

MMT Observatory

Tucson, Arizona 85721-0065

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This report covers the period 1 October 1999 - 30 September 2000.

1. INTRODUCTION

The MMT Observatory (MMTO) is a department of the University of Arizona and is jointly funded by the Smithsonian Institution (SI) and the University of Arizona (UA). Its primary mission is to operate, maintain, and develop the MMT for use by the scientific staffs of the parent organizations. The MMT is located on the 2600 m summit of Mt. Hopkins, approximately 60 km south of Tucson, Arizona, on the grounds of the F. L. Whipple Observatory (FLWO).

2. PERSONNEL

As of 30 September 2000, the MMTO staff complement of 21 consisted of C. B. Foltz (Director), J. T. Williams (Conversion Project Engineer), S. Criswell (Conversion Project Manager), S. West (Associate Staff Scientist), B. Russ (Administrative Assistant), H. Lester (Business Manager), S. Callahan (Mechanical Engineer), T. Trebisky (Computer Specialist), K. Harrar (Electronic Engineer), C. Heller, J. McAfee, and A. Milone (Telescope Operators), W. Kindred (Instrument Specialist, Sr.), D. Smith (Instrument Specialist), P. Spencer (Electrical Engineer), M. Alegria (Engineer Associate), D. Clark (Electrical Engineer, Sr.), K. Van Horn (Electrical Engineer), P. Garrison (Designer/Drafter), V. Venkatraman and P. Kandalu (Graduate Research Assistants).

3. ASTRONOMICAL RESEARCH

Until its shutdown in early 1998, ninety-four percent of the scheduled time on the MMT was devoted to astronomical research, with the remainder going to telescope and instrument maintenance and improvement. Most astronomical research made use of the MMT facility instruments: MMT spectrograph-blue channel, MMT spectrograph-red channel, and echelle spectrograph.

On the morning of March 2, 1998, the chamber doors closed on the 4.5 m MMT. The telescope was decommissioned in preparation for the installation of the new 6.5 m instrument. Progress on this project is described below.

The MMTO maintains a web site containing documentation on the telescope and instruments, as well as information on the progress of the MMT Conversion Project. It can be accessed at the following URL: <http://sculptor.as.arizona.edu>. (Address comments or queries to cfoltz@as.arizona.edu.)

4. TELESCOPE INSTRUMENT DEVELOPMENT: CONVERSION OF THE MMT TO A SINGLE-PRIMARY 6.5 M TELESCOPE

As a result of the success of spin-casting of mirrors at the Steward Observatory Mirror Laboratory (SOML), the

MMTO and its two parent institutions have replaced the six 1.8 m primary mirrors with a single 6.5 m diameter, f/1.25 paraboloidal borosilicate honeycomb primary mirror. Three secondary mirrors will be available: an f/9 classical Cassegrain to allow the use of existing instrumentation and high-resolution narrow-field imaging, an f/15 classical Cassegrain secondary for use in the infrared and for adaptive optics applications, and an f/5.27 Cassegrain, corrected to f/5.4 with a three-element refractive corrector with atmospheric dispersion compensation to produce a full one-degree field of view. The telescope is installed in the existing MMT building on the existing yoke. This observing period began with the installation of the secondary hub and spiders. A limited amount of testing followed at prime focus.

The need for storage of the large secondary mirrors, their attendant subsystems, and the large instruments that will be mounted on the telescope necessitated further modification of the MMT building. This was carried out throughout most of the winter months, finishing in mid-February 2000. The work included modification of laboratory space to accommodate the two large bench-mounted spectrographs and multi-fiber focal plane positioner, reinforcement of the floor in various locations, and relocation of several walls. Large white flat-field panels were mounted on the inside of the observing chamber doors. The airborne dirt produced by all this activity required that the telescope be tented and therefore not available for observing.

