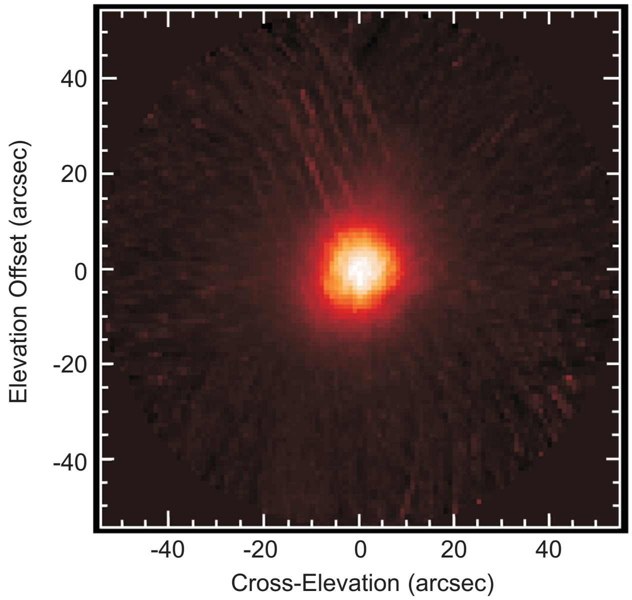
The GBT will have a restricted call for proposals for the upcoming 07B trimester. Due to the track shutdown, the total time available will be limited, with the telescope available only from approximately mid-August through September 2007. As we will be recommissioning the antenna systems, observations will be performed on a shared-risk basis only (i.e. unsuccessful observations will not be rescheduled).

During this period we will be prototyping ideas for a new dynamic scheduling system for the GBT. As a result, observers who propose for this period should be willing to participate in testing the dynamic scheduling system. Further information on GBT dynamic scheduling will be made available in spring 2007. The complete call for proposals, along with a list of all receivers and backends available for this call, will be emailed to the gbtnews exploder and made available on the GBT website in early January.

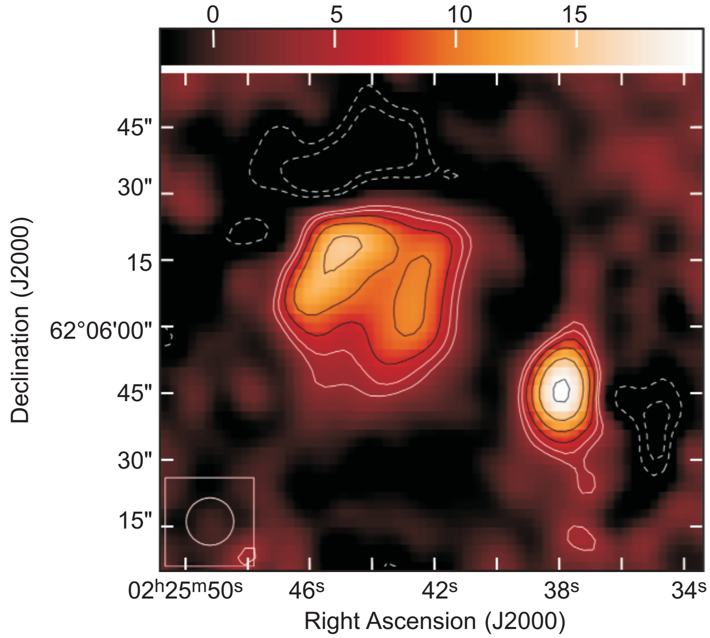
R. Prestage and K. O'Neil

GBT Instrumentation Update

Penn Array: On September 26, 2006, the GBT had first light at 90 GHz with MUSTANG (the Multiplexed SQUID/TES Array for Ninety Gigahertz, formerly known as the Penn Array). This is a 64-pixel TES bolometer array designed to make high-resolution continuum images with the GBT. This is the first use of a multi-pixel imaging array on the telescope and the highest frequency at which the GBT has collected data. In an engineering run lasting from mid-September through the end of October, data were collected which have enabled the project team to verify basic functionality of the receiver optics, cryogenics, DAQ electronics, and software. The GBT proved to be a reliable platform for diagnostic 90 GHz observations and shows an aperture efficiency (about ten percent), which is consistent with what is expected from holographic surface accuracy measurements. Even with such a low aperture efficiency the GBT has a collecting area comparable to the largest millimeter facilities presently in operation. During the upcoming year the MUSTANG team will work to improve the robustness and sensitivity of the receiver, concurrent with a planned campaign of antenna improvements in



MUSTANG first light map of Saturn at 90 GHz. Saturn's disk at the epoch of observation had a diameter of about 16 arcseconds.



A GBT 3mm continuum image of the W3 main star forming region acquired with MUSTANG. The morphology is similar to that seen in an 8 GHz VLA map of similar resolution, suggesting that at 90 GHz free-free emission still dominates over thermal dust emission. (Data processing and image courtesy of Bill Cotton.).

