Astrophysical Research Consortium
Apache Point Observatory
Sunspot, New Mexico 88349

This report covers the period from November 1, 1995, to October 31, 1996.

1. CHARTER, AFFILIATE INSTITUTIONS, AND PERSONNEL

The Astrophysical Research Consortium (ARC) was chartered in 1984 to build and operate observatory facilities at Apache Point for the shared use of consortium astronomers and students. The major projects at the site are the 3.5-meter telescope which has been in full operation since 1994, and the Sloan Digital Sky Survey (SDSS) telescope whose installation is near completion. ARC Consortium members are University of Chicago (UC), Institute for Advanced Study (IAS), Johns Hopkins University (JHU), New Mexico State University (NMSU), Princeton University (PU), University of Washington (UW), and Washington State University (WSU). Additional funding support and contributing institutional partnerships for the SDSS come from the Alfred P. Sloan Foundation, the Fermi National Accelerator Laboratory (FNAL), a group of Japanese astronomers (JPG), the US Naval Observatory (USNO), and the National Science Foundation (NSF).

Chairperson of the ARC Board of Governors is T. Heckman (JHU, replacing B. Margon). D. York (UC) is Observatory Director and Director of the SDSS. E. Turner (PU) is Associate Director for the 3.5-meter telescope, and C. Stubbs (UW) is 3.5-meter Telescope Scientist. R. Kron (UC) is Survey Director for the SDSS, J. Pier (USNO) is SDSS Project Manager (replacing T. Dombeck), and J. Gunn (PU) is SDSS Project Scientist. J. Peoples (FNAL) is chair of the SDSS Advisory Council, and A. Szalay (JHU) heads the SDSS Scientific Advisory Committee.

NMSU operates the observatory under contract to ARC. K. Anderson is Site Director, B. Gillespie is Site Operations Manager, M. Klaene is Deputy Site Manager and Observatory Engineer, J. Fowler is Observatory Computer System Manager, D. Long and K. Gloria are Observing Specialists, and G. Van Doren is Records Specialist, J. Davis is Telescope Systems Engineer, J. Brinkmann is Scientific Instruments Engineer, and a third Observing Specialist position has been filled by T. Hoyes (replacing E. Bergeron), M. Reyero is housekeeper, and J. Wagner is grounds maintenance. D. Pacheco and others at the NMSU Las Cruces campus provide administrative support to the site.

2. FACILITIES

APO is located in the Sacramento Mountains at 2800 meters elevation near Sunspot, New Mexico. Observing facilities at APO include a 3.5-meter telescope used for general visible and IR imaging and spectroscopy, the SDSS 2.5-meter survey telescope, a 0.6-meter telescope which is used to calibrate survey photometry, and a 1-meter telescope owned by NMSU. The site also contains operations and support buildings, plus dormitories. Additional temporary housing and workspace were provided this year to accommodate SDSS installation and commissioning activities.

3. 3.5-METER TELESCOPE OPERATIONS HIGHLIGHTS

The 3.5-meter telescope is completing its second year of scientific operation. Useful scientific and engineering observations were taken during 70% of the scheduled observing time, the balance given to inclement weather (25%) and unscheduled downtime (5%). As reported elsewhere, published scientific results based on data taken with the telescope continue to appear in refereed journals.

About two hundred astronomers and students are certified to remotely operate the telescope; remote observing comprises about two-thirds of the observing time. By coupling remote observing and rapid instrument changes (by one person in fifteen minutes), the ability to conduct long-term synoptic programs and to react to last-minute scheduling changes (e.g., targets of opportunity, time swaps, etc.) has been clearly demonstrated. For example, E. Turner and his collaborators at PU and APO have been conducting a synoptic gravitational lens program consisting of half-hour observations every other night, and recently have published results that derive the Hubble constant to a claimed accuracy of 10%. An on-line preprint of this paper can be found at http://www.astro.princeton.edu/ library/preprints/pop687.ps.gz.

