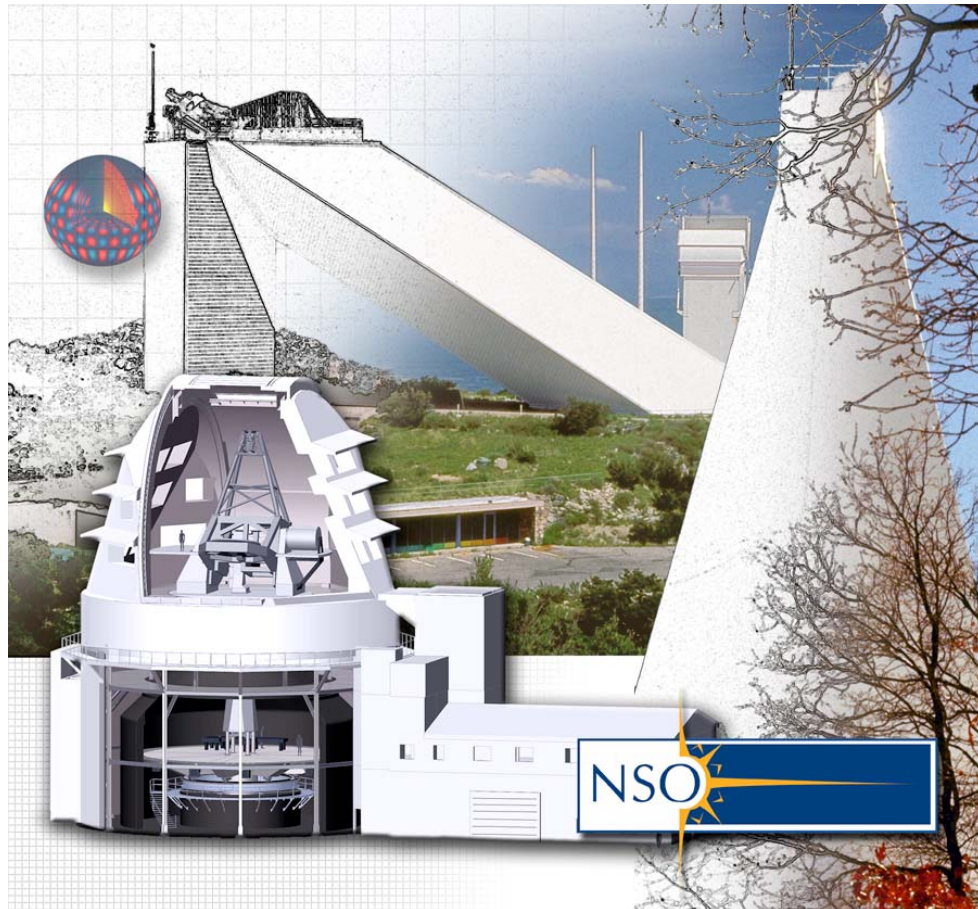


# ANNUAL REPORT OF THE NATIONAL SOLAR OBSERVATORY FY 2004



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## 1 EXECUTIVE SUMMARY

This report summarizes scientific, operational, and programmatic activities at the National Solar Observatory (NSO) for the period 01 October 2003 to 30 September 2004.

The National Solar Observatory, with facilities on Kitt Peak near Tucson, at Sacramento Peak in New Mexico, as well as at several other sites distributed globally, is operated by the Association of Universities for Research in Astronomy, Inc. (AURA), for the National Science Foundation (NSF). The mission of the NSO is to advance knowledge of the Sun, both as an astronomical object and as the dominant external influence on Earth, by providing forefront observational opportunities to the research community. The NSO fulfills its mission by operating cutting-edge facilities, by leading the development of advanced instrumentation in collaboration with the solar physics community, and by conducting solar and related research. The NSO is also active in the conduct of educational and public outreach programs.

The NSO facilities for observing and data reduction are available to the entire astronomical community. The NSO Home Page, accessible through the World Wide Web at <http://www.nso.edu/>, provides online information about NSO services, including telescope schedules, instrument availability, and information about how to apply for telescope time.

AURA is a private, non-profit corporation that operates world-class astronomical observatories through its operating centers. NSO is an operating center managed by AURA under cooperative agreement with the NSF. More information on AURA and its organizational structure can be found at <http://www.aura-astronomy.org/>.

The NSO reached several key milestones in its multi-year program to renew national ground-based solar observing facilities. Among these milestones were the submission of the construction phase proposal for the 4-meter Advanced Technology Solar Telescope (ATST); deployment of the Vector Spectromagnetograph (VSM) and the Integrated Sunlight Spectrometer (ISS) of the new Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility to the operations site on top of the former Kitt Peak Vacuum Telescope; upgrade of the low-order adaptive optics (AO) system to high-order (76 degrees of freedom) at the Dunn Solar Telescope (DST), as well as delivery and installation of a high-order AO system at the Big Bear Solar Observatory; excellent progress of the upgraded Global Oscillation Network Group (GONG) facility towards achieving scientific operations; completion of the final development phase of the Diffraction-Limited Stokes Polarimeter (DLSP), now planned for commissioning as a user instrument in the spring of 2005, as well as initiation of the development of a Spectro-Polarimeter for Infrared and Optical Regions (SPINOR)—both are upgrades of the Advanced Stokes Polarimeter (ASP); and significant progress in the development of a prototype for the Virtual Solar Observatory (VSO).

The major components of the NSO long-range plan include: continuing to lead the development of the 4-m ATST; developing adaptive optics (AO) systems that can fully correct large-aperture solar telescopes; deploying and operating the instruments comprising SOLIS; operating GONG in its new high-resolution mode; and collaborating with the community in the establishment of the Virtual Solar Observatory for the archiving and dissemination of solar data. These new and planned instruments and facilities, as the principal foundations of the NSO along with its scientific staff, are key elements in a vigorous program of scientific leadership by the United States in ground-based solar physics.

The NSO encourages broad community involvement in its programs through partnerships to build instruments, develop new facilities and to conduct scientific investigations. Agreements have been established

with the High Altitude Observatory (HAO), the New Jersey Institute of Technology (NJIT)/Big Bear Solar Observatory (BBSO), the University of Hawaii, and the University of Chicago for their efforts in the ATST collaboration.

NSO and HAO have completed Phase II in the development of the Diffraction-Limited Stokes Polarimeter, a high-resolution version of the Advanced Stokes Polarimeter that will take full advantage of adaptive optics to measure small-scale solar magnetic fields, and will enable diffraction-limited polarimetry at the Dunn Solar Telescope (DST). Both institutions have started another collaborative effort to develop SPINOR, which will augment capabilities for research spectro-polarimetry at the DST.

The NSO is in discussion with potential international partners that are interested in the establishment and operation of a SOLIS/VSM global network. The NSO also maintains active contacts with colleagues in the solar radio community in the context of the development of FASR, the Frequency Agile Solar Radio telescope facility. The NSO works closely with the Air Force, NASA, and NOAO to provide critical synoptic observations that, in addition to producing noteworthy science, also support space weather monitoring and prediction as well as space and other ground-based observations.

## 2 PROGRESS TOWARD THE FUTURE

### 2.1 Advanced Technology Solar Telescope (ATST)

The FY 2003 annual report described progress of a community-wide project to develop the Advanced Technology Solar Telescope—the next generation, facility-class telescope to advance high-resolution solar physics and the measurement of solar magnetic fields. What follows is an update of the progress on the ongoing ATST design effort as well as the construction phase proposal review.

With its 4-meter aperture and integrated adaptive optics, the ATST will resolve areas on the Sun over an order of magnitude smaller than current meter-class solar telescopes. Its high photon flux and broad spectral coverage will allow it to make sensitive magnetic field observations at heights from the photosphere into the corona.

Observations have established that the photospheric magnetic field is organized in small fibrils, or flux tubes, with sizes below current resolution limits. Theory and models predict that these fibrils have scales of just a few tens of kilometers ( $\leq 30$  km) and that they play fundamental roles in solar dynamo processes, atmospheric heating, and solar activity. Resolving and measuring the properties of the magnetic field at its fundamental scale is thus a primary goal for the ATST. A complete description of science goals, and project information, can be found at <http://atst.nso.edu>.

#### 2.1.1 ATST Science Working Group (SWG)

Current membership of the Science Working Group can be found at <http://atst.nso.edu/-swg/members.html>. The SWG met several times during the past year to quantify many of the observing capabilities specified for the ATST to meet its science goals. The SWG met in October 2004 to review the Site Survey Working Group (SSWG) final report and to recommend the primary and alternate sites for the ATST.

Detailed requirements and derived observational performance requirements can be found in the science requirements document (SRD). The SRD is a living document that will evolve as trade studies are completed and risks assessed. It is available on the ATST Web site, or directly from Project Scientist Thomas Rimmele ([rimmele@nso.edu](mailto:rimmele@nso.edu)). Community inputs into the requirements and ATST science capabilities are welcome.

#### 2.1.2 ATST Project Organization

The major change to the ATST project organization over the past year was the departure of Project Manager Jim Oschmann. After leading the engineering team through a successful conceptual design review and submission of the management and technical sections of the construction phase proposal in January 2004,

**TABLE 1. Summary of Top-Level Science Requirements**

<b>Aperture</b>	4 m
<b>FOV</b>	3 arcmin minimum; goal of 5 arcmin
<b>Resolution</b>	<i>Conventional AO Case:</i> Diffraction limited within isoplanatic patch for visible and IR wavelengths. <i>MCAO (upgrade option):</i> Diffraction limited over $>1$ arcmin FOV.
<b>Adaptive Optics</b>	Strehl (500 nm): $>0.3$ median seeing; $>0.6$ good seeing
<b>Wavelength Coverage</b>	300 nm - 28 $\mu$ m
<b>Polarization Accuracy</b>	Better than $10^{-4}$ of intensity
<b>Polarization Sensitivity</b>	Limited by photon statistics down to $10^{-5} I_c$
<b>Coronagraphic</b>	In the NIR and IR
<b>Instruments</b>	Well instrumented - access to a broad set of diagnostics, from visible to thermal infrared wavelengths.
<b>Operational Modes</b>	Flexibility to combine various post focus instruments and operate them simultaneously; Flexibility to integrate user supplied instruments.
<b>Lifetime</b>	30 – 40 years

Jim Oschmann accepted a position with Ball Aerospace in Boulder, Colorado, in July. A project manager search committee was established shortly thereafter and several qualified candidates are being interviewed at this writing. In the interim period, the deputy project manager, Jeremy Wagner, has assumed interim project manager responsibilities and duties.

The engineering team reports to the project manager and the science team to Thomas Rimmele. NSO Director Steve Keil is the ATST project director. See Appendix E for the ATST organizational chart.

The Co-PI's and other collaborating institutions participate in both design and science activities. Agreements for the primary efforts in instrumentation and support of the site survey have been established through Memoranda of Understanding. The following agreements are in place:

- **High Altitude Observatory** (Visible Light Spectro-Polarimeter Design; Near IR Spectro-Polarimeter Contributions).
- **University of Hawaii** (Sky Brightness Monitor and Dust Monitor; Near Infrared Spectro-Polarimeter Design (Lead); Site Survey Operations on Haleakala and Mauna Kea).
- **University of Chicago** (Site Survey Project Engineer; Theoretical Support for Science Working Group).
- **New Jersey Institute of Technology** (Site Survey Operations at Big Bear; Tunable IR Filter Design).

The project continues to seek additional participation by international collaborators.

### ***2.1.3 Construction Phase Proposal Review***

Since submission, the ATST construction phase proposal has undergone both write-in reviews and a face-to-face panel review at the NSF. Both reviews were extremely positive and have recommended that NSF fund the construction of ATST. The next steps are to present the project to the NSF Major Research Equipment Facilities Construction (MREFC) prescreening panel, and then to the National Science Board for inclusion in the MREFC funding line.

### ***2.1.4 Design Progress***

The first major milestone of the year was submission of the construction phase proposal, which included a detailed technical description of the ATST. The preparation of the technical description was led by the project's systems engineer, and input to the description was provided by the entire engineering team. Design activities during the past year were focused on completing follow-up activities from the Conceptual Design Review (CoDR) committee recommendations, refining engineering flow-down of requirements, performance modeling, and related activities leading to the Systems Design Review (SDR) scheduled for March 2005.

The design efforts have focused on the enclosure ventilation and thermal control, coude platform simplification, M1 thermal control performance and instrumentation development, and integration with the systems design.

For most of the year, project efforts concentrated on the enclosure design and its ventilation and thermal control. This enclosure design is a co-rotating ventilated dome with external skin cooling. A ventilated dome allows the ability to minimize primary mirror, telescope structure, and internal dome air seeing, while having



Figure 1. Current ATST layout design.

the flexibility to control telescope shake and mirror buffeting during high wind conditions. This design is used for all newer, large nighttime telescopes, but presents a new challenge for daytime viewing. During the day, the Sun will heat the dome structure unless it is actively cooled. The ATST enclosure design pays particular attention to thermal control and ventilation details and ensures that the dome will have minimum impacts on local seeing. A Computational Fluid Dynamics (CFD) analysis of the enclosure design has been completed and the results are satisfactory for optimizing dome ventilation. M3 Engineering was placed under contract to evaluate and analyze the thermal control of the enclosure design. M3 completed their work and presented a final report at a review held in Tucson in October 2004.

In parallel, thermal control concepts for the primary mirror and other optics have evolved, with concentration on the primary and secondary mirrors. The thermal models have been updated to include seeing effects based upon work by Nathan Dalrymple (USAF/AFRL). These models were also extended to apply to mount and dome shell seeing. The latter are the primary technical concerns of efforts leading to the SDR.

The adaptive optics (AO) design effort has made significant progress in the past year. A key risk area for the AO systems and the overall optical design was the thermal performance of the deformable mirror (DM). Xinetics was placed under contract to analyze the thermal control requirements for our DM concept. They have completed their study and submitted their final report in October 2004. Other AO-related work has concentrated on identifying and defining the interfaces between the adaptive optics, active optics, guiding, and software control systems.

Work on the telescope mount has included refinement of the design using input from the completed finite-element analysis of flexure and windshake, assuming a loose soil configuration. Details of the coudé lab design have evolved and a great deal of simplification has been done along with analysis of tolerances with respect to the optics.

To allocate requirements and assess performance at a systems level, ATST Systems Engineer Rob Hubbard has made significant progress on the error budget for several key cases, including bottom-up performance modeling that includes statistical input from the sites in the area of seeing, wind and thermal properties. Tying these with Nathan Dalrymple's thermal modeling of the M1 assembly is providing a good assessment of the range of likely performance that is guiding our design efforts.

### **2.1.5 Site Survey**

The choice of a site for the ATST is a critical aspect in its design. The dominant site requirements are: minimal cloud cover, many continuous hours of sunshine, excellent average seeing and many continuous hours of excellent seeing, good infrared transparency, and frequent coronal skies. In order to perform a quality site evaluation and selection for the ATST, an ATST Site Survey Working Group (SSWG) was established early on with broad community participation. This committee has representatives from other nations that have expressed interest in participating in the ATST.

