National Radio Astronomy Observatory

Newsletter

April 2006

Issue 107

The Huygens Doppler Wind Experiment: First Results from Observations at the Green Bank and Parkes Telescopes

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

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This image of the cluster of galaxies known as Abell 194 shows two radio galaxies shooting out huge, powerful jets of material from the regions surrounding the black holes at the galaxies' centers. These jets are visible in the radio data from the VLA telescope, shown in purple, overlaid on the color image of the cluster from the Lick Observatory 120-inch telescope.

Investigator(s): Wil van Breugel et al.

Fred K. Y. Lo, Director

The challenges of long-term planning have been amply illustrated by recent developments. Concerns represented by the National Academy of Sciences report, *"Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,"* appear to have caught the attention of Federal policy makers, so that funding prospects for research in physical sciences may brighten. In his January State of the Union Address, President Bush announced the American Competitiveness Initiative (ACI) that would increase Federal investment in the physical sciences, including doubling the NSF budget over the next ten years. On January 25, several high-ranking Senators also introduced new legislation—Protecting America's Competitive Edge (PACE)—that authorizes ten percent annual increases for the NSF and NASA budgets through 2013. The President's FY07 budget request did contain an overall 7.9 percent increase for the NSF and a 7.7 percent increase for the NSF-AST Division.

Given the depressing weight of the NSF/AST Senior Review process on the astronomy community in the past year, based on the assumption that the AST budget will grow no faster than inflationary increases for the remainder of the decade, these developments are clearly welcome. This "glimmer of hope," that the future may not appear as bleak as assumed less than a year ago, is a real boost to our morale and outlook. I sincerely hope this glimmer will develop into a bright glare!

Returning to science, I would like to mention a new program that is using the GBT and the VLBA to determine the Hubble Constant to < 3 percent accuracy. It will make geometrical measurements of distances to circumnuclear water megamasers in galaxies that are up to 100 megaparsecs away and well within the Hubble flow. The famous Hubble Space Telescope Key Project on the Extragalactic Distance Scale was a great success, providing a Hubble Constant to ten percent accuracy (Freedman et al 2001, ApJ, 553, 47). While the standard cold dark matter (CDM) cosmology has excellent concordance with cosmic microwave background (CMB) and other data (e.g. Spergel et al., 2003, ApJS, 148, 175), the single most important complement to the CMB for probing the nature of Dark Energy and refining other cosmological parameters is the determination of the Hubble Constant to better than a few percent (Hu 2005, ASP Conf Ser, 339, 215). The GBT is the most sensitive instrument for discovering water masers in narrow-line active galaxies from the Sloan Digital Sky Survey and other surveys, and the current detection statistics indicate that it can find ten or more circumnuclear megamasers similar to those in NGC 4258 within two years. Megamaser accelerations measured by GBT spectroscopy and proper motions measured with exquisite accuracy by the VLBA can determine the Hubble constant to <3 percent. A key project to accomplish this goal in the next five to ten years has been initiated by scientists from the Harvard-Smithsonian Center for Astrophysics and the NRAO.

This Dark Energy project is but one example of how, in modern astronomical research, large-scale and long-term observations are needed to address the most important scientific questions. To identify new scientific opportunities and facilitate the use of all NRAO facilities for such projects, a Legacy Projects Workshop will be held on May 17, 2006 in Socorro (see page 31). All astronomers who might be interested in proposing such use of NRAO facilities are invited to attend. With guidance from our user community, we hope to proceed quickly from this workshop to proposal solicitation and assignment of significant telescope times to Key and Legacy Projects to optimize the science impact of NRAO facilities. The NRAO time-assignment policy is ultimately determined by the scientific demands of its users, and a proper balance between small and large programs will be maintained.

The North American ALMA Science Center (NAASC) in Charlottesville hosted its first workshop in mid-January titled *"From z-Machines to ALMA:*

(Sub)Millimeter Spectroscopy of Galaxies" that brought together more than 70 astronomers to discuss the exciting science of dusty high-redshift galaxies and how to optimally exploit ALMA's unique capabilities. Additional NAASC workshops are planned, and a special session at the June 2006 American Astronomical Society meeting in Calgary will discuss ALMA's potential for probing star formation in our galaxy, in other nearby galaxies, and at high-redshift.

During the past year, the ALMA project has been undergoing a major scope and cost review. This exercise culminated in an ALMA Cost Review by an international panel appointed by the ALMA Board in October 2005 in Garmisch, Germany. A second "Delta Cost Review" was convened in January 2006 in Washington D.C. to address the impact of having two antenna designs, and finally a Cost and Management Review was convened by the NSF in Charlottesville immediately following to review the North American part of ALMA. The outcomes of the reviews are generally positive: ALMA's technical readiness is very high despite it's immense complexity; the current management of the project appears to be working well; the cost increases are understandable consequences of initial under-costing, the complications of a large international collaboration, commodity price increases, remote and challenging site, and a booming economy in Chile. On March 2, NSF Director Arden Bement Jr. provided testimony before Congress on the agency's FY 2006 budget request and, in later questioning, identified ALMA as a transformational instrument. The NSF Director's Office will make its recommendation regarding future ALMA funding to the National Science Board in mid-May.

ALMA construction continues steadily, and images of the civil engineering work at the Chilean site are available on-line at *http://www.alma.nrao.edu/almanews/almagallery.html.* I encourage you to periodically check on our progress and share the excitement of watching ALMA come to life.

The next Decadal Review will begin in two to three years, and discussions have started in the community about the near and long-term future of meter- and centimeter-wavelength astronomy and the developments for the Square Kilometer Array (SKA). With the construction of ALMA and EVLA Phase I entering a more routine phase, NRAO is now able to be more engaged in discussing and working with the community on all these important issues. It is essential that the national facilities, the university groups, and others in the community work together in a coordinated and collaborative approach to prepare for the Decadal Review. To facilitate this dialog, an informal meeting involving a number of community representatives was organized jointly by NRAO and NAIC and took place on Saturday, February 11 near the Chicago O'Hare Airport. There were very fruitful discussions at the meeting and all agreed that more such meetings should be held. Within NRAO, an SKA Working Group is being organized to work with the community towards developments beyond ALMA.

Fred K. Y. Lo

Science

The Huygens Doppler Wind Experiment: First Results from Observations at the Green Bank and Parkes Telescopes

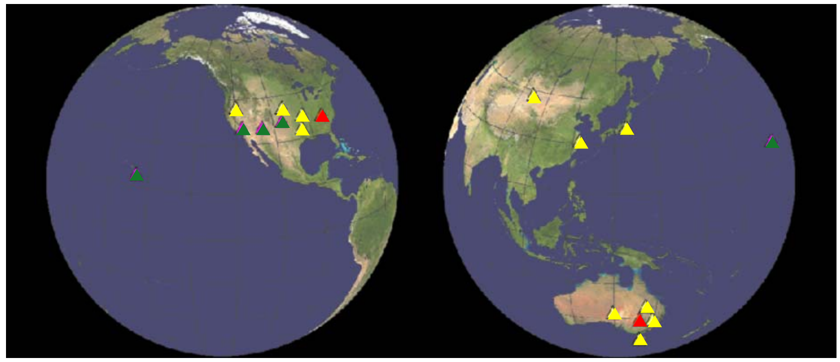

Figure 1. The Huygens Earth-based radio astronomy network (ref: supplementary information to Lebreton et al., Nature, 438, 758-764, 2005). All telescopes participated in VLBI observations. The Green Bank Telescope and the Australian Parkes Telescope (red) were the two principal stations participating in the Earth-based segment of the Huygens Doppler Wind Experiment. Four stations of the Very Long Baseline Array (VLBA), Pie Town, Kitt Peak, Owens Valley and Mauna Kea (green), also participated in the Earth-based DWE.

Tension was mounting at the European Space Operations Center (ESOC) in Darmstadt, Germany, where mission operators were waiting to hear if the ESA Huygens probe, following eight years of prelaunch preparations and a seven year piggyback cruise with the NASA Cassini orbiter, would survive its daredevil mission on Saturn's moon Titan. The entire Huygens science team and a host of multi-national reporters, space agency officials, and politicians had gathered on a cold but sunny Friday, January 14, 2005 to witness a new chapter in the history of space exploration.

It was known by all that Huygens would enter Titan's atmosphere at 09:06 UTC and immediately begin its dual-band telemetry broadcast of mankind's first *in situ* data from one of the most exotic objects in the solar system. That broadcast, coming from a 12 watt transmitter and broadbeam antenna, was designed for reception only by the Cassini orbiter, which was flying overhead at the relatively close distance of 60000 km. Using its high-gain antenna for reception of the Huygens signal, Cassini would not be able to turn around and start playing the probe data back to Earth until after the maximum foreseen duration of the Huygens mission on Titan. Even then, since the news would be delayed by another 67 minutes for the data to traverse the distance to Earth, the first bytes of data on the ground were not expected at the ESOC until 16:17 local time.

Meanwhile, on the other (night) side of the world, many telescopes observing at many different wavelengths were trained on Titan to provide Earth-based support during the Huygens mission. Noteworthy among these was the Huygens radio astronomy network, including the NRAO Robert C. Byrd Green Bank Telescope (GBT), the CSIRO Parkes Telescope in Australia, and eight antennas of the NRAO Very Long Baseline Array (VLBA), which were basically "eavesdropping" on the Huygens-to-Cassini radio signal from a distance of more than 1.2 billion kilometers. These radio telescopes were all equipped for receiving the unusual Huygens S-band transmissions (Channel A: 2040 MHz; Channel B: 2098 MHz), a band nominally allocated to deep space "uplink" communication.

Goal number one of the Earth-based radio observations was just to detect such a weak signal, thereby verifying the vitality of the Huygens probe after its atmospheric entry and nearly five hours prior to the projected arrival of its science data via the Cassini orbiter relay. Beyond this minimum achievement for success, the mere presence of a signal would allow an estimate of its frequency, thereby yielding valuable information about the probe motion during descent from the associated Doppler shift. The Earth-based Doppler detections were conducted as part of the Huygens Doppler Wind Experiment (DWE), a radio investigation to determine probe motion using primarily the frequency measurements on the radio link from Huygens to Cassini. The additional link to Earth, when combined with the Doppler data along the ray path to the orbiter, provided the opportunity to separate the two components of horizontal motion and, together with the vertical velocity measured on the probe, fully determine the three-dimensional probe descent trajectory.

The Earth-based Huygens radio astronomy network was also used to make precise position measurements of the probe on the sky (to within one kilometer at the distance to Titan) during the descent. This Very Long Baseline Interferometry (VLBI) experiment used the correlator facilities at the Joint Institute for VLBI in Europe (JIVE, Dwingeloo, the Netherlands) and a grand total of 17 radio telescopes (Figure 1), six of which were also enlisted for the DWE Earth-based measurements (Lebreton et al., Nature, 438, 758-764, 2005). Combining the Doppler and VLBI data will eventually provide a complete three-dimensional record of the Huygens trajectory during its mission at Titan.

One of us (S.W. Asmar), in charge of the Huygens radio detection efforts at GBT, monitored a specially integrated Radio Science Receiver (RSR) on loan for the experiment from NASA's Deep Space Network. It was a dramatic moment when the faint signal from Huygens was seen poking up out of the noise on the real-time RSR spectral display at 10:18 UTC, or 5:18 a.m. in Green Bank, West Virginia. Waiting for the spectrum on the screen to refresh three times, Asmar reached for the phone with a hotline to Darmstadt and announced the detection of the Huygens Channel A radio signal to the apprehensive multitude. A description of the activities associated with the Huygens radio detection at the GBT was published in an earlier NRAO Newsletter (No. 103, April 2005).

The glad tidings from Green Bank pretty well dominated the discussions in Darmstadt for the rest of the afternoon, which was characterized by smiles, optimistic interviews, and pats on the back. More encouraging news came later from the Parkes Telescope, where the real-time recordings clearly indicated that Huygens had landed and was continuing to transmit from Titan's surface. It was in this environment that the good mood took a sudden turn for the worst. It started with some rumors about a problem in the initial data segments coming back from Cassini. These had nothing to do with the telemetry from the Huygens probe, but rather with the settings of the Huygens receivers on the Cassini orbiter, prior to their actual reception of the Huygens signal.

Arriving at the ESOC main control room full of cautiously hopeful scientists monitoring the incoming data, one couldn't help notice the unexpectedly stern expressions on the faces of the DWE co-investigators. The cause of their uneasiness was one single bit in the data stream indicating the status of the DWE ultra-stable oscillator in the Channel A receiver. In contrast to all previous checkouts and tests, that bit was not the expected "1" (power on), but rather an incredible "0" (off). Even worse, the ultra-stable oscillator had been intentionally "selected". This had been enabled by a separate toggle switch to designate the DWE unit, rather than the powered internal oscillator, as the receiver's active local oscillator. Without power to its local oscillator, the receiver was incapable of locking onto the incoming signal from Huygens. All of the Channel A data, including the DWE Doppler measurements, about 350 images from the Descent Imager/ Spectral Radiometer (Huygens camera), and smaller pieces of data from other investigations, were lost. As later determined, the command to switch on the ultra-stable oscillator had been omitted from the critical command sequence for the probe relay event. Channel B, which functioned perfectly from beginning to end, saved the Huygens mission.

