NOAO/NSO Newsletter

NATIONAL OPTICAL ASTRONOMY OBSERVATORY/NATIONAL SOLAR OBSERVATORY

ISSUE 100 – JANUARY 2010

50 Years of the National Observatory

NOAO System Science Center

National Solar Observatory

Education & Public Outreach

focus on>>>

A Celebratory Issue!

With this *Newsletter* we celebrate several milestones. First, we celebrate the establishment of the National Observatory 50 years ago with the dedication of Kitt Peak National Observatory, located on the land of the Tohono O'odham Nation. Second, we celebrate 50 years of open access to forefront scientific capabilities based on peer review, enabling visiting astronomers to make our facilities scientifically productive and to share their results with the community. Third, we celebrate the 100th issue of the *NOAO/NSO Newsletter*, which began in 1985.

We are marking these events with a special 43-page celebratory section. This includes a variety of articles, as well as a timeline covering many of the major events of the last 50 years. One article highlights a variety of science discoveries, one covers a history of the early years at Kitt Peak, and another details the early years at CTIO. There is an article on the role of education at NOAO, with links to letters from former students, individuals now well known to the community. The history of the *Newsletter*, and related changes with the times, is included. And for the first time, the entire issue is printed in color (the online issue has been posted in color for more than a decade).

The Editors want to thank all of the individuals who worked very hard to make this unique issue possible. We appreciate the special effort that has gone into researching historical events, finding and scanning images, and soliciting interviews. We hope all the Section Editors and contributors have had as much fun with this issue as we did!

The future is bright, and we look forward to changes that will best serve our readers in the astronomical community. In response to various observatory committees' suggestions, the *Newsletter* will begin appearing every six months, in March and September. We will continue to encourage readers to access the *Newsletter* online, where you will find active links to important resources. Our goal, as always, is to make the *Newsletter* as useful and informative as possible to all our readers.

Publication Notes

This *Newsletter* is presented with active links online at

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On the Cover

This month's cover presents a retrospective of science images from *Newsletter* covers over the past decade, since cover images became a regular feature. In order of appearance (left to right, top to bottom), they include:

March 2000, Deep wide-field survey, Mayall 4-m, KPNO
September 2001, NGC 6853, Dumbbell Nebula, WIYN 3.5-m, KPNO
December 2002, Centaurus A, Blanco 4-m, CTIO
September 2003, Jupiter, Gemini-N, Gemini
December 2004, Large Magellanic Cloud region, Curtis Schmidt, CTIO
June 2005, Sun, SOLIS, NSO
December 2006, Bubble Nebula, Mayall 4-m, KPNO
September 2007, NGC 3582 in Sagittarius, Blanco 4-m, CTIO
December 2007, Edge-on spiral galaxy NGC 891, WIYN 3.5-m, KPNO
June 2008, Omega Centaurus, Blanco 4-m & Spitzer data, CTIO
September 2008, NGC 5427, 5426 in Virgo cluster, Gemini-S, Gemini
September 2009, Star cluster NGC 6520, Blanco 4-m, CTIO

Remembrances and Visions of the NOAO Director

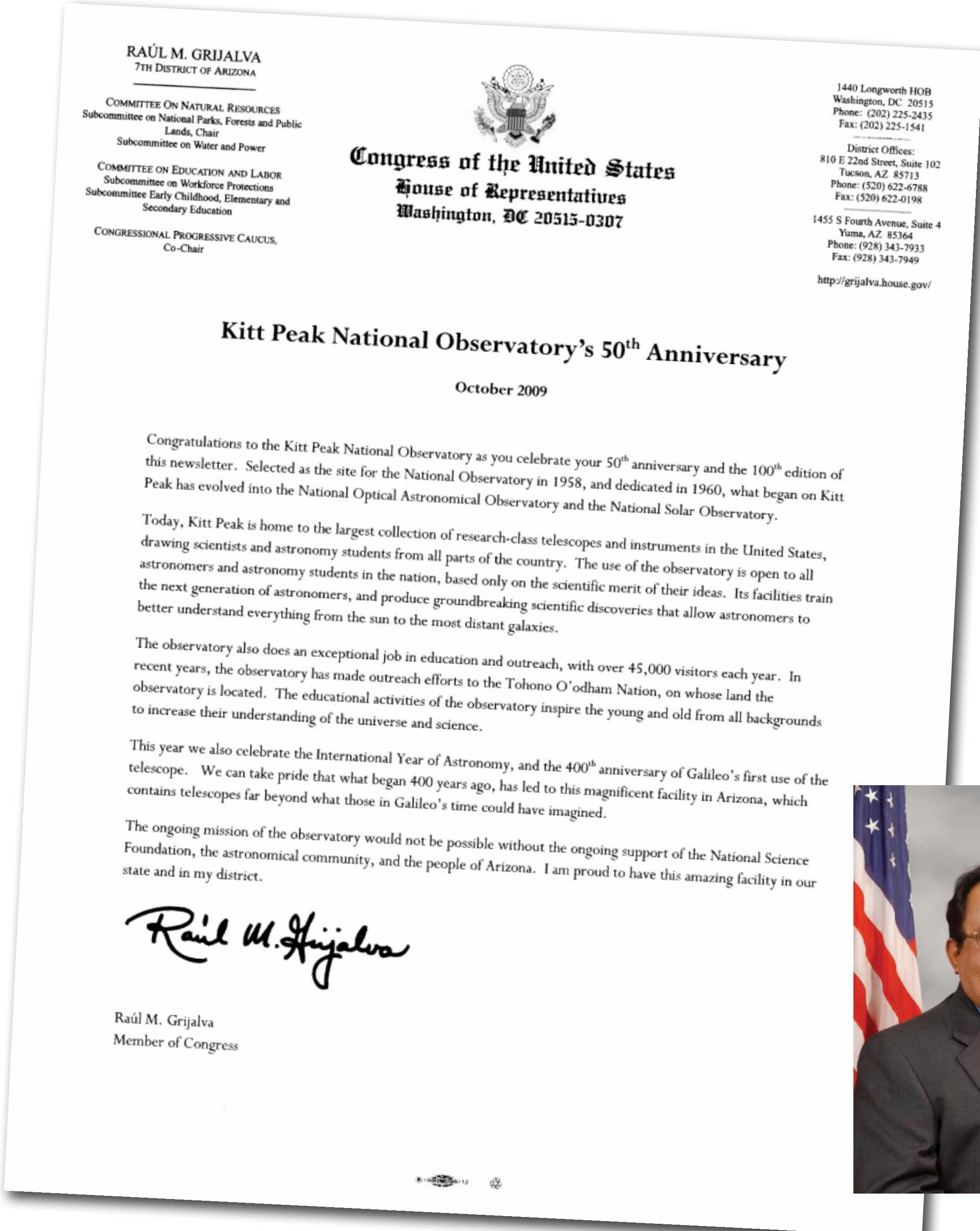
David Silva

My passion to renew the National Observatory and increase its relevance for the US community has its roots in my own story. My career has revolved around NOAO in general and KPNO in particular from the start. From my first night at a professional telescope as a University of Arizona undergraduate through my many nights at the MDM Observatory, I learned the craft of optical imaging and spectroscopy on Kitt Peak, often from NOAO staff members. Being offered a Kitt Peak post-doc and later a staff scientist position to commission the WIYN 3.5-meter telescope launched my professional career. In between, I spent tens of nights on Kitt Peak supporting users and working in my own research time with the then new and cutting-edge infrared arrays being deployed by NOAO. During those early years, I watched NOAO incubate what became the Gemini Project, and so I was thrilled later to be offered a position in the US Gemini Project Office. However, the siren call of the European Southern Observatory (ESO) proved to be too strong, and I spent the next nine years in Garching, Germany. Of course, the core missions of ESO and NOAO are not so different—provide world-class science capabilities and open access via peer review to the broadest possible community. When I returned to the States to work for the Thirty Meter Telescope (TMT) project, I came back as an NOAO staff scientist under the auspices of the then active partnership between AURA and TMT.

And so here I am, NOAO director, almost 30 years after that first night on Kitt Peak. After 18 months on the job, I am even more excited and optimistic about the road ahead than I was when I started. The evolution from a stand-alone, vertically-integrated national observatory to an organization dedicated to the development of science capabilities across the entire US system of federal and non-federal observatories has not come painlessly. Yet, this evolution has borne real fruit in the form of federal funding (mostly from NSF) for Gemini, the Telescope System Instrumentation Program (TSIP), Renewing Small Telescopes for Astronomical Research (ReSTAR), Large Synoptic Survey Telescope (LSST) design and development, and Giant Segmented Mirror Telescope (GSMT) design and development. Most of this funding has not gone to NOAO but to other US observatories and institutions. In return, the entire US community, public and private, has benefited from access to world-class science capabilities now while laying the foundations of continued international leadership in the future.

Whither NOAO? Building on the legacy of the TSIP, ReSTAR, and Access to Large Telescopes for Astronomical Instruction and Research (ALTAIR) processes, we will continue as the leader and coordinator for development of the Optical/Infrared (O/IR) System based on community input. NOAO looks forward to the deployment of new science capabilities and the execution of major science projects on US 4-meter-class facilities, especially on Kitt Peak, Cerro Tololo, and Cerro Pachón. Helping to deploy new, world-class science capabilities on 8-meter-class telescopes in return for increased community access is also a high priority. NOAO will continue to advocate for a Gemini instrumentation suite that is more aligned with the desires of the US community and for a significantly larger number of US nights. We believe both are achievable without a much larger US investment. NOAO is already involved in LSST and GSMT design and development activities, and we expect to have significant construction and operational roles in such facilities if federal funding is forthcoming.

There are great nights ahead for NOAO and the O/IR System. I am excited to be part of the team that is enabling that future collaboratively with our peers across the US and the rest of the world. But I am most excited for the kids out tonight looking through a telescope for the first time, for I remember that night in my life very well indeed. When those kids are ready for us, NOAO and the US System will be ready for them. *Excelsior*! (Ever higher!)



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7TH DISTRICT OF ARIZONA

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Kitt Peak National Observatory's 50th Anniversary

October 2009

Congratulations to the Kitt Peak National Observatory as you celebrate your 50th anniversary and the 100th edition of this newsletter. Selected as the site for the National Observatory in 1958, and dedicated in 1960, what began on Kitt Peak has evolved into the National Optical Astronomical Observatory and the National Solar Observatory.

Today, Kitt Peak is home to the largest collection of research-class telescopes and instruments in the United States, drawing scientists and astronomy students from all parts of the country. The use of the observatory is open to all astronomers and astronomy students in the nation, based only on the scientific merit of their ideas. Its facilities train the next generation of astronomers, and produce groundbreaking scientific discoveries that allow astronomers to better understand everything from the sun to the most distant galaxies.

The observatory also does an exceptional job in education and outreach, with over 45,000 visitors each year. In recent years, the observatory has made outreach efforts to the Tohono O'odham Nation, on whose land the observatory is located. The educational activities of the observatory inspire the young and old from all backgrounds to increase their understanding of the universe and science.

This year we also celebrate the International Year of Astronomy, and the 400th anniversary of Galileo's first use of the telescope. We can take pride that what began 400 years ago, has led to this magnificent facility in Arizona, which contains telescopes far beyond what those in Galileo's time could have imagined.

The ongoing mission of the observatory would not be possible without the ongoing support of the National Science Foundation, the astronomical community, and the people of Arizona. I am proud to have this amazing facility in our state and in my district.

Raúl M. Grijalva
Member of Congress

1539
Spanish explorers arrive, and discover that the indigenous people regard the mountain Iolkam as one of the favorite places of I'itoi, the "Elder Brother"

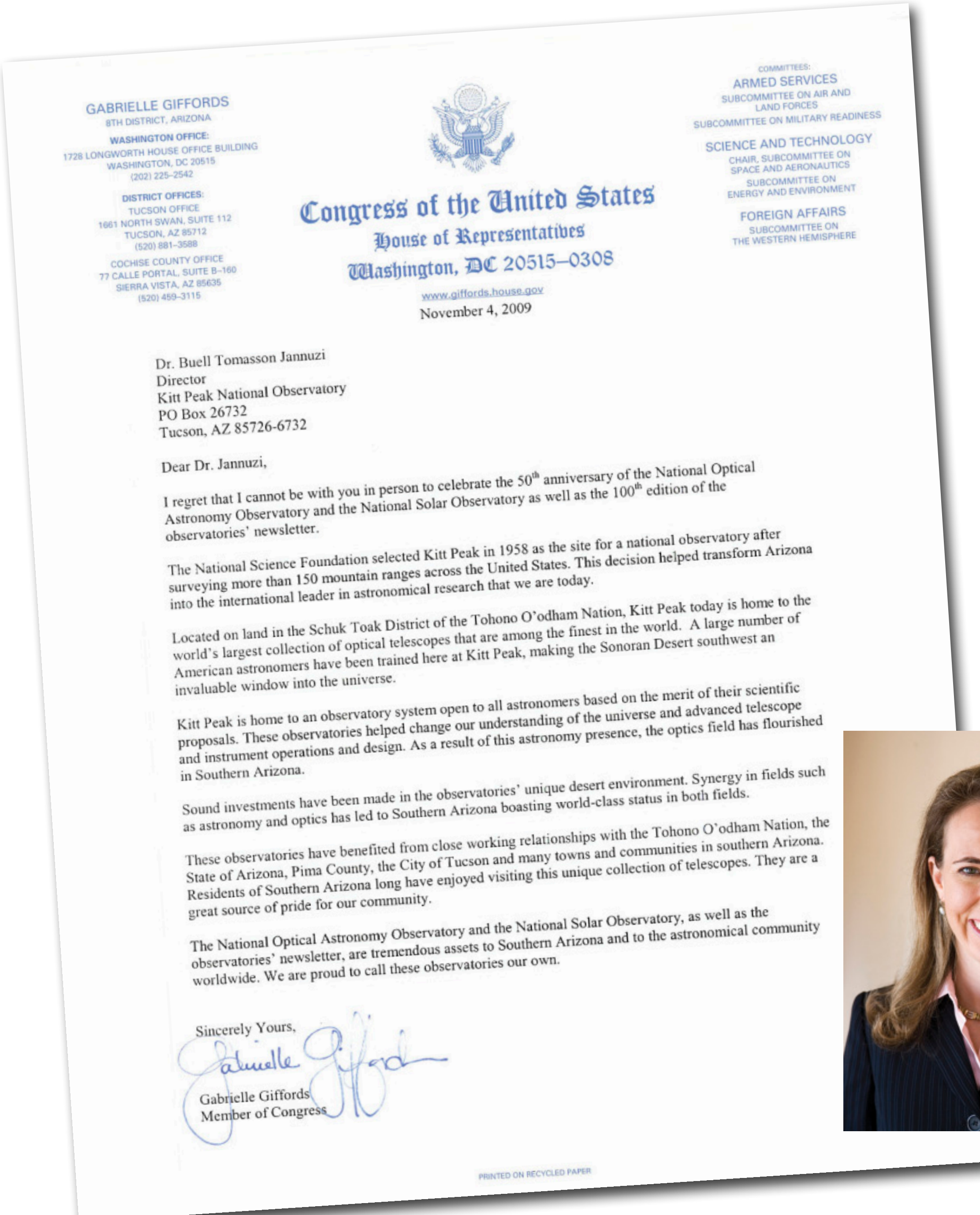
1874
Arrival in Arizona Territory of George Roskruge, who became Pima Country Surveyor and who named Kitt Peak after his sister Philippa Kitt

Feb. 14, 1912
Arizona becomes a US state

1930
The United States Geographic Board officially adopts "Kitt Peak" as the name of the mountain

Aug. 1953
Sponsored by the new National Science Foundation, 35 prominent astronomers from a variety of institutions meet in Flagstaff to examine the need for a "national observatory"

1954
John W. Evans appointed first Director of Sac Peak Observatory



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November 4, 2009

Dr. Buell Tomasson Jannuzi
Director
Kitt Peak National Observatory
PO Box 26732
Tucson, AZ 85726-6732

Dear Dr. Jannuzi,

I regret that I cannot be with you in person to celebrate the 50th anniversary of the National Optical Astronomy Observatory and the National Solar Observatory as well as the 100th edition of the observatories' newsletter.

The National Science Foundation selected Kitt Peak in 1958 as the site for a national observatory after surveying more than 150 mountain ranges across the United States. This decision helped transform Arizona into the international leader in astronomical research that we are today.

Located on land in the Schuk Toak District of the Tohono O'odham Nation, Kitt Peak today is home to the world's largest collection of optical telescopes that are among the finest in the world. A large number of American astronomers have been trained here at Kitt Peak, making the Sonoran Desert southwest an invaluable window into the universe.

Kitt Peak is home to an observatory system open to all astronomers based on the merit of their scientific proposals. These observatories helped change our understanding of the universe and advanced telescope and instrument operations and design. As a result of this astronomy presence, the optics field has flourished in Southern Arizona.

Sound investments have been made in the observatories' unique desert environment. Synergy in fields such as astronomy and optics has led to Southern Arizona boasting world-class status in both fields.

These observatories have benefited from close working relationships with the Tohono O'odham Nation, the State of Arizona, Pima County, the City of Tucson and many towns and communities in southern Arizona. Residents of Southern Arizona long have enjoyed visiting this unique collection of telescopes. They are a great source of pride for our community.

The National Optical Astronomy Observatory and the National Solar Observatory, as well as the observatories' newsletter, are tremendous assets to Southern Arizona and to the astronomical community worldwide. We are proud to call these observatories our own.

Sincerely Yours,

Gabrielle Giffords
Member of Congress

PRINTED ON RECYCLED PAPER

Jan. 1954
An advisory panel of six (from the 35) forms to study costs, sites, instrumentation, etc. related to the establishment of a national observatory

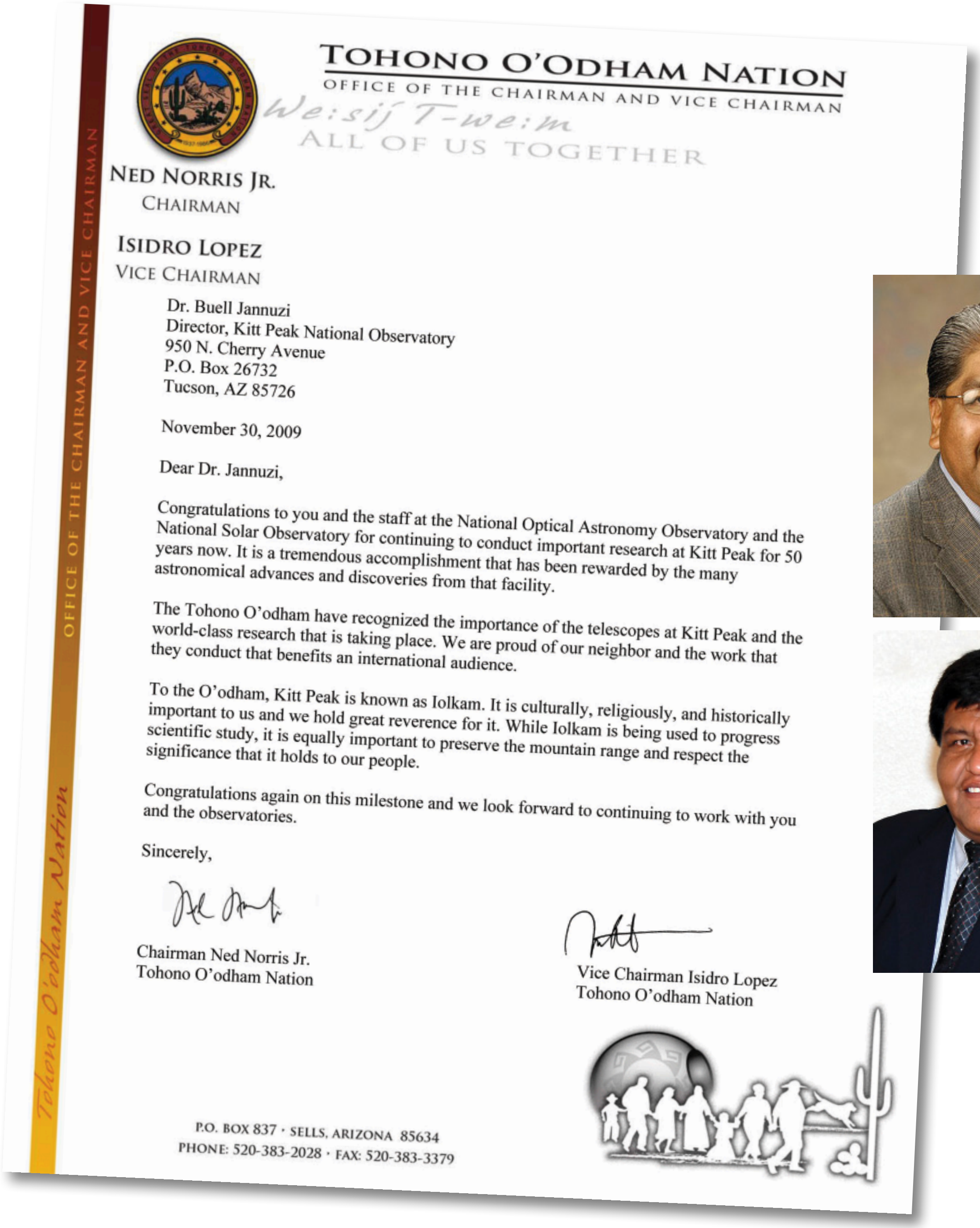
1955
The advisory panel recommends that the NSF support the establishment of a national observatory, and urges immediate construction of three major telescopes, including the world's largest solar telescope

1955
Site selection begins with rocket photography of mountain ranges in CA, AZ, NM, NV, and UT. The possibilities are cut quickly to about 150 sites. Aerial photography and site visits by vehicle, horseback, and on foot soon follow.

1956
Permission granted by the Papago Tribe (now the Tohono O'odham Nation) for construction of a "test site" on Kitt Peak

1956
Possible national observatory sites reduced to five mountaintops instrumented with 60-foot towers to measure and record wind velocity, relative humidity, temperature, and other site characteristics. Instrument data soon cut the list of possibilities to two: Kitt Peak and Hualapai Mountain, southeast of Kingman.

Mar. 1957
Kitt Peak and Hualapai Mountain sites staffed by one person each and sky monitoring using 16-inch telescopes begins



TOHONO O'ODHAM NATION
OFFICE OF THE CHAIRMAN AND VICE CHAIRMAN
We:sij T-we:m
ALL OF US TOGETHER

NED NORRIS JR.
CHAIRMAN

ISIDRO LOPEZ
VICE CHAIRMAN

Dr. Buell Jannuzi
Director, Kitt Peak National Observatory
950 N. Cherry Avenue
P.O. Box 26732
Tucson, AZ 85726

November 30, 2009

Dear Dr. Jannuzi,

Congratulations to you and the staff at the National Optical Astronomy Observatory and the National Solar Observatory for continuing to conduct important research at Kitt Peak for 50 years now. It is a tremendous accomplishment that has been rewarded by the many astronomical advances and discoveries from that facility.

The Tohono O'odham have recognized the importance of the telescopes at Kitt Peak and the world-class research that is taking place. We are proud of our neighbor and the work that they conduct that benefits an international audience.

To the O'odham, Kitt Peak is known as Iolkam. It is culturally, religiously, and historically important to us and we hold great reverence for it. While Iolkam is being used to progress scientific study, it is equally important to preserve the mountain range and respect the significance that it holds to our people.

Congratulations again on this milestone and we look forward to continuing to work with you and the observatories.

Sincerely,

Chairman Ned Norris Jr.
Tohono O'odham Nation

Vice Chairman Isidro Lopez
Tohono O'odham Nation

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OFFICE OF THE CHAIRMAN AND VICE CHAIRMAN

Tohono O'odham Nation

Oct. 27, 1957
Association of Universities for Research in Astronomy (AURA) Inc. created to operate the national observatory for the NSF

1958
Aden B. Meinel appointed as first KPNO Director

1958
First contract pertaining to the 84-inch telescope is awarded

Mar. 1, 1958
Kitt Peak is selected as the best site for the national observatory

Jun. 1, 1958
Prof. Federico Ruttlant of the U. of Chile visits Yerkes Observatory and proposes a cooperative observatory project to Drs. Kuiper and Hiltner

Jul. 7, 1958
Dr. Kuiper contacts Dr. Shane to explore possible AURA interest in the cooperative observatory. AURA is not then in a position to consider the project.

The National Observatory—50 Years of Science

John Glaspey, George Jacoby, Verne Smith & Mark Giampapa

When the National Astronomical Observatory was established on Kitt Peak 50 years ago, the primary goal was to provide telescope access to the whole community of astronomical researchers. While the site on Kitt Peak was just starting to be developed, a search for a comparable site in the Southern Hemisphere was being undertaken in Chile, which led to the creation of Cerro Tololo Inter-American Observatory. Early in the 1980s, the National Optical Astronomy Observatory, NOAO, was formed to encompass KPNO, CTIO, and NSO, including Sac Peak. A decade ago another division was added to NOAO to support the US access to the Gemini Observatory. Two years after that, the National Solar Observatory was created as a programmatically separate organization and an AURA center.

Looking back, we can be proud that so many scientists were able to achieve their goals of doing first-class science. Thousands of peer-reviewed publications have resulted from the countless days and nights of observation. Highlighted below are a very few of the diverse discoveries that have resulted from work based largely on observations made at Gemini with US time and at CTIO, KPNO, and NSO.