The SSWG determined ATST siting criteria, verified the validity of the site testing procedures, and prepared a final report that contains the results of the data collection and analysis effort through September 2004. That report can be found on the ATST Web site at <http://atst.nso.edu/site/>. At the time of the group's final report, site survey towers and instrumentation had been operated for approximately two years at the following three finalist sites: Big Bear Solar Observatory, California; Mees Solar Observatory, Haleakala, Hawaii; and Observatorio Roque de Los Muchachos, La Palma, Canary Islands, Spain.

The SSWG presented their final report to Project Scientist Thomas Rimmele, who met with the Science Working Group in October 2004 and prepared a recommendation for the primary site and alternate sites on the basis of the sites' scientific quality.

It is expected that the final site selection will be announced publicly by mid-December 2004.

### **2.1.6 Plans**

Project plans for FY 2005 begin with convening the Systems Design Review (SDR) in March 2005. The SDR will cover the impact of the selected primary site on designs, cost estimates and planning. This includes requirements flow down, performance modeling, interface control, and overall design status. The project efforts during the remainder of 2005 will focus on the preliminary design. The work breakdown structure (WBS), planning, and schedule for the construction phase presented in the construction phase proposal is also being refined. This includes major milestones such as final or fabrication reviews, measurable fabrication stages, acceptance, shipment, integration, testing, and commissioning. Each engineer responsible for a WBS element has been detailing the plans and schedules for individual areas within the WBS, including budgets. Contingency will be held centrally. Prioritization of tasks will be based on feedback from the SDR, Science Working Group review of the SDR, and contractor feedback. The project budget status will determine the extent to which we utilize major contractors throughout this phase.

Instrumentation designs will evolve, again concentrating on impacts to the facility design. With the selection of the primary site in December 2004, we will initiate environmental impact assessments for the primary site, and detailed building designs will start by spring 2005.

With science objectives in mind, key observing scenarios will be worked out to better understand and develop operations planning. The plan calls for two major reviews to be held during the design and development phase. These include:

- **Systems Design Review (2005)**
  - Systems-level design of the baseline approach established after the conceptual design phase.
  - Requirements flow down.
  - Interface definition and control.
  - Instrument integration and operational considerations.
  - Involvement of partner and manufacturing organizations in the process where possible.
- **Critical Design Review (2006)**
  - Preparing construction detailed design and specifications.
  - Procurement planning.
  - Integration, test and commissioning planning.
  - Operational planning.

The details of these reviews will evolve as we move closer to the review dates. Decisions on the level of contractor involvement, based upon evaluations in process, will affect the details, timing and format of these two remaining reviews. Project efforts continue toward early procurement of the primary mirror blank.

## 2.2 Synoptic Optical Long-term Investigations of the Sun (SOLIS)

SOLIS is a project to obtain optical measurements of processes on the Sun, the study of which requires well-calibrated, sustained observations over a long time period. The project was conceived in 1995, proposed to the NSF in January 1996, and received partial funding in January 1998. The design and construction phases required five years. The 25-year operational phase of the major instrument started late in FY 2003.

As funded, SOLIS comprises three instruments initially mounted on the top of the refurbished Kitt Peak Vacuum Telescope tower. The mounting is transportable so that SOLIS can be moved to a different site in the future. The three full-disk instruments on a common mount are: (1) A Vector Spectromagnetograph (VSM) to measure the strength and direction of the photospheric magnetic field, the line-of-sight component of the chromospheric magnetic field, and the spectral line characteristics of the helium chromosphere. (2) A Full-Disk Patrol (FDP) that provides digital, one-arcsec pixel images of the full disk, showing the intensity and line-of-sight velocity in a number of spectrum lines at high cadence. (3) An Integrated Sunlight Spectrometer (ISS) that furnishes Sun-as-a-star spectra at both high and medium spectral resolutions with emphasis on high photometric precision and stability.

The productivity of SOLIS is enhanced when working in concert with other observing projects, both in space and on the ground—in particular, currently operating space missions, including the Solar and Heliospheric Observatory (SoHO), Transition Region and Coronal Explorer (TRACE), and Ramaty High Energy Solar Spectroscopic Imager (RHESSI), as well as future missions, such as the Japanese SOLAR-B (08/2006) and NASA's Solar TErrestrial Relations Observatory (STEREO) (02/2006) and Solar Dynamics Observatory (SDO) (04/2008).

This report covers the period October 2003 through September 2004 of the startup phases of the 25-year SOLIS project. During this period, emphasis was on completion of major elements of the SOLIS system, and initial observing with the VSM.

A major milestone was achieved when the VSM and the SOLIS mounting were moved from a temporary observing site to the top of the old Vacuum Telescope tower on Kitt Peak. The ISS was later moved to an environmentally controlled room one floor below the SOLIS mount. Regular observations with the VSM have been underway since August 2003 except for a six-week interruption during the VSM move. Figure 2 shows the SOLIS mount and VSM on top of the renamed Kitt Peak SOLIS Tower.



*Figure 2. The SOLIS mount is installed on top of the old Vacuum Telescope Tower located on Kitt Peak. The VSM is the box-like structure on top with its entrance window exposed. A 50-cm aperture telescope occupies the near half of the box and a spectrograph the distant half. The entire instrument is filled with helium for thermal and seeing control.*

The VSM is regularly producing high quality full-disk magnetograms of the Sun that are far superior to those from its predecessor, the Vacuum Telescope and spectro-magnetograph. A major component of SOLIS is data processing, distribution and archiving. A Storage Area Network located on Kitt Peak now collects the raw observations in real time. A data processing pipeline that runs on a Linux cluster automatically reduces the observations. The reduced observations are transferred to Tucson via a 45-MB-per second data link, after which they promptly appear on the SOLIS Web site along with a variety of derived data products such as synoptic maps. Examples of full-disk images derived from observations are shown in Figure 3.

The ISS is a double-pass grating spectrograph equipped with a CCD camera in its final focal plane and fed by a number of optical fibers. Its purpose is to measure changes of selected lines in high-quality spectra of the Sun with no spatial resolution, i.e., like a star. The instrument is installed one floor beneath the SOLIS mount in a temperature and humidity controlled room on an air-supported table to reduce vibrations. Two of the fibers are fed by a small lens that forms an image of the Sun on the end of the fibers. Uranium-argon (UA) and thorium-argon (ThAr) emission lines are used for wavelength calibrations. Sunlight fed to one of the fibers passes through an iodine vapor cell that serves as a super-imposed stable wavelength reference for ultra-high precision Doppler shift measurements. Sunlight is thoroughly scrambled by the time it passes through the fibers into the spectrometer. Terrestrial atmospheric extinction across the solar disk is measured by a CCD television camera and an optical system that

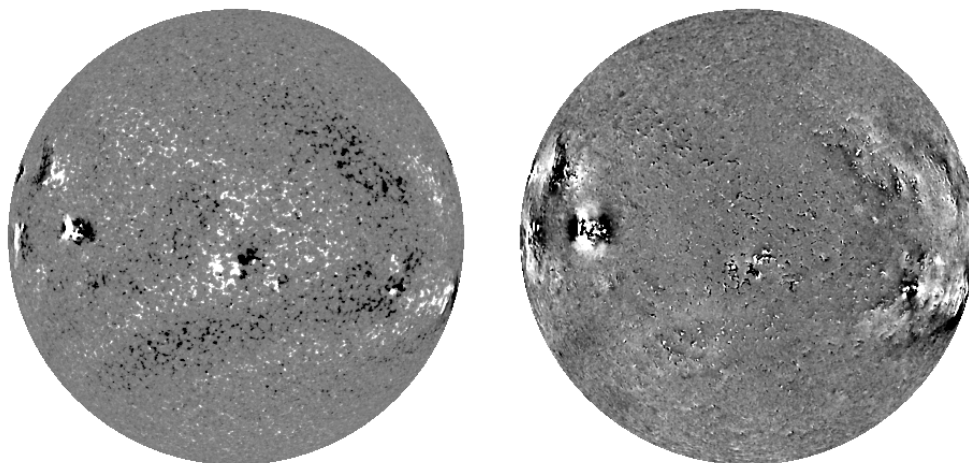


Figure 3. The line-of-sight component of the solar magnetic field measured in the photosphere (left) and the chromospheric field minus that of the photosphere (right). Lighter shades indicate a field pointed toward the observer and the departure from gray is proportional to the strength of the field. Note the presence of large areas of diffuse magnetic field in the chromosphere, mainly near the solar limb (and thus predominantly horizontal).

simultaneously forms images of the Sun at five different wavelengths. At this writing, the fibers that pass sunlight to the spectrometer have not been installed. Earlier tests showed that variations in atmospheric pressure are the largest source of wavelength drift in ISS data. A sample ISS spectrum of the solar Ca II K line at 393 nm is shown in Figure 4.

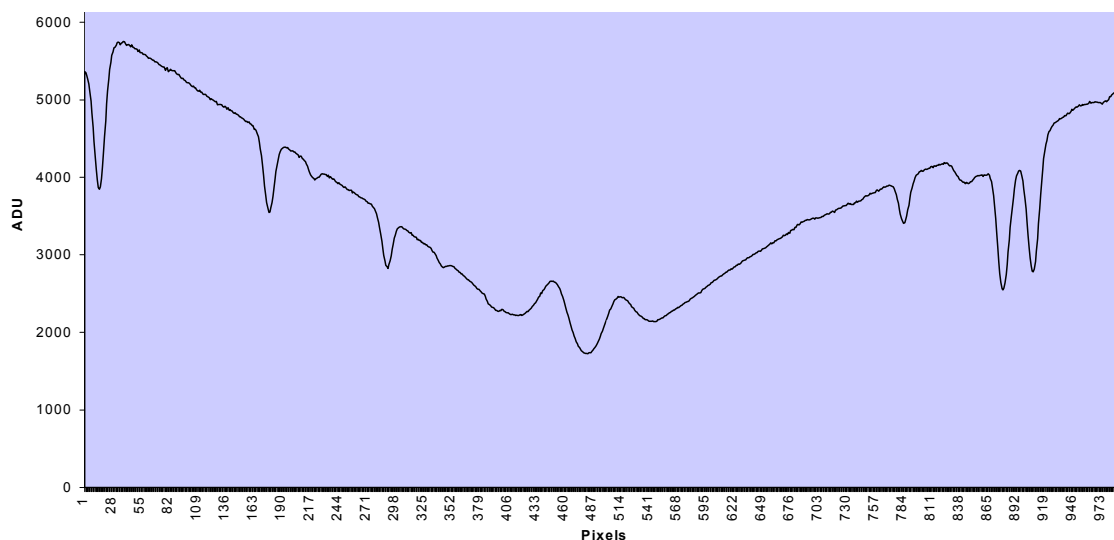


Figure 4. The inner part of the Ca II 393-nm K line is shown in this scrambled sunlight spectrogram made with the ISS. No dark current or gain corrections have been applied to this spectrogram in order to show the good intrinsic quality of ISS spectra.

The FDP is the least unique of the SOLIS instruments and has not yet been completed since priority was given to the VSM and ISS. The FDP is currently located in a Tucson lab where it can be fed with sunlight from a rooftop heliostat. The FDP is designed to make full-disk images of the Sun in selected narrow wavelengths. It suffered from a failure of its two  $2K \times 2K$  CCD cameras that took several months to diagnose and repair. The cameras are again operational, and work toward completing the FDP is proceeding as personnel availability

permits. The instrument is presently equipped with two narrowband filters, one for the 656 nm H-alpha line and one for the He I 1083 nm line. Each filter is arranged to simultaneously feed two cameras with different wavelength combinations around the spectrum lines of interest. A tunable filter that covers the wavelength range from 390 to 670 nm will eventually replace the 656 nm filter. The new filter is partially constructed. Finishing that filter and installing beamsplitters in front of the CCD cameras are the major remaining tasks for the FDP.



*Figure 5. The FDP in its assembly and test configuration. Sunlight is fed to it by a rooftop heliostat. The objective lens is in the shiny cylinder at the bottom. The pupil of the instrument is a fast tip-tilt mirror at the far end of the upper bay. The 1083-nm filter is in the white cylinder just below the fast mirror. The left-hand bays contain the guider sensor and feed optics, and the right hand bays house the electronics for the cameras, temperature controllers and mechanism controllers.*

SOLIS operations commenced in August 2003, with a period of overlapped observations between the VSM and the old spectromagnetograph. Comparison of these observations showed excellent agreement and allows a 30-year series of old observations to be seamlessly merged with the new VSM data. Until recently, it was only possible to record 100 GB of raw VSM data per day. That restricted the observing program to one each of a full-disk photospheric longitudinal magnetogram, a vector magnetogram, a chromospheric longitudinal magnetogram, a 1083 nm spectra-spectroheliogram and accompanying calibrations. Now, a storage area network system ingests data without this limitation. However, until SOLIS is autonomously or remotely operated, personnel limitations restrict the length of the observing day to about five hours, and the daily observing program remains as described. Engineering and special calibration observations are frequently conducted to learn more about the VSM and its characteristics. Several VSM component replacements, upgrades and major adjustments are planned for the near future. The short observing day is mainly a consequence of the unexpected loss of observing support from former partners in operating the synoptic observing program. To partly fill this gap, and extend the amount of observing, a proposal was submitted to NASA's Living With a Star (LWS) program and was accepted for funding. The plan is to use those funds to hire another observer as well as a scientist to help exploit the unprecedented new series of daily full-disk vector magnetograms.

Only engineering observations with the ISS are being conducted at present. The FDP is not completed yet. When these facilities are operational, by using the observation scheduler developed for SOLIS, the extra load on observers should be minimal. Transition from manual, engineering-style observing to automated or remote observing is expected to take several years with the present level of programming assistance that is assigned to SOLIS.

Acquired raw data are reduced by pipelines for each instrument and then transported to Tucson, where it is archived and made available to the user community through the Virtual Solar Observatory (VSO), the NSO Digital Library, or via a SOLIS Web site. Several organizations are already making use of the data. Developing and coding the reduction algorithms is a long and difficult process to ensure that the intrinsic high quality of the data is preserved and fully utilized. Six PhD scientists are doing this at part-time levels that range from a few percent to about 75 percent. Adding a full-time scientist supported by the NASA grant will greatly help and focus this effort to provide the community with new results.

In the National Research Council's most recent ten-year plan, "Astronomy and Astrophysics in the New Millennium," an expansion of SOLIS from one installation to a three-site network is the highest priority small solar initiative, and third priority following the Advanced Technology Solar Telescope (ATST) and the Frequency Agile Solar Radiotelescope (FASR) as ground-based solar projects. The cost of this extension was estimated at \$4.8M and an additional \$200K per year for operations. Preliminary plans suggest duplicating SOLIS except for the ISS and FDP, for which arguments for high continuity of observation and uniqueness are not as strong as for the VSM. This would allow a collaborating foreign partner and site host to use the declination axis normally used for the FDP and ISS to mount an instrument of their own for their own research purposes. Some informal contacts with potential international partners have been made with interest being expressed. No concrete plans have been developed as efforts have been focused on making SOLIS 1 operational.