Green Bank, and aims to return for a system commissioning and early science run in Fall/Winter 2007/2008. The NRAO's first millimeter-wave astronomy was done in Green Bank using a bolometer in November 1962 by Frank Low, the 2006 Jansky lecturer. MUSTANG was funded by the NRAO's Universities Instrumentation Program; the collaboration includes the University of Pennsylvania, NASA Goddard Space Flight Center, NIST, Cardiff University, and the NRAO.

S. Dicker, P. Korngut, and B. Mason

Upgrade to the C-Band Receiver: We have been having reliability problems with the Model 22 cryogenic refrigerator used in the C-Band receiver. This fall, we replaced the refrigerator with a Model 350 which is more reliable and has greater cooling capacity. The refrigerator upgrade had a nice side effect: the system temperature across the receiver's band is now 15–20 K, an improvement from the 22–30 K before the modifications. The reduction in system temperature corresponds to about a factor of two reduction in integration time needed to get to a given noise level.

The extra cooling capacity allowed us to cool the receiver OMT to 20 K, compared to 80 K previously. Because the OMT is now cooled to the same temperature as the cryogenic amplifiers, there's no need for thermal isolation between the OMT and amplifiers, allowing us to eliminate a section of coaxial cable between the two. Both of these changes reduced the noise contribution before the amplifiers.

The change in refrigerator is the first phase of our plans for this receiver. The second phase will probably be completed next summer and will be aimed at improving the receiver's baseline performance by increasing the level of integration in the room temperature electronics, eliminating most coaxial interconnections, and using shorter transmission lines. C-Band is being used as a test bed for possible future enhancements to other receivers.

R. J. Simon, R. D. Norrod, and R. J. Maddalena

Ka- and Q-Band Receivers: As reported in previous newsletters, we have been trying to mitigate the intermittent, irregular baseline structures in the GBT Ka-Band (26–40 GHz) and Q-Band (40–50 GHz) receivers. We have also upgraded the Q-Band system so that both feeds and polarizations will have good system temperatures from 40 to above 49 GHz.

Both receivers went through extensive lab tests in late summer and early fall and then were installed on schedule in October. At the time of writing (late November) we are conducting astronomical commissioning of the receivers, which will not be completed before mid December. The commissioning time is being shared by these tests and commissioning of the Penn Array and Zpectrometer.

While the receivers were in the lab, we used the new Lab Spectrometer, a miniature clone of the GBT Spectrometer, to test various aspects of the receiver modifications, including ways to mitigate the baseline problems. Without the Lab Spectrometer, it would have been either impractical to investigate baseline problems or our tests would have been greatly prolonged. The Lab Spectrometer should prove useful for helping us better test other receivers while they are still in the lab and thereby reduce the time needed to test receivers after they are on the telescope.

The modifications to Ka-Band included tightening up loose waveguide joints and installing absorber within the dewar. We also reconfigured parts of the RF/IF section, exchanged locations of the card cage, and have gone to a constant current phase switch driver. As described in previous articles, Ka-Band is a correlation receiver. The changes have greatly increased the stability of the Ka-Band receiver, resulting in significant improvements in its use in traditional beam-switched observations. The continuum performance of the receiver has also significantly improved. However the receiver's performance as a correlation receiver is still compromised. We plan to look further into this issue during the spring/summer 2007.

We have isolated the intermittent, irregular baseline structure in Q-Band to the first stage amplifiers and found that these effects are somehow coupled with other components within the dewar. Most of the improvements to Q-Band came from taking great care in our choice of amplifiers and in the installation of absorber in the dewar. We cannot employ fast switching for Q-Band since it is not a correlation receiver.

Our 'before and after' lab tests with both receivers showed that we are no longer seeing baseline changes on short time scales with ripple frequencies between 10 and 40 MHz. Some of our tests included runs of typically 4 to 6 hours with warm and cold loads. After averaging, the noise remained within 20 percent of theoretical across the central few hundred MHz of the spectra. The lab tests show that the remaining baselines now seem to be similar to those we get from all our other receivers. Our tests also show that we have successfully extended the useful frequency coverage of Q-Band.

Although our ability to test receivers in the lab is much better than ever before, lab tests are not sufficient. The effects of a varying atmosphere and a cold sky cannot be mimicked well in the lab. At this time we do not have any astronomical results for Q-Band. Our preliminary results for Ka-Band show baseline structures that, although improved from last year, still seem to be significant. We are exploring various calibration algorithms that might improve Ka-Band's baselines.

If our commissioning tests are successful, we expect to schedule Ka- and Q-Band projects this winter, giving priority to those projects that have been waiting the longest for these improvements.