The telescope regularly uses an infrared imager and spectrometer, a medium-resolution visible-light spectrograph and imager, and a large-format drift-scan CCD camera. A high-speed infrared CCD imager, a prototype large-format visible light CCD imager, and an adaptive optics system are also being integrated with the telescope. An echelle spectrograph is scheduled for delivery at APO in the coming year. Technical details for these instruments is available from the world wide web server for APO; the URL is given below. Planning for next-generation facility instrumentation has been initiated. Under an NSF grant, C. Stubbs (UW) is developing a very large mosaic CCD imager for use on the 3.5-meter telescope. His team recently installed a prototype of this camera on the 3.5-meter telescope which is collecting useful science data.

Provided by and for the SDSS project, a prototype all-sky 10-micron scanner is in regular use to monitor and archive sky conditions, producing an image of the sky in the thermal infra-red every few minutes at half-degree resolution. Clouds that are otherwise undetectable by eye are easily seen in the images during dark time. This system has become very popular with the remote and on-site observers.

APO has a dedicated T1 circuit to NMSU enabling remote operation of the 3.5-meter telescope through the Internet, nominally at about 10% of T1 data rates due to Internet bottlenecks. A modem backup system is in place. Because new instruments with larger CCDs will tax the existing network systems, plans for increasing the data bandwidth to the site are in progress. Visits to the site by astronomers are mainly for installation and testing of new instruments, or for training purposes. Observing functions, which include complete telescope control, instrument control, quick-look quality assurance, and data retrieval, are all accomplished by the remote observer.

The telescope is scheduled two months in advance by quarters, with two to three programs frequently scheduled for separate time intervals in the same night. These science programs often involve different instruments, observers, and institutional affiliations. Multiple remote users can also connect simultaneously from several geographical locations, allowing ''eavesdropping'' or even active collaboration at a distance. Routine remote operation of the telescope has been conducted by ARC astronomers from Israel and the United Kingdom, and once via satellite from the South Pole.

More than 20% of this year's scheduled observing time was dedicated to engineering programs, which included characterization of system performance in addition to routine maintenance. Scientists and engineering staff at UW, APO, NMSU, and UC have made substantial progress in the analysis of telescope and instrument performance, and have implemented several repairs to improve performance. Mechanical and electronic upgrades have been made to improve telescope pointing accuracy and stability, yielding improvements in open-loop tracking and blind pointing, image jitter, and the median image size. Pointing model residuals are now consistently 2 arcseconds rms, and blind pointing errors at the instrument detectors are routinely about 5 arcseconds. The mean delivered point spread function has improved by more than 0.2 arcseconds compared to last year, and is typically close to 1 arcsecond fwhm (multi-second exposures with instruments that oversample the image).

Measures of scattered light and instrument throughput have led to plans to modify telescope and instrument baffling systems, and to have all telescope optics realuminized at the end of this year. Enhancements were made to the calibration systems and additional improvements are planned. UW is providing equipment and assistance that has enabled a baseline guiding capability (to soon be upgraded), plus a reflecting slit-jaw imager which sees considerable use on the dual spectrograph. The four main wheels on the telescope enclosure are cracked and being replaced this year.

Monthly telephone meetings of the 3.5-meter Users Committee were held during the year. In August 1996, E. Turner convened a face-to-face meeting of 3.5-meter users in Baltimore. A day-long discussion of observatory projects led to a prioritized list of improvement items which are scheduled to be completed during the next three years. Included are the replacement of the existing secondary mirror (the new blank has been acquired and rough-figured), improvements to the primary mirror support servo, stiffening of optical supports, control of vibration and scattered light, upgrades for calibration systems, and several others improvements which will augment observatory performance and efficiency.

E. Kibblewhite and his group at UC continued testing their adaptive optics instrument on the 3.5-meter telescope, and their guide star laser beacon was installed on the telescope and tested. In one recent test of the adaptive optics system on bright stars, an improvement in image size from 1 arcsecond to less than 0.2 arcsecond was reported before and after correction. A great deal of effort was expended in dialog with the Federal Aviation Agency (FAA) and local military officials in developing protocols for the safe use of the laser guide star system. These dialogs led to a discussion forum at the national level involving several large observatories, the FAA, and the U.S. Air Force. It is hoped that sensible national guidelines for the use of research lasers in astronomy will result from this effort.