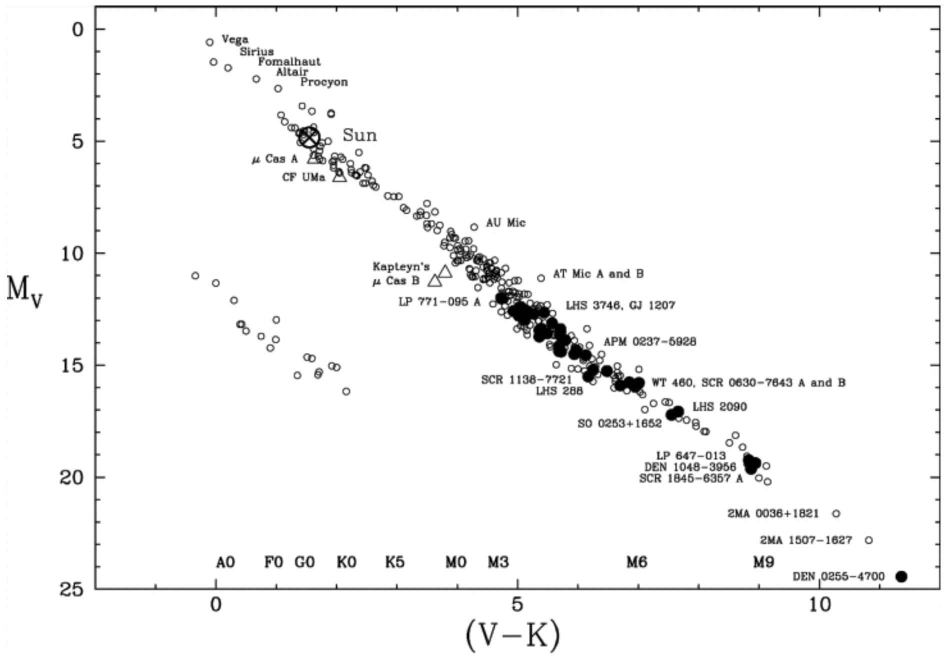


Figure 1: RECONS sample of objects plotted on an H-R Diagram, using M_V vs. V-K. Open circles represent objects known in 2000 and filled circles represent RECONS discoveries. (Image from Henry et al. 2006, reproduced with permission of AAS.)

The Nearest Stars and the RECONS Survey

Although the census of nearby (within 10 parsecs) stars is complete for Sun-like and brighter stars, it is likely that many more faint red dwarfs remain to be discovered. Although of low luminosity, these intrinsically faint stars are the dominant population by number and by mass in our galaxy. The Research Consortium on Nearby Stars (RECONS) group has been conducting a classical trigonometric parallax study to identify stars in the solar neighborhood. The survey uses the CTIO 0.9-meter and 1.5-meter telescopes within the SMARTS Consortium and is led by T. Henry of Georgia State University. In one paper out of several in this series, for example, Henry et al. (2006, *AJ*, 132, 2360) reported on the identification of 25 new stars within 10 parsecs of the Sun (figure 1). Most of these stars appear to be cool M dwarfs, but there are several L and T dwarfs, some of which may be brown dwarfs. These new stars amount to 16 percent of the total mass in the solar neighborhood. RECONS has also identified 33 new white dwarfs within 25 parsecs of the Sun (Subasavage et al. 2007, *AJ*, 134, 252), one of which may be within 10 parsecs. White dwarfs are very low luminosity, and a reasonably complete sample can only be drawn from the solar neighborhood. These local white dwarfs are important for constraining the underlying physics that govern the behavior of matter at high densities.

continued

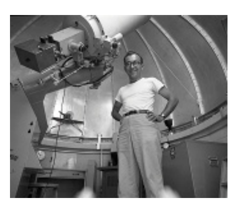
Aug. 28, 1958
Lease agreement for use of Kitt Peak with the Papago tribe (now the Tohono O'odham) approved by Congress

Oct. 24, 1958
The Kitt Peak lease for 200 acres is signed, with 2,200 other acres of land available for use within restrictions

Jan. 8, 1959
U. of Chicago applies to the US Air Force for funds for a 40-inch telescope in Chile to be located near Santiago. The Air Force expresses interest and agrees to fund site testing program.

May-Jun. 1959
J. Stock (later CTIO's first director) travels to Chile; with U. of Chile personnel and equipment, a site testing program is organized. The first sites tested were near Farellones and Cerro El Roble.

Jun. 1, 1959
Arlo Landolt first official KPNO observer



Jun. 1, 1959
The Universities of Chile, Chicago, and Texas sign an agreement for a cooperative observatory to be funded by the US Air Force. The 40-inch telescope project becomes a 60-inch telescope project. Dr. Clemence suggests the project title: "The Inter-American Observatory in Chile."

It is impressive that a program such as RECONS is using only small telescopes to derive fundamental data and knowledge of the local solar neighborhood, providing information and constraints to a variety of fields, from stellar physics to galactic structure.

Solar Oscillations

Measurements of the Sun in 1968 by E. Frazier from Kitt Peak using the McMath Solar Telescope demonstrated that the properties of the 5-minute oscillations depended on their horizontal scale, opening a new chapter that led to their identification as sound waves trapped beneath the visible surface. By the 1980s, teams of NSO, NASA, and university solar astronomers were measuring high modes of oscillations, yielding the first measurements of the internal sound speed and rotation throughout most of the Sun. This work laid the foundation for the implementation of the GONG program of helioseismology just a few years later. Such observations provided important constraints on the models of the solar interior that were ultimately necessary to explain the observed solar neutrino flux. (For more solar highlights, see "History of McMath Pierce Solar Telescope" in this issue.)

First Direct Images of Exosolar Planets: The Multiple-Planetary System around HR 8799

Images taken with the Gemini North telescope and its adaptive optics system allowed an international team (on a joint program for which about half of the observing time came from the US) to make the first direct imaging detection of multiple planets around another star. The discovery of two planets around the star HR 8799 occurred using images taken on 17 October 2007 and is shown in figure 2. The team, led by C. Marois of Canada and with members from the US and UK, confirmed this discovery and found a third planet orbiting even closer to the star with images obtained at the Keck II telescope (Marois et al., 2008, *Science*, 322, 1348). In both cases, adaptive optics technology was used to correct in real time for atmospheric turbulence to obtain historic infrared images of an extra-solar multiple-planet system. The host star, HR 8799 (a young, 1.5 solar-mass star), is about 40 parsecs away from Earth. A comparison of multi-epoch data shows that the three planets are all moving with, and orbiting around, the star, proving that they are associated with it rather than just being unrelated background objects coincidentally aligned in the image.

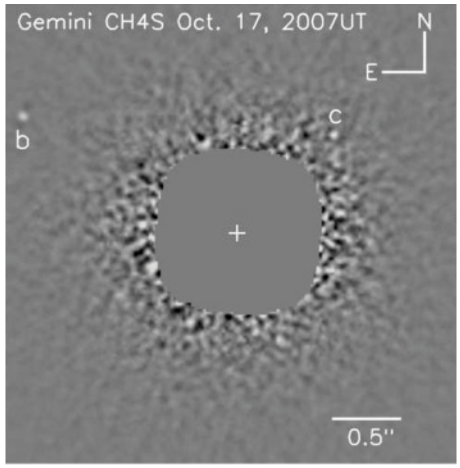


Figure 2: Gemini Observatory discovery image using the ALTAIR adaptive optics system on the Gemini North telescope with the Near-Infrared Imager (NIRI). The image shows two of the three confirmed planets indicated as "b" and "c" on the image. The "b" is the ~7 Jupiter-mass planet orbiting at about 70 AU, the "c" is the ~10 Jupiter-mass planet orbiting the star at about 40 AU. (Image from Marois et al. 2009.)

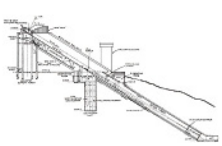
The planets, which formed about sixty million years ago, are young enough that they are still glowing from heat released as they contracted. Analysis of the brightness and colors of the first two objects shows that these are planets having about seven and ten times the mass of Jupiter. As in our Solar System, these giant planets orbit in the outer regions of this system—at roughly 25 AU, 40 AU, and 70 AU. The furthest planet orbits just inside a disk of dusty debris, similar to that produced by the comets of the Kuiper Belt objects of our Solar System (just beyond the orbit of Neptune at 30 AU). In some ways, this planetary system seems to be a scaled-up version of our Solar System orbiting a larger and brighter star. HR 8799 observations are part of a survey of 80 such young, dusty, and massive stars located in the solar neighborhood. The survey is using Gemini, the W.M. Keck, and Very Large Telescope observatories' adaptive optics systems to constrain the Jupiter-mass planet populations in a range of separations inaccessible to other exoplanet detection techniques, i.e., separations similar to the outer giant planets of our Solar System.

Radial Velocities of an Eclipsing Brown Dwarf System: The First Direct Measurements of Brown Dwarf Masses and Radii

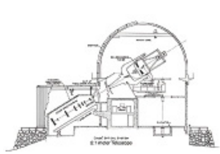
A US team of astronomers, led by K. Stassun of Vanderbilt University, used the high-resolution infrared spectrograph Phoenix on the Gemini South telescope to measure radial velocities in the eclipsing brown dwarf system 2MASS J05352184-0546085 (2006, *Nature*, 440, 311). This system is a member of the 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

continued

Jun. 1959
Completion of the design for the solar telescope on Kitt Peak



Jul. 1959
Contract is awarded for construction of 84-inch telescope mount on Kitt Peak



Aug. 19, 1959
I. Epstein of Columbia U. starts another site testing program in Chile with NSF funding. This program aimed at comparing sites in Chile, Argentina, Australia, and South Africa. A month later J. Stock and I. Epstein coordinated their programs. Eventually, the U. of Columbia and Yale U. established an astrometric observing station near San Juan, Argentina.

Oct. 19, 1959
G. Keller of the NSF expresses the interest of the NSF in supporting the Chilean Observatory project. A policy advisory committee with AURA, NSF, Air Force, and Universities of Chile, Chicago, and Texas representatives is formed to consider the future of the project

Dec. 1959
Contract is awarded for construction of a paved highway up to Kitt Peak

Feb. 1960
Completion of the first major telescope on Kitt Peak, a 36-inch

Cerro Tololo Inter-American Observatory. The Phoenix data have a spectral resolution of ~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 3. Since this is a double-lined, eclipsing system, the masses and radii of both components are derived. The masses are 0.054 (±0.005) and 0.034 (±0.003) solar masses, respectively. Thus, both components 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 these particular brown dwarfs in the Orion Nebula Cluster are only about a million years old). One surprise is that the less 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 R. Mathieu of the University of Wisconsin-Madison and J. Valenti of the Space Telescope Science Institute.

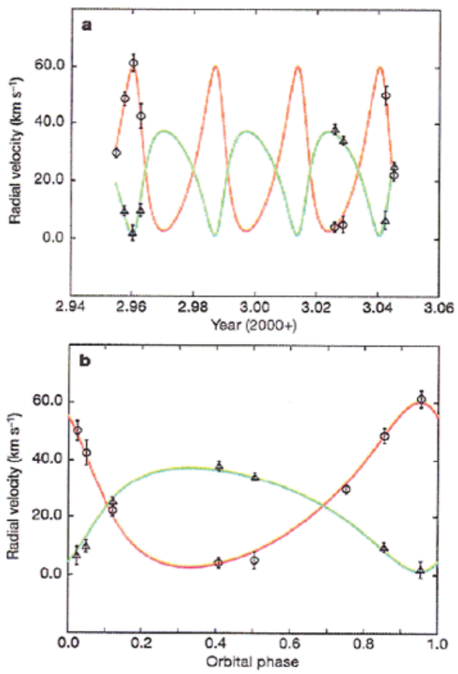


Figure 3: Individual radial velocity measurements (points) and the orbit solution (solid curves). The cross-correlation of the individual spectra against a radial velocity standard star yields the radial velocities of the two components at each observed phase. Here, the individual, heliocentric radial 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. (Image from Stassun et al. 2006, reproduced with permission of Nature Publishing Group.)

Flat Rotation Curves for Spiral Galaxies

Starting in the mid-1960s, V. Rubin of the Carnegie Institute of Washington and her collaborator W. Ford began spectroscopic observations to determine the rotation curves of distant galaxies. Using the KPNO 2.1-meter telescope, they determined the rotation curve of M31, which provided important evidence that contradicted expectations of how matter is distributed inside a spiral galaxy (Rubin and Ford, 1970, *ApJ*, 159, 379). Since the light falls off sharply with increasing distance from the center of the galaxy, they expected the rotation curve to show that mass fell off sharply as well. Instead, the mass density remains constant as far out from the center as they could measure. Subsequent observations of large samples of spirals at the 4-meter telescopes on both Kitt Peak and Cerro Tololo confirmed this effect. Combining this with other clues ultimately led to the conclusion that most of the mass in the universe is in a form hidden from normal means of observation, still one of modern astrophysics' major mysteries forty years later.

The Butcher-Oemler Effect

In 1978, KPNO astronomer H. Butcher and Yale University astronomer A. Oemler published the results of their study of galaxies in clusters (1978, *ApJ*, 219, 18). They used the ISIT vidicon imaging camera on the Kitt Peak 2.1-meter telescope to obtain colors and magnitudes of galaxies in moderate redshift (z ~ 0.4) clusters down to faint magnitudes. Statistical analysis of the data indicated that the more distant clusters had a significant excess of bluer galaxies relative to the content of clusters nearer our Galaxy. This result indicated an evolution in the morphological class of galaxies in clusters that depended on the age of the cluster. The more distant clusters are younger than those nearby, which have lost most of their young spiral galaxies. This conclusion pioneered the development of the current theories of how their local environment influences the evolution of spiral galaxies.

Gravitational Arcs

The first reported spectra of arcs caused by gravitational lensing were taken at Kitt Peak on the Mayall 4-meter telescope. In 1981, A. Hoag reported on imaging and slitless spectra

continued

Feb-Aug. 1960
Site surveys for an observatory in Chile extended northward to include Tololo, Morado, and other mountains near Vicuña

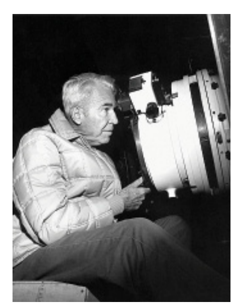
Mar. 15, 1960
Kitt Peak National Observatory is dedicated

Mar. 1960
Construction of solar telescope on Kitt Peak begins

May. 25, 1960
AURA is asked to take over construction and operation of a "joint Chilean Observatory"

Jun. 30, 1960
AURA assumes reponsibi1ity of site surveys for US observatory in Chile under the auspices of the US Air Force and subsequently the National Science Foundation

Oct. 1, 1960
Nicholas Mayall appointed KPNO Director



50 Years of Science continued

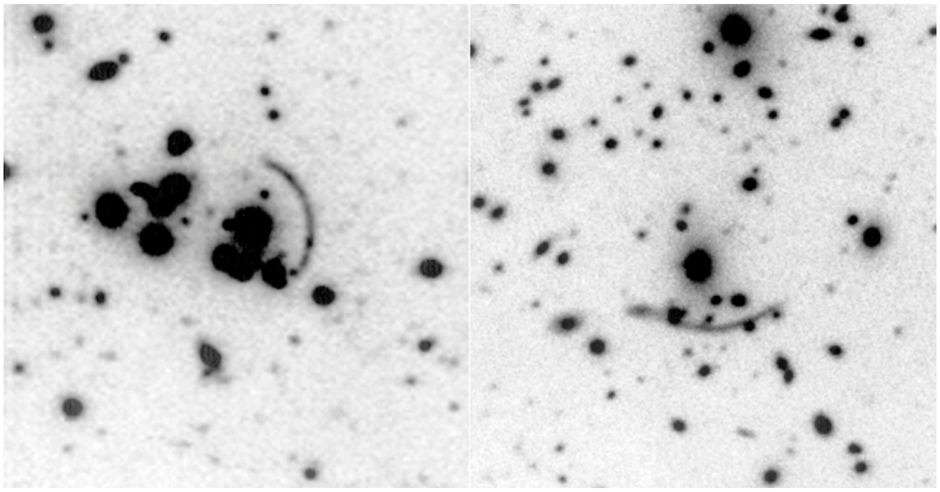


Figure 4: Images of Cl2244-02 and Abell 370 showing the gravitational arcs in each cluster of galaxies. (Images courtesy of C. R. Lynds, NOAO.)

of Abell 370, but his data did not reveal the high redshift of the arc itself (Hoag, 1981, *BAAS*, 13, 799). A few years later, R. Lynds and V. Petrosian reported on the existence of these arcs in two clusters at a AAS meeting (1986 *BAAS*, 18, 1014) from observations made with the Mayall 4-meter telescope. In 1989, they published a more thorough study using some of the same data, as well as additional observations (1989 *ApJ*, 336, 1). They resolved spectra of parts of the arc itself, not just the lower redshift galaxies in the lensing cluster (figure 4). This was one of the first thorough discussions of the various types of observational data of the arcs pointing to gravitational lensing of more distant galaxies as the physical explanation. Since then, studies of many other clusters showing this effect have led to considerable progress in understanding the mass distributions, including Dark Matter.

Weak Lensing and Dark Matter

Weak gravitational lensing promises to be a powerful tool for studying the distribution of matter in the universe and, in particular, for revealing much about Dark Matter. The earliest example of this technique was carried out on the Blanco 4-meter telescope at CTIO by J. A. Tyson, F. Valdes, and R. Wenk (1990 *ApJ*, 349, L1*)*, who demonstrated the approach on two clusters of galaxies. The technique even allowed D. Wittman et al. (2001, *ApJ*, 557, L89) to discover a previously uncatalogued cluster of galaxies based on the lensing effect. Jarvis and collaborators (2003 *ApJ*, 125, 1014) carried out a more extensive study using the Big Throughput Camera (BTC), which was the 4K × 4K wide-field imager on the Blanco until the Mosaic-2 camera arrived. Systematic wide-field weak-lensing studies permitted by these cameras also led to significant improvements in the estimation of cosmological parameters (Jarvis et al., 2006, *ApJ*, 644, 71), an important result once the supernovae results suggested the existence of Dark Energy.

Lyman-Alpha Forest

The 2.1-meter telescope at Kitt Peak was commissioned in 1964 at a time when the study of Quasi-Stellar Objects (QSOs) was still in its infancy. In 1966, KPNO astronomer R. Lynds and University of Arizona graduate student A. Stockton used the Cassegrain image-tube spectrograph on the KPNO 2.1-meter telescope to record a high-quality spectrum of a QSO that showed a large number of very sharp absorption lines in the vicinity of the red-shifted Lyman-alpha line (Stockton and Lynds, 1966, *ApJ*, 144, 451) (figure 5). These and subsequent observations of other QSOs came to be understood as demonstrating the existence of clouds of inter-galactic gas along the line of sight between the Earth and the distant QSO.

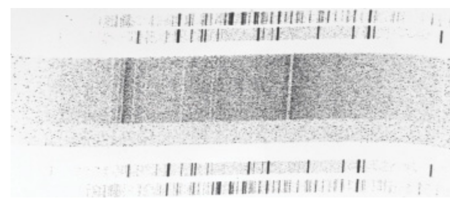


Figure 5: Spectrum of the quasi-stellar object 3C 191 ($z = 1.947$) taken by Stockton and Lynds, revealing the sharp absorption lines near the broad Lyman-alpha emission. (Image courtesy of C. R. Lynds, NOAO.)

There are many more clouds that produce the absorption lines for high-redshift QSOs, so a very dense array of absorption lines can result, now referred to as the "Lyman-alpha forest." This is the only direct observational evidence we have of the existence and physical properties of the gas in the inter-galactic medium.

continued

Mar. 1961
Decision made that 158 inches is the appropriate size for the main mirror of the second major telescope on Kitt Peak

Aug. 1961
0.41-m telescope hauled to Cerro Tololo on mule-back for tests of site

Dec. 1961
AURA and the U. of Chile sign an agreement for establishment of the observatory in Chile

Dec. 1961
CTIO's first administrative office opens at the Chilean National Observatory at Cerro Calan, Santiago

Oct. 11, 1962
An 8-hectare lot is purchased in La Serena for offices

Nov. 1, 1962
First light at McMath solar telescope on Kitt Peak

First Gravitational Lens

In 1979, the first gravitational lens was discovered accidentally by D. Walsh, R. Carswell, and R. Weymann using the Kitt Peak 2.1-meter telescope (1979, *Nature*, 279, 381). It became known as the "Twin Quasar" because it initially looked like two identical quasars; it is officially named Q0957+561. The two images turned out to have identical redshifts, which could be explained by separate objects at the same distance. Another possibility would be a pair of images of the same QSO created by a gravitational lens, formed when the light from a very distant, bright source (such as a quasar) is bent around a massive object (such as a massive galaxy) between the source object and the observer. Later discoveries of other examples of "multiple" QSOs confirmed the gravitational lens explanation. Gravitational lensing has since become an extremely important technique in the study of the distribution of Dark Matter throughout the universe and provides another tool to measure the expansion rate of the universe.

Supermassive Black Hole Growth and Chemical Enrichment in the Early Universe

Infrared spectra obtained from both the Gemini South and Gemini North telescopes have been used by a team of astronomers from the US and Germany, led by L. Jiang (University of Arizona), to study the kinematics and chemistry of some of the most distant and youngest known quasars (Jiang et al. 2007, *AJ*, 134, 1150). The six quasars observed have redshifts ranging from z = 5.8 to 6.3, corresponding to a time when the universe was only about one billion years old. Using the Gemini Near Infrared Spectrograph (GNIRS) at Gemini South and the Near-Infrared Imager and spectrograph (NIRI) at Gemini North, the team found these very young quasars to be already super-enriched in heavy elements.

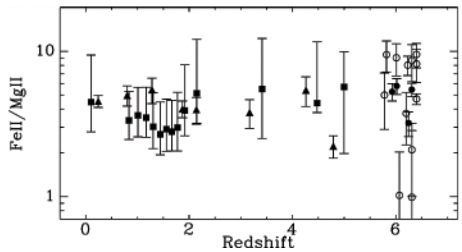


Figure 6: Fe II/Mg II abundance as a function of redshift indicating no significant relative chemical evolution as a function of age, even as far back as z ~ 6. (Image from Jiang et al. 2007, image reproduced with permission of AAS)

Quasars are thought to be powered by radiation from matter accreting onto supermassive black holes at the center of host galaxies in the process of forming. Dense gas in the region surrounding the black hole moves at high velocities giving rise to a broad line region (BLR) in spectra. Chemical abundances in the BLR will depend on the history of star formation in the host galaxy. In particular, the ratio of iron (Fe) to the so-called "alpha elements," such as oxygen or magnesium, is expected to have a strong correlation with the time since star formation began.

Emission line ratios from Fe II and Mg II in the infrared spectrum of the quasars indicate super-solar abundances, with $Z_{quasar} \sim 4\ Z_{sun}$ (figure 6).

The elevated metallicity found in these high redshift quasars indicates that extensive and rapid star formation, followed by significant element enrichment, has occurred in quasar host galaxies in the first billion years after the big bang.

Supernovae and Cosmology: The Nature of the Universe

One of the most exciting astrophysical discoveries in recent times was what is now referred to as Dark Energy, a cosmological description of how the acceleration of the expanding universe could be explained. Much of the photometric data to discover Type-Ia Supernovae was obtained at the CTIO Blanco 4-meter telescope in the mid to late 1990s (Riess et al., 1998, AJ, 116, 1009; Perlmutter et al., 1999, ApJ, 517, 565). Followup photometry was obtained at several 2- to 4-m class telescopes, including the Blanco and the WIYN 3.5-meter telescope on Kitt Peak. Spectro-

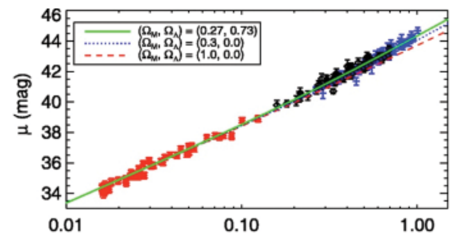


Figure 7: Illustrates the ESSENCE team's Hubble Diagram, plotted as the relative luminosity distance modulus versus redshift, with different model universes plotted for comparison. When finally completed and the entire data set analyzed, the ESSENCE team expects to have constrained the value of w to ±5 percent. (Image from Wood-Vasey et al. 2007.

continued

Nov. 2, 1962
Completed McMath solar telescope is dedicated

Nov. 23, 1962
Cerro Tololo chosen as site for US observatory in Chile, and the observatory's current name (CTIO) adopted

Nov. 25, 1962
AURA buys the property El Totoral, 30,000 hectares, with Cerro Tololo near its center

Dec. 2, 1962
Traditional flag-raising ceremony held on Cerro Tololo in company of Chilean officials who climbed the mountain on horseback

Jan. 1963
New highway to the Kitt Peak summit is opened to the public; during this first year, almost 60,000 people visit

Jan. 1963
Chilean Congress, with sponsorship of the U. of Chile, approves duty-free importations by AURA. Such importations were to be handled by the U. of Chile.

50 Years of Science continued

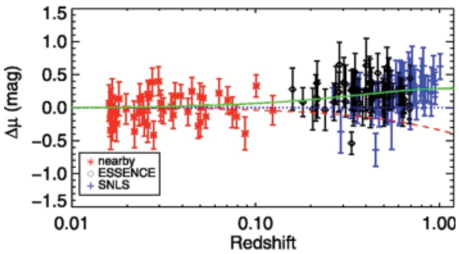


Figure 8: Relative luminosity distance modulus vs. redshift for the ESSENCE, SNLS, and nearby SNe Ia for MLCS2k2. For comparison, the over-plotted solid line and residuals are for a ΛCDM (w, Ω_M, Ω_Λ) = (-1, 0.27, 0.73) universe. (Image from Wood-Vasey et al. 2007.)

scopic measurements of the corresponding galaxy redshifts came from large telescopes at several other observatories. All of these observations were difficult, but a competing team, using an identical approach on different telescopes, soon confirmed the results.