On the Huygens probe side, thankfully, the matching DWE ultra-stable oscillator designated to drive the Channel A radio link was not forgotten. It was selected and powered. Indeed, it performed flawlessly and provided the ultra-stable radio signal necessary for the Earth-based detections. To commemorate the unanticipated great success of the Earth-based radio detection, the Huygens-to-Earth link was later dubbed "Channel C".

The Earth-based measurements, the only useable DWE data, thus largely compensated for the loss of the primary data set from the Cassini orbiter. The complete set of Huygens Doppler shift measurements recorded at the GBT is shown in Figure 2.

The relation between the recorded data and the predicted Doppler curves (with and without wind) in Figure 2 implies that the "truth" lies somewhere between the two predictions. Indeed, a preliminary analysis of Earth-based telescope data has revealed that the wind on Titan blows preferentially from west to east, but not as strong in magnitude as predicted by the engineering

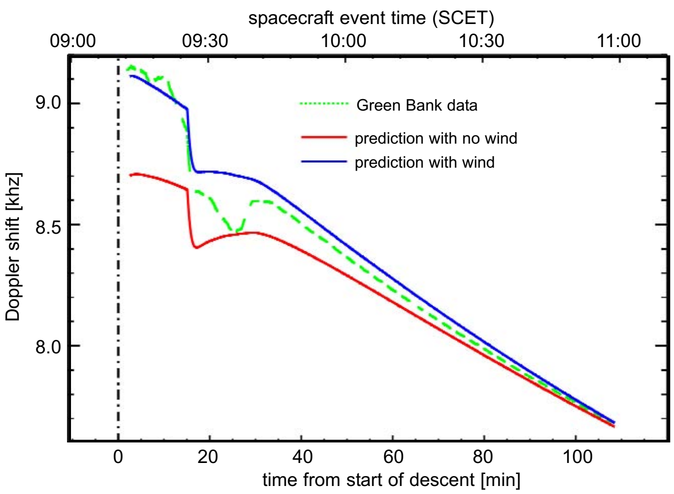

Figure 2. GBT frequency measurements from the start of the Huygens broadcast until the end of the track. The recorded data (green) generally lie between the predicted Doppler values from a pre-mission engineering model assuming no winds (red curve) and a model with a moderate prograde wind (blue curve). Each measurement is shown as a green dot (integration time: 10 s), and a series of measurements contains typically 10 points. The gaps between measurement segments are times when the telescope was pointed at a phase calibration source for the simultaneously conducted VLBI observations. The sudden drop in frequency 15 minutes after the start results from the exchange of the main parachute for a smaller stabilizer chute.

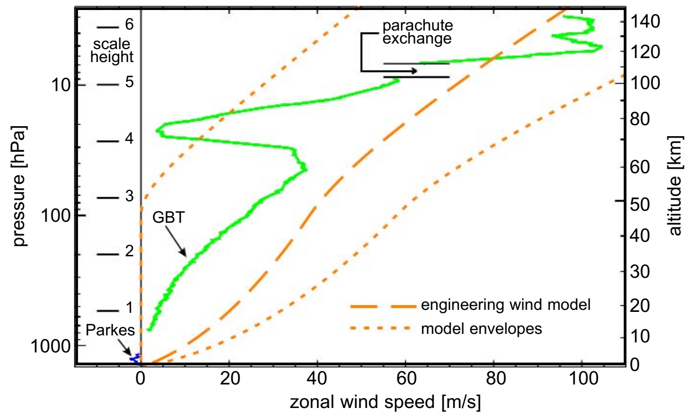

Figure 3: Zonal wind speed during the Huygens mission. The zonal wind profile derived from GBT and Parkes observations is compared with the Huygens engineering wind model and its envelopes. The winds at high altitude are strictly prograde (positive zonal wind) but also feature a significant reduction in the wind speed down to a minimum of 5 m/s at a height of 75 km. The 60-second interval where the parachutes were changed has not yet been fully analyzed. A monotonic decrease in the zonal wind speed is recorded from 60 km down to the end of the GBT track. The Parkes observations could not begin until 24 minutes later, thereby excluding wind determinations in the height region from roughly 14 down to 5 km. By this time Huygens was in a region of weak (1 m/s) retrograde winds. The data gap between GBT and Parkes may be closed later with additional Doppler measurements obtained by combining the recordings from the participating VLBA stations located in the intervening longitude range (Figure 1). The wind shear layer in the height range between 60 and beyond 100 km was unexpected and is presently unexplained.

model. This also provided first empirical proof of "superrotation" in the Titan atmosphere, i.e., atmospheric motion in the same direction as the moon's rotation (so-called "prograde" wind). Initial DWE results (Bird et al., Nature, 438, 800-802, 2005) were published together with first reports from the Huygens *in situ* investigations. Figure 3 shows the Titan vertical wind profile published in this preliminary report.

Highest wind speeds of 110 m/s (nearly 400 km per hour) and considerable wind speed fluctuations were measured right after the start of descent at altitudes of about 120–140 km. The wind was found to be quite weak (1 m/s) near Titan's surface, increasing gradually up to almost 40 m/s at an altitude of about 60 km. The big surprise was a layer with both positive and negative wind shear between 60 km and about 100 km, which featured a drastic dip in the wind speed down to only a few m/s at the minimum near 75 km height. The cause of this unexpected behavior is presently unknown.

In summary, the Huygens Doppler Wind Experiment may be considered a classic example of success being snatched from the brink of failure. In this sense, it has a lot in common with the Huygens mission itself. Both had prudently arranged for contingencies in the form of backup operations or measurement systems. Hopefully, such lessons will be duly heeded by future ventures in solar-system exploration.

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The Origin of Short Gamma-ray Bursts

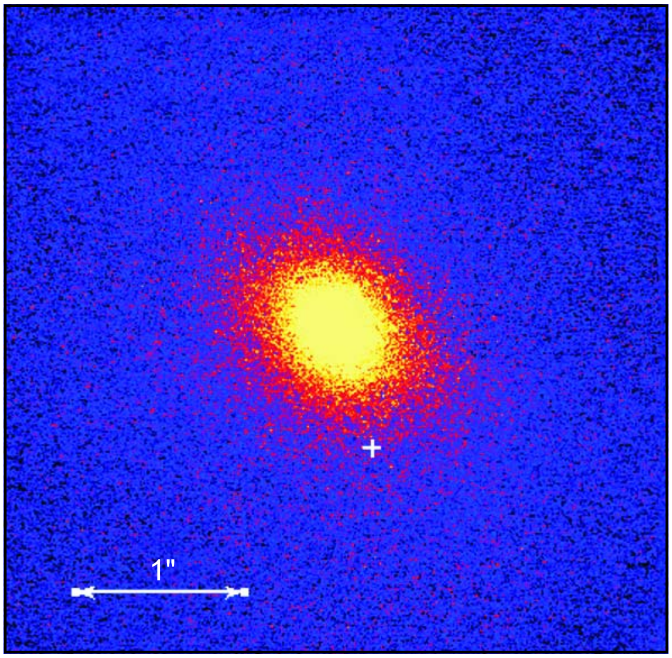

Figure 1. A Keck Laser Guide Star image of the host galaxy of the short-hard burst GRB 050724. The cross marks the location of the burst whose afterglow was initially localized to arcsecond accuracy by the VLA (Berger et al. 2005, Nature, 438, 988). The GRB appears to be located in a luminous red elliptical galaxy showing little evidence of ongoing star formation (less than 0.03 solar masses per year). These observations support the idea that short-hard bursts (unlike long-soft bursts) are associated with an older stellar population. [Image provided by B. Cameron and S. Kulkarni (Caltech) and used with their permission.]

Thanks to a multi-wavelength effort involving most of the largest telescopes in the world, the long-standing mystery of the origin of the short-duration gamma-ray bursts may be coming to an end. Gamma-ray bursts (GRBs) are of two distinct types, classified on the basis of their burst duration and spectral hardness. Long-soft bursts came under intense scrutiny after the launch of the Italian/Dutch satellite *Beppo*SAX. The defining moment occurred in 1997 when long-lived "afterglows" were discovered at X-ray, optical, and radio wavelengths. The flurry of research that followed this discovery has given us a reasonably clear (but not yet complete) picture. A long-soft GRB results from the core collapse of a massive star in a star-forming galaxy releasing of order 10^{51} ergs into the surrounding gas-rich medium, in the form of both an isotropic supernova and highly relativistic jets. Radio telescopes, including the VLA and the VLBA, have been involved in the study of long-soft GRB afterglows from the beginning. They have made some of the key measurements on burst calorimetry and environments and have provided the most direct confirmations of the relativistic fireball model.

But what of the short-hard burst population? The burst durations of 10 ms to 1 s are too short to be produced in the interiors of collapsing massive stars (aka collapsars). Possible progenitors include coalescing compact objects (black holes or neutron stars), hyperflares from highly magnetized neutron stars (aka magnetars), and accretion-induced collapse (AIC) of white dwarfs to neutron stars. To make progress and to distinguish between various models, astronomers had to wait for the launch of the *Swift* satellite in November 2004.

Swift is a NASA Midex mission specifically designed to detect about 100 GRBs per year and make follow-up observations of their afterglows at X-ray, ultraviolet, and optical wavelengths. Short-hard bursts are expected to be rare (1 in 20 GRBs), in part because the Burst Alert Telescope (BAT) on *Swift* is sensitive to hard X-rays (10–150 keV), not hard gamma-rays. Nonetheless, on May 9, 2005 *Swift* finally got to strut its stuff with the detection of GRB 050509B, a 40 ms burst. A rapid slew of the X-ray telescope on board revealed a faint (11 photons!) but clearly fading afterglow. To date *Swift* and the *HETE* (High Energy Transient Explorer) satellite have seen another five short-hard bursts. Here, in brief, is what we have learned from a study of their X-ray, optical, and radio afterglows.

The short-hard bursts arise from a cosmological population that is at systematically lower redshifts than the long GRBs (typical redshift $z = 0.5$ versus 2.8). Their isotropic radiated energies span a range from 10^{48} to 10^{51} ergs, lower than the energies of long bursts by about a factor of 100. Breaks in the decay slopes of the light curves are interpreted as evidence that the outflows are collimated with opening angles of 10–20 degrees. In contrast to long bursts, sensitive late-time searches have failed to find evidence for supernovae above detection limits 2–3 magnitudes fainter than the faintest GRB supernovae.

The differences between short and long bursts are most distinctive when comparing the environments in which they are found. Long bursts are found exclusively in galaxies forming stars at the rate of more than one solar mass per year, and their locations in these galaxies closely trace the blue light from young stars. Short-hard bursts, like Type Ia supernovae, occur in both spiral *and* elliptical galaxies. For example, GRB 050709 occurred in a star-forming dwarf galaxy at $z = 0.16$, while the host of GRB 050724 (Figure 1) is a massive elliptical at $z = 0.26$, and GRB 050813 appears to have occurred in a distant cluster at $z = 1.8$. Stronger constraints come from the three events with high-quality radio, optical and X-ray afterglow data. In these cases afterglow fitting yields surrounding densities of order 10^{-1} to 10^{-3} cm^{-3} — about 1000 times lower than the gas densities around typical long bursts.

Taken together, these constraints on distance, energy, geometry, host-galaxy type, and environment pose problems for the magnetar and AIC models but are consistent with the compact coalescence model. Puzzles still remain, so it is clear that a larger sample is needed. Radio observations will continue to play a crucial role, first in helping to provide the arcsecond localizations that begin all serious follow-up studies, and second in breaking the degeneracy in the physical parameters of the afterglow that results from using only X-ray and optical data. In the future, should LIGO (Laser Interferometer Gravitational-wave Observatory) detect the definitive gravitational-wave signature of binary coalescence, then the burst will be close enough for the VLBA to image the relativistic ejecta from the merger remnant.

Dale Frail (NRAO)

Probing Changes in Fundamental Constants with a New OH Absorber/emitter at $z \approx 0.765$

A fairly generic feature of modern higher-dimensional theoretical models is that fundamental constants such as the fine-structure constant α, the electron-proton mass ratio $\mu \equiv m_e / m_p$, and the proton gyromagnetic ratio g_p depend on the scale lengths of the extra dimensions of the theory. In the current theoretical framework it is implausible that these scale lengths remain constant, implying that α, μ, etc. should vary with time. The search for such changes provides an avenue to explore new and fundamental physics.

