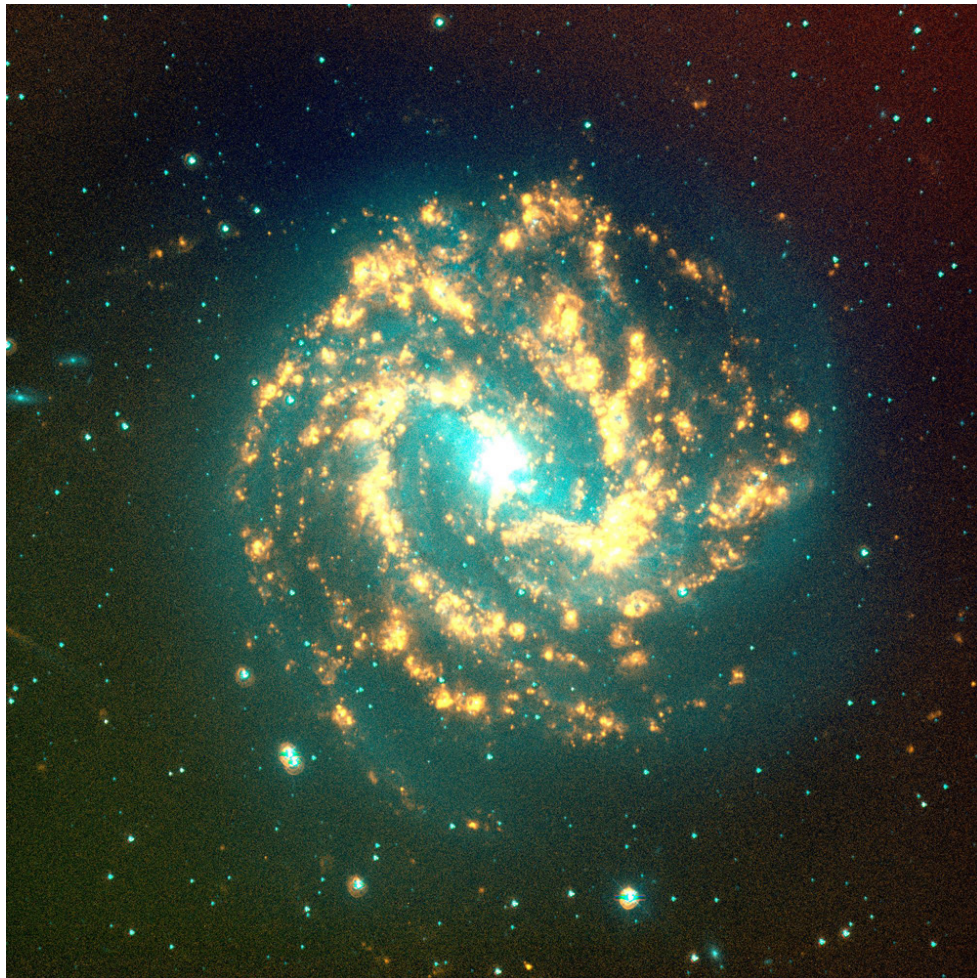




AURA/NOAO ANNUAL REPORT FY 2006

*Submitted to the National Science Foundation
November 1, 2006*



Spiral Galaxy NGC 5236 (M83)
NOAO Survey Program, H alpha and continuum image (<http://sungg.pha.jhu.edu/>)
Photo by: Gerhardt Meurer (JHU), the SINGG Survey Team and NOAO/AURA/NSF



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EXECUTIVE SUMMARY

A theme of each of the observatories' reports this year is the rapid development of new instrumentation. There are two good reasons for this: one qualitative, one quantitative. In the first instance, exciting new areas of investigation are opened up by advanced new capabilities, such as coronagraphy, directed at imaging extrasolar planets. Second, when we instrument a dramatically larger field of view, projects of a scale that would not have been proposed before become suddenly possible. Either way, state-of-the-art telescope instrumentation is a key to discovery.

The NOAO Gemini Science Center reports progress on NICI, Gemini's Near Infrared Coronagraphic Imager, and on FLAMINGOS 2, its multi-object infrared spectrograph. Gemini sources instruments from its partners, and NGSC has assisted both project teams, Mauna Kea InfraRed and the University of Florida, with advice and oversight. Gemini has just commenced design work on the next generation, the "Aspen" instruments, offering in the first two instances, quantum performance jumps in imaging planets (PFI) and in wide field optical multi-object spectroscopy.

There are striking new capabilities under development for NOAO's 4-meter telescopes north and south. The expectations from these new instruments are as large or a larger step forward than those of the generation they replace, when they replaced their predecessors. The NOAO Extremely Wide Field IR Imager (NEWFIRM) was inspired by the first workshop on the System of U.S. telescopes and designed and constructed by NOAO's Major Instrumentation Program. NEWFIRM will complete deep surveys of Northern Hemisphere molecular clouds an order of magnitude faster than SQUID and FLAMINGOS 1. NEWFIRM surveys of the evolution of clusters of galaxies will be directed at questions such as the evolutionary history of the galaxy luminosity function in clusters, a discriminant between hierarchical and monolithic galaxy formation scenarios. NEWFIRM surveys of red envelope galaxies will be directed at questions including the space density of Extremely Red Objects (ERO). How are EROs relevant to galaxy formation/evolution? NEWFIRM surveys, including narrow band surveys, for primeval galaxies will be directed at questions such as: What is the earliest epoch of galaxy formation/existence?

NOAO's public-private partnerships, WIYN and SOAR, have progressed major new instruments in the past year. WIYN's One Degree Imager (ODI) and SOAR's Adaptive Optics module (SAM) passed Preliminary Design Reviews. SAM is a pioneer instrument in Ground-Layer Adaptive Optics. ODI belongs to the generation that will step out beyond the Mosaic CCD imager, whose success has been shown most dramatically in the NOAO Deep Wide Field Survey. The Dark Energy Camera (DECam) is being designed as a further step in that progression by Fermilab. Planned to make use of the full corrected prime focus field of the Blanco telescope, DECam will see clusters of galaxies at their earliest epoch and provide state-of-the-art constraints on dark energy. When they take their place at the telescope, all three of these instruments can be expected to see the widest possible scientific application by NOAO's users. The Dark Energy Camera is an instrument that will make the Blanco telescope uniquely capable.

This report also details progress in the optical-infrared decadal survey projects, the Large Synoptic Survey Telescope (LSST) and the Giant Segmented Mirror Telescope (GSMT). The LSST selected its site on Cerro Pachón, home of Gemini South and SOAR. The Thirty Meter Telescope (TMT) completed its Concept Design Review midyear and its Cost Review at the end of the year. NOAO contributions to TMT fall in the site testing, optics, AO laser launch, and instrumentation areas. The alternate GSMT concept, the Giant Magellan Telescope, passed its Concept Design Review milestone and added an NOAO technical contact from the NOAO scientific staff.

NOAO's outreach program communicates broadly. We have also deepened our involvement in our host community Chile. We continued to involve students and teachers in a number of established programs, such as ASTRO and Hands-On Optics. Our outreach program is always innovating, for example, through a global program of night sky brightness measurement.

1.1 NOAO GEMINI SCIENCE CENTER

Radial Velocities of an Eclipsing Brown Dwarf System

A U.S. team of astronomers, led by Keivan Stassun of Vanderbilt University, used the high-resolution infrared spectrograph Phoenix on Gemini South to measure radial velocities in the eclipsing brown dwarf system 2MASS J05352184-0546085 (2006, *Nature*, 440, 311, “Discovery of two young brown dwarfs in an eclipsing binary system”). This system is a member of the Orion Nebula Cluster. The Phoenix observations complemented photometry from the 0.9-meter telescope at Kitt Peak and the 0.9-meter, 1.0-meter and 1.3-meter telescopes at the Cerro Tololo Inter-American Observatory. The Phoenix data have a spectral resolution of $\sim 30,000$, which yielded radial velocities with an accuracy of ± 2 kilometers per second.

The Gemini-Phoenix results consist of eight velocity measurements taken over a time period of about a month and sample the velocity curve across the system’s 9.78-day period. Both components can be detected in the Phoenix spectra, allowing Stassun and co-workers to determine the velocities of both components, as shown in Figure 1. Since this is a double-lined, eclipsing system, both component masses and radii are derived. The masses are 0.054 ± 0.005 and 0.034 ± 0.003 solar masses, respectively. Thus, both components of 2MASS J05352184-0546085 are brown dwarfs. The radii are 0.669 ± 0.034 and 0.511 ± 0.026 solar radii, respectively. These are the first direct determinations of masses and radii for brown dwarfs and are useful benchmarks for comparisons with brown dwarf models.

Although these findings reveal the radii of the brown dwarfs to be quite large, this is what models predict for young objects (as are these particular brown dwarfs, since the Orion Nebula Cluster is only about a million years

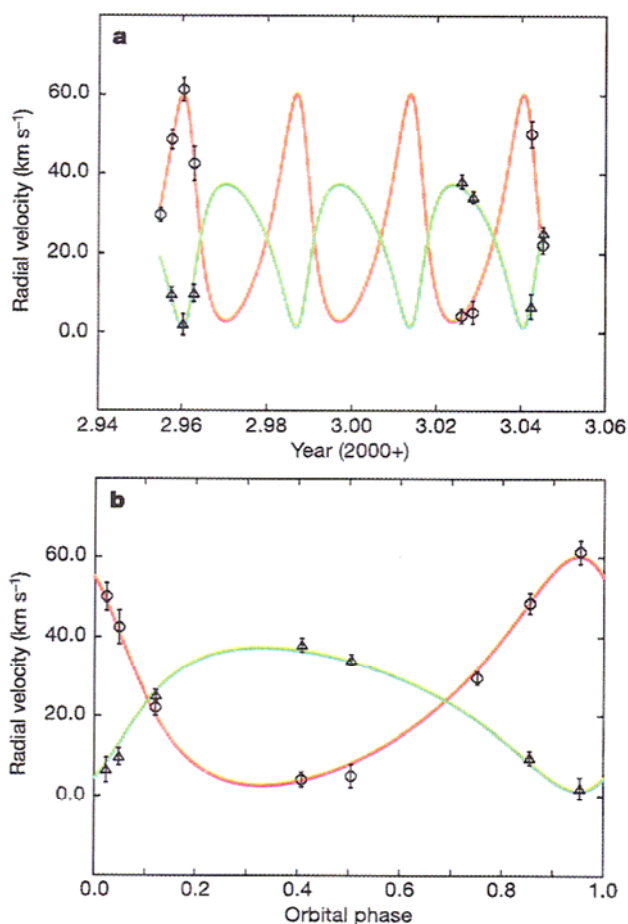


Figure 1: Individual radial velocity measurements (points) and the orbit solution (solid curves). The cross-correlation of the individual spectra against a radial velocity standard star yields the radial velocities of the two components at each observed phase. Here, the individual, heliocentric radial velocity measurements of the components of 2MASS J05352184-0546085 are shown as functions of both time (top panel) and orbital phase (bottom panel). Orbital phase is measured with respect to the time of periastron passage.

old). One surprise is that the lesser massive of the pair is hotter than the larger one. These temperature results are contrary to models, but may suggest that the two brown dwarfs are not quite coeval.

The team also included Robert Mathieu of the University of Wisconsin-Madison and Jeff Valenti of the Space Telescope Science Institute.

Suppressed Star Formation in Galaxies at High-Redshift

An international team led by Mariska Kriek of Leiden Observatory (Holland) and Yale University has found that many massive high-redshift galaxies exhibit very low or no star formation activity (2006, ApJ, 649, L71, “Spectroscopic Identification of Massive Galaxies at $z \sim 2.3$ with Strongly Suppressed Star Formation”). The existence of such massive galaxies showing little or no detectable star formation is unexpected. The observed sample consisted of 20 galaxies with redshifts in the range of $z=2.0-2.7$. Some 45% of the sample exhibit very little, if any, star formation, which is surprising since at this time in the universe it was expected that young galaxies should be forming stars at high rates.

This group used the Gemini Near InfraRed Spectrograph (GNIRS) on Gemini South to obtain their spectra. The equivalent width of the Balmer H-alpha line was used to derive the ratio of current to past star formation rates. The derived star formation rates vary by about a factor of 100 in this sample of galaxies: some show no detectable star formation at all. Modeling shows that star formation in the inactive galaxies is likely suppressed.

Kriek and co-investigators suggest that suppression is driven by such physical processes as supernova explosions, or the winds from active galactic nuclei (AGN). The explosive energy from supernovae or the mechanical energy in winds from an AGN can remove a large fraction of a galaxy’s supply of interstellar gas. Since this gas is the raw material from which new stars are made, its loss can lead to very low levels of star formation, as is observed in many of the sample’s galaxies.

Several recent studies have concluded that most of the stars in high-mass galaxies were formed at a higher redshift (that is, at an earlier time in the universe) than those of low mass galaxies. This recent work adds more data to the idea that most massive galaxies formed at a very early epoch in the universe.

1.2 CERRO TOLOLO INTER-AMERICAN OBSERVATORY (CTIO)

A Blast from the Past

In a study of old images from the SuperMacho survey, Armin Rest and collaborators have discovered evidence of a light echo from an ancient supernova explosion in the Large Magellanic Cloud.

Light echoes were first predicted by the Swiss-American astronomer Fritz Zwicky in the 1940s. They are the reflection of the flash of light from a supernova explosion on dust layers or shells surrounding the exploding star. In some cases, the dust may originate from the star itself. In the case of SN1987a, reflections off the dust shells expanding from the star’s previous Asymptotic Giant Branch phase were detected. In the more recent case of V838 Monocerotis, the dust shells appear to lie in interstellar space and may be associated with the young star-forming region in which V838 Mon. appears to be embedded.

An artist's impression of the process is shown in Figure 2. Light is reflected back to us from the dust layers in interstellar space. This means that we can use the reflections as “archival footage” of the explosion and reconstruct the ancient event that took place.

Using the Gemini telescope spectroscopy showed that the features in the reflected light are most consistent with the explosion of an overluminous supernova of Type Ia, an exploding white dwarf.

Future work will focus in identifying other examples of light echoes from the SuperMacho survey and other databases. This identifies a profitable field of study for the upcoming LSST telescope, to be built on Cerro Peñón in 2014. LSST will obtain repeated images of the entire Southern sky at frequent intervals. Searches for echoes may allow us to identify ancient supernova explosions in the Southern Hemisphere, which were not recorded by ancient civilizations.

In the same vein, Suntzeff and collaborators are searching for echoes from historical Supernovae in our Galaxy, such as Lupus (1006), Crab (1054), the two 1572 and 1604 supernovae and Cassiopeia A, which appears to have exploded in the 1700s. This will lead to an identification of the supernova type for these famous historical explosions.

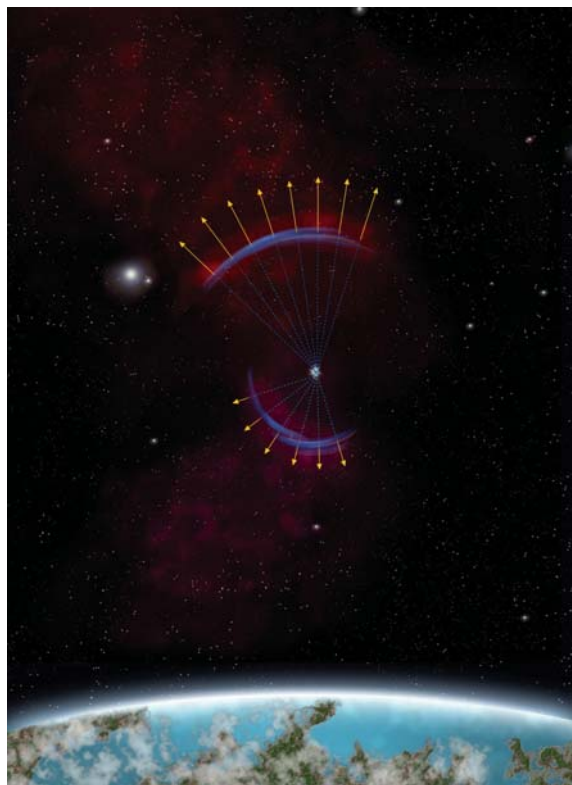


Figure 2: Artist's concept of light echoes from ancient supernovae.

The Nearest Cool Dwarf

A group of astronomers from Georgia State, the University of Virginia and the Universidad de Chile, have used the CTIO 1.5m telescope to determine the trigonometric parallax of the faint star DEN 0255-477. They discovered that this is the closest L dwarf to us. L dwarfs are not real stars, in that they are not powered by nuclear reactions in their centers. They do not have the mass to ignite the conventional hydrogen burning, but instead obtain their energy by gravitational contraction.

Jupiter is another, but much smaller, example of such “failed stars”. These objects eventually stop contracting and lose heat until they become completely dark.