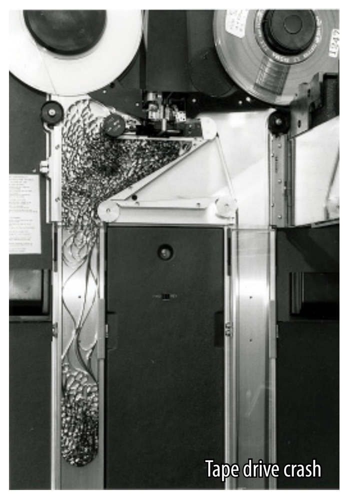
A follow-up program called the Equation of State: SupErNovae trace Cosmic Expansion (ESSENCE) supernova survey (an NOAO Survey program), is now nearing completion. ESSENCE is aimed at improving our understanding of Dark Energy, using wide-field images taken at the Blanco 4-meter telescope with the Mosaic-2 camera. Wood-Vasey et al. (2007, *ApJ*, 666, 694) show that, assuming a flat Universe and with priors from the measurements of baryon acoustic oscillations, the equation of state parameter (w) found is consistent with the Dark Energy being a cosmological constant (w = -1). The result is strengthened if the supernovae discovered by the similar (northern) sample from the SuperNova Legacy Survey (SNLS) are included (figures 7 and 8).

The Evolution of Digital Data at NOAO

Rob Seaman

In the fifty years since the National Observatory was founded, our instrumentation, computers, networks, image displays, and other data handling hardware and software have been replaced or updated over and over again. To do justice to this long and tangled history would require several volumes whose list of references alone would be much longer than this article. I will instead focus on just a few of my own experiences.

The early years of the observatory were an era of analog photographic cameras and photoelectric detectors of one sort or another (for example, see *Observatories of the Southwest*, Isbell & Strom, 2009). There was a transitional period of scanning photographic plates using digitizing microdensitometers. As a graduate student of Steve and Karen Strom during the mid 1980s, I first encountered data from Kitt Peak in the form of digitized Mayall prime focus plates stored as overlapping quadrants on 9-track tapes. To access such images, it was necessary that users write their own programs to parse the FITS (Flexible Image Transport System) format files.



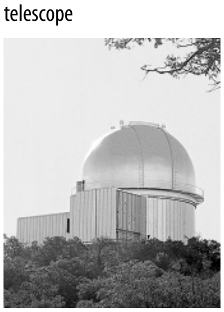
Tape drive crash

Indeed, no discussion of astronomical data would be complete without mentioning FITS. Scientific investigators outside of astronomy face a Babel of data formats; astronomers may not appreciate how exceptional a resource FITS truly is. NOAO was instrumental in the creation of FITS and the observatory's continued support has been critical to its ongoing success over three decades. Don Wells of KPNO and Eric Greisen of the National Radio Astronomy Observatory finalized the original definition of FITS in March 1979 (*fits.gsfc.nasa.gov/birthday.news*).

continued

Feb. 1963
NSF approves the funding of a 0.92-m telescope for CTIO

Apr. 1, 1963
First light at KPNO 84-inch telescope



Apr. 14, 1963
First KPNO Aerobee rocket flight, planned by Russell A. Nidey, takes place at White Sands Missile Range. This flight failed. Later flights that year had mixed results.

Apr. 1963
J. Stock appointed first CTIO Director

Mid 1963
Temporary CTIO powerhouse, warehouse, and maintenance shops completed, and 25 years later, the "temporary" structures are still in use

Jun. 28, 1963
David Crawford appointed project director for 158-inch telescope

The Evolution of Digital Data at NOAO continued

Numerous subsequent FITS documents and conventions have been developed by NOAO staff and are widely promulgated. This has led to the present day with Betty Stobie and Dick Shaw of NOAO's Science Data Management group serving on the International Astronomical Union FITS Working Group technical panel that produced v3.0 of the FITS Standard (*fits.gsfc.nasa.gov/standard30*) in July 2008.

That other touchstone of astronomy, the charge-coupled device (CCD), was first developed as a digital imaging sensor by Willard Boyle and George Smith at Bell Labs in 1959. For their work, Boyle and George Smith were awarded the 2009 Nobel Prize in Physics. Astronomers were early and enthusiastic adopters of this new technology. A major milestone for the adoption of these devices in the astronomical community was the 1991 Tucson CCD School organized by Steve Howell (NOAO) and with faculty contributions from several other NOAO and NSO staff members ("Astronomical CCD Observing and Reduction Techniques," ASP Conf. Ser. 23, 1992).

A later student encounter of mine with NOAO data required writing a tailored FITS program to read 320 × 512-pixel images from an early KPNO RCA CCD (with a read noise of 71 electrons). Accomplishing science using these data required writing a second program to subtract the overscan, correct for dark current, and flat field the data; then writing a third program to display the image and to perform primitive aperture photometry.

This enhanced image of the Moon was taken with the NOAO Mosaic CCD camera.
Credit: T.A.Rector, I.P.Dell'Antonio/NOAO/AURA/NSF

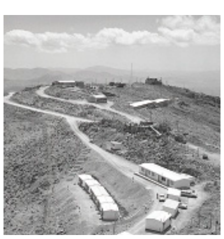
In those days, astronomers visited the observatory not only to use the telescopes on Kitt Peak, but to reduce the resulting images in the Interactive Picture Processing System (IPPS) Lab in the basement of the Tucson headquarters (and later, to use IRAF on Sun workstations in the same room). The software paradigm thus shifted from "rolling" your own to utilizing a standard package. Some features of the IPPS have yet to be duplicated by later systems; the twinkly lights of the centering algorithm are fondly remembered. Modern cursor positioning devices are toys compared to the original industrial trackballs and joysticks.

IRAF—what to say about IRAF in a single paragraph? As a member of the former Image Reduction and Analysis Facility (IRAF) group, I am grateful to Doug Tody and Jeannette Barnes for the opportunity to work on so many great projects. Perhaps having had to write one's own image processing code to undertake even the simplest of chores makes a standard package that much more desirable. Many thousands of scientific papers have benefited from this one NOAO facility—as will many more yet. The longevity of IRAF was designed into it through its rugged portability. In newly evolving systems, it will outlive code that has yet to be written, and it will be used to reduce data from instruments not yet built. Rather than give a single reference to IRAF (but see *iraf.net* as well as *iraf.noao.edu/iraf/web/faq/FAQsec01.html#1020*), it may be best to point out that the IRAF group was instrumental in the creation of the annual Astronomical Data Analysis Software and Systems (ADASS) conference series, which recently held its nineteenth conference. See any of the ADASS conference proceedings to realize the influence of this small software group. A more comprehensive discussion of the impact of IRAF appears in "IRAF—More than Just a Four Letter Word" in this *Newsletter*.

A milestone for both NOAO and IRAF was the development of the IRAF Control Environment (ICE) for acquiring data from CCDs. ICE is an extension of the CCD data acquisition (ccdacq) package

continued

Jun. 1963
Representatives of ESO and AURA meet to discuss possibility of the European Southern Observatory being located on CTIO's grounds. In 1965 ESO decides on La Silla for its location.



Sept. 1963
First vehicle driven to Cerro Tololo on the primitive, but passable, 38-kilometer access road

Dec. 1963-Feb. 1964
Mt. Wilson and Palomar Observatories Director H. Babcock visits CTIO to initiate a site survey on AURA's grounds for a Carnegie Southern Observatory. After initial tests at Cerro Pachón, further testing was limited to Cerro Morado. Eventually the Carnegie Observatory is established on Las Campanas.

1964
Kitt Peak Visitor Center completed

Jan. 1964
Construction begun on the Headquarters building in La Serena, Chile

Jan-Jun. 1964
Leveling of the top of Cerro Tololo carried out

The Evolution of Digital Data at NOAO continued

written by Skip Schaller to support CCD cameras at the University of Arizona Steward Observatory. ICE (*www.noao.edu/kpno/manuals/ice*) represents just one of many successful community partnerships during the heyday of IRAF. The package continues to be used nightly on Kitt Peak after 20 years. ICE is a client-server application for combining information from and coordinating the behavior of telescopes, instruments, and detectors. The flexibility of this architecture has permitted a rich evolution of data-taking features such as support for nod-and-shuffle spectroscopy, for the Mayall prime-focus short-scan imaging mode, and to take heliocentrically cadenced observations for asteroseismology. ICE originally produced IRAF-format images, but automatically inherited support for FITS when the IRAF FITS kernel was introduced. When FITS added the unsigned short integer pixel type, ICE enabled 16-bit ADC upgrades on KPNO cameras. When FITS became Y2K (Year 2000) compliant, so did ICE.

Of course, ICE is only one of several data acquisition packages in use on NOAO telescopes. ARCON-controlled CCDs on Cerro Tololo rely on a separate ICE-like package. Infrared (IR) detectors used the WILDFIRE package. The Mosaic Data Handling System was developed to interface to a new generation of more complex instrumentation. Many people worked on these projects. They are not discussed here in the great detail deserved because I don't know all of the details. One common goal, however, is that great attention was paid to the challenging issue of header keyword standards—a goal that is still important to recent NOAO-developed instrumentation such as NEWFIRM and now includes the development of a comprehensive NOAO Data Handbook (*archive.noao.edu/doc/NOAO_DHB/NOAO_Data_Handbookv1.1.pdf*, Shaw, 2009). The last several years have seen a rich set of instrument partnerships between NOAO and external organizations. One challenge with such projects is precisely to maintain a coherent set of common data and metadata standards.

A key aspect of the general trend from analog toward digital technologies was the shift of user interfaces and the accompanying logistics from a manual paradigm to something that could be automated. Paper log books and observing reports are largely a write-only medium. NOAO still receives shipments of photographic plates being returned after many years of sitting on the shelves of former observers. By comparison, digital technologies permitted bookkeeping by computers.

To compute or not to compute is not the question. The question is how to best use the computers. NOAO operates about a dozen telescopes on three mountaintops in two hemispheres. Many instruments are used each semester between the various telescopes. Those instruments are supported by dozens of computers with idiosyncratic combinations of hardware interfaces, operating systems, and data acquisition software. Creating a manageable infrastructure that can be safely and efficiently comprehended by visiting observers—as well as by staff scientists, engineers, and programmers—requires a coherent observing environment.

Such an environment was the goal of the KPNO "Going X" project (support for the Unix X-windows graphical user interfaces) in collaboration with Bruce Bohannan and with input from many astronomers. The necessary design decisions were too numerous to mention here, but critical components were the IRAF Ximtool and Xgterm applications. Adding to the complexity was the need to support innovative observing modes ("New Observing Modes," Boroson, Davies & Robson, eds., ASP Conf. Ser. 87, 1996) such as service/queue observing and remote operations ("Observing at a Distance," Emerson & Clowes, eds., 1993).

The transition from physical media (e.g., photographic plates and chart recorder tracings) to digital media (CCDs and IR array detectors) was also accompanied by a paradigm shift in the preservation of data. NOAO retains ownership of the glass plates created at its telescopes. Like many observatories, we maintain a plate vault at the Tucson headquarters. The flip side of the ease of copying digital data is that, unlike a plate, no one copy can be identified as the original. What does it mean to "own" digital data, and how best might they be permanently preserved?

The "Save the Bits" (STB) project was initiated by Caty Pilachowski to address this looming crisis. Rather than relying on the observer or staff to write a "T-tape" (when a copy was retained at all), a separate archival copy of the data from all telescopes was automatically queued for writing to Exabyte tapes at a central location. This system was activated on Kitt Peak on 20 July 1993 and then on Cerro Tololo a year or two later. It has evolved through many stages since then, including the CD-based WIYN Data Archiving and Distribution System, support for Multi-Extension FITS files from the two Mosaic cameras, a version writing DAT tapes, installations at Keck (HIRES data now in the Keck Observatory Archive) and Lick Observatories, and finally the purely online holdings created by

continued

Feb. 1964
First radio messages sent between CTIO and KPNO. The U. of Chile allowed CTIO to use its assigned wavelengths and call letters.

Mar. 1964
AURA Board approves five-year master plan for development of CTIO

May 1964
First 800 books acquired for CTIO library

Jun. 1964
Water being pumped to Cerro Tololo from a spring at Los Placeres

Mid 1964
The U. of Chile, La Serena Branch, on a cost-free basis, allows CTIO to build an access road to CTIO headquarters across its property

Jul. 1964
Within weeks of leveling the summit of Cerro Tololo, housings were started for the 0.41-m, 0.92-m, and 1.5-m telescopes

The Evolution of Digital Data at NOAO continued

iSTB. Through it all STB has been operating continuously at one telescope or another for 16 years and counting.

The iSTB daemon is responsible for merging diverse sources of archival metadata, for instance, from the telescope schedule and proposal database. It must verify the FITS conformance of data from diverse instrumentation. It attaches a reliable timestamp to validate the instrument clocks. A serial number permanently identifies each file. A checksum is generated and written to the file (an interesting problem since this itself changes the checksum of the file). The file is compressed. Finally the files are passed to the NOAO Data Transport System (DTS) to merge and replicate the data from NOAO's far-flung mountaintops and data centers at the central NOAO Science Archive (NSA).

The NSA (*www.noao.edu/noao/noaonews/jun08/pdf/94dpp.pdf*) forms one component of the larger NOAO End-to-End Science Data Management (SDM) system (*www.noao.edu/sdm*). Other SDM components such as the NOAO High-Performance Pipeline System and the NOAO VO (Virtual Observatory) Portal are likewise beyond the scope of the current article. Data and metadata standards are what tie all these diverse systems together into a unified whole. These trends are larger than NOAO, of course, reaching their current expression in the concept of a unified optical/IR observing system (System). Among everything else that it is, the System represents a shift of focus to coherent management of community data assets. The context for such management is found in the standards of the International Virtual Observatory Alliance (*www.ivoa.net*) and in the US coordination through the Virtual Astronomical Observatory (*www.us-vo.org*). For the early history of the VO see "Virtual Observatories of the Future" (Brunner, Djorgovski & Szalay, eds., ASP Conf. Ser. 225, 2001).

This is a retrospective article, but the immediate future of NOAO will be as exciting a time for digital data wranglers as any to date. The Dark Energy Camera and One Degree Imager gigapixel cameras will strain our infrastructure far beyond the total of all previous instrumentation on NOAO telescopes. New technologies such as the FITS Tile Compression convention (*heasarc.gsfc.nasa.gov/fitsio/fpack*) will be required to reduce bloated data handling requirements to manageable levels. Infrastructure improvements such as a new DTS will be needed to handle the flood of data.

Ultimately the challenge is not one solely of changing technology, but of how the art and science of astronomy is evolving to benefit from these changes. Gigapixel cameras will spawn petabyte surveys (leading up to the Large Synoptic Survey Telescope) that will push into new realms of investigation, in particular, of the time domain. Adequately addressing such projects will require new ways of understanding issues of digital data (for example, *arxiv.org/abs/0910.3733* or *arxiv.org/abs/0802.0262*), not simply better ways of solving old problems. NL

IRAF—More than Just a Four Letter Word

Rob Seaman, Mike Fitzpatrick, Frank Valdes & Elizabeth Stobie

Just as digital detectors changed the way astronomers collect data, the Image Reduction and Analysis Facility (IRAF) changed the way astronomers reduced those data. IRAF provided a common framework that allowed astronomers for the first time to reduce data at the telescope or their home institutions and publish results that could be universally understood. Indeed, "data were reduced by IRAF" is an accepted description of the data reduction in journals, and astronomers at all levels of seniority are able to swap common stories about their experiences with the system. While current software practices might produce a much different system, it is its architecture that has kept IRAF functional and relevant to the community as the package nears its 30th anniversary.

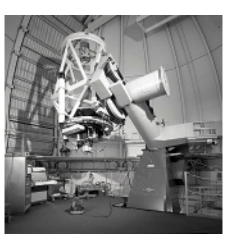
"The IRAF project began in earnest in the fall of 1981," asserted Doug Tody (Tody, Proc. SPIE Instrumentation in Astronomy VI, 1986). Earnest is a good word to describe the many contributions to IRAF made over the years by numerous individuals and software projects at

continued

Sept. 1964
84-inch telescope on Kitt Peak is available for research

Dec. 31, 1964
AURA signs contract with General Electric to purchase the fused silica glass blank for the 158-inch KPNO telescope

1965
50-inch telescope installed on Kitt Peak, with early attempts at robotic control



Jun. 30, 1965
The CTIO staff consists of seven employees, two of whom were at Tucson, Arizona. By January 1976 when the 4-meter telescope was put into operation, the staff numbered 175.

Dec. 1965
First 50,000-gallon water storage tank installed on Cerro Tololo

Dec. 1965
An additional hectare containing a house is added to the La Serena compound at its western end (Calle Cisternas)

IRAF—More than just a Four Letter Word continued

NOAO and elsewhere. The first public release of IRAF was v2.3 in 1986, with major releases following roughly annually through v2.10 in 1992. This early era was marked by explosive growth in the IRAF community as individuals and projects such as STSDAS (Space Telescope Science Data Analysis System) and the multi-mission PROS (Post-Reduction Off-line Software) x-ray package adopted the system, quickly making it the standard data reduction package for community data as well as for NOAO instrumentation.

For IRAF, the 90s was largely a decade of external package development, requiring only a few major releases and continued support of new platforms, including the first ports to PC platforms such as Linux. Individual astronomers likewise began developing their own script tasks, observatories developed reduction packages for local instruments, and some sophisticated analysis packages also emerged from the community. During this time period, the IRAF Help Desk saw a peak in activity and the paper newsletters were replaced by Web-accessed information. The broadening community perspective on astronomical software resulted in NOAO and the IRAF Group hosting the first Astronomical Data Analysis Software and Systems (ADASS) conference in Tucson in 1991.

IRAF's third decade began with a Year 2000 (Y2K) tune-up to prepare the system for a new millennium. Despite a growing trend toward project-specific software development, the emergence of the international Virtual Observatory projects showed there was still great interest in development to benefit the broader community. IRAF became one system in a much larger software landscape both inside and outside NOAO.

Mission-critical systems at NOAO have IRAF highly integrated into them: the NOAO High-Performance Pipeline System relies on scripted IRAF modules to tailor complex algorithms to instrument-specific needs; the NEWFIRM camera's Quick-Look Pipeline is a necessary component if observers are to make efficient use of this complex instrument, and it remains a staple of data reduction for the scientific staff and visiting observers. An IRAF-based observing environment is ubiquitous on the NOAO mountaintops as well as at many other telescopes to perform a multitude of image processing chores. The NOAO archival systems such as Save the Bits and the NOAO Science Archive have similarly used IRAF for offline and online purposes. The IRAF Group has produced key non-IRAF software such as the Mosaic and NEWFIRM Data Handling Systems and the Ximtool and Xgterm display clients that are relied on widely across the community. All this is in addition to the central mission of IRAF to support data reductions from optical and infrared imagers and spectrographs.

Some IRAF statistics:

Overall Numbers:	
Number of OS platforms supported since the first IRAF release	27
Minimum number of external packages known to exist	106
Number of users registered on iraf.net	1,379
Cumulative help desk questions answered	48,774
Number of journal citations to IRAF-based software	8000+
Core system (IRAF + NOAO package):	
Number of tasks	1200+
Number of CL scripts	330
Number of packages	80
Lines of code	1.28 million
External Packages (of 64 currently in use):	
Number of tasks	3300+
Number of CL scripts	1991
Number of sub-packages	255
Lines of code	1.46 million

NOAO remains committed to the future of IRAF, and there is every reason to believe the current system can continue to be ported to new hardware platforms as they come along. Recent development projects such as the 24-bit Ximtool and 64-bit IRAF are helping to modernize parts of the existing system as we evaluate what place IRAF might hold in a next-generation analysis environment. The move toward large-format mosaic detectors, catalog science, and multi-wavelength analysis represents a fundamental shift in the way astronomy will be done in the future. Funding realities simply emphasize that the large community investment in existing software systems must be protected. No doubt, new frameworks for astronomy will emerge in coming years. We are confident IRAF will play a part in these systems and continue to provide trusted science applications to the NOAO community. NL

1966-1967
CTIO Acting Directors: F.K. Edmondson, Alex Smith, W.A. Hiltner, Orren Mohler, Art Hoag

Mid 1966
Five houses completed on Cerro Tololo

Oct. 26, 1966
AURA concludes agreement with the U. of Michigan to install the Curtis Schmidt telescope on Cerro Tololo on a 10-year loan basis; the agreement was extended for 25 years in 1975

Dec. 1966
Ford Foundation decides to donate $5 million on a matching-grant basis with NSF for construction of a 4-m telescope in the Southern Hemisphere

Mar. 1967
0.92-m telescope acquired and installed outdoors; moved to its permanent housing at CTIO in May

Apr. 3, 1967
The housing for the Curtis Schmidt telescope is completed

Kitt Peak National Observatory— The Early Years

John W. Glaspey

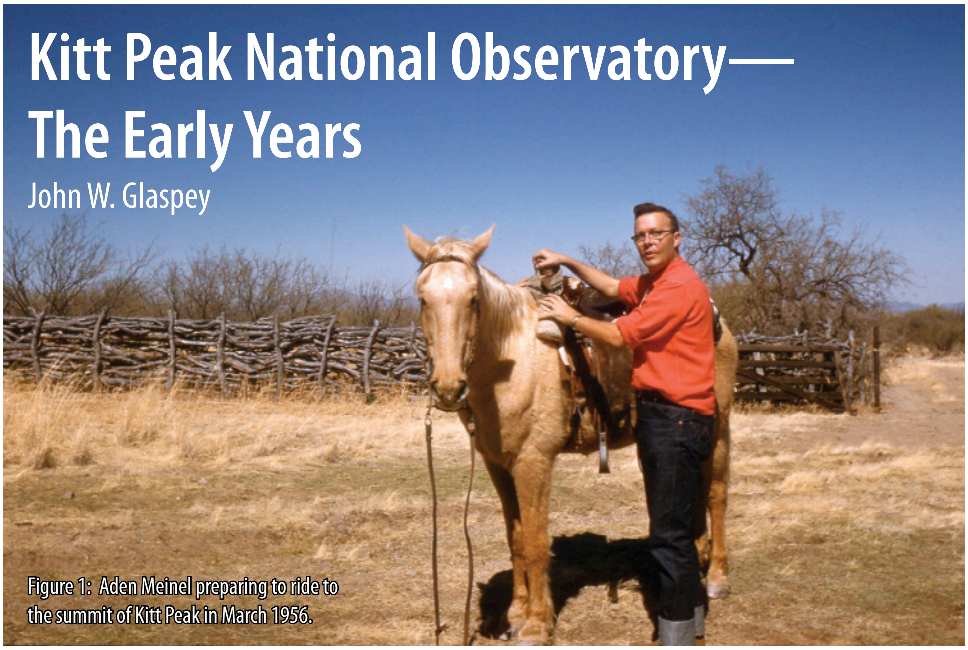


Figure 1: Aden Meinel preparing to ride to the summit of Kitt Peak in March 1956.

One of the joys of looking into the events covering the early years of Kitt Peak as a center for astronomy has been rediscovering a large collection of pictures (and movies!) that most of us have never seen. The NOAO online Image Gallery has a nice variety of what are described as historical images, but even more have been found, some of which accompany this article.—J. Glaspey

Much of the early history of the National Science Foundation's decision to fund a National Astronomical Observatory is documented in Frank Edmundson's book (*AURA and its US National Observatories*, Cambridge University Press, 1997). In 1954, an initial grant was given to the University of Michigan to fund an Advisory Panel headed by Robert McMath to begin the site selection process. The committee selected Aden Meinel, then of Yerkes Observatory, to lead the effort. The charge to the committee essentially predetermined that the site would be in the Southwest. Meinel reports having examined photos taken by sounding rockets to help get started (remember, all of this was before the first artificial satellite, Sputnik!). These photos confirmed that there were many mountains in Arizona and New Mexico that looked promising. Helmut Abt, also of Yerkes and a frequent observer at McDonald Observatory in West Texas, was tasked with hiring a pilot to fly him around the Southwest to have a better look at the mountaintops than could be obtained by examining topographic maps. Abt's description of his adventures is described in his interview included in the American Institute of Physics oral history project. (*www.aip.org/history/ohilist/23364.html*).

Once Arizona became the most likely region, Meinel established a base of operations in Phoenix, AZ. Abt, Meinel, and Harold Thompson, a draftsman for Meinel at Yerkes, drove from Yerkes to Phoenix in Abt's convertible. Abt later drove around Arizona looking at various mountains from whatever roads got close to each mountain. One interesting possibility was Mt. Graham, near Safford, AZ. He asked about a guide to go with him to the summit and was told to contact a local high school student who loved astronomy and was an outdoorsman, namely, Gary Chapman. (Chapman eventually received his PhD in astronomy from the University of Arizona and later worked at UC Riverside.)

Figure 2: Harold Thompson adjusting his gear on the horseback ride to Kitt Peak. Ramon Lopez is in the background.

Abt had taken many pictures, but he also collected and organized thousands of other images taken during the site survey phase of the project by Meinel and others. Figures 1 and 2 are examples, showing Meinel and Thompson preparing for what was their first ascent to the summit of Kitt Peak, thanks to the assistance of two Papago (now called Tohono O'odham) ranchers who provided horses and helped wend their way up the pathless mountainside. Thompson remembers that in those days Meinel always seemed to have his 35 mm camera (an Ansco, he believes) with him whatever they were doing.

continued

Apr. 1967
Site construction for 158-inch telescope begins on Kitt Peak

Apr. 1967
At Punta del Este, Uruguay, US President Johnson and Chilean President Frei jointly announce that the Ford-NSF 158-inch (4-meter) telescope would be installed on Cerro Tololo

Apr. 1967
David Crawford appointed as project director for the Cerro Tololo 158-inch telescope, built in parallel with Kitt Peak's

May 1967
Housings for the 0.41-m and 0.92-m telescopes are completed on Cerro Tololo

credit: J. Glaspey

Aug. 1967
Victor M. Blanco appointed CTIO Director

Sept. 1967
Previously planned houses on Cerro Tololo for the CTIO director and a mountain superintendent, as well as three other houses, are eliminated from the Master Plan

Kitt Peak—The Early Years continued

Figure 3: Preparing to tow equipment up the steep road to the summit.