Although null results have been obtained in all terrestrial studies of evolving constants, such measurements only probe fairly small fractions of the age of the Universe. They cannot rule out earlier changes in the constants, quite possible if these changes are non-monotonic in nature. Astrophysical techniques are needed to examine the possibility of changes at earlier times (e.g. Murphy et al. 2003; Srianand et al. 2004). These involve a comparison between the apparent redshifts of two different spectral lines whose frequencies have different dependences on the fundamental constants. If the lines originate from the same gas (so they have no intrinsic velocity offsets), then a measured difference between the line redshifts would imply that the fundamental constants change with time. The four OH (hydroxl) lines at 18 cm wavelength are excellent candidates for this purpose as they have very different dependences on α, μ, and g_p. Their apparent redshifts can be compared with each other and with that of the HI (neutral hydrogen) 21cm wavelength hyperfine line to study the evolution of these constants (Chengalur & Kanekar 2003). Unfortunately, very few redshifted OH absorbers are known, primarily owing to terrestrial radio interference.

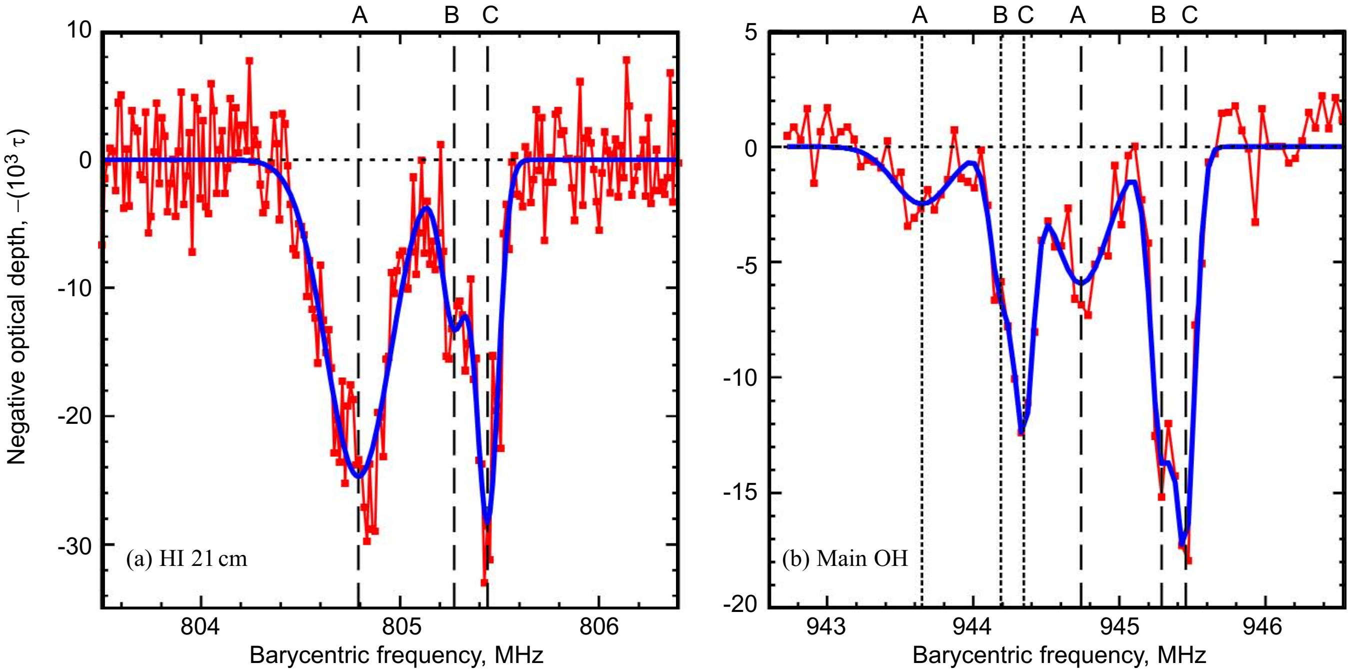

Figure 1. GBT HI 21cm (left panel, [a]) and OH main line (right panel, [b]) spectra toward PMN J0134-0931, with negative optical depth ($-10^3 \times \tau$) plotted against barycentric frequency in MHz. The solid line in each panel shows the three-gaussian fit. The vertical lines in each figure indicate the locations of the three components (marked A, B and C), with the dashed and dotted lines in the left panel showing the 1667 and 1665 components, respectively.

We (Kanekar et al. 2005) have used the GBT to detect all four 18 cm OH lines in the redshift $z \approx 0.765$ lens towards the radio source PMN J0134-0931 and have also obtained a high-resolution spectrum in the HI 21 cm line. The HI 21cm and "main line" (1667 and 1665 MHz) OH spectra are shown in Figures 1(a) and (b), while the three panels of Figure 2 show the 1720 and 1612 MHz satellite spectra and the sum of 1720 and 1612 MHz optical depths. The latter sum is consistent with noise; the satellite lines are thus "conjugate" with each other. Such conjugate behavior arises from competition between the intra-ladder 119 micron and cross-ladder 79 micron decay routes to the OH ground state after the molecules have been pumped by collisions or far-infrared radiation into the higher excited states (e.g. van Langevelde et al. 1995). This is only the second redshifted conjugate system known and is at a far higher redshift than the first, at $z \approx 0.247$ towards PKS 1413+135 (Kanekar et al. 2004). The luminosity of the 1720 MHz line is about 3700 solar luminosities, making this the brightest known 1720 MHz megamaser by more than a factor of ten; it is also the most distant OH megamaser by a factor of three in redshift.

Comparisons between spectral lines of different species to probe the evolution of fundamental constants suffer from the drawback of possible systematic velocity offsets between the species. However, the velocities of main OH and HI 21cm absorption are expected to be well correlated with a dispersion less than 1.2 km/s, based on observations in our galaxy (Liszt & Lucas 2000; Liszt, private communication). This makes them good candidates for such a comparison, allowing one to measure changes in the quantity $F \equiv g_p [\alpha^2/\mu]^{1.57}$ (Chengalur & Kanekar 2003).

The HI 21cm profile of Figure 1(a) has three components, two of which are blended and well separated from the third. In passing, we note that we have now obtained a new GBT HI 21 cm spectrum that shows the three components even more clearly. Similarly, both the 1667 and 1665 MHz OH lines of Figure 1(b) show two clearly resolved components, with the lower-

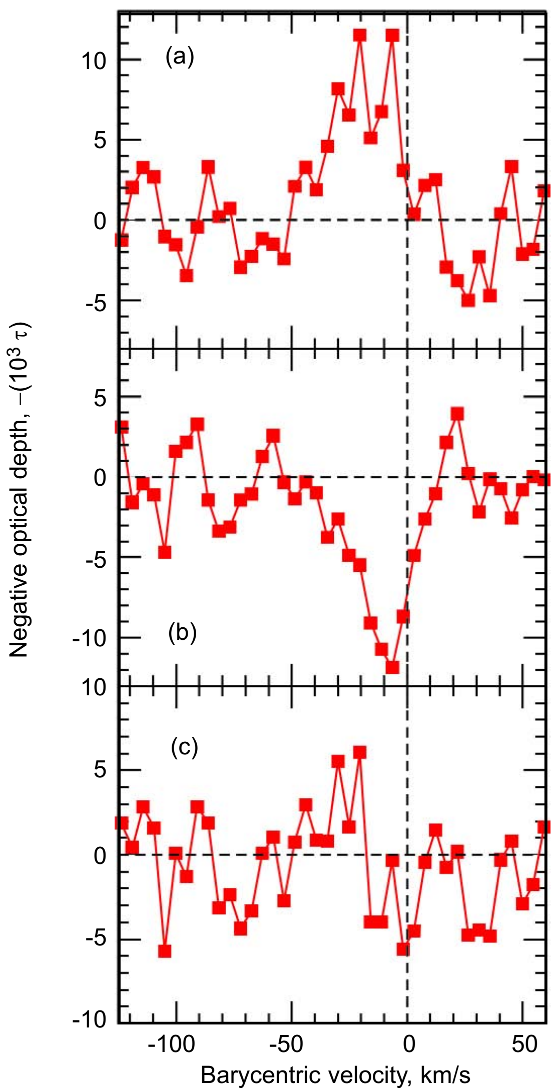

Figure 2. OH satellite line spectra, with negative optical depth ($-10^3 \times \tau$) plotted against barycentric velocity in km/s, relative to z = 0.76355, the redshift of component C. (a) 1720 MHz transition, redshifted to ≈ 975.6 MHz; (b) 1612 MHz transition, redshifted to ≈ 912.2 MHz; (c) Sum of the 1612 and 1720 MHz spectra, consistent with noise.

velocity one somewhat asymmetric, suggesting that it is blended. A three-gaussian template was hence used to locate the peak redshifts of the different 21 cm and main OH absorption components (see Kanekar et al. 2005 for details). Table 1 lists the 21 cm and main OH redshifts of the different components and the value of $[\Delta F/F]$ for each component. The last line of the table lists the same quantities for the $z \approx 0.685$ absorber towards B0218+357, the only other known system with OH and HI data of a similar quality (Chengalur & Kanekar 2003). A weighted average of the values in the last column gives $[\Delta F/F] = (0.44 \pm 0.36$ [statistical] ± 1 [systematic]$) \times 10^{-5}$, where the systematic error calculation assumes a conservative velocity dispersion of 3 km/s between the OH and HI lines (typical of internal motions within a molecular cloud). The result is consistent with the null hypothesis of no evolution in the different constants. The strong dependence of F on α and μ ($F \sim \alpha^{3.14}$ and $F \sim \mu^{-1.57}$) implies a 2σ sensitivity of $[\Delta\alpha/\alpha] < 6.7 \times 10^{-6}$ or $[\Delta\mu/\mu] < 1.4 \times 10^{-5}$ to fractional changes in α and μ from $z \approx 0.7$ (i.e. a lookback time of about 6.5 billion years) to today. Assuming linear evolution, these correspond to 2σ sensitivities of $(1/\alpha)\,[\Delta\alpha/\Delta t] < 1.1 \times 10^{-15}$ per year or $(1/\mu)[\Delta\mu/\Delta t] < 2.1 \times 10^{-15}$ per year, among the best present sensitivities to changes in μ (e.g. Ivanchik et al. 2005).

The conjugate nature of the satellite OH lines in Figure 2 ensures that they arise in the same physical region and, crucially, that systematic velocity offsets are not an issue. The different dependences of the sum and difference of the 1720 MHz and 1612 MHz frequencies on α, μ, and g_p allows us to measure changes in the quantity $G \equiv g_p\,[\alpha^2/\mu]^{1.85}$ (Kanekar et al. 2004). The low signal-to-noise ratio of the 1720 and 1612 MHz spectra precludes such an estimate at the present time. However, the high redshift of the system implies that it is an excellent target for deep integrations in the satellite lines, providing a laboratory for precision tests of the evolution of fundamental constants over half the age of the Universe. A comparison between the results from the conjugate systems in PKS1413+135 and PMN J0134-0931 will also allow one to probe true spatio-temporal changes in the above constants (instead of merely averaging over spatial effects), especially since the two sources are very widely separated on the sky.

While the size of the radio sample is still small, surveys are being carried out that will significantly increase the number of known redshifted OH and HI 21 cm absorbers thanks to the wide frequency coverage of the GBT and its location in the National Radio Quiet Zone, which

Component	HI redshift	OH redshift	$[\Delta F/F] \times 10^{-5}$
A	0.764938(15)	0.764872(42)	-3.7 ± 2.8
B	0.763881(33)	0.763852(19)	-1.6 ± 2.1
C	0.763515(14)	0.763550(10)	+2.0 ± 1.0
0218+357	0.684675(5)	0.684682(56)	+0.35±0.40

Table 1. The H 2 1cm and OH "main-line" redshifts of the three components towards PMN J0134-0931 and the $z \approx 0.685$ lens towards B0218+357. The last column lists the estimates of changes in the quantity $F \equiv g_p [\alpha^2/\mu]^{1.57}$ from each component.

allow observations to be carried out at hitherto unaccessible frequencies. Comparisons between radio lines are thus likely to provide an important independent constraint on changes in fundamental constants in the future.

Nissim Kanekar (NRAO)

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Where are the Milky Way's Spiral Arms?

A picture of the Milky Way, taken by an observer in another galaxy, would reveal many bright knots of emission where massive stars have ionized their placental environment. Photographed from afar, these ionized (HII) regions would appear as glittering jewels, perhaps tracing out a beautiful spiral pattern. Unfortunately, we can't take this picture directly. We observe the Milky Way from the inside and only see a single bright band across the sky, projecting spiral arms on each other. Unraveling this projected "mess"' has been a challenge for nearly a century, since it was recognized that the Milky Way was similar to other "spiral nebulae."