DEN 0255-477 appears to be well underway to this stage. It has a surface temperature of only 1700 K and its atmosphere shows evidence of containing superheated water, as well as exotic lines of elements such as cesium, potassium and rubidium.

This is the closest L dwarf yet discovered. Numerous stars in the solar neighborhood have not yet been identified: they consist mostly of faint M dwarfs and brown dwarfs like DEN 0255-477.

The Magellanic Clouds in Full Color

One of the main drivers of Southern Hemisphere astronomy has traditionally been the possibility of studying the Magellanic Clouds. The two nearest galaxies to the Milky Way, the Magellanic Clouds are a unique laboratory to study star formation in detail, unhampered by the dusty environment of our disk. The Magellanic Clouds have played an important role in our understanding of stellar populations and the calibration of the extragalactic distance scale.

The Magellanic Clouds are also an excellent place to study the intergalactic medium and its interaction with the young stars. Stars form out of Giant Molecular Clouds and interact with their environment in complex ways. Young massive stars sweep away their parent clouds with their strong stellar winds and ionizing radiation, stopping star formation. Later, their supernova explosions return polluted gas to the interstellar medium and generate compression waves that trigger further star formation.

At the same time less massive stars, like our sun, eventually return most of their gas to the interstellar medium, enriched with dust, and produce glowing planetary nebulae and white dwarfs. The latter, in a binary system, eventually explode as Type Ia supernovae.

Using the 0.9-m Curtis Schmidt telescope at CTIO, a multi-institution team has produced images of the entire Large and Small Magellanic Clouds in two continuum bands and in emission lines of hydrogen, oxygen and sulfur. Hydrogen emission identifies the HII regions that are the birthplaces of young stars. Oxygen (5007 Angstrom) lines are prominent in planetary nebulae, the glowing envelopes shed by nascent white dwarfs and what our Sun will become in 5 billion years. Sulfur is instead often found in supernova shells.

Figure 3 shows a panorama of HII regions, small planetary nebulae, isolated supernova shells and multiple supershells, where several supernovae have gone off over a short period of time. The MCELS team has made the science images public, and, in conjunction with other surveys, such as the Spitzer survey of the Magellanic Clouds or broadband imaging being carried out at the Blanco Telescope, these data will provide a wealth of information on the processes behind the birth and death of stars.

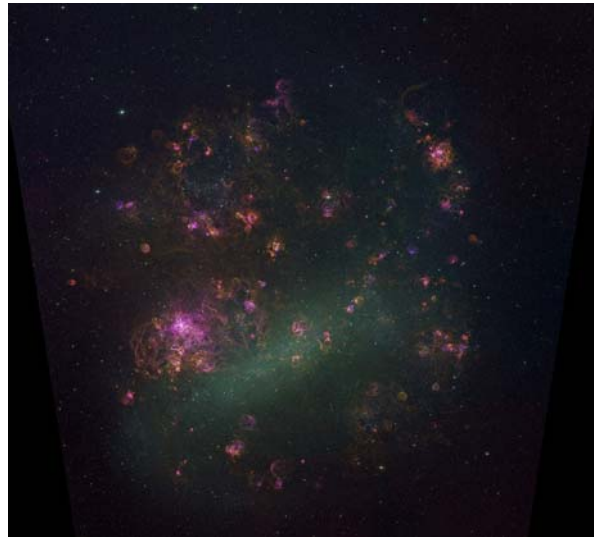


Figure 3: The MCELS image of the Large Magellanic Cloud.

ChaMP and ChaMPlane

Over the past year, two projects have used the Blanco telescope to follow up and identify sources observed with the Chandra X-ray telescope within the framework of the Chandra Multiwavelength Project (ChaMP). The survey uses 13 square degrees of Chandra archival images searching for serendipitous X-ray sources. The fields are then followed up optically, using the Blanco and the Mayall telescopes.

Barkhouse et al. present some of the first results of the ChaMP survey: identification of galaxy clusters via X-ray and optical methods. They attempt to find coincidences between extended X-ray

sources in the Chandra imaging and the presence of the characteristic cluster red sequence. They find 115 optical clusters, of which 11% are also detected in X-rays and 28 X-ray clusters, of which 46% are also optically detected. The median redshift of clusters detected in both X-rays and the optical is 0.41, which is consistent with the relatively shallow X-ray imaging.

Looking in the plane of our galaxy and using a combination of broadband optical and emission line imaging, the ChamPlane survey attempts to characterize the populations of low luminosity (X-ray) accreting white dwarfs, neutron stars and stellar mass black holes in the Galactic Plane and the bulge.

J. Grindlay et al. present preliminary results from 65 deep mosaic pointings with the Blanco and the Mayall 4-m telescopes. They obtain initial constraints to the space density of cataclysmic variables (usually white dwarfs accreting from a late-type primary star) for 14 fields in the Galactic anticenter and they find that their space density is at least 3 times lower than detected in the solar neighborhood.

The surveys were granted Long Term status on both telescope and these results derive from about 10% of the data which have been acquired and reduced to date. Further constraints on faint active galactic nuclei, cataclysmic variables and clusters may be expected in the near future.

SMARTS: Fast, Cheap and Good

The small telescopes on CTIO are now managed by a consortium of U.S. universities and CTIO. These provide quick and easy access to Southern Hemisphere observing, particularly for complex and lengthy survey programs and for projects requiring a quick response, such as monitoring newly discovered transients (supernovae, variables, gamma-ray bursters).

This has been realized in a number of occasions over the past year. In particular the 1.3m ANDICAM telescope has participated in the follow-up observations of GRB050408, a bright gamma-ray burst that was found to probe an atypical galaxy environment (Foley et al. 2006).

The SMARTS consortium also obtained optical and infrared light curves of the supernova SN2006aj. This supernova appears to be a new example of a class of low luminosity gamma-ray bursts (Cobb et al. 2006). If gamma-ray bursts span a large range of intrinsic luminosities, as suggested by the burst associated with SN2006aj, it may hamper attempts to use gamma-ray bursts as cosmological standard candles.

1.3 KITT PEAK NATIONAL OBSERVATORY (KPNO)

Observing Programs Continue Broad Scientific Impact

The telescopes of Kitt Peak National Observatory and of our sister observatories that share the lease to operate on I'olkam (Kitt Peak) continue to have broad scientific and educational impact. Twenty-six telescopes currently operate on the mountain. These include those operated by the National Optical Astronomy Observatory, the National Solar Observatory, and the National Radio Astronomy Observatory, as well as many telescopes operated by individual and groups of universities. These facilities are used for basic astrophysical research and education. Those taught about the universe range from the general public to students at all stages of their education. The students range in level from elementary through graduate school. They come from the Tohono O'odham Nation and from many countries around the world. The impact of the work enabled by Kitt Peak National Observatory continues to be broad.

Kitt Peak telescopes continue to enable scientific results of the highest quality and at a rate comparable or higher than their larger 8m cousins. For the past three years, KPNO publications have surpassed 150 refereed publications per year. The range of topics studied is extremely broad, as evidenced from the titles of these selected publications:

The Starburst in the Abell 1835 Cluster Central Galaxy: A Case Study of Galaxy Formation Regulated by an Outburst from a Supermassive Black Hole -- McNamara et al., ApJ, 648, 164.

The First Extrasolar Planet Discovered with a New-Generation High-Throughput Doppler Instrument -- Ge et al., ApJ, 648, 683.

Discovery of a $z=6.1$ Radio-Loud Quasar in the NDWFS -- McGreer, Becker, Helfand, and White, ApJ, in press

Mid-Infrared Selection of Brown Dwarfs and High-Redshift Quasars -- Stern et al., ApJ, in press

Constraining the Evolution of the Ionizing Background and the Epoch of Reionization with $z\sim 6$ Quasars II: A Sample of 19 Quasars -- Fan et al., AJ, 132, 117.

Discovery of an Extraordinarily Massive Cluster of Red Supergiants -- Figer et al., ApJ, 643, 1166.

Dynamics and Stellar Content of the Giant Southern Stream in M31. I. Keck Spectroscopy of Red Giant Stars -- Guhathakurta et al., AJ, 131, 2497

Discovery of two young brown dwarfs in an eclipsing binary system -- Stassun et al., Nature, 440, 311

High-metallicity photoionized gas in intergalactic large-scale filaments -- Aracil, Tripp, et al., MNRAS, 367, 139.

In addition to the science results represented by the papers above, several of the NOAO Survey programs that make use of KPNO telescopes were completed, publicly released their data products, and continued to publish their results. Representative publications include the following:

A Survey of Local Group Galaxies Currently Forming Stars. I. UBVRI Photometry of Stars in M31 and M33 -- Massey et al., AJ, 131, 2478.

The FLAMINGOS Extragalactic Survey -- Elston, Gonzalez, et al., ApJ, 639, 816.

Three Years of ChaMPlane Northern Field WIYN Spectroscopy -- Rogel et al., ApJS, 163, 160

NOAO Fundamental Plane Survey. II. Age and Metallicity along the Red Sequence from Line-Strength Data -- Nelan et al., ApJ, 632, 137.

Previously completed NOAO Surveys continue to yield results at a high rate. An example, the NOAO Deep Wide-Field Survey, a large optical and near-IR imaging survey completed in 2003 and whose Boötes Field data products were released in 2004, has contributed to more than 50 refereed publications (<http://www.noao.edu/noao/noaodeep/ndwfspublications.html>).

The educational impact of the operations on Kitt Peak continued at a high level of quality and activity. More than 25 PhD programs were supported by the National Observatory telescopes during FY06, including travel and observing expenses in addition to the observing time. Many others were supported by the “private” observatories on the mountain, those run by individual or groups of Universities. Our PAEO office added a third telescope to their very popular nightly public observing program during FY06. The addition of a third telescope increased the number of students and members of the general public that can take advantage of the clear and dark skies available from Kitt Peak. Groups of students from all over the country, including the Santa Rosa School of the Tohono O’odham Nation and the Tohono O’odham Community College, took advantage of this opportunity during FY06.

2.1 THE GEMINI TELESCOPES—NOAO GEMINI SCIENCE CENTER

Support of U.S. Gemini Users and Proposers

The NOAO Gemini Science Center (NGSC) supports the U.S. community's use of the Gemini 8-meter telescopes. This support work includes informing the U.S. community of Gemini scientific observing opportunities, answering U.S. proposers' and users' queries, performing technical reviews of U.S. Gemini observing proposals, applying the NOAO TAC process to the U.S. Gemini observing proposals, interfacing with Gemini on the implementation of the selected U.S. Gemini proposals, providing assistance with and checking of the U.S. Phase-II submissions, and providing selected operational support to Gemini.

The NGSC saw a strong response from the U.S. community to the Gemini Call for Proposals for semester 2006B. On Gemini North for 2006B, 138 proposals were received: 55 for GMOS-North, 36 for NIRI, 22 for Michelle, and 14 for TEXES. In addition, time trades with Keck led to 5 proposals for HIRES, while a time trade with Subaru resulted in 3 proposals for SuprimeCam and 3 for MOIRCS. There were 99 U.S. proposals for Gemini South: 35 for GMOS-South, 25 for GNIRS, 13 for Phoenix, 19 for T-ReCS, and 6 for bHROS. In total, the U.S. community proposed for 383.8 nights on the two Gemini telescopes (208.0 for the north and 175.8 for the south) resulting in oversubscription factors of 3.6 for Gemini North and 3.7 for Gemini South.

The U.S. community's enthusiasm continued in response to the Gemini Call for Proposals for semester 2007A. On Gemini North for 2007A, 131 proposals were received: 72 for GMOS-North, 41 for NIRI (17 of the NIRI proposals requested its use with the Altair adaptive optics system), 19 for Michelle, and 9 for NIFS (8 of these requested use with the adaptive optics system). There were 81 U.S. proposals for Gemini South: 25 for GMOS-South, 24 for GNIRS, 16 for T-ReCS, 11 for Phoenix, and 5 for bHROS. The oversubscription factors of 3.5 at Gemini North and 3.8 at Gemini South demonstrate healthy community engagement.

The Gemini observing process requires the submission of a Phase-II program once an observing program is approved. NGSC staff performed Phase-II reviews and related proposer interactions for U.S. Gemini proposals. Because the Phase-II submission must describe an observation completely and conform to numerous rules and conventions, few users submit a correct Phase-II initially. Usually, multiple iterations and communications with the PI are required.

NGSC organized a booth for the Washington, D.C., AAS meeting in January 2006. The booth (see Figure 4) featured displays on how to propose for Gemini observing opportunities, brochures on available Gemini instruments, and tutorials on preparing Phase-II programs. Numerous community members visited the NGSC booth.

A meeting of all of the partner National Gemini Offices (NGO) was hosted by NGSC and held in Tucson on November 29–30, 2005. This meeting focused primarily on technical discussions concerning Gemini



Figure 4: NGSC booth at January 2006 AAS.

instruments, observing, software, data reduction, and user support. Figure 5 shows the meeting participants.



Figure 5: Participants in NGSC-hosted meeting of all of the partner National Gemini Offices.

NGSC provided observing support and maintenance of the NOAO-built Phoenix high-resolution infrared spectrograph on Gemini South. NGSC staff members V. Smith, K. Hinkle, R. Blum, and A. Boogert provided Phoenix user support at Gemini South for community science programs during FY06. NGSC regularly sends staff to the Gemini telescopes to provide assistance with queue observing and for training on Gemini observing procedures. Witnessing firsthand how Gemini telescopes, instruments, and queue observing function is essential to supporting the U.S. community. NGSC staff have also participated in instrument commissioning and system verification at the Gemini telescopes. In FY06, NGSC staff helped support 111 nights of observing and/or testing at the two Gemini telescopes.

Providing U.S. Scientific Input to Gemini

The U.S. Gemini Science Advisory Committee (SAC), which serves as NGSC's community-based advisory committee, met by teleconference and had numerous e-mail discussions during FY06. The SAC met in Tucson on October 3, 2005, and were briefed by T. Armandroff and V. Smith on the status of the Gemini telescopes and instruments, the U.S. instrumentation effort, and current scientific and technical issues. The U.S. Gemini SAC discussed the current state of observing capabilities on Gemini, future opportunities, and how the priorities of the U.S. Gemini community should be enunciated. Membership of the U.S. Gemini SAC is described at <http://www.noao.edu/usgp/staff.html>. Five members from this group participated in the Gemini Science Committee meetings in La Serena, Chile, on October 12–13, 2005. T. Armandroff represented the United States at the Gemini Operations Working Group (OpsWG) meeting in

February 2006 in Hilo, Hawaii, while V. Smith attended OpsWG meeting in August 2006 in Victoria, B.C. Canada.

U.S. Gemini Instrumentation Program

One component of the U.S. Gemini Instrumentation Program consists of instruments being built or designed by NOAO for use on Gemini. Such NOAO-enabled projects are described below in the Major Instrumentation Program section of this report.

The other class of U.S. Gemini instruments consists of those being built at other U.S. institutions under an AURA contract awarded by NOAO, with NGSC technical and managerial oversight. Progress on two such instruments is described below.

- **NICI**, the Near Infrared Coronagraphic Imager, will provide a 1- to 5-micron dual-beam coronagraphic imaging capability on the Gemini South telescope. Mauna Kea Infrared (MKIR) in Hilo is building NICI, under the leadership of D. Toomey. During FY06 the final integration and testing of NICI occurred. At the close of FY06, acceptance testing was underway, with the expectation that NICI would be shipped to, and arrive at Gemini South sometime during semester 2007A.
- **FLAMINGOS-2** is a near-infrared multi-object spectrograph and imager for the Gemini South telescope. FLAMINGOS-2 will cover a 6.1-arcminute-diameter field at the standard Gemini f/16 focus in imaging mode, and will provide multi-object spectra over a 6.1×2-arcminute field. It will also provide a multi-object spectroscopic capability for Gemini South's multi-conjugate adaptive optics system. The University of Florida is building FLAMINGOS-2 under the leadership of PI S. Eikenberry. In FY06 the FLAMINGOS-2 team worked on the total integration and testing phases of the instrument. At the close of FY06, the project was 94% complete and it is expected that FLAMINGOS-2 will be shipped to Gemini South sometime in semester 2007A.

2.2 CTIO TELESCOPES

FY06 efforts were concentrated in four areas: (1) completing repairs to the SOAR telescope primary mirror support system and the start of regular science operations, (2) operating the Blanco telescope with a suite of wide-field instruments, (3) advancing the Dark Energy Survey (DES) project, and (4) facilitating the commencement of operations of the small telescopes by the SMARTS II consortium.

Blanco 4-m Telescope

FY06 began with a major engineering shutdown of three weeks, during which the primary mirror edge supports were repaired and re-positioned, and an improved design of edge support was installed for the four systems that had become detached. Subsequent tests of telescope image quality showed substantial improvements of image point-spread-function stability as a function of position in the sky, and an improvement in average image quality as judged by a before-after analysis of star images. The behavior of the primary support system is being monitored by an array of position sensors and by analysis of star images. A further system re-tuning and/or replacement of supports with the new design is scheduled for FY08.