Eventually two very promising sites were selected for further testing: Kitt Peak and Hualapai Mountain near Kingman, AZ. Permission was obtained to erect seeing test towers at each of those sites. For Kitt Peak, a crude road up the northeast slope to the summit was made using a bulldozer. Figure 3 shows some of the equipment being towed up the steep grade, which reached 78 percent in at least one spot!

While these efforts proceeded, Meinel worked with well-known engineer Bill Baustian of Lick Observatory to help design and build two 16-inch telescopes and simple photometers for verifying photometric conditions at Kitt Peak and Hualapai. The first 16-inch telescope was moved to Kitt Peak in the summer of 1957, with Chapman—by then a college student—assisting in its delivery and installation. One of the observers hired to carry out photometric and transparency monitoring, J. C. Golson, continued working at KPNO, participating in David Crawford's development of the Stromgren Photometric system until Golson's death in 1984. The 16-inch telescopes eventually became the first telescopes to operate scientifically at both Kitt Peak and Cerro Tololo in Chile.

Figure 4: Assembling the seeing towers was not work for the faint of heart!

In March 1958, Kitt Peak was officially selected by the NSF as the permanent location of the National Astronomical Observatory, and a perpetual lease was negotiated and signed in late 1958 by the NSF and the Papago Tribe, now known as the Tohono O'odham Nation. A better road was begun in mid-1958 with a maximum 18-percent grade, which enabled heavy equipment for the initial telescopes to be safely delivered. The survey work for the 5-percent grade, public-access road commenced in late 1958.

Figure 5: The 16-inch telescope on the way to Kitt Peak.

The goals of the fledgling National Observatory were to build several nighttime telescopes, including two 16-inch telescopes for photometry and one each 36-inch and 80-inch multi-purpose telescopes. By the time the Kitt Peak lease was signed in 1958, detailed studies for the construction of both the 36-inch and 80-inch were well under way, with the solar telescope project not far behind. A long-term goal of building a large, 150-inch-class telescope was also included in the long-range plans right from the start.

One of the prime criteria for selecting the site was that it be near a major university, preferably one with an astronomy program. Thus, the University of Arizona was an important partner, even if it was not initially an AURA member. Director of Steward Observatory Ed Carpenter was eager to expand the astronomy program and had the support of the university administration. Carpenter had already been looking into moving the Steward 36-inch telescope away from Tucson, but he had not been considering Kitt Peak until Meinel contacted him. Although there had been some investigations of the mountain for mining, Kitt Peak was completely undeveloped.

continued

Oct. 1967
158-inch mirror blank arrives on Kitt Peak

Oct. 1967
1.5-m telescope installed on Cerro Tololo

Oct. 1967
The round administrative/scientific office building is completed on Cerro Tololo

credit: J. Glaspey

Oct. 1967
Astronomers' Dormitory and Dining Hall first occupied on Cerro Tololo

credit: J. Glaspey

Nov. 1967
Cerro Tololo instrument shop completed; it subsequently becomes the electronic shop, and eventually the visitors' center

Nov. 1967
The U. of Chile and CTIO jointly sponsor a conference on Astrophysical Photometry in Santiago as part of the CTIO inauguration program

Kitt Peak—The Early Years continued

Figure 6: Early construction work on the dome for the first 36-inch telescope.

Figure 7: Loading of the raw glass for the 84-inch mirror into the furnace at Corning Glass.

Figure 8: Aden Meinel inspecting the 84-inch mirror blank at Corning after it was removed from the mold.

AURA negotiated a long-term lease for land adjacent to the campus, and the Kitt Peak National Observatory (KPNO) Headquarters was opened in 1960 at 950 North Cherry Avenue, across the street from Steward Observatory. The proximity has clearly benefited both organizations. Furthermore, Gerard Kuiper chose to move his planetary studies group to the U. of Arizona in the early 1960s, setting up what is now the Lunar and Planetary Laboratory.

Construction of the 36-inch telescope and (what became) the "80-inch" telescope began in 1959. The final design was for an 84-inch primary working at f/2.7, unusually fast for that era, but slower than the f/1.5 that Meinel had first proposed. KPNO also showed innovation by developing cooled, low-light-level television tubes as detectors. Other groups apparently were going to work only with studio-quality systems.

KPNO also created a Solar Division. Dr. Keith Pierce had joined the organization in 1958 and worked with Robert McMath to design what became the world's largest telescope for solar observations. Initial site work began in mid-1959 and the telescope had first light in 1962, unfortunately, after McMath had passed away.

Before any large, ground-based telescope was installed on Kitt Peak, KPNO had a Space Division, headed initially by Meinel and later by Dr. Joseph Chamberlain. Initially, this group was active in the planning of the early Orbiting Astrophysical Observatory projects. This group also launched instruments in Aerobee rockets and built the 50-inch telescope for what would have become the first Remotely Controlled Telescope. The latter proved to be too difficult for the technology of the time and the project was stopped. The group's name was changed to the Planetary Science Division in 1969. In the early 1970s, newly appointed KPNO Director Leo Goldberg cancelled the rocket program for financial reasons.

Public access to the observatory on Kitt Peak began in 1963, once the paved road was completed. The gift shop operated in the lobby of the visitor's entrance to the 84-inch dome.

The 36-inch telescope was replaced in 1966 by a Boller & Chivens telescope with a 38-inch primary and was joined by a similar telescope that was intended mainly for photoelectric photometry. Although the mirrors were bigger, they were still referred to as "36-inch," which I believe was a joke Dr. Art Hoag played on the community!

A few years after changing from the employ of KPNO to that of the U. of Arizona in 1961, Meinel began forming a group of optics specialists, which became the Optical Sciences Department. The Optical Sciences Center was built in the early 1970s. The contributions to the local economy of everything that Meinel and KPNO brought to Tucson are invaluable.

And lest we forget: Site selection for what was referred to as the "Chile telescope" started while the early construction at Kitt Peak was just beginning. A note in the 1961 Annual Report for Kitt Peak mentioned that in early 1960 the site selection efforts in Chile moved from the Santiago area to near Vicuña, some miles inland from La Serena. By 1961, the

continued

Nov. 6, 1967
First light on the 1.5-m telescope on Cerro Tololo

credit: J. Glaspey

Nov. 7, 1967
Official inauguration of CTIO. The benediction is by Msgr. Fresno, later Cardinal Fresno. Chilean President Frei visits Cerro Tololo.

Dec. 1967
Excavation started for 158-inch (4-m) telescope housing on Cerro Tololo

Late 1967
Late in the year, the decision is made to locate in La Serena all CTIO service shops not needed on Cerro Tololo: e.g., the instrument shop, ETS offices and shops, the library, receiving warehouse, main garage, and computer center

Mar. 1968
An additional eight hectares are added to the La Serena compound at its eastern end (hilltop)

Mid 1968
Negotiations initiated to modify importation procedures of CTIO shipments

Kitt Peak—The Early Years continued

second 16-inch telescope for the northern site survey had been refurbished in Tucson in such a way that it could be disassembled for transport on mules to a suitable mountaintop in Chile—the beginning of the Cerro Tololo Inter-American Observatory. Now, what began on one peak in Arizona—the National Astronomy Observatory—is some 50 years later the National Optical Astronomy Observatory, providing the US astronomical community with telescope capabilities in the Northern and Southern Hemispheres.

Further reading for more information:

Goldberg, L. 1983, *Sky & Telescope*, 65, 228.
Meinel, A. 1958, *Sky & Telescope*, 17, 493.

History of the NSO Facilities on Kitt Peak

Mark Giampapa

Figure 1: McMath-Pierce solar telescope (foreground) and SOLIS Tower surrounded by three lightning protection towers (background) on Kitt Peak. (Image credit: NSO/AURA/NSF.)

> *"The great new solar telescope at the Kitt Peak National Observatory in Arizona is a source of pride to this nation. The largest instrument for solar research in the world, it presents American astronomers with a unique tool for investigating the nearest of stars, our Sun. This project is of exceptional interest to all of our citizens...."—President John F. Kennedy*

This excerpt from the letter by President John F. Kennedy commemorating the commissioning of the McMath solar telescope on Kitt Peak ushered in a new era of discovery for our nearest star and arguably the most important astronomical object to humanity—the Sun. Dated October 22, 1962, in the midst of the Cuban missile crisis, the letter for the occasion of the commissioning of the world's largest telescope for investigating the Sun must have been a welcome though brief distraction for the young president during the "missiles of October."

Among the first telescopes on Kitt Peak, the McMath was renamed in 1992 as the McMath-Pierce solar telescope in recognition of the seminal contributions and dedicated service to the National Observatory of long-time Kitt Peak and National Solar Observatory (NSO) staff member A. Keith Pierce. For nearly 47 years, the architecturally distinctive McMath-Pierce (see figure 1) remained the largest, optical solar telescope in the world, only to be equaled in aperture by the recently commissioned 1.6-meter New Solar Telescope at Big Bear Lake, California.

The McMath-Pierce main telescope is the largest, unobstructed-aperture optical telescope in the world with a diameter of 1.6 meters. The east and west Auxiliary telescopes are among the largest solar telescopes (both with 0.9-meter-diameter and 0.8-meter-clear aperture) and share the same all-reflective, unobstructed design of the main telescope. The light path is thermally controlled to minimize internal seeing. The large, light-gathering power, the extended wavelength range from the ultraviolet to

continued

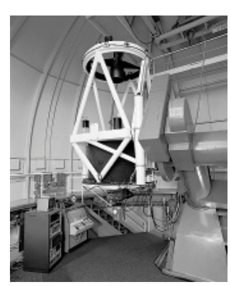
Jul. 1968
Concrete pier for the 158-inch telescope is poured on Kitt Peak

Jul. 1968
The first prefabricated houses for CTIO's US hires

Aug. 7, 1968
With AURA approval, the CTIO director and the rector of the U. of Chile sign an agreement allowing telescope time for U. of Chile astronomers

Dec. 1968
The Government of Chile extends to CTIO's US hires certain benefits enjoyed by foreign employees of the United Nations branch office in Santiago

1969
50-inch telescope converted to manual operation and a new mirror is installed on Kitt Peak



1969
KPNO Space Division is renamed the Planetary Sciences Division

History of the NSO Facilities on Kitt Peak continued

the far infrared (IR), and the well-behaved polarization characteristics of the telescopes make them unique instruments that have stimulated extensive solar and even nighttime research. Used both day and night, the McMath-Pierce solar facility is scheduled for more observing hours than any other large NOAO telescope on Kitt Peak. With existing post-focus instruments that are state-of-the-art, the McMath-Pierce solar telescope has been and continues to be the source of new insights on the Sun. Included in the record of distinguished scientific discoveries achieved at the McMath-Pierce are the:

- discovery of ^{3}He, B, Ho, F, Cl, and H_2O in the spectrum of the Sun,
- discovery of magnetically-sensitive emission lines near 12 microns and the first measurements of magnetic fields at 1.6 and 12 microns,
- best published atlases of the spatially resolved and unresolved solar spectrum from 0.3 microns to 22 microns,
- discovery of complex magnetic fine structure in the quiet sun,
- first direct measurements of kilo-gauss fields outside of sunspots,
- discovery of the intra-network fields,
- discovery of canopy magnetic fields,
- first magnetic-field vector measurements in the chromosphere,
- discovery of cold structures in the solar chromosphere,
- first visible-light interferometric measurements of solar granulation and sunspots,
- first high-resolution images at 1.6 and 10 microns,
- detection of a solar cycle-dependent variation of photospheric convection, and
- multi-decadal monitoring of key chromospheric and photospheric features in the spectrum of the Sun-as-a-star and at the center of the solar disk as carried out by W. Livingston.

The McMath-Pierce telescope also was the location of some of the earliest observations for modern helioseismology. Measurements in 1968 strongly suggested that 5-minute oscillations must arise from acoustic waves trapped below the photosphere. Using the main spectrograph, a team of NSO and university solar astronomers obtained measurements in 1982 of the p-mode oscillations with degrees up to 150 yielding the first measurements of the internal sound speed and rotation throughout most of the sun. This work laid the foundation for the implementation by the NSO of the Global Oscillation Network Group (GONG) program of helioseismology just a few years later.

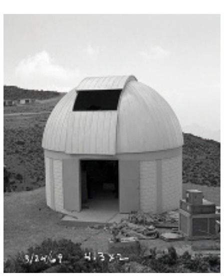
This is only a partial listing of the notable contributions by the McMath-Pierce to solar physics. The current NSO program at the McMath-Pierce under the leadership of telescope scientist Matt Penn emphasizes infrared observations of the Sun with forefront instrumentation that enables diffraction-limited IR imaging and high-resolution spectropolarimetry, particularly long-ward of 2.5 microns for which the McMath-Pierce is uniquely qualified. (Currently no other solar telescope in the world can obtain similar observations.) In this role, the McMath-Pierce on Kitt Peak is serving as a pathfinder for IR solar science and instrumentation for its revolutionary successor, the 4-meter Advanced Technology Solar Telescope (ATST).

Perhaps less well-known but still profound in scientific importance are the non-solar contributions resulting from observations carried out at the McMath-Pierce. Some of the highlights include the first direct detection of magnetic fields on solar-type stars and, later, with the operation of an active nighttime program of synoptic stellar spectroscopy at the McMath-Pierce, the direct observation of a magnetic cycle on a solar-type star. In solar system work, new results obtained at the McMath-Pierce include the discovery that the atmosphere of Venus contains little or no water, the highest-resolution spectrum of a daytime comet, and the discovery of a natural maser in the atmosphere of Mars. The McMath-Pierce continues to host an active program of solar-system research supported by NASA grants to individual investigators.

The McMath-Pierce is home to the Fourier Transform Spectrometer (FTS) (figure 2). Constructed in the 1970s by former (late) staff member James Brault, the FTS is a unique national resource in wide demand by atmospheric physicists and chemists as well as astronomers. A highly stable Michelson interferometer sealed in a vacuum tank, the FTS can capture segments of the solar spectrum from the near ultraviolet to the far infrared at unparalleled precisions

continued

Mar. 1969
Lowell 24-inch telescope installed on Cerro Tololo



May 21, 1969
Harvard and Yale Universities and MIT plan possible installation on Cerro Morado of 90-inch, 36-inch, and l6-inch telescopes

Jul. 25, 1969
The 4-m Cervit mirror blank is cast by Owens-Illinois Company of Toledo, Ohio. The l7-ton casting is the largest casting ever made.

Sept. 1969
Passage by the Chilean Congress of a law modifying importation procedures and freeing CTIO from certain taxations and limitations of its operations

Jun. 1970
The U. of Chile and AURA award the first jointly-financed fellowship for Chilean graduate students in astronomy

Sept. 1970
Completion of 158-inch telescope building on Kitt Peak

History of the NSO Facilities on Kitt Peak continued

and accuracies. In solar physics, the FTS is the source of benchmark spectrum atlases of the Sun and sunspot umbrae. A byproduct of the compilation of the umbral observations was the discovery of water (steam) on the Sun in exceptionally cool spots. The FTS is applied in studies of solar magnetism because of its ability to acquire a broad range of spectral lines simultaneously and because of its extremely high spectral resolution that enables the direct detection of Zeeman splitting without polarization optics.

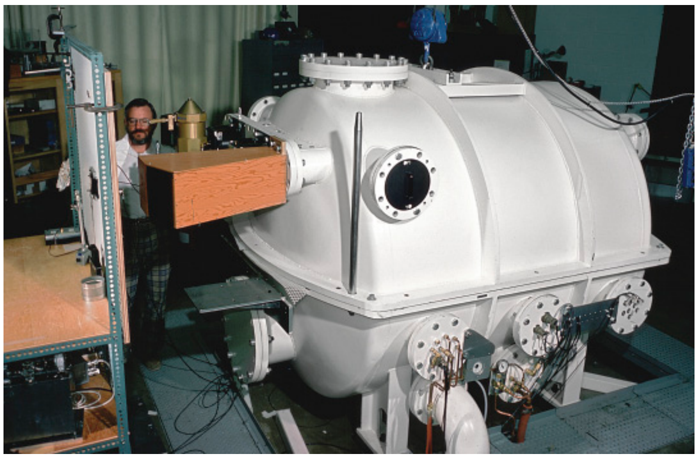


Figure 2: The enclosure for the Solar Fourier Transform Spectrometer (FTS) at the McMath-Pierce solar facility on Kitt Peak. In the background is optical physicist Raleigh Drake. (Image credit: Tom Eglin, Mark Hanna/NOAO/AURA/NSF.)

Interestingly, the FTS has played a crucial role in the detection of extrasolar planetary systems by Doppler spectroscopic methods. In particular, this technique utilizes an iodine absorption cell in the beam as a superimposed wavelength reference on the stellar spectrum, which enables the necessary precisions of 3 meters per second to be achieved for extrasolar planet detection. The calibration of the iodine absorption cell constructed at Lick Observatory was accomplished with the FTS. The resulting "sacred" McMath-Pierce FTS Iodine atlas ultimately led to the discovery of five out of the first six known extrasolar planets at Lick Observatory. It is only with the McMath-Pierce FTS calibration spectrum that it has been possible to unlock the information in the rich iodine spectrum. Most active astronomical iodine absorption cells have been calibrated at the FTS. In this sense, about two-thirds of the known extrasolar planets have a direct lineage to the McMath-Pierce FTS.

The McMath-Pierce solar telescope was joined in 1973 by the newly constructed (in record time!) Kitt Peak Vacuum Telescope (KPVT). The addition of the KPVT further established Kitt Peak as a center for forefront solar observations. This vacuum tower instrument with its magnetograph was designed to obtain full-disk images of the Sun and the solar magnetic field on a daily basis. During the lifetime of the KPVT (1973–2004), approximately 1300 papers based wholly or in part on data from this facility were published with approximately 10 PhD theses utilizing the solar data from the KPVT. Some of the distinguished scientific contributions of the KPVT include the:

- discovery that flares can be triggered by new magnetic flux that cancels old flux,
- discovery of sudden openings of the coronal magnetic field to interplanetary space,
- discovery that open magnetic fields are associated with coronal holes and high-speed solar winds throughout the solar cycle,
- discovery that size distribution of magnetic eruptions does not change shape during the solar cycle,
- discovery that the frequencies of global solar oscillations are closely correlated with the total surface magnetic flux,
- first speckle image reconstruction of solar features,
- first measurements of the rotation rate of supergranulation, and
- first demonstration that most coronal holes rotate differentially.

The KPVT was replaced in 2004 with the new Synoptic Optical Long-term Investigations of the Sun (SOLIS) suite of instruments (figure 3) on top of the newly designated Kitt Peak SOLIS Tower (KPST). The principal instrument of SOLIS is its Vector Spectromagnetograph (VSM) (figure 3). Like the KPVT, SOLIS is a synoptic instrument that acquires full-disk, high-precision observations of the Sun each day. But unlike the KPVT, the SOLIS VSM adds new, critical information about the vector magnetic field configuration in the photosphere at

continued

Mar. 1971
NASA, the U. of Chile, and the Smithsonian Institute install on Cerro Morado a station to observe barium clouds injected into the upper atmosphere by Germany's Max Planck Institute

Mar. 1971
The U. of Chile puts into operation a seismograph station on Cerro Tololo

May 8, 1971
Symposium held to honor Nicholas Mayall on his 65th birthday

Sept. 1, 1971
Leo Goldberg appointed KPNO Director

1972
Solar IR program begins

Mar. 1972
4-m telescope housing completed on Cerro Tololo

History of the NSO Facilities on Kitt Peak continued

Figure 3: SOLIS mount and the Vector Spectromagnetograph (VSM) instrument installed at the Kitt Peak SOLIS Tower (formerly the Vacuum Telescope) surrounded by lightning protection towers. (Image credit: Kevin Schramm/NSO/NOAO/NSF.)

unprecedented precisions. A unique feature among either ground- or space-based magnetographs is that the VSM obtains information about the magnetic field of the Sun in its chromosphere.

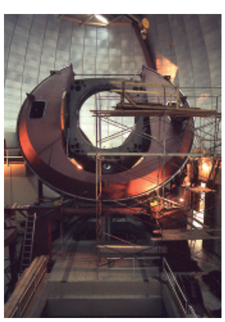
New insights about the solar magnetic field already have emerged from SOLIS. An analysis of VSM chromospheric magnetograms revealed a strong latitudinal dependence for the distribution of the magnetic flux in the polar regions of the Sun. In another demonstration of the impact that combined facilities can have in solar research, a team using both GONG and SOLIS-VSM data discovered that the photospheric magnetic field outside of active regions and the network is found to have a dynamic line-of-sight component that strengthens from disk center to limb as expected for a nearly horizontal orientation. These "seething" horizontal magnetic fields appear to be ubiquitous in the solar atmosphere.

SOLIS will continue to provide unique observations of the Sun on a continuing basis for several decades using state-of-the-art techniques. These long-term studies of the astronomical object most important to humanity will provide fundamental data to understand the solar activity cycle, sudden energy releases in the solar atmosphere, and solar irradiance changes and their relationship to global change.

If past is prologue, then the modern instrumentation at the McMath-Pierce solar telescope and the addition of the innovative SOLIS facility to the array of forefront capabilities on Kitt Peak will ensure that, in the closing words of the commemorative letter from President Kennedy, Kitt Peak will continue to have "…a salient role in the modern exploration of the sun and the universe of stars."

Jun. 1972
Yale University agrees to lend its 1-m telescope to CTIO. The telescope is put into operation one year later.

Dec. 1972
158-inch (4-m) mirror mount installed on Kitt Peak



1973
Kitt Peak rocket program ends

1973
Solar vacuum telescope opens on Kitt Peak

1973
McMath-Pierce FTS begins operations on Kitt Peak

Feb. 27, 1973
First light at KPNO 4-m telescope (D. Crawford, N. Mayall, A. Hoag are first observers)

Aerial Surveillance of Kitt Peak

Figure 1: Kitt Peak in 1959 was undeveloped except for a seeing tower.

John Glaspey &
Buell T. Jannuzi

The development of Kitt Peak National Observatory is easily traceable in the following series of aerial photographs taken over the past fifty years. The initial plans for the observatory always included several telescopes and the necessary supporting facilities, but the details of the development evolved over time. These aerial photographs illustrate the significant planning and effort that went into developing the observatory. It is clear from these images how the infrastructure provided by the national facility also has supported the development of numerous tenant facilities pursuing astronomical research and education.

In 1959 (figure 1), the summit was nearly undeveloped, with only the seeing tower visible from a distance. The dirt construction road that wove around the northeast side of the mountain is hidden in this view from the west. By 1961, the 36-inch (0.9-meter) and 84-inch (2.1-meter) domes had been completed and the rapidly developing solar telescope, soon to be the world's largest, were accompanied by administration (Admin) and maintenance buildings that are still in use today (figure 2). The "new" state road (highway 386) was nearing completion.

In 1974, the recently commissioned Mayall 4-meter telescope was the largest addition since the early 1960s, but the Steward Observatory 36-inch and 90-inch (Bart Bok 2.3-meter) domes, the Solar Vacuum Telescope, the 50-inch (formerly the Remote Control Telescope), a second 36-inch, and two 16-inch domes were all now part of the family of facilities on the mountain (figure 3). Subsequent additions are clear by 1984 (figure 4), including the Case Western Reserve Burrell Schmidt and a facility operated by MIT, as more projects saw the advantages of Kitt Peak as a viable and productive site for astronomical work.

The most modern nighttime telescope on the mountain, the WIYN 3.5-meter, was dedicated in 1995, but its distinctive dome was already present in 1993 (figure 5). WIYN was built on the site of the old No. 1 36-inch telescope, portions of which were moved to the Southeastern Association for Research in Astronomy dome near the Schmidt. By 2004 (figure 6), some of the most recent additions to the mountain are visible, including another Spacewatch telescope on the Steward Observatory sub-lease, the Calypso Telescope below WIYN, and the Kitt Peak Visitor Center 24-inch telescope. Telescopes have come and gone over the first 50 years of operations on Kitt Peak, changing and improving to meet the needs of the researchers who use them. These facilities have been extremely productive and will continue to be so, well into the future.

continued

Mar. 1973
First photographs taken with KPNO 4-m telescope

Jun. 19-20, 1973
The KPNO Mayall 4-m telescope, the world's second largest, is dedicated, completing the list of projects recommended by the original advisory panel in 1955

Jul. 1, 1973
KPNO Mayall telescope construction project ends; Roger Lynds becomes astronomer in charge of telescope.

Jul. 1973
Fred Gillett joins Kitt Peak staff to head infrared program

Mid 1974
Low-wattage microwave relay station erected on a side spur of Cerro Tololo by the Chilean Telecommunications Agency, ENTEL, per agreement with AURA

Dec. 1975
Completion of fine tuning of and addition of the Cassegrain secondary to the CTIO 4-m telescope

Aerial Surveillance continued

Figure 2: Kitt Peak in 1961 had completed domes for 36-inch (0.9-meter) and 84-inch (2.1-meter) telescopes and administration and maintenance buildings with construction of the Solar Vacuum Telescope underway.

Figure 3: Kitt Peak in 1974 included the Mayall 4-m telescope, the Steward Observatory 36-inch and 90-inch domes, the Solar Vacuum Telescope, the 50-inch (formerly the Remote Control Telescope), a second 36-inch, two 16-inch domes, and the water catchment basin.