R. J. Maddalena, R. D. Norrod, G. N. Anderson, G. K. Watts, D. S. Balser, L. Morgan, and D. J. Pisano

Zpectrometer: The Zpectrometer is an ultra-wideband cross-correlation spectrometer that analyzes the entire output band of the Ka-Band receiver at modest

(150 km/s) resolution. Its main target is searches for low-J CO lines from galaxies at z > 2, taking advantage of the correlation receiver architecture's stability compared with total-power receivers. This project is a University-NRAO collaboration funded by an NSF grant to the University of Maryland. In September, as planned, the Maryland group brought the correlator to Green Bank, where it had several days of successful testing in the lab with the Ka-Band receiver and passed its RFI testing in the anechoic chamber. The instrument followed the Ka-Band receiver onto the telescope in October, where it is installed next to the receiver on the GBT receiver turret. Commissioning work in November included complete system integration with the GBT's observing and data acquisition system, system tests on the sky, and test astronomical spectra. The Maryland group and NRAO staff are analyzing data from the lab and telescope to identify the source of baseline structure in the spectra; the current focus is on imbalances within the Ka-Band receiver. The baseline structure is non-ideal systematic structure that currently prevents the system from reaching its full potential as a correlation spectrometer.

A. Harris and K. L. O'Neil

Green Bank Workshop on Future Instrumentation for the GBT

On September 7, 8, and 9, 2006, a workshop was held in Green Bank which brought together more than 60 engineers and scientists to consider the scientific and technical drivers for future instrumentation for the GBT. It was an exciting and productive meeting, in part because it mixed interested parties from diverse backgrounds. The Workshop was motivated by the need to consider the next generation of GBT instruments in view of our experience with the current instruments, the changing demands of the science, and recent technical developments. Besides equipment built by NRAO staff, there have been a number of instruments developed for the GBT in cooperation with university groups, and we are keen to understand future possibilities for collaborations of this sort and to take advantage of expertise wherever it may be found.

Participants at the Green Bank Workshop on Future Instrumentation for the GBT examine the telescope's active surface.

The Workshop included sessions on the high-frequency performance of the telescope, bolometer cameras, science drivers for focal plane arrays, advances in digital techniques, requirements for pulsar detectors, highly redshifted lines, planetary radar, receiver technology, interstellar chemistry, and wideband spectroscopy. There were evening sessions on new software tools and the prospects for beam-forming focal plane arrays. A highlight of the Workshop was a tour of the GBT, allowing participants first-hand experience of the complexities and delights of the telescope and its instrumentation. Materials from the workshop, including some of the presentations, are available on the Workshop website: *http://www.nrao.edu/GBT/fi/index.shtml*.

Information generated as a result of the Workshop will be key in forming the GBT development plans for the next five years. Many, many more excellent projects were proposed than can be funded in current circumstances. Some possible instruments, such as beam-forming focal-plane arrays, will require considerable engineering developments before they are practical, while others, like some digital detectors or multi-feed receivers, seem straightforward extensions of existing technology and can be achieved given the proper resources. Rick Fisher, the Observatory Technical Leader, has produced a memo on possible GBT projects that might be undertaken at the Central Development Laboratory. We are continuing our efforts to match the NRAO resources with the most scientifically productive projects.

Unlike many telescopes, the GBT was not designed to have all of its capabilities in place at first light. Instead, it was envisioned that continued developments in surface control, servos, pointing, and optics would allow its operation to progress from the upper limit of 15 GHz delivered by the contractor to ever higher frequencies. Work by the Green Bank staff since first light has now led to routine operation of the GBT up to 49 GHz at night in benign weather, opening up unique opportunities for new science. The mechanical performance of the antenna is simply outstanding, and there is no doubt that given the appropriate resources, full 3 mm operation is well within our grasp. The recent Workshop made it clear that the GBT has now reached its stride as a working telescope, and a relatively modest program of instrumental development will produce greatly increased capabilities for the astronomical community.

F. J. Lockman

Fourth NAIC-NRAO School on Single Dish Radio Astronomy

The Green Bank (NRAO) and Arecibo (NAIC) observatories are organizing the fourth NAIC-NRAO School on Single Dish Radio Astronomy. The summer school will take place from July 8–15, 2007 at the Green Bank Observatory in Green Bank, West Virginia. It is intended for students, postdocs, and experts in other fields of astronomy who would like to explore emerging techniques and applications of single-dish radio astronomy.

Details of how to register for the school along with a preliminary scientific program will be made publicly available shortly through the Arecibo and Green Bank websites (*www.naic.edu* and *www.gb.nrao.edu*).

Larry Morgan

Socorro

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
C	20 Oct 2006	16 Jan 2007	1 Jun 2006
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

Note: For the configuration cycle in 2007/2008 there is, at present, considerable uncertainty about the duration of each configuration as well as about the ordering of the configurations. This is because of the possibility of increased observing time for large proposals and because of requirements of EVLA commissioning. The community will be informed of future configuration schedules in upcoming editions of the NRAO Newsletter as well as by email and on the web.*

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 21cm (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). At the beginning of the A configuration in 2007, the Sun will be at an RA of ~04^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.*

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; 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/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 coversheet, 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, 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, handled as described below.

