NATIONAL**SOLAR**OBSERVATORY

TUCSON, ARIZONA • SAC PEAK, NEW MEXICO

From the NSO Director's Office

Steve Keil

It is my pleasure to report steady progress on projects and science capabilities this past quarter at the National Solar Observatory (NSO). The first full-disk magnetogram has been obtained with the SOLIS vector spectromagnetograph (VSM). This first image indicates that the VSM will indeed improve the quality of solar magnetic field measurements. The VSM has been at the GONG farm in Tucson for testing and debugging and will soon be joined there by the full-disk patrol (FDP) instrument. When debugging and cross-calibration are complete, the two instruments, along with the integrated sunlight spectrometer (ISS) and their mounts will be installed at the Kitt Peak Vacuum Telescope (see page 40).

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Adaptive optics (AO) has become a staple to feed both imaging and spectroscopic instruments at the Dunn Solar Telescope (DST). A number of exciting instruments are being fed by the new high-order AO system (76 degrees of freedom) and the older, low-order system (24 degrees of freedom). The low-order AO system, which we plan to upgrade in the near future, presently feeds the narrowband tunable filters and the horizontal spectrograph (which includes the Advanced Stokes Polarimeter). Recently, scientists from the Arcetri Observatory installed their Italian BI-dimensional Spectrometer (IBIS) at the DST. IBIS is also fed with the low-order AO-corrected beam. We intend to make the system available to users early next year. The Diffraction-Limited Stokes Polarimeter (DLSP), which is fed by the high-order AO system, is nearing the end of its Phase II development.

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On the Advanced Technology Solar Telescope (ATST) front, a miniworkshop to discuss enclosure concepts and instrument efforts was held in May at the High Altitude Observatory, followed by teleconferences to discuss the results of the meeting with the Science Working Group and potential design reviewers (see page 37). Thermal tests of existing vented and unvented domes were conducted to get an idea of how venting would help during the day. Installation of sky brightness monitors at all of the ATST test sites was also completed. Several talks presenting updates on AO, instrumentation, and ATST efforts were presented at the August SPIE meeting in San Diego.

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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 Klaus Hartkorn did extensive work at NSO under the supervision of Thomas Rimmele, receiving his PhD this May with a thesis on high-resolution studies with the DST and AO. Thomas is also advising a second PhD student jointly sponsored by NSO and NJIT, Jose Marino, whose thesis is on 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. Dave Byers from Utah State University is working on a PhD, supervised by K. S. Balasubramaniam, assessing methods of predicting solar activity based on surface flows. Michael Eydenberg, also supervised by Balasubramaniam, just completed his Master's thesis at the New Mexico Institute of Mining and Technology on the inversion of stokes profiles using principal component analysis. In addition to all of this, NSO has created an ATST graduate student fellowship to support work on narrowband, tunable filter designs for the ATST using Fabry-Perot filters. The candidate for this fellowship, Laura Allaire, a graduate student at the University of Rochester, spent the summer at Sunspot, familiarizing herself with various design aspects of the current filters.

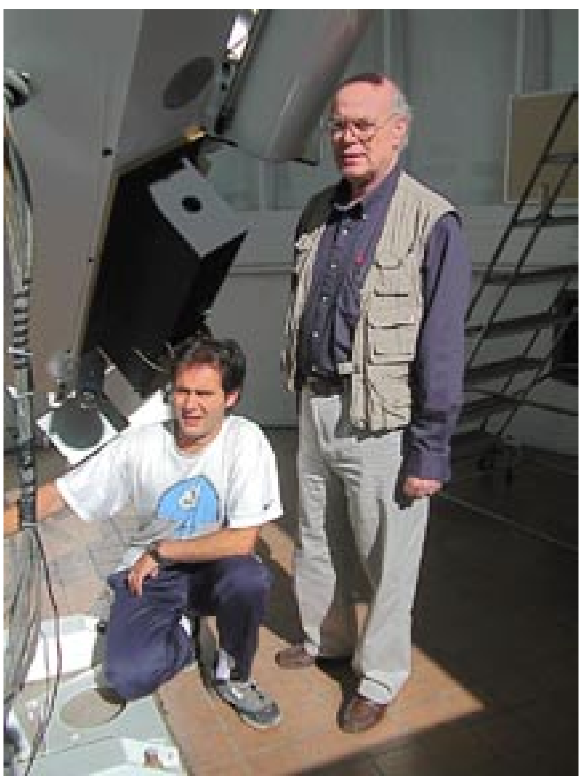
NSO also had another busy and successful summer with six undergraduates (three at each site) and three high school teachers as part of the 2003 Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) programs. NSO fosters close interaction among our undergraduate and graduate students, teachers, and the scientific and technical staff. In addition to research projects conducted at the respective sites, the teachers and students (including the KPNO summer students) exchanged site visits that included the traditional stopovers at the White Sands National Monument and the Very Large Array in Socorro, NM. Information about individual summer projects is available at the NSO Educational Outreach Web site (*eo.nso.edu*).