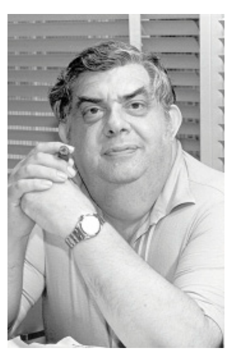
continued

Jan. 1, 1976
First visiting astronomers use the CTIO 4-m telescope

1977
At the request of CTIO, the Government of Chile declares Cerro Tololo a privileged scientific sanctuary where mining is prohibited without permission of the President of Chile

1978
Jack Zirker appointed Sac Peak Obs Director

1978
Geoffrey Burbidge appointed KPNO Director



1979
First *Kitt Peak National Observatory Newsletter*, distribution to astronomers with proposals in 1978. T. D. Kinman and J. Goad editors.

Mar. 1979
NOAO and NRAO create the Flexible Image Transport System (FITS)

Aerial Surveillance continued

Figure 4: Kitt Peak in 1984 shows the addition of the Case Western Reserve Burrell Schmidt and a facility operated by MIT.

Figure 5: Kitt Peak in 1993 shows the addition of the distinctive dome for the WIYN 3.5-meter telescope (far left), which wasn't commissioned until 1995.

continued

Jan. 1980
Workshop held in Tucson on Optical and Infrared Telescopes for the 1990s

Dec. 1980
KPNO, UA, UC, UT technology development proposal for a 15-m telescope. Telescope design concepts are either a segmented primary or a multiple mirror telescope. Proposal will investigate lightweight, 5- to 7-m diameter mirrors and protected mirror coatings. (Proposal approved Dec 1981.)

Jan. 1981
Patrick Osmer appointed CTIO Director

1982
Start of the solar-stellar program at the McMath-Pierce

Aug. 1982
Design workshop in Flagstaff for National New Technology Telescope (NNTT); working group formed at KPNO

Nov. 1982
Columbia University starts operation at CTIO of a 1-m diameter, millimeter radio telescope

Aerial Surveillance continued

Figure 6: Kitt Peak in 2004 had added a second Spacewatch telescope on the Steward Observatory sub-lease, the Calypso Telescope below WIYN, and the Kitt Peak Visitor Center 24-inch telescope.

A Thankful Observatory

Buell T. Jannuzi

Those of us who work for Kitt Peak National Observatory are justifiably proud of the role our facility has played in the development of both the National Optical Astronomy Observatory and the National Solar Observatory. Providing merit-based access to talented researchers to pursue their astronomical research has led to many exciting discoveries and helped train generations of astronomers. Our successes would not have been possible, however, without the assistance of many people and organizations. It is appropriate that we take some space to say thank you.

We are grateful to the people of the Schuk Toak District and the entire Tohono O'odham Nation for sharing their sacred land and their labor in support of the mission of the observatory. Our telescopes are located on Kitt Peak, known to the O'odham as Iolkam Duag. We are honored and grateful to be able to operate from such a superb site for astronomical research. This would not have been possible without the agreement of the Tohono O'odham in 1958 for the creation of the observatory. By working together on areas of common interest, we continue to develop and strengthen our relations with the Tohono O'odham Nation. Several successful joint educational programs are in place, and we are looking forward to future collaborative activities in the years ahead.

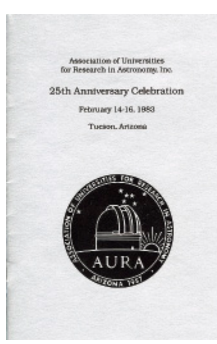
We are grateful for the support received in protecting the darkness of the night sky, so critical to our continuing operation of a world-class research facility. The people, businesses, and governments (cities, counties, and the State) of Arizona have supported the adoption and enforcement of strong outdoor lighting codes. Many government, business, and non-

continued

Nov. 1982
AURA Board of Directors approves creation of NOAO as the combined reorganization of CTIO, KPNO, and Sac Peak Obs (SPO)

1983
The solar programs at KPNO and SPO merge to form the National Solar Observatory.

Feb. 14-16, 1983
25th anniversary celebration for AURA and KPNO



Apr. 1983
NNTT site evaluation at Mauna Kea, Mt. Graham, and CTIO begins

Apr. 1983
Scale models of the two 15-m NNTT telescopes produced

Jun. 1983
AURA moves from Tucson to Washington, DC

A Thankful Observatory continued

profit groups (like the International Dark-Sky Association) have worked together to educate the public on the importance of protecting the night sky.

We are grateful for the support and funding of our observatory by the federal government through a series of cooperative agreements between the National Science Foundation and AURA, Inc.

We thank the talented observatory staff for their hard work and passion for the support of astronomical research and education. They are directly responsible for our ability to offer world class facilities to our users.

We thank the dedicated docents and educators who work so successfully with our staff to use our facilities to educate the public about our facilities, astronomy, and our Universe.

We thank the students and researchers who have turned their ideas and dreams into proposals, come and used our facilities to conduct innovative and important research, and made the effort to share their results with the world. They have kept our facility scientifically productive for 50 years. We are grateful for their efforts and are looking forward to enabling them to pursue many more exciting research programs in the years ahead. NL

Education and Public Outreach at the National Observatories

Katy Garmany & Ken Mighell

Public Information? Outreach? Education? The name attached to this enterprise has changed over the years as the program evolved from its simple beginning to the modern era, which includes national teacher programs, dark sky education around the observatories, and collaboration with many national astronomy education programs. There is also a continuously growing cadre of astronomers who have spent time at NOAO as students and recall their time here with special fondness.

But we begin at the beginning. The Kitt Peak lease signed by AURA with the Papago Tribe (now Tohono O'odham Nation) in 1958 stipulated that there would be a place at the mountain for members of the tribe to sell their crafts. For the first few years, the basket display and visitor's center was in the lobby of the 2.1-meter telescope at Kitt Peak. In 1965, the original visitor's center was completed: it provided a place to display baskets for sale, some wall displays of planets and galaxies, but little else. Posters, slides, and pictures taken at the 4-meter telescope were also for sale. Visitors could take a simple self-guided tour, but there were no nighttime programs for the public.

Education outreach to pre-college students did not play a significant role at the National Observatory in the early years: the astronomical community did not see this as part of the mission. Although the NOAO annual reports did not include a section on education outreach and public affairs until the FY 2000 report, dedicated individuals were responsible for and involved in many programs; in recent decades, education outreach grants have made various programs possible.

continued

Figure 1: Elizabeth Estrada, buyer of Papago baskets for Kitt Peak Visitor Center, with a variety of baskets.

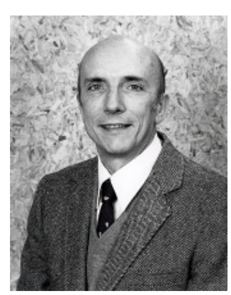
Jun. 1983
Single mirror and multiple mirror NNTT design groups formed

Aug. 1983
NNTT SAC (Bob Gehrz chair) starts work on technical specifications

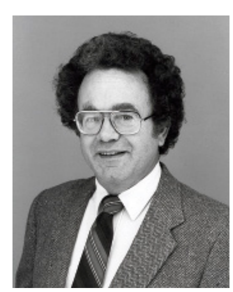
Jan-Apr. 1984
NNTT fabrication and instrumentation workshops; no "show stoppers"

Feb. 1, 1984
NOAO officially formed with John Jefferies appointed first NOAO Director

1984
Bob Howard appointed first NSO Director



May 1984
Advanced Development Program formed at NOAO, Jacques Beckers director



Tohono O'odham Baskets and Elizabeth Estrada

Although not strictly education-related, it is important to recognize the early outreach efforts on the Tohono O'odham reservation by Elizabeth Estrada (figure 1). Estrada worked at Kitt Peak as an editor and research assistant to astronomer Roger Lynds during the 1960s. She also served as the Papago basket buyer for the Kitt Peak Visitors Center and drove all over the reservation in her white station wagon seeking weavers. Estrada was made an honorary member of the Papago tribe (now Tohono O'odham) in 1962 due to her unceasing efforts to revitalize basket crafts. In a 1979 *Newsletter* article, she said there were about 400 women on the reservation weaving baskets, and about half of them sold their baskets through the Kitt Peak gift shop. As a result, the Visitor Center developed a reputation as one of the best places around to purchase these crafts. Estrada's Irish backbone was appreciated by all, as was her skill at editing. She continued in her role as buyer and Visitor Center "basket explainer" until she passed away in 1985.

Public Nighttime Programs on Kitt Peak

What is now called the Education and Public Outreach (EPO) program began as the Public Information Office (PIO). A number of people held the position of public information manager. In 1978, Connie Rodriguez was appointed the director of PIO, and under her direction, the mountain held the first open night for the Papago tribe on 6 April 1979. About 500 people came and enjoyed eyepiece viewing at many telescopes. These Tohono O'odham family nights have become a popular tradition; the most recent one, held in September 2008, drew over 1000 people.

The first evening program for the public was held in September 1980. People began lining up on Cherry Avenue in front of the NOAO office by 1 am for ticket sales that did not begin until 8 am. The Kitt Peak bus held only 36, so many were turned away. The intense interest led to a regular monthly program, run by Don Karl, during the 1980s. Visitors lucky enough to snag a ticket (cost $10) were transported by bus to the mountain, where they saw a movie and ate their picnic supper, watched the sunset (often at the solar telescope), and then were treated to some eyepiece viewing at the 16-inch telescope then located behind the 2.1–meter telescope. Agnes Paulsen, a staff member who coordinated these, remembers this program fondly. An astronomer was always recruited to accompany the group: Paulsen recalls Dave Crawford and Bill Livingston as frequent volunteers. She also remembers the excitement over Halley's Comet in 1986. One former public information manager recalls the night that a couple was left behind at the radio telescope, the last stop by the bus on the way down the mountain! That created quite a commotion as there was no obvious way to retrieve them.

In 1996, the Visitor Center opened its 0.4-meter telescope for the Public Observing Program. With the agreement that visitors could drive up themselves as long as they left the mountain using only parking lights, it became possible to run nightly programs. Today, the programs on

continued

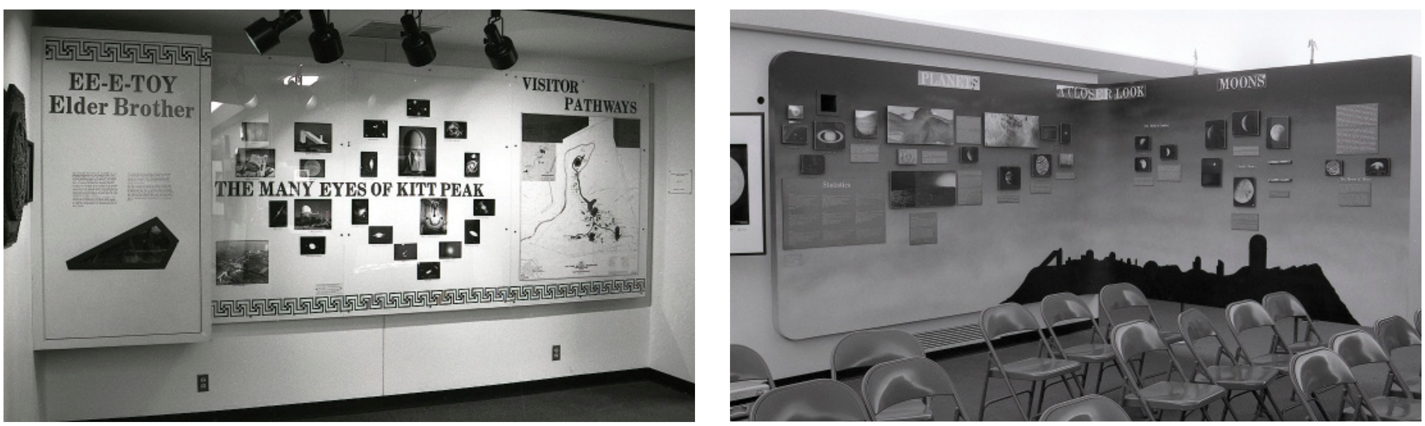
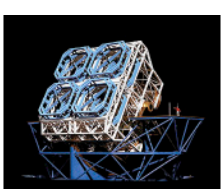


Figure 2: Visitor Center displays for the public.

Sept. 1984
Sidney Wolff appointed KPNO Director

Sept. 1984
The MMT design with four 7.5-m mirrors is selected for the NNTT



Sept. 1984
ADP group starts adaptive optics work

Mar. 1985
Testing on 1.8-m borosilicate mirror starts; discussions with ESO

Mar. 1985
First issue of *NOAO Newsletter* (later named *NOAO/NSO Newsletter*)—the first newsletter from all of AURA's ground-based observatories

Jan. 1986
NSF Astronomy division Committee on Large Telescopes formed (Bob Kirshner chair)

Education and Public Outreach continued

the mountain include guided and self-guided daytime tours, as well as the very popular Night Observing Program and the Advanced Observing Program (*www.noao.edu/outreach/kpvc/*) with three visitor telescopes now in operation. The Advanced Observing Program offers individuals the opportunity to use the telescope all night for imaging or photography with an experienced guide to assist them. There are many volunteer docents who lead walking tours on the mountain and interpret the operations and scientific work of Kitt Peak telescopes. Docents receive a comprehensive eight-week training session that covers topics ranging from astronomy to zoology in order to interpret the mountain to the visitors (now estimated at over 40,000 a year).

IN CHIRICAHUAS

Clawed Camper Tells Of Brush With Bear

By MARGE KUEHLTHAU

George Lockwood, of 510 N. Warren Ave., showed up for work yesterday with a three-inch scratch on his face and a tale of a weekend encounter with a big black bear in the Chiricahua Mountains.

Lockwood, 22, a summer employe at the Kitt Peak National Observatory office at 950 N. Cherry Ave., told fellow workers he was alone at the Morris Campground in the Turkey Creek area Sunday when his unexpected camp visitor arrived.

The 400-pound bear, believed by Lockwood to be a full-grown male, circled his tent for about five minutes, he said, clawing holes in the canvas.

"FINALLY, the bear jumped on the back of the tent and the tent collapsed with me in it," Lockwood said. "When I crawled out, the bear chased me to my car. After I got inside, he leaned over the hood of the car and stared at me through the Volkswagen's windshield.

"Things happened pretty fast, but I believe I got the scratch

—Citizen Photo

George Lockwood

on the side of my face when the bear was clawing through the sides of the tent."

E. T. Carr, district forest ranger with headquarters at Douglas, said that imprints of the bear's paws could be seen on the small car.

HE ALSO said today that "although there are many bears in that area this year, we never before had one attack a camper."

When the bear tired of waiting for Lockwood to leave his refuge and disappeared, the camper gathered up his mauled gear and went to a forest ranger station for first aid.

Lockwood said he had no food in his tent. Forest rangers have urged maintenance of clean grounds as one means of discouraging such unwanted visitors.

Lockwood, whose home is in Hampton, Va., will be a second year graduate student this fall at the University of Virginia.

Graduate and Undergraduate Students Working at KPNO/NOAO

Right from the start there were summer students working at Kitt Peak. In the early years, the program was primarily for graduate students; the current editor of this Newsletter was one of them. Many commented on this experience as seminal to their career. Below are letters from several of these individuals and links to additional statements. Fortunately, only one recalls a close encounter with a bear during his summer stay: Wes Lockwood (Lowell Observatory) made the local paper (see following newspaper clipping) after his first weekend in Tucson.

Letters:

"I applied for an NOAO Kitt Peak summer internship after seeing an ad posted on our department bulletin board in 1974 when I was a junior majoring in astrophysics at Princeton (I was the first female undergraduate in Princeton's history to major in astrophysics, since the university had just recently gone co-ed). I felt very fortunate to be selected, and was Judy Cohen's research assistant. We did a spectral analysis of Feige stars at high galactic latitude, and my time there included some observing as well.

I was already committed to a career in astronomy when I accepted the position, but the summer experience solidified my love of observational research. It was a magical time for me, being at NOAO headquarters and getting to observe at Kitt Peak. It was also important to have Judy as a mentor, since I hadn't seen too many women in the field at that time. Plus, we got a publication out of the work, which I'm sure helped in my admission to graduate school. Summer internships were not as common 35 years ago as they are now, so Kitt Peak was truly a leader in drawing undergraduates into research. I have very fond memories of that experience, and was happy to see one of my own

continued

Jan. 1986
Robert Williams appointed CTIO Director

Feb. 1986
First public release of the Image Reduction and Analysis Facility (IRAF)

Mar. 1986
NNTT site testing ends

1987
Richard Green appointed KPNO Director

Mar. 1987
Sidney Wolff appointed Acting NOAO Director

Jun. 1987
Mauna Kea selected as site for the NNTT

Education and Public Outreach continued

undergraduates participate in the program this past summer."—*Professor Debbie Elmegreen, Vassar College, President-elect of the American Astronomical Society*

"Those three summers provided experiences and opportunities that I think were absolutely crucial to the subsequent development of my career." [Continued online]—*Dr. Pat Osmer, Ohio State University*

"…I took the majority of my PhD thesis data at KPNO and the staff were wonderful teachers (Dick Joyce and Rich Capps taught me how to use the first KPNO IR detectors, Jeannette Barnes taught me IRAF). For all of the above, NOAO (KPNO) will always be a special place for me."—*Professor Paula Szkody, University of Washington, Editor, Publications of the ASP*

For additional statements from some of our successful students, go to the following:

www.noao.edu/noao/noaonews/dec09/letters/

Undergraduate Education, 1980 to the Present

KPNO initiated more formal undergraduate programs beginning in 1980 with a pioneering summer program at Kitt Peak for Native American, Hispanic, and African American undergraduates, which was funded by the NSF.

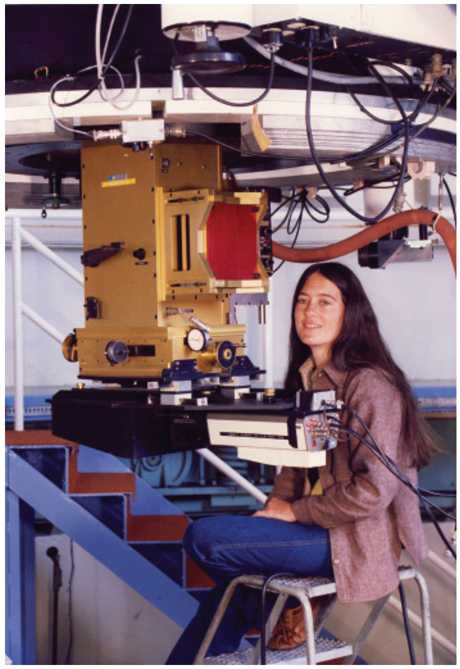


Figure 3: Paula Szkody at the KPNO 50-inch telescope with an IR camera

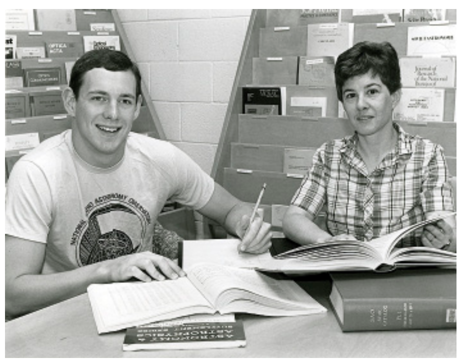


Figure 4: Chris Smith (now CTIO director) and Caty Pilachowski, summer 1986.

This program was developed and managed for three years by staff astronomer Beverly Lynds. The participants did observing, attended classes, and received University of Arizona credit for their work.

The NSF-funded Research Experiences for Undergraduates (REU) programs at KPNO and CTIO have evolved as a vital part of the ongoing commitment of NOAO to meet the nation's need for training of future scientists. Since its 1989 inception, 127 bright undergraduates have participated in the KPNO REU program, and over 80 percent of them have gone on to do graduate research in astrophysics or have pursued a career in the scientific, engineering, or technical workforce.

The KPNO REU and CTIO REU programs offer undergraduate students the opportunity to engage in challenging research activities with NOAO staff astronomers and scientists working at the forefront of astronomy and astrophysics in Tucson and La Serena, respectively. Working and interacting on a daily basis with scientists from diverse research specialties and subdisciplines, REU students at NOAO are exposed to many different aspects of a professional career in astronomy. This day-to-day exposure to a wide range of scientific and technical occupations in astronomy and engineering—available only at a national observatory—is one of the chief benefits of the REU site programs. These programs also provide their REU participants with valuable exposure to non-PhD options for those interested in astronomy, such as instrumentation, technical support, education, and public outreach.

Each year six KPNO REU students are hired as full-time research assistants to work with

continued

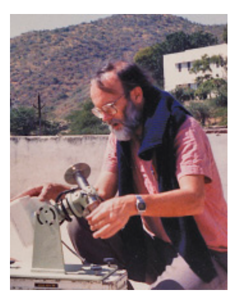
Aug. 1987
Sidney Wolff appointed NOAO Director

Aug. 1987
AURA recommends that NOAO propose to build two 8-m telescopes rather than the 16-m NNTT

Aug. 1987
ADP group testing wavefront sensing

Dec. 1987
Newsletter article "AURA and NOAO Plan 8-m Telescope Program"

1988
John Leibacher appointed NSO Director



Aug. 1988
Pat Osmer leads 8-m proposal effort

Education and Public Outreach continued

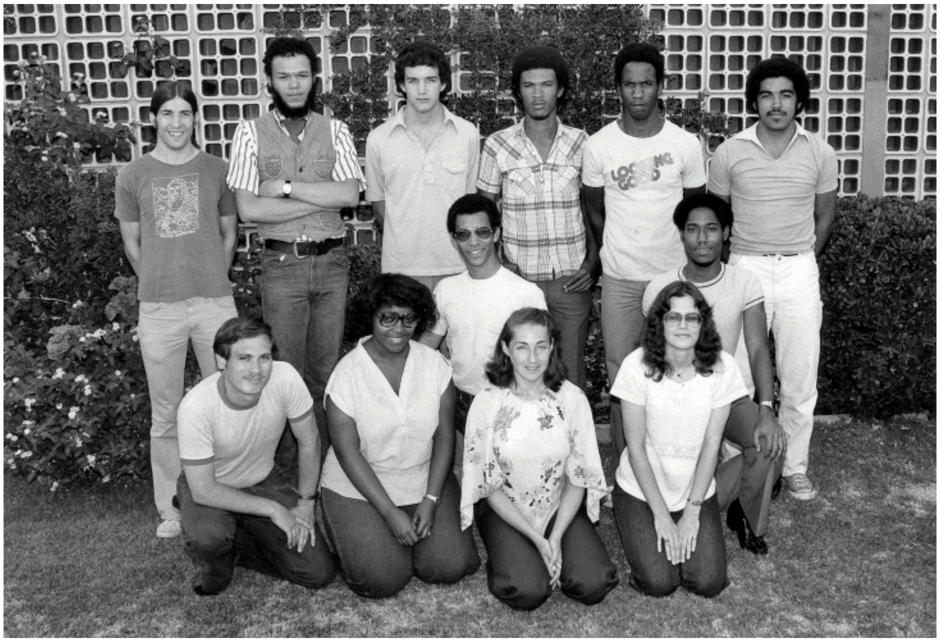


Figure 5: Summer students in 1980 included both graduate students and undergraduates. Those who continued in the field include Evan Skillman (back row, far left), Mike Lesser (back row, third from left), and Gloria Koinegsberger (front row, second from right).

Tucson-based NOAO astronomers and scientists on selected research projects for a period of 10–12 weeks over the summer. As part of their research activities, the REU students gain first-hand experience with the state-of-the-art telescopes and instrumentation of KPNO, and develop expertise in the tools of data analysis specific to astronomical research. All KPNO REU students are encouraged to attend (at the expense of the KPNO REU program) the AAS winter meeting that follows their program to present a poster or deliver a paper. In addition to the research project, the KPNO REU program features weekly scientific lectures and colloquia by NOAO and visiting astronomers, informal lunches and group discussions, and field trips to other telescope facilities in the Southwest.

The CTIO REU program began in 1995. Six American REU students and two Chilean Prácticas de Investigación en Astronomía students are selected every October and begin a 10-week REU program the third week of January.

This year, a third program has been added to the mix of undergraduate programs: the Fisk-Vanderbilt bridge program has been extended to include a research internship called GO-FAAR.

Programs for K-12 Teachers and Students at KPNO

In the 1980s, education outreach, beyond graduate and selected undergraduates, was not generally considered a priority by the astronomical community. As former NOAO Director Sidney Wolff notes, "NOAO and the committees that oversee the observatory did not feel that hiring someone as public outreach director was an appropriate use of funds." But in 1995, while NOAO director, Wolff appointed Suzanne Jacoby as education officer, the first such position at NOAO. Jacoby, who began work at NOAO as part of the IRAF team in the mid 1980s, initiated the first formal teacher programs in 1996 when she received a NASA IDEAS grant to begin Project Astro at NOAO. Project Astro, developed by the Astronomical Society of the Pacific, teams astronomer partners with teachers to bring astronomy into their classrooms. Every year, teachers meet their astronomer partners at a two-day workshop and then continue the partnership all year. The astronomer partner visits the class as "their" astronomer, bringing hands-on activities and content knowledge. By 2000, NOAO was the lead Project Astro institution and hosted the annual site meeting. Project Astro continues as a vital component of EPO at NOAO, and currently must turn away teachers excited about having an astronomer partner.

In 1997, Jacoby received an NSF grant for a teacher summer workshop, titled Research Based Science Education (RBSE). In collaboration with Don McCarthy of Steward Observatory and Jeff Lockwood, a local high school teacher, Jacoby began a four-week summer course open to high-school and middle-school teachers from around the nation. This has

continued

Nov. 1988
Site testing for 8-m telescope starts at Cerro Tololo and Cerro Pachón

Feb. 1989
Discussions with UK exploring 8-m telescope partnership

May 1989
Discussions with Canada exploring 8-m telescope partnership

Sept. 1989
"The NOAO 8-m Telescopes" proposal to build and operate two 8-m telescopes, one in Hawai'i and one in Chile, submitted to NSF

Jun. 1990
Original 0.9-m telescope site cleared to build WIYN 3.5-m telescope

Jan. 1991
Project finally named "Gemini" at meeting of International Steering Committee for 8-m Telescopes

Education and Public Outreach continued

evolved over the 12 years of its active existence to include an online course designed to give teachers the content in astronomy and analysis they need for the different directed research projects, a summer workshop that includes observing on four different telescopes at Kitt Peak, and follow-up observing opportunities that include online data sets for directed research and a student journal.