An interesting possibility has recently emerged to join SOLIS and the Improved Solar Observing Optical Network (ISOON) in a three-site network consisting of the SOLIS VSM providing magnetograms and ISOON providing narrowband imagery and a common data base system. Such a combination may be of interest to the US Air Force for its operational needs. The research emphasis of SOLIS would have to be preserved in such an arrangement. Another potential funding opportunity is afforded by a developing Major Research Equipment (MRE) initiative at the National Science Foundation called Distributed Arrays of Small Instruments.

### **2.3 High-Order Adaptive Optics**

Since August 2000, the NSO, in primary partnership with the New Jersey Institute of Technology, has been developing high-order solar adaptive optics for use at the 65-cm telescope at Big Bear Solar Observatory (BBSO) and the 76-cm Dunn Solar Telescope (DST) at Sacramento Peak. The National Science Foundation has sponsored this project within the Major Research Instrumentation program with substantial matching funds from the participating partner organizations, which include the NSO, the NJIT, the Kiepenheuer Institute in Germany, and the Air Force Research Laboratory.

The NSO AO program, led by Thomas Rimmele, made significant progress, with the low-order AO system at the DST being upgraded to high-order (76 degrees of freedom) this fiscal year. There are two high-order AO systems in the DST, one feeding the new Diffraction-Limited Spectro-Polarimeter (DLSP) and the other feeding the Advanced Stokes Polarimeter (ASP) and the narrowband filter of the Italian Interferometric BiDirectional Spectrometer (IBIS). Both ports have room to set up additional filters and cameras. The port with the DLSP is dedicated to the DLSP and the setup frozen to minimize set-up time between users. In addition to the AO systems on the DST, the AO team delivered and installed a high-order AO system to the Big Bear Solar Observatory.

## 2.4 Global Oscillation Network Group (GONG)

The Global Oscillation Network Group (GONG) is an international, community-based program conducting a detailed study of the internal structure and dynamics of the Sun by measuring acoustic waves that penetrate throughout the solar interior. In order to overcome the limitations of observations imposed by the day-night cycle at a single observatory, GONG operates a six-station network of extremely sensitive and stable solar velocity mappers located around the Earth, obtaining nearly continuous observations of the “five-minute” pressure oscillations.

The instruments obtain  $800 \times 800$  velocity, intensity, and magnetic flux images once a minute with a duty cycle near 90%. Data products, including individual images, time series,  $p$ -mode frequencies, and “science products” such as flow maps are available online at <http://gong.nso.edu>.

Observations and analysis of the low-order, global  $p$  modes continues tracking the evolution of the interior through the solar cycle and we now have excellent measures of the propagation of the torsional oscillations (regions of faster and slower rotation) propagating toward the equator, and—having seen the long-standing neutrino deficit resolved in favor of the Sun and supporting new physics of the neutrino—are watching the debate around the substantial changes in the internal structure implied by a proposed, new lower value of the heavy element abundance ( $Z$ ).

The GONG data processing pipeline system, designed to handle 32 times more data than the initial  $256 \times 256$  images, made excellent progress towards achieving routine scientific operations. Processing of the higher resolution data focuses on high-order ( $\ell \approx 1000$ ) global  $p$ -mode processing to probe closer to the solar surface and local helioseismology methods—tracking and remapping ring diagrams, time-distance, and holography—to probe the inhomogeneous and intermittent structure below the surface. The ring-diagram analysis, which yields “subsurface solar weather” flows, remains the principal technique being exploited, and the first 37 consecutive Carrington rotations (1,000 days) have been generated. Six rotations of flow maps are shown in Figure 6. Travel time measurements (“time-distance helioseismology”) of the meridional flows down to the base of the convection zone, going back to the beginning of GONG, have been derived. Progress that has been made in imaging the back, or farside, of the Sun with near-real-time data should help forecast active regions up to two weeks before they rotate into view, thus providing useful information to a broad range of users ranging from solar astronomers planning upcoming observing campaigns to space weather forecasting. Results are already beginning to come out of the high-time-cadence magnetograms, which should enable a new community of users of GONG data and complement the SOLIS data by providing a continuous temporal context.

GONG continues its evolution from a limited-term project to an NSO flagship facility. The site and instrument operations team faces the challenge of maintaining and improving network reliability and maintainability, but can also look forward to the opportunities of increased communications bandwidth, which should result in near-real-time data verification and diagnostics, better performance, and eventually near-real-time data transfer and science. In order to mitigate risk, a replacement instrument is under development. Improvements to the magnetograph modulator should substantially reduce the uncertainty in their zero point. Data processing operations in Tucson continue to become more automated and efficient with the implementation of computer servers, shared resources, and process-controlled pipelines.

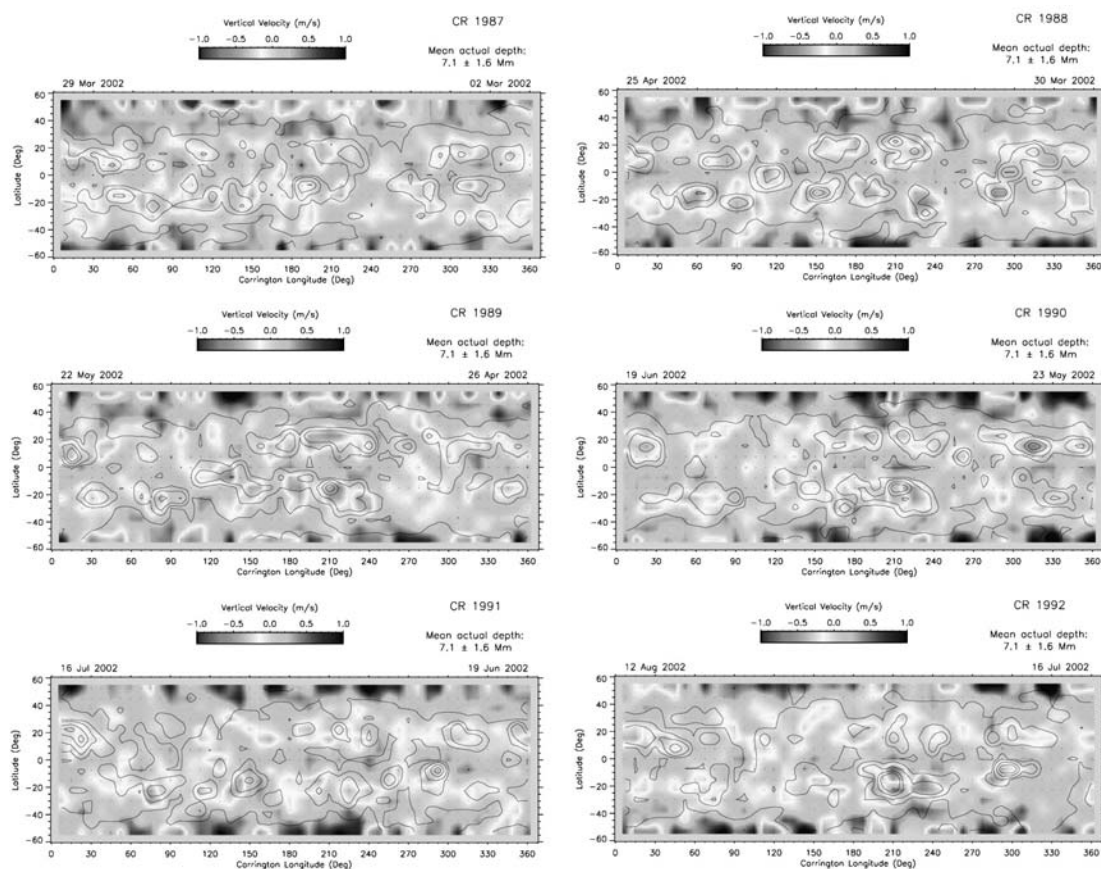


Figure 6. Six rotations of subsurface flow maps.

## 2.5 Virtual Solar Observatory (VSO) and Digital Library

In FY 2004, NSO continued to lead the development of the Virtual Solar Observatory (see <http://vso.nso.edu/>), a unified distributed solar data archive and analysis system with access through the WWW. The system was released for public use as a beta version in December 2003, and has already attracted considerable interest, with nearly 1,000 accesses as of June 2004. Currently, the VSO provides access to data from 40 different observatory/instrument sources, both space- and ground-based. The data can be searched on the basis of observatory or instrument, physical observable, time, event, and spectral range. The VSO provides two types of interfaces—a Web-based interface for browsing, and an Application Programming Interface (API) so that users can access the VSO directly from their own personal software. In FY 2005, the initial development phase of the VSO will be completed and will provide the capability to search by spatial coordinate; an adopter's kit to install additional archives; a shopping-cart style data delivery mechanism, and an improved graphical user interface. The VSO is being constructed by NSO, NASA Goddard Space Flight Center, Stanford University, and Montana State University. As the internet continues to develop, the VSO is expected to become the tool of choice for locating and acquiring archived solar data.

The need for a VSO is clearly demonstrated by the experience of NSO in providing synoptic data sets over the Internet to the research community. This service has seen an enormous increase in usage. Over the last two years, the average number of NSO data files distributed per quarter has increased by a factor of seven. In FY 2004, nearly 400,000 files on average were distributed each quarter to approximately 600 users. These figures exclude any NSO or NOAO staff members. Currently, the Digital Library holds the entire set of daily solar images from the Kitt Peak Vacuum Telescope, Fourier Transform Spectrometer data, a portion of the Sacramento Peak spectroheliograms, GONG data, and SOLIS magnetograms. With the advent of the VSO, solar researchers as well as educators and the general public will be able to easily find solar data for their research or educational needs.

### 3 SCIENTIFIC AND KEY MANAGEMENT PERSONNEL

The NSO staff is located in Sunspot, New Mexico and Tucson, Arizona. The observatory director is Dr. Stephen L. Keil, who is based in Sunspot but spends time at both operational sites. Dr. Mark S. Giampapa is deputy director and responsible for the Tucson operations. Mr. Rex Hunter is site manager at Sacramento Peak at Sunspot. Mr. Steve Hegwer is the project and telescope manager at Sunspot. Mr. Jeremy Wagner is the interim ATST project manager as well as SOLIS project manager. Ms. Patricia Eliason is the GONG facility manager, and Mr. Dave Dooling is the ATST/NSO educational outreach officer. NSO and affiliated scientific staff are listed below, along with their primary area of expertise and key observatory responsibilities.

#### 3.1 Sunspot-Based Staff

##### *NSO Staff*

**K. S. Balasubramaniam** – Solar activity; magnetism; polarimetry; International Heliophysical Year liaison and editor of the IHY Newsletter .

**Stephen L. Keil** – Director; solar variability; convection.

**Maud P. Langlois** (ATST/AO) – Adaptive optics (high-order AO and multi-conjugate AO); instrumentation.

**Alexei A. Pevtsov** – Solar activity; coronal mass ejections; Scientific Coordinator, NSO REU/RET Program.

**Thomas R. Rimmele** – Solar fine structure and fields; adaptive optics; instrumentation; ATST Project Scientist; Dunn Solar Telescope Program Scientist.

**K. Sankarasubramanian** (ATST) – Solar fine structure; magnetism; Stokes polarimetry.

**Han Uitenbroek** – Atmospheric structure and dynamics; radiative transfer modeling of the solar atmosphere; Ch., NSO/SP Telescope Allocation Committee.

##### *Grant-Supported Staff at Sunspot*

**Gilberto Moretto** – Optical instrumentation; adaptive optics.

##### *Air Force Research Laboratory Staff at Sunspot*

**Richard C. Altrock** – Coronal structure and dynamics.

**Nathan Dalrymple** – Polarimetry; thermal analysis.

**Joel Mozer** – Coronal structure; remote sensing; space weather.

**Richard R. Radick** – Solar/stellar activity; adaptive optics.

#### 3.2 Tucson-Based Staff

**Mark S. Giampapa** – NSO Deputy Director; stellar dynamos; stellar cycles; magnetic activity; Ch., Tucson Project Review Committee; SOLIS PI.

**Irene E. González Hernández** – Helioseismology.

**John W. Harvey** – Solar magnetic and velocity fields, helioseismology, instrumentation; SOLIS Project Scientist; Ch., NSO/KP Telescope Allocation Committee.

**Carl J. Henney** – Solar MHD; polarimetry; space weather; SOLIS Facility Scientist.

**Frank Hill** – Solar oscillations; data management.

**Rachel Howe** – Helioseismology; the solar activity cycle.

**Christoph U. Keller** – Solar polarimetry; adaptive optics; instrumentation.

**Shukur Kholikov** – Helioseismology; data support.

**John W. Leibacher** – Helioseismology; GONG Program Scientist.

**Matthew J. Penn** – Solar atmosphere; solar oscillations; polarimetry; near-IR instrumentation; Co-Site Director, NSO REU/RET Program.

**Jeffrey J. Sudol** – Helioseismology; data support.

**Clifford Toner** – Global and local helioseismology; image restoration; data analysis techniques.

**Sushant Tripathy** – Helioseismology.

#### ***Grant-Supported Staff in Tucson***

**Michael Dulick** – Molecular spectroscopy; high-resolution Fourier transform spectrometry.

**Rudolph W. Komm** – Helioseismology; dynamics of the convection zone.

**Elena Malanushenko** – Structure of the solar chromosphere and transition region; coronal holes.

**Roberta Toussaint** – Helioseismology; image calibration and processing; data analysis techniques.

#### ***NASA Staff in Tucson***

**Harrison P. Jones** – Solar magnetism and activity.

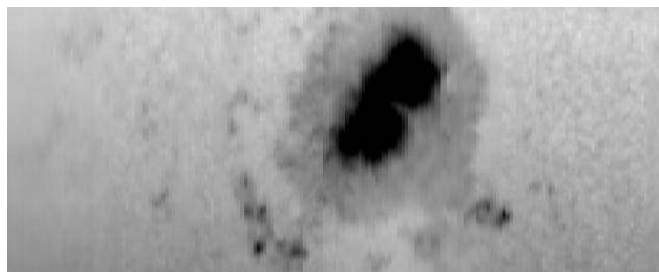
## **4 SCIENTIFIC RESEARCH AND DEVELOPMENT HIGHLIGHTS**

Use of NSO facilities produces a significant number of research papers each year while also providing solar data that support a wide range of solar and solar terrestrial studies and solar activity forecasting. The latter includes data in support of space missions such as SoHO, RHESSI and TRACE, and data sent to the NOAA Space Environment Center in Boulder for predicting and understanding solar activity. NSO makes solar data available to a diverse community of scientists and educators through its Digital Library (<http://diglib.nso.edu/>), and Earth atmospheric measurements made at the NSO FTS facility are included in the Network for the Detection of Stratospheric Change (NDSC) archive. Some of NSO's recent science highlights are described in the following section.

