NATIONAL RADIO ASTRONOMY OBSERVATORY

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Issue 109

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Detecting CO(1-0) Emission from $z \gtrsim 4$ Quasar Host Galaxies with the GBT

XTE J1810−197: A Remarkable Radio-emitting Magnetar

Gigantic Superbubble Discovered in the Inner Milky Way

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Cover: The Crab Nebula, located in the constellation of Taurus, is the remnant of a supernova in 1054 AD, observed as a "guest star" by ancient Chinese astronomers. Investigator: M. Bietenholz (York University)

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.

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Fred K. Y. Lo, Director

More than fifty years ago, the NRAO had its genesis in a conference organized by Associated Universities, Inc. (AUI) President Lloyd Berkner. Convened at AUI's New York City office on May 20, 1954, this seminal meeting grew out of informal discussions among scientists from Harvard University, the Massachusetts Institute of Technology, the United States Naval Research Laboratory, Columbia University, and the Franklin Institute on what was perceived as an urgent need for a radio astronomy research facility. Attended by 37 scientists and engineers from 28 U.S. institutions, this conference led to the signing of a contract for a national radio astronomy facility just two and a half years later, on November 17, 1956. The signers were National Science Foundation Director Alan T. Waterman and AUI President Berkner, who became the Acting Director of the Observatory.

This contract formally launched the NRAO, and events proceeded quickly. Groundbreaking took place at Green Bank on October 17, 1957; the Howard E. Tatel 85 Foot Telescope was dedicated just a year later; the 300 Foot Telescope began astronomical observing on September 21, 1962; and Sebastian von Hoerner made the first scientific observations with the new 140 Foot Telescope in May 1965. We have never looked back, and the official NRAO history now includes five decades of service to the community alongside our world-class facility development and operations at these telescopes and the Green Bank Interferometer, the 36 Foot / 12 Meter Telescope, the Very Large Array, the Very Long Baseline Array, and the Green Bank Telescope.

Through five decades of research, the NRAO telescopes and instrumentation have enabled astronomers from all over the world to contribute to progress in virtually every field of modern astronomy. For example, the NRAO telescopes along with their sensitive receivers played a pivotal role in unveiling the importance and pervasiveness of the molecular phase of the interstellar medium. The detection of the first interstellar organic molecule, H_2CO, with the 140 Foot Telescope in Green Bank and the first detection of the CO molecule in the Milky Way and external galaxies, with the 36 Foot Telescope on Kitt Peak in the early and late 1970's, respectively, led to the discovery of molecular clouds and the eventual recognition of their importance to star formation and galaxy formation. ALMA is being built to explore this "Molecular Universe."

The NRAO played an important role in the development of Very Long Baseline Interferometry, which led to the discovery of superluminal expansion in compact radio sources due to relativistic outflows from active galactic nuclei, which is important evidence for the super-massive black hole paradigm. The NRAO Very Long Baseline Array (VLBA) enabled measurements of the relativistic phenomenon of gravitational bending with unprecedented accuracy. Imaging of water mega-maser emission in the nucleus of the Seyfert galaxy NGC 4258 by the VLBA provided the first direct observational evidence for a Keplerian thin accretion disk rotating about a super-massive black hole and an independent determination of the distance to NGC 4258. A project to determine the Hubble Constant to < 3 percent accuracy has recently been proposed using the VLBA which has a remarkable, but perhaps under-appreciated, astrometric precision at the few micro-arcsecond level. A high precision Hubble Constant is the one of the most important measurements that can help constrain the equation of state of Dark Energy.

The sensitivity of the Green Bank 100m Telescope has helped to drive the recent resurgence of exciting pulsar research, such as precise measurements of the new double-pulsar, and the discovery of the fastest millisecond pulsar among the 33 pulsars discovered in a single globular cluster, Terzan 5. Other GBT observations have tested whether Nature's fundamental constants vary with time, uncovered remarkable small scale structure in the Galactic HI halo, discovered multiple biologically-significant molecules, and a water giga-maser from a Type II quasar at z = 0.66. The measurement of distances to galaxies at z ~ 1, using such giga-masers, would help to determine the rate of expansion of the Universe, which is a very strong science case for the Square Kilometer Array (SKA).

The unprecedented sensitivity and resolution at centimeter wavelengths brought by the VLA ushered in a new era in which pictures of radio sources are comparable in resolution to optical images, giving astronomers the capability to discover the remarkable spiral-shaped plasma falling towards the Galactic center, enigmatic stellar pairs that are micro-quasars, and unmatched details in the structure of radio galaxies. The VLA, by pinpointing and measuring the spectral energy distribution of the after-glow radio emission of gamma-ray bursters (GRB), helped unravel the nature of both the long and short duration GRBs, a major scientific puzzle for more than three decades. Observations of neutral hydrogen with NRAO telescopes permitted the exploration of individual galaxy rotations curves to large radii, yielding one of the early hints of dark matter's existence in galaxies.

Using the VLA at a frequency well beyond its design goal, astronomers have been able to image the distribution of CO molecules surrounding a quasar at z = 6.42, currently the highest redshift quasar known, revealing the physical conditions of gas surrounding a quasar in the earliest epoch of structure formation in the Universe. The study of galaxies and quasars in the earliest stages of formation will become more practical with the completion of the Atacama Large Millimeter / Sub-millimeter Array (ALMA) and the Expanded Very Large Array (EVLA).

In the near-term, the ALMA will be used by astronomers from around the world. Providing extraordinary sensitivity and resolution in the millimeter and sub-millimeter wavelength range, ALMA will probe the origins of stars and planets, and image the earliest galaxies. At longer wavelengths, the EVLA will extend the VLA's research capabilities across its entire radio spectrum through a ten-fold increase in continuum sensitivity, or a 100-fold increase in speed, vastly improved spectral resolution and coverage, and sub-arcsecond angular resolution.

The NRAO will strive to support the astronomy community by providing more than simply telescope time. We will collaborate with research groups in the community on new instruments and projects. We will endeavor to help train the next generation of astronomers, especially those who would be proficient with instrumentation, via student, co-op, postdoctoral and Fellowship programs. And, as part of our drive to make the Observatory more user-friendly, a coherent data management system is being built by the NRAO so that its data products are available community-wide for research and educational purposes to every user of the National Virtual Observatory.

The NRAO will continue to enable transformational research, supporting our users in their quest to explore new scientific frontiers, as well as operating and maintaining NRAO's facilities as world-class tools that will serve the research of astronomers from the U.S. and the world for decades to come.

New Pulsar Group at West Virginia University

West Virginia University (WVU) in Morgantown, a 2.5 hour drive north of Green Bank, appointed two young radio astronomers to the faculty of the Physics Department this past summer: Duncan Lorimer and Maura McLaughlin. This husband and wife team are two of the most promising young pulsar astronomers in the world. They also hold joint appointments at the NRAO.

Before coming to WVU, both Lorimer and McLaughlin worked at the Jodrell Bank Observatory in the U.K. Lorimer received his Ph.D. in 1994 from the University of Manchester and is interested in searching for and timing neutron stars, modeling their galactic population and evolution, compact object binaries and their merger rates, and a wide variety of other topics relating to neutron stars. In addition, he just co-authored his first book: *A Handbook of Pulsar Astronomy* published by Cambridge Universty Press.

McLaughlin received her Ph.D. in 2001 from Cornell University and works on multi-wavelength observations of neutron stars; radio transients; radio, X-ray, and gamma-ray searching and timing; magnetars; properties of the Galactic interstellar medium and many other aspects of pulsar astrophysics. McLaughlin led the effort that uncovered the surprising Rotating Radio Transients (aka RRATs) as recently reported in *Nature*.

Duncan Lorimer and Maura McLauglin.

Both Lorimer and McLaughlin are members of the team that discovered and has been studying the Double-Pulsar system J0737-3039, and both are very active in the ongoing Pulsar-ALFA surveys at Arecibo. And if all that wasn't enough, they recently became parents with the birth of their son, Callum.

Together with Scott Ransom and Walter Brisken of the NRAO scientific staff, Vlad Kondratiev, a postdoctoral fellow sponsored jointly by WVU and the NRAO, and students from WVU and University of Virginia, they will form an active group in pulsar research taking advantage of the very sensitive GBT, and the EVLA when it is completed. Plans for the future include developing the next generation pulsar instrumentation and forming a North American consortium to undertake a Pulsar Timing Array to detect gravitational waves from merging super-massive black-holes.

http://www.wvu.edu/~physics/news/radioastronomy.htm
http://www.wvu.edu/~physics/faculty/lorimer.htm
http://www.wvu.edu/~physics/faculty/mclaughlin.htm

AUI

NRAO Director Fred K. Y. Lo Appointed for Second Term

The Board of Trustees of Associated Universities, Inc. is pleased to announce that it has enthusiastically endorsed the reappointment of Dr. Fred K. Y. Lo as Director of the National Radio Astronomy Observatory. Dr. Lo is a highly respected scientist with a clear vision for radio astronomy, strong scientific intuition, and a dynamic approach to transforming his vision into reality.

Dr. Lo has directed NRAO for the past four years. During this time, NRAO has successfully embarked on many new initiatives and further strengthened its ties with the university community. A new organization structure has strengthened management and scientific direction. ALMA has been shepherded through a challenging period and construction is well underway. The Expanded Very Large Array is also well-advanced, and the Robert C. Byrd Green Bank Telescope is producing forefront science. The Board of Trustees looks forward to Dr. Lo's continuing stewardship of the NRAO as the premier U.S. radio astronomy observatory.

Ethan Schreier
President

Science

Planetesimals in the Disk Around TW Hydrae

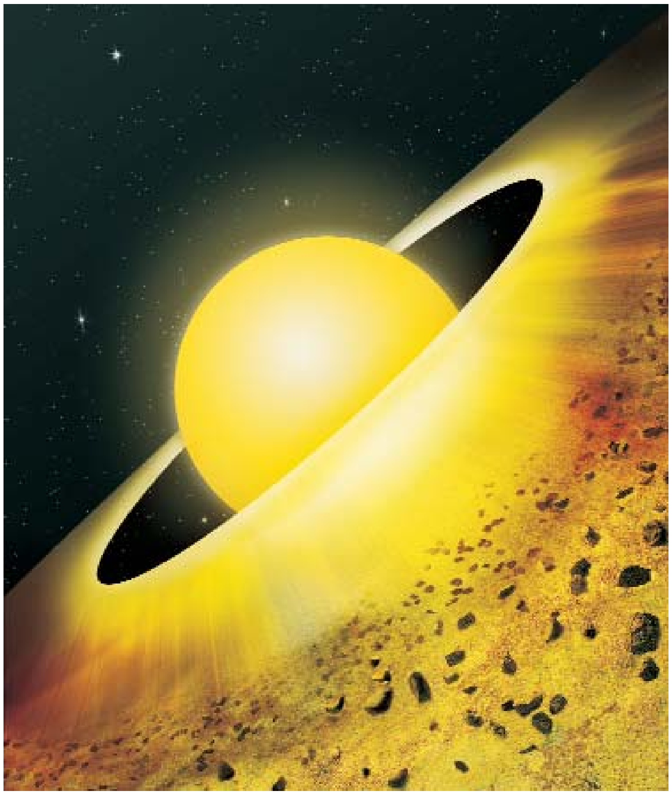

Figure 1. Artist's concept of a dusty disk around the young star TW Hydrae. Credit: Bill Saxton, NRAO/AUI/NSF

Many young stars show thermal emission from solids in circumstellar disks with properties thought to be similar to those in the early solar system. Observations of dust emission over a wide range of wavelengths provide diagnostic information about dust particle properties (e.g. Beckwith et al. 2000). Recently recognized nearby stellar associations offer prime targets for observations to address the evolution of dust toward planets (Zuckerman 2001). The TW Hydrae association, which contains more than 20 stellar systems with ages estimated to be 5–10 Myr, is the nearest known site of recent star formation activity (Song et al. 2003). The classical T Tauri star TW Hya, an apparently single star of mass 0.8 $M_\odot$, has become the focus of considerable attention because of its proximity (56 pc), and because it retains a remarkable face-on circumstellar disk of radius 225 AU visible in scattered light and in thermal emission from dust and trace molecules (e.g. Weinberger et al. 2002; Kastner et al. 1997; Qi et al. 2004).

The dust in the TW Hya disk, like the dust in disks around many younger stars, has long been known to show evidence for size evolution from the primordial interstellar distribution. Observations of the thermal dust emission at submillimeter and millimeter wavelengths have been robustly interpreted as evidence for particle growth to sizes on the order of 1 mm or more (Calvet et al. 2002; Natta et al. 2004). Since the particle size probed by radio observations is comparable to the wavelength used, detection of dust emission at centimeter wavelengths has the potential to reveal the development and location of larger "pebbles" within solar-system sized disks. Historically, two problems have thwarted this goal (Mundy et al. 1993): (1) the opacity per unit mass decreases for larger particles and the resulting emission is weak; and (2) the centimeter-wavelength emission of younger (~1 Myr) stars is often dominated by hot plasma in the system, either gyrosynchrotron emission associated with chromospheric activity or thermal bremsstrahlung emission from partially ionized winds. For TW Hya, its proximity and advanced age mitigate these problems.