A second attempt at the in-situ aluminization of the primary mirror was done in April 2000. While a better coating was achieved than during the previous year's attempt, the achieved reflectance was not satisfactory. The coating was contaminated with copper that had evaporated from the power cables connected to tungsten rods wetted with aluminum. Since it was expected that the reflectance would not be severely compromised at red and longer wavelengths, it was decided to defer another aluminization until summer 2001.

Progress was made on all three secondary mirrors during this reporting period:

Polishing of the f/9 secondary blank was completed at SOML. The optic was successfully mounted and tested in its cell. It was then removed from the cell for aluminization and transported to the mountain for installation in the telescope in early May. The hexapod actuator that is used to move this secondary in six degrees of freedom was delivered from ADS Italia, assembled and tested at SOML, transported to the mountain and installed on the telescope, and is performing to specification.

The 70 cm diameter, 1.6 mm thick f/15 Zerodur 'shell' for the adaptive f/15 secondary was polished at SOML. The control system, which will provide adaptive correction to 320 voice coil actuators, is under construction. Delivery of the actuator system is expected in late 2000. The shell will then be installed and the secondary tested at SOML before it is shipped to the telescope. Integration of the adaptive system on the telescope is expected to begin in early summer 2001.

Polishing of the 1.7 m diameter f/5 secondary is ongoing at SOML. Loose abrasive grinding is finished, and polishing has begun with testing via a swing-arm profilometer. At the end of the reporting period, the surface error was 180 nm. Final polishing will be done with a computer-generated hologram written on a meniscus test plate. The polishing of the test plate was finished at the University of Arizona's Optical Sciences Center, and a chrome coating was applied in preparation for the writing of the hologram. The design of the telescope cell is nearing completion. Delivery of the secondary and cell to the mountain is expected in spring 2001.

The three-element wide-field corrector lenses were prepared to receive their anti-reflection coatings. The large fixture to dip the corrector lenses into a Sol-gel solution (to produce antireflection coatings) was shipped to Raytheon Optical Systems. This fixture will be tested by coating the 16 inch diameter Hectospec instrument's lenses, and then will be used for coating the corrector optics. Following antireflection coating, Raytheon will mount the coated lenses into the corrector cell, with SAO oversight.

The 6.5 m telescope saw First Light at Cassegrain focus (f/9) on May 17. The optical performance of the telescope exceeded expectation, easily resolving a binary star with 0.7 arcsec separation and producing images with about 0.3 arcsec (FWHM) cores. The thermal control system for the primary mirror was not installed and only a few aberrations were corrected, and those were assessed 'by eye.'

The MMT was rededicated on the evening of May 20, 2000. Speeches were given by C. Foltz (MMTO Director), P. Strittmatter (Director, Steward Observatory), and I. Shapiro (Director, Smithsonian Astrophysical Observatory). University of Arizona President, Peter Likins, and the Smithsonian Institution's Undersecretary, Dennis O'Connor, also spoke. Approximately 200 people enjoyed a dinner after the speeches and then returned to hear after-dinner addresses by Roger Angel (UA) and Robert Kirshner (SAO). At roughly 8:00 PM MST, C. Foltz introduced Project Engineer, J.T. Williams, who gave the command by radio to move the telescope and break the ceremonial ribbon that spanned the observing chamber. The event was transmitted to the Whipple basecamp via a microwave video link. A good time was had by all.

A limited amount of scientific observing began on the telescope in June. The first instrument to be mounted was the MIRAC/BLINC mid-infrared camera and nulling interferometer. Diffraction-limited images were achieved. Observing began in earnest in mid-September with the commissioning of several instruments. Sixty percent of the available observing time in the third trimester of calendar year 2000 was made available for scientific programs, with the remainder going to telescope development and optimization.

The instrument rotator assembly was assembled and mounted on the telescope in late summer. The Heidenhain optical tape encoder was installed and tested. This encoder will provide absolute position information using two read heads. The servo control system for the rotator was completed and tested.