The key to determining the spiral structure of the Milky Way is to determine distances to massive star forming regions. With distances, one can construct a plan view—a view from above the plane—of the Milky Way and see its true structure. However, astronomical distances are very hard to measure. Distances to the nearest stars can be directly measured by a technique called trigonometric parallax (discussed later). Once distances to some stars are measured, their intrinsic brightnesses are easily determined, and they become what are termed "standard candles." When other stars with similar characteristics (usually spectral lines or period of variability) are found, one can estimate their distances by comparing their observed brightnesses with similar standard candles. This begins a long chain of indirect methods to determine distances in astronomy.

Once distances and motions (from Doppler shifts of spectral lines) for some objects across the Milky Way are estimated, one can construct a model of the rotation of the Milky Way. Then, if one measures the velocities of stars or interstellar gas, one can estimate their "kinematic" distances by matching the observations with the model predictions. With kinematic distances to star forming regions, one can then locate them in three-dimensions and construct a plan view of the Milky Way. Unfortunately, many problems arise when constructing a plan view of the Milky Way, including:

1) difficulties in determining an accurate rotation model;
2) distance ambiguities in some portions of the Milky Way (where an observed velocity can occur at two distances); and
3) departures from circular rotation (as might be expected for spiral structure).

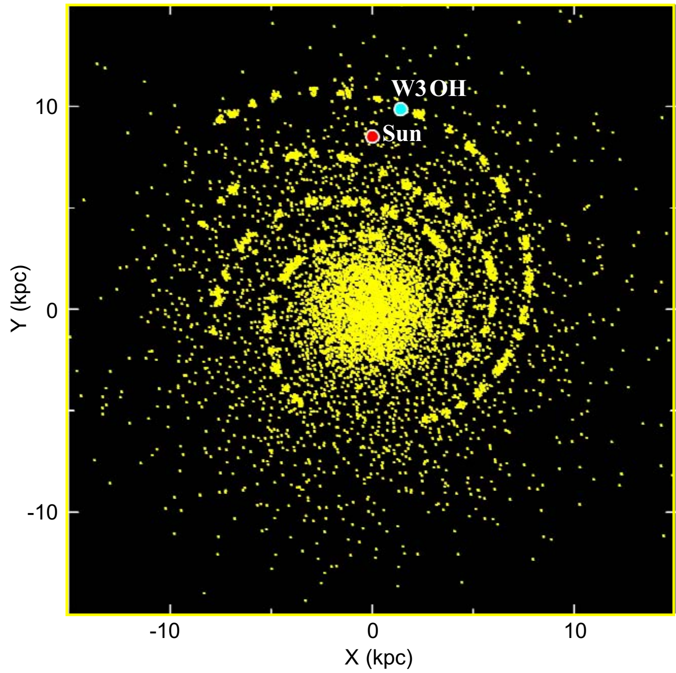

Figure 1. A plan view of the Milky Way as seen from its north pole. Estimated positions of spiral arms (Georgelin & Georgelin 1976; Taylor & Cordes 1993) are indicated by numerous dots and named after the prominent constellations onto which they are projected. The locations of the Sun and W3OH in the Perseus Arm are indicated.

The Perseus arm is believed to be the nearest spiral arm outward from the Sun, as shown in Figure 1. There are many young stars in the Perseus arm for which distances have been estimated photometrically (by the standard candle method). Toward the W3OH star forming region, indicated in Figure 1, photometric distances are ≈ 2.2 kpc (Humphreys 1978). However, kinematic distances for this and other star-forming regions are ≈ 4.5 kpc. This discrepancy had never been resolved.

The problem of the distance to the Perseus arm, and ultimately of the spiral structure of the Milky Way, can be resolved by determining accurate distances to massive star-forming regions. The "gold standard" for measuring distance in astronomy is a trigonometric parallax. A trigonometric parallax is determined by observing the change in position of a star, relative to very distant objects such as quasars, as the Earth moves in its orbit about the Sun. The parallax is simply the maximum angular deviation of the apparent position from its average position over a year. The distance D to a source is easily calculated from its parallax π by triangulation: D (kpc) = 1 / π (mas). Thus, one needs a measurement accuracy of 0.05 milli-arcseconds (mas) to achieve 10 percent accuracy for a source at 2 kpc distance, which would be sufficient to resolve the Perseus arm discrepancy. By comparison, trigonometric parallaxes obtained by the Hipparcos satellite (Perryman et al. 1997) typically have uncertainties of ≈ 1 mas, which are inadequate for our purposes.

The VLBA is the best telescope for precise astrometric measurements ever constructed. An ideal candidate for a trigonometric parallax measurement is the massive star-forming region W3OH located near O-type star associations in the Perseus spiral arm. W3OH has strong masers which can serve as bright beacons for astrometric observations at radio wavelengths. We observed 12 GHz methanol masers from W3OH and three compact extragalactic radio sources at five epochs over one year in order to measure the position of W3OH relative to extragalactic radio sources. In Figure 2 we plot the positions of one maser spot in W3OH relative to the three background radio sources.

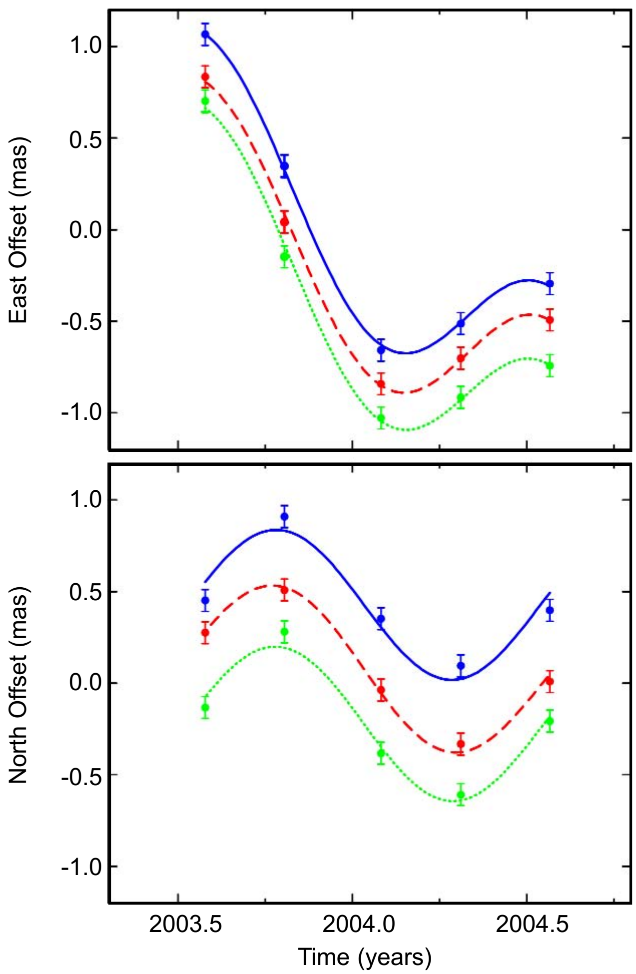

Figure 2. Position versus time for one methanol maser spot in W3OH relative to three background radio sources. The top and bottom panels show the eastward and northward offsets, respectively. The large difference in position between W3OH and each background source has been removed and the data for the different background sources have been offset for clarity. Also plotted are the best fitting models, specified by five parameters: one for the parallax and two for the proper motion in each coordinate.

The change in position of a maser spot relative to a background radio source was then modeled by the parallax sinusoid in each coordinate, completely determined by one parameter (the parallax) and a linear proper motion in each coordinate. These results for the three background sources were consistent within their formal errors, and a weighted average of all the data yielded $\pi = 0.512 \pm 0.010$ mas and, hence, a distance of 1.95 ± 0.04 kpc.

Our trigonometric parallax estimate is consistent with a similar measurement of 2.04 ± 0.07 kpc made with the VLBA using H2O masers in the W3OH region (Hachisuka et al. 2006). These distances for W3OH in the Perseus spiral arm conclusively resolve the long-standing discrepancy between its kinematic distance of 4.5 kpc and a luminosity distance of ≈ 2.2 kpc, based on O-type stars nearby in the same spiral arm. The luminosity distance is consistent with the trigonometric parallaxes but the kinematic distance is not, so W3OH must have a large kinematic anomaly.

In addition to measuring the distance, we have determined the proper motion of W3OH. It is orbiting 14 km/s slower than the Galaxy spins. Also, W3OH is not in a circular orbit, but is moving with a speed of 17 km/s toward the Galactic Center. The total peculiar motion of W3OH is 22 km/s with all of its motion in the plane of the Galaxy, as expected for a massive star-forming region.

The large magnitude of the peculiar motion is puzzling. For an axially symmetric distribution of mass in the Galaxy, rotational velocities cannot fall more rapidly with Galactocentric radius r than $1/\sqrt{r}$. The 14 km/s slower rotation of W3OH,would therefore require essentially no mass between the Galactocentric radius of the Sun (8.5 kpc) and W3OH (9.95 kpc). This seems unlikely and provides motivation for a non-axisymmetric mass distribution, such as might be provided by spiral density-wave theory (e.g., Lin, Yuan, & Shu 1969; Roberts 1972).

Our observations have established that the VLBA can achieve a parallax accuracy of 0.01 mas and proper motion accuracy of better than 1 km/s for Galactic sources with only 5 observations spanning 1 year. With this accuracy, the VLBA can be used to measure distances to 10 kpc with better than 10 percent accuracy, approximately a factor of 100 better than the Hipparcos satellite and comparable to future billion-dollar space missions such SIM and GAIA. Based on these results, we believe that the VLBA, and ultimately the Japanese Very Long Baseline Interferometric project VERA (VLBI Exploration of Radio Astrometry; Honma, Kawaguchi & Sasao 2001), can map the spiral structure and full kinematics of massive star forming regions in the Milky Way.

M. J. Reid
(Harvard-Smithsonian Center for Astrophysics)

Y. Xu & K. M. Menten
(Max-Planck-Institut für Radioastronomie)

X. W. Zheng (Nanjing University)

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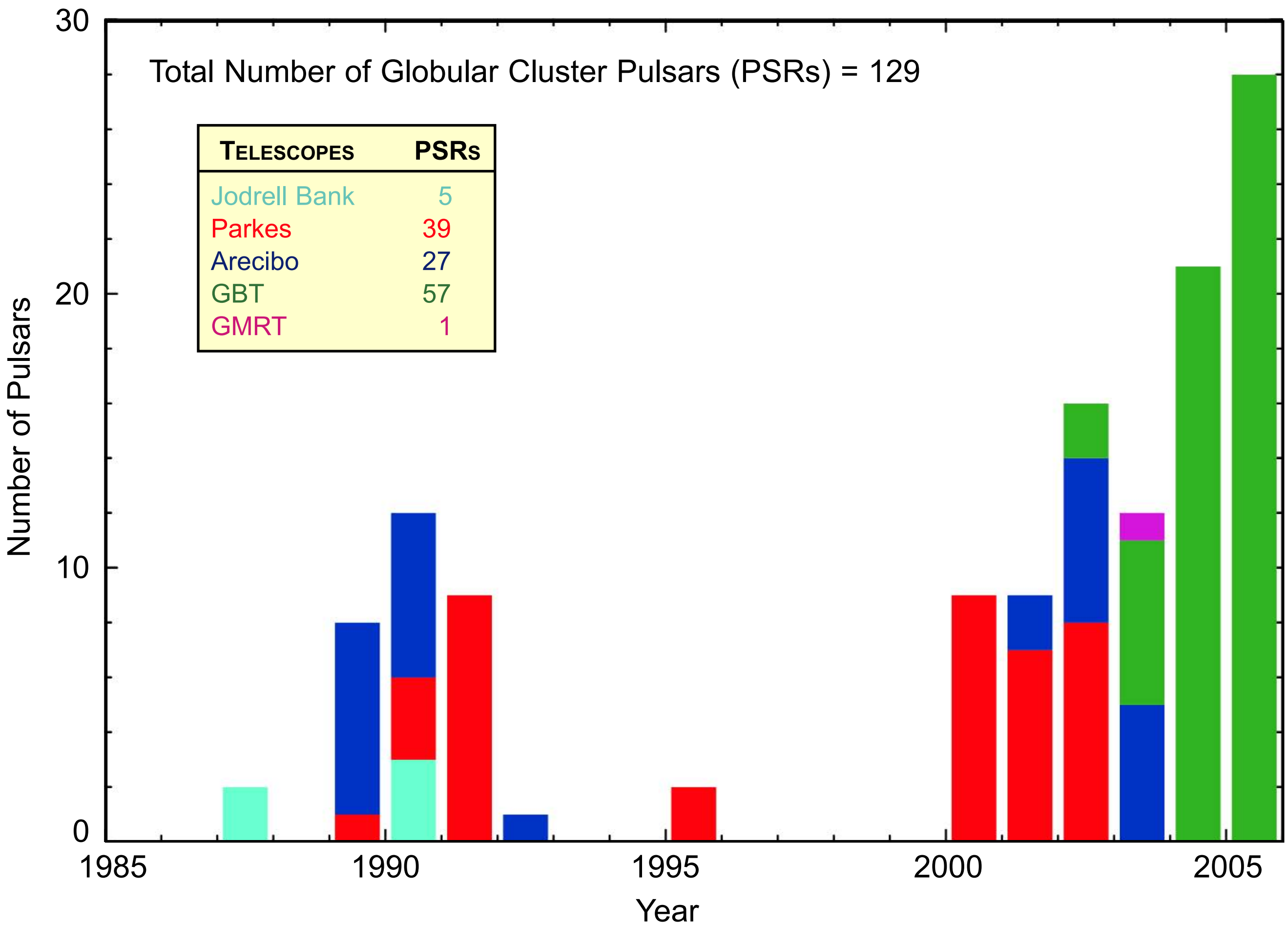
Annual Pulsar Discoveries in Globular Clusters



A second wave of pulsar discoveries in globular clusters began in 2000 because of computing advances, the Arecibo Gregorian feed upgrade, the Parkes 20 cm multibeam system, and the construction of both the Giant Metre Radio Telescope (GMRT) and the Green Bank Telescope (GBT).