We present new observations of TW Hya at centimeter wavelengths using the VLA that strongly argue for emission from a population of large dust particles in the disk. We used the VLA in late 2001 and early 2002 to observe TW Hya at a wavelength of 3.5 cm at approximately bi-weekly intervals in the D configuration, providing ~8" resolution (450 AU), and at seven epochs in the A configuration, which provided ~0.25" (15 AU) resolution. In addition, we observed TW Hya at 6 cm in the DnC configuration in late 2001 to provide supplemental spectral index information. Figures 2 and 3 show the results of these observations.
Figure 2 shows the TW Hya D configuration 3.5 cm measurements. No variations from the mean were observed within the uncertainties. Re-analysis of earlier

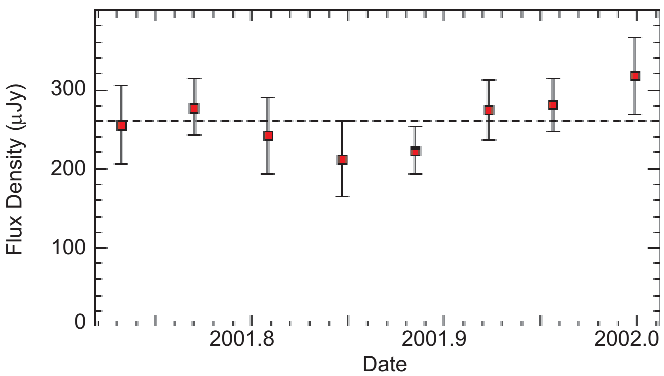

Figure 2. The 3.5 cm continuum emission from TW Hya shows no variability. The flux density of the TW Hya system was monitored at eight epochs using the VLA in the D configuration with ~8" resolution. The points show the measured fluxes with error bars that represent the rms noise in each observation. The dashed line indicates the 260 microJy/beam mean value.

(1991) observations are also compatible with no time variability of the radio emission. The A configuration observations at 3.5 cm spatially resolve the emission region. Figure 3 shows the real part of the 3.5 cm visibility as a function of baseline length, combining all the observed A configuration epochs. The fall-off in visibility amplitude at longer baselines is the signature that the emission is highly spatially resolved.

The lack of time variability, together with the large spatial extent of the radio emission provide strong constraints on the emission mechanism. Chromospheric activity, on stellar size scales, which would be expected to be variable, cannot be responsible for the 3.5 cm emission. An ionized wind does not present a viable explanation for the 3.5 cm emission either. The 6 cm upper limit constrains the spectral index (from 6 to 3.5 cm) to be greater than 0.3, which is incompatible with either optically thin ionized gas or ionized winds from young stars. More important, the peak brightness temperature at 3.5 cm in the resolved data is only ~10 K, requiring a very low opacity for ionized gas.

Dust emission can naturally account for all the properties of the 3.5 cm emission. A simple dust disk model with two grain populations (including a plausible population of large grains) can easily match the spectral data and the brightness distribution. Such simple models are not unique, but the large grains that account for the 3.5 cm emission must be present to radii of at least tens of AU to match the observed brightness distribution. The elevated 3.5 cm emission and a change in the spectral slope of the dust emission from submillimeter to centimeter wavelengths are difficult to explain unless substantial particle evolution has occurred throughout the disk.

Independent of the details of the disk model, the detection of dust emission at centimeter wavelengths provides a strong indication that an early phase of the planet-building process is underway in the TW Hya disk. A substantial mass fraction of orbiting particles must have agglomerated to at least centimeter size. This dust emission provides direct evidence for much larger particles than have been detected before in a nebula like the one from which the solar system is thought to have emerged.

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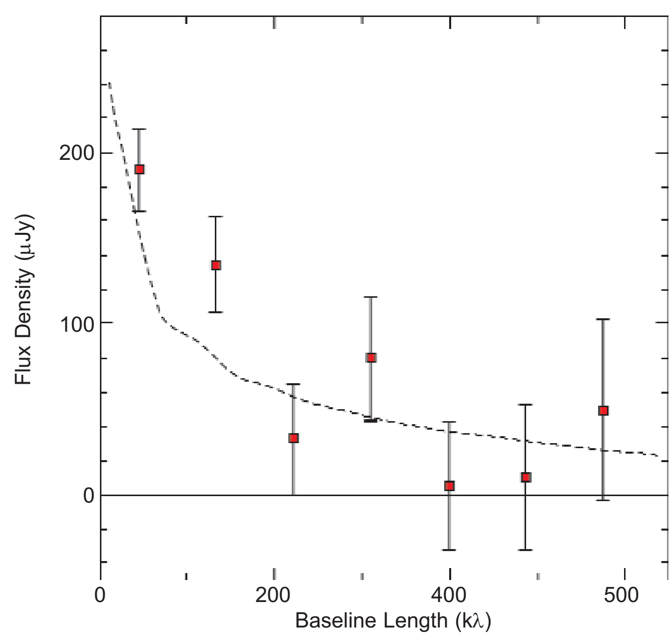

Figure 3. The 3.5 cm continuum emission in the A configuration. The points show the real part of the 3.5 cm visibility as a function of baseline length. The error bars represent ± 1 standard deviation for each bin. The dashed curve shows the predicted emission from an irradiated accretion disk with a population of large dust particles.

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Detecting CO(1-0) Emission from $z \gtrsim 4$ Quasar Host Galaxies with the GBT

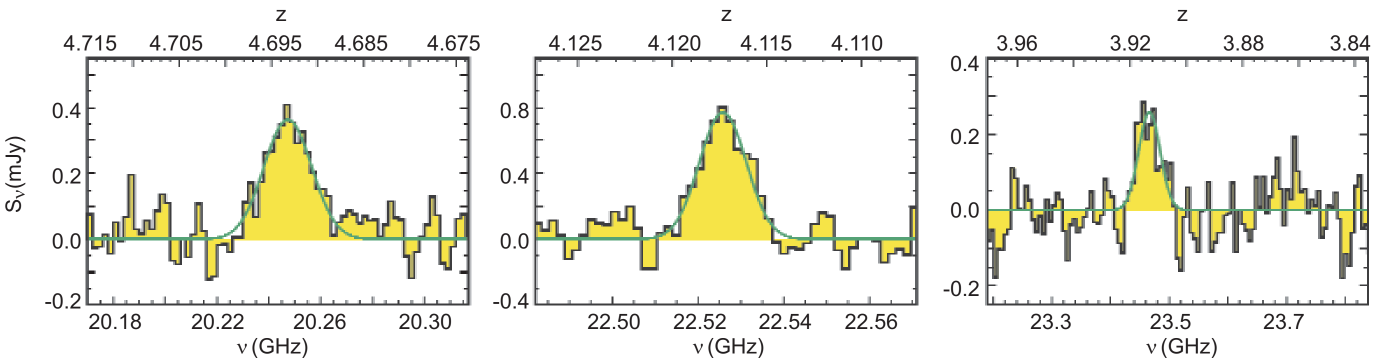
Observations of carbon monoxide (CO) are a key tool for studying the formation and evolution of galaxies in the early universe. Over the past decade, great progress has been made in this field, leading to the detection of CO emission toward more than 15 quasar host galaxies between redshifts of 2 and 6.4, right into the epoch of reionization (see Solomon & Vanden Bout 2005 for a review). Most of these discoveries have been obtained with millimeter-wave telescopes. At redshifts $z > 2$, only rotational transitions of the CO molecule with $J \geq 3$ (J denotes the upper rotational quantum number of the transition) are shifted into the millimeter atmospheric windows. Although these higher-J transitions exhibit higher peak flux densities than the ground-state (J=1-0) transition, in general, it is possible that emission from these higher-order transitions is biased towards the more excited gas close to a central starburst. Therefore, these transitions do not necessarily trace the bulk of the molecular gas reservoir which is seen in emission from the CO (J=1-0) transition.

It is thus desirable to complement observations of these higher-J CO transitions with observations of the CO (J=1-0) transition, which is observable in the 1.2 cm window beyond a redshift of 3.5. This has been done in few cases with the Very Large Array (VLA) and the Australia Telescope Compact Array (ATCA). While these radio interferometers have the ability to resolve the CO emission, their limitations in bandwidth require very precise redshifts, and prevent detailed information about the profile of the emission line from being obtained.

The largest single-dish radio telescopes, the NRAO Green Bank Telescope (GBT) and the MPIfR Effelsberg Telescope have collecting areas comparable to that of the VLA, and are equipped with spectrometers of larger bandwidth and spectral resolution than available at the VLA or the ATCA.

We have used the GBT to search for CO (J=1-0) emission towards three quasars between redshifts of 3.9 and 4.7 (1.3 - 1.6 Gyr after the Big Bang) which have been detected in multiple CO transitions previously. With a typical on-source integration time of 20 hours, we clearly detect CO (J=1-0) towards all three sources (see Figure). These spectra represent the first high redshift detections of CO emission with the GBT. These observations reveal the full line profiles at a spectral resolution which has never been achieved before in a CO (J=1-0) detection at high redshift. The two sources with the highest redshifts in our sample have also been targeted and detected with the Effelsberg telescope, highlighting the feasibility of these kinds of observations with single-dish 100m radio telescopes.

From our CO (J=1-0) observations and large velocity gradient models of all previously observed $J > 1$ CO



Spectra of CO (J=1-0) emission observed with the GBT toward BR 1202-0725 (z=4.69), PSS J2322+1944 (z=4.12), and APM 08279+5255 (z=3.91, left to right). The green lines are Gaussian fits to the line profiles. The resolutions and rms per channel values are 2 MHz (30 km s^{-1})/75 µJy, 1.8 MHz (24 km s^{-1})/140 µJy, and 5.86 MHz (75 km s^{-1})/65 µJy (left to right).

transitions, we derive molecular gas masses of typically 4×10^{10} $M_\odot$, which are in agreement with those derived from higher-J transitions. We therefore find no evidence for additional, less excited molecular gas reservoirs. Such reservoirs contribute a significant fraction to the molecular gas mass in ordinary spiral galaxies like the Milky Way, but are apparently not pronounced in bright redshift 4 quasars. Since all three quasars in our sample are known to have star-formation rates of 1000 $M_\odot yr^{-1}$ or higher, a constant starburst of 100 percent efficiency would still deplete these massive molecular gas reservoirs in 10^7–10^8 years. See Riechers et al. 2006, for more details on these observations.

D. A. Riechers, F. Walter (MPIA Heidelberg)
C. L. Carilli (NRAO)

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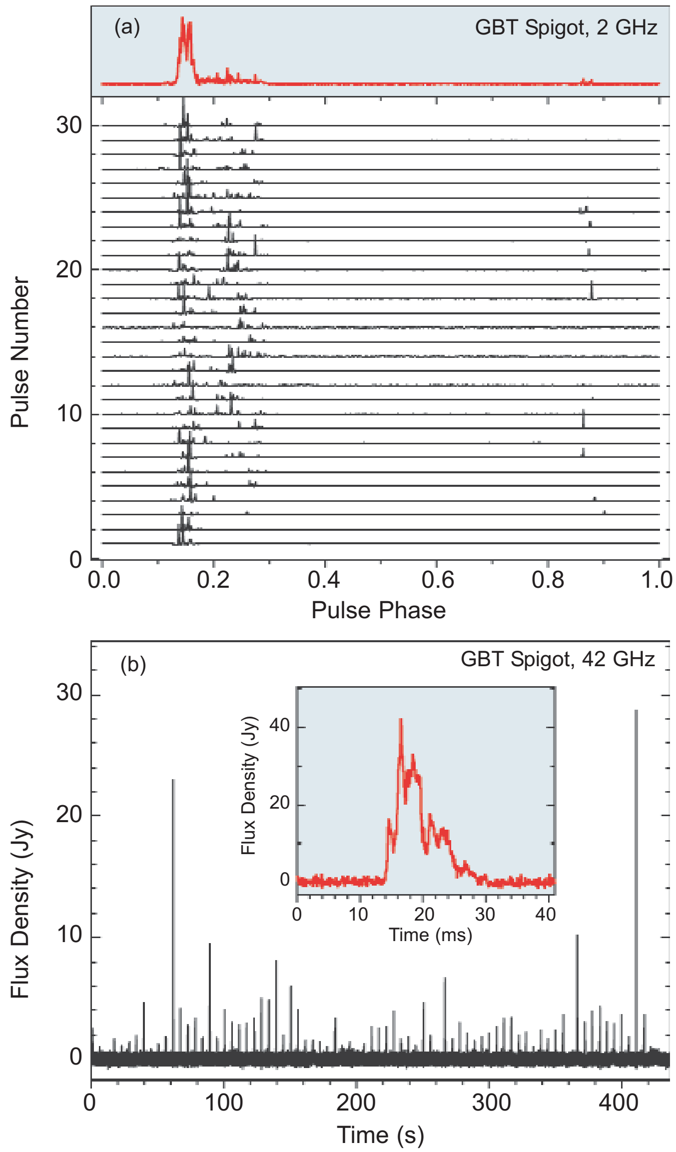
Solomon & Vanden Bout 2005, ARA&A, 43, 677

XTE J1810–197: A Remarkable Radio-emitting Magnetar

On March 17, 2006, using the ATNF Parkes telescope, we detected very strong pulses repeating every 5.54 sec from the anomalous X-ray pulsar (AXP) XTE J1810–197. These pulses, subsequently shown with GBT and Parkes observations to have extraordinary properties, represent the first detection of magnetospheric pulsed radio emission from a magnetar and, among other implications, link ordinary radio pulsars and magnetars.