Pointing and tracking tests are ongoing. Using a simple six-term geometric model, the pointing at Cassegrain focus is

accurate to about 8 arcsec rms. Mount servo performance is adequate although additional tuning is required to stiffen the elevation axis, which is still a bit soft. The telescope slew rates in both axes are 1.5 degrees/sec, meeting specification.

The reporting period ended on a high note. Using the interferometric Shack-Hartmann wavefront sensor mounted at the f/9 Cassegrain focus, S. West began optimization of the primary mirror's figure and collimation. Coma coefficients as a function of secondary tilt were measured, and on-axis coma was easily nulled to below 50 nm wavefront error. Figure optimization then concentrated on improving image quality by bending both astigmatism and quadratic astigmatism into the primary mirror using the wavefront sensor as feedback. Correction forces were applied to the pneumatic force actuators that support the primary. In all, over 2 microns of astigmatism and 0.75 microns of quadratic astigmatism were bent out of the mirror, and about 0.5 microns of coma were then removed. Having started with a calculated on-axis diffraction point spread function of about 0.6 arcsec FWHM, the optimized telescope delivered a point spread function near 0.25 arcsec consisting mainly of trefoil. This bodes extremely well for the future imaging performance of the telescope.

5. SEEING MONITORING PROGRAM

No seeing data were taken during this reporting period. Seeing monitoring will be reinstated in 2001.

6. PUBLIC ACCESS TIME ON THE 6.5 M TELESCOPE

A significant amount of observing time on the 6.5 m telescope of the MMT Observatory is made available to the astronomical community through the NOAO proposal process. Under an agreement with the National Science Foundation, 162 nights of observing time will be allocated to the astronomical community over six years. This Public Access time will be distributed over the phases of the moon and the seasons of the year in the same proportion as the scientific observations scheduled for the staffs of the MMT Observatory's parent institutions, the Smithsonian Astrophysical Observatory and Steward Observatory. Therefore, roughly 27 nights per year will be allocated for national access, although the actual number of nights available in a given year will vary, particularly in the first year or so after the telescope's commissioning.

Access for visiting observers through the Public Access Program began in June 2000. Proposals are submitted through NOAO using the standard NOAO proposal form. The NOAO TAC reviews proposals, and those approved are forwarded to the MMTO for scheduling.

Procedures and forms to apply for telescope time can be found at <http://www.noao.edu/noaoprop/noaoprop.html>.

PUBLICATIONS

- Alonso-Herrero, A., Rieke, M. J., Rieke, G. H., Shields, J. C. (2000). "The Nature of LINERs," *ApJ*, **530**, 688.
- Barmby, P., Huchra, J. P., Brodie, J. P., Forbes, D. A., Schroder, L. L., Grillmair, C. J. (2000). "M31 Globular Clusters: Colors and Metallicities," *AJ*, **119**, 727.