Progress was made on several fronts relating to the Dark Energy Survey (DES) project, which plans to conduct a 5000-square-degree imaging survey on the Blanco telescope starting in 2010, using 30% of the observing time for five years to carry out a four-pronged project to study dark energy. The 500 Gpixel CCD camera (the Dark Energy Camera, DECam) and its data system, together with a new wide-field optical corrector to be provided by the consortium, would also be available as a facility instrument for NOAO users. During FY06 the design of the optical corrector passed its Preliminary Design review and was subsequently progressed to the point where glass could be ordered. DECam had a successful "Director's CD-1 review" in late FY06. DES Science Requirements and Technical Flowdown documents have been prepared, as has a Community Requirements document. Good progress was made with CCD testing, instrument design and data management system design. The latter is being tested by a series of formal data challenges being carried out at yearly intervals. The U.S. Dark Energy Task Force committees recommended that near-term medium-scale dark energy projects, such as the DES, be pursued with high priority, since future very large experiments such as LST and JDEM are 1–2 decades from completion. This recommendation, together with the positive CD-1 review result, are prerequisites for formal DOE approval, which is anticipated in FY07.

Southern Astrophysical Research (SOAR) Telescope

The SOAR partners (Brazil, Michigan State University and the University of North Carolina) raised significant capital, and NOAO committed substantial in-kind labor, for the replacement of the primary mirror lateral supports with fully active mechanisms. The project was completed on time and on schedule, and was found to be completely successful in greatly reducing the amplitude of the hysteresis in mirror deformation that took place when the telescope was moved around the sky. The mechanism design work was carried out by NOAO Tucson engineering staff. Other significant progress included baffling the telescope mirrors, which successfully removed scattered light effects and night sky light falling directly on the SOAR Optical Imager (SOI) focal plane. Following the mirror support repair, the two NOAO-provided instruments, SOI and OSIRIS, have been used for scheduled science programs during each dark-of-the-moon period. The fraction of time used for science is expected to reach 40-60% in semester 2007A as the remaining telescope subsystems are commissioned and characterized.

SMARTS Consortium and Other Small Telescopes

The Small and Moderate Aperture Telescope Research System (SMARTS) consortium completed its three-year project in December 2005. It was reborn a month later as the SMARTS II consortium, with a larger group of partners. The consortium structure was simplified to allow partners to join and leave on a semester or longer basis. The SMARTS II instrument complement and operations mode remains an attractive complement of imagers and spectrographs with classical, service and queue operational modes available. The 1.5-m telescope can be deployed with either the wide-field University of Montreal IR Imager CPAPIR or the RC Spectrograph; all other telescopes have fixed instrumentation. NOAO users averaged 25% of the scheduled time on the 0.9-m, 1.0-m, 1.3-m, and 1.5-m telescopes over the course of FY06.

The University of North Carolina Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) project consists of six small telescopes that rapidly follow-up gamma-ray bursts discovered by the SWIFT satellite and subsequently trigger a target-of-opportunity interrupt at SOAR. At other times, the telescopes will make observations as part of an extensive education and outreach program in North Carolina. The suite of telescopes began early science operations in

February 2006, with full science operations commencing six months later. The facility has successfully made GRB follow-up observations during this time.

U.S. institutions operate two other telescopes on Cerro Tololo. The University of Michigan operates the 0.6/0.9-m Curtis Schmidt telescope, now open part-time in a NASA-funded project to catalog space debris in geosynchronous orbits. The 0.4-m Lowell telescope remains closed to general users, although the Lowell Observatory occasionally operates it. Discussions were held with several other U.S. institutions regarding siting of facilities on Cerro Tololo, in particular the ALPACA project (lead institution Columbia University) that during FY06 installed a lunar acintillometer to measure the structure of ground layer turbulence above Cerro Tololo.

CTIO continued to host a Global Oscillations Network Group (GONG) station; the Swarthmore Robotic Survey camera; and the PICASSO project, operated by the University of Illinois to study the Earth's upper atmosphere and ionosphere.

Blanco Instrumentation

- **Mosaic 2:** The Mosaic imager at prime focus continues to be the most popular Blanco instrument, being scheduled for just under 50 percent of the observing time. It remains the pre-eminent wide-field optical imaging camera-telescope combination in the Southern Hemisphere.
- **ISPI:** The Infrared Side Port Imager is presently the widest field large-telescope IR imager in the Southern Hemisphere, covering 11 arc minutes square with 0.33-arc-second-per-pixel sampling at 1–2.4 microns. This complements the small-field, high angular resolution near-IR imaging capability soon to be available at SOAR, and the infrared spectroscopic instrumentation at Gemini South.
- **HYDRA-CTIO:** HYDRA is the third Blanco wide-field instrument; it can be installed concurrently with Mosaic and ISPI. It had an extensive upgrade in FY03, further attention to reliability issues in FY05 has apparently reduced the downtime of this complex instrument to the level of ISPI and Mosaic, and regular maintenance in FY06 has maintained this level of performance.
- **RC Spectrograph:** This spectrograph, still very popular, was scheduled in severely blocked mode in FY06. The Loral 3K CCD, after work in FY05 to reduce the dark count that had increased for unknown reasons, continued to behave satisfactorily. No spare is available, so longevity is a concern. The RC spectrograph is to be retired when the SOAR Goodman spectrograph enters full operation, which is not expected until semester 2007B. This retirement will allow the Blanco telescope to be operated with three fixed instruments.

SOAR Instrumentation

- **Optical Imager:** Built at CTIO, this instrument was regularly used on SOAR for commissioning and early science activities in FY05. During FY06, the instrument baffling was improved and relocation of the controller power supply to a position close to the controllers eliminated a source of fixed-pattern noise and, by removal of heavy cables, helped in the performance of the instrument rotator. SOI, together with OSIRIS, are the only two instruments available for science on SOAR.

- **OSIRIS:** The Ohio State Infrared Imager and Spectrometer, which is fitted with a CTIO $1K \times 1K$ Rockwell HgCdTe array, was moved to SOAR after several years of use on the Blanco telescope and successfully commissioned in FY05. It provides both an imaging and a modest-resolution near-infrared spectroscopy (up to $R=3000$) for the NOAO and SOAR community. OSIRIS has been in regular use for science operations during FY06.
- **Other SOAR Partner Instruments:** Three Lincoln Laboratory CCDs of the six expected were delivered in FY05 as the result of a less-than-successful foundry run involving several major observatories. After extensive testing these CCDs were declared to be non-science grade. A new detector system with Fairchild 4K CCD was purchased by SOAR partner University of North Carolina late in FY06 to be used with the Goodman spectrograph. Good progress was made at Michigan State University testing their IR imager SPARTAN, which is expected to be delivered to SOAR early in FY07.
- **SOAR Adaptive Module (SAM):** This instrument is being built at CTIO as part of the NOAO Major Instrumentation program, and is described in that section.

2.3 KPNO TELESCOPES

FY06 saw major work continue for new instruments for the observatory. For WIYN, highlights include progress on three new imaging instruments and an upgrade of its main spectrograph. For the Mayall 4-m, preparations continued during FY06 for the arrival of a major new near-IR imager in early 2007 and the public availability of the near-IR spectrograph IRMOS began. The 2.1-m continued to be maintained and upgraded, including the aluminization of its primary mirror and the first public observing run with the high-precision radial velocity spectrograph built by Jian Ge et al. of the University of Florida, the Exoplanet Tracker. Efforts continued to improve communication with the Tohono O'odham Nation, the hosts for our observatory, and to find a way forward for the VERITAS project. The effort to preserve dark skies continued in the local political arena. Instrumentation and operations partners were also secured for the observatory.

WIYN 3.5-m

Work continued to upgrade the Bench Spectrograph (part of Hydra). Led by M. Bershad (U. Wisconsin), P. Knezek (WIYN), D. Harmer (KPNO), and M. Hunten (NOAO/MIP), this major upgrade to improve system throughput and sensitivity is scheduled for completion in FY07. Major progress was made toward completing two new imagers for WIYN, QUOTA and ODI. Both will use the new technology devices with zonal fast guiding on-chip being developed by WIYN Director G. Jacoby in a collaboration with J. Tonry and the PanSTARRS group at U. Hawaii. These orthogonal transfer arrays of CCDs will enable superb delivered image quality over a wide field. A combination of WIYN partner funding and awards from the NSF (ATI and TSIP programs) has provided the funding necessary to deploy QUOTA in 2006 (first light October 8, 2006) and ODI in 2009. ODI passed its PDR in August 2006. The project scientist for QUOTA and ODI is D. Harbeck (WIYN). Finally, work continued to prepare WIYN for the arrival in June 2007, of a new high spatial resolution near-IR imager being built for WIYN by STScI, WHIRC.

A large number of maintenance and repair projects were conducted during FY06 in order to continue the high level of operations expected from the most modern telescope on Kitt Peak. These

efforts included design, fabrication and installation of a new tertiary mirror locking mechanism. Installed in August 2006, this enables the resumption of observations using the Cassegrain port.

Mayall 4-m

J. MacKenty's (STScI) IR Multi-Object Spectrograph (IRMOS) is now in operation at the Mayall 4-m telescope. IRMOS was produced for KPNO by STScI and the James Webb Space Telescope (JWST) project at Goddard Space Flight Center. The instrument employs a commercial digital micro-mirror array as a cold, programmable multi-slit mask. KPNO fabricated the optical bench and designed and fabricated the telescope mounting interfaces and handling cart. The instrument control system allows the user to image a field, design a slit configuration from the new image, dial in the grating of choice, and immediately take multi-object near-IR spectra. Our first public programs using this instrument were successfully carried out in FY06.

Work continued to prepare the Mayall 4-m telescope for the arrival of the wide-field near-IR imager NEWFIRM in early 2007. This new instrument will bring a powerful near-IR survey capability to NOAO's 4-m telescopes. Mounting this large instrument on the Mayall requires a new Cass Cage bottom to be constructed as well as the fabrication of a handling cart for installing the instrument on the telescope. These components have been designed and are now in fabrication. KPNO engineering also was heavily involved in the design, fabrication, and testing of the guider for NEWFIRM. We look forward to NEWFIRM commissioning runs January 2007.

During a late summer shutdown of the Mayall, the dome vents were painted by an outside contractor. Additional maintenance work was performed during the year. A new cooling station, necessary for NEWFIRM as well as several other instruments, is under design and will be built during FY07.

2.1-m

J. Ge and his University of Florida colleagues had several successful science runs with their innovative high precision radial velocity fiber-fed bench spectrograph. The optics project a fringe pattern from a Michelson interferometer at nearly right angles to the absorption features on the widened stellar spectrum. The recorded phase of the interference fringes is then extremely sensitive to small velocity shifts. The Florida team has been able to obtain 3.5 m/s repeatability, following a series of upgrades that provided significantly improved thermal stability. Very high throughput was achieved by acquisition of a larger diameter collimator and by implementing both beams of the interferometer. Use of the instrument on the 2.1-m now provides stable measurements on stars of 8th and 9th magnitude. In January 2006, Ge et al. reported the first planet discovered with their system in operation at the 2.1-m. Also in FY06, public programs were able to make use of this exciting instrument through an agreement between KPNO and the University of Florida. The next step in improving long-term stability is to provide an interferometer with full passive thermal compensation, very similar to the design used in the GONG network. The Exoplanet Tracker continues to be available to NOAO visiting astronomers in FY07.

Relations with the Tohono O'odham Nation and the VERITAS Project

Kitt Peak, I'olkam to the Tohono O'odham Nation, is still identified as the best site for the Very Energetic Radiation Imaging Telescope Array System (VERITAS) project. The scientific goal of VERITAS is to detect and characterize the extremely high energy gamma-rays that are produced by quasars, supernova explosions, and other compact objects by the optical flashes emitted when the

gamma-ray photons smash into the Earth's atmosphere. This project, which received high priority in the astronomy decadal survey, is led by Smithsonian Astrophysical Observatory (PI T. Weekes), and includes a consortium of universities: Purdue, Iowa State, Washington at St. Louis, Chicago, Utah, UCLA, McGill, Dublin Ireland, and Leeds in the U.K. The U.S. partners are funded by the Smithsonian Institution, DOE and NSF.

The observatory was designed to consist of four to seven 12-m (36-foot) optical imaging telescopes, each with 315 mirror segments, and a 3.5-deg field of view. The final array configuration is planned to be a filled hexagon with sides of 265 feet. The initially funded configuration consists of four telescopes. The telescope array does not need access to the horizons, but does need protection from ground-level lights. The project identified a bowl area, Horseshoe Canyon, suitable for placing the telescopes, support structures and control building.

After receiving approval to sub-lease a dedicated site of ~20 acres and beginning site preparation and telescope construction, work was halted by the NSF and DOE in summer 2005, in voluntary response to a subsequently dismissed lawsuit by the Tohono O'odham Nation requesting a halt to construction. The NSF decided to have a new Environmental Assessment and a Cultural Resources Report prepared. Both of these important efforts are now complete.

The Cultural Resources Report found that significant negative cultural impact would occur if the VERITAS project were to be brought into operation on Kitt Peak. As part of the Section 106 consultation process, the NSF began discussions with Chairwomen Vivian Juan-Saunders and other representatives of the Tohono O'odham Nation to see if a mutually satisfactory path forward for the completion of the project might be possible. A government to government meeting was held at the Schuk Toak District Office in January 2006. At this meeting (attended by the Acting KPNO Director), the NSF expressed its appreciation for the concerns of the people of the Tohono O'odham Nation and its desire to identify mitigation measures that might be of interest to the people and government of the Tohono O'odham Nation. During a subsequent meeting of the Tohono O'odham Legislative Council in May 2006, the NSF presented a mitigation plan for the Nation to consider. A response from the Tohono O'odham Nation to the written version of this plan is anticipated in October 2006 and a final decision on the future home of the VERITAS project is expected shortly thereafter.

Site Protection

The rapid growth of the Tucson metropolitan area requires a proactive approach to minimize the impact of light pollution on the operation of the observatory. In FY06, the Acting KPNO Director, B. Jannuzi made appearances at various government meetings to speak on behalf of protecting the night skies with enforcement of existing lighting codes. Jannuzi was appointed by the City of Tucson and Pima County to their respective Outdoor Lighting Code Committees in 2005 and continued to serve on these committees in FY06. Working together with other "dark skies" advocates and local citizen groups, Jannuzi worked toward a successful legal settlement (finalized in August 2006) of several long-standing disputes between Pima County and Clear Channel Outdoor, the major owner and operator of bill boards in the Tucson area. A major benefit of this settlement is that all of the lighting of Clear Channel's bill boards will be brought into compliance with the outdoor lighting code.

New Partnerships

During FY06, working with the NSF, AURA and its advisory committees, KPNO renewed its instrumentation partnership with the University of Maryland and began a new operations

partnership with Clemson University. In return for guaranteed access to telescope time, both the University of Maryland and Clemson University are providing monetary assistance and contributions in kind toward, respectively, new instrumentation for KPNO telescopes and continued operation of the Mayall 4-m telescope. These agreements are each for three years. The instrumentation agreement has already helped insure the completion of NEWFIRM and will assist KPNO/NOAO in meeting its obligation to WIYN for the ODI.

2.4 COMMUNITY ACCESS TO THE INDEPENDENT OBSERVATORIES

NOAO continues to coordinate the time allocation process for telescope time that is made available to the broad community on the large, private telescopes through the Telescope System Instrumentation Program (TSIP) and its predecessor, the Facility Instrumentation Program (FIP).

MMT Observatory and the Hobby-Eberly Telescope

In the late 1990s, NSF's Facility Instrumentation Program granted instrument funds to groups associated with the Multiple Mirror Telescope (MMT) and the Hobby-Eberly Telescope (HET). In return, the MMT Observatory agreed to schedule 162 nights at a nominal rate of 26 nights per year and the HET agreed to carry out observations equivalent to 101 clear nights at a nominal rate of 17 nights per year for telescope programs approved by NOAO's Time Allocation Committee (TAC). NOAO's role in this program is limited to the time allocation and community interface activities.

In semesters 2006A/B, NOAO received 37 proposals for time on the MMT, with requests totaling 100 nights. Overall, this amounts to an oversubscription rate of about 3.8. Ten of these 37 proposals were granted time.

Fourteen proposals for time on the HET were received in the two 2006 semesters, requesting a total of 24.5 nights. This amounts to an oversubscription rate of about 1.4 over the time available. Ten of these proposals were granted some or all of the time requested.

Keck and Magellan Telescopes

NOAO's role in TSIP includes not only the distribution of telescope time, but also the management of the annual TSIP proposal peer-review process and oversight of the instrument development activities of successful proposers. Those aspects of the program are discussed in Section 4.4 of this Annual Report.