Magneto-Optical Filter System Achieves First Light

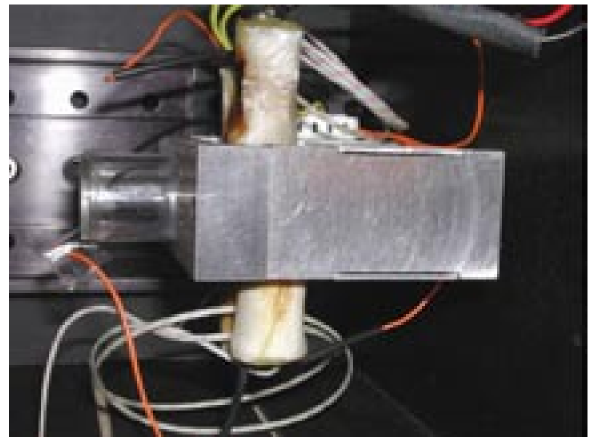
Dick Altrock (Air Force Research Lab) & Dave Dooling

Alessandro Cacciani of the University La Sapienza of Rome, Italy, has achieved "first light" at Sacramento Peak with his magneto-optical filter (MOF) system designed to image the Sun in sodium-D lines. Cacciani is a National Research Council Senior Associate, funded by the US Air Force, working at Sacramento Peak during 2003. He is assisted this summer by Ludovico Cesario, a graduate student from La Sapienza.

Sodium emits and absorbs yellow light at two narrowly separated lines at 588.995 and 589.592 nanometers. Also called the Fraunhofer D lines in the solar spectrum, they are formed in the lower chromosphere and are among the strongest in the solar spectrum. Cacciani is working to measure velocities and magnetic fields in the solar atmosphere. These can allow detailed studies of the buildup of energy in active regions that lead to flares or coronal mass ejections.



Alessandro Cacciani (standing), and Ludovico Cesario, both of University La Sapienza, with the MOF system (black box) mounted on the spar of the Hilltop Dome at Sac Peak.



Close-up view of the MOF filter unit mounted at the Hilltop Dome. The quartz container for the sodium vapor protrudes at left center from the magnet housing.

The MOF is a very narrowband filter that uses sodium vapor as a depolarizing element between two crossed polarizing filters. It takes advantage of the Zeeman and related effects to achieve stable and efficient transmission bands. The selection of the band's shape depends on the magnetic field imposed on the vapor and on its optical depth.

"At Sac Peak we have installed the first element of a chain that will be able to produce Doppler and magnetic maps of the Sun," Cacciani explains. "That is, we have at the moment a single sodium MOF to provide images on the core of the two D lines. With this first element we will study the linear polarization behavior in the center of the two D lines separately and in different locations on the Sun."

When the system is ready, the MOF will detect Doppler and magnetic signals simultaneously. Cacciani plans to use the MOF with the Dunn Solar Telescope and its low-order adaptive optics system to study the covariance of magnetic and Doppler signals. This would provide clear evidence of Alfven wave emissions from sunspots. He also plans a second system operating in the potassium line at 770 nanometers. This will capture data from the photosphere. This two-level detector was first used at the South Pole during the last Antarctic observing campaign in collaboration with former NSO staff member, Stuart Jefferies, who is now at the Maui Research and Technology Center.