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. Current and past VLBA schedules may be found at *http://www.vlba.nrao.edu/astro/schedules/*.

VLBI Global Network Call for Proposals

Proposals for Global VLBI Network observing 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, and must reach both the EVN scheduler and the NRAO on or before the proposal deadline. Proposals not in EVN sessions that request the use of the Socorro correlator must be sent to NRAO, even if they do not request the use of NRAO antennas. Similarly, proposals that request the use of the EVN correlator at JIVE must be sent to the EVN, even if they do not request the use of any EVN antennas. All requests for use of the Bonn correlator must be sent to the MPIfR.

Please consult *http://www.obs.u-bordeaux1.fr/vlbi/EVN/call.html* for advice about submission routes for Global proposals. As of this writing (late November), it seems likely that submissions will be possible using either (1) the NorthStar Proposal Tool or (2) the LaTeX proposal coversheet.

For submission route (2), please use the most recent proposal coversheet, which can be retrieved at *http://www.nrao.edu/administration/directors_office/vlba-gvlbi.shtml*. Proposals may be submitted electronically in Adobe Postscript format. For Global proposals, those to the EVN alone, or those requiring the Bonn correlator, send proposals to *proposevn@hp.mpifr-bonn.mpg.de*. For Global proposals that include requests for NRAO resources, send proposals to *propsoc@nrao.edu*. Please ensure that the Postscript files sent to the latter address request U.S. standard letter paper. Proposals may also be sent by paper mail, as described at the web address given. VLA/VLBA referee reports are distributed to proposers by email only, so please provide current email addresses for all proposal authors.

Global VLBI scheduling occurs only on fixed dates.

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

Completion of the VLBA's Transition to Mark 5

The VLBA's long transition to Mark 5 disk-based recording has been completed. The ten VLBA stations, the VLA, and the GBT are now recording all observations on Mark 5 disk modules, and a total of 17 units are available at the VLBA correlator's inputs. All 44 of the VLBA's original operational tape drives have been decommissioned. The 17-station correlation capacity is considered adequate for most high-sensitivity and/or global observations. Thus, it is anticipated that any funds available in the immediate future will be used to expand the media pool, rather than to buy additional playback units.

The current Mark 5 media pool totals 552 TB, in modules of varying size. A total of 1880 disk drives were purchased during 2004–2006, at costs corresponding closely to an exponential law with a 2.3-year price-halving time. For our target 30-day recording-correlation cycle, this media pool would support mean recording rates of 170 Mbps in full-time operation on the ten VLBA stations or 142 Mbps for all twelve NRAO VLBI stations. We have been able to meet the 30-day goal for most VLBA observations, but occasional unusual cases, and observations involving non-VLBA stations, sometimes cause delays in releasing modules for re-use.

Observations at 256- and 512-Mbps rates are both possible and strongly encouraged, but the required media resources must be justified in the proposals. Some minor changes will be required to support recording and correlation of 512-Mbps observations using a mixture of VLBA and Mark 4 formatters; we expect to complete these in time for proposals received by the February 1 deadline.

The implementation described above is based on the Mark 5A system, the only option that currently is fully operational and in widespread use. There are no plans to upgrade to the Mark 5B system recently released by Haystack Observatory. Mark 5B would enable peak recording rates of 1 Gbps but would require expensive modifications to the VLBA correlator. Any significant use of a 1-Gbps recording capability would have a corresponding impact on the media pool and impose substantial operations costs for correlation. Thus, Mark 5B would provide insufficient advantages to warrant its expense until we have been able to expand the media pool as planned. Furthermore, Mark 5B will probably not be directly compatible with future, wider-band observing and correlation options currently being developed.

J. D. Romney

VLA and VLBA Observational Status Summaries

New versions of the VLA and VLBA Observational Status Summaries have been completed and are available from the NRAO web sites. These documents are the basic references to the VLA and VLBA, containing a great deal of background and reference material on each array. The VLA Observational Status Summary contains considerable new information about EVLA status and impact on the VLA. See *http://www.vla.nrao.edu/astro/guides/vlas/current/* for the html version; Postscript and pdf versions are available from the same directory under file names *vlas.ps* and *vlas.pdf*, respectively.

The VLBA Observational Status Summary has had its annual update and has considerably fewer changes than the VLA document. Primary changes are those related to the change from tape to disk recording and playback at the correlator, as well as a new section on future VLBA developments. The VLBA document is available in the directory *http://www.vlba.nrao.edu/astro/obstatus/current/*, with respective file names *obssum.html*, *obssum.ps*, and *obssum.pdf* for the html, Postscript, and pdf versions.