In both 2006 semesters, time from TSIP awards was available to the community on the Keck and Magellan telescopes. In 2006A and 2006B, six nights were available on each of the Keck 10-m telescopes in each semester. For those semesters, a total of 68 proposals requesting 122.7 nights were received. The resulting over-subscription rate was about 5.1. Seventeen of these observing proposals were granted time on one of the Keck telescopes.

In the two 2006 semesters, four nights were available on the Magellan I telescope and five nights on the Magellan II telescope. NOAO received 25 proposals requesting a total of 51 nights, an oversubscription rate of 5.7. Six of these proposals were granted time.

2.5 JOINT NOAO-NASA TIME ALLOCATION

NOAO has organized several ad hoc programs to address the needs of projects that require time on ground-based telescopes associated with observations made on one of NASA's Great

Observatories (Chandra, HST and Spitzer). The goal of these arrangements is to eliminate the double jeopardy of two peer reviews for proposals that require both sets of observations to accomplish their objectives. In FY06, two Spitzer proposals and four Chandra proposals were approved for NOAO observations. No HST proposals that requested NOAO time were approved in this cycle.

2.6 NOAO SURVEY PROGRAMS

The NOAO Survey Program has been very successful, with 18 surveys undertaken since inception in 1999. The surveys tend to be multi-year projects and often are aimed at generating complete data sets. In 2003, it was realized that NOAO should make an effort to adjust its allocation of telescope time to accommodate weather and instrumental problems that survey projects have encountered in order to improve the chances of success. Consequently, no new survey proposals were solicited in 2003 or 2004. Instead, the annual meeting of survey PIs was held with the survey panel of the NOAO TAC as audience, and the PIs were asked to address the needs of their surveys for supplemental telescope time.

In January 2005, the AURA Observatories Council reviewed the survey program and endorsed its continuation. The 2006B solicitation was the second opportunity to propose since the program was restarted. Ten proposals were submitted and two were approved. The surveys selected are “The Outer Limits Survey: Stellar Populations at the Extremities of the Magellanic Clouds,” (PI: A. Saha, NOAO); and “ChaMPlane II: Optical spectra and IR imaging identification of ChaMPlane X-ray sources,” (PI: J. Grindlay, CfA).

2.7 NOAO DATA PRODUCTS PROGRAM

Following the launch of the NOAO Science Archive (NSA) in mid-2002, the Data Products Program has focused on the development of an integrated data management and processing system that will provide efficient access to NOAO data and data products for the astronomical community. The short-term goal of the program is to move from the current archive holdings—limited to data products provided by the survey teams—to the storage of all raw data from all NOAO facilities, together with the pipeline reduction of a substantial fraction of those data. The intent is to provide a new channel for access to data by making data available to the community after a proprietary period, and also to assist observers by providing a simple way to download raw or reduced data following observing runs. This end-to-end system (E2E) thus provides data transport, data safe store, and data access, and will be compatible with standards, interfaces, and tools that are being developed by the National Virtual Observatory effort. This is a large undertaking and is starting to come together at the end of FY06.

Work on the NSA in FY06 focused on design and development of Release 3, which was scheduled to be completed in late FY06, but has slipped into early FY07. This will be the release at which the “interim” NSA, put in place to serve the NOAO survey program data to the community, will be replaced by a carefully engineered, scalable archive into which data from all NOAO telescopes and instruments will flow. The approach being taken is that of a service-oriented architecture with multiple services that will be installed over a widely distributed system. The user interface of the NSA has been split off as a separate project, with the intent of utilizing Virtual Observatory protocols to enable a general-purpose portal that will provide access to data and tools, both internal and external. A prototype of the NOAO VO portal was released in January 2006, and has seen substantial public use since then.

Work on data reduction pipelines has moved from its early focus on the CCD mosaic imagers to NEWFIRM, the wide-field near-IR imager that is now under construction. This development is being undertaken with the assistance of two personnel from the University of Maryland, a scientist and a software developer. The first release of the NEWFIRM pipeline, to support commissioning of that instrument, is scheduled for early 2007. The data transport has been in operation since August 2004, and the old tape-based Save-the-Bits program has been discontinued. Raw data repositories are currently maintained in La Serena, Tucson and at the National Center for Supercomputing Applications (NCSA).

The effort that will be needed to support the routine operation of the E2E system and support community use has begun to ramp up. Help desk and bug tracking systems have been adopted, and the staff has begun to track the daily flow of data and to identify and fix problems. One item that has been eliminated is user support of IRAF through e-mail. This activity has been successfully taken over by an external group who run an IRAF community-support Web site.

3.1 NOAO INSTRUMENTS

NOAO Extremely Wide-Field IR Imager (NEWFIRM)

NEWFIRM, a world-class capability for wide-field imaging in the near infrared, is a key element in the U.S. system of facilities provided by NOAO. It has a 27×27 arcmin field of view with 0.4 arcsec per pixel at 1–2.4 microns and will operate at the R-C focus on either 4-m telescope (Mayall or Blanco). The instrument per se will be complemented by a highly automated data reduction pipeline which will feed the NOAO data archive. FY06 saw the completion of initial assembly and substantial progress on system integration and testing. Because of delays in the receipt of the aspheric lenses from the vendor (UA Optical Sciences), the instrument was assembled in January 2006 with all the spherical lenses, and with spherical null lenses in place of two of the three aspheric elements (Lenses 1 and 8), to allow testing of on-axis performance. In this configuration, and with one engineering-grade detector in the focal plane, NEWFIRM was installed on the NOAO Flexure Testing Facility (the “flex rig”) on February 7, 2006, for its second cool-down and first round of operational testing (see Figure 6). This testing successfully established that on-axis image quality was as good as expected with the temporary null lenses, and that basic image motion due to flexure was within predicted limits. The testing also provided valuable insights into performance of both the instrument and detector controllers, as well as revealing changes needed to the internal detector wiring to improve noise performance.



Figure 6: NEWFIRM installed on the NOAO flex rig in February 2006. Team members are connecting the electrical, data and helium service lines prior to startup of the instrument.

Following this test, NEWFIRM was removed from the flex rig, warmed up and opened for rework and reassembly. Shortly after disassembly, Lenses 1 and 8 were received from UA Optical

Sciences. Lens 1 meets specifications in all regards except central thickness, and this deviation can be accommodated with a simple spacing adjustment. Lens 8 meets specifications overall but suffers from localized regions of troublesome high-frequency surface errors. Because the specifications for this type of error were not sufficiently stringent, it was decided to accept this lens from the vendor for use during further instrument testing, but also to immediately order a replacement lens from another vendor, using more stringent and carefully defined specifications for localized surface errors. These were installed in the optics housing, and a double-pass interferometric test was performed on the complete optical system (see Figure 7). This test showed straight fringes, indicating that the optical system was properly aligned as built and that no further rework of the lens mounts was needed beyond one minor and quickly implemented focus correction to the spacing of Lens 8. This test, however, was relatively insensitive to the localized surface errors on Lens 1, which are expected to produce significant variations in the PSF shape and size across the field of view. Successful completion of this test was the major milestone required during disassembly.

As FY06 ended, NEWFIRM was being reassembled for its first full-field optical testing. This test will use the full set of optics presently in hand. It will also use a fully-populated focal plane, although two of the four detectors are not science-grade arrays. Improved cold wiring harnesses for the detectors, obtained from a highly-qualified vendor, will also be incorporated, along with improvements to the power supplies and grounding for the controllers. The next cool-down is expected to begin in late October 2006, with full-field testing following immediately thereafter. The replacement Lens 8 is expected from the

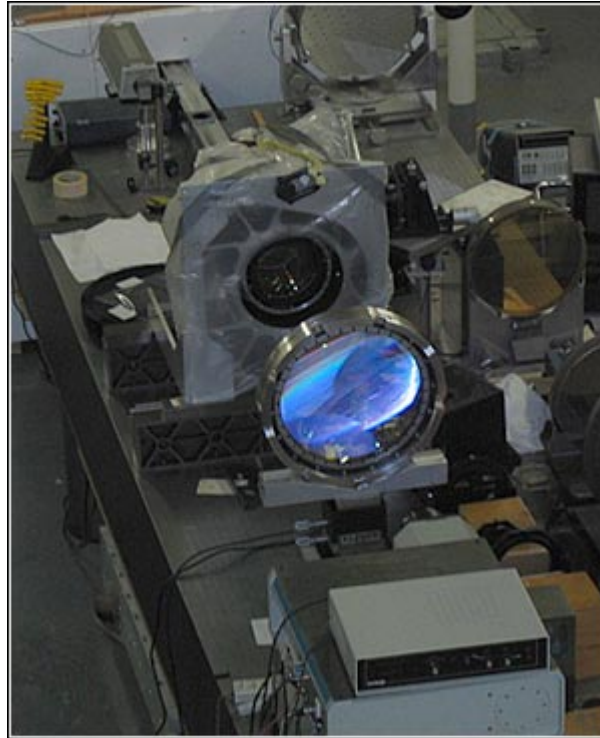


Figure 7: NEWFIRM's optical system undergoing interferometric bench testing. The main housing is partially wrapped in plastic sheeting for cleanliness. Lens 1, on a separate mount in front, shows a reflection of the optician in the blue anti-reflection coating.

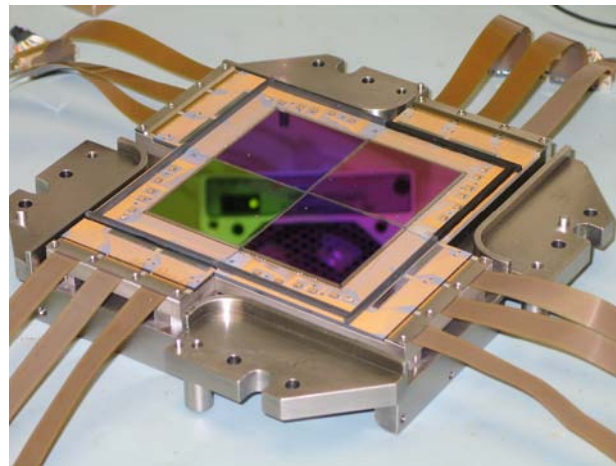


Figure 8: The fully assembled NEWFIRM mosaic focal plane, adjusted to co-planarity with less than 50 microns peak-to-valley surface error. The color differences are due to variations in the anti-reflective coatings between detector production runs and do not affect array performance in the infrared. The small whitish dots are the sites where photon-emitting defects were removed, and the resulting holes were filled in with opaque paint to prevent light from reaching the multiplexer.

new vendor (Tinsley) by the end of October 2007, and it will be installed in NEWFIRM after the completion of this next cold testing cycle. The NEWFIRM team anticipates one or possibly two further cycles of cold testing after installation of the replacement Lens 8.

Raytheon Vision Systems (RVS) made little progress on the production of ORION II $2K \times 2K$ InSb detector arrays for NEWFIRM in FY06. By early FY05 they had completed four of the twelve hybridization attempts called for under the foundry run contract. One of the four resulting devices proved to be science grade despite a minor problem with the anti-reflection coating applied. RVS encountered some problems late in FY05 with the repeatability of certain process steps, and further work was halted while the process was evaluated and the contract renegotiated to deal with the extra costs imposed. Two further hybridization attempts were carried out during FY06, but unfortunately both attempts failed to produce working devices. Different process errors not seen in previous attempts resulted in irreparable damage to the arrays. At the close of FY06, NOAO was again in negotiations with RVS for changes to the assembly protocols to reduce the risk of damage in the remaining hybridizations.

Electronics and software developments continue to proceed well and are not pacing the schedule. Also, the NOAO Data Products Program and the University of Maryland continued working jointly on the data handling system and data reduction pipeline to enable rapid scientific use of the large volume of data expected from NEWFIRM. This joint effort has completed the initial design and specification of both the data handling system and the pipeline, and work is underway now on producing the code modules that will be needed for delivery to the telescope. Some work on the data pipeline will necessarily have to wait until commissioning, for complete identification and removal of the instrumental signature and complete identification of all data products needed for both real-time observing support and later archival research.

Barring any major, unexpected problems in the remaining rounds of cold testing, NEWFIRM should see first light on the KPNO Mayall telescope in late January 2007.

SOAR Adaptive Optics Module (SAM)

The SOAR 4.2-m telescope on Cerro Pachón will produce very high quality images over a field of view 10 arcminutes square. The SOAR Adaptive Optics Module (SAM) is designed to enhance this image quality by correcting the turbulence in the first 5–10 km of atmosphere, reducing the image size by half during appropriate atmospheric conditions, which are expected to be available about half the time. SAM will incorporate a UV laser guide star working in Rayleigh backscatter mode, with laser pulses and shutter timings coordinated to select the altitude of the reflection used for the wavefront correction. SAM is being implemented in two overlapping phases: the first phase for the main Adaptive Optics (AO) module, and the second phase for the Laser Guide Star (LGS) system. The main AO module will be commissioned first and can be used for some limited science applications in natural-guide-star mode prior to delivery of the LGS.

The SAM project held a formal Preliminary Design Review in early December 2005. This review covered only the main AO module including the science channel. The LGS system was at a conceptual level only, and work on this system was deliberately deferred for about one year to level out the workload and budget for the project. The review panel was very impressed with both the quality of the design and the advanced state of work on the main AO module. The panel recommended proceeding full speed as recommended by the team, and they also called attention to several issues that warranted further consideration by the design team. The team addressed those

issues in a series of System Design Notes, and adopted one significant recommendation of the panel to change from glass to aluminum mirror substrates for the off-axis paraboloids (OAPs).

All optical components for the main module were ordered during the second half of FY06, and the flat optics—folding mirrors and dichroics—were received for testing prior to the end of the fiscal year. The OAPs and the lenses for the wavefront sensor camera are proceeding on schedule and are expected in the first quarter of FY07. The team is proceeding with detailed design of the main module mechanical components, releasing the drawings to the shop for fabrication as they are completed. The La Serena instrument shop began work on the first components in July 2006.

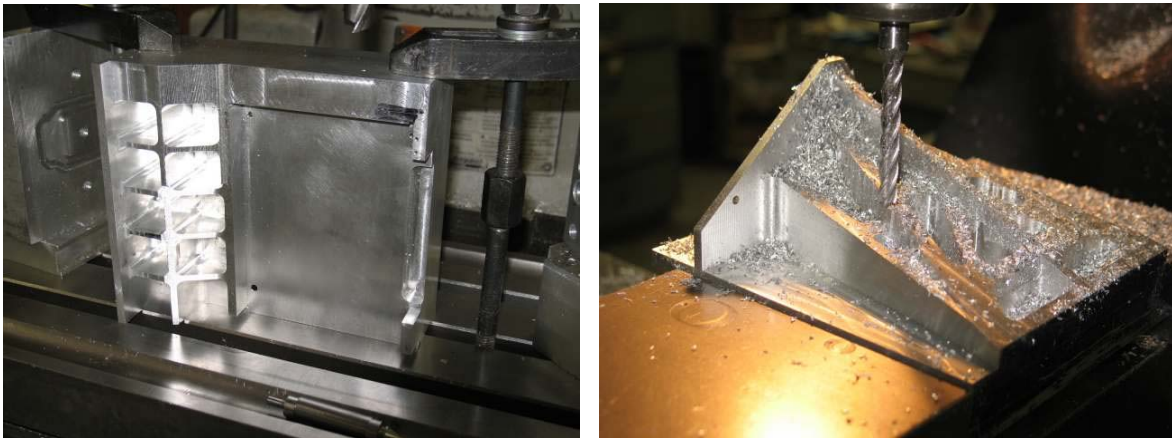


Figure 9: First opto-mechanical components for the SAM main module being fabricated in the La Serena Instrument shop. Note the large number of complex angle cuts required for these optics mounts.

Late in FY06, the team began developing the design for the LGS system, including the laser launch telescope, the beam transfer optics and the identification of suitable commercially available UV lasers. The team currently intends to hold a Preliminary Design Review for the LGS system during the first half of FY07. The main AO module should be delivered to the SOAR telescope late in calendar year 2007, and the LGS system should follow in late 2008.

MONSOON Detector Controller

The MONSOON image acquisition system is the NOAO solution for scalable, multi-channel, high-speed image acquisition systems required for next-generation projects. Monsoon is designed to be flexible enough to support CCD, CMOS and IR diode imaging arrays in a wide variety of uses, including science instruments, acquisition and guide cameras and wavefront sensors. It is under development jointly by staff at both NOAO North in Tucson and NOAO South in La Serena. FY05 saw the delivery of CCD controllers to the Dark Energy Camera consortium for their detector characterization and design development work, to WIYN for their QUOTA testbed instrument, and to Indiana University for their FHIRE instrument. An IR controller was delivered to Space Telescope Science Institute for the WHIRC instrument (coming to WIYN).