Magnetars, of which only a dozen are known, are young neutron stars whose very bright and highly variable X-ray emission is thought to be powered by the decay and reconfiguration of their ultra-strong magnetic fields ($B \gtrsim 10^{14}$ G). In this respect they differ fundamentally from the ubiquitous radio pulsars (>1700 are now known), since all the non-thermal radiation detected from the latter, from radio to gamma-rays, ultimately derives from the magnetic braking of the rotation of the neutron star. This is not possible for magnetars, because their X-ray luminosity greatly exceeds the energy-loss rate available from the rotational slow-down of the neutron star. Despite several searches, no radio emission had been detected from either AXPs or soft-gamma repeaters (SGRs), the two sub-classes of magnetars.



Single pulses from XTE J1810–197 observed with the GBT using the Spigot spectrometer. (a) Thirty consecutive single pulses (about 220 sec of data) from one observation at 2 GHz, where each row represents the full pulse phase. The sum of all 30 pulses is displayed at the top. Sub-pulses with typical width $\lesssim 10$ ms arrive at different phases and gradually build up the average profile—which, however, varies from day to day. (b) Train of about 77 consecutive single pulses detected at a frequency of 42GHz. Inset: A 40ms-long detail of the brightest pulse from the main panel.

XTE J1810–197 was identified as the first transient AXP when, in early 2003, its X-ray luminosity increased 100-fold (Ibrahim et al.). Pulsations with a period of 5.54 sec were immediately detected, with the period increasing by nearly 1 μsec per day. The spin-down of isolated neutron stars is caused by magnetic torques, with the rate of slow-down proportional to the magnetic field strength. The rate measured for XTE J1810–197 implies a huge magnetic field at its surface, $B \gtrsim 2\times10^{14}$ G. The X-ray flux has been decreasing exponentially since the outburst with timescales of a few hundred days (Gotthelf & Halpern), and will soon return to the historically quiescent level which, judged from archival data, it had maintained for at least 24 years. A radio source coincident with the magnetar, with a flux density at 1.4 GHz of $S_{1.4} = 4.5$ mJy, was detected in the VLA MAGPIS survey in early 2004 (Halpern et al.); its origin remained a mystery until we detected the remarkable radio pulsations.

Since late April we have been observing the pulsar using a variety of radio telescopes: at the GBT and Parkes we record pulse profiles and fluxes, and also scintillation and polarimetric properties; at Nançay we obtain nearly daily timing measurements, supplemented by those from Parkes and GBT; we have investigated the millimeter-wavelength properties of the emission at IRAM; and with the VLBA we are attempting to measure the proper motion and parallax of the star. In addition, we monitor its total flux with the VLA, and are using the ATCA to investigate whether any of it is unpulsed. We have also used the GBT to obtain hydrogen absorption spectra and are attempting detection of other species. Some early results based on data acquired at Parkes, GBT, and VLA are reported by Camilo et al.

The individual pulses that we usually detect from virtually every rotation of the neutron star at low frequencies (≈ 1 GHz) are composed of sub-pulses of typical width $\lesssim 10$ms that mainly arrive within a 150 ms window. Their peak flux densities can be $\gtrsim 10$ Jy—so large that we discovered the pulsar by eye in pre-search analysis while attempting to identify RFI in the Fourier spectrum! This, and the high degree of linear polarization, do not make the radio emission from XTE J1810–197 fundamentally different from that of some ordinary pulsars. However, at least four characteristics of this radiation make it unusual or unique.

1. The radio spectrum is very flat ($-0.5 \lesssim \alpha \lesssim 0$, where $S_\nu \propto \nu^\alpha$) over a range of about 100 in observing frequency (see single pulses detected at 42 GHz with GBT in Figure).

2. At a given frequency there is no stable "average" pulse profile; different pulse components change in relative intensity and new components sometimes appear.

3. The flux changes at all frequencies. At $\nu \gtrsim 8$ GHz at least some of this variation is due to interstellar scintillation (we have obtained beautiful dynamic spectra at up to 19 GHz), but at 1.4 GHz the variations by factors of 2–4 on ~day timescales are likely intrinsic.

4. The radio emission is transient: in 1997 and 1998 the flux was less than 10 percent of the smallest value measured in 2006. Evidently, the radio emission turned on as a result of the magnetospheric changes that occurred in XTE J1810–197 following its 2003 X-ray outburst.

We do not know why the radio emission from XTE J1810–197 should have these characteristics. Presumably the observations are telling us something important about the current conditions in the corona of this magnetar. Further radio, infrared, and X-ray observations may eventually provide a fuller picture. In any case, some of the observed X-ray emission implies the existence of currents in the magnetosphere, and the decay of this emission points to a subsidence of the currents. We thus expect that the radio emission will eventually cease, but we have no idea whether this will take place in 6 months or 50 years. The discovery of transient (and bright) radio emission from XTE J1810–197 also reminds us that the radio sky is far from a static place, requiring more frequent monitoring than we can generally obtain with current instrumentation.

F. Camilo, J. Halpern, D. Helfand, and
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J. Reynolds, J. Sarkissian (ATNF)

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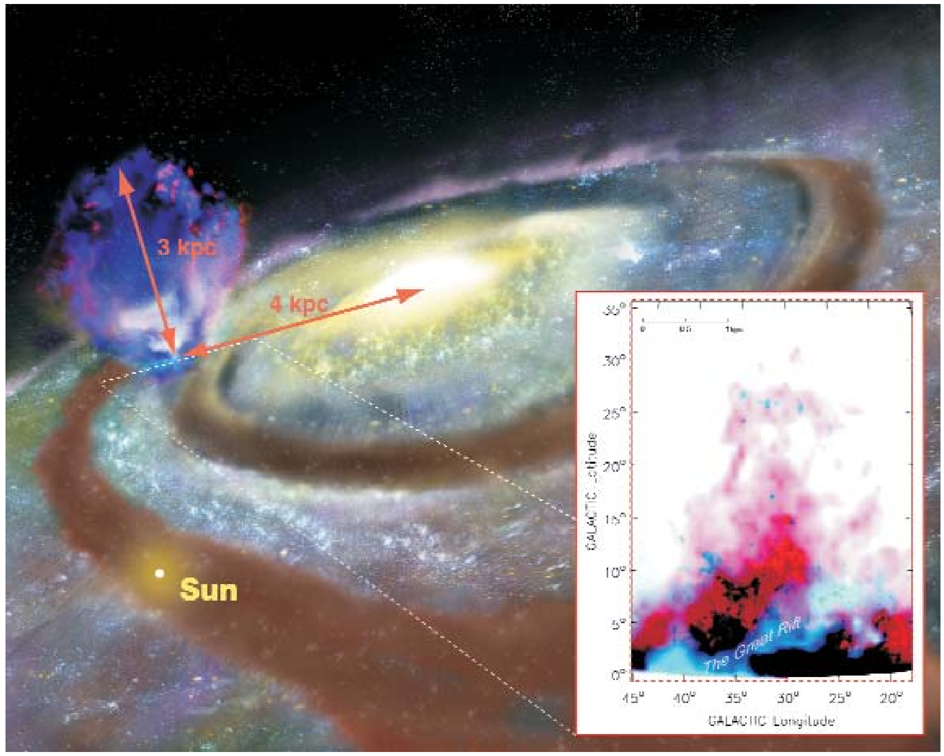
Gigantic Superbubble Discovered in the Inner Milky Way

Puzzling loop-like structures on the sky have been known since the work of William and Caroline Herschel, who probably discovered the famous Barnard loop in Orion in the 18th century, about 100 years before its study by E. E. Barnard. But it was not until the development of optical and radio spectroscopy in the mid-20th century that we understood that these are shells of dense gas surrounding sites of the formation of massive stars. The truly gigantic scale of this phenomenon was appreciated in the 1960s, when radio observations in the 21 cm line of neutral hydrogen revealed kiloparsec-sized holes in the hydrogen of the Magellanic Clouds. Initially thought to be a result of some huge "super-supernova" explosion, they were later identified as "superbubbles"—the result of collective work of winds and supernovae of dozens and sometimes even hundreds of the most massive and brightest O and B-type stars.

Superbubbles are common features of star-forming galaxies; they often consist of a neutral gas shell surrounding an interior of extremely hot ionized gas. The hot gas may eventually rise out of the disk of a galaxy to form a gaseous halo, while the dense shell may induce the formation of new stars. The superbubble phenomenon is now recognized as an important factor in the evolution of galaxies.



Neutral and ionized hydrogen observations of the superbubble are superimposed on an artist's concept of the system, showing its relative size and location in the Galaxy. In the inset, the HI data from the GBT are in green, and the Hα data from the University of Wisconsin's WHAM telescope are in red. The superbubble was produced by about 100 supernovae and extends far from its origin in the Galactic disk into the halo. The Great Rift, an interstellar dust cloud, obscures the optical Hα in the lower part of the figure.

We have been using the GBT to study neutral hydrogen in the interface between the disk and the halo of the Milky Way. In the course of this project we have discovered hydrogen emission from the walls and cap of an enormous superbubble which extends more than 600 square degrees on the sky. It covers about two-thirds of the constellation Ophiuchus in which most of it is located. This is larger than the area covered by a cafeteria tray held an arm's length away. The bubble required about 100 supernovae for its creation. Its top is so far above the plane of the Milky Way that it experiences a different gravitational force vector than most interstellar gas, and lags behind the rotation of the Galactic disk. Much of its interior is filled with warm ionized gas which is visible in optical emission lines. This gas is likely to be ionized by another cluster of young stars not associated with the formation of the superbubble. In all, this object contains about a million solar masses of neutral hydrogen and about the same amount of ionized hydrogen.

The superbubble lies over a spiral arm in the inner part of the Milky Way, about 7 kiloparsecs from the Sun and 4 kpc from the Galactic center. It is probably about 30 million years old and is now at its maximum expansion. It is beginning to fragment and will soon fall back to the disk and lose its form. Even now the cap at the top is showing signs of turbulence and instabilities. On the sides of the superbubble are pillars of hydrogen extending more than 1 kpc into the halo; the top of the bubble is more than 3 kpc above the disk.

About 250,000 HI spectra were measured with the GBT in the course of this investigation, most with an integration time of only two seconds. This gave enough sensitivity to reveal the main features of this system. This superbubble is a nearby example of a common phenomenon, and we should be able to study its structure in more detail than we can with more distant superbubbles.

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Atacama Large Millimeter Array

Initial Observations with an ALMA Band 6 Mixer-Preamp: Exciting Prospects for the Future

Figure 1. The ALMA mixer preamp mounted in an insert in the SMT 1.2 mm Dewar . The insert is at the 12 o'clock position.

During the past spring, spectral-line observations were conducted using a new receiver containing an ALMA Band 6 (211–275 GHz) mixer/preamp with the Submillimeter Telescope (SMT) of the Arizona Radio Observatory (ARO) at the University of Arizona. This project was a collaboration between the Central Development Lab of NRAO, Art Lichtenberger of the University of Virginia, and the ARO. The motivation behind these measurements was to evaluate ALMA technology and characterize mixer performance with real astronomical observations. The results of these tests were quite impressive, with record-breaking, single-sideband system temperatures and exceptional baseline stability over wide IF bandwidths.

To conduct these measurements, an ALMA Band 6 mixer-preamp was integrated into an insert at the ARO receiver lab and installed in the current 1.3 mm receiver Dewar at the SMT, as shown in Figure 1. The Dewar design at the SMT is similar to that used in the NRAO 12 m receivers, with insert positions arranged in a radial pattern. The insert with the ALMA components can be seen at the 12 o'clock position; two older 1.3 mm inserts are also visible in the Dewar. Although only a single polarization can be obtained from the one insert, the sideband-separating design of the ALMA mixer provides two IF signals: one from the upper and one from the lower sideband. The SMT spectrometer backends were configured to accommodate both sidebands simultaneously, each with an instantaneous bandwidth of about 2 GHz. The IF center frequency could also be steered in the range 5–7 GHz so that selected spectral transitions could be placed in the upper and lower sidebands. This flexibility was found to be useful for a variety of scientific programs.

The observations took place at the SMT (see Figure 2) in a series of 3–4 day sessions beginning in February and concluding in June. During the 21 total days of observations, various scientific studies were pursued: investigations of isotopic ratios in planetary nebulae; on-the-fly mapping of giant molecular clouds; and spectroscopy of circumstellar envelopes of supergiant stars, molecular clouds and extra-galactic objects. Record-breaking system temperatures were found at numerous frequencies across the band. At 230 GHz, for example, a total calibrated system temperature on the sky of 107 K, single sideband, at an elevation of 50 degrees, was recorded in the LSB; at 53 degrees elevation, measurements at 245 GHz yielded

Figure 2. The SMT facility, located on Mt. Graham, AZ, was used for the ALMA tests: elevation 10,543 ft.