Please notify the undersigned of any mistakes that are found in the Observational Status Summaries, for correction in future editions.

J. S. Ulvestad

Education and Public Outreach

NRAO's Press Office is Here to Help You

Your outstanding proposal won you observing time on one of NRAO's telescopes, you got great results, and you've put the finishing touches on the paper you're submitting to a journal. You're about to send the paper off to the editor, with copies to your collaborators.

There's one other place you should consider sending that paper—the NRAO Public Information Officer. We may want to feature your work in an NRAO press release. Publicizing important and interesting research results is one of the most effective means of maintaining public support for this Observatory and for astronomy in general.

The NRAO press office exists to help you. We can offer advice about publicity, help in preparing and distributing press releases, help in developing illustrations to accompany press releases, and help in preparing for media interviews and press conferences.

It's important to let us know about your research results as early as possible. Preparing a press release, getting it approved by all concerned, and developing new graphics takes time, and all this must be accomplished before the result becomes public through either publication in a journal or presentation at a scientific meeting.

Some journals have strict policies about advance publicity of submitted results, but those policies do not prohibit your advising either the NRAO press office or your own institutional press office about your results. Indeed, we work within the journals' media embargo rules on a regular basis and can help you navigate their sometimes confusing guidelines.

In addition to letting us know about upcoming publications, don't forget to tell us about presentations at scientific gatherings such as the American Astronomical Society (AAS) meetings. Such meetings attract media attention, and we can help you get some of that attention for your work.

Your own institution—university, observatory, laboratory, or other organization—may have its own press office. The NRAO is happy to join forces with these press offices to get the word out to the public about your work. We collaborate with other institutions frequently on news-media relations, and can prepare joint press releases, independently issued simultaneous releases, or whatever arrangement works best under the circumstances.

Let us know what you're doing, so we can help bring the excitement of cutting-edge research to the public.

Dave Finley
dfinley@nrao.edu

2006 NRAO/AUI Radio Astronomy Image Contest Prizes Awarded

The National Radio Astronomy Observatory and Associated Universities, Inc. (AUI) are pleased to announce the winners of the 2006 Radio Astronomy Image Contest. A total of 13 images were submitted by ten scientists and artists. The NRAO/AUI wish to thank all of the participants in this contest for their submissions.

The entries were labeled with a number and the title supplied by the sender as their sole identification. The Panel of Judges included Claire Chandler (NRAO), John Hibbard (NRAO), Karen O'Neil (NRAO), Kelsey Johnson (University of Virginia) and Tim Bastian (NRAO) and was chaired by Juan Uson. Mark Adams, Assistant Director for EPO, attended the meeting as well, but Adams and Uson abstained from voting.

The winners were notified by email and their images have been displayed on the NRAO website at *http://www.nrao.edu/imagegallery/image_contest/image_contest_2006_prizes.shtml* with links to the corresponding entries in the NRAO Image Gallery. These images are featured in the 2007 NRAO Calendar.

The Panel met on September 27, 2006 and awarded prizes to the following images:

First Prize ($1000)

A Majestic Gas Shell Revealed by the VLA, submitted by Jayanne English (University of Manitoba, Canada).

Second Prize ($500)

THINGS, submitted by Fabian Walter (Max Plank Institute fuer Astronomie, Heidelberg, Germany)

Honorable Mentions ($100 each)

Cassiopeia A at Dusk, submitted by Michael Bietenholz (York University, Canada)

See Extreme Stars Stretch the Fabric of Space-Time, submitted by Joeri van Leeuwen (U. British Columbia)

Supernova 1993J and its Fourier Transform, submitted by Michael Bietenholz (York University, Canada)

The VLA at Coma, submitted by Neal Miller (NRAO and Johns Hopkins)

A Nearby Superbubble in the Night Sky, submitted by Yurii Pidopryhora (NRAO and Ohio University)

The NRAO and AUI congratulate the winners and wish to thank everybody who submitted entries to this contest. The contest will be held again in 2007. We look forward to a larger participation and eagerly await the new submissions.

Juan Uson

2007 NRAO/AUI Radio Astronomy Image Contest

The NRAO invites submissions of images of astronomical objects to the third annual Radio Astronomy Image Contest. We hope to involve the community in a significant way and provide a means to showcase the community's work through its publication in the Image Gallery, a yearly calendar, and a series of posters. We welcome images that display multiwavelength information and contain data obtained with any telescope, however we request that they contain and showcase radio emission observed with an NRAO telescope.

The prizes are sponsored by Associated Universities, Inc. (AUI), the NRAO's parent organization, which will award a first prize, a second prize, a third prize and up to nine honorable mentions consisting of: First Prize ($1000); Second Prize ($500); Third Prize ($250); Honorable Mentions ($100 each).