Continued development work on the CCD version led to the first use of the MONSOON system for controlling Orthogonal Transfer Array (OTA) CCDs in the QUOTA system. QUOTA is a small-scale testbed instrument for WIYN, in preparation for the full-scale One Degree Imager

(ODI) instrument. Software and firmware for OTA control were developed jointly by staff from the Major Instrumentation Program and WIYN Observatory.

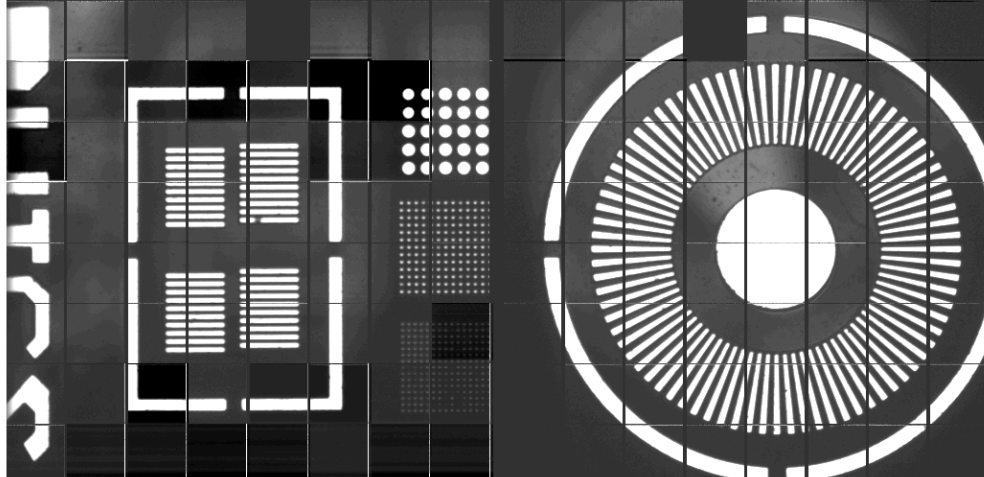


Figure 10: Early lab test image from the QUOTA instrument, with two of the four OTA CCDs installed. The dark gridlines are boundaries between the individual OTA cells; each OTA CCD has 64 such cells in an 8×8 pattern.

Late in FY06, the MONSOON system received two significant endorsements. The first was a recommendation by a review panel for the Dark Energy Camera project (DECam) that they continue to use MONSOON systems as their baseline controller design. The panel spoke highly of the maturity, reliability and extensibility of the MONSOON design. In keeping with the “open source” philosophy of development, the DECam team will themselves develop the specific modifications they need for their instrument and share their designs with the rest of the MONSOON community through the MONSOON Web-based distribution system moderated by NOAO. The second endorsement was a formal adoption by WIYN of MONSOON as the controller for their ODI instrument, and the approval of that decision in the ODI Preliminary Design Review. The staffs of WIYN and the Major Instrumentation Program will continue working together to perfect the OTA control algorithms and to reduce the space and power requirements of the hardware. The QUOTA instrument, with its MONSOON controller, should see first light on WIYN early in FY07. ODI is currently scheduled for delivery to the WIYN telescope late in FY08 or early in FY09.

4.1 AURA NEW INITIATIVES OFFICE (NIO)

Based in Tucson, the AURA New Initiatives Office (NIO) is charged with “ensuring broad astronomical community access to a 30-meter-class telescope that will be contemporaneous with ALMA and JWST, by playing a key role in scientific and technical studies leading to the creation of the Giant Segmented Mirror Telescope (GSMT).”

In FY06, NIO efforts focused on: (1) support of the activities of the Giant Segmented Mirror Telescope Science Working Group, a broadly-based group charged with providing advice regarding investments in a GSMT that will achieve the goal of community access to a 30-m class telescope by the middle of the next decade; and (2) active participation in the technical and scientific working groups critical to advancing the TMT concept during its Design and Development Phase. The following highlights additional FY06 accomplishments in specific areas.

Staffing

The NIO team is staffed primarily by NOAO engineers and scientists, many of whom have extensive experience with Gemini, WIYN and SOAR. Several members of the NIO staff are now based in Pasadena, holding key positions—Optics and Systems group leaders and Observatory Scientist—in the TMT Project Office.

Web Site

The NIO public Web site at <http://www.aura-nio.noao.edu> is an essential vehicle for communicating ongoing NIO activities, including the many technical studies completed by NIO staff, collaborating institutions and subcontractors. The Web site, which is updated periodically, also contains copies of project presentations and links to the sites of other Extremely Large Telescope (ELT) groups.

GSMT Science Working Group (SWG)

The NIO created a community-wide GSMT Science Working Group (SWG) in response to a request from the National Science Foundation. The charge to the SWG is to “advise the NSF Division of Astronomical Sciences on a strategy for guiding federal investment in a Giant Segmented Mirror Telescope (GSMT).” Rolf-Peter Kudritzki, Director of the Institute for Astronomy at the University of Hawaii, is the chair of the GSMT SWG, with NOAO’s Steve Strom as vice-chair. In FY04, the SWG presented the conclusions of its first major report, “Frontier Science Enabled by a Giant Segmented Mirror Telescope,” to the Astronomical Sciences Division of the NSF and to the Committee on Astronomy and Astrophysics (CAA). This report, which is available at http://www.aura-nio.noao.edu/gsmt_swg/SWG_Report/SWG_Report_7.2.03.pdf, recommends vigorous NSF investment in the GSMT technology development program.

In summer 2005, the GSMT SWG was charged with developing an understanding of the scientific performance of ELTs as a function of telescope aperture. Over the past year, the SWG has carried out a number of simulations for key ELT science programs aimed at quantitative understanding of performance versus aperture and determining whether there are any obvious “cliffs.” Preliminary drafts of the essential elements of the report were reviewed in August 2006. The goal is to complete a draft in early 2007 and to present the report to the NSF in spring of 2007.

The SWG continued to provide a public forum for discussion of technical progress and scientific capabilities of the two ongoing U.S. ELT programs: Giant Magellan Telescope (GMT)

and Thirty Meter Telescope (TMT). The SWG has also enjoyed high-level representation from the Japanese astronomical community. Several investigations of the GSMT SWG were supported by NIO staff members, who carried out technical, performance simulation and project planning studies.

Thirty Meter Telescope (TMT) Partnership

In May 2003, Letters of Intent to participate in a joint Design and Development of a 30-m class ELT were signed by AURA, the California Institute of Technology, the University of California, and the Association of Canadian Universities for Research in Astronomy (ACURA). The four partners have agreed to refer to the joint effort as the Thirty Meter Telescope (TMT) project.

The Letters of Intent state that each party will solicit funding from appropriate agencies to support the Design and Development phase of the TMT project. The California Institute of Technology and the University of California—which together have formed the California Extremely Large Telescope (CELT) Development Corporation—have received funding in the amount of \$35M from the Moore Foundation, while ACURA has been awarded funds from the Canadian Foundation for Innovation (CFI). AURA-NIO submitted a proposal to the National Science Foundation that would provide for its share of the Design and Development Phase for TMT as well as support for an alternate ELT concept. Partial funding of this proposal in FY05 and FY06 has provided funding both for TMT and the Giant Magellan Consortium.

Participation by AURA in TMT provides a strong voice for the U.S. community in shaping the design of the telescope and ensuring that its capabilities meet community aspirations. The TMT partners have agreed that all federal investment in TMT will result in access for the U.S. community.

The TMT partners have established an Interim Board of Directors, on which NOAO director J. Mould serves, and a Science Advisory Committee (SAC), on which S. Strom, J. Najita and J. Jensen (Gemini) are the AURA representatives, while Charles Telesco (University of Florida) serves as a community representative through AURA. The SAC is charged with developing and updating a Science Requirements Document and interacting with the TMT project office as cost-risk-performance trades are identified during the Design and Development Phase.

AURA Proposal to NSF

The July 2004 proposal submitted by AURA to NSF requested \$39.4M to provide:

1. The public portion (\$17.5M) of the funds needed to carry out the Design and Development Phase for a 30-m diameter segmented-mirror, optical/infrared telescope (i.e., TMT).
2. Funds (\$14M) sufficient to advance to the Design and Development Phase an alternative 20–30-m-class concept, such as the Giant Magellan Telescope (GMT), to the point where its performance, cost and risk can be assessed.
3. Technology development (\$2M) common to both TMT and the alternative concept.
4. \$1.5M for community groups to carry out conceptual designs for two instruments: one for TMT and one for the alternative concept.
5. \$3.5M to support an education and public outreach program.
6. \$0.9M to support a Theory Challenge program aimed at engaging theorists in shaping the design of ELTs.

The first of these investments leverages the \$35M in non-federal funding (donated by the Moore Foundation to the California Institute of Technology and the U. of California), plus funds requested of the Canadian Foundation for Innovation (CFI), and will enable AURA to participate fully on behalf of the U.S. community in a partnership to advance TMT.

The second major investment supports a design study aimed at developing an alternate technical approach. Following review of two proposals from the community, a review panel was selected for support of the Giant Magellan Telescope (GMT), a concept that provides the collecting area of a 21.5-m telescope by combining the light from seven 8.4-m mirrors. The GMT project is a partnership among the Carnegie Institution, Harvard/Smithsonian, the U. of Arizona, the U. of Michigan, and the Massachusetts Institute of Technology.

AURA will ensure strong community participation by both observers and theorists in shaping each of the ELT designs—both via the GSMT SWG and through the TMT SAC—so that the resulting facility performance fully meets community aspirations. This approach will allow AURA to keep apprised of the progress of both ELT programs in order to maximize transparency of technical studies, and to ensure that the imagination and technical talent in the U.S. community is fully engaged in developing key technologies and instrument concepts.

This joint approach has a precedent: NSF support of mirror technology in the 1980s, technology development that eventually led to the successful development of the Keck, Magellan, MMT, LBT, and Gemini telescopes. In this case, however, all of the NSF funding will result *directly* in community access to these telescopes. Moreover, the adaptive optics and detector technology will benefit the current generation of 6–10-m telescopes.

Initial funding in the amount of \$1M was received at the end of FY05. An additional \$2M was received during FY06. These funds are split between TMT and GMT in accordance with the proposal described above, on behalf of the U.S. community.

Site Testing for the Thirty Meter Telescope

Starting with a Memorandum of Understanding (MOU) with the California Extremely Large Telescope (CELT) group in FY02, AURA has played a major collaborative role in evaluating candidate sites for TMT. The work is now ongoing as a major work package for the TMT Project. The list of candidate sites has been narrowed by investigations of logistical issues such as land ownership, as well as by a series of remote sensing studies that have used satellite data to quantify the number of clear nights and the precipitable water vapor for each site. Each prime candidate site has also been modeled using computational fluid dynamics to investigate the boundary layer turbulence over the site under various wind speeds and directions.

In-situ site testing equipment has been developed, and multiple copies have been purchased and assembled. This equipment includes weather stations, differential image motion monitors (DIMMs) capable of recording integrated seeing through the upper atmosphere and ground-layer, and multi-aperture scintillation sensors (MASS) capable of mapping turbulence profiles above candidate sites. Weather stations, DIMM and MASS units have been deployed on 5 candidate sites.

TMT Work Packages

During FY06, NOAO staff made major contributions to technical development activities key to the successful completion of the Design and Development Phase for TMT. Specific work packages include:

- Designing of a Mid-Infrared Echelle Spectrograph (MIREs) in collaboration with U. Hawaii, U. C. Davis, Naval Research Laboratory, and other institutions. This feasibility study was completed in March 2006.
- Developing a Design Concept for the Laser Guide Star Facility, leading up to Conceptual Design Review in March 2006, and subsequently assisting in preparing detailed cost estimates for the TMT Cost Review, which was held at the end of September 2006.
- Developing the conceptual design for the mirrors, support systems, cells and positioners for the secondary and tertiary mirrors, which were reviewed in February and March 2006.
- Providing additional support for the Optics group, including assistance in preparation of detailed cost estimates for the telescope optics and auxiliary equipment for the TMT Cost Review.
- Providing support for the Systems Engineering group, particularly in the area of integrated modeling.
- Providing support for the Observatory Scientist's activities.

FY06 Technical Papers by NIO Staff and Affiliated Gemini and NOAO Staff

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Chun, M. R., J. Elias, B. Ellerbroek, T. Bond, M. Liang, R. Clare, A. Tokunaga, M. Richter, L. Daggert, "MIRAO: a mid-IR adaptive optics system design for TMT", [Proc. SPIE Vol. 6272](#), 62720S, Advances in Adaptive Optics II; B. L. Ellerbroek, D. Bonaccini Calia; Eds., July 2006.

Clare, R. M., B. L. Ellerbroek, J. -P. Véran, G. Herriot, D. Andersen, "Sky coverage and tip/tilt error analysis for TMT", [Proc. SPIE Vol. 6272](#), 627232, Advances in Adaptive Optics II; B. L. Ellerbroek, D. Bonaccini Calia; Eds., July 2006.

Daly, P. N., R. E. Marshall, M. J. Sirota, R. C. Jared, "Software control of the 3 active surfaces of the Thirty Meter Telescope", [Proc. SPIE Vol. 6274](#), 62740F, Advanced Software and Control for Astronomy; H. Lewis, A. Bridger; Eds., June 2006.

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4.2 LARGE-APERTURE SYNOPTIC SURVEY TELESCOPE (LSST)

The Large-aperture Synoptic Survey Telescope (LSST) is one of three major new ground-based facilities recommended for construction during the coming decade by the AASC. It has also been recommended as a high priority by two additional NRC decade surveys: one dealing with the interface between physics and astrophysics and the other with solar system exploration. A report by the Office of Science Technology Policy (OSTP) highlighted LSST as one of three high-priority facilities for characterizing dark energy.

The LSST Corporation, of which NOAO is a founding member, now has sixteen member institutions, double the number reported last year, and more applications are pending. Interest in joining has also been expressed by several European organizations. The chief officers of the project continued in their positions: John Schaefer from Research Corporation is President, the Director is

Tony Tyson of UC Davis, and Don Sweeney from LLNL is project manager. Zjelko Ivezic (U. Washington) was recently appointed systems scientist. (See http://www.lsst.org/lsst_home.shtml)

The project scientists and project managers for the three major components of the project are Steve Kahn and Kirk Gilmore (Stanford/SLAC) for the DOE effort to design the camera (Kahn is also the Deputy Project Director), Chuck Claver and Victor Krabbendam (NOAO) for the telescope and associated facilities (Krabbendam is also the deputy project manager for the entire LSST project), and Tim Axelrod (Steward Obs.) and Jeff Kantor (LSSTC) for data management. Near the end of FY05, the proposal for the design and development phase of the project was funded by the NSF. The goal of the project is to complete a construction proposal during the winter of CY06–07.

The science requirements for the LSST are now documented and under change control. The optical design provides a 3.5-degree FOV, and the fabrication plan currently being analyzed by the U of A involves casting the primary and tertiary mirrors together as a single monolith. Private funding has been raised in order to initiate the casting of the M1/M3 monolith. Private funding is key to early acquisition of items requiring a long lead time and hence to achieving the goal of first light at the end of CY13.

Cerro Pachón has been selected as the site for the LSST.

A team based at NOAO is responsible for telescope construction and site development. A baseline design has been established for the telescope and enclosure, and costs have been estimated. A draft of the NOAO section of the construction proposal was nearly complete by the end of FY06.

NOAO staff have worked closely with Kem Cook, Phil Pinto and others to develop an observing simulator that can be used to model various observing strategies along with the observing conditions at Cerro Pachón in order to determine the feasibility and compatibility of the various science goals. The work on the simulator is being shared with the PanSTARRS project, which will use the existing software as the basis for developing a tool to schedule observations.

Science collaborations, which are small groups of people working on specific scientific problems that will be addressed with LSST, have been established under the leadership of Michael Strauss. Initial membership on the dozen or so groups created to date was limited to scientists at member institutions and/or people who have done substantial work already on LSST. An opportunity for members of the community to apply for membership will be announced in the winter of CY06–07.

The project remains committed to open access to data with no proprietary period.

4.3 NATIONAL VIRTUAL OBSERVATORY (NVO)

Creation of a National Virtual Observatory (NVO) was the highest ranked priority initiative of the National Academy of Sciences decadal survey in the small project (less than \$100M) category. NOAO has been involved with the development of the NVO from its inception and has continued to play a significant role as this project has moved from the conceptual to the development stages and finally towards operations.

In FY06, the contributions from NOAO to the NVO continued at both the management and programmatic levels. D. De Young continued as a member of the NVO Executive Committee and as the Project Scientist of the NSF/ITR NVO initiative. De Young is also a member of the Executive Committee of the International Virtual Observatory Alliance (IVOA) and a member of the IVOA Theory Working Group. In FY06, De Young was elected to Deputy Chair of the IVOA.