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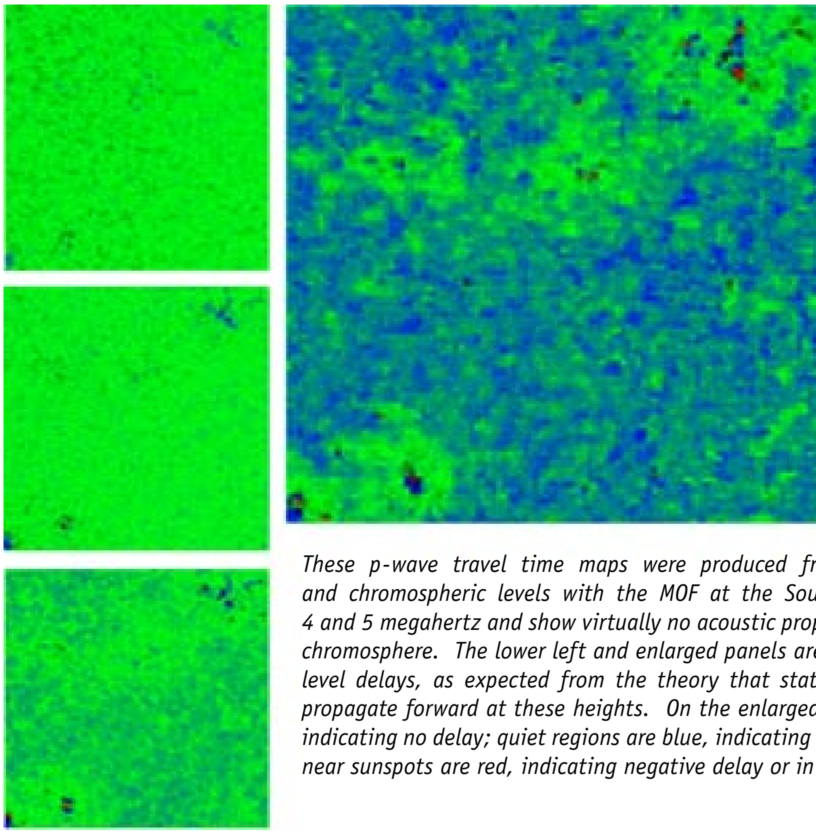
Magneto-Optical Filter System continued



These p-wave travel time maps were produced from Dopplergrams taken at photospheric and chromospheric levels with the MOF at the South Pole. The upper left panels refer to 4 and 5 megahertz and show virtually no acoustic propagation from the photosphere into the low chromosphere. The lower left and enlarged panels are at 6 and 7 megahertz and show different level delays, as expected from the theory that states that only high frequency p-waves can propagate forward at these heights. On the enlarged panel above, magnetic regions are green, indicating no delay; quiet regions are blue, indicating positive delay or escaping waves; and areas near sunspots are red, indicating negative delay or in-going waves.

ATST Design Progress

Jim Oschmann & the ATST Team

The highest priority task for the Advanced Technology Solar Telescope (ATST) project—the enclosure trade study—was completed in June following several meetings and debate. The result was a decision to pursue the "hybrid" design, while taking into account the technical issues raised by the reviewers. Other recent activities include the Conceptual Design Review (CoDR) that was held in late August, completion of the optical fabrication studies, preparation of Request for Proposals (RFPs) to bring outside contractor experience onboard, and organization of the construction-phase proposal efforts. The enclosure trades and several other aspects of our recent work are summarized here.

Enclosure Trades

To support the selection effort for the general type of enclosure that the project would pursue, a small workshop was held in Boulder, CO, with the ATST co-principal investigators and some of the project instrument groups. The presentations from this meeting were posted on the Web, and follow-up discussions with members of the CoDR committee and the Science Working Group were also held. The result of these meetings and our internal discussions

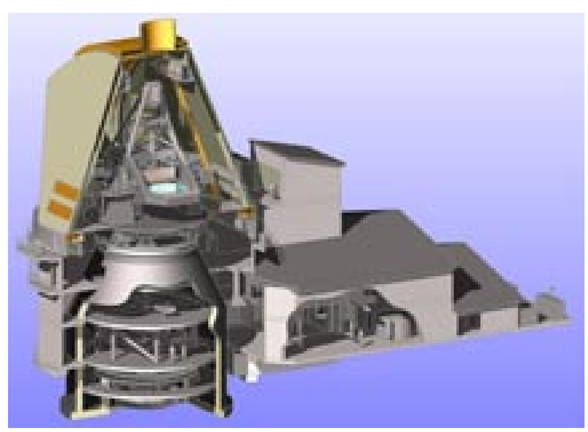


Figure 1. ATST enclosure concept.