Atacama Large Millimeter Array

ALMA Construction

Figure 1. The technical building at the 16,000 foot Array Operations Site took shape over the austral summer. Left-to-right: Eduardo Donoso (NA Site IPT lead), Bill Porter (NA Deputy Project Manager), Andres Zumaeta (Con-Pax Construction), and Jeff Zivick (NA Antenna IPT lead).

Figure 2. Vertex will assemble its ALMA antennas at the Operations Support Facility antenna laydown area, which was levelled in preparation for construction of that facility by Vertex.

The foundation for the Technical Building at the 16,000 foot Array Operations Site (AOS) has been completed and work has progressed substantially on the building shell itself. A contract for the final finishing work awaits approval by the ALMA Board and the funding agencies.

The area where Vertex will conduct its on-site antenna erection and testing has been graded. This site is located at the Eastern edge of the Operations Support Facility (OSF) area. The vendor is expected to begin development of the site shortly. The Vertex antenna acquisition continues toward delivery of the first antenna to Chile late in 2006. During February, a Preliminary Pre-Production Design Review was held to track progress and identify issues for resolution.

Before a quorum of the production antennas arrive in Chile, the prototype ALMA system is being assembled into a one-baseline interferometer using the remaining two prototype antennas at the ALMA Test Facility (ATF) in New Mexico. The Mitsubishi prototype antenna has been disassembled for return to Osaka, Japan retrofit to production designs.

At the ALMA Prototype System Integration group in Socorro, Peter Napier has assumed his new role as Team Leader. After final lab tests, the system now being measured in the New Mexico Array Operations Center (AOC) labs will be reassembled at the ATF for astronomical testing, which will commence in the fall. In early 2008, this process will be repeated at the OSF in Chile as production antennas become available.

Figure 3. ALMA prototype Water Vapor Radiometer installed on an antenna of the Submillimeter Array.

The ATF site lacks the atmospheric clarity needed for some ALMA component tests, including the water vapor radiometers (WVRs), which operate at the atmospherically

Figure 4. At the ALMA Test Facility, the Mitsubishi prototype antenna was disassembled for shipment to Japan, retrofitting to production specifications, and delivery to the ALMA site.

difficult 183 GHz water line. Therefore, tests of the two prototype WVRs are occurring on the Submillimeter Array on Mauna Kea. These tests should provide the confidence needed to let the production contracts for these systems.

As the last *NRAO Newsletter* was going to press, ESO had just signed (December 6, 2005) a contract with Alcatel Alenia Space to supply twenty-five antennas for the ALMA project. This was followed just before Christmas by the signing of a contract with Scheuerle Fahrzeugfabrik to supply two special vehicles for the transport of the radio antennas. These vehicles must lift the 110 ton antenna systems and transport them over the ALMA road, often for several tens of kilometers, to and from the antenna stations and the OSF. To do this, these vehicles are equipped with twin 1340 horsepower engines; the transporters measure 33 feet wide, 52 feet long, and 15 feet high.

As a result of the decision that ALMA would procure substantial numbers of antennas of differing design, the newly rebaselined budget, reviewed by an external panel last October, was further modified. This updated budget was then reviewed by a subset of the same panel which had met in October. This Delta Cost Review was held January 25 at the National Science Foundation. The performance of the production antennas can be predicted as a result of the tests performed to validate the specifications of the prototype antennas. At the NSF review, the Project Scientists reported that the effect of the two designs on ALMA science was minimal and that there may in fact be some benefits owing to the strict specifications on the production antennas.

During the week following the Delta Cost Review, a review of the ALMA North America Cost and Management was held in Charlottesville, Virginia. The review committee, composed of external experts, was chaired by Donald Hartill of Cornell. The report of this committee was to be delivered to NSF by the end of February.

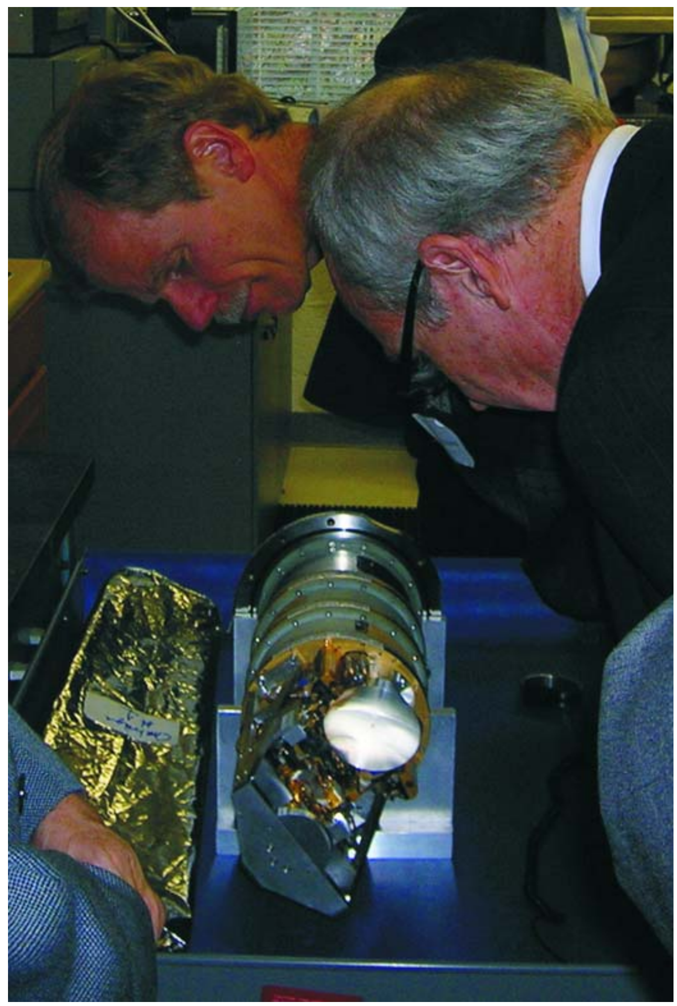


Figure 5. Michael Turner, NSF Asst. Director for Math and Physical Sciences, examines an ALMA 1.3 mm receiver cartridge with Review committee member Neal Erickson (Univerity of Massachusetts).

The President's FY2007 budget was delivered on February 7. On March 2, 2006, NSF Director Arden Bement provided testimony on the agency's $6.02 billion budget request to the House Appropriations Subcommittee on Science, the Departments of State, Justice, and Commerce and Related Agencies. The Administration's request would increase NSF's budget by $439 million, or 7.9 percent, over FY 2006. The increase is part of the President's American Competitiveness Initiative, which includes a commitment to double NSF's budget over the next ten years. At the hearing, Dr. Bement noted that "providing world-class facilities and infrastructure" is a top 2007 priority. "NSF has a long-established role in providing state-of-the-art infrastructure to meet major research challenges. Our strategy is to invest in tools that promise significant advances in a field of research and to make them widely available to a broad cross-section of investigators. Total funding in the Major Research Equipment and Facilities Construction (MREFC) account is proposed at $240.45 million." ALMA is one of five ongoing MREFC projects. In questions later, Bement identified ALMA as a transformational instrument. Details on the ALMA budget may be found at the NSF FY2007 budget website. $47,890,000 is requested for ALMA Construction. As may be seen in the ALMA Funding Profile Table, ALMA Operations and Maintenance funds are for the first time a major component of the FY2007 budget.

Al Wootten

North American ALMA Science Center

Paul Vanden Bout

The first quarter was one of change for the fledging North American ALMA Science Center (NAASC). We bid farewell to Paul Vanden Bout, who stepped down as the Head of the NAASC effective January 1, 2006. We owe Paul a great debt for his superb work in developing the plans for the NAASC and bringing it into reality. Of course, Paul was also pivotal in the genesis of the entire ALMA project. Luckily, he retains an office just a few doors away from the NAASC so we can continue to seek his experience and insight.

We are currently conducting an internal search for a full-time Head of the NAASC and expect to fill the post soon. In the interim, Adrian Russell, the NA ALMA Project Manager, has assumed the role of Acting Head of the NAASC, and John Hibbard has assumed the role of Acting Head of the NA ALMA Regional Center, a subset of the NAASC with responsibilities for the core ALMA Operations functions in North America.

Crystal Brogan

We have also recently welcomed Crystal Brogan into the NAASC. Crystal joined the NRAO scientific staff on March 6, 2006 having arrvied from Hawaii, where she was the JCMT Fellow at the Institute for Astronomy in Hilo. Crystal is familiar to all of us at NRAO, having been a Jansky Fellow in Socorro from 2000-2003. Prior to that Crystal obtained her Ph.D. in astronomy from the University of Kentucky under the guidance of Tom Troland. She brings to the NAASC expertise on sub-millimeter imaging and spectroscopy, imaging of galactic star forming regions, the structure of the ISM and magnetic fields, as well as familiarity with the ALMA offline reduction software through her prior role with the NRAO AIPS++ Users Group.

In keeping with the changing cast of characters involved with the NAASC, we have invited representatives from the National Research Council of Canada Herzberg Institute of Astrophysics (NRC-HIA) to our monthly NAASC organizational meeting. James Di Francesco has been designated as the official NRC-HIA liaison. Additional meetings are planned over the coming months to incorporate Canadian input into NA ALMA operations.

The NAASC staff continues to make progress preparing for ALMA's operational phase, including work on the organizational and staffing plan and participation in tests of critical ALMA elements, such as the proposal tool, the pipeline system, and the off-line data reduction software. Key tests are planned in this area in early 2006, as is a comprehensive internal review of the NAASC Operations Plan. Progress also continues on developing spectral line and calibrator databases for use with the ALMA observing tool. We are also busy planning for several meetings, including a special session at the June AAS meeting in Calgary Canada (see accompanying article), the IAU in Prague in August, and the ALMA Madrid meeting in November. More information on the NAASC is available at *www.cv.nrao.edu/naasc/*.

John Hibbard

ALMA North American Science Advisory Committee

The ALMA North American Science Advisory Committee (ANASAC) is composed of representatives of the wider North American astronomical community who provide scientific advice to the NRAO Director on the operation of the NAASC. The ANASAC met via telecon on February 24, 2006. The February meeting marked the end of the three year terms for five ANASAC members: Dick Crutcher (U. Ill.), Jason Glenn (U. Col.), Mark Gurwell (CfA, Harvard), Joan Najita (NOAO), and Min Yun (U. Mass). We thank these members for their invaluable input regarding ALMA. We are especially indebted to Dick Crutcher and Min Yun for their service and leadership as past ANASAC Chairs. Several new members have joined the ANASAC: Todd Clancy (SSI), Kelsey Johnson (UVa), Terry Herter (Cornell), Alycia Weinberger (OCIW-DTM); and Chris Carilli (NRAO) was appointed for an additional three-year term.

Topics discussed at the monthly ANASAC telecon include the results of the recent ALMA reviews, the current ASAC charges, future NAASC workshops, and a possible grants program to support work demonstrating the science goals of ALMA. The next ANASAC telecon is scheduled for April 28, 2006 where further discussion of future NAASC workshops and the grants program are planned. A listing of the current ANASAC membership and meeting schedule are given at *www.cv.nrao.edu/naasc/admin.shtml*. The community is encouraged to contact their ANASAC representatives with any ideas or questions on NA ALMA operations or the Science Center.