### **4.1 Infrared Magnetic Field Measurements Show Moving Magnetic Features**

Recently, the NSO/CSUN infrared array camera at the McMath/Pierce main telescope was used by Matt Penn (NSO) and colleagues to examine the vector magnetic field of a sunspot. The project also involved students Penn mentored as part of the NSO Research Experience for Undergraduates (REU) program.

On 24 June 2002, the large sunspot NOAA 10008 was observed for four hours with the IR camera and the main spectrograph. Polarimetric measurements were taken using a set of liquid crystal variable retarders of the Fe I 1565 nm line. This is a notable spectral line because it shows the highest magnetic sensitivity of any spectral line in the visible or near-infrared regions of the solar spectrum. The observations are unique because they cover such a long period of time; previous infrared sunspot observations are in general just single scans that are not useful for studying the time evolution of a sunspot.



*Figure 7. An image of the sunspot NOAA 10008 taken in the infrared at 1565nm on 24 June 2002. The magnetic fields in this sunspot are being studied to search for moving magnetic features in the penumbra of the sunspot.*

During the summer of 2003, the telescope instrumental polarization was characterized and removed from these data. The software to test and implement several techniques for removing the telescope polarization was written by Sarah Jaeggli, a University of Arizona student who participated in NSO's summer 2003 REU program. Since the observations cover four hours of time, the time variation of the telescope polarization was studied using

these data and compared with a simple model. Results show that the instrumental polarization agreed favorably with the model, and that after the telescope polarization is removed from the data, the remaining errors are at the level of only 1%.

After the data were calibrated, a Milne-Eddington model atmosphere was used to invert the spectro-polarimetric data to determine the magnetic characteristics of the sunspot. This type of analysis is often used with sunspot measurements made in the visible spectrum, but it is equally applicable at infrared wavelengths. Statia Luszcz, a student from Cornell University (and a summer 2004 NSO/REU participant) examined the time sequence of calibrated data in search of moving magnetic features. Surprisingly a large number of moving magnetic features were observed inside the sunspot penumbra. Normally the moving magnetic features around sunspots appear outside of the sunspot itself, in the surrounding quiet Sun, and move away from the spot. These new features appear inside the sunspot penumbra and move across the penumbra and out into the quiet Sun, away from the spot. It is likely that these new features will be important in the study of the evolution of the magnetic field in sunspots. A paper describing the results of these observations has been submitted for publication.

#### 4.2 The Zeeman Effect on the G Band

A substantial fraction of the magnetic flux on the solar surface exists in the form of small-scale structures with sizes just at or below the current resolution limit of solar telescopes. In order to understand and predict the behavior of the solar magnetic field, one must learn how these small-scale elements form, evolve, and disappear, what their role is in the global evolution of the magnetic field, and how much flux they represent. A popular method for tracking small-scale features is narrowband imaging in the G band with typical passbands of 1 nm FWHM. A draw-back of G-band imaging is that it does not provide measurement of the magnetic flux, which must be obtained by simultaneous and co-spatial magnetograms in magnetically sensitive atomic lines. This is an arduous process, involving careful alignment of images taken at different wavelengths. It would be preferable if magnetic flux could be measured in precisely those spectral lines that make up the G-band. Calculations now show that this should indeed be possible.

Most of the opacity in the G band is due to electronic transitions in the A-X band of the CH molecule with added contributions from atomic lines of different elements. Molecular lines are susceptible to the Zeeman effect in the presence of an external magnetic field and may

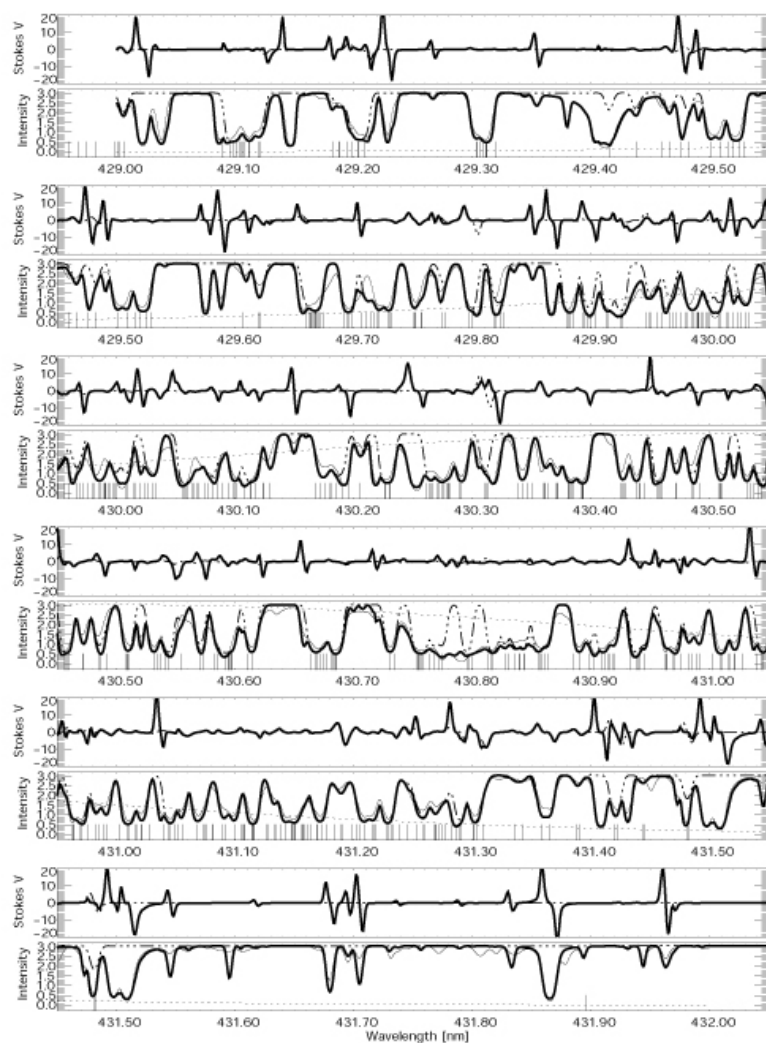


Figure 8. Calculated Stokes I and V spectra in the G Band (thick solid curves). Also shown are the observed intensity spectrum (thin solid curve), calculated spectra due to CH lines only, without contribution from atomic lines (thin dash-dotted curves), and the typical transmission curve of a G-band filter (dotted curve). Vertical lines at the bottom of the graphs mark the location of each CH line.

produce polarized radiation that can be analyzed to infer the properties of the field. If a molecule has a non-zero magnetic moment, the interaction of that moment with the magnetic field will split the molecular energy levels into a pattern that is, in general, more complex than in the atomic case because of the additional degrees of freedom inherent in molecular structure. When all interactions, including vibration and rotation, are accounted for, the resulting effective Lande factors often have negative values and rapidly tend to zero for increasing  $J$ .

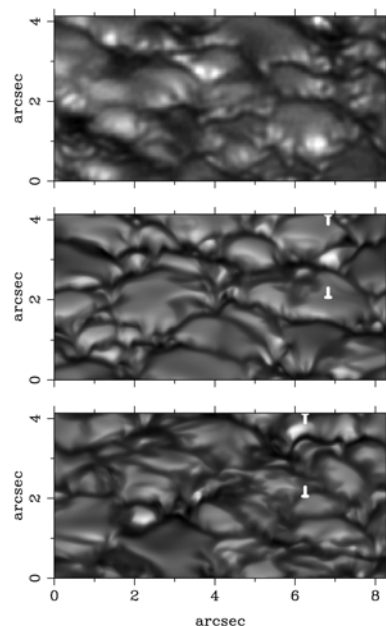
Although much of the required quantum mechanics had already been formulated by the end of the 1930s, employing molecular line polarization for magnetic field diagnostics is numerically intensive and is only now possible. With a new numerical code that includes the molecular Zeeman effect, the emergent intensity and polarization in the G band around 430 nm were evaluated by Han Uitenbroek (NSO) and colleagues for several different solar models. In one such calculation, the circular polarization signal (Stokes V) is less crowded than the Stokes I spectrum because the effective Lande factors of most CH lines are much smaller than one. In several locations, the polarization signal from CH lines is of the order of several percent of the continuum intensity and should be detectable with current polarimetric instrumentation.

### 4.3 Solar Faculae Explained

Apart from sunspots, faculae are the next obvious feature on the solar disk. Faculae appear close to the solar limb as bright, small-scale features that are related to magnetic fields. Faculae have been known since telescopes have been pointed at the Sun, but their origin has never been clearly revealed. The large number of faculae around sunspot maximum more than make up for the deficit due to sunspots, which explains the slightly higher solar irradiance at solar maximum. Understanding the origin of faculae has therefore a much broader impact than just explaining one of the most prominent solar surface features. Recently, images from the new 1-m Swedish Solar Telescope on La Palma have revealed the detailed brightness structure of faculae at an unprecedented spatial resolution. Facular brightenings often appear as relatively extended features on the centerward side of granules. Often there is a dark, narrow lane in front of the facular brightening.

Christoph Keller (NSO), in collaboration with Manfred Schüssler, Alexander Vögler, and Vasily Sakharov of the Max-Planck-Institute for Solar System Research, analyzed ab-initio three-dimensional simulations of non-grey radiative magneto-convection in the solar surface layers and showed that the simulations reproduce the observed small-scale features (see

Figure 9). In particular, the simulations qualitatively reproduce all features seen in the observations. These include: 1) The three-dimensional impression one obtains when looking at the images; 2) faculae appear predominantly in areas with a significant amount of magnetic flux; 3) facular brightenings occur on the disk-center side of granules; 4) the brightening can extend over about 0.5 arcsec; and 5) often there are narrow, dark lanes just toward the center of the facular brightening. The simulations reveal that the excess brightness of the faculae comes from a thin layer ( $\sim 30$  km thick), which is embedded in the



*Figure 9. Comparison of observations from the Swedish Solar Telescope (top panel) and simulated images at 488 nm based on simulations with an average vertical magnetic field of 400 G (middle panel) and 200 G (lower panel), respectively, at a heliocentric angle of  $60^\circ$ . The upward direction is towards the limb. The white marks point out two prominent faculae in the simulations. The images have been scaled individually such that their minimum and maximum intensities correspond to black and white, respectively. No attempt has been made to degrade the simulations to match the resolution of the observations.*

steep density gradient at the interface between the magnetic and the non-magnetic atmosphere (see Figure 10). The dark, narrow lanes often associated with faculae occur at the opposite side of the magnetic flux concentration and are due to an extended layer with lower-than-average temperatures.

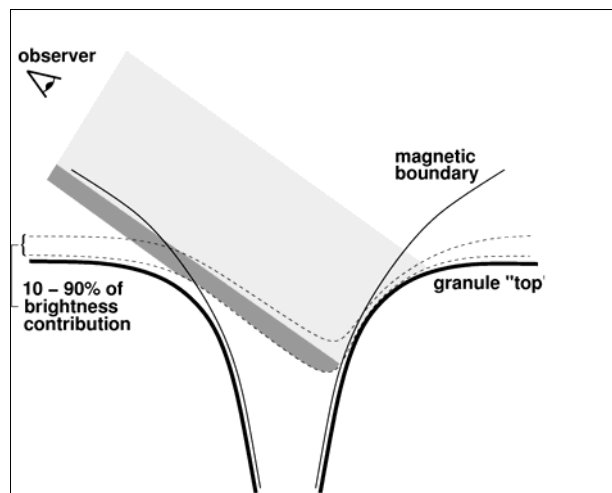


Figure 10. Schematic representation of a magnetic flux concentration (region within the thin lines) and adjacent granules (thick lines), illustrating the origin of the facular brightening and the dark lane. The dashed lines enclose the region where the dominant part (80%) of the continuum radiation is formed. The brightness enhancement of the facula mainly originates from a thin layer near the limbward interface between the magnetic flux concentration and the hot, non-magnetic granule. The intensity of the dark lane is formed in the relatively cool regions above the granule that's toward the center, and inside the flux concentration. The lines of sight for the facular brightening and for the dark, narrow lane are indicated with correspondingly shaded grey areas.

#### 4.4 Observational Evidence for Magnetic Flux Submergence

It is widely believed that the magnetic field on the Sun is generated by a dynamo operating at the base of the convection zone, although recent studies suggest that there may be a second dynamo operating at or near the visible solar surface, the photosphere. In 1984, Eugene Parker concluded that only a small fraction of magnetic flux threading the solar surface can escape. He also pointed out an inconsistency between the upper limit of magnetic flux stored at the base of the convection zone and the rate of flux emergence in a long-lived complex of activity. To resolve this “dynamo dilemma,” Parker suggested that magnetic flux retracts below the surface and is recycled several times. So far, however, this flux submergence has proven to be illusive.

Magnetic flux concentrations in the photosphere often disappear via flux cancellation when opposite poles collide with each other and vanish. The reconnection forms two loop-like structures: concave-up and concave-down. The magnetic tension would try to “shorten” newly formed “loops,” and thus, at the place of maximum curvature (apex/valley), one loop would show rising motions, and the other would show descending motions. The observer would see only one loop crossing the photosphere whenever the reconnection took place below or above the photosphere.

Using high-resolution vector magnetograms of active region NOAA 10043, observed on 26 July 2002 with the Advanced Stokes

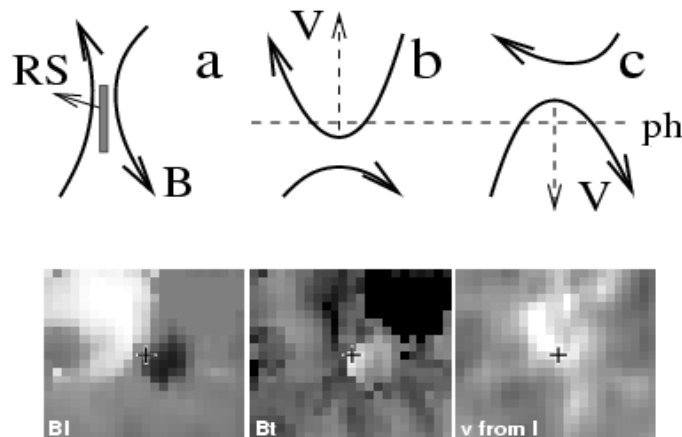


Figure 11. Upper panel: Schematic representation of the magnetic topology at a flux cancellation (reconnection) site (RS) prior to reconnection (a) and after the reconnection below (b) and above (c) the photosphere (ph, horizontal dashed line). Solid lines with arrows represent the magnetic field  $B$ , and vertical dashed arrows show the direction of motion of newly formed loops. Lower panel: Observations of a flux cancellation site; longitudinal field  $B_l$  (white/black corresponds to positive/negative polarity), transverse field  $B_t$ , and Doppler velocity  $V$  (white halftone corresponds to downward motions). The flux cancellation site is marked by a “+”.