- Barton, E. J., Kannappan, S. J., Kurtz, M. J., Geller, M. J. (2000). "Rotation Curve Measurement using Cross-Correlation," *PASP*, **112**, 367.
- Bechtold, J. (2000). "Observations of H2 in Quasar Absorbers," *H2 in Space* meeting in Paris, France, September 28 - October 1, 1999, eds. F. Combes, G. Pineau des Forts, Cambridge University Press, Astrophysics Series.
- Briceno, C., Calvet, N., Kenyon, S., Hartmann, L. (1999). "A Large-Scale Objective-Prism and X-Ray Survey in Taurus-Auriga," *AJ*, **118**, 1354.
- Cretton, N., Rix, H.-W., de Zeeuw, P. T. (2000). "The Distribution of Stellar Orbits in the Giant Elliptical Galaxy NGC 2320," *ApJ*, **536**, 319.
- Foltz, C. B. (1999). "AAS Annual Report," *BAAS*, **32**, 246.
- Gómez, P. L., Hughes, J. P., Birkinshaw, M. (2000). "A Merger Scenario for the Dynamics of Abell 665," *ApJ*, **540**, 726.
- Koranyi, D. M., Geller, M. J. (2000). "Kinematics and Mass Profile of AWM 7," *AJ*, **119**, 44.
- Lacy, C. H. S., Torres, G., Claret, A., Stefanik, R. P., Latham, D. W., Sabby, J. A. (2000). "Absolute Properties of the Eclipsing Binary Star FS Monocerotis," *AJ*, **119**, 1389.
- Lloyd-Hart, M., Cheselka, M., Hanson, R. (1999). "Verification of a System to Prevent Aircraft Illumination by Adaptive Optics Laser Beacons," *PASP*, **111**, 1577.
- Lloyd-Hart, M. (1999). "Thermal Performance Enhancement of Adaptive Optics by Use of a Deformable Secondary Mirror," *PASP*, **112**, 264.
- Luhman, K. L., Rieke, G. H. (1999). "Low-Mass Star Formation and the Initial Mass Function in the Rho Ophiuchi Cloud Core," *ApJ*, **525**, 440.
- Luhman, K. L., Rieke, G. H., Young, E. T., Cotera, A. S., Chen, H., Rieke, M. J., Schneider, G., Thompson, R. I. (2000). "The Initial Mass Function of Low-Mass Stars and Brown Dwarfs in Young Clusters," *ApJ*, **540**, 1016.
- McGuire, P. C., Langlois, M. P., Lloyd-Hart, M., Rhoadarmer, T. A., Angel, J. R. P. (2000). "Measurement of Atmospheric Turbulence with a Shack-Hartmann Wavefront Sensor at the New MMT's Prime Focus," SPIE conference on *Adaptive Optics Systems and Technology*, ed. P. Wizinowich, Munich 2000.
- Massey, P., Foltz, C. B. (1999). "The Spectrum of the Night Sky Over Mount Hopkins and Kitt Peak: Changes After a Decade," *PASP*, **112**, 566.
- Rector, R. A., Stocke, J. T., Perlman, E. S., Morris, S. L., Gioia, I. (2000). "The Properties of the X-Ray-Selected EMSS Sample of BL Lacertae Objects," *AJ*, **120**, 1626.
- Schmidt, G. D., Hoard, D. W., Szkody, P., Melia, F., Honeycutt, R. K., Wagner, R. M. (1999). "Accretion in the High-Field Magnetic Cataclysmic Variable AR Ursae Majoris," *ApJ*, **525**, 407.
- Schmidt, G. D., Stockman, H. S. (2000). "Time-Resolved HST Spectroscopy of Four Eclipsing Magnetic Cataclysmic Variables," to appear in *ApJ*.
- Scott, J., Bechtold, J., Dobrzycki, A. (2000). "A Uniform Analysis of the Lyman-Alpha Forest at $Z=0-5$: I. The Sample and Distribution of Clouds at $Z > 1.7$," *ApJ Supp*, **130**, 37.
- Scott, J., Bechtold, J., Dobrzycki, A., Kulkarni, V. (2000). "A Uniform Analysis of the Lyman-Alpha Forest at $Z=0-5$: II. Measuring the Mean Intensity of the Extragalactic Ionizing Background Using the Proximity Effect," *ApJ Supp*, **130**, 67.
- Torres, G., Lacy, C. H. S., Claret, A., Zakirov, M. M., Arzumanyants, G. C., Bayramov, N., Hojaev, A. S. (2000). "Absolute Dimensions of the A-Type Eclipsing Binary V364 Lacertae," *AJ*, **118**, 1831.
- Torres, G., Andersen, J., Nordstrom, B., Latham, D. W. (2000). "Absolute Dimensions of Eclipsing Binaries. XXIII. The F-Type System Ei Cephei," *AJ*, **119**, 1942.
- Torres, G., Stefanik, R. P. (2000). "The Cessation of Eclipses in SS Lacertae: The Mystery Solved," *AJ*, **119**, 1914.
- Vestergaard, M., Wilkes, B. J., Barthel, P. D. (2000). "Clues to Quasar Broad-Line Region Geometry and Kinematics," *ApJ Letters*, **538**, L103.