John Hibbard

NAASC ALMA Workshop: "From z-Machines to ALMA: (Sub)millimeter Spectroscopy of Galaxies"

On January 13-14, Charlottesville welcomed 75 scientists from 37 institutions in nine different countries to the first NRAO North American Science Center Workshop, "*From z-Machines to ALMA: (Sub)millimeter Spectroscopy of Galaxies*". In 26 oral and 23 poster presentations, the participants assessed the technical challenges and scientific promise of using wide-bandwidth spectroscopy to study distant, dusty galaxy populations. The first day closed with a reception sponsored by the NRAO Director, while the second ended with a freewheeling discussion of the role played by current NRAO facilities in this exciting scientific area, plus a view of the future provided by North American ALMA Project Director Adrian Russell. Proceedings for the workshop will be published by the Astronomical Society of the Pacific in 2006. The meeting program, electronic versions of the presentations, the conference photograph, and candid pictures of participants are available *at www.cv.nrao.edu/naasc/zmachines/*.

z-Machines conference participants (photo courtesy of Jim Condon).

As chairs of the scientific and local organizing committees, we were delighted by the community's enthusiasm for the workshop – the NRAO auditorium was at full capacity! – and by the participants' clear enjoyment. A great deal of the credit for this success goes to the Scientific Organizing Committee and Local Organizing Committee, notably Laurie Clark and Jennifer Neighbours. We hope this will be merely the first of many NAASC workshops on ALMA-related themes. Suggestions from the community for future events are welcome.

A. Baker and J. E. Hibbard

ALMA Town Meeting at January AAS Meeting

ALMA held a Town Meeting at the winter meeting of the American Astronomical Society in Washington, D.C. The Town Meeting was held on Monday, January 9 from 12:30 to 1:30 p.m. in the Cotillion Ballroom and was attended by over 200 AAS members.

NRAO Director Fred K. Y. Lo speaks at the ALMA Town Hall Meeting.

The NRAO Director, Fred K.Y. Lo, kicked off the meeting with a welcome and introduction, followed by a dynamic presentation by the North American ALMA Project Manager, Adrian Russell. This included a list of the impressive accomplishments achieved by ALMA over the past year, as well as current pictures of the on-going construction at the ALMA sites in Chile. Chris Carilli gave a presentation on the main science goals of ALMA, and Crystal Brogan described the plans for the North American ALMA Science Center. These presentations were followed by 30 minutes of discussion. All of the above presentations are available at *http://www.cv.nrao.edu/naasc/TownMeetings/*. After the meeting, members of the ANASAC joined Fred Lo and NRAO staff members for a lunch to discuss the ALMA project, the science center, and the NA community.

J. E. Hibbard and A. H. Wootten

ALMA Special Session at Calgary AAS Meeting: *"Imaging Star Formation in the Cosmos with ALMA"*

The Atacama Large Millimeter Array (ALMA) will provide quantum leaps in improvement compared to existing facilities, enabling entirely new science at millimeter and submillimeter wavelengths. Star formation in the Milky Way will be revealed with a hundred-fold increase in sensitivity and resolution, making it possible to see evidence of protoplanets in protostellar disks and to measure disk chemical differentiation. Star-forming molecular gas in nearby galaxies will be imaged with high sensitivity at parsec-scale resolution, providing new insight into the structure and evolution of galaxies. Multiple transitions of molecular and atomic gas will be imaged in distant galaxies back to the era of recombination, providing information on the chemistry, structure, formation, and evolution of the earliest galaxies.

The North American ALMA Science Center (NAASC) is sponsoring a special session at the 208th meeting of the American Astronomical Society, to be held June 4-8, 2006 in Calgary, Alberta, Canada. The special session will take place from 2:30-4:00pm on Monday June 5, in order to adjoin the meeting of the Canadian Astronomical Society (CASCA). It will feature review talks highlighting ALMA's capabilities and scientific potential in three key research areas:

Doug Johnstone (NRC-HIA): *Star formation in our galaxy: the need for ALMA*

Jean L. Turner (UCLA): *Imaging star-forming gas in nearby galaxies*

Andrew W. Blain (Caltech): *Imaging high-z starburst galaxies*

We invite AAS attendees to present relevant poster contributions to this session by selecting it when submitting their abstracts. The deadline for abstract submission is March 23, 2006 via the AAS website *http://www.aas.org/meetings/aas208/*.

H. A. Wootten, J. E. Hibbard, and M. T. Adams

Green Bank

The Green Bank Telescope

Continued development of our 25-50 GHz instrumentation remains a top priority for the GBT. After a very successful design review in December, we have developed a plan to increase the bandwidth of the Q-Band receiver to 40-49 GHz. This work will be performed during summer 2006. Our investigations of the Ka-Band (26-40 GHz) receiver in November/December cured a number of problems, although the baseline issues remain. The receiver was reinstalled on the telescope in December for use in continuum mode with the Caltech Continuum Backend. The articles on pages 21 and 22 by Roger Norrod, Dana Balser, and Brian Mason provide more details on these topics.

The Robert C. Byrd Green Bank Telescope (GBT) at Sunset. Photo by Harry Morton (NRAO).

We have now essentially completed the campaign of "out-of-focus" (OOF) holography described in the previous newsletter. The application of the model of residual gravitational deformations as a function of elevation is routinely available via Astrid; over the summer this will be incorporated directly into the active surface control system, so that it will be automatically available to all observers. Our hypothesis that the major day-time wave-front aberrations are due to sub-reflector mis-collimation, induced by thermal effects in the feed-arm, was tested during an excellent daytime commissioning period on January 12. The results suggest that this is indeed the case for the azimuth direction, but the situation for the elevation direction is more complex. These results, as well as the remainder of the OOF campaign, are being documented as a series of Project Notes; our understanding of the behavior of the GBT has increased dramatically as a result of this work. We are extremely grateful to Bojan Nikolic, our post-doc (who sadly for us has decided to return to the UK) for his excellent work in this area.

In other news, incremental improvements continue to be made to Astrid and GBTIDL. Work is proceeding well on the addition of flagging to GBTIDL, to be released this spring. During the end of 2005 and into early 2006, the Green Bank software development and computing divisions performed a major upgrade to the GBT control system infrastructure. This included upgrading the latest gcc compiler and the Red Hat Enterprise Linux 4 operating system (which included revising many drivers), better partitioning of hardware between the two Green Bank networks, replacing the main control computer with new Linux hardware, and adjusting the hosting of several databases to improve telescope reliability. These necessary upgrades make the control system and observing systems more reliable as well as more maintainable.

The remote operations upgrade to the 43m telescope has been completed, on time and to budget. Operation from the Jansky lab will commence in April, after a one month shake down. Starting at that time, the GBT operators will occasionally monitor the 43m status and call out other NRAO staff if necessary to deal with any anomalous conditions.

Finally, a request for approval to proceed with the GBT azimuth track refurbishment contracts was sent to the NSF in February. We certainly hope that by the time of publication of this newsletter, the contracts will have been awarded; the planned date for this work remains summer 2007.

Richard Prestage

GBT Student Support Program: Announcement of Awards

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

The January awards were in conjunction with approved observing proposals submitted at the October 2005 deadline. Requests totaling $254,000 were considered. Awards totaling $96,000 were made for the following students:

- M. Agueros (University of Washington) in the amount of $9,000 for the proposal entitled *"Detecting Pulsar Companions to Very Low-Mass White Dwarfs"*.

- P. Demorest (University of California, Berkeley) in the amount of $24,000 for the proposal entitled *"Long-term Precision Timing of Millisecond Pulsars"*.

- J. Hewitt (Northwestern University) in the amount of $9,000 for the proposal entitled *"Mapping Radio Recombination Line Emission Toward SNRs W28 and W44"*.

- D. Nidever (University of Viginia) in the amount of $19,000 for the proposal entitled *"HI Mapping of the Extended Magellanic Stream"*.

- L. Weintraub (Caltech) in the amount of $35,000 for the proposal entitled *"Definitive Detection of Excess Arcminute Scale CMB Anisotropies"*.

New applications to the program may be submitted with new GBT observing proposals at any proposal deadline. For details, please see *http://wiki.gb.nrao.edu/ bin/view/Observing/ GbtStudentSupportProgram.*

In the current financial climate, this program is very competitive. Each support application is judged both on the scientific merit of the observing proposal and on the expected impact on the student's professional development. Details of the selection criteria are posted at *http://wiki.gb.nrao.edu/bin/view/Observing/ GbtTermsAndConditions.*

For a cumulative record of past awards under this program, please see *http://wiki.gb.nrao.edu/bin/view/ Observing/GbtStudentSupportStatus.*

K. E. Johnson (University of Virginia),
D. J. Nice (Bryn Mawr College),
J. E. Hibbard, P. R. Jewell, R. M. Prestage,
J. M. Wrobel (NRAO)

Planned GBT Receiver Improvements

Preparations are underway for improvements and new capabilities for the GBT 40-50 GHz (Q-Band) and 26-40 GHz (Ka-Band) receivers, to be accomplished during the summer of 2006. This is the second winter of scheduled astronomy for the Q-Band receiver and the first for the Ka-Band. Ten Q-Band projects and four Ka-Band projects (over 200 hours for each receiver) are scheduled during the current season, but when high-frequency observing ends in May we have plans to accomplish several receiver improvements. Both of these receivers are two-beam, dual-polarization with cooled feed horns, polarizers, and HFET amplifiers. The Q-Band is a conventional heterodyne architecture, while the Ka-Band is a correlation architecture designed for optimum continuum performance (but also with spectral line capability).

Because of various hardware limitations, the Q-Band performance is less than desired below 41.5 and above 48 GHz. During the summer improvements will be made to the mixers, low-noise amplifiers, and other components which should result in good performance from 40-49 GHz. Above about 49.1 GHz, the polarizer axial ratio degrades significantly, and we do not plan to replace the polarizers at this time.

The Zpectrometer, an ultra-wideband spectrometer (14 GHz instantaneous bandwidth, 825 spectral channels, two polarizations), is under construction at the University of Maryland and is targeted specifically for use with the GBT Ka-Band receiver. Some relatively minor modifications to the receiver will be accomplished over the summer to provide interface ports for the Zpectrometer. System testing with the receiver and spectrometer is also anticipated before the receiver is reinstalled this fall.

During early science and commissioning observations in fall 2005, intermittent poor spectral baseline performance was noted with both receivers. Investigation revealed intermittent, irregular baseline structure with typical ripple periods between 10-40 MHz. Various Q-Band tests have isolated the source of the structure to between the front-end beam switch and the feed vacuum window. The feeds are cooled and reside within the cryostat while the beam switch is at room temperature. The spectral baseline structure at Q-Band is qualitatively different than baseline structure that has been previously studied with most GBT receivers, but is similar to that seen with the Ka-Band. The net effect is that over 1-2 hours integration the Q-Band system achieves between 2-4 times the theoretical RMS noise with the 50 MHz spectrometer modes performing better than the broadband 800 MHz modes. Still, the baseline structure always remains at some level. Mitigating or eliminating the irregular baselines will be a high priority for the work this summer. To assist, a scaled-down version of the GBT spectrometer for laboratory use is now being completed and tested.

Additional details about the Ka and Q receivers' current performance can be found at: *http://wiki.gb.nrao.edu/bin/view/Observing/WebHome*.

R. D. Norrod and D. S. Balser

The Caltech Continuum Backend

The Caltech Continuum Backend (CCB) was completed and successfully lab-verified in October and November 2005, and commissioned on the telescope with the 26-40 GHz (Ka-Band) receiver in December 2005 and January 2006. The instrument as a whole has proven extremely robust and easy to use, and more importantly, yields excellent continuum photometric performance—a factor of 20 better than existing GBT instruments. This performance gain is due to the fast switching (presently 4 kHz) provided by the CCB, the receiver's pseudo-correlation architecture, and careful attention to noise performance in the design. Up to integration times of a couple of seconds, performance of most of the 16 independent detector channels is within 25 percent of the fundamental limit set by photon noise statistics (i.e. the radiometer equation), yielding 0.4 mJy rms in 60 seconds of GBT time including overheads. This performance is more than adequate for a large "NVSS-source veto" project proposed in support of the Cosmic Background Imager (CBI) experiment; the veto survey has been granted 200 hours of GBT time and is well underway, with 80 hours successfully executed on the telescope and over 1000 sources observed with data that pass photometric filter criteria. Data are being analyzed with IDL routines written by the project team (project scientist Brian Mason; two-time graduate student intern Cristobal Achermann; & Caltech graduate student Lawrence Weintraub, who was recently awarded a GBT student support grant). On timescales longer than a few seconds 1/f effects limit the CCB+Ka sensitivity; the origin of this noise is being investigated, but it appears to be before the CCB itself. Fixing this will be important to open up a class of "deeper/fainter" science which is of great interest to Ka-Band continuum observers, and may be important for the performance of the near-future wideband Ka-Band spectrometer backend as well. The CCB will be available in the upcoming (June 1) call for proposals.