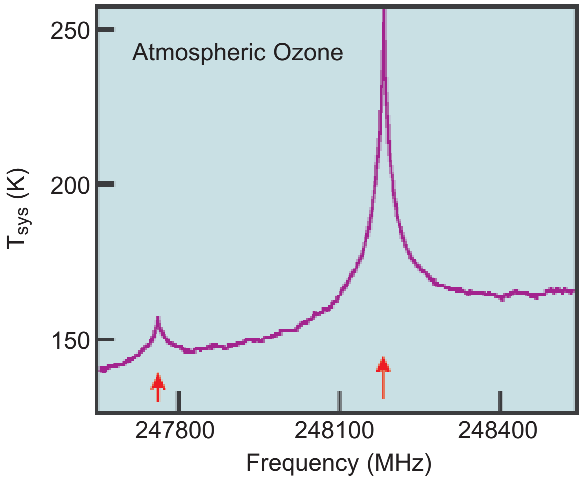


Figure 3. A calibration scan showing two atmospheric ozone lines near 248 GHz.

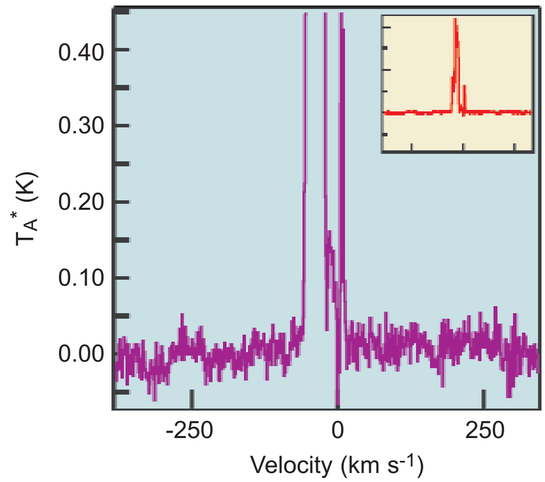


Figure 4: Baseline of a ^{12}CO, J=2-1 spectrum obtained towards the PN K3-55 in position-switching mode with a 4 degree OFF position. The integration time is 12 minutes. The full spectrum is shown as an inset in the upper left-hand corner.

T_{sys} = 105 K, single sideband, for the LSB. Typical system temperatures around 45 degrees elevation were around 120 – 140 K, SSB. Performance was consistent across the entire 211 – 273 GHz range. The high sensitivity of the receiver resulted in the detection of molecular lines in our own atmosphere. The unexpected observation of ozone occurred during the standard total power calibration process. A representative calibration scan is shown in Figure 3; ozone lines appear at 247.762 GHz and 248.283 GHz. The combination of receiver sensitivity and atmospheric attenuation due to these transitions locally increased the system noise.

Image rejection was also excellent. Although the ALMA image rejection specification only required 10 dB, the actual values were typically greater than 20 dB in the LSB and greater than 15 dB in the USB. Simultaneous measurements of ^{12}CO and ^{13}CO in opposite sidebands showed that the image rejection in the LSB was greater than 22 dB at 230 GHz.

During the ALMA test time, a survey of carbon isotope ratios in planetary nebulae was initiated by Xilouris and collaborators. Most of the 29 objects studied lie well in the Galactic Plane, and therefore large offsets were required in position-switching mode to reduce the contamination from Galactic CO. Even with an off position as far away as 4 degrees in Galactic latitude, baseline stability was excellent, as shown in Figure 4. Here a raw spectrum of the CO, J=2-1 transition observed towards PN K3-55 is displayed, covering over 400 MHz with no baseline removed from the data. This survey, although at its initial stage, has more than doubled the number of PNe where a carbon isotope ratio has been measured. Preliminary results indicate severe ^{13}C depletion, supporting the idea that at the end of stellar evolution, standard nucleosynthesis fails to match the observations. In particular, for low mass stars, non-standard mixing mechanisms need to be invoked.

Equally remarkable were data obtained in a spectral-survey of SgrB2(N), a dense cloud core, by Apponi, Ziurys, and students. Spectra were taken with almost 2 GHz of total bandwidth per IF channel. Figure 5 shows a single-sideband spectrum at 246 GHz obtained

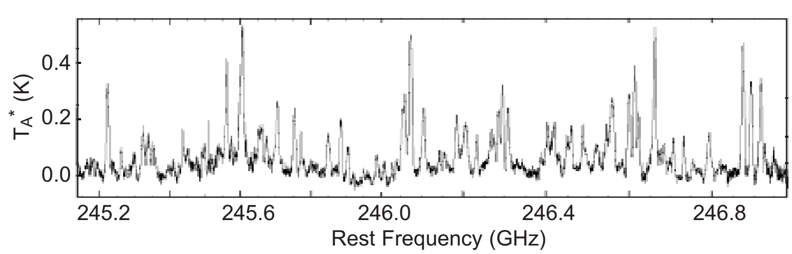


Figure 5. Spectrum of SgrB2 (N) near 246 GHz, taken in position-switching mode, with a total integration time of 30 minutes with almost 2 GHz instantaneous bandwidth. The rich chemistry of this region is striking, with the weakest lines detectable at a 3 sigma level of 15 mK.

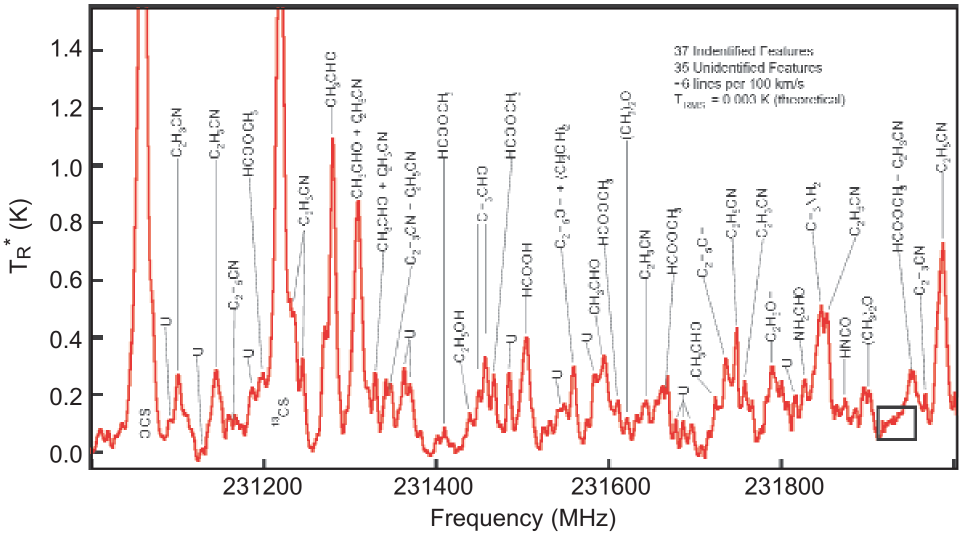


Figure 6. Confusion-limited spectrum obtained towards SgrB2(N) in 2 hours of total integration time. The image rejection is >20 dB and the large number of distinct features arise from the signal sideband—not all are marked. The actual noise level is indicated by the box on the lower right.

in position-switching mode with a 30 arc-minute offset in azimuth. Despite the relatively short integration time of 30 minutes, the spectral density is extremely high. Rejection of the image side-band was greater than 99 percent at this frequency, and therefore virtually every feature present in these data is in the signal sideband. A more detailed spectrum is shown in Figure 6. Here a sample of the survey is shown at 231.5 GHz, covering 1 GHz in frequency. The spectral-line confusion limit has been reached in these data after two hours of integration, and the noise level can be seen only in a small section of the spectrum at the right hand corner. The spectrum in fact is so congested that not all real spectral features are labeled on the plot. About 72 individual lines are present, half which are unidentified. Once again, the image rejection is better than 20 dB. These data are about a factor of ten more sensitive than any other current 1 mm spectral-line surveys. Obtaining confusion-limited spectra with high image rejection is the absolute best that can be achieved in this source. Analysis of this survey will prove definitively which complex species are actually present in this object.

Other surprising results were obtained with the new ALMA 1 mm system. A spectral survey of the oxygen-rich supergiant VY Canis Majoris was begun by Woolf, Milam, Apponi and Ziurys. In only a few days observing time, this study revealed that the envelope of this star has a chemistry far more complex than previously thought. An amazing array of interesting molecules was detected, including NaCl, PN and HCO^+. CN, HNC, HCN, and CS were also found—strong evidence that CO does not control the carbon chemistry in this source. On-the-fly (OTF) observations were made of the W3 and W51 giant molecular clouds by Peters and Bieging. The receiver was tuned to place the J=2-1 transition of ^{12}CO in the upper sideband and that of the ^{13}CO in the lower sideband, with good image rejection in both sidebands. A region 0.42 square degrees was mapped in W3 and 0.33 in W51, with high quality spectra in both cases.

More observations will be conducted with this receiver in the fall. However, these preliminary results have already demonstrated the superior quality of the ALMA Band 6 mixer-preamp. (A more complete description of the technical aspects of the test receiver can be found in ALMA Memo #553.) The extremely good sensitivity of the Band 6 system, coupled with the high stability, bodes well for the future. The data obtained here are an exciting prelude to the wonderful science that will emerge from ALMA at 1 mm.

Lucy M. Ziurys and the ARO Staff

ALMA Construction

Amendment #2 to the *Agreement Concerning the Construction of the Enhanced Atacama Large Millimeter/Submillimeter Array (ALMA) between ESO, NSF and the National Institutes of Natural Sciences of Japan* has been executed by all of the parties. We welcome our East Asian colleagues to ALMA, now enhanced in both capability and name.

Progress continues toward the completion of interior finish on the 16,570 foot altitude Array Operation Site (AOS) Technical Building (TB). After the Santiago ALMA Board meeting in June, Board members visited the building and the nearby Site Characterization facility as well as the site of the center of the ALMA array. Interior finish is underway in the building, which will hold the ALMA correlators and other electronics. The Integrated Project Schedule calls for completion at the end of March 2007, and this work is on schedule. One quadrant of the correlator has been under operation at the NRAO Technology Center (NTC) in Charlottesville for several months and is ready to occupy its new quarters.

The design of the road and fiber network interconnecting the AOS TB with the antennas and their foundations is progressing toward completion in the coming months. A system for interim network access to the building is in the final stages of planning; communication currently occurs through satellite phone.

Figure 1. Work on the interior of the AOS TB has continued during the austral winter. At 16,570 feet, this is the highest technical building in the world.

Nearby on the high site, the Atacama Pathfinder Experiment (APEX), equipped with a Vertex antenna very similar to the ALMA prototype antenna, continues its operations. A special issue of *Astronomy and Astrophysics* was published August 1, 2006 that is devoted to early science results obtained with the APEX. One highlight is the detection of the very high excitation J=13–12 CO line at 1,496.9 GHz. The nearby [N II] emission line at 1,461.3 GHz was unsuccessfully sought toward the Orion Bar.

The 21m wide road on which the transporter will carry antennas to the AOS from the Operations Support Facility (OSF) has been open for some time. Culvert construction and other drainage improvements continue. Not far above the OSF, a small stone corral, some 50 years old, used originally to contain animals and as sleeping quarters for local Atacamenho herdmen, was discovered during construction. It has now been restored as a historical site. It was reconstructed with the help of the local indigenous people and with the advice of the original owners. The opening ceremony for the reconstructed corral was held on July 27. The Region II Governor, Marcela Hernando, attended and delivered a speech. Archaeological study of the ALMA site has been underwritten by AUI, ESO, and NAOJ. A new book, *Desert Tracks* or *Huellas del Desierto*, decribes the archaeology of the ALMA site and may be obtained on-line at *http://www.nrao.cl/.*

Catherine Cesarsky, Director General of ESO, signed the contract for construction of the OSF on August 3. Its contractual partners, the VVMO Consortium, have held a kickoff meeting, and OSF construction has begun. ALMA will be operated from this building. ALMA personnel live in the nearby ALMA camp, which is now at capacity. A recreation room adjacent to the dining room was finished on time and on budget. An inauguration party was held on July 4, also celebrating U.S. Independence Day.

Figure 2. Bottom section of antenna jig installed and bolted to the foundation, and awaiting the first VertexRSI antenna at the OSF site.

Figure 3. VertexRSI production antenna yoke base under construction in Texas, (August 23).

Near the OSF at 9,600 feet elevation, the first ALMA antenna foundation has been completed. It is located at the Vertex Site Erection Facility adjacent to the future OSF. The most difficult part of an antenna foundation's construction is the installation of the steel inserts upon which each antenna is placed. Each antenna sits on a foundation supported by three precisely positioned semi-cylindrical structures. The tolerances are measured in tenths of millimeters.