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ATST Design Progress continued

was a decision to pursue the “hybrid” ventilated dome. This enclosure concept is shown in figure 1.

While the decision to pursue this design was largely supported by these meetings, concerns—based on experience about having any type of enclosure—were expressed. The project takes these concerns seriously and will address them as we move forward with the hybrid concept. Examples of the challenges with this design include the ability to cool the exterior skin of the structure and to maximize the amount of passive ventilation that can be achieved. Cooling plans are being worked in more detail and studies are underway with potential suppliers of domes. In addition, an outside study has been initiated for a computational fluid dynamic (CFD) analysis to better assess the passive ventilation properties of the dome. The first-cut results of this CFD modeling were presented at the August CoDR.

Thermal Considerations

Thomas Rimmele and Nathan Dalrymple completed measurements of dome seeing at Big Bear this summer with the help of the staff at Big Bear Solar Observatory. Although the data are still being analyzed, some first-order conclusions were obtained. The largest effect observed was a degradation in seeing with an increased temperature difference between the ambient air and the air within the dome. With respect to the dome temperature differences, the measurements resulted in effects consistent with the expectations based upon Nathan’s modeling of the Big Bear dome. We are also looking at the wavefront sensor (WFS) measurements to get the spatial distribution of the local seeing that was generated. These measurements will be used to help assess error budget estimates for the adaptive optics use of ATST. This is a valuable addition to our base of modeling and testing from dome temperature and lab seeing tests.

Telescope and Facility Design

The three-dimensional models have been translated into finite-element (FE) models for the telescope, pier, coudé lab, and interface to the ground, using placeholder soil properties. Jeff Barr is gathering the correct soil properties for the six ATST candidate sites to update the model. With line-of-sight models incorporated in the FE models, analyses can provide an indication of the magnitude of windshake, as well as the amount of protection required for a given level of performance. This will help identify critical aspects of the design, and focus our optimization efforts. The current design, situated on loose soil, is dominated by global telescope and pier rocking and translation. This same soil-dominated performance effect has been witnessed on various existing telescopes and is not a surprise. It is also very difficult to improve upon, so the range of performance will vary at the different sites. The protection provided by the enclosure and the ability to adjust wind effects on the telescope structure will affect how we operate in various conditions at the different sites. It will be equally important that the foundations of the enclosure and any other surrounding buildings are sufficiently isolated from the ATST pier. This will minimize the transfer of vibrational energy from wind striking these other structures and propagating through the soil into the pier. This has been a consideration in most recently-built large telescopes. The effect of vibrational energy is amplified as one tries to increase the telescope height above the surrounding terrain.

The static gravity deformations of the telescope are being fed into alignment and active optics studies. This will provide initial dynamic range requirements for the active primary and secondary, and will determine if further active control of the feed optics or improvements in the structural design are needed.

Optics

The primary mirror fabrication studies were completed in May. All vendors were confident that their proposed methods for manufacturing and testing would lead to a successful primary mirror effort. The methods and risks varied, but no significant problems were identified with our baseline mirror configuration. Some vendors recommended further work to quantify some design aspects in more detail. The estimates of time were largely consistent with our proposed schedule, though some advance work may be required. Cost estimates covered a large range, depending upon the level of development required and the experience of the vendor. We are assessing how this information will be incorporated into our overall plans.

Ron Price has been working on requirements for the optical assemblies, and we now have contractors on board to help review these requirements and approaches. He and Nathan Dalrymple are also extending the thermal control consideration for the optical assemblies.