Polarimeter and low-order adaptive optics system at the NSO Dunn Solar Telescope, Alexei Pevtsov (NSO), in collaboration with Jongchul Chae (Seoul National University and Big Bear Solar Observatory) and Yong-Jae Moon (Korea Astronomy Observatory and Big Bear Solar Observatory) studied the magnetic field topology and line-of-sight velocities at two flux cancellation sites. The observations showed that near the cancellation site, the longitudinal magnetic field vanishes, but the transverse field reaches its maximum. This implies that the magnetic field is mostly horizontal there, as at the top of a loop connecting two canceling bipoles. However, the velocity map shows significant downflows where the magnetic field is horizontal, suggesting that the magnetic field is moving downwards. Detailed analysis of Stokes profiles at the flux cancellation site support the above description of plasma motions and the magnetic field topology. These rare observations provide the first observational evidence for submergence of magnetic flux on the Sun. Further studies of magnetic flux submergence would provide important clues for understanding the origin and evolution of magnetic flux on the surface of our nearest star.

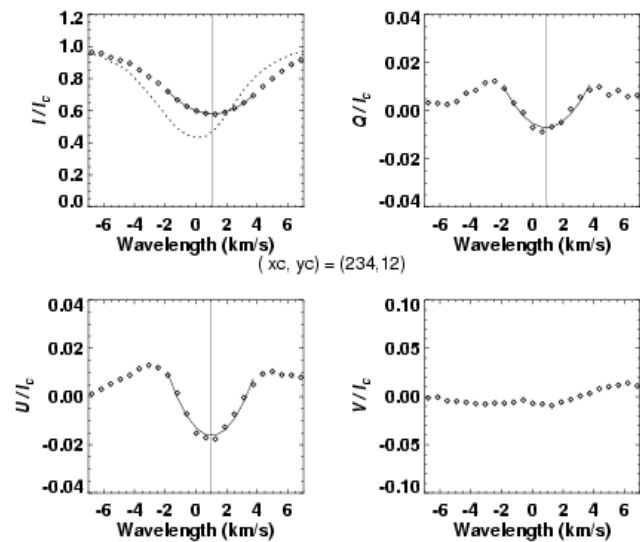


Figure 12. Stokes profiles at the flux cancellation site shown in Figure 11. The wavelengths for all profiles are expressed in units of velocity relative to the nearby quiet Sun. Negative velocity corresponds to blueshift, or upward (with respect to image plane) motions. The dotted curve in the top left panel shows the Stokes I profile from the quiet Sun area. The vertical solid line represents the center of the Stokes profile.

## 4 BRIDGES TO THE FUTURE

The advent of solar adaptive optics and its routine use at the Dunn Solar Telescope as well as the increased use of IR arrays in conjunction with a new AO system at the McMath-Pierce Solar Telescope mark the major changes in NSO operations. The NSO telescope upgrade and instrument development program is guided by the scientific and technical imperatives for developing a new Advanced Technology Solar Telescope. Telescope and instrument upgrades and operations are reviewed and supported on the basis that they serve as necessary preludes to the ATST initiative while concurrently serving the needs of the scientific community. Details of the scientific and technical operations can be found at <http://www.nso.edu>. Brief summaries of the primary projects and operational changes are provided in this section.

### 5.1 Kitt Peak

#### 5.1.1 NSO Array Camera (NAC)

The ATST will be an all-reflecting, open solar telescope; currently the closest analogy is the NSO/Kitt Peak McMath-Pierce telescope. The all-reflecting design of the McMath-Pierce gives it access to the entire solar spectrum that is transmitted through the Earth's atmosphere. Exploring the infrared parts of this spectrum is a high priority for NSO, and the wavelength range from 1,000-5,000 nm is the focus of the new NSO Array Camera program. The NAC will be a closed-cycle, cooled InSb  $1024 \times 1024$  pixel camera and will obtain images, spectroscopy and polarization data in the 1,000-5,000 nm window. The NAC will replace the aging NSO NIM instrument, and will have lower read noise, faster read-out, and 16 times more pixels. The NAC project is currently expecting to obtain first light images in 2005.

The NAC instrument will target several exciting science questions using spectroscopy and polarimetry at these infrared wavelengths. First, filament dynamics and magnetic field measurements using the He 1083 nm absorption line will be observed. The polarization of the He 1083 nm spectral line will provide critical tests of several magnetic models of filaments, and will be used to constrain modeling efforts currently underway at several institutes. The NAC instrument with its large format will be well-suited to study active region magnetic fields using the polarization of the Fe I 1565 nm spectral line. This line provides the most sensitive probe of the magnetic field in the quiet Sun and in parts of sunspots. Current tests using this line have been made with smaller cameras at the McMath-Pierce, and the instrumental contribution to the observed polarization is well-understood. The NAC instrument should make regular maps of the vector magnetic field of solar active regions for years to come. The plasma in the solar atmosphere will be studied in several ways with the NAC camera; the cold plasma of the chromosphere will be investigated using CO absorption lines at 4600 nm, and the hot plasma of the corona will be studied with emission lines from Fe XIII at 1075 nm and Si IX at 3934 nm. Finally, exploratory work at infrared wavelengths will be done using Ti I lines near 2200 nm, and using molecular lines throughout the wavelength range, in order to study sunspots and even to understand the basic physics of molecular line formation itself.

The NAC system is also planned to be a bridge to the Advanced Technology Solar Telescope (ATST) near-infrared instrumentation. The NAC dewar is flexible with plenty of internal space available, and can accommodate upgrades for use with the ATST first-light instrumentation. Tests are planned with the NAC to make polarimetry observations beyond 2200 nm and the instrumentation developed during those tests will be directly applied to the ATST. Certainly the scientific discoveries that will come from the NAC observing runs during the next few years will drive near-infrared science programs at the ATST.

### **5.1.2 Seeing Improvement**

Tests of potential improvements to the telescope seeing have been conducted during the last several years, including fans blowing air across the image-forming mirror, which is heated by the incoming sunlight. The wavefront sensor in the adaptive optics system has also revealed other sources of telescope seeing such as the interface between the telescope and the observing room. Appropriate changes have been made to improve the internal seeing. During FY 2005, we expect to install fans similar to what is used at European Southern Observatory's New Technology Telescope facility to reduce the mirror seeing on M2.

### **5.1.3 Adaptive Optics (AO)**

The infrared adaptive optics system at the McMath-Pierce telescope has been used extensively for scientific observations, and most infrared observing runs now request the adaptive optics system. Full documentation as well as the source code for all of the software are available on the web. The success of this low-cost approach is also illustrated by the fact that solar research groups in Switzerland and India are currently duplicating the system.

During FY 2005, the conversion of the prototype system to a user system will be completed by upgrading the few remaining components that limit the full field of view. Initial observations of Mercury, Io, and stars down to 7<sup>th</sup> magnitude using the tip-tilt system have been successful. During FY 2005 a modified version of the existing AO system will provide, in addition to high-resolution solar observations, fully AO-corrected observations of Mercury and other solar system objects, which is of high interest to future US and European space missions.

#### **5.1.4 McMath-Pierce Telescope Control System (TCS)**

A new telescope control system is needed to ensure that the McMath-Pierce facility remains competitive and maintainable. It is expected that the entire TCS will be based on commercial components that will be integrated by a vendor. Funding possibilities and the efforts that would be involved for a new TCS are being investigated. The total cost is beyond the amounts available for telescope upgrades internally, so we will continue to explore options for external funding while accumulating internal funds to that end. Cost estimates will also be refined and kept up-to-date until funding becomes available.

#### **5.1.5 Integral Field Unit for the McMath-Pierce**

Thanks to a grant from NSF/ATI, Deqing Ren (NJIT) and Christoph Keller will develop an advanced all-reflective image slicer for AO-corrected infrared observations with the McMath-Pierce vertical spectrograph. This will allow strictly simultaneous spectroscopy and polarimetry over a two-dimensional field of view, a crucial capability for studying various phenomena in the solar atmosphere. During FY 2005, the unit will be designed and constructed. Deployment at the telescope is expected late in FY 2006.

### **5.2 Sacramento Peak**

#### **5.2.1 Spectro-Polarimeter for Infrared and Optical Regions (SPINOR)**

SPINOR is a joint High Altitude Observatory (HAO)/NSO program to upgrade the existing Advanced Stokes Polarimeter (ASP) at the Dunn Solar Telescope (DST). The ASP has been the premier solar research spectro-polarimeter for the last decade. Its ability to explore new spectral lines and to observe in multiple lines simultaneously is still unique. The ASP wavelength range, however, is restricted to the visible, limiting its ability to sample new solar diagnostics, and its hardware is becoming outdated and difficult to maintain. HAO has received National Center for Atmospheric Research (NCAR) funding to start building SPINOR. SPINOR extends the wavelength of the ASP from 750 nm to 1600 nm with new cameras and polarization optics, provides improved signal-to-noise and field-of-view, and replaces obsolete computer equipment. Software control of SPINOR will be brought into the DST control system as opposed to the stand-alone ASP. SPINOR will augment capabilities for research spectropolarimetry at the DST and extend the lifetime of state-of-the-art research spectropolarimetry at the DST for another decade.

#### **5.2.2 Charged Couple Device (CCD) Upgrade**

The primary goal of the CCD project is to provide a reliable and stable data acquisition system for the Dunn Solar Telescope (DST). Additional benefits include: providing interchangeable camera-computer configurations on a day-to-day basis, and easing the required maintenance effort of the entire camera system. The new data acquisition system was released to DST users earlier this year. Special thanks go to Chris Berst, Steve Fletcher, Brady Jones, and the project team for their outstanding efforts.

The new configuration consists of: a) seven SUN Blade 100s running SOLARIS OS; b) 500 GB Sun Fiber Channel SAN; c) DLT tape library with four DLT 8000s with 30 cartridge capacity; d) media-transfer stations for transfer of data from DLT to media of choice; and e) a universal camera hardware interface. The CCD upgrade is one of the critical components of the current Dunn Solar Telescope development plan. Additional tasks include: development of “fixed” instrumentation, experiment control system development, and critical hardware replacement. These are essential activities for ensuring that the DST remains a competitive solar facility.

The term “fixed” instrument refers to an instrument that is permanently located at one of the DST exit ports and is ready to operate at opportune times (good seeing, opportune targets, etc.). The aim of this effort is to reduce observing set-up time and improve scientific productivity by capitalizing on excellent observing conditions. The Diffraction-Limited Spectro-Polarimeter (DLSP) is the first of such instruments.

The development of an experiment control system is required to allow near-simultaneous operation of multiple instruments and cameras. The critical hardware replacement is necessary to reduce downtime and improve efficiency. Many existing DST hardware components are now obsolete. Failure of such components will lead to considerable downtime while new solutions are developed. The DST team is currently developing a base-line project plan for these two activities.

### **5.2.3 Evans Solar Facility (ESF)**

The Evans Solar Facility provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the most thoroughly instrumented in the world. The ESF 40-cm coronagraph currently is used primarily by NSO's USAF partners, while the coelostat is used in the NSO Ca II K-line monitoring program. After six months of simultaneous operations with SOLIS, the ESF K-line program will be closed. SOLIS also replaces the spectroheliogram capability of the ESF. The Air Force group provides funding for a part time observer and provides NSO with some funds for minimal maintenance. The High Altitude Observatory has expressed recent interest in using the coronagraph for a visible and IR coronal polarimeter, building on the recent tantalizing observations of coronal magnetic fields. This new instrumentation would provide core capabilities for the next generation of ground- and space-based coronal telescopes.

## **6 EDUCATIONAL AND PUBLIC OUTREACH**

NSO has a comprehensive public affairs and educational outreach plan that includes public programs, media information, elements of distance learning (Internet) education, K-12 education, undergraduate and graduate research, teacher research and research-to-classroom experiences. Scientists at each site have responsibility for the local educational and public outreach program, with additional support provided by other members of the scientific and support staff and, during the summer, by resident students. In addition to conducting public relations and outreach as part of the ATST program, Educational and Public Outreach (EPO) Officer Dave Dooling coordinates the ATST educational and public outreach (EPO) efforts with that of the NSO and other ATST partners.

Dave Dooling developed new outreach concepts during the ATST construction phase proposal process. The concepts are to be developed for delivery through, and in support of, existing EPO activities (TLRBSE, Project ASTRO, etc.), rather than developing new channels. These activities are to be defined during the first two quarters of calendar 2005 with the goal of having prototype materials ready for testing:

- *Max 2008* is a program with activities focused on the Cycle 24 which starts in 2007-2008, the International Heliophysical Year in 2007, and the centennial of Hale's discovery of magnetism in sunspots in 1908. Significant work was done during 2004 on defining a museum exhibit on solar magnetism as part of Max 2008.
- *Other Suns for Other Worlds*, a program to connect nighttime astronomy with the Sun, specifically by exploring concepts for determining what stars would be most hospitable for life.
- *The Sun on Wheels*, an education van outfitted to take current and future educational materials to schools, including telescopes for students to observe the Sun.

## 6.1 Educational Outreach

### 6.1.1 Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET)

Over 700 announcements about the Summer 2004 Research Experiences for Undergraduates Program at NSO were sent to astronomy, physics, engineering, mathematics, and natural science departments throughout the US and Puerto Rico. An announcement about the NSO Summer 2004 Research Experience for Teachers (RET) Program was widely distributed electronically via the National Astronomy List Serves, Arizona Physics Teachers List Serves and the Arizona Science and Math Education Center; announcements were also sent to schools districts throughout New Mexico and in Tucson. The NSO 2004 Summer Outreach Program supported six undergraduates and four high school teachers under the NSF-funded REU and RET programs, respectively; four undergraduate research assistants under NSO grant-funded and the US Air Force undergraduate research programs; and three graduate students under the NSO graduate summer program.



Figure 13. NSO 2004 REU, RET, and Summer Research Assistantship (SRA) Program participants. From left: Creighton Wilson (RET, Lovelady High School), Michelle McMillan (REU, Northern Arizona Univ.), Drew Medlin (Grad SRA, New Mexico Tech), Leah Simon (Grad SRA, Macalester College), Maria Kazachenko (Undergrad SRA, St. Petersburg Univ., Russia), Michael Sinclair (RET, Kalamazoo Math and Science Center), Brian Robinson (ATST Fellow, Univ. of Alabama-Huntsville), Stuart Robbins (REU, Case Western Reserve Univ.), Brian Harker-Lundberg (Grad SRA, Utah State Univ.), Frances Edelman (REU, Yale), Statia Luszc (in front of Frances – REU, Cornell), Joel Lamb (REU, Univ. of Iowa), Mark Calhoun (RET, Sabino High School), Heidi Gerhardt (in front — Towson Univ.). Missing from photo are Matt Dawson (RET, Brockton High School), Cheryl-Annette Kincaid (Undergrad SRA, Univ. of North Texas), Kimberly Moody (Undergrad SRA, Univ. of Arizona), Anna Malanushenko (Undergrad SRA, St. Petersburg Univ., Russia).