Brian Mason

The Removal of Hanning Windowing from the SDFITS Filler

On February 15, we removed from the SDFITS filler the step of Hanning windowing of Spectrometer data. We believe the change will reduce the confusion observers might have when they are interpreting their data.

For those unfamiliar with windowing functions, windowing is performed by default by some autocorrelation backends. Windowing reduces the leakage or sinc(x) "ringing" caused by the use of a finite Fourier transform. The ringing occurs whenever there is a sharp discontinuity in the spectra, such as a very narrow RFI line or when the spectral resolution under-resolves a very strong astronomical line. [For further information on leakage, see references like E.O. Brigham, "The Fast Fourier Transform" (1974, Prentice-Hall, Inc.)]

However, Hanning windowing has the consequences that it acts like a smoothing function and reduces spectral resolution to about twice the channel separation. It correlates information between channels so that the measured noise does not statistically behave as one expects. Smoothing functions, for example, do not reduce the noise as one would think. Observers who select a frequency resolution that actually under-resolves their lines can become confused or misinterpret their data since fitted line widths will suggest the line is resolved.

We have found that, except for computational "noise", the Hanning windowing performed by the filler is identical to a Hanning smooth performed within a data reduction package like GBTIDL. Those observers who wish to continue to apply windowing, or need to remove the ringing from, say, an RFI spike, can do so by adding the simple step of Hanning smoothing to their data reduction.

By removing mandatory windowing from the filler, and replacing it with optional smoothing in data reduction packages, we have essentially given observers scan-by-scan control as to when Hanning is to be applied. Observers will be made more aware of the consequences of Hanning since they will be explicitly invoking the function. For narrow line work, we have removed a potential source of confusion and reduced the possible misinterpretation of data.

Observers may want to confer with their NRAO contact scientist for their projects, especially if they are expecting to combine old data that has been Hanning windowed with new data. We can help observers add the necessary steps in their data reduction to make new data comparable to old. And, we can instruct observers on how to refill old data so as to make them comparable to new data.

Ron Maddalena

Socorro

Extragalactic Blank Field Proposal Summary

Last year, we made a special call for VLA proposals on "Extragalactic Blank Fields," to be submitted at the October 3, 2005 proposal deadline. We received eight such proposals, requesting a total of 874 hours of observing time. Most of the requested observing time was in the highest resolution A configuration of the VLA.

The Blank Field proposals were evaluated by at least eight of our normal (non-NRAO) proposal referees, and then discussed in a teleconference among a non-conflicted subset of these referees. NRAO provided the teleconference participants with information about the logistics of proposal scheduling and about the impact of the sidereal times requested, but otherwise placed no constraints on the deliberations. The referees recommended allocating most or all of the requested observing time to four of the eight observing proposals, and a small amount of time to a fifth proposal to complete a previously observed field. All the recommended time was at a frequency of 1.4 GHz, except for AO201, which will be observed at 327 MHz. NRAO is proceeding to implement those recommendations, which primarily involve observations in the A configuration during the first trimester of 2006. A total of 303 hours of observing time has been awarded.

Below, we list the proposal codes, investigators, and proposal titles for which observing time was granted via the process described above:

> AI121, Ivison et al., *"Completing a Survey of the XMM/Newton and SHADES Fields in the Lockman Hole."* Awarded 4 hours of time in C configuration.
>
> AM857, Morrison et al., *"A Deep & Unbiased Probe of Star Formation in the GOODS Northern Field."* Awarded 77 hours of time in A configuration.
>
> AO201, Owen et al., *"The SWIRE Deep Field at 90cm: A Steep Spectrum MicroJy Radio Population?"* Awarded 60 hours of time in A configuration and 6 hours in C configuration.
>
> AS859, Schinnerer et al., *"Follow-up of the COSMOS 1.4 GHz Imaging Survey: Identification of Dusty Massive Starforming Systems."* Awarded 60 hours of time in A configuration.
>
> AY164, Yun et al., *"An In-depth Investigation of the Nature of the Faint 24 Micron Spitzer Sources and 1100 Micron AzTEC Sources in the FLS Verification Strip."* Awarded 88 hours of time in A configuration and 8 hours of time in B configuration.

All four PIs who have received large amounts of observing time have committed to make data products available publicly within 16 months of the date of the last observation in their proposal. The approximate data release dates may be found via the Blank Field web site at *http://www.vla.nrao.edu/astro/blankfield/*. When data products become available, we plan to add links that will provide access to these products.

Jim Ulvestad

Proposal Tool

The third release of the NRAO-wide proposal tool was successfully employed for the February 2006 GBT and VLA proposal deadline. For the GBT it was the third time in succession that this tool was used, whereas for the VLA it marked the first. The GBT received 42 proposals, and the VLA 97. Though for this release we also accepted VLA proposals prepared in the traditional way using a LaTeX form, we were pleased to find that 61 of the 97 proposals were submitted using the new tool. This exceeded our expectations, and has brought us useful feedback for further improvements which we expect to have implemented in time for the next GBT and VLA proposal deadline in June 2006. In addition, responses to a survey we conducted after the deadline among users of the online tool were overwhelmingly positive.

For the June 1, 2006 proposal deadline, and for proposals submitted subsequently to this deadline, we will require the use of the proposal tool for submission of all VLA proposals. This includes, as of June 1, 2006, all VLA Target-of-Opportunity and Exploratory Time proposals. No other method for the submission of VLA proposals will be considered. Note that this does not apply to the submission of VLBA or global VLBI proposals; support in the proposal tool is not yet available for VLBA/VLBI proposals.

The new NRAO user database now contains the names of roughly 600 astronomers and 380 institutions around the world. We advise every astronomer who has not done so yet to register at any time at *http://e2e.nrao.edu/userdb/*; it makes future proposal preparation easier not only for yourself, but also for those who wish to add you as a co-investigator. Please note that this same URL is used to access the proposal preparation tool. An additional benefit of registration is that eventually we plan to use it to grant access to other proprietary information, such as data from the archive.

Gustaaf van Moorsel

VLA Configuration Schedule

Configuration	Starting Date	Ending Date	Proposal Deadline
A(+PT)	03 Feb 2006	17 May 2006	3 Oct 2005
BnA	26 May 2006	12 Jun 2006	1 Feb 2006
B	16 Jun 2006	18 Sep 2006	1 Feb 2006
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	10 Sept 2007	1 Feb 2007
BnA	21 Sep 2007	08 Oct 2007	1 Jun 2007
B	12 Oct 2007	14 Jan 2008	1 Jun 2007
CnB	25 Jan 2008	11 Feb 2008	1 Oct 2007
C	15 Feb 2008	12 May 2008	1 Oct 2007

VLA Proposals

Please use the new VLA Proposal Tool, which is described above. The maximum antenna separations for the four VLA configurations are A-36 km, B-11 km, C-3 km, and D-1 km. The BnA, CnB, and DnC configurations are the hybrid configurations with the long north arm, which produce a circular beam for sources south of about -15 degree declination and for sources north of about 80 degree declination. Some types of VLA observations are significantly more difficult in daytime than at night. These include observations at 90cm (solar and other interference; disturbed ionosphere, especially at dawn), deep 20cm 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). Proposers should defer such observations for a configuration cycle to avoid such problems. In 2006, the C configuration daytime will involve RAs between 13^h and 20^h. In 2007, the D configuration daytime will involve RAs between 21^h and 03^h. Current and past VLA schedules may be found at *http:// www.vla.nrao.edu/astro/prop/schedules/old/*. EVLA construction will continue to impact VLA observers; please see the web page at *http://www.aoc.nrao.edu/evla/archive/transition/impact.html*.

Approximate VLA Configuration Schedule

	Q1	Q2	Q3	Q4
2006	D,A	A,B	B	C
2007	C,D	D,A	A,B	B
2008	B,C	C,D	D,A	A

J. M. Wrobel and B. G. Clark
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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 ten-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 *http://www.nrao.edu/HSA*). Any proposal requesting NRAO antennas and antennas from two or more institutions affiliated with the European VLBI Network (EVN) is a Global proposal, and must reach **both** the EVN scheduler and the NRAO on or before the proposal deadline. VLBA proposals requesting only one EVN antenna, or requesting unaffiliated antennas, are handled on a bilatteral basis; the proposal should be sent both to the NRAO and to the operating institution of the other antenna requested. Coordination of observations with non-NRAO antennas, other than members of the EVN and the DSN, is the responsibility of the proposer.

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VLBI Global Network Call for Proposals

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

Date	Proposals Due
01 Jun to 20 Jun 2006	01 Feb 2006
19 Oct to 09 Nov2006	01 Jun 2006

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

EOP Errors on the VLBA Correlator

A significant problem was found with the Earth Orientation Parameters (EOP) used on the VLBA correlator between May 2003 and August 2005. The problem adversely affects projects that depend on an accurate correlator model. Such projects include any that use phase referencing or that try to solve for the atmosphere using sources scattered around the sky. Projects that depend primarily on self calibration on the target source or that use the total delays from the correlator are not affected.

The problem was the result of a bug in the correlator job generator that caused it to use predicted values of EOP rather than measured rapid service values. The predictions were from only about two weeks before observe time. But it turns out that the Earth's rotation is sufficiently variable (it is related to the weather) and VLBI data are sufficiently sensitive to EOP for this to cause significant phase offsets.

The magnitude of the EOP errors is roughly equivalent to having source position errors of about 10 milliarcseconds (mas) before June 2004 and about 20 mas afterward. The worst cases were about four times these values. To first order, corrections based on calibrator observations will fix the phases on a target. But, as with any other geometry error, the residual error on the target after calibration will be approximately the calibrator phase error reduced by the calibrator/target separation in radians (typically well under 0.1). This phase residual can shift measured positions. But it is not completely equivalent to a position shift so it can also degrade phase reference image dynamic range and, in extreme cases, can prevent detection of the target.

The job generator was fixed on August 8, 2005. The AIPS task CLCOR was modified so that it could correct EOP values based on the record in the AIPS tables of what was used in correlation and on a file from the geodetic VLBI community at the GSFC and USNO that contains the latest measured values.

Note that even before the bug was found, VLBA correlation was based on rapid service EOP values from close to the date of observation, not on the final values that are only available later. Users wanting high accuracy may wish to make corrections for any observations. On about November 21, 2005 the source of EOP values for correlation was switched to the same file used by CLCOR. Projects whose correlator jobs were prepared after that date will have better EOP.

Details about the bug and how to deal with it are presented in VLBA Test Memo Number 69 available at *http://www.vlba.nrao.edu/memos/test/*.

After the Test Memo was written, the first leap second in many years occurred at beginning of 2006. The VLBA observing and correlation survived without impact. But the EOP correction in CLCOR broke. The problem was found and fixed before February 13, 2006. Users with data recorded after January 1, 2006 and who intend to make EOP corrections should update their AIPS versions.

Thank you to Mark Reid of CfA for calling to our attention to the fact that we were using EOP values with significant errors.

Craig Walker

Tenth Summer Synthesis Imaging Workshop

Activities are well underway for the Tenth Summer Synthesis Imaging Workshop. Within the first three weeks of registration, more than 80 students have registered for the workshop. The Workshop will include beginning and advanced lectures, data reduction tutorials and tour of the Very Large Array, with plans still to be made for the traditional shade-free hike at 98 degrees Fahrenheit, 8000 feet elevation and 5 percent humidity—always a hit with Dutch astronomers. While the core content of the Workshop remains unchanged, instrument lectures this year will highlight the newly-funded Long Wavelength Array as well as the Expanded VLA and Magdalena Ridge Observatory. In response to student requests for more scientific examples, there will be interspersed lectures covering galactic and extragalactic science. The deadline for early registration is April 3. We have requested money for student support for students from Mexico and the U.S. and have started a financial aid waiting list. We hope to see you all this year in Albuquerque!

Information and registration is available from *http://www.phys.unm.edu/~kdyer/2006/info.html*

Please send questions to *Kristy.Dyer@nrl.navy.mil*.