To locate these properly on the foundation, the Antenna IPT has designed an installation jig, which was used on July 27 for the first time. The foundation is ready to receive the first antenna, which will be preassembled in Texas during the coming months. It arrives at the new foundation in Chile at the end of the year. The large VertexRSI Site Erection Facility building will also be constructed during the next few months.

In North America, progress continues on Prototype System Integration. The first ALMA Band 7 (270–373 GHz) receiver cartridge, shipped from IRAM in Grenoble, arrived at the North American Front End Integration Center (FEIC) at the NTC, where it joined the Band 6 (211–270 GHz) receiver cartridge constructed at the NTC (see article page 11). The Band 3 (84–116 GHz) cartridge will soon arrive for integration at the FEIC from the Hertzberg Institute of Astrophysics in Victoria, Canada. The first ALMA receiver will be tested on the prototype antennas at the NRAO Very Large Array site as part of the prototype ALMA system early next year.

Scientists are keenly anticipating ALMA, which Arden Bement, Director of the National Science Foundation has called "very transformational". ALMA's prospects were the subject of a talk given by Jean Turner at the IAU General Assembly in Prague. Later in the meeting, the current status of ALMA construction was described by the ALMA Director, Massimo Tarenghi, and others at a special session *The ALMA Era for Astrophysics Begins*.

For the past several months, the two prototype ALMA Water Vapor Radiometers have been deployed for testing on antennas of the Smithsonian Millimeter Array on Mauna Kea. Results of these tests and others will be discussed at a Workshop on *Measurement of Atmospheric Water Vapor: Theory, Techniques, Astronomical and Geodetic Applications* to be held October 9–11, 2006 in Wettzell / Hoellenstein, Germany.

ALMA science topics will be the focus of a meeting *Science with ALMA: A New Era for Astrophysics* to be held November 13–17, 2006 in Madrid, Spain.

Attendance at the meeting was oversubscribed; about 300 persons registered. At press time, the complete schedule of scientific sessions has just been published.

Al Wootten

Transitions

The process has begun to select the Joint ALMA Office Project Scientist (JAO PS) in Santiago, Chile. The JAO PS will lead the commissioning of ALMA. Until this position is filled, the regional project scientists will continue to rotate through the JAO in Santiago on four month terms. On September 1, 2006, Al Wootten (NRAO) assumed the post from Ryohei Kawabe (NAOJ).

Jody Bolyard has recently spent a year in Santiago working for the JAO, helping document ALMA safety policies and procedures. Although he has now returned to his duties at NRAO, Jody will continue to spend 20 percent of his time as ALMA System Safety Manager.

Mauricio Pilleux, ALMA/NA Chilean Business Manager, is relocating to Charlottesville for a period of three years to lead a special project that will implement supply chain management for ALMA NA. He will continue to be the Chilean Business Manager and will be supported in Chile by the staff there.

Jonathan Williams of the Institute for Astronomy at the University of Hawaii was appointed as the new ALMA North American Science Advisory Committee (ANASAC) Chair. Jonathan has been enlisted to organize ANASAC input into key U.S. community issues, such as the upcoming general review of the North American ALMA Operations Plan.

Al Wootten

The North American ALMA Science Center (NAASC)

The primary activities at the NAASC have centered on two key documents: (1) the global ALMA operations plan, and (2) the NSF proposal for North American ALMA operations funding. NAASC staff have been working closely with the Joint ALMA Observatory and the other Executives to revise the ALMA operations plan to include the addition of Japan to the project, to account for changes arising from the project rebaseling, and to update values based on regional costs. In parallel, we have been revising the NAASC operations plan in preparation for a proposal to the NSF for North America's portion of ALMA operations funding. The ANASAC has been incorporated into the process, providing key input on community related issues such as development funding and a user grants program. The Canadian role in ALMA operations, and in developing the operations plan, has been the subject of a number of telecons and a face-to-face meeting in Tucson in early August. Both the revised ALMA operations plan and the NAASC operations plan are to be delivered to the ALMA Board and the NSF, respectively, prior to the ALMA Board meeting in November.

Beyond the work on the operations plan, the NAASC staff is busy supporting ALMA software testing and archive planning. The NAASC participated in a test of the ALMA Observing Tool in August, and will participate in tests of the Pipeline and Offline systems in December. Work continues on a NAASC-supported *Spectral Line Catalogue* ("Splatalogue"), and we anticipate a public release in the near future. Details should follow in the next issue of the NRAO *Newsletter*. Finally, planning for the second NAASC Science Workshop is well along, with a theme of protostellar and protoplanetary disks, to be held in June, 2007 in Charlottesville (see article on next page).

C. L. Carilli and J. E. Hibbard

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

On June 22-24, 2007, the NRAO North American ALMA Science Center 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*. 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. To solicit talks on the most cutting-edge research, we will be requesting proposals for specific presentation topics in the near future. Students are especially encouraged to attend. Please bookmark our meeting page, and visit often for updates—we will be open for abstract submission soon!

Crystal L. Brogan

Expanded Very Large Array

Progress on EVLA Project

A key milestone for the EVLA project was achieved on August 1, 2006, when an announcement was made that all EVLA antennas accepted by telescope operations are now included in astronomical observations by default. Prior to this date, the reliability of some EVLA antennas was in need of improvement and astronomers specifically had to request that EVLA antennas be included in their observations. EVLA antennas 13, 14, and 16 were included routinely on August 1, 2006. EVLA antenna 18 was included beginning on August 16, 2006, and we anticipate antenna 24 will be included in observations starting in early September 2006. For further details please see the next article.

The retrofitting of three additional antennas to the EVLA design is in various stages of completion. The retrofitting of antenna 24 is essentially complete, and it has been moved on to the array for evaluation and testing. The outfitting of electronics on antenna 26 is nearly complete. The mechanical overhaul of antenna 23 should be complete in early October. The pace of antenna retrofits has been accelerated to achieve our goal of retrofitting a total of 12 antennas by the end of September 2007.

Significant progress has been made in the production of feed horns for the EVLA receivers. Component parts have been fabricated for all the C-Band horns, and all but three of the horns have been assembled. A total of 14 L-Band feed horns have been assembled, including the application of their fiberglass lamination. L-Band horn production is well ahead of the antenna retrofitting schedule. RF tests of a half-scale version of the S-Band feed horn were successfully completed, and an order was placed for the fabrication of a full-size, prototype S-Band horn. An order was also placed for the production of all Ka-Band feed horns.

Tests of the octave bandwidth, L-Band orthomode transducer (OMT) that were conducted earlier this year showed that the RF performance of the OMT was excellent, but that its noise performance was in need of improvement. Additionally, cryogenic cooling tests showed that the cool-down time of the L-Band receiver was much too long and that the OMT was not cooling to the desired temperature. The cooling problems were resolved by installing a robust thermal strap on the OMT and by correcting thermal shorts found in the OMT installation hardware. These cooling problems effectively caused resistive losses in the OMT which contributed to the receiver's mediocre noise performance. Additional mechanical improvements have been made to the L-Band receiver, and we are optimistic that RF tests over the next month will show that the noise performance of the L-Band receiver meets our expectations. The resolution of these issues allows us to proceed with the designs of the C-Band and S-Band OMTs, which are scaled versions of the L-Band design.

Preparations for the installation and production of the EVLA correlator are underway. The installation of the correlator shielded room was completed earlier this year. The installation of the room's HVAC system, lighting, fire protection system, and electrical power distribution system was completed this summer. Proposals to install the correlator's 48VDC power plant were requested. Prototype correlator chips are under evaluation. The delivery of prototype baseline boards was delayed to the end of September because of a fabrication error.

Test observations with EVLA antennas revealed spurious emissions at 8192 MHz, which were attributed to harmonics of the 4096 MHz local oscillator in the IF downconverter module (T304). The harmonics were adequately suppressed with shielding of module components and the installation of RF-absorbing material in the module.

Excessive temperature fluctuations have been observed in the upper vertex room of the antenna during the hot, summer months. The temperature fluctuations may cause variations in the phase of the RF/IF signals from the receivers in the vertex room. A plan has been developed to minimize the temperature fluctuations.

In the software area, work on the High Level Architecture for Science Support Systems (SSS) software continues to concentrate on the development of its component models. The first application to use these models is the Observation Preparation Tool (OPT). Software for antenna checkout and acceptance has been tested and released to VLA Operations for operational acceptance tests that determine whether or not an EVLA antenna can be included in VLA observations. Development work has also begun on the interim version of the data capture and format (IDCAF) software. IDCAF is the software that will format and write VLA-format archive records from the EVLA monitor and control system.

Mark M. McKinnon

The Return of EVLA Antennas to Normal VLA Observing

On August 1, 2006, EVLA antennas passing a specific set of hardware and software operational tests are now included in astronomical observations by default, instead of requiring a specific request. As of this writing (mid-September 2006) four EVLA antennas (13, 14, 16, and 18) are included, and a fifth (antenna 24) is anticipated to be included in late September 2006. While we have returned EVLA antennas to the array (and will continue to do so), these antennas are operated in a transition mode that does not yet have all

VLA features available, and the antennas may be less reliable than unmodified VLA antennas. Also, not all receiver systems are necessarily available on returned EVLA antennas. For example, the 15 GHz systems are not available on any EVLA antenna, since this system is not scheduled for deployment until late in the EVLA project.

As we have previously reported, a web page *http://www.vla.nrao.edu/astro/guides/evlareturn* provides up-to-date information on the status of returned antennas (and receivers), as well as giving guidelines to users about the best way to use EVLA antennas in different observing modes. It is vital that VLA users (who will be receiving returned EVLA antennas by default) read the information on this page before their observations. For questions or comments about observing with EVLA antennas, please email *cchandle@nrao.edu*.

M. J. Claussen and C. J. Chandler

End to End Operations

NRAO Software Conference Held in Socorro, August 8-10

A large group of NRAO software engineers from all projects (including scientists heavily involved in software systems development) gathered in Socorro in August to share information, ideas, and southwestern cuisine. The three-day conference was conceived and organized by Amy Shelton (Division Head for Software Development in Green Bank) and Paul Marganian (Software Engineer at Green Bank), with local organization and management by Bryan Butler (Division Head for Software Development in Socorro). Terry Romero (Socorro) was particularly instrumental in planning and made sure that the logistics went smoothly, with support from Liz Cryer (Socorro).

Sharing ideas about software development was the focus of the recent NRAO Software Conference held in Socorro.

During the introductory session, 62 people were in attendance, and for the remainder of the conference nearly 40 people attended each talk. Introductory talks were first given to broaden awareness of the current status and issues of the various software development efforts at NRAO. "Birds of a Feather" sessions were held on topics that included Java, Python, cluster computing, and Virtual Observatory implementation.

Based on feedback from the attendees, focused workshops will be planned in the future to further encourage a culture of collaboration in software development across NRAO, and identify key opportunities for NRAO to become more cost-effective and innovative in software development.

N. M. Radziwill and A. L. Shelton

The Beginning of End to End

In the July *Newsletter*, the new NRAO End to End Operations Division was announced. Its mission is to help broaden access to NRAO telescopes and data facilities, and help the organization make the most of its investments in software development and services. The new division has been ramping up over the past few months, establishing the relationships and approaches to coordination that will ensure success in establishing operational archives, proposal services, data processing and automation, and shared metadata repositories.

Over the past three months, several initiatives have started, for example, producing calibrated data and images from 25 years of VLA archive data, improving the NRAO archive and linking it to the global community, developing calibration catalogs and semi-automatic scheduling tools, and improving the CASA interface for all users. Stay tuned for updates in these areas over the upcoming months.

N. M. Radziwill and E. B. Fomalont

Help NRAO Improve its Data Archive

Throughout its history, a wealth of science data has been generated by NRAO instruments. Additionally, individual researchers have generated a vast collection of science data products which remain inaccessible to other researchers. To broaden access to researchers working at any wavelength, the science data products which have been or can currently be generated from archival data must be made more widely available. A major thrust of NRAO End to End Operations through 2007 will be to use the extensive raw data available to generate spectra and images for broader scientific use via the NVO, as well as to improve the utilities to access the archives.

The NRAO Archive has been operational since 2003. To date, over 1000 users from 300 institutions have downloaded over 5 TB of telescope data (nearly 45,000 data files). The download rate has climbed to approximately 15 GB per day, and the archive system logs indicate that several hundred archive queries are received daily. The archive presently contains all VLA data back to 1976, GBT data from 2002 to 2004, raw VLBA data back to 1999 (with gaps), and some VLBA calibrated data from this time period. Efforts to expand the VLBA data back to 1992, and the GBT data after 2004, are underway and both are scheduled for completion in 2007. Throughout the next two years, work will be focused on establishing an archive presence for the EVLA in the context of an NRAO-wide federated model, to include the ALMA archive which will be part of the North American ALMA Regional Center. This federated model will be expanded upon, with science pipeline support incrementally added, through 2011. Possibilities for a full data center, with clusters for data reprocessing, are being explored.

Successful continued development depends upon hearing and responding to suggestions from scientists who have already used the NRAO Archive. If you are one of these people, we strongly encourage you to visit the NRAO Archive System Survey at *http://www.surveymonkey.com/s.asp?u=950572530730* to provide your comments and perspectives which will be used as input to the continued development process.