The prizes will be awarded by a panel of scientists appointed by the NRAO that will include one scientist who is not a member of the NRAO staff. The membership of the panel will be made public when the results of the contest are announced. The deadline for submission is September 4, 2007. The winners will be notified by email and announced on the NRAO website by October 15, 2007.

Details of the contest as well as a submission tool can be found on the NRAO website at: *http://www.nrao.edu/image-contest.html*.

We expect that the contest will add significantly to the NRAO Image Gallery, which has been on-line since 2002 (*http://www.nrao.edu/imagegallery/php/level1.php*). The Gallery contains astronomical images of objects observed with the NRAO telescopes (often showing multi-wavelength emission) organized by object classes and can be browsed using a comprehensive Search Tool with links to the NASA Extragalactic Database (NED), the SIMBAD database, and also to the corresponding scientific and popular papers. The Image Gallery includes a web-based submission tool (*http://www.nrao.edu/imagegallery/php/ext_sub.shtml*).

M. T. Adams and J. M. Uson

Second NRAO Charlottesville Community Open House

NRAO Deputy Director Phil Jewell presents a $100 savings bond to Paul Syverud, Charlottesville resident and student. Paul completed the "Passport to the Universe" challenge and his entry was picked at random by Director Fred Lo.

A line forms to take a turn at the multiple radio and optical telescopes in the front parking lot at the NRAO Edgemont Road facility.

Given the success of the inaugural NRAO Charlottesville Community Open House in 2005, EPO personnel organized the event again this year. The 2006 Open House took place at the Observatory's Edgemont Road facilities from 11:00 a.m. to 4:00 p.m. on Sunday, November 5, 2006 and was a great success. Approximately 900 of our Charlottesville neighbors and friends, including numerous young persons and teachers, visited the NRAO to enjoy activities that included comet-making, StarLab planetarium shows, ALMA and EVLA exhibits, Ask an Astronomer, Make a Constellation, Make a Star Wheel, face-painting, Birthday Star, and more. The extensive high technology demonstrations and exhibits organized by the Central Development Lab scientists and engineers were very popular. Visitors truly enjoyed sampling a taste of ice cream made from liquid nitrogen. A series of well-attended half-hour talks included an overview of the Observatory by Director K.Y. Lo, Public Information Officer Dave Finley's first-hand account of Pluto's apparent demotion at the recent IAU General Assembly in Prague, Bob Rood's entertaining *Search for Unicorns & Extraterrestrial Civilizations*, and Crystal Brogan's thought-provoking talk about supernovae explosions and remnants. Jim Braatz delighted the audience with his talk on supermassive black holes, and Scott Ransom concluded the afternoon session with another of his enthusiastic talks about pulsars, complete with sound effects.

Members of the Charlottesville Astronomical Society along with the NRAO staff spent the day demonstrating multiple radio and optical telescopes in the front parking lot. The abundant early November sunshine combined with the excellent instrumentation to provide many fine learning opportunities and much pleasure for our guests. Albemarle Amateur Radio Club members used two High Frequency (HF) amateur radio rigs and an HF wire dipole antenna to create a high quality amateur radio station and communicate around the world. Ham operators demonstrated HF communication and described what it takes to become an amateur radio operator.

The NRAO EPO program is extremely grateful to the nearly 100 persons who contributed their time and energy to this Open House, including Observatory staff and family members, several of our University of Virginia colleagues, as well as members of the Charlottesville Astronomical Society and the Albemarle Amateur Radio Club.

M. T. Adams and L. M. Clark

New NRAO General Public Brochure

The NRAO Education and Public Outreach Division has just published a new, comprehensive brochure that describes the Observatory's mission and science for the general public. Free copies of this brochure are available to interested individuals, institutions, teachers, and students. Please send your request for copies of this new NRAO brochure to Mark Adams via e-mail to *mtadams@nrao.edu*.

Mark Adams

50th Anniversary Lectures in Socorro

Debra Shepherd gives a lecture at the 50th Anniversary celebration in Socorro.

Socorro Education and Public Outreach was given the unique opportunity to celebrate the NRAO's 50th anniversary with a poster and lecture series during the fall semester at the New Mexico Institute of Mining and Technology. More than 20 posters recounting the history of radio astronomy and the NRAO, as well as details of scientific research and the instruments used in that research, graced the walls of the second floor of Tech's Joseph Skeen Library.

A series of three lectures was kicked off in September by Clint Janes, Division Head for Electronics for ALMA. *In Fast Flying Photons Fatalities: Optical and Radio Instrumentation*, Janes discussed the similarities and differences in hardware for optical versus radio telescopes.

In October, Education and Public Outreach Assistant Director Mark Adams traveled to Socorro to talk about the future of radio astronomy, including ALMA, EVLA, and SKA.