K. Dyer, G. Taylor, and C. Chandler

Education and Public Outreach

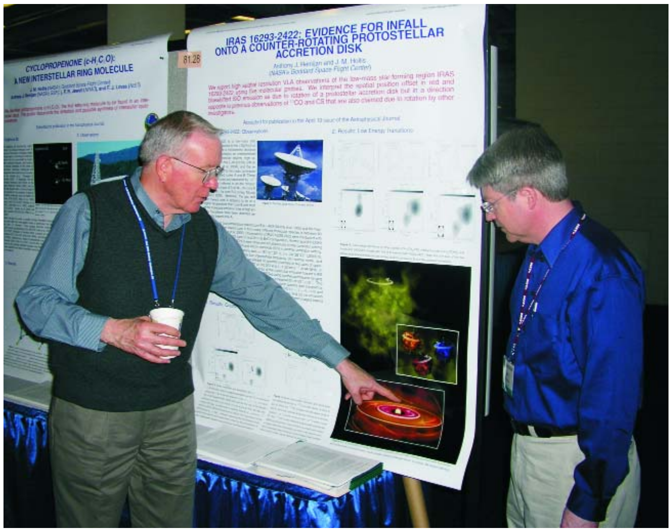
The NRAO at the American Astronomical Society Winter Meeting

The 2006 winter meeting of the American Astronomical Society (AAS) took place Sunday, January 8 through Thursday, January 12, 2006 in Washington D.C. Approximately 3,100 persons attended this meeting, shattering the previous AAS meeting attendance record set last winter in San Diego.

The Observatory's recently re-designed, three-panel exhibit debuted at this meeting and featured the entire NRAO facilities and project suite: the Atacama Large Millimeter Array (ALMA), the Expanded Very Large Array (EVLA), the Green Bank Telescope (GBT), the Very Large Array (VLA), and the Very Long Baseline Array (VLBA). NRAO Education and Public Outreach personnel Dave Finley, Sue Ann Heatherly, and Mark Adams staffed these exhibits, assisted by members of the Observatory's scientific staff and management team.

The press conference panel at the AAS meeting (from left to right): Scott Ransom, Jason Hessels, Chris Carilli, Crystal Brogran, Jim Ulvestad, Mark Reid, and Dale Frail.

Numerous meeting attendees visited our exhibits seeking information about radio astronomy and the NRAO, to converse with Observatory staff, and to pick up the



Scientist's discuss poster at the AAS meeting.

available materials including a new 2006 NRAO Calendar, a revised ALMA brochure, an EVLA brochure, a GBT update, two high-quality color posters, the announcement of the 2006 NRAO Radio Astronomy Image Contest, the January 2006 issue of the NRAO Newsletter, and the ever-popular NRAO luggage tags.

The 2006 NRAO calendar included all of the prize winners of the 2005 NRAO Radio Astronomy Image Contest and proved to be very popular. Nearly 2,000 copies of this calendar were distributed at the AAS meeting. The two large-format posters were also popular with the meeting attendees: the Fornax-A radio-optical composite created by NRAO EPO Scientist Juan Uson, and the Virgo cluster radio-X ray composite crafted by Aeree Chung (Columbia University) which took First Prize in our 2005 image contest. We were also pleased by the large number of queries about the Radio Image Contest.

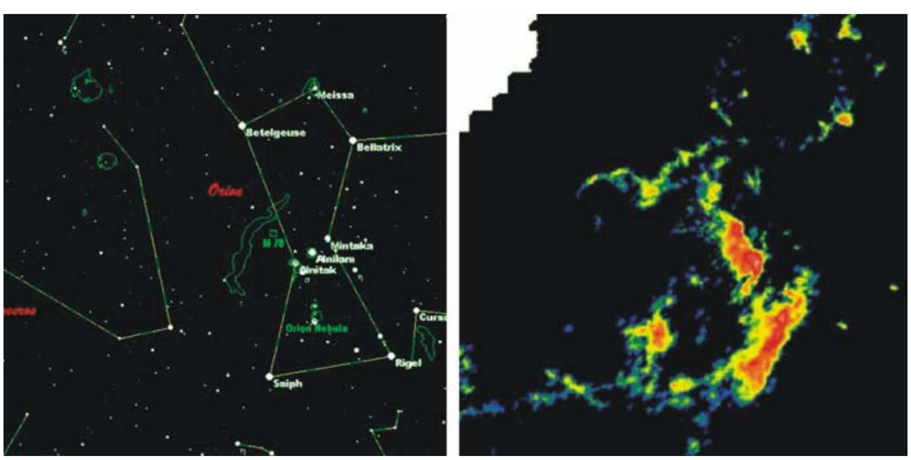
The 2006 NRAO / AUI Radio Image contest was announced at this Washington D.C. AAS meeting, and we hope to receive numerous submissions from our astronomical colleagues. The submission deadline is September 1, 2006. Full contest details are available on-line at *http://www.nrao.edu/imagegallery/image_contest/image_contest.shtml*.

This Washington D.C. AAS meeting also featured an ALMA Town Meeting on Monday afternoon and an EVLA Town Meeting on Tuesday afternoon. The Observatory also hosted a Press Conference and Press Reception on Monday afternoon and evening that featured exciting new research results, including the discovery of the fastest milli-second pulsar at the Green Bank Telescope.

We enjoyed seeing and talking with the many AAS meeting attendees who visited the Observatory's exhibits and look forward to seeing our colleagues again at the up-coming summer meeting in Calgary.

Mark Adams

NRAO Astronomer's Web Site Wins Education Award



Two of the images featured on Ron Maddalena's award winning web site. From left: Optical and CO.

If there's one constellation people know, it's probably Orion. Ron Maddalena exploited this fact to create an engaging website that teaches people about radio astronomy. Since its launch in 1998, the Tour of Orion site has invited visitors to explore the constellation at several different wavelengths. Recently, the website won the prestigious Griffith Observatory Star Award.

At Maddalena's web site, five images display Orion at optical, infrared, millimeter, centimeter and meter wavelengths. A sixth image illustrates the Greek mythology of Orion. All of the images are to the same scale allowing easy spatial comparisons. Stars, old supernova shells, stellar nurseries, and hot dust are readily seen as you toggle between images. Accompanying text describes the process that produces the emission in each image.

At the end of the tour, you can elect to take a quiz. Over the last few years, as more people have discovered the site, the number of quiz takers has risen dramatically; over 1400 people took the quiz in 2005 .

If you'd like to take the Orion Tour, go to: *http://www.gb.nrao.edu/epo/OrionTour/.*

Sue Ann Heatherly

In General

New Assistant Director for Green Bank Operations

The NRAO is pleased to announce that Richard Prestage became the new Assistant Director for Green Bank Operations effective February 1, 2006, succeeding Phil Jewell. Richard's appointment to this important position is for a three-year renewable term.

Richard Prestage

After receiving his B.Sc. degree in physics from the University of Leeds, Richard obtained his Ph.D. at the University of Edinburgh, where his thesis was titled "*The Environments of Radio Galaxies*." Over the past fifteen years, Richard has succeeded in several positions that have combined scientific, technical and managerial responsibilities, including ten years working for the James Clerk Maxwell Telescope in Hilo, Hawaii. Richard first joined the NRAO in September 1999 as an Associate Scientist for 12 Meter telescope operations in Tucson, and he relocated to Green Bank in July 2000. Richard served as the interim Assistant Director for Green Bank Operations from June 2005 through January 2006, and as Deputy Assistant Director for the previous four years.

Richard's extensive experience and skills will make him a strong leader for the continued development and effective scientific operation of the Green Bank Telescope and the Green Bank site.

Fred K.Y. Lo

New Division of Science and Academic Affairs Division Head

Effective April 1, 2006, Dale Frail will become the next Head of the Division of Science and Academic Affairs (DSAA). Dale will succeed Miller Goss, who has served as the first DSAA Division Head for the past three years.

Dale Frail

The DSAA is the focal point for all scientific and academic matters at the NRAO, supporting the astronomical user community, NRAO operations, and the scientific staff. The responsibilities of the DSAA include formulating the science case for the Observatory, providing oversight of scientific proposal review and telescope assignment, as well as student, postdoctoral and visitor programs, colloquia and workshops, and scientific staff research support, review, and promotion.

Dale received his M.Sc. and Ph.D. from the University of Toronto. After holding a National Sciences and Engineering Research Council (NSERC) Postdoctoral Fellow, Dale joined the NRAO as a Jansky Fellow in 1990. He became a NRAO Assistant Scientist in 1993, Associate Scientist in 1995, and tenured Scientist in 1999. Dale's research has most recently focused on improving the observational and theoretical understanding of the origin of gamma ray bursters and soft gamma ray repeaters, and he is a Co-Investigator on the NASA Medium-Explorer (MIDEX) mission, Swift. He has supervised many students and has performed a wide range of professional community service including terms on the Observatory Committee on Tenure and Appointments, the NRAO Science Council, the Chandra Proposal Peer Review committee, and the Publications Board of the Astronomical Society of the Pacific.

Dale's broad experience in research, mentoring, and service, together with his leadership skills and familiarity with the international astronomical community, position him well for his new position as Head of the NRAO Division of Science and Academic Affairs.

Fred K.Y. Lo

New Expanded Very Large Array (EVLA) Project Manager

When Peter Napier announced that he would step down from his position as the Expanded Very Large Array (EVLA) Project Manager, the Observatory initiated a broad search for his replacement. This search has now been completed, and I am pleased to announce that Mark McKinnon has agreed to serve as the next EVLA Project Manager, effective April 3, 2006. Mark has previously been the Deputy Project Manager for the EVLA, and he has also functioned as the Interim EVLA Project Manager since Peter Napier moved to the ALMA Project in late January 2006. As EVLA Project Manager, Mark will be responsible for maintaining schedule and budget in delivering all the scientific requirements for the EVLA.

Mark McKinnon

Mark received his M.Sc. and Ph.D. degrees in Physics from the New Mexico Institute of Mining and Technology after completing a B.Sc. Degree in Chemical and Petroleum Refining Engineering at the Colorado School of Mines. He first joined the NRAO as a Research Assistant in Socorro in 1986, and was a Jansky Postdoctoral Fellow at Green Bank from 1992 to 1994. After completing his postdoctoral work, Mark moved into a Scientist role at Green Bank and served as the Deputy Assistant Director there from 1997 to 2001. Since 2001, Mark has been the Deputy Assistant Director for VLA/VLBA Operations in Socorro, with responsibility for the Electronics and Engineering Services Divisions. To permit Mark to concentrate on his important new role as EVLA Project Manager, he will step down from the Deputy Assistant Director position on April 3.

Mark's experience and skills are an excellent match to the requirements of his new position. I am confident that Mark's management will guarantee the astronomical community and the NRAO continued excellent progress in the EVLA Project.

Jim Ulvestad

Scott Ransom Awarded the Bok Prize

It is our great pleasure to announce that Scott Ransom has been awarded this year's Bart J. Bok Prize from Harvard University. The Bok Prize, established in 1956, is given annually in honor of Professor Bart J. Bok on the recommendation of the Department of Astronomy to a recent holder of a Ph.D. in Physical Sciences from Harvard University who is under 35 years of age. The award is preferably based upon a doctoral thesis, book or research paper, in the area of Milky Way research by observational methods.

Scott Ransom

Ransom's Bok Prize Lecture was entitled *"Exotica and Basic Physics: A Globular Cluster Pulsar Renaissance with the GBT."* He was introduced by his thesis advisor, Dr. Giovanni Fazio, and presented the award by the Chair of the Astronomy Department, Lars Hernquist on February 9, 2006. Bart Bok's grandson, Alex Bok, attended the festivities. Ransom was honored at a dinner following the colloquium which was attended by his colleagues at the Harvard-Smithsonian Center for Astrophysics.

Fred K. Y. Lo and M. T. Adams

Space VLBI Collaboration Wins Publication Award

The paper describing the Japanese VSOP space VLBI mission entitled *"The VLBI Space Observatory Programme and the Radio-Astronomical Satellite HALCA"* by Hirax Hirabayashi and collaborators was recently selected for the *"Publications of the Astronomical Society of Japan (PASJ) Excellent Paper Award"*. This award is presented annually to the author(s) of the most outstanding paper published in PASJ, with all papers published during the preceding five years being eligible. The award will be made at the spring meeting of the Astronomical Society of Japan, in Wakayama from March 27 - 29. All co-authors will receive a certificate commemorating the award. NRAO co-authors include: Edward Fomalont, John Benson, Mark Claussen, Chris Flatters, George Moellenbrock, Jon Romney, Jim Ulvestad, Glen Langston, Anthony Minter, and Larry D'Addario.

Glen Langston

NRAO Legacy Projects Workshop

The National Radio Astronomy Observatory (NRAO) invites all astronomers to a one-day Legacy Projects Workshop on Wednesday, May 17, 2006 at the Array Operations Center in Socorro, NM. Legacy projects should produce results of high scientific impact or data of long-term value to the entire astronomical community. They may require large amounts of time on one or more telescopes, collaborations of many astronomers from several institutions, new instrumentation and software, and new modes of observing. The goal of this workshop is to bring together like-minded people who can identify the leading scientific and technical opportunities for legacy projects and refine NRAO's policies for implementing them. The program includes invited speakers, a panel discussion, and both oral and poster sessions enabling every participant to present ideas related to legacy programs involving NRAO facilities. To learn more about this workshop, visit the web pages *http://www.aoc.nrao.edu/events/legacy/*.

Jim Condon