D. De Young, C. Miller and M. Fitzpatrick comprised three of the twelve faculty members at the third NVO Summer School held in Aspen, CO. In addition to the NOAO faculty, H. Lanning and P. Warner were accepted into the NVOSS 10-day intensive program as students. Lectures

taught by the NOAO NVOSS faculty included topics on infrastructure, science and overviews of the current state of the NVO. NOAO NVOSS faculty members are currently dedicating time towards an NVO textbook based on the lectures given at the three NVO Summer Schools. The textbook is scheduled for completion in FY07. M. Fitzpatrick is one of the three editors of this textbook.

The NOAO Data Products Program deployed its revised NOAO NVO Web page (<http://www.nvo.noao.edu/>). The Web page acts as a portal to all NOAO NVO-related efforts. At nvo.noao.edu, users will find software libraries written by NOAO staff for using the VO (e.g., C. Miller's IDL VOlub client library), Web-based applications designed and implemented under the guidance of the NVO Science Steering Committee (e.g., M. Fitzpatrick's IRAF-based WCSFixer), Web-form access to NVO standard services currently deployed at NOAO (e.g., the NOAO Science Archive Simple Image Access Service and catalog Cone Search Services), etc. The WCSFixer service has become a very popular tool and allows user to upload an image and retrieve a revised World Coordinate System (WCS) based on a star-catalog of their choice. The tool is fully browser-based and contains tutorials and examples.

Also available through the NOAO NVO Web portal is the proto-type NOAO NVO Portal. The NOAO NVO Portal is a browser-based tool that enables users to visually discover, access and analyze data that exist under VO-compliant access points. The NOAO NVO Portal was debuted at the January 2006 AAS meeting and has been active since. DPP Operations was responsible for deploying and operating the Portal and the NOAO NVO Web page, and they monitor user statistics, which indicate that roughly 10–20 unique users per day access the NOAO NVO Portal. The Portal provides a “Google-maps” style front-end, where users see instrument wire-frames distributed across the sky. The Portal currently provides access to NOAO Science Archive images, HST, Chandra, XMM, CNOC, and the SDSS DR3 archive. Users can select data from multiple archives with the simple click of a mouse and download multi-archive datasets from one centralized location. The Portal also provides a time (calendar) view, so that users can also see when data were taken. Finally, the Portal provides a direct link to NVO analysis services, like the WESIX source extraction tool and the NOAO WCSFixer tool.

The NOAO NVO Portal debut at the January 2006 AAS included a security interface demonstration. This was a coordinated effort between DPP staff (A. Cooke, A. Egana and C. Miller) and NCSA staff (R. Plante and R. Williamson). This VO security effort continues to move forward in its collaborative development and will become a backbone of both the NOAO Science Archive (i.e., access by NOAO community astronomers) and the NVO (i.e., wider community usage).

In FY05, the NVO Research Initiatives program announced small (\$25K) research grants on a peer-reviewed basis to members of the astronomy community who wish to carry out NVO-based research or to develop NVO-related software programs. Out of the 15 awards, two were made to NOAO staff members (C. Miller and R. Seaman). Other NOAO staff members are active co-investigators on two separate awards (D. Gasson, C. Smith and P. Warner).

NOAO hosted the VO Event II workshop in Tucson in December 2005. This workshop focused on interoperability with the GCN, LSST science operations, SNe alerts, among many other timely subjects. R. Seaman was the meeting organizer. NOAO staff members also attended the International Virtual Observatory Alliance (IVOA) interoperability meetings in Victoria, Canada and Moscow, Russia. NOAO staff members continue to regularly attend NVO Technical Working Group meetings and telecons.

4.4 TELESCOPE SYSTEM INSTRUMENTATION PROGRAM (TSIP)

The Telescope System Instrumentation Program (TSIP) had its fifth annual cycle in FY06. TSIP has the goal of strengthening the system of public and private optical/IR facilities by funding the development of facility instruments for large private telescopes, and thereby broadening community access to these telescopes. The program was established in FY02 as a \$4M per year program administered and coordinated by NOAO for NSF. In May 2004, NOAO held a community workshop to discuss the status and plans for the ground-based O/IR system of facilities. One of the goals of this workshop was to review the status of TSIP and to update the guidelines and instrument priorities. The recommendations, which include efforts to broaden the program by allowing proposals to improve instruments or operations, and to encourage proposals from smaller telescopes, were incorporated into the FY05 and FY06 solicitations. The complete report of the workshop is available at http://www.noao.edu/meetings/system2/system2_report.pdf. The next System Workshop—which may well have an impact on future cycles of TSIP—is planned for November 2006.

The solicitation for the FY06 cycle was issued in October 2005, and six Letters of Intent to propose were received in December 2005. Five proposals were received by the deadline at the end of February 2006. For a second straight year, only \$2M of new funding was provided for TSIP in FY06. Although previous cycles had committed \$760K of future TSIP funding, none of that commitment was due in FY06. The five proposals requested a total of just over \$8M. A peer review panel, chaired by C. Pilachowski (Indiana U.), included individuals with appropriate instrumental and scientific expertise. This panel reviewed the four proposals in April 2006 and recommended funding two of them: one for a new focal plane camera for IMACS, an optical multi-object spectrograph on the 6.5-m Baade (Magellan) telescope; and one to complete the design and fabrication of MOSFIRE, a multi-object near-infrared spectrograph for the Keck-1 telescope. T. Boroson and C. Pilachowski presented the panel recommendations to NSF/AST on April 26, 2006.

The Magellan sub-award will provide 15 additional community nights on the Magellan telescopes starting in semester 2007A. The Keck sub-award will provide 48 nights on the Keck telescopes starting in semester 2007A.

Throughout FY06, T. Boroson and M. Trueblood participated in management oversight activities for the instrumentation projects funded in previous TSIP cycles. These activities included monthly reports (both written and via teleconference) from the projects MMIRS, MOSFIRE, ODI, and MODS. In addition, Boroson and Trueblood attended the PDR of MOSFIRE and Trueblood attended the PDR of ODI.

4.5 ADAPTIVE OPTICS DEVELOPMENT PROGRAM (AODP)

Following the successful model of the Telescope System Instrumentation Program, the Adaptive Optics Development Program (AODP) was established in 2003 to advance technologies critical to the development of AO systems on future- and current-generation large telescopes. NOAO was asked by the NSF to take responsibility for: (a) developing and updating an AO “road map” aimed at identifying areas critical for investment, (b) setting up a Web site for the program and issuing the first program description/proposal solicitation (<http://www.noao.edu/system/aodp/>), (c) assembling the external peer-review panel and process for evaluating received proposals, and (d) monitoring progress against plan of awarded projects.

Six awards for development programs spanning three to five years duration were made following a community-wide solicitation of proposals. The awarded programs include two efforts to develop low-noise detectors for wavefront sensors, two to develop reliable sodium lasers, one to develop advanced deformable mirrors, and one to develop new wavefront sensing algorithms. The funded groups are all making satisfactory progress. NOAO staff involved in tracking the funded projects include S. Ridgway, S. Strom, and Technical Manager, D. Eklund.

Reviews of a second cohort of proposals were completed during FY05. However, owing to an interregnum in funding for AODP, no awards were made. With the promise of additional funding from NSF, we expect to make additional awards based on the priorities recommended by the independent review panel.

5.1 EDUCATIONAL OUTREACH (EO)

NOAO's Educational Outreach group is responsible for managing and developing the national observatory's efforts in formal and informal science education. NOAO EO programs train teachers and astronomers to communicate scientific research principles and the latest discoveries in astronomy to pre-college students. The EO group also supports the Research Experiences for Undergraduate programs at Kitt Peak and Sacramento Peak, and helps facilitate graduate and post-graduate opportunities at KPNO and CTIO.

FY06 highlights in educational outreach included the worldwide success of GLOBE at Night, the first "Astronomy From the Ground Up" workshop, and the national impact of Hands-On Optics.

Teacher Leaders in Research-Based Science Education

In FY06, the NOAO Teacher Leaders in Research-Based Science Education (TLRBSE) program completed its phased three-year transition to core funding in the NOAO budget, as mandated by the NSF Education and Human Resources (EHR) grant that established the program. The program is now more tightly focused on its primary objectives of the acquisition of astronomy content knowledge by teachers and bringing astronomical research to the classroom. We have also expanded our repertoire of teacher/student research projects.

The 2006 cadre of 18 teachers came from 12 different states, and included one African-American and one Native American teacher. The cadre completed a 14-week distance learning course and then met in Tucson for a very successful, culminating two-week summer workshop covering astronomy content, research protocol, mentoring, and leadership. They spent four nights on Kitt Peak observing with four different telescopes, and each research group presented their results on the final day of the workshop.

The RBSE journal, our research journal for students whose teachers have completed this program, continues to receive a large number of submissions. These papers are based on the research projects the teachers have instigated in their classrooms, as well as some related projects, including the Spitzer student and teacher research project, which is available to TLRBSE program graduates. The acceptance rate for the journal is considerably lower than in professional astronomical journals, but all teachers and students receive detailed feedback on their submissions.

In order to reach a wider audience, the research projects from TLRBSE are being placed on the NOAO Web site, with documentation and scaffolding activities. The novae search project and the variable star spectroscopy project are now online, with Kitt Peak data and analysis software available to any student. The other projects (in the areas of solar magnetic fields and AGNs) are expected to be online shortly (see <http://www.noao.edu/outreach/tlrse/>).

This was the third year of the follow-on TLRBSE program known as the Teacher Observing Program (TOP), where teachers and small groups of students can propose to make observing runs for unique research projects at KPNO. The proposals accepted were of continuing high quality. A TOP student who observed with the 0.9-m WIYN telescope won first place in the SciEnTeK-12 Foundation High School Space Science category for an individual project at the Southern Arizona Regional Science and Engineering Fair (SARSEF) in Tucson, and another student won at the state level in Connecticut.

Four TLRBSE-related workshops were held at the National Science Teachers Association meeting in San Diego in April 2006. Successful alumni of the program made presentations at each of our workshops, which were uniformly well-received.

The NOAO-SSC Spitzer Space Telescope Teacher and Student Observing program continued into a second round this year, with the selection of six new teachers from across the country. These teachers are working with NOAO Goldberg Fellow Greg Rudnick on a project involving galaxy clusters. All of the Spitzer teachers (the first cadre of 12 teachers, plus this second cadre) met for a workshop at the January 2006 AAS meeting in Washington, where research results from the projects were also presented. Additional follow-up observing time for Spitzer teacher projects from the first round were approved by the Spitzer Science Center director, and for the new project led by Rudnick, following submission of a successful proposal in February. Several teacher-student groups visited Pasadena to work on data reduction and analysis.

The Astronomical Society of the Pacific awarded its annual Thomas J. Brennan Award, for excellence in the teaching of astronomy in grades 9–12 to Thomas Morin of Belmont High School in Belmont, NH, who is a TLRBSE teacher from 2003. Tom is the third TLRBSE teacher to receive this prestigious education award.

Project ASTRO/Family ASTRO

The trio of ASTRO programs at NOAO were productive throughout the entire year. After a Family ASTRO training workshop on “Night Sky Adventures” on October 1, 2005, participants tested their newly learned activities with the public and enjoyed viewing the night sky from a dark site location at Pima Community College West. The event’s featured speaker, Dr. Richard Poss (Steward Observatory), spoke on the historical and cultural intrigues of southwestern Native American archeoastronomy. A similar training model was used for the Moon Mission workshop on September 10, which featured Dr. Steven Croft as the guest speaker who gave an intriguing historical perspective on missions to the Moon. FY06 closed with the Family ASTRO training workshop “Race to the Planets” and FY07 will open with “Cosmic Decoder.”

Early in October 2005, PAEO hosted the annual two-day Project ASTRO-Tucson training workshop, partnering astronomers with teachers new to the program. Held at the University of Arizona, the workshop trained the partners in a dozen hands-on activities, mostly on the solar system. Two motivational high points were a talk by well-known comet hunter/author David Levy, and a nighttime trip to Kitt Peak National Observatory.

On February 4, 2006, participants in Project ASTRO and Family ASTRO were treated to a very special workshop at the home-based observatory of David and Wendee Levy. The highlights of the evening’s activities included a poetry reading by poet laureate of Tucson and MacArthur Fellow, Dr. Ofelia Zepeda, on astronomy as seen through the eyes of the Tohono O’odham. A new NOAO-created activity called “Constellations at Your Fingertips” introduced participants to easy-to-make, glow-in-the-dark constellations to help children find them in the night sky. Participants were also shown how to make Rico Tyler’s frugal telescope and given essential parts.

A total of 22 new teacher-astronomer Project ASTRO partnerships were formed in FY06, directly impacting an estimated 5,650 students in Tucson and surrounding communities. An estimated 158 Project ASTRO partnerships are currently active.

NOAO has trained more than 60 Family ASTRO event leaders to date, with the expectation that each will conduct at least one event for their communities. Family ASTRO training in 2006 is still pending; the eight trainees in the 2005 Family ASTRO included the star party coordinator for the local Tucson amateur astronomy club, another staff person from Pima County Parks and Recreation, an employee of Raytheon who is also an amateur astronomer, a graduate student in astrophysics from UA, and a teacher from Tucson Unified School District. Input from applicants and trained event leaders indicates that Family ASTRO materials are being used in creative ways to

augment public star parties, school science nights and public programs at local attractions such as Arizona-Sonora Desert Museum and Pima County Parks and Recreation, in addition to more standard Family Astro after-school events.

The annual Site Leaders Meeting for Project and Family ASTRO was held in Hilo, Hawaii, in March 2006. In addition to presenting an update report on behalf of the Tucson site, NOAO site leader C. Walker was part of a team that gave a talk on how to better align Project ASTRO activities with state science standards.

ASTRO-Chile

The NOAO ASTRO-Chile effort (funded jointly with Gemini Observatory) reached a new level of maturity in FY06 with the first full year of centralized budgeting and strategic planning, and the dedication of the Centro de Apoyo a la Didáctica de la Astronomía (CADIAS) in Chile, a small ranch house in Altovalsol that now serves as a local community science outreach center and library.

Another major landmark in ASTRO-Chile activities occurred during an NOAO outreach staff visit to La Serena in early December 2006, when C. Walker and Antonietta Garcia (Gemini Observatory) presented two bilingual Family ASTRO workshops for about 20 Chilean and Argentinian teachers and planetarium staff: one workshop was on the Moon and the other on the night sky.

The ASTRO-Chile educational videoconference series developed its most original curriculum to date, with the formulation, fine-tuning and field testing of a new comparative remote-sensing activity for bilingual science students at middle and high school grades in Tucson and their counterparts in Chile. Launched in mid-March 2006, the activity had students identifying features in satellite images taken first of their own location and then of the other location. In April, the students acted as rovers, taking pictures from the ground for students in the other location based on e-mail communications.

The capstone event was a special student-to-student ASTRO-Chile videoconference between NOAO North and South in Tucson and La Serena on May 12, 2006. A half-dozen schools with a couple hundred students in Chile participated over the months of February, March and April. About 50 of those students were in attendance in the AURA-Gemini conference room in La Serena. There have been five teachers with almost as many students in Tucson. Twenty-six students attended the videoconference in the Tucson main conference room, with all but one of their five presentations given in Spanish.

The remote sensing activity allowed students to become better acquainted with the geography and geology of their own areas, while experiencing the chance to interact directly with fellow students in another hemisphere. This creative activity was written by NOAO astronomer and instrument engineer R. Probst, with guidance and testing led by C. Walker and H. Ochoa in PAEO.

Late in the year, the small telescope dome at CTIO known as “El Enano” was relocated temporarily to CADIAS, thanks to a donation from Las Cumbres Observatory and W. Rosing. Over the next two years, this dome and a 14-inch telescope will be moved to the nearby Cerro Mayu Observatory and automated for Web-based access for outreach in both hemispheres.

Hands-On Optics

The NSF-funded ISE “Hands-On Optics” has finished the creation of all six optics modules under the leadership of project Co-PI S. Pompea, who was appointed project director early this year, C.

Walker, who supervises the kit creation effort at NOAO, and R. Sparks, who conducts the professional development efforts nationwide with Walker.

The NOAO HOO team conducted professional development workshops this year at the California Science Center, Lawrence Livermore National Labs, Maryland Science Center, New Mexico (Albuquerque), Colorado (Longmont), 'Imiloa Astronomy Center of Hawaii (Hilo), the SPIE meeting in San Diego, Chabot Science Center (Oakland), Orlando Science Center, and in Tucson, for Arizona MESA after-school program teachers. In a major effort, a commercial vendor was identified through a competitive RFP process for assembly and further distribution of the kits at professional development workshops. A significant local extension of the project was created by adding Hands-On Optics as a core program at two Boys & Girls Clubs—one in the city of South Tucson and the other in Sells on the Tohono O'odham Nation. These efforts required flexible reprogramming of HOO materials for a younger audience, and are challenging in terms of ongoing coordination and travel support.

HOO mini-workshops were also conducted as part of NOAO's involvement in the NSF-funded "Astronomy from the Ground Up" project, and the program was featured in an invited talk at the biannual International Conference on Education and Training in Optics and Photonics. The HOO program has reached more than 12,000 students over the past three years.