### 6.1.2 Teacher Leaders in Research-Based Science Education (TLRBSE)

During the winter and summer quarters, NSO staff (Claude Plymate, Matt Penn, Frank Hill, Carl Henney), in collaboration with NOAO and University of Arizona/ Steward Observatory staff, worked with groups of high school teachers and students on observing runs at the McMath-Pierce Solar Telescope as part of a continuing

solar research program for TLRBSE teachers and students on infrared spectroscopy. An article describing an aspect of the research project and featuring three of the high school students from Longview, Washington appeared in Longview's local *Daily News* ([http://www.tdn.com/-articles/2004/03/08/this\\_day/news01.txt](http://www.tdn.com/-articles/2004/03/08/this_day/news01.txt)). Three of NSO's summer 2004 REU students assisted in the summer observing run. Publications on the results of observations have been submitted to *The Astronomical Education Review*, as well as to popular astronomy journals, and the *RBSE Journal*.

### **6.1.3 Project ASTRO**

Throughout the year, Irene Gonzalez Hernandez and Kerri Donaldson-Hanna worked with students at Esperanza Elementary School in South Tucson, and Rudi Komm worked with students at the Arizona State School for the Deaf and Blind. Plans have been established for hosting the annual (October 2004) Project ASTRO Teacher/Astronomer Workshop at Sacramento Peak, in conjunction with the New Mexico Museum of Space History.

### **6.1.4 Further Undergraduate and Graduate Education**

NSO continues with its strong commitment to supporting graduate education and attracting students to solar physics research. New Jersey Institute of Technology (NJIT) graduate student Jose Marino continues work towards his PhD under the supervision of Dr. Thomas Rimmele. Marino is developing techniques for using the AO wavefront sensor to obtain the instantaneous point spread functions of AO-corrected images so they can be fully restored. Supervised by Dr. K. S. Balasubramaniam, David Byers from Utah State University completed his PhD on assessing methods of predicting solar activity based on surface flows. Dr. Alex Pevtsov is the thesis advisor to graduate student Maria Kazachenko of the St. Petersburg University Astronomy Department in Russia. Maria is working on a Masters thesis on the role of large-scale reconnection in coronal heating. Dr. Matt Penn continues to work with University of Arizona undergraduate students on Astronomy 499 independent study projects. This year he advised undergraduates Ali Schmidt, who worked on physical models of ATST Sky Brightness Monitor variation, and Sarah Jaeggli, who is working on infrared data analyses. Dr. Joel Mozer taught an introductory course in Astronomy, "A Survey of the Universe," during the fall/winter semester at New Mexico State University (NMSU)-Alamogordo, and Dr. Han Uitenbroek gave a talk on numerical modeling of the solar spectrum to a General Introduction to Science class at the same institution.

K. S. Balasubramaniam presented a poster on the "Synergy of Solar Physics Research and Education Programs" at the Fall meeting of the American Geophysical Union in San Francisco, and handed out small reprints of the poster and other materials on NSO. Dooling attended the annual conference of the New Mexico Space Grant Consortium at New Mexico State University in Las Cruces on Jan. 9, and gave a talk on solar physics research to a science seminar class at NMSU-Alamogordo in February. NSO also provided materials on REU and other education opportunities to the annual meeting of the American Indian Science and Engineering Society in Albuquerque (an exhibit at the 2004 AISES meeting in Anchorage is planned).

### **6.1.5 Other Educational Outreach**

The NSO joined as a co-investigator with the University of Arizona in the submission of a proposal to a new NSF program entitled "Faculty Development in the Space Sciences." This novel program, administered by the Atmospheric Sciences Division of the NSF, offers the opportunity to compete for the funds required to initiate and sustain for a five-year period new tenure-track faculty positions in the space sciences, solar physics and other related fields. The Space Sciences Department of the University of Arizona invited the NSO to collaborate with them in the submission of a proposal for a new faculty position in solar physics. The location of the NSO-

Tucson site on the University of Arizona campus can facilitate and enhance the collaborative opportunities available to a new solar physics faculty member of the university community.

Throughout the year, scientific staff at both sites gave talks at local elementary schools and organized star parties for students, parents and teachers. NSO officials from Sac Peak and Tucson also assisted with city and regional science fairs in their areas. In April, Allentown High School (NJ) teacher Linda Stefaniak (summer 2003 NSO/RET participant), along with Punahou (Hawaii) School teacher Michael Gearen and longtime NSO partner-in-residence Harry Jones (NASA/GSFC), presented a joint NSO-NASA-NOAO workshop on "Data and Activities for Solar Learning (DASL)" at the National Science Teachers Association Convention in Atlanta. DASL provides a classroom learning environment based on 25 years of NSO data/images of solar magnetic activity. Dave Dooling and Jackie Diehl also represented NSO at the NSTA Convention. Dooling mentored a partially sighted high school student, Billy Casson of Los Alamos, during his summer training with the New Mexico Commission for the Blind in Alamogordo. Billy provided some writing support for a high-school guide to solar anatomy, and conducted a tour for other blind students at the end of the program.

## 6.2 Public Outreach

### 6.2.1. Sunspot Visitor Center

A new effort this year was planning for a community solar system centered on the Sunspot Astronomy and Visitors Center. The overall objective is to learn about the need for solar studies by providing a 16-foot walkthrough model of the Sun as the destination in a 16-mile trip across the solar system starting in Cloudcroft. Signs and scaled planet models will be placed at appropriate locations along the Sunspot Scenic Byway (NM 6563). Don Neidig, who retired in September as ISOON project scientist and continues as an NSO emeritus scientist, is the principal investigator. Agencies solicited as partners include the Cloudcroft Chamber of Commerce, Space Museum in Alamogordo, the Las Cruces Museum of Natural History, the state Scenic Byways office, and the Otero County Tourism Council.

<b>Sunspot Astronomy &amp; Visitor Center Summary of Visitors and Tours (12 Months Ending 09/30/04)</b>	
<i>Group/Program</i>	<i>No. of Visitors</i>
General Public Tours (Visits to Center and Self-Guided Tours)	16,579
Guided Public Tours:	
- School Groups K-12	972
- Special Tours	1281
<b>Total Visitors</b>	<b>18,832</b>

The Sunspot Visitor Center continued development work on the heliostat viewer, which has been built up from the original helioseismology telescope that operated at the South Pole in the 1980s. It is located outside the Visitor Center and projects an image into the building. Preliminary operations of the viewer have begun.

During the year, the Visitor Center hosted approximately 19,000 visitors. Another 6,000 to 8,000 visitors toured the NSO grounds (open sunrise to sunset) without entering the Visitor's Center. Public lectures, and guided tours were held daily at 2 pm during the summer months when RET and REU interns were available. More than

400 invitations to visit the Center were mailed to New Mexico and West Texas (El Paso) schools and youth groups (scouts, Girls Inc., etc.).

### **6.2.2 Other Public Outreach**

Mark Giampapa and Dave Dooling represented the NSO at the NSF's "Universe from the Ground Up" public event on the future of ground-based astronomy, held Oct. 7-8, 2003 in Washington. The event included a lecture by Giampapa and other NSF-funded astronomers and a display. Sunspot initiated a series of quarterly public lectures with the Lodestar Planetarium at the New Mexico Museum of Natural History in Albuquerque. Lecturers were: Director Steve Keil, on ATST, in March; Joel Mozer, on space weather, in June; K. S. (Bala) Balasubramaniam, on solar spectroscopy, in Sept.; and Han Uitenbroek, on the COMosphere (planned, Dec. 21). Bala worked with a video crew shooting material for an educational video at Sunspot. In September 2004, the scientific staff and a few of the technical staff were filmed/interviewed in Tucson and at Kitt Peak by Kris Koenig for a Coast Community College documentary on Astronomy Education.

### **6.2.3 External Coordination**

On May 30 – June 3, 2003, nineteen NSO staff and two NSO/REU students attended the 35th Solar Physics Division (SPD) meeting of the American Astronomical Society in Denver. Seventeen poster papers and six talks were presented by NSO staff and resident partners; eight other posters were co-authored by NSO staff. Five of the NSO posters involved current or past NSO REU or RET program participants. NSO was an exhibitor at the SPD meeting, with a double booth featuring poster displays and handouts on the Observatory's major projects and initiatives.

Steve Keil hosted a U.S. Department of Commerce tour of Federal labs for science delegates from various Federal agencies in June. Dooling met with Dr. Evelina Felicite-Maurice, outreach director for the Living With a Star (LWS) program at NASA's Goddard Space Flight Center, to determine how NSO can best contribute to, and benefit from, the program. He also attended the Conference on Communicating Astronomy to the Public held in October 2003 at the National Research Council, and is participating in an *ad hoc* committee formed to simplify the problems faced by teachers in locating scientifically sound resources on the web. NSO hosted the planning workshop for the 2007 International Heliophysical Year (IHY) in April 2004 at Sacramento Peak. NSO continued its support of the Southwest Consortium of Observatories in Public Education (SCOPE) at semi-annual meetings in Sunspot (November) and Mt. Hopkins, AZ (April), and with materials for a new poster.

## **6.3 Media and Public Information**

### **6.3.1 Press Releases and Image Releases**

Major stories during the year were the selection of three sites as candidates for the ATST, and observations using the high-order adaptive optics at the Dunn Solar Telescope. NSO/Sunspot was visited by three reporters, John Fleck of the *Albuquerque Journal* (with photographer Richard Pipes), Krista West on assignment for *StarDate* and for *Scientific American*, and Arlen Ponder of the *Mountain Monthly* in Cloudcroft. Fleck wrote an article that ran in November, profiling NSO and Air Force Research Laboratory work in tracking and studying solar active regions, and another, 20 January 2004, on drawing sunspots. Curt Suplee, a freelance writer, discussed NSO among other observatories in a major article on the Sun in the July 2004 issue of *National Geographic* (a result of a December 2002 visit to Sunspot and Tucson). NSO provided a fact sheet about the June 8, 2004 transit of Venus and provided Web-based coverage of GONG observations of the event. NSO hosted a meeting and tour at Sunspot for New Mexico members of the National Association of Science Writers on June 18.

### PRESS RELEASES ISSUED IN FY 2004

- **American Astronomical Society:**
  - June 3, 2004: "Site Survey for World's Largest Optical solar Telescope Passes Midpoint" (ATST) [http://www.nso.edu/press/AAS\\_0604/AAS04\\_sitesurvey.html](http://www.nso.edu/press/AAS_0604/AAS04_sitesurvey.html)
  - June 3, 2004: "ATST Design Update" [http://www.nso.edu/press/AAS\\_0604/AAS04\\_ATST\\_update.html](http://www.nso.edu/press/AAS_0604/AAS04_ATST_update.html)
  - June 1, 2004: "Infrared Camera Peeks below the Visible Surface of the Sun" [http://www.nso.edu/press/AAS\\_0604/AAS04\\_NJIT2.html](http://www.nso.edu/press/AAS_0604/AAS04_NJIT2.html)
  - May 31, 2004: "Combined Optical Techniques Confirm Magnetic Shear in Sunspot Motion" [http://www.nso.edu/press/AAS\\_0604/AAS04\\_NJIT1.html](http://www.nso.edu/press/AAS_0604/AAS04_NJIT1.html)
  - May 31, 2004: "New Instrument Makes Highest-Resolution Magnetic Measurements inside a Sunspot" [http://www.nso.edu/press/AAS\\_0604/AAS04\\_DLSP.html](http://www.nso.edu/press/AAS_0604/AAS04_DLSP.html)
  - May 31, 2004: "New Eyes on Old Telescope Provide Insight into Solar Storm" [http://www.nso.edu/press/AAS\\_0604/AAS04\\_AO76.html](http://www.nso.edu/press/AAS_0604/AAS04_AO76.html)
- **Venus Transit:**
  - May 28, 2004: "Modern Solar Telescope Network's View of Venus Passage Will Help Students Use Web to Recall Historical Era" [http://www.nso.edu/press/venus\\_transit/venus04-eo.html](http://www.nso.edu/press/venus_transit/venus04-eo.html)
- April 15, 2004: "Scientists to Plan International Heliophysical Year" <http://www.nso.edu/press/ihy2004.html>
- December 18, 2003: "Peering into the Heart of a Storm" [http://www.nso.edu/press/disp\\_dec03/](http://www.nso.edu/press/disp_dec03/)
- December 8, 2003: "Three Sites Selected as Candidates for World's Largest Solar Telescope" [http://www.nso.edu/press/ATST\\_CandidateSites.html](http://www.nso.edu/press/ATST_CandidateSites.html)
- November 11, 2003: "ATST Interim Site Survey Report Released" [http://www.nso.edu/press/ATST\\_SiteSurvey.html](http://www.nso.edu/press/ATST_SiteSurvey.html)
- October 30, 2003: "Sun Acts Up on Its Way to a Quiet Time" <http://www.nso.edu/press/AR10486/>
- October 27, 2003: "Two Major Sunspot Regions Viewed from Kitt Peak, AZ" [http://www.nso.edu/press/oct03\\_sunspots.html](http://www.nso.edu/press/oct03_sunspots.html)

### 6.3.2 Special Information Products

Two fact sheets, "A Quick Tour of the Sun" and "Tour of Sunspot" have been prepared for use by the Sunspot Visitor Center and for hand-out to educational groups. An extensive research effort has been initiated to survey the status and capabilities of high-resolution optical solar telescopes in the context of science requirements identified for ATST. This is planned as a white paper and as a poster for AAS/SPD in 2005. The ATST booklet was published and widely distributed, and a quarterly newsletter on the ATST is being planned with the first issue to be released in the first quarter of FY 2005. A new version of the visitor's walking tour guides for the Sunspot Visitor Center, with a companion flyer on "A Quick Tour of the Sun" has been produced; it provides an easily read overview of solar anatomy.

### 6.3.3 Web-Based Outreach

The NSO WWW site (<http://www.nso.edu>) contains several public outreach areas. These include a live solar image that is updated once per minute so the public (and the scientific community) can see how the Sun is behaving in H-alpha. These images allow the observer to quickly assess the state of solar activity. Virtual tours of the NSO sites, including telescope descriptions, are available. There is an interactive solar tutorial that provides information about the Sun and its processes. "Ask Mr. Sunspot" provides an area where questions can be asked

about the Sun and astronomy in general. Answers are posted on the Web and indexed so visitors can easily look at past answers by subject. A data archive is also available. While intended for scientific research, it is also accessible by the general public and to students working on solar projects.