The final lecture, *Diversity in Astronomy: Women at Different Wavelengths*, featured Debra Shepherd, Deputy Director for North American Computing at NRAO (ALMA) and Eileen Ryan, Project Manager for the 2.4-meter telescope at the Magdalena Ridge Observatory. They spoke about their own research, the challenges they'd encountered during their educational pursuits, and their view regarding what it is like to be female in this predominantly male profession.

Robyn Harrison

Astro-Viz '06 Convenes in Pasadena

In November NRAO EPO participated in Astro-Viz '06, an astronomy visualization workshop hosted by the Spitzer Science Center and held concurrently with the Pasadena Cool Stars XIV conference. The visualization meeting participants included artists, scientists, engineers, animators, planetarium professionals, and media experts from observatories and science centers around the United States.

The meeting's three-day agenda explored state-of-the-art visualization techniques for image processing, data visualization, illustration, animation, and video production, as well as audio and video podcasting. Exchange techniques and practices were also widely discussed and debated, as were community issues such as standards, resource sharing, and ethics.

The public outreach highlight of the workshop was "The Art of Astronomy," a large format outdoor display of images and videos celebrating astronomy. The looping film was assembled from the work of the workshop attendees and ran nightly from dusk until 11 p.m. at One Colorado Courtyard, an upscale Pasadena shopping center. The NRAO was well represented in "The Art of Astronomy" film, which also featured contributions from Hubble, Spitzer, Chandra, NOAO, JPL and other research institutions.

Bill Saxton

The Travel Channel visits the Very Long Baseline Array (VLBA) site near St. Croix in the Virgin Islands. Shane Reynolds (orange hard hat, left center) hosts "Not Your Average Travel Guide" for the Travel Channel; Jerry Merten (far left) is a local videographer. NRAO site techs Ken Klose (far right) and Greg Worrell (center right) hosted the Travel Channel team at the VLBA antenna. Image courtesy Jane Watkins.

In General

Opportunities for Undergraduate Students, Graduating Seniors, and Graduate Students

Applications are now being accepted for the 2007 NRAO Summer Student Research Assistantships. Each NRAO summer student conducts research under the supervision of an NRAO staff member at one of the NRAO sites, on a project in the supervisor's area of expertise. The project may involve any aspect of astronomy, including original research, instrumentation, telescope design, or astronomical software development. Examples of past summer student research projects are available on the Summer Student website at *http://www.nrao.edu/students/NRAOstudents_summer.shtml.*

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

The program runs from 10–12 weeks over the summer, from early June through early August. At the end of the summer, participants present their research results in a student seminar and submit a written report. Often, these projects result in publications in scientific journals. Financial support is available for students to present their summer research at a meeting of the American Astronomical Society, generally at the winter meeting following their appointment. Besides their research, students take part in other activities, including a number of social events and excursions, as well as an extensive summer lecture series which covers various aspects of radio astronomy and astronomical research. Students also collaborate on their own observational projects using the VLA, VLBA, and/or GBT.

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

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

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

The stipends for the 2007 Summer Student Program are $475 per week for undergraduates, and $510 per week for graduating seniors and graduate students. These stipends include an allowance for housing, since housing is not provided. Students who are interested in Astronomy and have a background in Astronomy, Physics, Engineering, Computer Science, and/or Math are preferred. The same application form and application process is used for all three programs, and may be accessed at *http://www.nrao.edu/students/summer-students.shtml*. Required application materials include an on-line application form (including a statement of interest), official transcripts, and three letters of recommendation. The deadline for receipt of application materials is Monday, January 29, 2007.

Jeff Mangum,
NRAO Summer Student Coordinator

NRAO Visitor and Pre-doctoral Student Programs

The NRAO has several programs that can support visits to the observatory by Ph.D. scientists and engineers, or by graduate students doing thesis work in radio astronomy or related fields, in order to interact with NRAO staff at times other than while observing.

1. Scientific Visitor Program: This program can support visits to the NRAO by scientists or engineers at the post-doctoral or faculty level to facilitate research collaboration with NRAO staff. Support for the visitor can range from paying for their accommodation or per diem costs, travel, or providing some summer or sabbatical salary support, according to need.

The program is open to all scientists who wish to visit the NRAO to interact with the observatory's staff for an extended time, but we are particularly interested in encouraging visits by junior faculty at colleges and universities and in encouraging collaborations that may lead to "first light" science with new NRAO instruments.

Most visits supported by this program are a few weeks, rather than months, in length, but it may be possible to support longer visits if needs are known sufficiently far ahead.

2. Pre-doctoral Student Programs: These programs are intended for graduate students whose faculty advisors want them to have a concentrated exposure to research in radio astronomy, its instrumentation, or computational methods, under the supervision of an NRAO staff astronomer or engineer.