Other Educational Outreach Programs

Astronomy from the Ground Up

"Astronomy from the Ground Up" (AGFU) is an NSF informal science education (ISE) project with the Astronomical Society of the Pacific (ASP) and the Association of Science Technology Centers. Twenty-two outreach staff members from the western United States were hosted by NOAO and Kitt Peak from April 19–21, 2006, as the attendees at the first face-to-face workshop of the AFGU project. In a special effort by NOAO, the attendees received "mini-kit" versions of kits from the NOAO-SPIE-OSA Hands-On Optics program. The workshop included training in binoculars and solar projection from ASP President Dennis Schatz of the Pacific Science Center. Past ASP Director Andy Fraknoi and NOAO astronomer (and past ASP President) Katy Garmany modeled for the group techniques and demonstrations to teach about extrasolar planets and other cutting edge astronomy current events. Other activities included tours of the major telescopes at Kitt Peak National Observatory, and using the Visitor Center Observatory's 20-inch telescope to stargaze at night.

GLOBE at Night

More than 18,000 citizen-scientists in 96 countries submitted 4,591 observations of the darkness of their local night skies by looking at the constellation Orion during the 10-day GLOBE at Night event in March 2006. PAEO staff presented a poster on these impressive results of the GLOBE at Night program at the June 2006 AAS meeting. Widespread news coverage of this rousing success included the [New York Times](#) Science section, the [Honolulu Star-Bulletin](#), page 1 of the local section of the [Arizona Daily Star](#), and a "Slacker Astronomy" Podcast. GLOBE at Night is a collaboration between The GLOBE Program; the National Optical Astronomy Observatory (NOAO) in Tucson, AZ; Centro de Apoyo a la Didáctica de la Astronomía (CADIAS) in Chile, funded partly by NOAO and Gemini; Windows to the Universe; and Environmental Systems Research Institute, Inc. (ESRI).

Tohono O'odham Outreach

K. Garmany taught her third class in Introductory Astronomy at Tohono O'odham Community College (TOCC) in Sells, AZ. Eight students completed the class, which met twice a week. TOCC is now accredited by the NCA, and students can transfer to Pima Community College, or the University of Arizona. At the request of TOCC, she also served on an advisory committee as they prepared a proposal to the NSF Tribal Colleges and Universities Program, supported by a letter from NOAO.

A special effort to take the Hands-On Optics (HOO) program to the Sells Boys & Girls Club over the summer of 2006 was very well received. On the last day, the club program director asked for a show of hands among the three dozen children in attendance of how many kids had participated in the HOO program, about 90 percent of the children raised their hands. She then asked how many would be interested in having the program continue, likewise, 90 percent of the children raised their hands. In addition, the NOAO HOO team participated in a special optics event at Pisinemo, in association with the Tohono O'odham "Truck of Love" summer day camp.

Garmany served as a Project ASTRO astronomer for a 7th grade class at Baboquiviri Middle School in Topaya. She visited them several times, and the class visited Kitt Peak on a field trip. She also served as a judge for the annual Tohono O'odham rodeo parade in February.

EO Meetings and Events

The NOAO educational outreach and public outreach groups co-hosted four booths with numerous activities from Hands-On Optics and Project ASTRO at the 4th Annual Math, Science, and Technology Funfest at the Tucson Convention Center. Held in conjunction with the yearly Southern Arizona Regional Science and Engineering Fair (SARSEF), FunFest brings together scientists and elementary through high school students to share in the wonders and excitement of science. During the March 2006 FunFest, NOAO hosted three sessions each day on different Hands-On Optics (HOO) themes, and co-sponsored a fourth. Between the four sessions (The Essence of Luminescence, Hit the Target, Kaleidoscopes, and Telescopes), more than 1,700 students and 400 adults participated over the three days. The secret ingredient that made the sessions successful were the 16 volunteers: nine from NOAO staff, five students working with the HOO program, and two Tucson teachers involved with NOAO's outreach programs.

For the third consecutive year, EO staff (C. Walker, S. Croft, and S. Pompea) represented NOAO at the winter American Geophysical Union meeting, leading three sessions in December 2005 on teacher professional development programs that promote authentic research in the classroom. Eight talks were given in each of two oral sessions and 24 posters in one poster session. The varied topics underscore the remarkable breadth of EO scientists: astronomy, seismology, oceanography, geology, polar research, physics, environmental science, as well as, evaluation methodologies, special needs programs, and handling large data sets. Two of the NOAO EO staff (C. Walker and S. Croft) chaired three sessions, with all three staff each giving a presentation in the oral sessions on various aspects of the either TLRBSE or the LSST EO program. For more detailed information on the three AGU sessions, see <http://www.noao.edu/education/agu/>.

Investigating Astronomy

The "Investigating Astronomy" NSF instructional materials development (IMD) project with TERC and the ASP remained very active this year with S. Croft playing a key role in the review and critique of the content of this new national high school, standards-based, astronomy curriculum. Croft has played a key role in the project in the choice of astronomical imagery,

image processing tools and other software tools in this curriculum for modules 4–6. NOAO also led Spanish translation of key developmental materials.

Collaborative to Advance Teaching, Technology, and Science (CATTS)

NOAO continued its participation in FY06 in CATTS (with S. Pompea serving as project Co-PI) with three NOAO GK-12 Fellows during this fiscal year. Janelle Bailey and Erin Dokter served as CATTS Fellows from May 2005 to May 2006 conducting outreach on astronomy and optics with Tucson teachers. Janelle has now taken a faculty position at University of Nevada-Las Vegas in science education. Erin is completing her PhD in astronomy education at the University of Arizona, but remains active with NOAO in her outreach work with the Boys & Girls Clubs.

New GK-12 Fellow Brenae Bailey began work in May 2006 for a one-year term. She is a PhD candidate in the Department of Mathematics at the University of Arizona. She brings an undergraduate degree in astronomy to the program and is helping add math connections to projects such as Hands-On Optics, in addition to her outreach work using the GEMS guides.

LSST Educational Outreach

In FY06, S. Croft conducted a detailed examination of the concept of follow-up observations of LSST asteroid detections as a possible student-teacher research venue for LSST outreach, including consultation with the leading experts in the field of asteroid research and a variety of local teachers. The results of this effort (which included an exploratory teacher workshop at Kitt Peak, poster presentations at four major science meetings, networking with leading asteroid science experts, and a curriculum outline) show that asteroid characterization is a valid theme to pursue for middle school students, with the potential to become a signature formal education program of LSST EPO.

Research Experiences for Undergraduates (REU)

(<http://www.noao.edu/kpno/reu/> and <http://www.ctio.noao.edu/REU/reu.html>)

NOAO continued its long-standing participation in the NSF Research Experiences for Undergraduates (REU) program, preparing future generations of professionals who will sustain U.S. preeminence in astronomy and contribute to a scientifically-literate nation. NOAO North scientist K. Mighell is the site director for the KPNO REU summer program in Tucson; NOAO South research associate S. Kafka is the head of the CTIO program in La Serena.

Over the FY06 summer, the six undergraduate students in the KPNO program (including three females and one Hispanic) worked closely with NOAO Tucson staff for a 10–12 week period, developing skills as scientific researchers and furthering their professional development.

In the winter of FY06, CTIO hosted six U.S. REU students and three Chilean undergraduates under the similar *Prácticas de Investigación en Astronomía (PIA)* program. (Three more REU students worked with staff of the National Solar Observatory, with direct logistical support from PAEO staff.)

Large color posters highlighting the REU program at KPNO and CTIO were displayed in the NOAO exhibit booth at the winter and spring AAS meetings, respectively, along with new recruitment fliers that were sent in two separate mailings to hundreds of leading universities.

The opportunity to present original research findings at the most important national meeting of U.S. astronomy is one of the most prized benefits enjoyed by REU students in NOAO site programs.

Students from the KPNO and CTIO 2005 program did so at the January 2006 meeting of the American Astronomical Society (AAS) in Washington, DC, including Mark Keremedjiev (see Figure 11). Mark has just started his graduate studies at the University of Florida, where he joins two former KPNO REU students pursuing their doctorates in astrophysics (Cynthia Gomez-Martin and Valerie Mikles).

Astronomy Education Review (AER)

The *Astronomy Education Review* (AER), a refereed online journal at <http://aer.noao.edu/>, is now in its fifth year of operation. The goal of the journal, which is edited by S. Wolff and A. Fraknoi (Foothills Community College), is to disseminate research about astronomy and space science education, along with innovative ideas for classroom use, resource lists, reviews, and commentary.

By every metric, the journal has been extremely successful. In FY06, it continued to receive a steady stream of papers from well-known leaders in the field of astronomy and space science education and from instructors with innovative ideas who are working in a variety of institutional settings. The papers are being read, as indicated by the statistics for the Web site. During the school year, the journal has received as many as 250,000 hits in a month. One-third of the subscribers are from 92 different countries outside the U.S. The online articles cover a wide range of topics, from elementary to college-level education, including the teaching of students with disabilities. As we hoped, the journal is serving a diverse audience.

The most recent issue provides a round table discussion of the debate about Pluto, emphasizing how to use the controversy as a teachable moment. The previous issue had articles on podcasting as a method of astronomy outreach, the use of clickers in the classroom, a summary of the science standards in all 50 states, resources and ideas for working with the visually impaired, and a list of music related to astronomy. S. Wolff was awarded the Education Prize by the AAS, in part, as recognition for her work in creating the journal.

We have approached both the AAS and the ASP about taking over the journal and providing a secure, long-term home for it. The AAS has recently established an ad hoc committee to evaluate whether or not to assume responsibility for AER. We will also approach NASA and/or the NSF for bridge funding to keep the journal in operation while the transition to one of the professional societies is being explored and, we expect, implemented.

5.2 PUBLIC OUTREACH

NOAO's Public Outreach group manages all activities at the Kitt Peak Visitor Center, including the center's educational exhibits and retail operations, three daily tours of Kitt Peak observatories, the Kitt Peak docent program, and the popular fee-based nighttime observing experiences for both the general public and advanced amateurs.



Figure 11: Mark Keremedjiev (REU) at January 2006 AAS.

Kitt Peak Visitor Center

The world-famous Nightly Observing Program (NOP) at Kitt Peak expanded into a third telescope building in April 2006, with the complete refurbishment of the Roll-Off-Roof building near the Burrell Schmidt observatory at KPNO, including a new 16-inch RC Optics telescope. Meanwhile, three new solar refractors donated by Meade/Coronado Telescopes were installed in the old Razdow dome as part of efforts to expand sky-viewing opportunities for daytime visitors at Kitt Peak.

The formal Kitt Peak membership group for the public, initiated in FY05, grew to over 100 members in FY06. This program (\$35 individual, \$55 family) entitles the member to special discounts, a newsletter, and a members-only star party, among other benefits.

Weathercaster Chuck George of KOLD ABC-TV in Tucson, did three live broadcasts from Kitt Peak on October 26, 2005, showing live images of Mars to the largest local television news audience in Tucson at 10 P.M., and interviewing D. Isbell and R. Wilson of NOAO PAEO about Kitt Peak public nighttime programs and how to best view the red planet this winter.

Special events on Kitt Peak were anchored by Dr. Adam Showman of the Lunar and Planetary Laboratory/University of Arizona and the Tucson Girls Chorus.

Public Outreach staff worked out an agreement with a local transportation company to offer a fee-based public shuttle service to Kitt Peak during the day and at night for the popular NOP; no funds come to NOAO.

Public outreach-related improvements to the Visitor Center and mountain facilities included a new historical construction photo display for the 2.1-m telescope lobby, new botanical signs around the mountain, exterior fiberglass signs for the sun dial and sun clock on the Visitor Center patio, a new external information kiosk, new safer floors installed in all three public outreach observatories, and the start of the design process for a revitalized telescope mirror exhibit, scheduled for completion in 2007.

Other Public Outreach

NOAO staff arranged and conducted numerous special tours, talks and booths for schools, university groups, and film and video production companies in FY06, including Congressman John Culberson (R-TX), Universo Television, the Travel Channel, a freelance writer for Tucson

Kitt Peak Visitor Center FY06 Program Attendance and General Visitors [vs. FY05]	
Guided Public Tours	12,326 [13,422]
School Groups K-12	529 [1,220]
Special Tours	104 [23]
Nightly Observing Program	6,136* [6,504]
Advanced Observing Program	268 [274]
Total General Visitors (est.)	60,000 [63,000]

* Note: Lost 81 NOP nights due to bad weather in FY06, compared to 68 in FY05. Visitation levels were also hurt by high gasoline prices and major delays on Route 386 due to road construction and resurfacing.

Weekly and Inside Tucson Business newspapers, the Pima County Educator Fair, the University of Arizona Elderhostel, the new Laurel Clark Earth Camp (honoring the late NASA astronaut), and a week-long astronomy day camp conducted by public outreach staff and organized by Arizona Youth University–University of Arizona and attended by 14 high school students.

Articles highlighting the beauty of Kitt Peak and the appeal of its public outreach programs appeared in the Arizona Republic, the Arizona Daily Star, *Astronomy* (May 2006 issue), CNN.com, the September/October issue of SkyWest/Delta Airlines magazine, and the St. Paul (MN) Pioneer-Press.

PAEO public outreach staff worked with the Tucson Airport Authority to secure an extended run of 3-foot by 8-foot banner space in the luggage claim area of the airport, again at no charge. This colorful and attractive second-generation banner advertises Kitt Peak and its public programs to hundreds of arriving passengers per day.

Coordination with the External Community

NOAO Public Outreach Manager R. Fedele authored major articles in *Dimensions*, the magazine of the Association of Science-Technology Centers, titled “Sharing the Science: Public Outreach at Kitt Peak,” and *Legacy*, the publication of the National Association of Interpretation (NAI), titled “Bringing the Stars to Earth.” Fedele also completed formal NAI certification as a master interpreter.

PAEO staff again continued to contribute significantly to the Southwestern Consortium of Observatories for Public Education (SCOPE), attending the meeting at McDonald Observatory in February to discuss future cooperation in Hands-On Optics, and designing a new tourist marketing brochure for the group.

5.3 MEDIA AND PUBLIC INFORMATION

NOAO’s media and public information group coordinates news releases, media events and visits, fact sheets, posters, the NOAO Newsletter, and other visual products that explain NOAO’s latest research and organizational activities. It also coordinates NOAO’s public Web presence and external use of NOAO imagery, and serves as the primary response point for public inquiries and general e-mails.

Media Activity

NOAO issued 14 formal press releases in FY06, and worked extremely closely with the Gemini Observatory, the Spitzer Science Center, Vanderbilt University, the University of Florida, and LSST Corp. on several others (see Table below).

Media highlights of the year included:

The first press briefing of the January 2006 AAS meeting in Washington, DC, (likely the largest astronomy meeting in history) focused on the latest news about black holes, including results from a team led by Kambiz Fathi (Rochester Institute of Technology) based on data from the Gemini Multi-Object Spectrograph (GMOS) on the Gemini South 8-m telescope. This result was covered by Reuters wire service (widely reprinted around the world), *ScienceNOW*, SpaceDaily.com, Space.com, PhysOrg.com, and many others.

Jian Ge (University of Florida) was part of a lively press briefing panel at the January 2006 AAS on exoplanets, where he announced the first planet to be discovered by “ET”—the Exoplanet Tracker instrument in use at the 2.1-m telescope and Coudé feed at Kitt Peak National Observatory. At the June AAS meeting in Calgary, Knut Olsen of NOAO reported results about the core of M31 using adaptive optics near-infrared images of the core obtained with Gemini.

A combination WIYN-Hubble Space Telescope image of M82 was the cover of the December 2005 issue of *Discover* magazine.

News stories about NOAO, NSO and Kitt Peak appeared regularly in the Arizona Daily Star.

PAEO Associate Director D. Isbell was interviewed by KOLD-TV Tucson for stories on the new solar cycle and the controversy over the re-classification of [now] dwarf planet Pluto.