Another important educational effort was the inception of the *Astronomy Education Review* (AER), an online journal for research related to education. Wolff and Andy Fraknoi, San Francisco State University, began this NOAO-hosted journal in 2002 (*aer.noao.edu/cgi-bin/issue.pl?id=1*). The cover letter to Volume 1, Issue 1 clearly lays out the need for this journal. It fills an important need in the astronomical education community. Wolff's long support for education was recognized by the astronomical community when she was awarded the AAS Education prize in 2006.

Recent years have witnessed the growth of educational projects, those supported by outside grants and those representing partnerships with other organizations. These include Hands-on Optics, Astronomy From the Ground Up, and Globe at Night. And in 2009, the International Year of Astronomy, there have been many important educational efforts that originated with the NOAO EPO group, including the Galileoscope telescope, a low-cost telescope that students can assemble themselves.

And in Closing

Caty Pilachowski, Professor at Indiana University, former NOAO staff member, and past president of the AAS has written eloquently:

> "At one of our Indiana University summer workshops for teachers, I overheard two middle-school teachers discussing their favorite class activities in astronomy. To my surprise, one was sharing her enthusiasm for the 'Jewels of the Night,' a star cluster color-magnitude diagram activity developed at NOAO so long ago that I can't remember when! She loved using it in her class.
>
> (*www.noao.edu/education/jewels/home.html)*
>
> The impact of efforts toward education and public outreach are difficult to measure, but are as important as the technical and scientific output of NOAO. How many of us reading this *Newsletter* must attribute at least a part of our success as astronomers to our own experiences at NOAO as students learning to observe and undertaking dissertation research? Education programs range from graduate training and undergraduate research internships all the way to visits by staff to elementary schools. NOAO's efforts to share research with in-service teachers through Research Based Science Education, to provide kids with hands-on experiences with optics and astronomical data, and to engage the public in the International Year of Astronomy extend the reach of the Observatory well beyond traditional boundaries.
>
> As a university professor with a commitment to public science education, I find NOAO's education resources to be a crucial component in my own classes and in our own community outreach programs. NOAO, thank you!" NL

Apr. 1991
Modular units placed on roof of NOAO Tucson main building for (temporary) Gemini Project offices

1992
Solar telescope renamed the McMath-Pierce on the 30th anniversary of the dedication to honor Dr. Keith Pierce, who headed the development of the telescope

Mar. 14, 1992
Groundbreaking on Kitt Peak for WIYN telescope, designed to provide a wide-field view of the sky

May 1992
Richard Green named first US Project Scientist and US office established for Gemini program

Jun. 1992
Sidney Wolff named Acting Gemini Project Director and takes leave from NOAO directorship; Richard Green appointed Acting NOAO Director and US Gemini Project Scientist to oversee US project office

Sept. 1992
Gemini project MOU among the NSF (US), PPARC (UK), and NRC (CA) signed

Education and Outreach at Cerro Tololo

Malcolm Smith

The second CTIO director, Victor Blanco, understood clearly from the outset the need to interact with the local community in what is now called public outreach. He also understood the many sensitivities involved in interactions between two cultures with different languages. He always insisted on respect for the host country from expatriate CTIO staff. Blanco handled brilliantly the sharp political changes that occurred at the end of the 1960s and early 1970s that, with lesser wisdom, could have quickly terminated the astronomical endeavor in Chile that was just becoming established. In the US, it was being suggested that Chile had become so politically unstable that the 4-meter mirror being built for what eventually became known as the Victor M. Blanco telescope should not be sent down to Chile, but should be kept by NASA for its Large Space Telescope project (which was eventually scaled down to the size of the Hubble Space Telescope primary mirror).

In addition to the huge amount of technical support that KPNO provided to Cerro Tololo throughout that early period, Art Hoag (head of the stellar division at Kitt Peak and acting director of CTIO in 1966) also understood the need to make some long-term effort to protect the skies over Tololo from light pollution. This effort had gained a firm foundation in Tucson with the formation of the International Dark-Sky Association. One of the two founding members was (then) KPNO staff member, Dave Crawford. Nevertheless, by the early 1990s, bright, coastal lighting was being used—successfully—to attract tourists to La Serena.

To protect the skies, we needed stronger legislation, public outreach and education, and a support organization. The legislative effort took 5 years (1993–1998) to produce results—Supreme Decree 686/98, the "norma luminica." Now CTIO had to concentrate on more effective outreach and education programs.

Students

In 1998, Hugo Ochoa (of CTIO) and KPNO staff member Ron Probst decided to work with a new network of seven local schools, "RedLaSer," to take advantage of an opportunity to observe a transit of Mercury. After the event was over, the schools presented a superb joint exhibition with the title (in Spanish, of course) "The Sun, Our Star." This first move away from earlier tendencies to try to show "my school is better than your school" and instead combine their strengths was a huge success. Local grade-school teachers, who were intimidated initially by the scientific content of modern astronomy, became aware of its potential in the classroom and included not only scientific experiments, but also dance, photography, art, essays, etc. CTIO took the bold step of making increasing use of the Internet from the outset.

Doing much of this work on his own time, Ochoa was committed firmly to helping improve science awareness and education in local schools. A huge boost came from the donation by Gemini of a portable planetarium. This additional work in the schools with the planetarium clearly started to impact Ochoa's daytime design and drafting job. Eventually, the priority of one project became so high that, in 2001, CTIO took him off the RedLaSer project and hurriedly tried to find someone else. David Orellana was approached to see if he would take on this work for a year on a trial basis. He gave up his job as a school teacher and dedicated himself to the new task without any guarantee of employment beyond the trial year.

One day, Orellana and Maria Antonieta Garcia (from Gemini South) pointed out that the Municipality of La Serena (where both had strong contacts) was losing so much money on the Astrology Center in the nearby village of Altovalsol that AURA should bid to use the building there to set up an astronomy education center. Astrology was clearly gaining ground in the community and was strongly supported by the previous mayor as a further way to attract tourists—to the "energy and mystique of the Elqui Valley." A local university even proposed establishing a Department of Astrology. After some reluctance to get involved in something like this, it was decided to support the effort of Orellana and make a bid for a home for his fledgling "Didactic Support Center for Astronomy" (CADIAS). The bid by AURA was successful, and a joint venture was set up with the Municipality of La Serena and the University of La Serena (not the university that wanted to support astrology education in the area).

CADIAS adopted the model of asking teachers to propose science programs that CADIAS could support. No attempt was made to pretend that we had all the answers as to how best to carry out astronomy education in the Region. CADIAS has since become a success and an education and outreach model for others,

continued

Sept. 1992
Science requirements document developed by US infrared committee adopted by Gemini Science Committee (US, UK, CA), and Gemini Board

1993
Jacques Beckers appointed NSO Director

1993
Upgrade of KPVT from 512-channel to spectromagnetograph

Feb. 1993
Fred Gillett of NOAO named Acting US Gemini Project Scientist

Apr. 1993
AURA Board urges AURA to establish a US Gemini Office as a separate office within NOAO on a par with KPNO, CTIO, NSO

Jun. 1993
Jay Gallagher named Interim Associate US Gemini Project Scientist

Outreach at Cerro Tololo continued

who now frequently consult with Orellana and his small team.

For just one of many examples where Tucson support has benefitted CTIO directly, the first action of the renewed EPO group in Tucson was to provide CADIAS with a Spanish-language version of *Universe at Your Fingertips*. This formed the real nucleus of an educational library in the CADIAS building, which is supported now by a fourth member of the CADIAS consortium. The National Directive of Libraries and Museums annually provides 200 new books to what has become the village library in Altovalsol! More recently, Hugo Ochoa came back to head up the CTIO EPO department.

Public Programs

Proposals in the early 1990s to change street lights to protect the night sky did not receive a positive reaction from local authorities initially. It was necessary to start by taking small, but high-quality steps to produce a turnaround. CTIO decided to work with a small group of amateur astronomers in the nearby village of Vicuña; most of that early work by Tololo staff was done by Oscar Saa. Our new colleagues in Vicuña worked very hard and never gave up when the going was tough. With the support of AURA, CTIO ordered a 12-inch Meade LX200


32/ EL DIA Jueves, 29 de Febrero de 1996

El Telescopio de Vicuña

El director de El Tololo, Dr. Malcolm Smith, entrega el telescopio a las autoridades de Vicuña.

La comunidad vicuñense exteriorizó su complacencia por el gesto que tuvo el director del Observatorio Interamericano de Cerro Tololo, Dr. Malcolm Smith, al entregar un telescopio de 16 pulgadas que formará parte del Observatorio Comunal de Vicuña.

El telescopio quedará ubicado en el sector de La Totorita, unos seis kilómetros al noreste de Vicuña, donde se habilitará a futuro un lugar que servirá a los usuarios para realizar pequeñas observaciones. Al mismo tiempo, se pretende que sea un sitio donde los turistas puedan comprobar la claridad de los cielos elquinos considerados entre los más aptos de la tierra para la labor de los científicos de la astronomía.

Figure 1: The handover of the Mamalluca telescope to the Mayor of Vicuña.

telescope, a commercial CCD camera, and a computer. When NSF heard about this project, they suggested CTIO submit a proposal to fund the purchase, which was promptly approved in full. The Mamalluca Observatory project was underway. The amateur astronomers in Vicuña made a proposal to CONICYT—Chile's equivalent of the NSF—to fund the dome base building. Their bid was rejected, but their commitment showed when they returned to the charge with a proposal to the Chilean National Arts Council for a building designed in the local indigenous Diaguita style. This was accepted, and the project got underway. The Municipality built a road, Tololo provided an old, unused dome, and the project opened 29 February 1996 (see figure 1). A few more years were needed to complete the building and get things underway.

Over 20,000 visitors now come from outside Chile each year to visit the observatory. Local authorities have understood that such visitors need to eat somewhere and sleep somewhere. However, while "astrotourism" was supported early on by Cecilia Prats (then head of the local tourism department), she was widely criticized at the time for diverting attention from supporting the tradition of "sun and sand" as the way to make money from tourism. Prats' support has been vindicated as seven new public observatories are in operation in the Coquimbo Region and its symbol of tourism (figure 2) calls attention to this Region of Chile as The Star Region. The University of La Serena, working

Región de Coquimbo
La Región Estrella

Figure 2: The Coquimbo Region's symbol of tourism proclaims it The Star Region.

through CADIAS, recently set up a training program in Astronomical Tourism, funded by the Chilean government, in response to the need for quality certification. The multiplicative, collaborative, and supportive approach adopted by CADIAS is having a clear and significant impact now, and the protection of dark skies is now

continued

Oct. 1993
Gemini Observatory established with signing of agreement among the NSF (US), PPARC (UK), and NRC (Canada)

Nov. 1993
Malcolm G. Smith appointed CTIO Director

Dec. 1993
First US Gemini Program section in *Newsletter*

Jan. 1994
Todd Boroson named US Gemini Project Scientist and NOAO Associate Director

Jun. 1994
First light at WIYN 3.5-m telescope

Aug. 1994
First NOAO page on the World Wide Web

Outreach at Cerro Tololo cont.

a community interest, not just a CTIO interest.

Research Experiences for Undergraduates
In 1995, Eileen Friel (now director of Lowell Observatory) started the NSF-funded Research Experiences for Undergraduates (REU) program in Chile. Its operation during the summer months of the Southern Hemisphere—January, February, and March—required that participating undergraduate students come from US schools flexible enough to let their students miss some of the school year and support the REU experience as a positive step by their students. With only one break, the program has continued under a series of directors since then, as can be seen on the CTIO REU Web site (*www.ctio.noao.edu/REU/reu.html*). Six US students live during the summer on the CTIO campus in La Serena, along with two graduate students from Chile who participate in CTIO's Prácticas de Investigación en Astronomía program—providing mutually-beneficial experiences of cultural and language differences. Each student works on a research project with a CTIO staff mentor, and almost all students present their research results at the following January AAS meeting.

A Very Brief Early History of the Cerro Tololo Inter-American Observatory

Víctor Blanco

Editor's Note: This is an excerpt of a much more comprehensive article that can be found at: www.ctio.noao.edu/diroff/ctio_history.htm. *(Pictures are available on this Web site as well.) Editorial changes have been made to match the style of the* NOAO/NSO Newsletter. *The CTIO 4-meter telescope was dedicated to Víctor M. Blanco on 8 September 1995, and is now known as the Blanco 4-meter telescope*

In 1960, there were only 10 astronomical observatories in the Southern Hemisphere compared to the 88 that operated north of the Equator. None of the southern observatories was located in a site chosen carefully for atmospheric excellence, and their telescopes could only collect 10 percent of the light collected by the northern ones. Most astronomers recognized that this imbalance in the world-wide distribution of optical telescopes was especially objectionable because of the location in the southern skies of such astrophysically unique objects…as the Magellanic Clouds, the brightest globular clusters, and the clusters and nebulae-rich Carina-Centaurus Milky Way region.

The earliest published AURA reference to what eventually became the Cerro Tololo Inter-American Observatory (CTIO) is found in the Annual Report of the Kitt Peak National Observatory, 1961. The report described how site surveys had been initiated by Dr. Gerard P. Kuiper and placed under the direction of Dr. Jurgen Stock of the University of Chicago and the U[niversity] of Texas with the sponsorship of the US Air Force, and with the cooperation of the University of Chile. On 30 June 1960, urged by the National Science Foundation, the AURA Board of Directors agreed to take over this project. The role of the U. of Chile in the establishment of CTIO can not be overemphasized. The site surveys had concentrated on various mountains in the southern fringes of the Atacama desert near the town of Vicuña in Chile. During 1961, Cerro Tololo was found to be the best site in the Vicuña vicinity. On 23 November 1962, the decision was made to locate the new observatory on Cerro Tololo and to call it the "Cerro Tololo Inter-American Observatory." Prior to that, CTIO was usually referred to by AURA officials as the "Chile Project." Before the selection of Tololo, in August 1961, a 0.41-meter telescope had been hauled to the mountain top, on mule back, for the final site testing and was used part of the time for serious astronomical research.

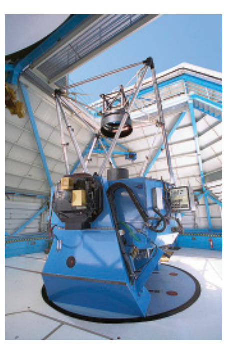
Dr. Stock was named CTIO's first director in 1963, and served as such until early in 1966. He was succeeded by the writer in July 1967, by Dr. Osmer in 1981, and Dr. Williams in 1986. During 1966 and early 1967, CTIO had several Acting Directors including Drs. Hoag, Edmonson, and Hiltner. The conceptual design for the "modern Southern Hemisphere telescope" of the "Chile Project" was initiated at KPNO in 1963 and a 1.5-meter telescope was then envisioned. In 1963, the National

continued

Oct. 1994
50-inch telescope on Kitt Peak closed because of budget constraints

Oct. 1994
Gemini breaks ground at Mauna Kea and Cerro Pachón

Oct. 15, 1994
WIYN 3.5-m telescope dedication ceremony



Nov. 1994
Sidney Wolff: "Call me the First Director" [of Gemini Observatory]

1995
GONG Network deployed

Oct. 1995
NOAO selected by an independent NSF review panel to build GNIRS; workscope signed 12 Oct 1995

A Very Brief Early History of CTIO continued

Science Foundation approved funding a 0.92-meter telescope for CTIO. Excavations for the buildings to house this and the 1.5-meter telescope, which had been funded by the US Air Force, were started within weeks of the leveling of the summit in 1964. The topography of the Tololo summit was too irregular for the building programs that were envisioned and it was decided to flatten the mountain top to a level 14 meters below the top. Between January and June 1964, by blasting and bulldozing, Cerro Tololo was given what some AURA Board members referred to as a "crew cut."

The master plan for the Tololo summit, prepared in March 1964, showed what CTlO was expected eventually to look like. CTlO—under AURA's guidance—would become the largest observatory in the Southern Hemisphere. Since the planners were at KPNO headquarters in Tucson, Arizona, and the builders were in Chile, rapid communications were essential. By February 1964, the first radio messages were exchanged between KPNO and CTIO. To make this possible, the University of Chile let AURA use the wavelengths and call-letters assigned to it. In regard to the telescopes, the need for a Schmidt-type telescope at CTlO was satisfied by an agreement concluded in 1966 by AURA and the University of Michigan to transfer the Curtis telescope to CTlO on a 10-year loan. In 1966, at the suggestion of Dr. Leo Goldberg, the Ford Foundation decided to donate five million dollars on a matching-fund basis for the fabrication of a Southern Hemisphere 4-meter telescope similar in design to the one then being planned for KPNO. The US Congress provided an equal amount of money to the National Science Foundation.

Thus the future of CTlO as a truly major observatory was assured. This gave much importance to the 7 November 1967 inauguration. The main construction effort at CTlO in the year following the inauguration was related to the 4-meter telescope. In the early long-range planning, space on the southern part of the Tololo summit was reserved for such a telescope. The excavation for the telescope building started in December 1967. The "AURA Construction Company" supervised by Srs. Stuart Hurdle and José Guarini tackled this job and successfully completed it in late 1972. Meanwhile, a 4-meter Cervit mirror blank was being polished in the KPNO Optical shop. Although a 150-inch blank had been ordered, expansion of the Cervit-casting moulds resulted in the delivery of a 158-inch blank, i.e., exactly 4.013 meters. In order to take advantage of the additional inches, the telescope tube was enlarged during its design stage. Meanwhile, in 1969, AURA built the housing for a 0.6-meter telescope that the Lowell Observatory acquired for planetary observations. This telescope became AURA property five years later. And in 1974 Yale University agreed to lend CTIO its 1-meter telescope, and this was also put into operation in an AURA-built dome within a year.

By the end of 1975, AURA had put into operation eight telescopes. These were indeed proud achievements especially if one considers the complex supporting infrastructure that the telescopes require in order to operate effectively at a remote location. NL

Panoramic view of Cerro Tololo Inter-American Observatory. Credit: T. Abbott

1995
NSO solar-stellar program closed

Aug. 1996
CCD Mosaic Imager has first light at the Mayall telescope

Nov. 1996
Gemini Science Requirements document approved by Gemini Board

1997
Vents installed in Mayall telescope to improve temperature control.

1997
Doug Rabin appointed Acting NSO Director

1999
Steve Keil appointed NSO Director

The Beginnings of Gemini

Sidney C. Wolff

By the mid-1980s, the 4-meter telescopes at Kitt Peak and Cerro Tololo had been operational for about a decade, and there was much discussion within NOAO and by its many advisory committees about what the next big project should be. Much of the observatory effort during the early 1980s had been devoted to exploring conceptual designs for the National New Technology Telescope (NNTT), which was to be a 16-meter telescope with four 8-meter mirrors on a single mount. By 1987, when I was appointed director of NOAO, it had become clear that there was limited community support for this initiative, perhaps because the science case was focused too strongly on its then revolutionary capabilities for interferometry.

Coincident with my appointment, the full AURA Board held a retreat to review options for a major initiative and determined that NOAO's goal should be to construct two 8-meter telescopes, one in the Northern Hemisphere and one in the Southern Hemisphere. As input, the AURA Board relied heavily on the report of the committee on future directions for NOAO. This committee was chaired by Steve Strom, who was then at the University of Massachusetts, and the recommended priorities were strongly influenced by Frank Low, who developed a persuasive case for the scientific potential of an infrared-optimized telescope. Over the next two years, NOAO staff, led by Pat Osmer, prepared a construction proposal for the two-telescope project and submitted it to the NSF.

At that time, the directors of each of the national astronomy observatories met annually with the director of NSF to discuss plans and programs. In the spring of 1988, Goetz Oertel and I went to see Erich Bloch. As had Geoff Burbidge and John Jefferies before me, I had been faced with a major budget cut during the first year of my appointment (I sometimes think this is a rite of passage for NOAO directors), and so I tried to make the case that aimless budget cutting was pointless and that what was needed was to restructure the observatory so it could move in new directions. I then described the possibility of undertaking a major international project to build two 8-meter telescopes in partnership with the UK and Canada. We had already had informal discussions and knew that astronomical goals and design specifications for new telescopes were very similar in all three countries. Erich Bloch had been very clear in previous discussions that the NSF alone would not support the construction of two 8-meter telescopes. He was also convinced that scientists' ambitions for new facilities greatly exceeded the resources that were likely to be available from the US government, and he was looking for an international project that could be implemented quickly.

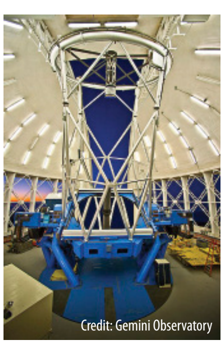
Oertel told me immediately afterwards that he thought that Bloch had bought into the idea of an international telescope project. I was not quite so optimistic, but indeed within two months, Bloch and the science ministers of the other G-7 nations set up an international working group in astronomy, and a year later the group recommended that the US, UK, and Canada join together in the construction of two 8-meter telescopes. To show his commitment, Bloch included a request for initial funding for what became the Gemini Project in the budget submitted to Congress by the president in January 1990.

Although construction funding had already been requested by the NSF, John Bahcall determined that the then ongoing Astronomy and Astrophysics Survey should prioritize the national telescope project. Since there were several ongoing telescope projects supported by non-federal funds (Keck, Magellan, Large Binocular Telescope), Bahcall and committee felt very strongly that the national telescope should offer a unique capability. The committee determined that the national telescope should be infrared (IR)-optimized in order to exploit the remarkable advances in IR detectors that were being made at that time. Fred Gillett, with input from Frank Low, carefully and thoroughly analyzed what IR-optimization required; it turned out that in addition to low emissivity, superb image quality was the most important ingredient. The resulting design was not only IR-optimized but produced a superb optical telescope as well.

Funding and a positive recommendation from the Astronomy and Astrophysics Survey Committee proved necessary but far from sufficient. There were additional challenges: on-again, off-again decisions about funding from the partners; the Congressional requirement that the US pay no more than half of the cost of two telescopes; debate over whether the US would be better served by a single, entirely US telescope on Mauna Kea; the controversy over the choice of mirror technology; etc. But the telescopes do exist, and the image quality and IR properties are indeed superb.

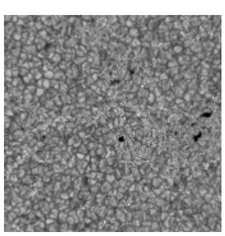
continued

Jun. 1999
Gemini North dedication



Credit: Gemini Observatory

2000
Adaptive optics system installed at McMath-Pierce



Feb. 2000
Bob Schommer (La Serena) named US Gemini Project Scientist, Caty Pilachowski (Tucson) named US Deputy Project Scientist, and Taft Armandroff (Tucson) named US Gemini Project Manager

Jun. 2000
First observing semester at Gemini North was GN-2000QS (QS=Quick Start=2000B)

2001
NSO becomes programmatically independent of NOAO and becomes an AURA Center

Apr. 2001
Jeremy Mould appointed NOAO Director

The Beginnings of Gemini continued

What are the lessons learned? In no particular order:

1. In order to obtain support for expensive facilities, it helps if those facilities serve more than one scientific community and/or more than one societal agenda. It is doubtful that the Gemini telescopes would have been funded as expeditiously as they were if they had not also met the NSF goal of initiating a major international project.

2. Complex partnerships succeed best if they are built on a firm foundation of common scientific goals and performance requirements and are not merely a marriage of financial convenience.

3. Paying for the operation of multiple national plus international observatories is extremely expensive. The only way I have found to cut the costs of operations significantly is to run multiple telescopes with a common infrastructure. Close integration of national with international or other partnership facilities can also help ensure that the entire suite of facilities available to the US community is balanced and responsive to community needs.

4. It is essential to remain in touch with the goals and needs of the user community. National observatories must provide leadership in the sense of anticipating what their user communities will require in future years—but at the same time, national observatories must respond at a reasonable level to a diverse set of current scientific opportunities.

Development of the US Scientific Hopes for Gemini

Richard Green

From 1991 to 1994 we at NOAO were engaging US astronomers to define the instrument suite and scientific performance of the Gemini telescopes. Those aspirations then met the reality of a fixed project budget. Spice was added to our activities with selecting the primary mirror and developing the structure connecting the International Gemini Project with the US effort and NOAO.

A US instrument panel was working in 1991 to define an optical imager, optical moderate-dispersion and high-dispersion spectrographs, near-infrared (IR) imager and spectrograph, and mid-IR capability. The panel formulated their recommendation to the US Gemini Science Advisory Committee (SAC) in the context of their concept for the configuration of the two telescopes. The SAC reported in August 1992, and that document shows the durability of US scientific expectations.

The SAC strongly endorsed Fred Gillett's and Frank Low's vision of a fully IR-optimized telescope for Mauna Kea. They recommended an *f*/16 configuration with protected silver coatings for a goal of 2 percent emissivity. Excellent image quality was to be achieved with fast tip/tilt guiding, evolving to adaptive optics correction. There would be four instruments: a 0.4- to 5-micron imager, a 1- to 5-micron spectrometer, an 8- to 30-micron imager/spectrometer, and an optical R-C spectrograph with a 7-arcminute field. Today's Gemini North (with a renewed Gemini Near Infrared Spectrograph) comes quite close to that concept.