The survey will be open until December 31, 2006. Archive users are encouraged to submit comments as often as they like.

N. M. Radziwill, J. M. Benson, and J. E. Hibbard

GREEN BANK

The Green Bank Telescope

At the time of writing, we are just in the transition from our summer maintenance period to the start of winter high-frequency observing. This has been an extremely busy summer in Green Bank. As well as normal routine maintenance, this summer has seen structural inspections, painting, and preparations for next summer's azimuth track refurbishment work. As well as the telescope activities, the last few months have been extremely busy for all the Green Bank divisions. In addition to the normal programs of research experience for undergraduates and teachers, we hosted or participated in an almost constant series of education and public outreach activities including: the annual meeting and 25th anniversary conference of the Society of Amateur Radio Astronomers; Star Quest III; the NASA Quiet Skies Workshop; a Joint NASA/NRAO Astronomy Institute for Teachers; the National Youth Science Camp and the 2nd Annual West Virginia Governor's School of Math & Science. These activities stretched our resources close to the limit, but all went extremely well, and were greatly appreciated by the various participants.

In addition to their normal workload, the Software Development Division (SDD) participated in two additional activities this summer. The SDD initiated, largely organized and participated in the NRAO Software Conference held in Socorro on August 8-10 (see the article on page 19). Two members of the SDD, along with one Green Bank Staff Scientist made a week-long trip to the Joint Astronomy Centre for discussions with JCMT, UKIRT, and Gemini staff regarding their dynamic scheduling capabilities. The information gathered during the trip will be extremely useful as we continue to develop our strategy and implementation for the GBT.

A significant fraction of the efforts of our engineering and science staff have gone into continued instrumentation development work. Progress on the Ka-Band (26–40 GHz) and Q-Band (40–50 GHz) receivers is described in more detail in the article below. In addition to these two receivers, work is underway on the C-Band (4–6 GHz) receiver to improve its cryogenic performance. In addition, we are using the C-Band receiver as a development vehicle for techniques expected to improve spectral baseline performance. These include: replacing dewar output coaxial lines with shorter cables to improve impedance match and reducing the frequency period of mismatch ripple; integrating most of the post-dewar RF electronics into a small number of modules, reducing the number of coaxial interconnects and the electrical length of connections, and generally minimizing the electrical length of interconnections in the RF and IF electronics. Experience gained with this receiver will in turn be applied to future instrument refurbishments. In parallel with the front-end work, good progress is being made on Zpectrometer, the ultra-wideband spectrometer being built by Andy Harris at the University of Maryland in collaboration with NRAO. This is now scheduled for delivery to Green Bank in September, with initial installation and engineering commissioning tests on the telescope at the end of October.

The Penn Array Receiver (PAR) project has made tremendous progress since our last newsletter report, principally in the fabrication and extensive lab characterization of two detector arrays. The arrays suffered a number of teething problems which have been addressed. Chief amongst these was an unexpected electrothermal oscillation between the TES detectors and the SQUID feedback circuit, which was eliminated by speeding up the SQUID feedback circuit. The second array has been operated in the lab with over half of its detectors simultaneously sensitive to light and there is a strong hope that modest changes will retrieve most of the remaining pixels before first light. In August the project underwent a very successful in-progress review in Philadelphia chaired by William Duncan of NIST; other panel members were Suzanne Staggs (Princeton) and Adrian Russell (NRAO). The panel endorsed the project team's continuing efforts and made a number of specific technical recommendations on how to proceed. The PAR is cooling in the lab at Green Bank in preparation for some final lab tests leading, we hope, to first light on the GBT in September.

By the time you read this article, the September workshop, *Future Instrumentation for the Green Bank Telescope*, will have been completed. The purpose of the workshop is to revisit GBT development priorities in light of recent scientific, technical, and software/data-handling advances, and to plan a second generation of GBT instrumentation which would include wide-field imaging arrays. A summary of the meeting and other information will be posted on the workshop website at: *http://www.nrao.edu/GBT/fi/index.shtml*.

Richard M. Prestage

Green Bank Telescope Azimuth Track Remediation

As has been described in previous Newsletter articles, the GBT azimuth track will be replaced in the summer of 2007. Deterioration of track components was found during the early commissioning phase of the telescope. The basic cause of the deterioration is the high wheel load—over one million pounds per wheel of dead load, which is the highest loading of any wheel-on-rail application known. The goal of the replacement is to restore the 20 year service life of the components. The replacement involves every component of the track between the top of the concrete foundation and the bottom of the wheels.

- New, higher strength base plates, made from bridge steel. Each base plate will be welded to the next, and also to the splice plates below each joint.
- New, tougher wear plates. These plates will have higher impact and fatigue strengths, and be over 50 percent thicker than the existing plates. The wear plates will overlap the joints of the base plates below them. The wear plates will also be as wide as the base plates beneath them, and have a V-shaped joint instead of the 45 degree mitered joint used now.
- A layer of bronze/teflon/molybdenum will be sandwiched between the wear plates and the base plates to reduce the chance of fretting wear.
- The plates will be held together by bolts that go all the way through both the wear plates and base plates. These will replace the screws that go only a short distance into the base plates. The bolts will be located further away from the wheel path to reduce fatigue stresses on them.
- The cement grout that fills the void between the base plates and the top of the concrete will be replaced by a high strength, two part epoxy grout. The old grout was packed into the void by hand, whereas the new grout will be poured in and allowed to completely fill the void.

This work is planned to start April 30 and finish August 3. The telescope will remain on the track during this time, and the four 1/8th arc segments between the wheels will be replaced. The telescope will then be driven onto the new sections, and the remaining 1/8th arc sections will be replaced. Following final engineering checkout, the telescope will enter a one month phase of re-characterization and shared risk observing, which will finish August 31.

Bob Anderson

Ka and Q-Band Receiver Status

The GBT Ka-Band (26–40 GHz) and Q-Band (40–50 GHz) receivers show intermittent, irregular baseline structure with typical ripple periods between 10–40 MHz. This baseline structure is qualitatively different than baseline structure that has been previously exhibited by most GBT receivers. It varies on short timescales and therefore the RMS noise level partially integrates down with time; however some spectral baseline structure usually persists even after 1–2 hours of integration. This spectral baseline structure makes observations of wide lines, like those from high redshift CO, extremely difficult. If the source velocity is well known the two orthogonal polarizations may be used to help distinguish true cosmic signals from instrumental effects.

Investigations in summer 2006 have indicated that the problem arises from the first stage amplifiers and is somehow coupled with other components within the dewar. Our investigations will continue but the performance may not improve over the 2006/2007 observing season. In general the spectral baseline performance at Ka-Band is worse than the performance at Q-Band. Loose waveguide joints were found and corrected between the feed and the OMT in the Ka-Band receiver that exacerbated these baseline effects. Moreover, the ability of fast switching with the Ka-Band receiver may help mitigate these spectral baseline problems. Tests in the near future will determine if there is significant improvement in the receiver performance as a result of recent work. Until then the advertised performance of the Ka-Band receiver stands as it did at the end of winter 2006. In summary, RMS noise levels may be as bad as seven times that of theoretical with intermittent baseline structure of order 10 MHz.

The baseline performance of Q-Band is similar to that of Ka-Band. A noticeable difference is that two of the Q-Band channels have at times much better baseline performance than the others. But, even the good channels can be unstable at times. After one hour of integration with a 50 MHz bandwidth, the "typical" baseline structure produces an RMS that is twice theoretical. In an 800 MHz bandwidth, the RMS is four times theoretical. As with Ka-Band, the noise will reduce as one integrates but the noise will always be a few times higher than theoretical.

In addition to baseline instabilities, as described in past *Newsletter* articles, the effective frequency coverage of the Q-Band system was much narrower than desired. For some of the receiver channels, system temperatures were unusably high at frequencies below 42 GHz or above 46 GHz. Good progress has been made on the solution to this problem, and when the receiver is restored to service we expect to provide good performance from 40 GHz to at least 49 GHz. Since the upgrade will not be completed until late September 2006, at this time we cannot provide details on the expected system temperatures. It is likely however that the baseline instabilities will remain at a similar level to now.

We are on schedule to reinstall both of these receivers on the telescope in October/November, with commissioning to follow in November/December. As we continue our engineering and commissioning work, updates on performance will be made available at: *http://wiki.gb.nrao.edu/bin/view/Projects/SpectralBaselines.*

D. S. Balser, R. J. Maddalena, L. Morgan, and R. D. Norrod

Socorro

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
CnB	29 Sep 2006	16 Oct 2006	1 Jun 2006
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	*	1 Feb 2007

Note: For the next configuration cycle 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

The NRAO Proposal Submission Tool, which is accessed through portal *http://e2e.nrao.edu/userdb/*, is required for all VLA proposal submissions. 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 degrees declination. Some types of VLA observations are significantly more difficult in daytime than at night. These include observations at 90 cm (solar and other interference; disturbed ionosphere, especially at dawn), deep 20 cm observations (solar interference), line observations at 18 and 21 cm (solar interference), polarization measurements at L-Band (uncertainty in ionospheric rotation measure), and observations at 2 cm and shorter wavelengths in B and A configurations (trophospheric phase variations, especially in summer). At the beginning of the A configuration in 2007, daytime will involve an RA of 04^h. Current and past VLA schedules may be found at *http://www.vla.nrao.edu/astro/prop/schedules/old/*. EVLA construction will continue to impact VLA observers; please see the web page at *http://www.aoc.nrao.edu/evla/archive/transition/impact.html*.

VLBA 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. Fax submissions will not be accepted. 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 10-element VLBA must justify, quantitatively, the benefits of the additional antennas. Any proposal requesting a non-VLBA antenna is ineligible for dynamic scheduling, and fixed date scheduling of the VLBA currently amounts to only about one third of observing time. Adverse weather increases the scheduling prospects for dynamics requesting frequencies below about 10 GHz.

See *http://www.vlba.nrao.edu/astro/schedules/* for a list of dynamic programs which are currently in the queue or were recently observed. VLBA proposals requesting the GBT, the VLA, and/or Arecibo need to be sent only to the NRAO. Note also the possibility to propose for the High Sensitivity Array (see the article on page 26 in this *Newsletter*). Any proposal requesting the NRAO antennas and antennas from two or more institutions affiliated with the European VLBI Network (EVN) is a Global proposal, and must reach **both** the EVN scheduler and the NRAO on or before the proposal deadline. VLBA proposals requesting only one EVN antenna, or requesting unaffiliated antennas, are handled on a bilateral basis; the proposal should be sent both to the NRAO and to the operating institution of the other antenna requested. Coordination of observations with non-NRAO antennas, other than members of the EVN and the DSN, is the responsibility of the proposer.

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

VLBI Global Network Call for Proposals

Proposals for VLBI Global Network observing are handled by the NRAO. There are three Global Network sessions per year, with up to three weeks allowed per session. Plans for Global Network 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 European VLBI Network (EVN) is a Global proposal, and must reach **both** the EVN scheduler and the NRAO on or before the proposal deadline. Fax submissions of Global proposals will not be accepted. A few EVN-only observations may be processed by the Socorro correlator if they require features of the EVN correlator at JIVE which are not yet implemented. Other proposals (not in EVN sessions) that request the use of the Socorro correlator must be sent to NRAO, even if they do not request the use of NRAO antennas. Similarly, proposals that request the use of the EVN correlator at JIVE must be sent to the EVN, even if they do not request the use of any EVN antennas. All requests for use of the Bonn correlator must be sent to the MPIfR.

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

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

No Pie Town Link in Next VLA A Configuration

The VLA-Pie Town link has been used for over 1000 hours of observing in the last four A configurations, and has increased the potential VLA resolution by a factor of two during that period. For several years, we have discussed with our user community the possibility that we would need to stop offering access to the link if the resources used to support this operational capability were critical for EVLA development. During the A configuration in 2007, we will be at a critical stage in decommissioning the old VLA control computers, preparing for the arrival of the prototype EVLA WIDAR correlator, performing detailed testing of the user interface for the CASA post-processing software, and completing a transition to routine EVLA antenna commissioning at the rate of one antenna every two months. For these reasons, we have made the difficult decision that we will be unable to support the Pie Town link in the A configuration during 2007.

Therefore, proposals requesting the Pie Town link will not be accepted at the February 2007 proposal deadline, and no Pie Town link observations will be scheduled during 2007. After the EVLA becomes operational, we hope to be able to digitize the Pie Town link and offer it again with bandwidths of up to 1 GHz, as permitted by the VLBA intermediate frequency system at Pie Town.

Jim S. Ulvestad

High Sensitivity VLBI Array and Phased VLA

Past proposals to the High Sensitivity VLBI Array (HSA) were limited to an aggregate bit rate of 256 Mbps. Starting with the June 1, 2006 deadline, HSA proposers were permitted to request 512 Mbps for the VLBA, GBT, Effelsberg, and Arecibo. The phased VLA is limited to 256 Mbps by the bandwidth of its two phased IFs. However, the VLA may still be used at 256 Mbps along with the other HSA telescopes operating at 512 Mbps.