Instrumentation

The optics that feed the coudé labs have evolved to include a smaller collimated beam, as well as configurable feeds that allow for multiple, simultaneous instrument use. A beam reducer relays the 200-millimeter pupil into each lab at a 100-millimeter size. Ming Liang is investigating various transmitting optics that can provide changeable plate scales, thereby providing telecentric, flat focal planes to feed the spectrographs. The High altitude Observatory (HAO) and the University of Hawaii Institute for Astronomy (IfA) are converging on designs for the visible and infrared (IR) spectropolarimeters. We also intend to explore reflecting-type options, but wish to have at least one example of a multiple instrument arrangement for the CoDR.

continued

ATST Design Progress continued

The interfacing option mentioned above is concentrating on *f*/20 and *f*/40 options to feed fixed instrumentation, allowing for two plate scales. The new interface option allows for insertion of dedicated beam splitters, allowing flexibility of instrument location. In addition to the work at HAO and IfA, Allen Gary (NASA/MSFC), K. S. Balasubramaniam and Gil Moretto (NSO), and Thomas Kentischer and Michael Sigwarth (Kiepenheuer Institute) have been making progress on a visible tunable filter system design. The team has also been helped with the addition of Laura Allaire (University of Rochester), a graduate student under the supervision of R. Boyd and J. Thomas. The initial optical design of the tunable visible filter system comprises three cascaded Fabry-Perot etalons, 200 millimeters in diameter in a *f*/300 telecentric configuration. Additional studies of the proposed filter system will include the optimization of spatial and spectral ghosts, surface quality and mounting of large etalons, polarized ray-tracing, and thermal stability and drift.

Under the leadership of Haimin Wang, the New Jersey Institute of Technology team is investigating the near-IR tunable filter system. In its present concept, this system will be a combination of a tunable Lyot-type filter and a Fabry Perot. Don Jennings (NASA/GSFC) is leading an effort to develop a concept for a far-IR spectrograph.

Controls and Software

Bret Goodrich and Steve Wampler are continuing to evaluate methods of implementing a common infrastructure for the ATST control and software communications environment. The choice of candidates for communications is narrowing to 1) adapting a form of the Atacama Large Millimeter Array (ALMA) control system; and 2) a Networking Delivery Data Service (NDDS)-type system from Real-Time Innovations (RTI). The goal is to have an easy-to-implement, but flexible, system that can be interfaced to a variety of other software and hardware platforms, including LabVIEW and EPICS.

Systems Engineering

Rob Hubbard has completed the main top-down system-level error budgets. His efforts have focused on the three highest priority budgets, all of which bear on delivered image quality: 1) diffraction-limited performance in the visible spectrum with closed-loop active and adaptive optics; 2) best-case seeing-limited performance in the near-IR using closed-loop active optics only; and 3) coronal imaging where no wavefront feedback is available. We are now adding initial bottom-up estimates where they are straightforward, as well as some statistical analyses for things such as windshake and seeing effects. The top-down error budgets are available on our Web site. Analyses performed to date were presented at the CoDR in August.

Sensitivity and tolerance analyses of major optical and mechanical interfaces have been initiated. This work examines interactions between the mechanical design, optics, and error budget constraints for the various modes of operation. An initial optical-alignment plan is also being discussed, and will be documented soon.

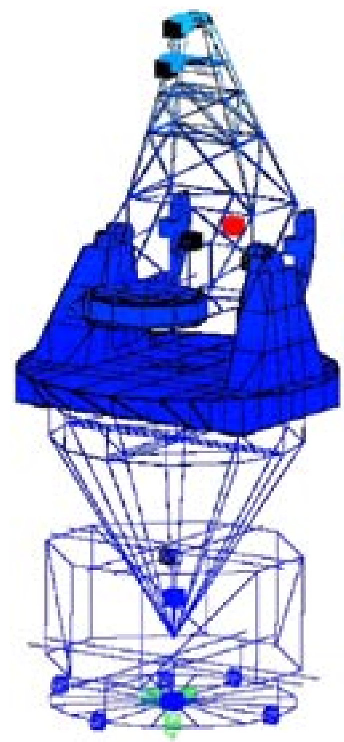

Figure 2. Finite-element model of the telescope system.

Photon Engineering is working to complete some diffractive-based stray light analysis. They have completed most of the geometrical analysis, and their interim report is available on the Web. Their analysis supports the latest work from the University of California at San Diego, and leads us to conclude that stray light is not a large driver of enclosure concept decisions.

Upcoming Milestones

The project's upcoming major milestones include site selection in October, completion of the construction phase proposal at the end of this calendar year, and moving into the preliminary design stage at the beginning of the new year. Keep an eye on our Web site for the latest developments. It promises to be a very busy fall/winter period.