The striking difference is Gemini South. The telescopes were originally designed with interchangeable top ends, to provide an optical wide field. Gemini South was to have the *f*/6 secondary, with all optics aluminum-coated. The highest priority was a high-dispersion optical spectrograph, followed by development of a multi-fiber spectrograph covering a 45-arcminute field of view. Optimization and simplicity of operation were the driving considerations, to provide competitive capability for optical and IR, even if separated by a hemisphere.

That overall concept had to be revised, ironically because of the prompt success of the Gemini NSF proposal, with its frozen project budget based on NOAO's early conceptual design. Good imaging performance required

continued

Jul. 2001
GONG+ high-resolution network provides first data

Sept. 2001
Phoenix shipped to Gemini South

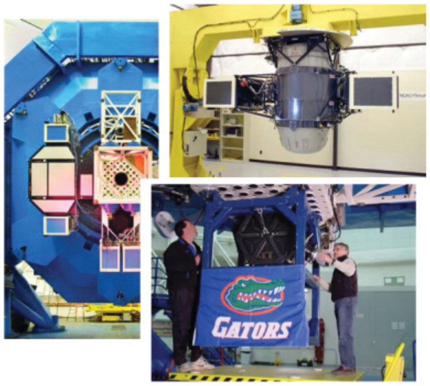
Jan. 2002
Gemini South dedication

Jun. 2002
Solar vacuum telescope retired in preparation for SOLIS

Jan. 2003
First NOAO Gemini Science Center section in *Newsletter*; program name change on Web in Jan, announced in *Newsletter* Issue 73

May 2003
NGSC hosted meeting in Tempe, AZ on the "Future Instrumentation for the Gemini 8-m Telescopes: U.S. Perspective in 2003"

US Scientific Hopes for Gemini continued



From top right, clockwise: The Gemini Near Infrared Spectrograph (GNIRS) on the NOAO Flexure Test Facility (December 2002). The Thermal-Region Camera Spectrograph (T-ReCS) on the Gemini South telescope (April 2003). The Gemini Multi Object Spectrograph (GMOS) mounted on the Gemini North telescope.

a well-ventilated primary mirror, placing its vertex near the elevation axis. Without a way to a Nasmyth focus with an interesting field, the international SAC was forced to drop the Nasmyth platforms. The international project then constrained the two telescopes for budgetary reasons to be identical. The wide field was lost, and the adopted alternative was a Gemini Multi-Object Spectrograph in each hemisphere.

The most heated controversy of that day has passed, the choice of primary mirror. All three technology choices—meniscus and structured borosilicate monolithic primaries and segmented primaries—have all proven to deliver excellent image quality. All have required active mechanical and thermal control to achieve that goal, and each has pros and cons.

One of our early goals has remained elusive. The international partner astronomers intended to create a structure for the new international observatory that would provide effective site-based operations, cultivate instrument development capability in partner communities, and strengthen the functioning of existing national observatories. The outcome was to be a steady contribution of new instrumental capability with well-defined and actually achieved costs and schedules. The upcoming renewal of the international agreement will offer another chance for full success with those intentions. NL

Gemini—The Construction Phase

Todd Boroson

The construction of the Gemini telescopes, from the groundbreakings in October 1994 through the first community scientific observations in early 2001, was a fascinating and exciting period to be involved with this project. Because it was difficult to capture the attention of communities that were engaged with the here and now, the project scientists from the partner countries worked as a close-knit team to develop many of the concepts that came to define the Gemini capabilities.

One of the earliest hurdles was how to get the instruments built. We were all torn by conflicting desires: to get the best and most advanced instruments, to engage the best instrument builders in our communities, to divide the work and the resources fairly. Luckily, even after the wide-field top end was eliminated, there was a large and diverse set of instruments in the first round, a near-infrared (IR) imager (NIRI), a near-IR spectrograph (GNIRS), a pair of medium-resolution optical imaging spectrographs (GMOS), a high-resolution optical spectrograph (HROS), a mid-IR imager (MIRI, which became T-ReCS), a pair of acquisition and guide units (A&G), and the natural guide-star adaptive optics system (ALTAIR). The national project offices scoured their communities for interest in building these, or pieces of these, and they were divided in a way that was equitable and matched up fairly well to the interests expressed.

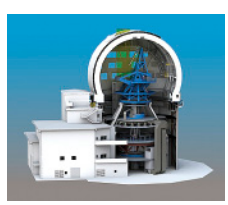
continued

Oct. 2003
GNIRS shipped to Gemini South

Nov. 2003
Alistair R. Walker appointed CTIO Director

May 2004
KPVT decommissioned and SOLIS installed. KPVT renamed KPST (Kitt Peak SOLIS Tower)

Oct. 14, 2004
Haleakalā selected as ATST site



Sept. 2005
Buell Jannuzi appointed Acting KPNO Director

Feb. 2007
First light for NEWFIRM imager at Mayall 4-m telescope

Gemini—The Construction Phase continued

In the end, the University of Hawai'i built NIRI, the University of Florida built T-ReCS, NOAO provided the IR arrays and controllers for both near-IR instruments, and a competition was staged for GNIRS. This was a challenge, since my office—the US Gemini Program, a division of NOAO—had the job of running the competition, but NOAO wanted to propose. This was resolved by isolating the groups from each other and carrying out the entire process with a lot of scrutiny from the NSF and Gemini staff, and the NOAO proposal was selected. As many of the "winning" instrument builders discovered, this was a mixed blessing because of fixed-price contracts with no contingency, no overhead, and rigorous oversight.

As the instrument construction proceeded, the national projects scientists turned their attention to operations. When compromises that resulted in loss of capabilities had to be made, we always tried to find ways to use those decisions to our advantage. The loss of the Nasmyth focus and the wide-field secondary meant that all instruments would be mounted on the faces of a cube behind the primary mirror. We saw this as a situation that would facilitate queue-scheduled operation, a mode that supported the most effective use of Gemini in its low-emissivity configuration. Clearly, when water vapor was lowest, one would use the telescope for mid-IR observations that could not be done during average conditions. More generally, one could optimize the use of the telescope against many variable conditions, such as image quality, sky brightness, and cloud cover. This piqued my interest, and I spent a lot of time exploring the consequences of running a telescope this way, both through Monte Carlo simulations and through real observing experiments using the WIYN telescope on Kitt Peak.

While it was straightforward to convince myself that there were theoretical gains by matching programs to conditions and guaranteeing success for the scientifically highly ranked programs, the challenge of convincing the community that the telescopes should be operated this way was much larger. Astronomical observing is a rare combination of art and science, and each observer believes that he/she is best qualified to carry out the program that he/she has created. Eventually, there was consensus within the Gemini Science Committee that a 50-50 split between queue and classical time would allow the advantages of each approach. Of course, once this was settled, we had to actually develop a scheme for how we would run the queue-scheduled observing. This was eventually taken over by Phil Puxley, who masterminded the system of scientific priority bands and atmospheric conditions that Gemini uses. The details of this have evolved a bit, but the approach has been basically sound.

As the telescopes came together, the final step was getting the US community geared up to take advantage of their new access to these state-of-the-art facilities. This required a change (and increase) in personnel in the group providing this support. During the construction phase, the US Gemini Program consisted of me; Mark Trueblood, an engineer who bore the brunt of overseeing the instruments and subcomponents that were being built in the US; an administrative support person who typically had additional duties elsewhere; and occasional scientists, including, for the last half of 1996, David Silva, now the NOAO director (see "Remembrances and Visions of the NOAO Director" in this issue). Over time, the US Gemini Program evolved to the NOAO Gemini Science Center, and the number of proposals received each semester now for Gemini typically exceeds those for CTIO and KPNO combined. The scientific staff has increased to include fractional but significant efforts of a dozen scientists, and the administrative support is now full time.

It was an invaluable experience for me to have participated in this effort. Partnerships, particularly international ones, are certainly the way of the future, and there is no substitute for seeing the dynamics of such a partnership from the inside. Although Gemini has had some technical difficulties (what observatory hasn't?), it stands as a scientific testament to a small group of people who imagined an ambitious new observatory and brought it to completion, supported by the communities of seven different countries. NL

Mar. 2007
Buell Jannuzi appointed KPNO Director

Apr. 2007
Todd Boroson appointed Interim NOAO Director

Jul. 2008
David Silva appointed NOAO Director

Nov. 2008
Robert C. Smith appointed CTIO Director

Aug. 2009
ATST construction funding approved

Sept. 2009
NSO receives separate (from NOAO) cooperative agreement from NSF

A Short (and Slightly Irreverent) History of the NOAO Newsletter

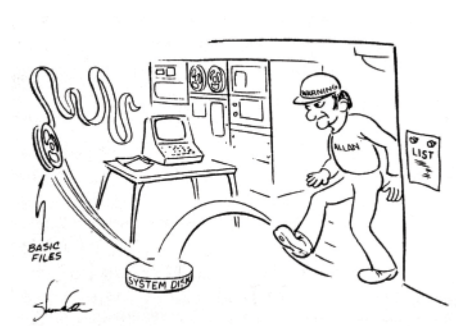
Katy Garmany

The *NOAO/NSO Newsletter* has its roots in an in-house staff newsletter that first appeared in July 1973, a product of the Kitt Peak Office of Public Information. Leo Goldberg was the Kitt Peak director at that time. A note in the first issue described the test of a shuttle bus that would begin regular runs to Kitt Peak, replacing the motor pool. This was primarily a gas-saving measure (events in the Middle East made this a prudent step: oil had spiked from $10 to about $40 a barrel, in 2008 dollars). The newsletter contained a few pictures, including one showing "obvious spiral structure in the Large Magellanic Cloud." It was noted that Senator Barry Goldwater visited Kitt Peak in November 1974, landing by helicopter, where he was met by Goldberg and the AURA president. There was an item that, "Rebecca Isaacs has left $40,000 to the observatory. She was unknown to the staff." In 1974, the staff newsletter was renamed "The Observer," which remained its name until 1979, when it was changed to "Prime Focus."

The *Kitt Peak National Observatory Newsletter* for the entire astronomical community first appeared in 1979. The first issue was to be mailed to everyone who had submitted observing proposals in 1978. The editors were Tom Kinman and Jean Goad, who urged in their first editorial that recipients circulate the *Newsletter* among their colleagues. It was published six times a year and carried a variety of information relevant to observing at Kitt Peak, including notes on the weather statistics. And, in what became a regular feature until the advent of the Web, the annual Kitt Peak Observing Calendar was included. There were also a series of cartoons, including one that subsequently appeared on many astronomers' doors around the country about "booting the tape drive."

KPNO Newsletter No. 9 carried a note from Steve Strom asking about the whereabouts of some 4-M plates of his that had gone missing. The *Newsletter* circulation figure stood at 938 in 1980. There was no word if Strom got his plates back.

The 1982 *KPNO Newsletter* No. 23 carried a note on the impending merger of KPNO, CTIO, and SPO (Sac Peak Obs) and the celebration of the 25th anniversary of the observatory. The last issue of the *KPNO Newsletter* described the new role of the *Newsletter*, with each section to have its own editor. Jean Goad was to be the "super editor."



In March of 1985, *NOAO Newsletter* No. 1 appeared! It was 30 pages long, with the Table of Contents on the cover. Issue No. 2 included an article by Phil Massey about CCDs that became an underground classic: "What Chip is right for you?". In May 1986, in another sign of things to come, Steve Grandi included a list of "electronic mail addresses" for NOAO Tucson plus his notes on using Bitnet and Internet addresses. He wrote, "It is probably a good idea to contact a person on the telephone before trying to initiate an electronic conversation." Some might say this is still the case.

Frank Hill became editor-in-chief in March 1988. That issue carried an article titled "Rushin' around Looking for the Supernova," which began, "Afterwards we called it a snipe hunt…." A new requirement that observers supply 15 copies of their observing proposals was included: it was titled "No worse than Space Telescope." The REU program began—a previous summer student program had been the victim of budget cuts. The IRAF section noted that 218 sites were using IRAF (sites, not number of computers). The *Newsletter* now carried more information on the TAC process as well as the User's Committee reports and the names of committee members. A CTIO article noted that observing proposals would henceforth be accepted by email, as sending telephonic facsimiles (FAX) had proved problematic. The observers' calendar was still an important feature in the *Newsletter* every year.

In December 1989, Taft Armandroff became editor-in-chief. It was announced that Craig Wheeler would be the first AURA visiting professor; he would spend time at both CTIO and KPNO. A request was made on the last page to "return this sheet if you wish to continue receiving the Newsletter." There are no data on the return numbers. A continuation of Massey's CCD article in issue No. 2, "What Chip is right for you, Revisited?" was included in issue No. 21.

In 1991, the *Newsletter* noted that Dave Silva had arrived as a postdoc from the University of Michigan. (In 2008, the *Newsletter* documented his arrival as NOAO director.) Also in 1991, the "temporary" placement of modular units on the roof of the east wing for the Gemini Project staff was accomplished. (Eighteen years later, these are used by NOAO and WIYN staff.) By this point, the newsletter had grown to about 44 pages in length. Issue No. 28 included "Flat Fields: More Involved than You Might Have Guessed!" by George Jacoby, Bill Schoening, and Jim De Veny. And an article, "Wondering What the Weather Was Like," begins, "Traditionally, telescope logs on Kitt Peak have been kept on pieces of paper. However, Dave Chamberlin has recently provided operators and users with a program that allows a log to be kept via the mountain computer network."

The early 90s saw increasing changes in observing: issue No. 33 carried a note that the mountain would no longer stock photographic plates, and that there were no longer any darkroom facilities at the 4-meter. But other things did not change: in 1992 the Director's Office section included articles titled, "The Budget Increase that Isn't Quite," followed by, "And Next Year Will Be Worse."

Tod Lauer became editor-in-chief with issue No. 36 in 1993. He inaugurated the NOAO Highlights section, which later became the present Science Highlights section. Pictures began to appear on the first page of the *Newsletter* as part of these articles. And now, KPNO proposers could submit their proposals via email, instead of the previous 15 paper copies. An article by Jay Elias discussed "Estimating Lunar Phase Requirements." The TAC was still divided into Bright and Dark panels, but by September

continued

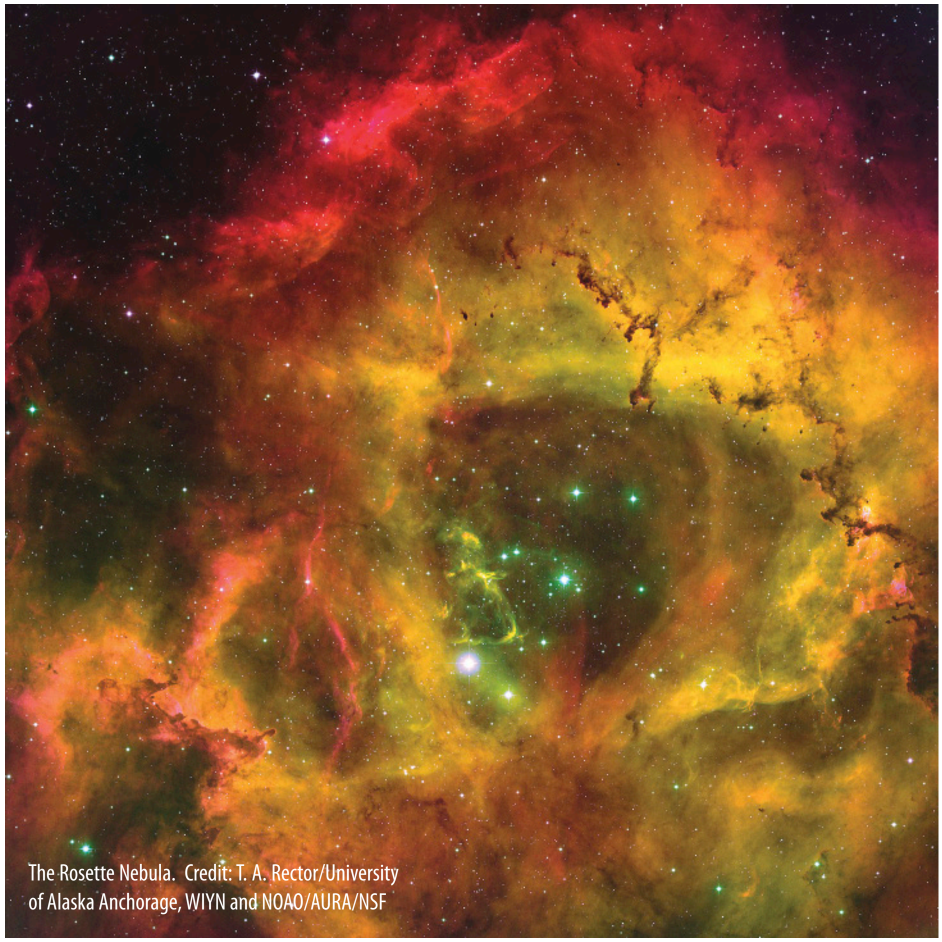
A Short History of the NOAO Newsletter continued

1994, Kitt Peak had "a World Wide Web home page that can be browsed with Mosaic." And George Jacoby wrote an article in issue No. 42 on non-astronomical places that were using IRAF for projects ranging from brain scanning to the National Gallery of Art's examining IR reflectivity to determine what lay underneath various pieces of art.

In March 1996, issue No. 46 announced a new format for the TAC: Galactic and Extragalactic would replace Bright and Dark. The following year saw a notice of a new Web proposal form for both CTIO and KPNO. Hemisphere-neutral designators A and B were introduced to replace spring and fall for the proposal cycles. And the TAC continued to evolve with articles describing changes in the TAC process to allow data acquisition at multiple telescopes including HET, MMT, and Gemini. Night lunch could now be ordered on the Web—but Exabyte taping was no longer supported at KPNO telescopes.

Full color images on the *Newsletter* covers have only been a feature for the past decade. The first was the Rosette Nebula in the December 1999 issue. This last issue of 1999 contained an article on NOAO and Y2K (Year 2000—remember that?). In June 2001, Doug Isbell became the new editor and solicited reader comments and suggestions on page 2. The NOAO Highlights section was renamed Science Highlights, and a new public face for NOAO on the World Wide Web was announced.

With this publication of the 100th issue of the *NOAO/NSO Newsletter*, change continues, but the issue of flat budgets remains a constant. The readership is being urged to read the *Newsletter* online where a full-color version is posted. While it has been posted online since 1992, many readers have been unaware of this. With issue No. 99, we began a policy of sending an email to all subscribers when a new issue is posted. We are dropping most foreign subscriptions except for libraries. After 100 issues, our goal remains to make the *Newsletter* as useful and informative as possible to our readers.



The Rosette Nebula. Credit: T. A. Rector/University of Alaska Anchorage, WIYN and NOAO/AURA/NSF

50th Anniversary Science Symposia in 2010

March 14–17: "From First Light to Newborn Stars"
Symposium on the physics of star formation in galaxies: from the Milky Way to galaxies at high-z.

March 17–20: "The Eventful Universe"
Symposium on exploring the time-axis in observational phenomena: extragalactic, galactic, and solar system.

March 17: Both symposia come together for reflection on the past and future roles of our National Observatory in furthering scientific progress.

Refer to ***www.noao.edu/kp50*** for additional details.

Faces of Former and Current Employees at November Reunion

A reunion of retired, former, and current employees of Kitt Peak National Observatory, Cerro Tololo Inter-American Observatory, the National Optical Astronomy Observatory, and the National Solar Observatory took place in November 2009 as part of our continuing celebrations for the 50th anniversary of our national observatory. These pictures are from this two-day event.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This page (top left, clockwise): (1) Jorge Simmons, Aden Meinel, Sidney Wolff, Helmut Abt (2) Agnus Paulsen, Aden Meinel, Don Loomis (3) Dick Torresdahl, Frank Stuart (4) Don Loomis, Roger Lynds, Steve Maran (5) Aden Meinel, Don Loomis, Helmut Abt, Harold Thompson.

Facing page (top left, clockwise): (1) Duane Miller, Buell Jannuzi, Aden Meinel (2) Steve Maran, Roger Lynds, Skip Andree (3) Kurt Crammer, Ed Avery (4) Larry Randall, Charles Slaughter, Harold Thompson, David Crawford (5) Bettye Hanna, Mark Hanna, Bill Llvingston (6) Dale Schrage, Ed Bell.


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The NOAO System Science Center

Verne V. Smith

The new fiscal year at NOAO has seen the transformation of the NOAO Gemini Science Center (NGSC) into the NOAO System Science Center (NSSC). This division handles all of the former duties of NGSC, as well as other existing NOAO activities related to connecting the US user community to the present and future science capabilities of the open-access, US ground-based optical/infrared (O/IR) system (System).

The structural organization of NSSC allows staff astronomers to more easily move between supporting current facilities and engaging the community with new facilities under development, as well as streamlining user access to the System as a whole. NSSC is divided into System User Support (which includes the functions of the former NGSC), System Data Management (previously known as Data Products Program), and System Community Development. The newly organized System Community Development program will track community desires for the evolution of capabilities within the System and guide development to provide such capabilities.

Overall, NSSC will provide the following services:

- User support for observing proposal preparation and submission for all of the System facilities as well as help with questions about post observing data processing
- Assist non-NOAO facilities as appropriate to help with their interface to the community-at-large
- Work with the community-at-large to define and prioritize new capabilities of the System
- Ensure that current and new capabilities of the System are being advertised to the widest possible audience

In short, NSSC will evolve over the coming year into a center for end-to-end user support of the System, as well as a focal point for developing new operational relationships between NOAO and other science facilities and capabilities within the System.

If you have any questions or comments about the role of NSSC in your System, do not hesitate to contact me at *vsmith@noao.edu*.

NOAO at the 2010 Washington AAS Meeting

Ken Hinkle & Verne V. Smith

NOAO will have a booth in the exhibit hall of the January 2010 AAS meeting. A number of our scientific staff will be present. Please stop by. We look forward to talking you and to helping you with any questions or issues dealing with NOAO.

The January AAS meeting overlaps the range of dates that Gemini users have to complete their semester 2010A Phase II forms. As the US national representatives for Gemini, NOAO staff are the first contacts for the Phase II process. Many of the staff contacts will be present at the NOAO booth at the AAS meeting. We will have a high-speed Internet connection and can work with you to complete your Phase II. In the past, we have been able to condense days of email communications into less than an hour of one-on-one interaction at our booth. If you have a Gemini observing program scheduled for 2010A, stop by and let us help you with your Phase II!

NOAO will also host two town hall meetings. The first one will be an NOAO Town Meeting on Tuesday, 5 January 2010, from 12:45 to 1:45 pm, where NOAO will seek community input and feedback on a variety of issues and opportunities relating to ground-based optical/infrared (O/IR) astronomy in the context of the Astro2010 process and other initiatives. NOAO will present a summary of its long-range planning and objectives for developing the US O/IR System of capabilities. We will discuss the status of the development activities for small- and large-aperture telescopes resulting from the Renewing Small Telescopes for Astronomical Research and Access to Large Telescopes for Astronomical Instruction and Research proposals, respectively.

The second NOAO-hosted meeting is a US Gemini Town Hall on Wednesday, 6 January 2010, from 12:45 to 1:45 pm. For this meeting, NOAO is particularly interested in community views on desirable, general purpose (workhorse) instruments that could be deployed in the next three to five years. In addition, the topic of implementing large programs on Gemini (those requiring more than 10 nights) will be discussed. However, all topics related to Gemini and its relation to the US community-at-large will be open for discussion. Plan to attend and bring your questions and comments with you.

FLAMINGOS-2 Achieves First Light

Knut Olsen

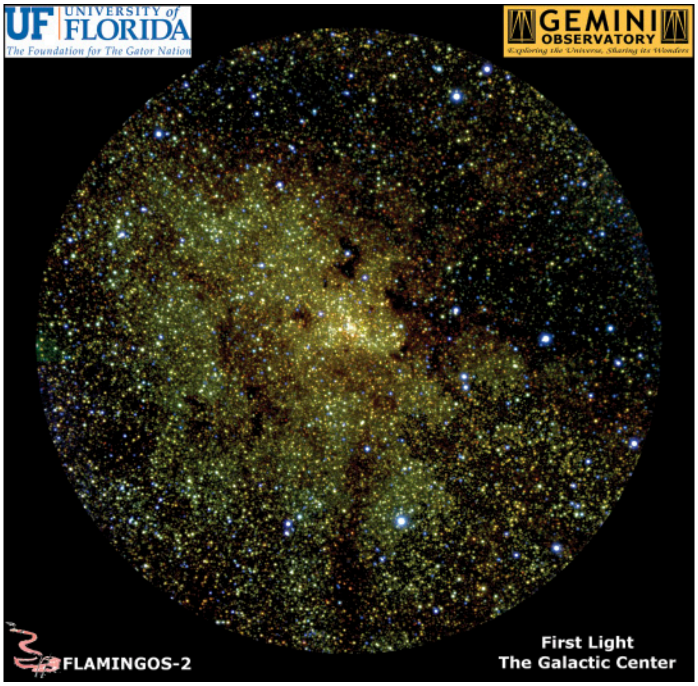


Figure 1: FLAMINGOS-2 image of the Milky Way Galactic Center. (Image credit: Gemini Observatory/University of Florida/AURA/Anthony Gonzalez)

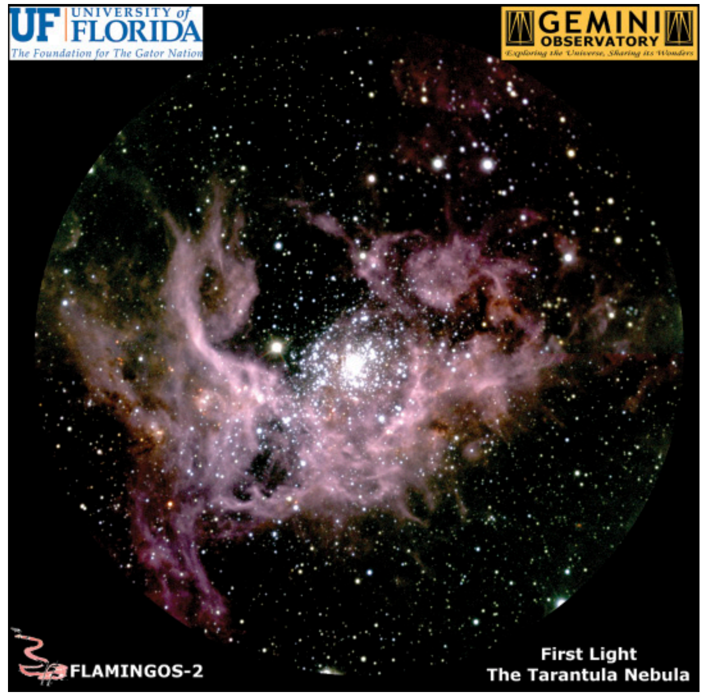


Figure 2: FLAMINGOS-2 image of the Tarantula Nebula (30 Doradus) located in the Large Magellanic Cloud, a satellite galaxy to the Milky Way. (Image credit: Gemini Observatory/University of Florida/AURA/Anthony Gonzalez)

The Florida Array Multi-object Imaging Grism Spectrometer (FLAMINGOS-2), which brings capabilities of near-infrared imaging, long-slit spectroscopy, and multi-slit spectroscopy to Gemini South, delivered its first light images in September 2009. The JHK composite images, one of the Galactic center (figure 1) and the other of the giant H II region 30 Doradus in the Large Magellanic Cloud (figure 2), demonstrate the FLAMINGOS-2 promise of delivering both excellent image quality and large numbers of spectra in crowded fields. The images have spatial resolution of 0.6–0.7 arcseconds, limited only by the natural seeing at the time, and round point spread functions. Further information on the first light images can be found at the Gemini Web site, *www.gemini.edu/node/11328*, or through the University of Florida's press release, *news.ufl.edu/2009/09/15/new-imager/*.