As part of APO's support to public outreach programs, the Adler Planetarium in Chicago continued its regular Friday evening program that demonstrates the use of APO's remote observing system to the public. Astronomers at the planetarium control the telescope and instruments during evening twilight and transfer images for public viewing. Also, APO is a partner in the Sunspot Astronomy Center which is planned for completion early next year, located nearby at the National Solar Observatory. To promote regulation and control of outdoor lighting, K. Anderson and B. Gillespie continued interactions with local groups and government officials. State-wide interest in the problem of light pollution has been kindled.

4. SLOAN DIGITAL SKY SURVEY

The engineering of the 2.5-meter SDSS telescope is the responsibility of UW, under the direction of P. Waddell. Engineers C. Hull and W. Siegmund (UW) oversaw and checked the final L&F delivery and installation of the 2.5-meter telescope mechanical structures. The telescope wind baffle fabrication was completed by local machinists under the direction of S. Limmongkol (UW). Working from original concepts and designs, engineers at FNAL and APO are carrying forward the completion of telescope drives, interlocks, and enclosure upgrades with help from FNAL engineers supervised by P. Mantsch and W. Boroski (FNAL), and by M. Klaene and J. Davis (APO). A class 100 clean room is being added with help from G. Pauls (PU) to the main operations building to enable SDSS photometric camera work at the site. All of these and other SDSS projects are being managed by J. Pier (USNO).

The polishing of the 2.5-meter primary and the secondary mirrors was completed this year under the oversight of P. Waddell and E. Mannery (UW). M. Klaene and other APO staff arranged with Kitt Peak National Observatory to have the 2.5-meter primary mirror aluminized at Kitt Peak following its acceptance from the Optical Science Center in Tucson. Both the primary and secondary mirrors were delivered to APO, and will be installed in the telescope shortly. FNAL engineers and J. Davis (APO) made measurements of the 2.5-meter telescope resonance and motion characteristics, and installed and tested storage and handling equipment for the fiber spectrograph plug plates.

T. McKay and A. Smith (University of Michigan) and others from UC, FNAL, PU, and APO worked on completing the commissioning of the SDSS 0.6-meter Monitor Telescope. This telescope is used to establish photometric standards and extinction data for the main survey.

Several staff members from FNAL led by D. Petravick (FNAL), with help from J. Fowler (APO), installed the Data Acquisition system and infrastructure for the on-site data reduction system. The software for reducing the data is currently being collected for commissioning at FNAL, under the auspices of Computing Coordinator S. Kent, B. Yanny, D. Petravick (all FNAL), and G. Knapp and A. Miksin (PU). Simulated data equivalent to 1% of the ultimate Survey has been successfully put through the data reduction pipeline and data base storage system. Scientists from JPG are providing quality assurance by testing the output of the simulations. A. Szalay (JHU) and other staff at JHU are completing a prototype science archive system, including tools for scientists to access terabyte-sized data sets.

J. Gunn and PU engineers; aided by M. Sekiguchi (JPG), C. Rockosi (UC), and J. Brinkmann (APO); are completing the mosaic (54 CCDs) imaging camera. P. Feldman and A. Uomoto (JHU) are completing the two fiber-fed spectrographs, which take up to 640 spectra simultaneously. Lab tests are being finished, and the instruments are expected at APO shortly.

In support of overall SDSS planning, APO hosted several meetings at the site, including reviews of operations planning, Monitor Telescope commissioning, and project installation strategy. Also, a meeting of the SDSS Advisory Council was held in Cloudcroft, NM.

Additional information about Apache Point Observatory and the Sloan Digital Sky Survey is available on the world wide web at http://www.apo.nmsu.edu.

Bruce A. Gillespie