SOLIS

Jack Harvey & the SOLIS Team

This is an exciting time for the SOLIS project. The major instrument, the 50-centimeter aperture vector spectromagnetograph (VSM) has frequently been pointed to the Sun since late May. This was very tentative at first, as heating of the optics by the *f*/6 Ritchey-Chretien telescope was a natural concern. The active cooling system does its job well, and even after all-day operation and outside temperatures exceeding 110°F, the optics maintain temperatures as expected. The spectrograph entrance slit receives flux of about 300 times normal sunlight and it remains unfazed. Presently installed at the GONG testing site at the Campus Agricultural Center of the University of Arizona, the SOLIS mount and VSM look somewhat strange in such a flat, farm environment.

As with any new major instrument, there are many commissioning issues that have to be addressed. One significant surprise was an inability to rotate the grating as far as needed to reach all of the spectrum lines to be observed. This problem was addressed by duct-taping a plastic sheet "bubble" around the base of the VSM, which was pressurized with HEPA-filtered, air-conditioned air, allowing the back of the spectrograph to be opened by brave "bubble-men," who diagnosed and fixed the problem. As expected, there is flexure of the optical system during the course of the day as the gravity vector changes. There are servo systems built into the grating cell to compensate for this flexure, and tests are ongoing. The instrument was also opened to install light traps near the telescope focal plane to reduce scattered light in the spectrograph.

An instrumental surprise was etalon fringing at 1083 nanometers within the silicon image-sensing layer of the hybrid silicon-on-CMOS interim camera detectors. This layer is more than 0.1 millimeters thick, and we expected absorption to minimize any etalon effects. This was not the case, and the team is modeling the fringes following ideas in a paper by Malumuth et al. (*PASP* **115**, 218, 2003). There are no fringes at the other VSM wavelengths.

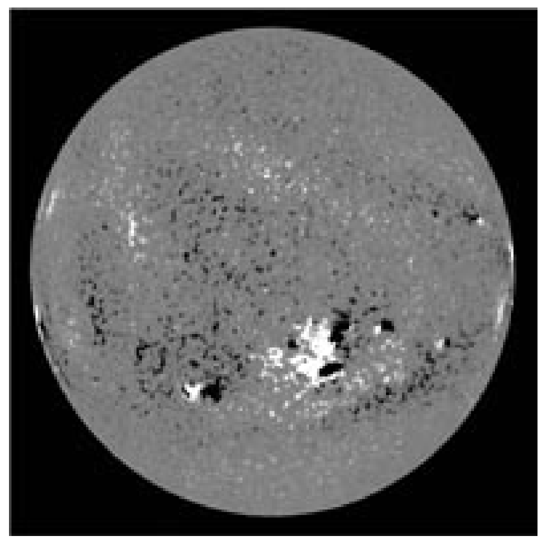

Figure 1. The first full-disk magnetogram obtained with the VSM (8 August 2003). The display saturates at ±150 gauss and the solar image was scanned in 11 minutes.

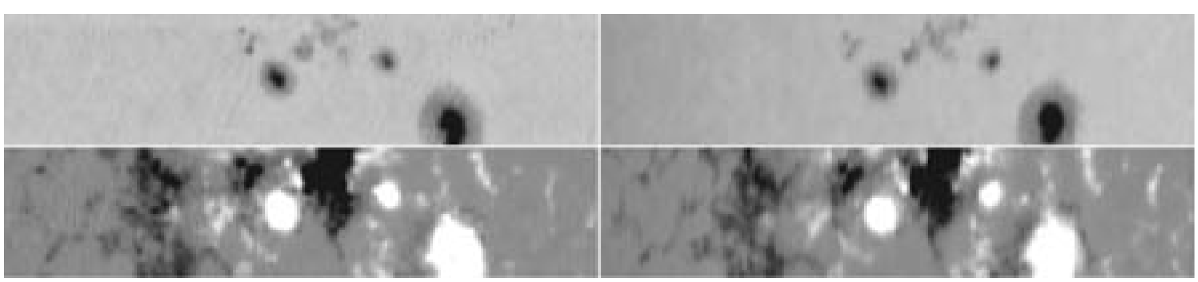

Figure 2. A solar active region observed in poor seeing on 1 July 2003 with the new SOLIS vector spectromagnetograph (left) and the old spectromagnetograph (right). The area shown is about 110x500 arcsec. The top row is intensity and the lower row is the line-of-sight component of the magnetic field. The VSM observation is a crude manual scan consisting of only 20 1-arcsec–high lines across the solar disk, spaced every 5 arcsec and interpolated to fill in the gaps. Single exposures of the polarized solar spectrum were reduced using a primitive algorithm. The noise in this observation (~5 gauss) should be reduced by a factor of ~10 in regular observations.

continued

SOLIS continued

As of this writing, we have not completed a full-disk scan with all systems properly adjusted. A variety of software and hardware issues have prevented us from reaching that major milestone.