The installation of a Mark 5 recording system at the VLA, and populating of the VLBA correlator with 14 Mark 5 playback systems, are both scheduled for September 2006. From that time forward, observations with the HSA will make use only of the Mark 5 disk recording system, providing higher data reliability than was available with mixed disk and tape recording in the array.

Before the end of the 2006 calendar year, we expect that retrofitted EVLA antennas that have been turned over to VLA Operations (see article elsewhere in this *Newsletter*) will be phased with the VLA antennas, and included in the VLA phased-array output. This will mean that the phased VLA typically will include 25 or 26 antennas, versus the minimum number of 20 or 21 in August/September 2006. Potential proposers should note that the retrofitted EVLA antennas will not have 15 GHz receivers for several years, so the phased VLA will see a steady decrease from 21 antennas at 15 GHz to near zero antennas over the next several years.

Jim S. Ulvestad

Education and Public Outreach

The XXVIth IAU General Assembly

More than 2,500 astronomers from around the world participated in the XXVIth General Assembly of the International Astronomical Union (IAU) held in Prague, Czech Republic, August 14–25, 2006. Prague is a city with a rich astronomical history going back to the 14th century, when the oldest central European university was established there, and it is one of the few cities to have hosted the IAU General Assembly twice.

Anyone reading the print and on-line news stories from this IAU might have reasonably concluded that the General Assembly was devoted solely to the definition of a planet and the status of Pluto. An enormous variety of science was presented and discussed, however, with multiple contributions by NRAO scientists. Jim Braatz gave a talk in one of the two IAU Hot Topics sessions: *Precision Cosmology using H_2O Megamasers*. Scott Ransom participated in a Joint Discussion on Pulsar Emission and Related Phenomena with a presentation about *A Decade of Surprises from the Anomalous X-ray Pulsars*; and contributed to a session on Neutron Stars and Black Holes in Star Clusters with a paper on *GBT Observations of Radio Pulsars in Clusters*. Tim Bastian spoke on *Low-Frequency Radiophysics of the Sun and the Heliosphere* in Joint Discussion 12, *Long Wavelength Astrophysics*. Ed Fomalont gave two invited talks. He spoke about *Synergy Between Radioastronomy and Astrometry* for Commission 08 (Astrometry), and gave a joint paper with S. Kopeikin (U.Missouri-Columbia) for Commission 31 (Time) on *Jovian and Solar Radio Deflection Experiments*. Ken Kellerman co-authored a paper with Ellen Bouton, *The Beginnings of the U.S. National Radio Astronomy Observatory* for a Division XII session on Historic Radio Astronomy. *Studying the First Galaxies at Centimeter and Millimeter Wavelengths* was contributed by Chris Carilli to Joint Discussion 7, *The Universe at z > 6*.

Jean Turner (UCLA) spoke about ALMA to a standing-room-only audience on the morning of August 16 as part of an IAU Special Session on *Astronomical Facilities of the Next Decade*. On August 24 a special meeting, *The ALMA Era for Astrophysics Begins*, was held from 9:00 until 12:30 for another standing-room-only group. This meeting included ALMA construction project updates from M. Tarenghi (JAO), A. Beasley (JAO), and R. Kawabe (NAOJ); and science talks by A. Wootten (NRAO), T. Wilson (ESO), and S. Sakamoto (NAOJ).

Scientific and EPO personnel staffed NRAO and ALMA exhibits, and represented the Observatory throughout the General Assembly. I also organized a productive half-day kick-off meeting of an ALMA EPO Working Group that included participants from ESO, NAOJ, AUI, NRAO, and JAO.

The NRAO "Magic Cubes" that EPO designed and distributed to interested attendees as a keepsake proved to be enormously popular. Every one of the 2,000 cubes that we brought to Prague was rapidly swept up, and we were gratified to hear that most attendees intended to pass their cube or cubes along to young people. Several attendees told us their cubes would be used as science fair prizes for middle and elementary grades. Since the IAU, we have received additional requests from educators for these cubes. The Fornax A poster of Juan Uson et al, the Virgo Cluster poster of A. Chung et al, and the latest NRAO *Newsletter* were also quite popular.

Dave Finley demonstrates the NRAO "Magic Cube" at our IAU General Assembly exhibit. The cubes were a hit, especially with educators.

Mark T. Adams

Summer Educational Programs in Green Bank

School's out for summer? Not at NRAO – Green Bank! In summer 2006 we conducted ten major programs for college professors, K-12 teachers, students, and amateur astronomers. But school for us doesn't mean term papers and boring lectures. In all of our summer programs, we model John Dewey's maxim—"Learn by Doing"—and engage our participants in observing with the 40 Foot Telescope.

Our summer season began over Memorial Day weekend with the 19th annual Chautauqua Short Course series for college professors. In Green Bank, we hold two 3-day courses back to back, the first on

CLEA participants with 40 Foot Telescope data.

radio astronomy led by NRAO staff, and the second on teaching introductory astronomy led by Gareth Wyn-Williams (University of Hawaii).

This year, we also hosted college professors taking the biennial Contemporary Laboratory Exercises in Astronomy (CLEA) workshop. The CLEA project is led by Larry Marschall at Gettysburg College. The workshop introduces participants to research techniques in astronomy; the capstone is a two-day visit to NRAO-Green Bank.

Three programs comprise our summer suite for K-12 teachers.

- *The Astronomy Institute*, our longest running program, has been held yearly since 1987. Over 1,000 teachers have participated in the Institute and have in turn impacted their students in the classroom. In its current guise, the Institute is funded by the NASA Goddard Space Flight Center and is one week long. This year eighteen teachers from five states in the eastern U.S. conducted research using the 40 Foot Telescope, attended an astronomy mini-course led by Tom Troland (University of Kentucky), and developed classroom projects to try back at home.
- *Research Experiences for Teachers (RET)* is a program patterned after the Research Experiences for Undergraduates (REU) program, only . . . for teachers. This year three teachers (from Louisiana, Massachusetts, and Kansas) worked with Green Bank astronomers for eight weeks on topics ranging from Green Bank Telescope (GBT) calibration data, to astrochemistry, to the study of low surface brightness galaxies.
- *The Quiet Skies Workshop* was a new summer program in 2006. In an effort to introduce students to radio astronomy around the country, Ron Maddalena and I co-wrote a grant to the NASA IDEAS program to develop an inexpensive (under $500) instrument to detect RFI in the frequency range of 800 – 1700 MHz. These "Quiet Skies Detectors" will be loaned to schools. Data collected by students will ultimately result in a radio version of the "Earth at Night" image depicting light pollution. Culminating two years of development work, this summer we held our first workshop to introduce teachers to the detectors and the associated curriculum. For more information about the Quiet Skies Project, visit our website at *http://www.gb.nrao.edu/epo/ideas/*.

Again this year, the Observatory hosted the West Virginia Governor's School for Math and Science (GSMS) for bright West Virginia students just entering their freshman year in high school. These students complete a rigorous application process similar to the REU application. Of the approximately 400 students who apply, 60 are selected for the Green Bank camp. In residence for two weeks, these students are immersed in the research center environment that is NRAO. The 2006 program was very successful once again thanks to the efforts of many at the NRAO, dedicated teachers, and our partnership with the National Youth Science Foundation. You can find a detailed description of this program in the October 2005 edition of this *Newsletter*.

The fourth annual GEAR UP Camp followed immediately on the heels of the GSMS. This four-day camp is for local 9th grade students in the GEAR UP program, a federally-funded program to assist low-income students in becoming ready to attend college and to succeed in college once they get there. GEAR UP Camp students participate in 40 Foot Telescope

GSMS students at GBT controls.

The quest continues as amateur astronomers attend Star Quest III.

research, soldering activities, as well as team building exercises led by Marshall University staff.

Now in its 15th year, the *Educational Research in Radio Astronomy (ERIRA)* program offers a great one-week camp for high school and undergraduate students. The NRAO provides this program with space and access to the 40 Foot Telescope. Thanks to the careful work of the students who have participated in ERIRA over the years, 40 Foot Telescope data have made it all the way to the *Astrophysical Journal* in an article on the fading of Cassiopeia A (Volume 537, Issue 2, pp. 904 - 908)! ERIRA is organized and supervised by Dan Reichart of University of North Carolina– Chapel Hill. Enrollment is open, so if you know a student who might be interested, send them to the ERIRA web site: *http://www.physics.unc.edu/~reichart/erira.html.*

Amateur astronomers of both the optical and radio persuasions are not left out during our summer program series. This was our third year hosting the Green Bank Star Quest star party, which is unique in that the program is a 50– 50 mix of optical and radio astronomy. About 160 people participated this year.

And finally, the Society of Amateur Radio Astronomers celebrated the 25th year of their annual conference in Green Bank by announcing a welcome collaboration with the NRAO. Together, we are

Major Summer Educational Programs at NRAO– Green Bank

Audience	Summer Program	Duration	Funded By	Number Served 2006
College Professors	• Chautauqua Short Courses	3 days	NSF, colleges	34
	• CLEA	2 days	NSF	25
K-12 Teachers	• Astronomy Institute	6 days	NASA	18
	• Quiet Skys Workshop	4 days	NASA IDEAS	10
	• RET Program	8 weeks	NSF	3
Student Camps	• GEAR UP Camp	4 days	U.S. Dept. of Edu.	22
	• GSMS	2 weeks	WV EPSCoR	55
	• ERIRA	6 days	Fees	15
Amateur Astonomer	• Star Quest Star Party	4 days	Fees	160
	• SARA Conference	3 days	Free	64

NRAO Navigator David Fields with group in Oak Ridge, Tennessee.

launching a pilot program called NRAO Navigators that will employ volunteers to deliver radio astronomy programs at informal venues across the United States. This program is modeled on the successful NASA Ambassadors program, but with one difference: our volunteers are equipped with working model radio telescopes, thanks to the hard work of SARA member Kerry Smith. We hope to make the NRAO Navigator program a big success in coming years.

Sue Ann Heatherly

Radio Astronomy for Teachers

Six teachers spent the last two weeks of July exploring observational radio astronomy through a class offered in the New Mexico Tech Master of Science Teaching program. Dr. Lisa Young, New Mexico Tech Physics professor and Robyn Harrison, Socorro Education Officer, facilitated the class, which included an in-depth tour of the Very Large Array, lectures and hands-on activities, as well as observations using the Small Radio Telescope and the NMT/NRAO Instructional Interferometer.

Lisa Young and Barry Clark lead the Radio Astronomy class for teachers on a tour of a VLA antenna.

The teachers represented grade levels from second grade through high school, and content areas from conceptual physics to mathematics to biology. Their task was to design an observation using at least one of the instruments, perform the observation, make sense of the data, and present their findings to the class. The frustration of cantankerous instruments and data reduction was broken by our NRAO guest speakers who lectured on Ruby Payne-Scott, star formation, planetary radio astronomy, image making, and black holes and AGNs.

The teachers' presentations can be seen on the web at: *http://www.aoc.nrao.edu/epo/teachers/RAFT/.*

Robyn Harrison

In General

GBT Student Support Program: Announcements of Awards

Two awards were made in August 2006 as part of the GBT Student Support Program. The program is designed to support GBT research by graduate or undergraduate students at U.S. universities or colleges, thereby strengthening the proactive role of the Observatory in training new generations of telescope users.

The August 2006 awards were in conjunction with approved observing proposals submitted at the June 2006 deadline. Awards were made to the following students:

- J. Foster (Harvard-CfA) and J. Pineda (Harvard-CfA) in the amount of $35,000 for the proposal entitled: *A COMPLETE Census of Dense Cores in Perseus*.
- A. Kepley (University of Wisconsin) in the amount of $3,000 for the proposal: *Magnetic Fields in Irregular Galaxies.*

New applications to the program may be submitted along with new GBT observing proposals at any proposal deadline. For full details on this program and a cumulative record of past rewards, select the GBT Student Program from the GBT Astronomers page at the Green Bank home page or access the program description directly at *http://wiki.gb.nrao.edu/bin/view/Observing/GbtStudentSupportStatus*.

R. C. Bignell, D. A. Frail, R. M. Prestage (NRAO), K. E. Johnson (University of Virginia), and D. J. Nice (Bryn Mawr)

The NRAO Student Support Program

To promote the training of new generations of astronomers, NRAO has initiated a program to support research by students. This is an expansion of the successful GBT student support program begun in 2002. Regular VLBA and GBT proposals are now eligible for funding, while regular VLA proposals are not. Large proposals for the VLA, VLBA, GBT and any combination of these telescopes are eligible. In the 12 months starting in October 2006, it is anticipated that there will be a total of $330,000 available to assist students who are enrolled at U.S. universities and colleges. The funding cap for student stipends (undergraduate and/or graduate) is $32,000 with an additional amount of up to $3,000 for miscellaneous expenses (computer hardware for student use and/or student travel to domestic meetings to present acquired data). Funding proposals will be accepted from principal investigators or co-investigators who are employed at U.S. institutions. Details about the application and evaluation process are posted on the Division of Science and Academic Affairs web page (*http://www.nrao.edu/administration/dsaa/*).