#### **6.3.4 Image Requests**

NSO responded to several requests from the *Albuquerque Journal*, *StarDate*, and *Scientific American*. Images were provided to the NSF for posting as part of the image gallery associated with the *Universe from the Ground Up* event. Plans are being developed for a Web-based catalog of NSO-related images, especially ATST images that would be easily searched by the media and educators. NSO also provided pictures of the armillary sphere outside the Sunspot Visitor Center, and H-alpha and sunspot images for a college textbook.

## APPENDIX A

## OBSERVING AND USER STATISTICS

In the 12 months ending 30 September 2004, 69 observing programs, which include 8 thesis programs, were carried out at NSO. Associated with these programs were 67 scientists from 35 US and foreign institutions.

NSO Observing Programs by Type (US vs Foreign)			
<i>12 Months Ending Sept-2004</i>	<i>Nbr</i>	<i>%</i>	<i>Total</i>
Programs (US)	52	75%	
Programs (non-US)	9	13%	
Thesis (US)	5	7%	
Thesis (non-US)	3	4%	
<b>Total Number of Unique Science Projects*</b>	<b>69</b>	<b>100%</b>	

\*Includes observing programs conducted by NSO/NOAO staff scientists.

Users of NSO Facilities by Category					
	Visitors				NSO/NOAO Staff
	US	Non-US	Total	% Total	
PhDs	42	25	67	83%	19
Graduate Students	6	3	9	11%	-
Undergraduate Students	2	0	2	2%	-
Other	1	2	3	4%	9
<b>Total Users</b>	<b>51</b>	<b>30</b>	<b>81</b>	<b>100%</b>	<b>28</b>

Institutions Represented by Visiting Users**				
	US	Non-US	Total	% Total
Academic	14	9	23	66%
Non-Academic	8	4	12	34%
<b>Total Academic &amp; Non-Academic</b>	<b>22</b>	<b>13</b>	<b>35</b>	<b>100%</b>

\*\*Note: Total number of institutions represented by users do not include departments or divisions within an institution as separate entities (e.g., US Air Force and NASA are each counted as one institution even though several different sites/bases/centers are separately listed in the data base.

Number of Users by Nationality			
Canada	3	Japan	4
Chile	2	United Kingdom	3
Germany	5	United States	79
Italy	13		

## INSTITUTIONS REPRESENTED BY USERS

## US Institutions (22)

American Institute of Physics  
 California Institute of Technology  
 California State University, Northridge  
 College of William & Mary  
 Colorado Research Associates  
 Cornell University  
 Dickinson College  
 High Altitude Observatory, NCAR, Boulder  
 Jet Propulsion Laboratory  
 NASA Goddard Space Flight Center  
 NASA Langley Research Center  
 NASA Marshall Space Flight Center  
 New Mexico Institute of Mining & Technology

New Jersey Institute of Technology/Big Bear Solar Observatory  
 Sabino High School  
 Southwest Research Institute  
 Space Telescope Science Institute  
 University of Arizona  
 University of Colorado  
 University of Hawaii, Institute for Astronomy  
 University of Wisconsin, Madison  
 University of Maryland  
 University of Washington  
 US Air Force, Los Angeles AFB  
 US Air Force/Philips Lab (USAF/PL/GSS)

## Foreign Institutions (13)

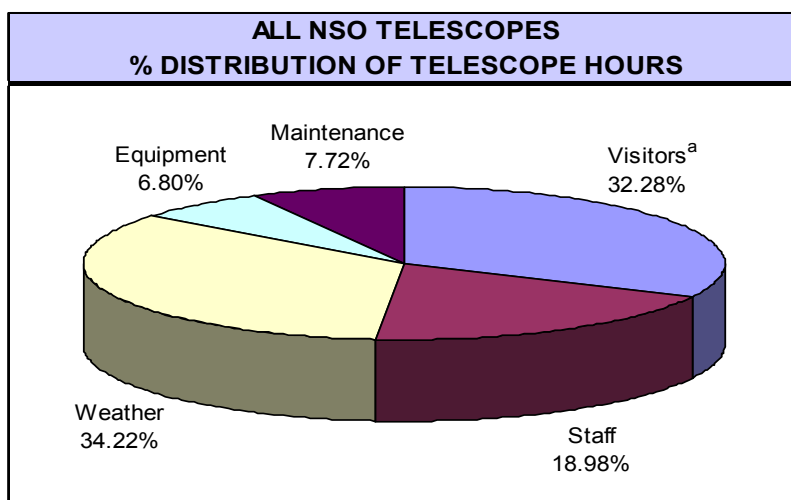
European Southern Observatory  
 INAF - Arcetri Astrophysical Observatory  
 Kyoto University, Hida Observatory  
 Kyoto University, Kwasan Observatory  
 Max-Planck-Institut für Aeronomie  
 Osservatorio Astronomico di Capodimonte  
 University of Calgary

University of Cologne  
 University College London  
 University of Florence  
 Università "La Sapienza," Rome  
 University of Rome "Tor Vergata"  
 University of Waterloo

## FY 2004 USER STATISTICS – TELESCOPE USAGE AND PERFORMANCE DATA

In the fiscal year ending 30 September 2004, 32.3% of the total available telescope hours at NSO/Sacramento Peak and NSO/Kitt Peak went to the observing programs of visiting principal investigators; 19.0% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 7.7% of total allotted telescope hours.

Total “downtime” (hours lost to weather and equipment problems) for NSO telescopes was 41.0%. Almost all of these lost observing hours were due to bad weather (34.2%), with 6.8% lost to equipment problems.



<b>NSO TELESCOPES</b> <b>Percent Distribution of Telescope Hours</b> <b>(Scheduled vs. Downtime)</b> <b>October 1, 2003 - September 30, 2004</b>						
Telescope	Hours Available	% Hours Used By:		% Hours Lost To:		% Hrs. Lost To: Scheduled Maintenance
		Visitors <sup>a</sup>	Staff	Weather	Equipment	
Dunn Solar Telescope/SP	3,648.2	24.7%	24.9%	31.6%	8.2%	10.7%
McMath-Pierce*	3,345.0	32.4%	37.2%	26.8%	3.7%	0.0%
KP Vacuum Telescope <sup>b</sup>	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
FTS Lab*	1,297.5	28.7%	4.6%	0.0%	21.6%	45.1%
Evans Facility	1,099.5	22.1%	18.2%	52.1%	7.1%	0.5%
Hilltop Dome	3,308.0	45.3%	0.0%	52.1%	2.5%	0.0%
<b>All Telescopes</b>	<b>12,698.2</b>	<b>32.3%</b>	<b>19.0%</b>	<b>34.2%</b>	<b>6.8%</b>	<b>7.7%</b>

<sup>a</sup>Includes synoptic programs for which all data are made available immediately to the public and scientific community at large.

<sup>b</sup>The KPVT was closed on 22 September 2003 to prepare for SOLIS. The KPVT will become the Kitt Peak SOLIS Tower (KPST).

\*Totals include both day and night hours. (All others are day only.)

## FY 2004 USER STATISTICS – ARCHIVES/DATA BASES

NSO/SACRAMENTO PEAK

Combined User Demographics (NSO/SP)		
Demographic Group	Requests	Traffic
U.S. Science (.gov, .edu, .mil)	9.2%	6.1%
Other U.S. (.com, .net, misc.)	65.2%	72.0%
Foreign	20.7%	17.4%
Unresolved	4.9%	4.5%

## FTP Archive Statistics

There were 824,538 successful user requests serving 4,918 distinct files to 33,191 distinct hosts. A total of 91.591 Gbytes were served averaging 256.275 Mbytes per day.

FTP User Demographics (NSO/SP)		
Demographic Group	Requests	Traffic
U.S. Science (.gov, .edu, .mil)	6.6%	4.9%
Other U.S. (.com, .net, misc.)	72.1%	79.8%
Foreign	18.3%	12.1%
Unresolved	2.9%	3.2%

FTP Products (NSO/SP)		
Demographic Group	Requests	Traffic
Realtime Images	33.3%	65.2%
Corona Maps	63.7%	22.9%
Sunspot Numbers	1.0%	0.2%
Staff Outgoing	1.6%	10.8%
Other	0.4%	0.9%

## World Wide Web Statistics

There were 5,015,409 successful user requests serving 29,253 distinct files to 328,894 distinct hosts. A total of 86.955 Gbytes were served averaging 243.285 Mbytes per day.

WWW User Demographics (NSO/SP)		
Demographic Group	Requests	Traffic
U.S. Science (.gov, .edu, .mil)	9.6%	7.4%
Other U.S. (.com, .net, misc.)	64.1%	63.8%
Foreign	21.1%	22.9%
Unresolved	5.2%	5.8%

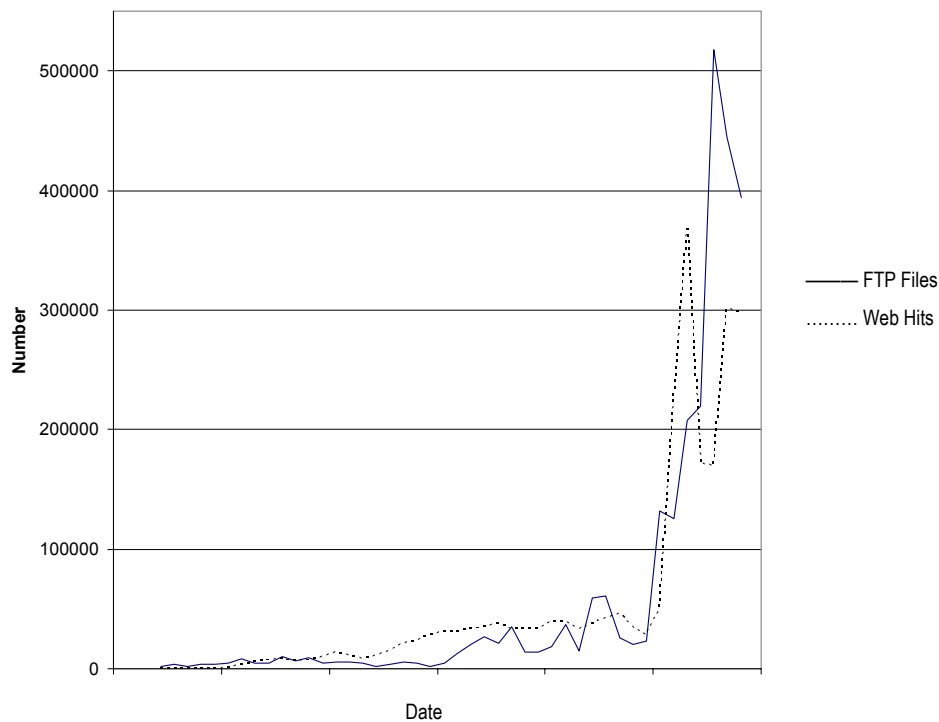
WWW Products (NSO/SP)		
Demographic Group	Requests	Traffic
Realtime Images and Movies	10.4%	19.5%
Other Images	5.1%	23.0%
General Icon and Background Images	32.1%	11.6%
Public Relations Pages	12.9%	9.9%
Press Releases	2.3%	4.8%
Telescope Home Pages	9.6%	5.6%
ISOON	1.9%	0.7%
Adaptive Optics Pages	0.9%	3.7%
General Information	8.7%	5.1%
Staff Pages	2.4%	4.8%
Other	13.7%	11.3%

Note: The statistics on this page exclude the internal use of these services from within the NSO/SP Local Area Network. The numbers do not include NSO/Tucson.

**NSO/TUCSON**

- 2,221 FTP users
- 164,209 FTP logins
- 1,576,868 files downloaded via anonymous FTP
- 941,084 Web page hits (not counting in-line images)
- 6,494,772 Web page hits including in-line images
- Distribution of downloaded data products by number of files for most of the fiscal year:
  1. 4% KPVT (magnetograms, synoptic maps, helium images)
  2. 4% FTS (spectral atlases, general archive)
  3. <1% Sac Peak spectroheliograms (H $\alpha$ , Calcium K images)
  4. 92% GONG (magnetograms, spectra, time series, frequencies)

NSO TUCSON WEB &amp; FTP USAGE



Note: These statistics exclude internal use of these services from within the NSO/Tucson Local Area Network. The numbers do not include NSO/Sunspot.

## APPENDIX B

FY 2004 PUBLICATIONS  
October 2003 through September 2004

**Author**—NSO Staff   **Author**—REU  
**Author**—RET   **Author**—Grad Student  
**Author**—Non-REU Undergrad

*The following is a **partial** list of papers published during FY 2004 by NSO staff, as well as papers resulting from the use of NSO facilities.*

**Refereed Journals (91)**

Altrock, R. C. 2003, "Use of Ground-Based Coronal Data to Predict the Date of Solar-Cycle Maximum," Sol. Phys. 216, 343

**Balasubramaniam, K. S., Christopoulou, E. B., & Uitenbroek, H.** 2004, "Promises and Pitfalls of Solar H-Alpha Zeeman Spectropolarimetry," ApJ, 606, 1233

**Balasubramaniam, K. S., Pevtsov, A. A., & Rogers, J. W.** 2004, "Statistical Properties of Superpenumbral Whorls around Sunspots," ApJ, 608, 1148

**Barban, C. & Hill, F.** 2004, "Comparison of GONG and MDI Solar p-Mode Background," Sol. Phys., 220, 399

**Barban, C., Hill, F., & Kras, S.** 2004, "Simultaneous Velocity-Intensity Spectral and Cross-Spectra Fitting of Helioseismic Data," ApJ, 602, 516

Basu, S. & Antia, H. M. 2004, "Constraining Solar Abundances Using Helioseismology," ApJ, 606, L85

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## APPENDIX C

### ORGANIZATIONAL PARTNERSHIPS

Through its operation of the majority of US ground-based solar facilities and its ongoing synoptic programs, NSO is clearly important to the solar community. In turn, NSO must closely work with the solar community and provide leadership to strengthen solar research, renew solar facilities and to develop the next generation of solar instrumentation. Some past examples of NSO meeting this responsibility include development of GONG, solar adaptive optics, infrared observing capabilities in collaboration with NOAO, NASA and the University of Hawaii, development of a solar dual image motion monitor with the University of Chicago, participation in the development and upgrades of the Advanced Stokes Polarimeter with the High Altitude Observatory (HAO), and development of the Zürich Imaging Polarimeter (ZIMPOL) with ETH- Zürich. Table C-1 lists several joint projects and development efforts.

NSO sponsored several community workshops and forged an alliance of 22 institutions to develop a proposal for the design of the Advanced Technology Solar Telescope (ATST) and its instrumentation. NSO will continue to work closely with this group in leading the successful completion of the design and planning for construction of the telescope. An ATST Science Working Group has developed the detailed science requirements for the telescope.