**NOAO Press Releases Issued in FY06
And Associated Media Coverage**

<u>ID</u>	<u>Date</u>	<u>Title</u>	<u>Media Coverage/Highlights</u>
05-10	11/04/05	<i>Kitt Peak National Observatory Visitor Center Offers New Public Membership Program</i>	Arizona Daily Star
05-11	12/06/05	<i>Galaxy Collisions Dominate the Local Universe</i>	ScientificAmerican.com, New Scientist.com, and Space.com (reposted at MSNBC.com and USATODAY.com)
05-12	12/21/05	<i>Flashes from the Past: Echoes from Ancient Supernovae</i>	United Press International, Space.com (reposted at MSNBC.com), and numerous science news Web sites in Europe
06-01	1/09/06	<i>Huge Images Show Majestic Beauty and Violence of Large and Small Magellanic Clouds</i>	“Astronomy Picture of the Day,” Space.com “Image of the Day,” back cover of <i>StarDate</i> magazine
06-02	1/09/06	<i>Dissecting Light from Ancient Stellar Explosions</i>	SkyandTelescope.com, Astronomy.com
06-03	1/10/06	<i>Rapidly Spinning Star Vega has Cool Dark Equator</i>	Science, Sky&Telescope, Space.com
06-04	1/10/06	<i>Spitzer Reveals Unexpected Disks Around Interacting Stars</i>	<i>Astronomy</i>
~	1/11/06	<i>Exoplanet Tracker Discovers Young Star with Planetary Companion (U. FL release with NOAO artwork)</i>	(More than 100 news and Web sites around the world, including Australia, the Netherlands and many in China)
06-05	1/25/06	<i>NOAO Astronomer Sidney Wolff Awarded Education Prize by American Astronomical Society</i>	Tucson Citizen
06-06	3/02/06	<i>Go Star Hunting with the “GLOBE at Night” Program—March 22- 29</i>	<u>New York Times</u> Science section, the <u>Honolulu Star-Bulletin</u> , page 1 of the local section of the <u>Arizona Daily Star</u> , and a “Slacker Astronomy” Podcast

**NOAO Press Releases Issued in FY06
And Associated Media Coverage**

<u>ID</u>	<u>Date</u>	<u>Title</u>	<u>Media Coverage/Highlights</u>
06-07	3/08/06	<i>Image of Cometary Globule Marks 1,000 Online at NOAO</i>	“Astronomy Picture of the Day,” NewScientist.com
~	3/15/06	<i>Magnificent Failures: Brown Dwarf Pair Measured by Gemini Observations (Gemini + Vanderbilt releases)</i>	<u>Milwaukee Journal-Sentinel</u> , United Press International, NewsScientistSpace.com, ScienceNow, ScienceDaily.com, UniverseToday.com
06-08	4/24/06	<i>GLOBE at Night Reaches More Than 18,000 Participants on Six Continents</i>	<u>New York Times</u> Science section, the <u>Honolulu Star-Bulletin</u> , page 1 of the local section of the <u>Arizona Daily Star</u> , and a “Slacker Astronomy” Podcast
LSSTC-04	5/17/06	<i>Cerro Pachón Chosen for LSST</i>	<i>Physics Today</i> , <u>Tucson Citizen</u> , <u>El Mercurio</u> , <u>El Día</u> , and Chilean national TV stations
TMT 06-01	6/01/06	<i>Thirty Meter Telescope Passes Conceptual Design Review</i>	<u>Le Figaro</u> , <u>El Mercurio</u> , the <u>Pasadena Star-News</u> , and <i>Physics World</i>
06-09	8/1/06	<i>Discovery of the Nearest L Dwarf: The Intrinsically Faintest Object at Visual Wavelengths Known Beyond Our Solar System</i>	Astronomy.com, SpaceRef.com, SpaceFlightNow.com
~	6/05/06	<i>Gemini Probes the Center of Andromeda Galaxy with Unprecedented Clarity (Gemini US-Canada joint release)</i>	Space.com, NewScientist.com
0 06-10	8/3/06	<i>NASA Funds Development of Destiny: The Dark Energy Space Telescope</i>	<u>Arizona Daily Star</u>
0 06-11	9/14/06	<i>New Transportation Service to Kitt Peak: Adobe Shuttle of Tucson to Provide Shuttle To/From Kitt Peak</i>	

Special Information Products

Public Affairs produced a variety of special posters, brochures, and handouts in FY06, including spectacular exhibit-sized color images of the Large Magellanic Cloud and Small Magellanic Cloud from the MCELS survey team, new graphics to explain supernovae light echoes, original artwork to illustrate the first exoplanet found at Kitt Peak (with the ET instrument) and a Spitzer-TLRBSE result about interacting binary stars, a poster on the design of the calotte dome for TMT, a color handout on CTIO instrumentation updates, an exhibit poster on LSST site testing, a panoramic poster of KPNO, a Spanish language LSST brochure, and a new bilingual postcard with an image of cometary globule CG-4 taken by the Blanco telescope.

PAEO staff worked with UA Space Grant Student Intern Shiva Kiani to conduct archival research and prepare text, photos and video for the upcoming 50th anniversary of KPNO in 2008.

This included a special effort with S. Andree to digitize fading still photo frames of the construction of the 158-inch (later Mayall 4-m) telescope and turn them into a movie, as well as a new historical poster series and a dozen audio history interviews.

Web-Based Outreach

NOAO continues to present a timely and lively public “face” on the Internet, changing the featured image on the main home page 34 times in FY06, and adding 26 images to the popular NOAO Image Gallery.

D. Isbell and M. Newhouse began serving as the primary editor and Web designer, respectively, of a new monthly electronic newsletter on the Thirty Meter Telescope project, the TMT “Newscast” (<http://www.tmt.org/newsletter>), sent to more than 3,000 recipients.

New Web sites were created for LSST.org and the Community Access Telescope Clearing House (CATCH), part of the O/IR System. The Web pages for the AURA New Initiatives Office received a major redesign.

Images from NOAO telescopes were highlighted 11 times on the popular “Astronomy Picture of the Day” Web page and were featured six times on the Space.com “Image of the Day.”

NOAO Web pages had 2.84 million unique visitors from October 2005 through September 2006, resulting in 16.5 million page views and more than 66 million hits (+6 million over the previous 12 months).

Image and Information Requests

More than 1,525 individual requests to use NOAO images for commercial and non-commercial applications were processed in FY06 (+425 over FY05), including approved requests for use in calendars, amateur astronomy software packages, children’s educational magazines, textbooks, and popular books. Over 8,250 mailings were sent out last year, as well as countless individual responses to requests for information on astronomy and our public programs received via telephone, e-mail and walk-ins.

5.4 EDUCATION AND PUBLIC OUTREACH AT NOAO SOUTH

Ongoing Efforts to Control Light-Pollution in Northern Chile

Last year’s success story involving Monte Patria, which is now the first municipality in Chile to fully comply with the DS686 (“Norma Lumínica”) legislation, has continued. The funding committed by the central government to eleven municipalities in the 4th region—in which Gemini South, SOAR and (in the near future) LSST are located—has now been made available and a call for tender has gone out to industry to provide the approximately 14,000 shielded luminaries to replace the existing, strongly polluting installations. It is hoped that the work will be done by the end of 2007 which will mean that more than 80 percent of all outdoor fixtures in the 4th region will have been upgraded and comply with DS686.

In La Serena, the main threat to the dark skies above the observatories, at 45 km distance, and a major source of light pollution, has been fixed: 420 projectors of 400 Watts each along the beach have been shielded and emit much less light toward the sky, as can be seen in the before and after pictures shown in Figure 12.

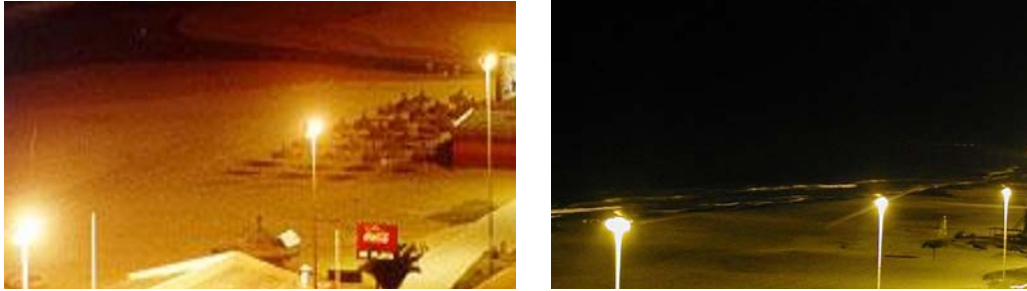


Figure 12: Avenida del Mar in La Serena before (left) and after (right) the installation of the shields.

The continuing problems with the gas supply to Chile from neighboring Argentina and general worries about increasing energy costs has helped this process through programs such as “Programa País de Eficiencia Energética” of the Ministry of Economics, which aims to make energy use in Chile more efficient. Outdoor lighting is a very “visible” part of this effort and lowering the installed power helps combat light pollution. Many official organizations such as CONAMA (the Chilean EPA) and the National Committee for Energy are now much more aware of the problems of light pollution and efficiency. Even the electricity utilities are under pressure to save energy, which also aids our light control efforts

The efficiency issue also strengthens our efforts to add maximum permitted illumination levels to the present legislation, which is in the process of its regular five-year revision. We are working with experts from the Catholic University of Valparaiso (UCV) to make this a practical and easily verifiable addition to the revised version of the DS686 legislation, thereby closing a potentially damaging loophole.

In the three astronomically active regions in Chile, the use of double-ballast luminaries is on the increase, too. These units switch to a lower power level at a time that can be set by the municipality, saving 40 percent of energy and reducing the light levels by about 35 percent from that time onward. Huasco (3rd region) and Monte Patria (4th region) are prime examples of the use of this modern technology.

Working with the OPCC* and the UCV, we have designed and built proto-type devices to measure the mounting angle of luminaries to help the relevant authorities to check the correct and legal installation of these fixtures.

Overall, the level of implementation in the north of Chile of the DS686 now stands at 75%, taking into account the 11 municipalities in the 4th region. We will continue our efforts and push toward 100% by the end of 2008!

* OPCC is the Office for the Protection of the Night Sky in Northern Chile sponsored by the observatories and CONAMA.

6 COMPUTER INFRASTRUCTURE AND NETWORK SERVICES

6.1 TUCSON

The downtown Tucson computing facilities continue to evolve as older systems are replaced by newer systems that are more cost-effective and easier to maintain, while providing enhanced services (higher processor speed and increased disk storage) to our computer users. In general, we try to replace our “core” facilities every 3 to 4 years. In particular, new rack-mounted systems running FreeBSD were installed in FY06 as our e-mail/DNS server (noao.edu), our FTP server (<ftp.noao.edu>), and our DHCP and syslog server (logs.tuc.noao.edu). Scheduled for early FY07 are replacements for the Web server (<www.noao.edu>) and a new system to provide a “bastion host” for remote logins via ssh and SSL VPNs.

The infrastructure in the Tucson computer lab was continually upgraded to meet the demands of computer installations for the various groups and projects within NOAO Tucson. In FY06, one new equipment rack was installed in the computer lab and a power controller was installed commissioning a second 50 kVA power feed into the lab.

The network infrastructure in the downtown Tucson office building was upgraded in FY06 to increase performance and reliability. The backbone of the network (an Extreme Networks Black Diamond 8810 switch) was expanded with more GigaBit Ethernet ports (allowing Gigabit connections to scientists’ and engineers’ desktops) and with redundant management and power modules to insure continued operation in the face of hardware failures. During FY06, a program was started to replace all the wireless access points in the building with HP 420 units to vastly increase reliability. At the end of FY06, preparations began to replace (in early FY07) the Ethernet switch supporting the Engineering building with a switch supporting Gigabit connections to desktops and a 3 Gigabit “backhaul” speed to the network backbone.

Efforts to improve the security and robustness of our network continued in FY06. On the e-mail front, we are currently blocking about 4500 Spam and virus messages per day (up by about 40% from FY05); Spam and virus messages constitute about 20% of our incoming e-mail.

6.2 KITT PEAK

The computer infrastructure at Kitt Peak was relatively stable for the past year. At WIYN the main control computer (“bone”) was upgraded to a system running Fedora Core 4. The new system also has an IPMI port, which allows for full remote system management. Other upgrades to mountain systems in the past year consisted of new disks and additional memory.

Several downtown development systems were put in place and are used to develop and test software and to evaluate new operating systems. Some of these machines occasionally travel to the mountain for testing. A Linux system was prepared to become the main 2.1-m observer computer, and will be installed at a Fall T&E. It will replace “lapis”, which moves to the computer room as a dedicated acquisition computer to be controlled via VNC.

The WWV/IRIG-B system at the Admin. building was retired and is no longer used by the nighttime telescopes. The time is now set by GPS and NTP.

At WIYN, scripts were installed to backup critical files on a daily basis using “rdist” to a downtown system. Also at WIYN, a computer inventory Web page was written that contains system descriptions and images.

In the next year, several new computers will be installed at WIYN to support instrument commissioning efforts for QUOTA and WHIRC. Other work on the mountain computer

infrastructure in the next year will be the ongoing upgrades of systems, disks, memory, and operating systems.

6.3 NOAO SOUTH—LA SERENA & CERRO TOLOLO

Our operating budget was significantly reduced from previous years, but with careful planning we have completed the year with a very slight overrun: mainly due to late charges by AOSS that were unforeseen. The CISS group personnel has remained unchanged and continues to accept new challenges. The mix is consolidated into three main groups: two System administrators, two Network administrators, one Windows administrator and a technician.

The main thrust of our efforts this last year has been on providing better network tools and diagnostics. Our centralized monitoring systems have enabled us to provide rapid response to problems, with someone on-call 24/7. We continually remain abreast of technology to provide a better service to the Users and upgrade our systems as funds become available. The newest addition is Netflow on our Gateway that enables us to fine grain monitor and account for packets to and from NOAO South. If ever we need to tax bandwidth, the tools are in place to accommodate this.

La Serena

We replaced our Intel commodity network to one utilizing Reuna infrastructure to Santiago and then Telmex to the U.S. Primarily we opted for a 2Mb circuit, but statistics showed that this needed to be upgraded to 4Mb, which has thus far satisfied users. However, with the onset of student season this may be inadequate.

Fedora has proved a reliable and secure OS but we continue to evaluate other systems. Our kickstart system currently installs FC2 on new systems, but we do have individual machines with FC4 and 64-bit architectures. As Scientists rotate, the old machines are replaced in the REU farm and modern machines purchased for the new Scientist. Thus we are able to maintain an approximate shelf-life of 5 years for most workstations in CTIO.

The LaCie terabyte disk-based User backup system we put in place will shortly be replaced with a 2U rack mount with 750GB Seagate drives. The LaCies have proved unreliable in the long term and suffer overheating. Several have failed.

Work is ongoing with the voip telephony. The main problem being the criteria AOSS has set for tariffication. However, we are well on the way to implementation throughout CTIO/SOAR and expect this to happen this coming year. The implementation will consolidate the current analog phone and new voip phones in CTIO. Asterisk has been chosen as the TDM, which is free source and negates the need for individual telephone licensing payments. The hope is that we can coordinate with NOAO North to utilize the network for inter-organizational telephony.

CISS continues to solely maintain the shared WAN backbone to the summits and International networking infrastructures. CISS provided support to Data Products, SuperMACHO, SMSN and TMT programs. All Scientists and ETS members have Gigabit ports to their desktops. CISS also provided support to the Mechanical Instrument shop for the specialized CNC software that has resulted in savings of multi-thousand dollars to the Observatory.

Cerro Tololo

The STB tape system was retired, and replaced with a cache feeding the DPP Archiving system. This freed space in the computer room allowed for the installation of a new rack to house rack

mounted workstations. The new 4m TCS machine is the first to occupy this space along with two new DPP raids. The goal is to replace some of the older legacy machines with rack mounts, concentrating legacy functions into one modern machine.

The legacy Sun DNS secondary server has been replaced with a modern Linux system with the latest version of named. Due to the aging hardware used by the Arcon system, SunOS, complete spares for each telescope have been purchased and configured to be hot spares in the event of failure. The main 6500 switch has been upgraded from a hybrid catOS/IOS to native IOS. This has allowed us to more easily implement the automatic failover to the redundant Supervisor engine. Statistics show that as a result of our efforts in upgrading the mountain networking that we are operating at 99.99% uptime. CISS continues to offer maintenance and upgrade support to SMARTS, PROMPT, SCISOL, who are clients at the summit.

Other

During this year we have almost completed the installation of all the new networking equipment that was purchased to give Las Campanas a redesigned network to create a modern secure environment that allows them ease of expansion in the future. A centralized mail server has been adopted with a secondary on lco. New DNS and HTTP servers have also been deployed. The link from La Serena to LCO was upgraded from 2Mb to 4Mb. We have an understanding that they will contribute monetarily in the future to the International link that we all share to Internet-2. CISS is essentially providing all systems and network administration to Las Campanas, and, so far, has received very positive feedback for our services.

We installed a DPP raid on Pachón for the data of SOAR to be cached for transfer to the DPP archives. We continue to work closely with UNC, Ohio and Brazil to implement secure and separate VNC connections for remote observing.

We replaced Windows archive server with a modern platform and array of 250Gb sata disks, and implemented a Windows machine with "routing" and private network for the new lateral link system for the primary mirror.

We have actively been involved with LSST design both in Networking and Computer Infrastructure. This involvement is expected to grow through the construction and operation of the telescope. Design and costing for the network from Pachón to La Serena has been accomplished by CISS. We are also involved in the International connectivity and negotiations for 10Gb/s bandwidth from La Serena to NCSA, Illinois. We have also served to integrate the three systems, camera, telescope and data management into one coherent network at the summit.