Figure 1 shows the first full-disk magnetogram obtained with the VSM. This was obtained with the telescope in less than best focus and without the benefit of a flat-field calibration. The geometry is not fully corrected and image tracking was unguided. In spite of these limitations, the noise level is low, and this first image indicates that the VSM will provide a significant improvement in the quality of solar magnetic field measurements. Figure 2 shows a crude, uncalibrated hint of the potential of the VSM.

It is a high priority to compare VSM measurements with simultaneous ones using the old spectromagnetograph. This will allow the existing 29-year database to be connected to forthcoming SOLIS data. Since the old and new instruments use different spectrum lines, some differences are expected (e.g., the dark ring around the large sunspot in figure 2). Once a month's worth of comparison observations are available, the old instrument will be shut down and the Kitt Peak Vacuum Telescope building will be made ready for installation of SOLIS. The detailed schedule depends on the availability of KPNO mountain staff.

Work on the remaining SOLIS instruments is slow because most people are working on the VSM. The full-disk patrol (FDP) instrument was moved from its basement assembly area to the lab formerly occupied by the VSM. This allowed sunlight to be fed into the FDP using a rooftop heliostat. Good images have been observed using the 1083-nanometer He I and 656.3-nanometer H I lines. When the guider is installed and used to drive the FDP active mirror to stabilize the badly jiggling solar image (due to building vibration of the heliostat), much better images will be obtained.

NASA Sun-Climate Task Group

Jack Eddy

Exploring the nature and extent of the impacts of solar variability on regional and global climate is a targeted research element in NASA's Living with a Star (LWS) Program. The National Solar Observatory (NSO) has been involved in the solar and stellar physics aspects of that endeavor from the inception of the program, initially through contributions to a NASA workshop and a subsequent report on Sun-Climate Connections held in Tucson in the spring of 2000, and through on-going research that addresses both solar and stellar variability.

This year, I joined the NSO staff as a visiting scientist with grant support to assist NASA in refining the focus and definition of the Sun-Climate portion of the LWS Program, in part through service on the NASA Targeted Research and Technology Task Group led by Jack Gosling (Los Alamos National Laboratory). I also established and now chair an interdisciplinary Sun-Climate Task Group with representation from solar physics, atmospheric physics and chemistry, climatology, paleoclimatology, and physical oceanography to examine needs and priorities in the context of the overall climate question. Other members are Gerard Bond (Lamont Doherty Geophysical Observatory), Ray Bradley (University of Massachusetts), Wally Broecker (Lamont Doherty Geophysical Observatory), Lennard Fisk (University of Michigan), Rolando Garcia (National Center for Atmospheric Research), Charles Jackman (NASA Goddard Space Flight Center), Judith Lean (Naval Research Laboratory), Gerry North (Texas A&M University), George Reid (University of Colorado), Michael Schlesinger (University of Illinois), Steve Schneider (Stanford University), George Withbroe (George Mason University), Michael Prather (University of California at Irvine), and David Rind (NASA Goddard Institute for Space Studies). Eleven of the fifteen members of the group met in Tucson in late May with four representatives from NASA Headquarters and NASA Goddard Space Flight Center (Dick Fisher, Lika Guhathakurta, Chris St. Cyr, and Don Anderson) to discuss and develop elements of a report that will be completed this year.

NASA Sun-Climate Task Group Meets in Tucson. Front row, left to right: Chris St. Cyr, George Reid, Michael Schlesinger, Len Fisk, Michael Prather, Lika Guhathakurta, Charley Jackman. Back row: Dick Fisher, Jack Eddy, Rolando Garcia, Gerard Bond, David Rind, Judith Lean. (Also participating were George Withbroe and Don Anderson.)