Dale A. Frail

Opportunities for Undergraduate Students, Graduating Seniors, and Graduate Students

Applications are now being accepted for the 2007 NRAO Summer Student Research Assistantships. Summer students conduct research under the supervision of an NRAO staff member at one of the NRAO sites on projects which 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*.

Summer students are chosen by each individual supervisor from all applications received, and the student will usually be located at the same NRAO site as the supervisor. Students are encouraged to review the web pages 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, to work on a specific scientific topic, and to work at a specific site.

The program runs 10-12 weeks 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. The summer projects often result in publications in scientific journals. Financial support is available for students to present their summer research at a meeting of the American Astronomical Society, generally at the winter meeting following their appointment.

Besides their research, students take part in other activities, including a number of social events and excursions, as well as an extensive summer lecture series which covers 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 positions 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. This 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.

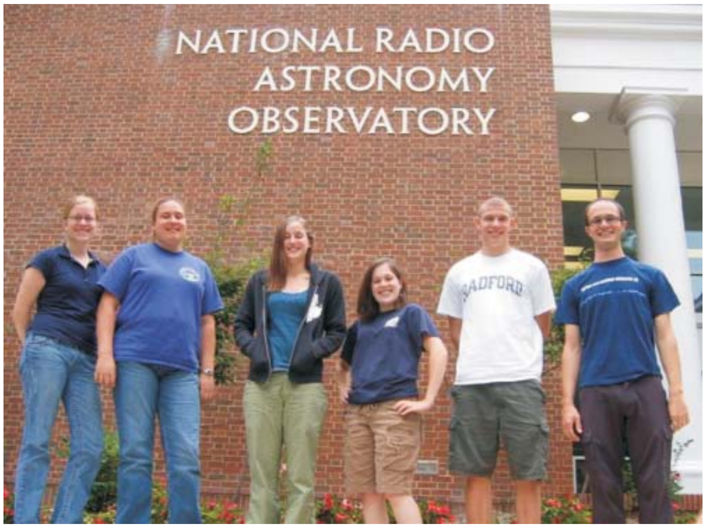
The stipends for the 2006 Summer Student Program were $475 per week for undergraduates, and $510 per week for graduating seniors and graduate students. The 2007 salary amounts are currently under review. Students who are interested in Astronomy and have a background in Astronomy, Physics, Engineering, 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 22, 2007.

Dale A. Frail

2006 NRAO Summer Student Research Program

Another NRAO Summer Student program has come and gone. The 2006 class consisted of 23 students: 14 undergraduate students supported by the National Science Foundation's *Research Experience for Undergraduates (REU)* program; and 9 graduating seniors or graduate students supported by the NRAO *Graduate or Undergraduate Summer Student* program. Ten students traveled to Socorro, six to Charlottesville, and seven to Green Bank.

The students spent 10-12 weeks this past summer working with an NRAO mentor on a project in the mentor's area of expertise. At each site students



Charlottesville Summer Students. Left to right: Claire Davy, Lucy Frey, Jennifer Katz, Nicole Gugliucci, Robert (Lecky) Stone, and Destry Saul. Not shown: Alok Singhal.

Green Bank Summer Students. From left to right: Emily Martin, Kushal Mehtaa, Kristen Thomas, A. J. Heroux, and T. J. Weadon. Not pictured is Manasseh Obi.

attended a summer lecture series, participated in informal lunch discussions with staff on various aspects of careers in astronomy, and went on field trips to other observatories. Students also conducted their own observing projects, with Socorro students observing with the VLA and VLBA, and Green Bank and Charlottesville students observing with the GBT.

The accompanying table lists the names and home institutions of all 2005 summer students, together with their NRAO mentor, site, and project title. More detailed descriptions of the student projects are available at *http://www.nrao.edu/students/archive/projects.php*. Applications for next year's Summer Student program will be accepted starting in October 2006. Details on these and all NRAO student programs are available at *http://www.nrao.edu/students/*.

Dale A. Frail

Socorro Summer School Students. Back row from left: Timothy Weinzirl, Laura Zschaechner, Wendy Bennett, Catherine Whiting, Malynda Chizek, Robert Edmonds, Kyle Willett. Seated (from left) Elisabeth Mills, David Sevilla, and Adam Ginsburg.

2006 NRAO Summer Students/Mentors

Student	School	Mentors	Site	Project	Program
Wendy Bennett	Drake University	Craig Walker	SOC	*Free-Free Absorption of the Counterjet in NGC1275*	NRAO uGRP
Malynda Chizek	University of Iowa	Bryan Butler	SOC	*Radar Reflectivity of the Martian Surface*	NRAO REU
Abhirup Datta	New Mexico Tech	Sanjay Bhatnagar	SOC	*Simulation of Non-Isoplanatic Ionospheric Effects*	NRAO GRP
Claire Davy	Bryn Mawr College	Jeff Mangum	CV	*The Structure and Evolution of a Class O Protostar*	NRAO REU
Robert Edmonds	University of New Mexico	Lorant Sjouwerman	SOC	*Galactic Center SiO Maser Monitoring With the VLA*	NRAO REU
Lucille Frey	Case Western Reserve University	Scott Ransom	CV	*GBT Observations of Exotic Pulsars*	NRAO REU
Adam Ginsburg	Rice University	Dave Meier	SOC	*The Youngest Super-Star Clusters in Nearby Galaxies*	NRAO REU
Nicole Gugliucci	University of Virginia	Rich Bradley	CV	*A Wide-Field Imaging Instrument at 150 MHz*	NRAO GRP
Aaron Heroux	University of Wisconsin, Whitewater	Jay Lockman	GB	*The Continuing Formation of the Milky Way*	NRAO REU
Jennifer Katz	Columbia University	Scott Ransom	CV	*GBT Observations of Exotic Pulsars*	NRAO GRP
Rosa Martha Torres López	UNAM	Amy Mioduszewski	SOC	*Parallaxs and Proper Motions of Young Stars*	NRAO GRP
Emily Martin	Wheaton College (MA)	Dana Balser	GB	*Isotopic Abundances in Planetary Nebulae*	NRAO REU
Kushal Mehta	University of Maryland, Baltimore Co.	Karen O'Neil	GB	*HST Study of the Massive Galaxy UGC 6614*	NRAO REU
Elisabeth Mills	Indiana University	James Aguirre	SOC	*Searching for Protostars in the Galaxy*	NRAO REU
Manasseh Obi	Idaho State University	John Ford	GB	*ALMA Front-End Bias Module Noise Analysis and Measurement*	NRAO uGRP
Destry Saul	University of California Berkeley	Jim Braatz	CV	*Radio Properties of Nearby Active Galaxies*	NRAO REU
Alok Singhal	University of Virginia	Rick Fisher	CV	*Modelling HI in Galaxies*	NRAO GRP
Robert Stone	Radford University	Al Wootten	CV	*Simulation of ALMA Observations: From Distant Galaxies to Proto-stellar and Protoplanetary Disks*	NRAO REU
Kristen Thomas	Mount Union College	Larry Morgan	GB	*Molecules in Star-Forming Regions*	NRAO uGRP
Timothy Weadon	West Virginia University	Art Symmes	GB	*Refinement of the GBT Structural Model*	NRAO REU
Timothy Weinzirl	Drake University	Wes Young	SOC	*Applications for the Exploration & Visualization of Interferometer Data*	NRAO uGRP
Catherine Whiting	University of Iowa	Amy Mioduszewski & Michael Rupen	SOC	*VLA Imaging of Cygnus X-3*	NRAO REU
Laura Zschaechner	The University of Montana	Vincent Fish	SOC	*OH Masers as Tracers of Conditions in Supernova Remnants*	NRAO REU

Synthesis Imaging Workshop

There were 170 attendees this June 13-20, 2006, at the largest of the Summer Synthesis Imaging Workshops. For the first time, Workshop lectures took place outside Socorro, hosted by the University of New Mexico (UNM) in Albuquerque. The Workshop provided transportation to Socorro for data tutorials at the NRAO Array Operations Center, and to the Very Large Array for a tour followed by a pool party at New Mexico Tech. Students stayed in the UNM dormitory, and attended lectures in the old Student Union Building (now housing anthropology) built in 1937, which still has the original flagstone and wooden carved beams.

Citizens of foreign countries made up 59 percent of the attendees (although only 49 percent reside outside the U.S.). There were significantly fewer women among the students this year—33 percent down from 40 percent in 2004, with the percentage only slightly higher among U.S. students. This is in contrast to current student membership of the American Astronomical Society which is 60 percent female (Kevin Marvel, Women in Astronomy II). 2006 is the first year that we have gathered information on U.S. minorities. U.S. minorities attending the Workshop included five of Asian descent (8 percent) and a single Hispanic student (2 percent).

Attendees were primarily graduate students (66 percent), followed by undergraduates (11 percent, half of which were summer students at the NRAO), engineers/ programmers/ operators (10 percent), postdocs (8 percent), and various faculty/ astronomers (4 percent). Thirty-six percent of the attendees had taken a course in Radio Astronomy, indicating that the university radio astronomy course is still alive and well.

This Workshop's new instrument talks highlighted ALMA, EVLA, the Long Wavelength Array, and the Magdalena Ridge Observatory. New this year were short science lectures, given by Cornelia Lang and Jim Ulvestad, designed to break up the long afternoon and motivate the more technical lectures. These were very popular with the students. Lecturers came from the NRAO, UNM, USNO, Harvard-Smithsonian CfA, University of Iowa, and New Mexico Tech. The Naval Research Lab sent several lecturers as well as tutors for the data tutorial.

We would like to thank the University of New Mexico, including the Department of Physics and Astronomy, the College of Arts and Sciences, and the Vice President's Office for Research and Economic Development for their support. We are deeply grateful to NRAO who provided financial support as well as furnishing the majority of the speakers and hosting the data tutorial and the VLA tour. We also acknowledge support from AUI, New Mexico Tech, and CONACyT.

More information including photos, audio, PowerPoint and PDF files of the lectures can be found at *http://www.phys.unm.edu/~kdyer/2006/* and the NRAO mirror at *http://www.aoc.nrao.edu/~kdyer/2006/*.

Kristy Dyer, on behalf of the
2006 Synthesis Imaging Workshop LOC

Workshop participants.

New Radio Astronomy Faculty in Universities

Starting in the fall term of 2006, there are seven new faculty members who specialize in radio astronomy in universities around the country. They are: Maura McLaughlin and Duncan Lorimer at West Virginia University, Geoff Bower at the University of California– Berkeley, Jeremy Darling at the University of Colorado– Boulder, Snezana Stanimirovic at the University of Wisconsin– Madison, Andrew Baker at Rutgers University, and Tony Wong at the University of Illinois.

Fred K. Y. Lo

The NRAO 50th Anniversary Announcement

It is my pleasure to announce the NRAO's 50th Anniversary Symposium has been rescheduled for June 17– 21, 2007, to commemorate the ground breaking at Green Bank in 1957. The symposium is entitled *Radio Astronomy at the Frontiers of Astrophysics: A Celebration of NRAO's 50th Anniversary.* It will be held at the Omni Charlottesville Hotel and we anticipate 250 registrants. Besides celebrating 50 years of contributions to astronomy and proud achievements by the NRAO, the symposium will focus on how radio astronomy can help answer the outstanding questions in astrophysics and astronomy in the future. Both the Scientific Organizing Committee and Local Organizing Committee are currently being formed, so please watch for additional announcements.

Fred K. Y. Lo

New NRAO *Newsletter* Science Editor

Tim Bastian

We are pleased to announce that, effective this issue, Tim Bastian is the new science editor for the NRAO *Newsletter*. If you have an interesting new research result obtained with an NRAO telescope that could be featured in this *Newsletter*, please contact Tim at *tbastian@nrao.edu*. As always, we particularly encourage Ph.D. students to describe their thesis work.

Tim's research interests include the physics of solar flares and the structure of the solar corona, and he is leading the effort to fund and construct the Frequency-Agile Solar Radiotelescope (FASR), a ground-based synthesis imaging radio telescope designed specifically for observing the Sun.

We also want to extend a sincere "thank you" to Jim Condon for almost three years of community and Observatory service as the NRAO *Newsletter* science editor. Jim did an outstanding job of finding and editing compelling science news for the *Newsletter*, and he invariably met the *Newsletter* production deadlines.

Mark T. Adams

The NRAO Library has published the NRAO publication statistics! Go to: *http://www.nrao.edu/ library/* and click on "Publication Statistics" for the full listing of NRAO instrument and author papers.

Marsha J. Bishop

Further Information

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

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(520) 882-8250

NRAO Results

For more information on recent scientific research with NRAO telescopes:

NRAO Press Releases: *http://www.nrao.edu/pr*
NRAO Preprints: *http://www.nrao.edu/library/listings/nrao_current.shtml*
VLA Observation Highlights: *http://www.vla.nrao.edu/genpub/current_obs/*

NRAO Products

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/*
The NRAO Data Archive System can be accessed and queried via the web: *http://e2e.nrao.edu/archive/*
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*.

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