<b>Table C-1. Joint Development Efforts</b>	
<b><i>Telescope/Instrument/Project</i></b>	<b><i>Collaborators</i></b>
Advanced Technology Solar Telescope	HAO, U. Hawaii, U. Chicago, NJIT, Montana State U., Princeton, Harvard/Smithsonian, UC-San Diego, UCLA, U. Colorado, NASA/GSFC, NASA/MSFC, Caltech, Michigan State U., U. Rochester, Stanford U., Lockheed-Martin, Southwest Research Institute, Colorado Research Associates, Cal State Northridge, Air Force Research Laboratory (AFRL)
Adaptive Optics	NJIT, Kiepenheuer Institute, AFRL
Diffraction-Limited Spectro-Polarimeter & Spectro-Polarimeter for IR & Optical Regions	HAO
Virtual Solar Observatory	NASA, Stanford U., Montana State U.
NSO Array Camera	NOAO, Cal State Northridge
Synoptic Solar Measurements	USAF, NASA
Fourier Transform Spectrometer	NASA, U. Wisconsin
Integral Field Unit	Penn State U.

NSO established collaborations with the New Jersey Institute of Technology (NJIT), the Kiepenheuer Institute of Solar Physics (KIS), and the Air Force Research Laboratory to successfully obtain resources from the NSF/MRI program for the development of the high-order solar adaptive optics (AO) system. NSO personnel have been working closely with personnel from NJIT to design, build and test the system, which is essential to ATST development.

NSO and HAO have renewed their partnership to develop the next generation of the Advanced Stokes Polarimeter, the Diffraction-Limited Spectro-Polarimeter (DLSP) and the Spectro-Polarimeter for Infrared and Optical Regions (SPINOR). The DLSP will take advantage of the diffraction-limited images delivered by

adaptive optics and SPINOR will augment capabilities for research spectropolarimetry at the Dunn Solar Telescope.

SOLIS is being developed by NSO to provide high-quality synoptic data to the community. While an NSO initiative, the SOLIS enterprise was highly endorsed by the solar community in both the NRC Parker Report and the Decadal Survey. NSO will assume leadership in forging alliances to expand SOLIS to a three-network system.

NSO leads a large consortium of scientists on the GONG program and has taken on the responsibility of upgrading the GONG network to provide data for the recently emerging field of local helioseismology for probing the solar interior near the surface.

NSO and NOAO share expertise in the development, acquisition and implementation of IR technologies for imaging and spectroscopic applications in astrophysics. The NSO received a  $1024 \times 1024$  ALADDIN array at no cost from the NOAO development program to initiate a new and powerful IR camera system for solar astrophysics. In the early stages of development, NSO and NOAO staff consulted on the technical aspects of this project. Those interactions will resume once the instrument is delivered and acceptance tests begin. Such interactions serve as an example of the inter-Center cooperation, which AURA management fosters.

Finally, NSO, in coordination with its ATST partners, is undertaking a vigorous expansion of solar outreach programs.

## **Operational Partnerships**

NSO's strategic planning embraces the interdisciplinary nature and dual objectives of solar physics: that it is both basic science and applied research. Likewise, NSO's relationships to its users reflect the diversity and richness of the communities they represent—solar and stellar astronomy, space plasma physics, solar-terrestrial relationships, space weather prediction, terrestrial atmospheric chemistry, and more.

NSO's mission to serve these communities, while remaining a scientific leader in solar physics, is critical because it is unique. NSO's solar telescopes are the largest and best instrumented in the world; NSO is unquestionably the dominant provider of ground-based solar observational facilities in the United States.

In accepting this significant responsibility, NSO has forged partnerships that strengthen its scientific and observational programs while satisfying partner needs. These partnerships range from long-term “residential” relationships to the cooperative development of individual instruments. In return, funding and co-located personnel from the partners permits NSO to operate a wider variety of instruments for longer periods that it could otherwise afford.

### ***Air Force***

The Air Force Research Laboratory (AFRL) maintains a staff of five to six scientists at NSO/Sacramento Peak. The AFRL program emphasizes studies of solar activity and activity prediction techniques, advanced imaging, and development of new instrumentation. Air Force funding is provided for several synoptic programs and for the general operation of Sacramento Peak. AFRL ongoing programs include synoptic observation of coronal emission lines using the Evans Solar Facility coronagraph, observations of chromospheric heating and variability, studies of the Sun as a star, imaging of solar mass ejections with the Solar Mass Ejection Imager (SMEI), and use of the new ISOON flare patrol data to study prominence evolution and filament eruptions.

The Air Force program has provided funding for adaptive optics, development of narrowband filters, procurement of infrared cameras, and CCD cameras. The AF staff collaborates closely with NSO scientists on both science and instrument development. The Air Force Office of Scientific Research has expressed interest in the ATST and plans to maintain the Air Force solar research presence as NSO transitions to ATST operations.

**Table C-2. Current NSO Partnerships**

<i><b>Partner</b></i>	<i><b>Program</b></i>
Air Force Research Laboratory	Solar Activity Research at NSO/SP; Telescope Operations; Adaptive Optics; Instrument Development; 6 Scientists Stationed at NSO/SP; Daily Coronal Emission Line Measurements; Provides Operational funding: \$400K-Base and Various Amounts for Instrument Development.
NASA	<p>KPVT Operations (final year); Collaborative Science; SOLIS Development; Instrumentation; 1 Permanent Scientist; 1 Research Fellow at NSO/T; Operational Funding: \$32K for Telescope Operations and Various Amounts for Instrumentation.</p> <p>GONG: Support for 3 Scientists (2.65 FTE) from Sun-Earth Connection Guest Investigator Program; Support for 1 Scientist from Living With a Star Program.</p> <p>SOLIS: Support for 1 Scientist (.75 FTE), 1 Postdoc, 1 Observing Asst., and 1 Instrument Specialist (.50 FTE) from Living With a Star Program.</p> <p>McMath-Pierce: Support for Operation of the FTS; Upper Atmospheric Research.</p>
NSF Chemistry	FTS Facility Support, including 1 Instrument Scientist

## NASA

The Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center (GSFC) has cooperated with NSO for over twenty years in operating and developing the Kitt Peak Vacuum Telescope (KPVT) and is extending this effort to SOLIS. GSFC currently has one civil service scientist stationed in Tucson and, through competitive proposals, funds a second scientist and provides additional funding for KPVT operations. NASA has obtained daily full-disk magnetograms and spectroheliograms for mission planning and scientific analysis plus rapid access to the KPVT for special observations. Many KPVT instrumentation projects have been partially funded through this cooperation including the current NSO/NASA spectro-magnetograph, and instrumentation funds have been used to procure components of the data and polarization modulation systems for SOLIS. Current research conducted by the NASA-supported staff focuses on use of the He I 1083 nm line as a diagnostic tool for solar mass loss and the association of magnetic features with solar irradiance variation.

The GONG program currently receives funds from NASA's Sun-Earth Connection Guest Investigator Program to support 2.65 scientists and from the Living With a Star (LWS) Program to support one scientist. Recently, the LWS Program awarded a proposal to use the SOLIS vector spectromagnetograph to characterize the solar vector magnetic field with emphasis on applications of potential use for space weather forecasting (supports a full-time postdoc, a .75 FTE scientist, and one full-time observing assistant). Another proposal for

translating and correcting KPVT data (supports a half-time instrument specialist) has also been funded by the LWS Program.

NASA also provides funding for operating, maintaining, and developing the Fourier Transform Spectrometer at the McMath-Pierce facility in support of upper atmospheric research conducted by scientists at several NASA centers (JPL, Langley, GSFC, and Ames). One full-time instrument scientist is supported through this task.

### ***NSF Chemistry***

The purpose of the laboratory program funded by the NSF Chemistry Division is to provide access to the high-resolution Fourier Transform Spectrometer facility at the NSO McMath-Pierce for visiting investigators not directly associated with astronomical research, but rather to the areas of atomic and molecular laboratory spectroscopy.

Part of the research funded by this program is indirectly involved with astrophysical research in that it provides important spectroscopic information, such as line assignments and atomic or molecular constants, derived from spectra of atoms or molecules generated under laboratory conditions. This information assists astronomers in establishing the presence of these species in sunspots, stellar atmospheres, and interstellar clouds.

The largest portion of the research is primarily devoted to problems of physical and chemical interests. For example, an ongoing study by Lawler at the University of Wisconsin involves measuring the branching ratios of lanthanide atomic spectra with the objective of developing high-intensity and efficient lighting sources for commercial and industrial applications. Much of the emission work done on the spectra of transition-metal diatomics (oxides, nitrides, fluorides, and chlorides) with this instrument by Bernath (University of Waterloo), Davis (UC-Berkeley), and O'Brien (Southern Illinois University, Edwardsville) has led to a wealth of new information about the electronic structure of these molecules, which not only benefits astronomy, but is also of equal importance to the area of high-temperature chemistry.

It should be noted that the combination of the high-resolution FTS coupled to a large solar telescope with infrared capability makes this facility ideally suited for research involving the chemistry of the atmosphere of the Earth.

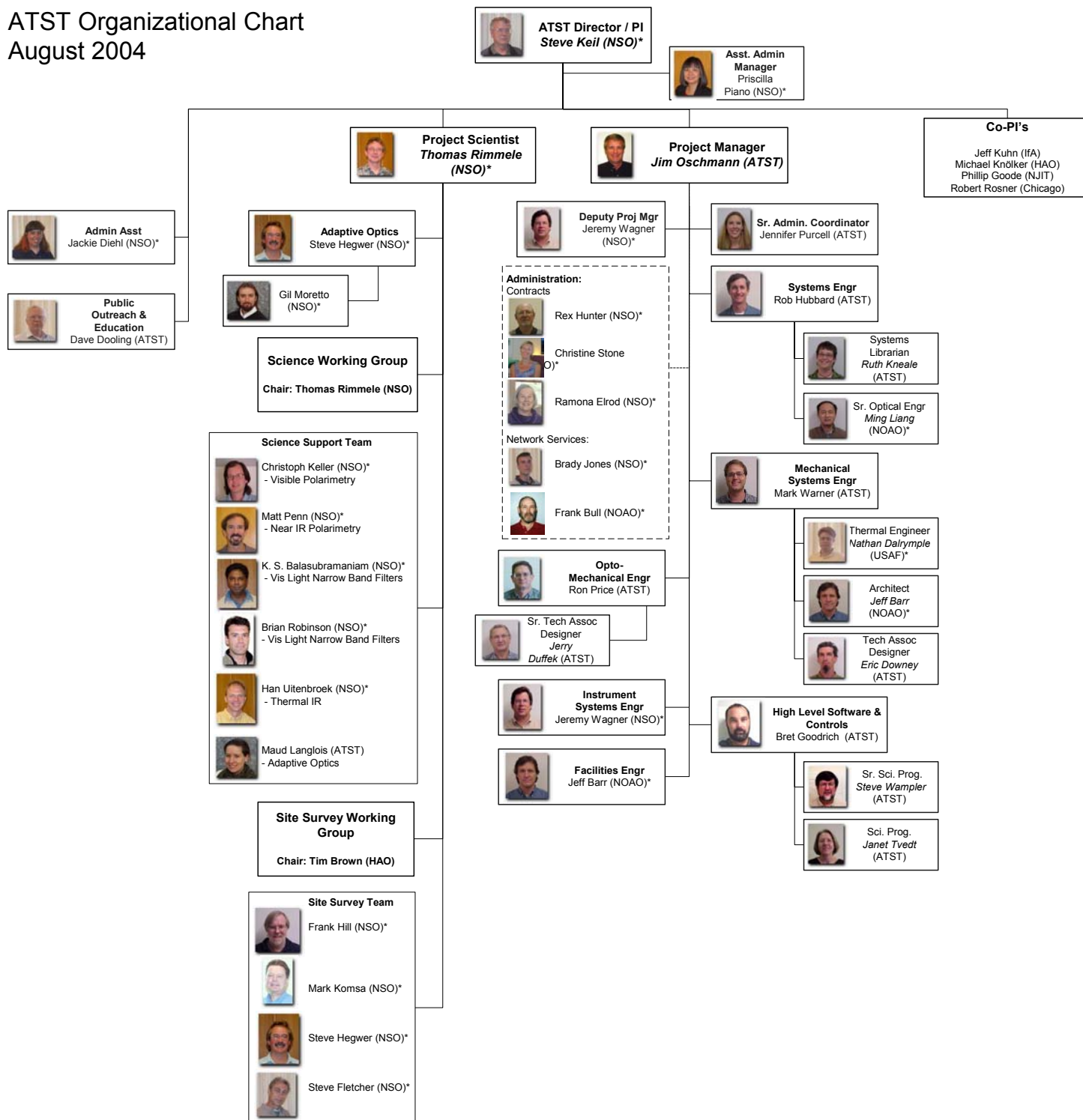
**APPENDIX D****NSO MANAGEMENT ROSTER**

Stephen L. Keil	NSO Director; ATST Project Director
Mark S. Giampapa	NSO Deputy Director; SOLIS Principal Investigator
Thomas R. Rimmele	ATST Project Scientist; Dunn Solar Telescope Program Scientist
John W. Harvey	SOLIS Project Scientist
Jeremy J. Wagner	SOLIS Project Manager; Interim ATST Project Manager
Stephen Hegwer	Project and Telescope Manager, Sacramento Peak
John W. Leibacher	GONG Program Scientist
Patricia Eliason	GONG Program Manager
Rex Hunter	Site Manager, Sacramento Peak

***NOAO Managers Who Provide NSO Program Support***

Karen Wilson	Associate Director for Administration and Facilities
James Tracy	Controller
Larry Daggert	Manager, Engineering and Technical Services (ETS)
Steve Grandi	Manager, Central Computer Services (CCS)
Sandra Abbey	Human Resources Manager
John Dunlop	Manager, Central Facilities Operations & Kitt Peak Facilities
Doug Isbell	Manager, Public Affairs and Educational Outreach

## APPENDIX E

ATST Organizational Chart  
August 2004

\* supports ATST project part-time

**APPENDIX F**  
**SCIENTIFIC STAFF PERSONNEL STATISTICS**

<b>Hired</b>			
<i>Date</i>	<i>Name</i>	<i>Position</i>	<i>Site</i>
06/22/04	Maud Langlois	Research Associate	NSO/SP
08/19/04	Sushanta C. Tripathy	Assistant Scientist	NSO/T
<b>Completed Employment</b>			
<b>Changed Status</b>			
10/01/03	Carl J. Henney	Promotion to Associate Scientist	NSO/T
02/23/04	Irene González Hernández	Promotion to Assistant Scientist	NSO/T
04/01/04	Michael Dulick	Promotion to Associate Scientist	NSO/T
<b>Visitors (one month or longer)</b>			
01/16/03- 01/15/04	Alessandro Cacciani	University La Sapienza, Italy	NSO/SP
09/01/03- 11/04/03	Isroil Sattarov	Ulugh Beg Astronomical Institute of the Uzbek Academy of Sciences, Uzbekistan	NSO/SP
04/12/04	Sabit Ilyasov	Ulugh Beg Astronomical Institute of the Uzbek Academy of Sciences, Uzbekistan	NSO/T
09/01/04	Sumner Davis	University of California, Berkeley	NSO/T