FLAMINGOS-2, was conceived by the late University of Florida (UF) Professor Richard Elston, and completed by a team led by UF Professor Stephen Eikenberry. FLAMINGOS-2 provides imaging within a 6.1-arcminute-diameter circular field and R = 1200–3000 spectroscopy within a 2×6 arcminute-area at wavelengths of 0.95–2.4 microns. In addition to its use in seeing-limited mode, it is designed to take full advantage of the 2-arcminute field of the Multi-Conjugate Adaptive Optics system under construction at Gemini South. Further details are available at Gemini's instrument Web page, *www.gemini.edu/sciops/instruments/flamingos2/*. Tests and commissioning are ongoing. Contingent on commissioning, Gemini will issue a special call for FLAMINGOS-2 Science Verification (SV) proposals. NOAO will publicize the SV call to the US community when it is issued. Watch *www.gemini.edu* and *www.noao.edu/ngsc* for the special call.

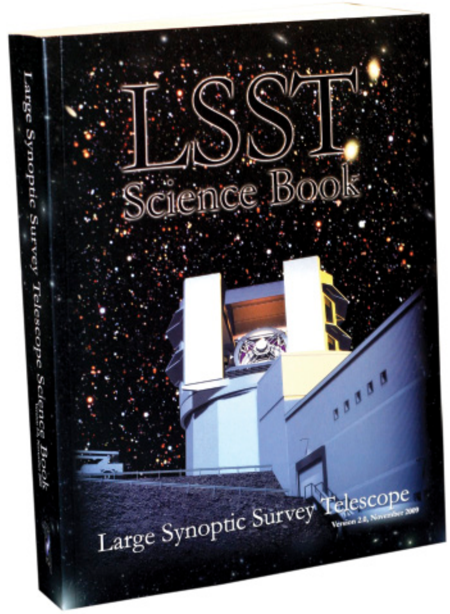
NOAO Science Support of the Large Synoptic Survey Telescope

Abhijit Saha

The Large Synoptic Survey Telescope (LSST), to be located on Cerro Pachón in Chile, is designed to have an effective aperture of 6.7 meters and will have a camera with a field of view of 9.6 square degrees. It will repeatedly image over 20,000 square degrees of sky in six pass-bands (Sloan-u′g′r′i′z′ and y) over a period of ten years. Individual images will reach point sources to a 5-sigma depth of $r \sim 24$ magnitude, with co-added depth over the 10 years to reach $r \sim 27.5$ magnitude. During the 10-year survey, LSST will generate tens of petabytes of data and processed data products. The data will address science problems in nearly every area of astrophysics ranging from the solar-system surveys through large-scale distribution of galaxies and mass tomography through dark matter distribution and dark energy and cosmology. Of particular interest is the discovery space that this repeated observing cadence will open up for temporal phenomena, both for moving objects as well as transients and variable objects. Further details of the design, capabilities, and science potential can be obtained from the LSST site (*www.lsst.org*). A detailed discussion of the scope of the science with LSST as current perspective allows was published as the LSST Science Book..

NOAO is a founding member of the LSST Corporation, which is a public-private partnership with 31 (and growing) partner institutions. The LSST project has committed to make the data and data products publicly available with no proprietary period. LSST also actively solicits participation from individual US scientists outside the formal institutional membership through its “science collaborations,” which are topical groups of interested scientists who wish to participate intellectually towards getting the best return from the LSST survey.

The LSST Science Book has resulted from contributions by 243 individual authors, who are members of one or other LSST science collaborations. NOAO conducts an annual proposal-based selection process (for details, see *www.noao.edu/lsst/collab_prop/Scicollab.htm*) for membership in these collaborations, as well as for forming new ones. The recent call to the community generated 44 proposals including two to form new collaboration groups.



NOAO scientists are involved in various aspects of the design of the LSST survey, the requirements on the data system and data products, and the observatory operations plan. This activity is focused through the LSST Science Working Group (LSWG), which is a part of the System Community Development program of the NOAO System Science Center division of NOAO. It is envisaged that NOAO will be a portal for community access to LSST resources. Below are a few examples of the kinds of things in which the LSWG is currently involved.

An observation simulator, which works within the bounds of the technical specifications and the site and weather conditions on Cerro Pachón, has been developed, predominantly through efforts at NOAO. This tool establishes the feasibility of the projected 10-year survey, and it is in further development that will help design and conduct the actual survey in a way that maximizes the total science return from LSST and can be used to balance science priorities. The simulations are being used by science collaboration members to study the efficacy of their particular science goals against various simulated observing scenarios. The LSWG is developing metrics to facilitate such evaluations.

NOAO scientists have been deeply involved with plans for how the LSST data are to be photometrically calibrated, including observing and analyzing real data to verify and establish procedures that serve the very demanding photometric requirements for LSST data.

A series of workshops that bring the geographically distributed membership of the LSST science collaborations as well as project personnel under one roof to discuss observational constraints and data product requirements are being hosted by NOAO in Tucson. A workshop with the Galaxies collaboration took place in May 2009, and in August, a joint workshop of the Stellar Populations and the Milky Way and Local Volume Structure collaborations was held. Collaboration members as well as project personnel designing the data processing, architecture, and management have reported finding these extremely useful. The community-wide workshop on “The Eventful Universe,” which will be held at NOAO in Tucson, March 2010, as part of the Kitt Peak half-centennial celebration, is also clearly relevant to future LSST science.

We welcome your thoughts on how you think the scientific return from LSST can be maximized. We encourage you to consider making a personal commitment to contribute to the success of LSST; the most viable way is to become a member of one of the LSST science collaborations (or start a new one) and enter the exciting dialogue!

NSO News & Announcements

ATST Awaits Final Decision

The ATST Team

The National Science Board (NSB) in early August "authorized the NSF Director, at his discretion, to make an award to the Association of Universities for Research in Astronomy (AURA) for the Approval of Construction Funding for the Advanced Technology Solar Telescope (ATST)." Pursuant to the relevant federal environmental and historic preservation statutes, the issuance of the award is contingent upon the publication by the NSF of a Record of Decision (ROD) authorizing the construction. Congress has appropriated construction funds that included $146 million in funds from the American Recovery and Reinvestment Act of 2009 (ARRA), and $7 million in FY 2009 funds. We now are awaiting the final Record of Decision by the NSF Director.

The ATST Science Working Group (SWG) met Sept. 9–11 in Boulder, CO, to review the project and discuss instrumentation development. The SWG also reviewed the development of all of the instrumentation, the procurement of detectors, a preliminary operating plan including observing modes and telescope allocation, and an adaptive optics requirement for observing prominences above the solar limb; they also started looking ahead to second-generation instruments. The SWG is considering reshaping itself to have a "core SWG" that meets more frequently to address issues in real time as construction ramps up.

GONG H-alpha System Passes Prototype Design Review

Frank Hill & The GONG Team

The US Air Force-funded H-alpha project passed a significant milestone in September with the successful completion of its Prototype Design Review. The review committee (Dave Jaksha and John Britanik from SOLIS, and Rob Hubbard from the ATST) concluded that:

> "The committee was impressed by the overall simplicity and robustness of the design, and the demonstration of the fully functioning prototype system. It is obvious that great care and attention to detail has persisted at all levels of the effort, and we expect that the final deployed systems will perform to specification."

Representatives of the Air Force Research Laboratory and the Air Force Weather Agency also participated in the review. Given the favorable outcome, we have begun the fabrication of the mechanical components of the system. All of the optics, filters, and cameras are in-house. Deployment is scheduled for the spring of 2010 and will be completed at Udaipur in the fall.

Second Quarter 2010 Proposal Deadline

The NSO/Sac Peak Telescope Allocation Committee

The current deadline for submitting observing proposals to the National Solar Observatory is 15 February 2010 for the second quarter of 2010. Information is available from the NSO Telescope Allocation Committee at P.O. Box 62, Sunspot, NM 88349, for Sacramento Peak facilities (*sp@nso.edu*) or P.O. Box 26732, Tucson, AZ 85726, for Kitt Peak facilities (*nsokp@nso.edu*). Instructions may be found at *www.nso.edu/general/observe/*. A Web-based observing-request form is at *www2.nso.edu/cgi-bin/nsoforms/obsreq/obsreq.cgi*. Users' Manuals are available at *nsosp.nso.edu/dst/* for the SP facilities and *nsokp.nso.edu/* for the KP facilities. An observing-run evaluation form can be obtained at *ftp://ftp.nso.edu/observing_templates/evaluation.form.txt*.

Proposers are reminded that each quarter is typically oversubscribed, and it is to the proposer's advantage to provide all information requested to the greatest possible extent no later than the official deadline. Observing time at National Observatories is provided as support to the astronomical community by the National Science Foundation.

2010 International Research Experiences for Students (IRES) Program in India

The GONG Team

Sponsored by the National Science Foundation (NSF) Office of International Science and Engineering (OISE), and administered by the National Solar Observatory (NSO)/Global Oscillation Network Group (GONG), the main goal of the program is to expose potential researchers to an international setting at an early stage in their careers. The program will take place in Bangalore, India, under the auspices of the Indian Institute of Astrophysics (IIA). The IIA is a premier national center devoted to research in astronomy, astrophysics, and related physics, with its headquarters in Bangalore and laboratories located at Kodaikanal, Kavalur, Gauribidanur, Hanle, and Hosakote.

The program will support four full-time summer research positions for eight weeks between 8 June and 2 August 2010. For each participant, the program will provide round-trip air-coach travel to and from Bangalore, India, a stipend of US$500 per week, accommodation, miscellaneous travel (field trips) and incidental expenses, and

continued

2010 IRES program in India continued

medical expenses. During their stay in India, participants will work and study in close collaboration with an IIA scientific staff mentor on a specific research project. Professional experiences will be enhanced by interactions with other IIA staff, affiliates, and visitors and field trips to other facilities. At the end of the program, participants will submit a detailed report on the results of their research projects and a report on their overall Indian experience.

Eligibility and Requirements: Applicants must be US citizens or permanent residents, age 21 years or older, and have a passport; be registered and in good academic standing in an Astronomy/Astrophysics (or related field in physics or applied math) graduate program in the US; and possess an adequate knowledge of computer programming and data analysis techniques. Further information and application material can be found at the program Web site at: *eo.nso.edu/ires/*. Applications will be accepted until 26 January 2010.

SOLIS/VSM

Kim Streander & The SOLIS Team

Development Update

SOLIS has recently made a number of important upgrades to both the hardware and the data processing software. First, improvements to the control electronics of the calibration motors have been made, resulting in higher reliability, repeatability of positioning, and overall image quality. Secondly, the data processing hardware on Kitt Peak is being brought up to the latest version of the operating system, resulting in faster and more reliable data processing performance. Finally, the development of the 10830 fringe removal code has been finished, and the code is now being installed in the processing pipeline. The next major steps are to finish the fringe removal for the Sarnoff cameras, install the cameras, install a new modulator to enable chromospheric vector magnetograms, and install the guider.

The first meeting of the Vector Magnetogram Comparison Group (VMCoG) was held October 27–29 in Tucson. The purpose of this group, which was formed at the June meeting of the Solar Physics Division of AAS, is to analyze and compare vector magnetograms from all sources to understand systematic effects and the differences between the measurements. This will provide better understanding of the data, improve the reliability of the science based on these observations, and prepare for the data that will be produced by the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory. Data sets from SOLIS, Hinode, the Michelson Doppler Imager on the Solar and Heliospheric Observatory, and the University of Hawai'i Facility InfraRed Spectropolarimeter have been collected and will be compared during the meeting.

Science Snippet

Solar activity has recently been at a level lower than has been seen for a century. This is an extraordinary opportunity to study the quiet sun and the development of solar activity at a pace much slower than normal. SOLIS produces daily images of the Sun's line-of-sight magnetic field component with excellent sensitivity. These images are combined into charts of the Sun's radial magnetic flux every day and every solar rotation. These charts can further be adjoined to show the time variation of magnetic flux along a strip in latitude about one day wide at the central meridian from pole to pole. Figure 1 shows preliminary results of this exercise from May 2006 to October 2009 in terms of total magnetic flux. Time runs from left to right and sine latitude from bottom to top; the equator is the center row.

Bright features are locations of active regions, i.e., magnetic flux eruptions. They frequently may be seen on successive solar rotations. The dying part of cycle 23 is seen near the equator strongly in the southern hemisphere. The very slowly developing new solar cycle 24 is seen as small bright features particularly at high latitudes in the northern hemisphere. The reason for this strong asymmetry is not known. Also of interest is a negligible variation of the background quiet sun flux back to the beginning of SOLIS observations in 2003.

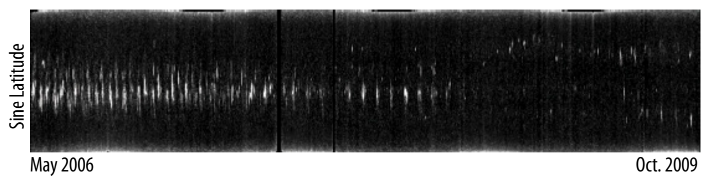


Figure 1: Five year display of total radial magnetic flux showing the transition from Cycle 23 to 24.

Inversions

Editor's Note: The figures for the first section of the SOLIS article in the September 2009 Newsletter were misidentified in the text and incorrectly sequenced (the online electronic version was corrected), thus the remainder of this article largely reproduces this portion of the September article with the text and figures corrected.

The recent (since April 2009) release of inverted vector magnetic field data from the Synoptic Optical Long-term Investigations of the Sun/Vector Spectromagnetograph (SOLIS/VSM) has initiated constructive critiquing among the solar community. In particular concerns were expressed regarding: 1) apparent "rings" around active regions when displaying the line-of-sight field inclination, 2) a need to adjust the gray scale when displaying the Milne-Eddington full disk images on the Web, and 3) a desire to see a comparison between data taken with the VSM and Hinode, the "gold standard."

The "rings" around active regions (shown in figure 2 "Original cubic convolution") were a by-product from applying an IDL interpolation scheme used in SOLIS data for, among other operations, slit correction and P-angle rotation. The SOLIS Milne-Eddington (ME) procedure inverts only those pixels where the percent polarization is above a computed threshhold, and non-inverted pixels are set to zero. This threshholding caused the existing cubic convolution interpolator to produce incorrectly skewed values whenever there were zero values in the 16-point interpo-

continued

SOLIS/VSM continued

lation neighborhood, because these zero values are treated as real data. This resulted in artificial rings around the islands of data after interpolation, which can be seen most clearly in the inclination plots.

The solution (shown in figure 3 "Hybrid") was to use a hybrid cubic/bi-linear interpolation algorithm written by John Britanik that used the usual cubic convolution when all 16 points in the interpolation neighborhood are non-zero, and gracefully degraded to a bi-linear interpolation otherwise. The bi-linear interpolation algorithm considers only the surrounding four points in the interpolation neighborhood. It gracefully degrades, such that if one neighbor is zero, a triangular form of bi-linear interpolation is used. If two neighbors are zero, then the simple linear interpolation is used, and if three neighbors are zero, then the non-zero neighbor is used as the "interpolated" value. The interpolated value is set to zero if all four neighbors are zero. The resulting output is free of the

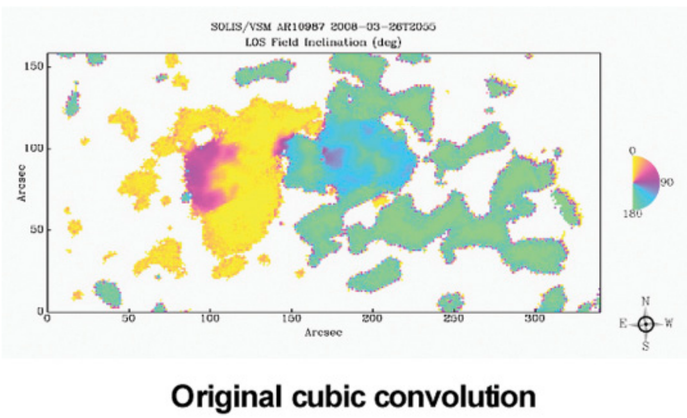


Figure 2

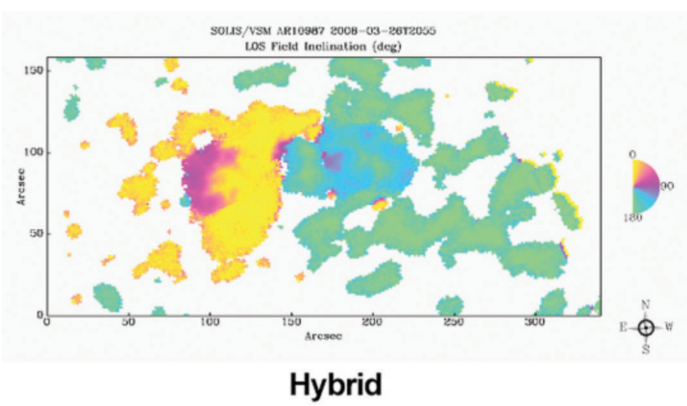


Figure 3

artificial rings.

Recent improvements to the Milne-Eddington inversion and plotting routine have greatly improved the appearance of the full-disk ME images on the Web (see figure 4). The field strength estimate returned by the ME inversions was improved in areas outside sunspots by using the quick-look field estimates as an initial guess, instead of a constant value of 1200 gauss, which had resulted in field strengths that were too high in regions outside of sunspots. The current code removes a non-linear scaler previously used to emphasize plage (but which resulted in saturation around areas of high magnetic field strength), applies a filling fraction, and computes the minimum and maximum with a 0.6 multiplier to enhance contrast so that

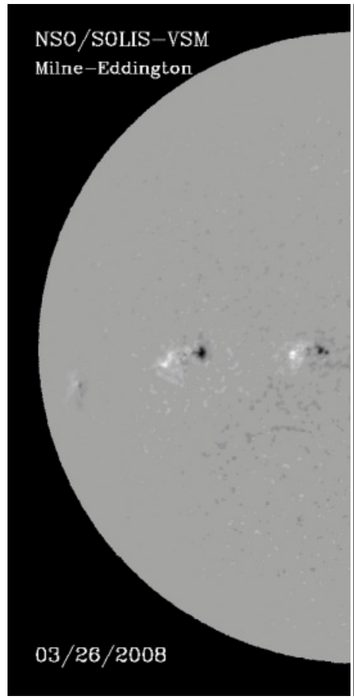


Figure 4: Current Web display (partial).

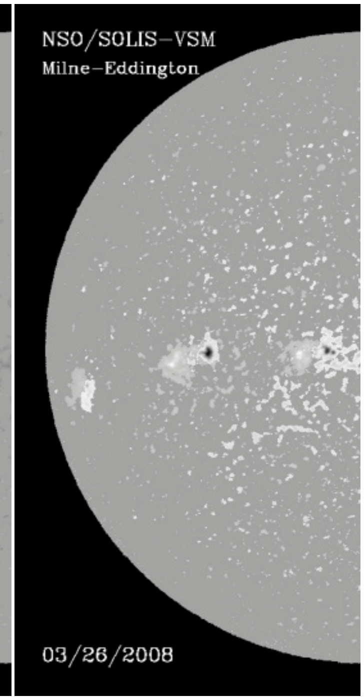


Figure 5: Previous Web display (partial).

the ME images look more like the quick-look images (compare with the previous processing of the same data in figure 5). We have since received favorable comments from the solar community for the improved appearance of the ME data on the Web.

At the suggestion of the National Solar Observatory Users Committee, Jack Harvey found an existing data set that could be used for comparing inversion techniques between the SOLIS VSM and Hinode. Hinode is a Japanese mission developed and launched by ISAS/JAXA, with NAOJ as domestic partner and NASA and STFC (UK) as international partners. It is operated by these agencies in cooperation with ESA and NSC (Norway). A preliminary comparison between the two data sets (figure 6) shows remarkable similarities when considering the different image resolutions and an approximate 6.5-hour time difference. Additional data sets and analyses will be compared over the next several months.

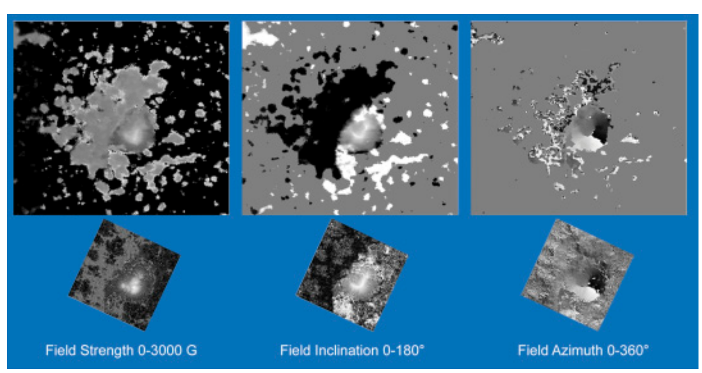


Figure 6: Milne-Eddington inversions of Stokes spectra taken 2 May 2007 with the SOLIS/VSM at 20:32 UT (upper row, 1.125" pixels in poor seeing) and with the Hinode SP in fast scan mode at 14:00 UT (lower row, 0.32" pixels). Azimuths have been disambiguated for the 180-degree ambiguity.

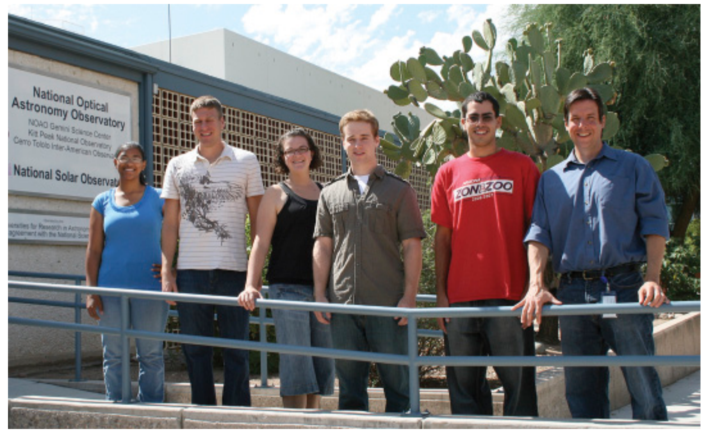
Students Needed for the 2010 REU Program at Kitt Peak

Ken Mighell

Each summer, a group of talented college students come to Tucson to participate in astronomical research at Kitt Peak National Observatory (KPNO) under the sponsorship of the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) Program. Like the parallel program at Cerro Tololo, the KPNO REU program provides an exceptional opportunity for undergraduates considering a career in science to engage in substantive research activities with scientists working in the forefront of contemporary astrophysics.

Each REU student is hired as a full-time research assistant to work with one or more NOAO staff members on specific aspects of major on-going research projects at NOAO. These undergraduates gain observational experience with KPNO telescopes and develop expertise in astronomical data reduction and analysis as part of their research activities. They also take part in a weekly lecture series and a field trip to New Mexico to visit the National Solar Observatory at Sacramento Peak and the Very Large Array in Socorro.

At the end of the summer, the students share their results with the Tucson astronomical community in oral presentations. As part of their internship experience, all six of our 2009 REU participants will present posters describing their astronomical research projects at the January 2010 American Astronomical Society meeting in Washington, DC.



The KPNO REU 2009 students. Left to right: Erica Jones (Louisiana State University), Stephen Messenger (University of Missouri), Tahlia DeMaio (University of Colorado-Boulder), Evan Kaplan (Vassar College), Ed Montiel (University of Arizona), and Davin Flateau (University of Cincinnati).

We will have six REU positions during the summer of 2010. Student participants must be citizens or permanent residents of the United States to meet NSF requirements.

The KPNO REU positions are full-time for 10–12 weeks between June and September, with a preferred starting date of early June. The salary is $650 per week, with additional funds provided to cover travel to and from Tucson. Further information about the KPNO REU 2010 program, including the online application form, can be found at *www.noao.edu/kpno/reu*. Completed applications (including official transcripts and at least two letters of recommendation) must be submitted to KPNO no later than Friday, 29 January 2010.