Three programs are available:

Summer Research Assistantships: Intended for students who will spend 10-12 weeks in the summer working with an NRAO advisor on a research project. This program is open to first and second year graduate students who are citizens or permanent residents of the U.S. or its possessions, or who are eligible for a Curriculum Practical Training (CPT) from an accredited U.S. Graduate Program. It is part of the regular NRAO summer student program; application for 2007 must be made through the on-line process described at *http:// www.nrao.edu/students/summer-students.shtml* by January 29, 2007.

Graduate Internships: Intended for Master's or Ph.D. level students who will come to the NRAO for periods normally from one to six months to work with an NRAO staff advisor while gaining experience relevant to their graduate degree. Support may range from accommodation and per diem support to a research stipend or salary, depending on circumstances. This program is available year-round and applications can be considered at any time.

Junior Fellowships and Research Assistantships: Intended for pre-doctoral students who have completed all academic requirements for their Ph.D. and who will come to the NRAO for up to two years to do their thesis research under the supervision of an NRAO staff member. The NRAO will pay the student's salary and can also support travel costs related to the research. Note that these pre-doctoral programs are in addition to the program *http://wiki.gb.nrao.edu/bin/view/Observing/NRAOStudentSupportProgram* which supports student involvement in regular observing proposals for the Green Bank Telescope (GBT), the Very Long Baseline Array (VLBA) and the High Sensitivity Array (HSA) or in large proposals for the VLBA, GBT, HSA, or VLA.

If you would like more information about the scientific visitor or pre-doctoral student programs, please contact:

Alan H. Bridle
abridle@nrao.edu

2007 Janksy Lectureship

The National Radio Astronomy Observatory invites nominations for the 2007 Jansky Lectureship (*http://www.nrao.edu/jansky/janskyprize.shtml*). The Karl G. Jansky Lectureship is an honor established by the trustees of Associated Universities, Inc., to recognize outstanding contributions to the advancement of astronomy. First awarded in 1966, it is named in honor of Karl G. Jansky who, in 1932, first detected radio waves from a cosmic source.

Please send nominations, including **one** supporting paragraph, by February 1, 2007, to Billie Orahood via e-mail at *borahood@nrao.edu* or via regular mail at Director's Office, National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA, 22903-2475.

K. Y. Lo and D. A. Frail

NRAO Timeline

To mark the 50th anniversary of NRAO's founding, the NRAO Archives presents a timeline at *http://www.nrao.edu/archives/Timeline/timeline.shtml*. The timeline begins with Karl G. Jansky's detection of radio waves from the Milky Way and Grote Reber's observations of "cosmic static," continues through the events leading to the establishment of NRAO, and traces 50 years of NRAO history since Lloyd V. Berkner and Alan T. Waterman signed the contract between Associated Universities, Inc. and the National Science Foundation on November 17, 1956.

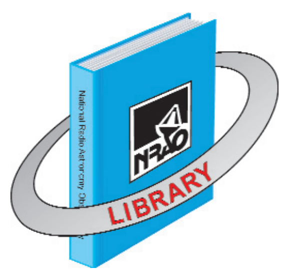
Ellen N. Bouton

Grant to NRAO Archives

The NRAO Archives has received a grant from the American Institute of Physics, Center for the History of Physics, to be used to organize and index the Director's Office files of the first two NRAO Directors, Otto Struve (1959-1961) and David S. Heeschen (Acting Director 1961-1962, Director 1962-1978). The Director's Office files cover not only instrument design and construction, but all other aspects of NRAO's scientific and organizational life: internal management matters, budgets and long range plans, committee minutes and reports, materials submitted to NSF and for National Academy of Sciences decadal reviews, site selection, radio frequency allocation and protection, computing in astronomy, electronics engineering, the physics of telescope surfaces, etc., as well as the complex sociology associated with the increasing dominance of NRAO as a large user-oriented facility.

Other materials in the Archives include the papers of Grote Reber, John Kraus, and other individuals, as well as Web resources outlining the work of H. I. (Doc) Ewen and Nan Dieter Conklin. See *http://www.nrao.edu/archives/* for further information.

Ellen N. Bouton



NRAO Library News

Need to be "in the know"? Check out the RSS feeds on the Library Web Page: http://www.nrao.edu/library/.

Authors: Proposal Numbers are now entered on papers submitted for publication (to link proposals to the papers that result). Please provide Proposal Numbers when requesting page charge support, which must be done prior to publication.

Marsha Bishop

Further Information

To obtain more information on the NRAO, visit the NRAO home page at: *http://www.nrao.edu*

NRAO Contact Information

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Very Long Baseline Array
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Las Condes
Santiago de Chile
Chile
(56) 2-210-9600

Tucson Site
Tucson, Arizona
(520) 882-8250

NRAO Results

For more information on recent scientific research with NRAO telescopes:

NRAO Press Releases: *http://www.nrao.edu/pr*
VLA Observation Highlights: *http://www.vla.nrao.edu/genpub/current_obs/*

NRAO Products

The NRAO Data Archive System can be accessed and queried via the web: *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/*

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

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

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