

## MMT Observatory

### Tucson, Arizona 85721-0065

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This report covers the period 1 October 1998 - 30 September 1999.

#### 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 1999, the MMTO staff complement of 19 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), D. Fisher and T. Trebisky (Computer Specialists), K. Harrar (Electronic Engineer), C. Heller, J. McAfee, and A. Milone (Telescope Operators), W. Kindred (Instrument Specialist, Sr./Vacuum Engineer), D. Smith (Instrument Specialist), P. Spencer (Electrical Engineer), M. Alegria (Engineering Aide), D. Clark (Electrical Engineer, Sr.), and K. Van Horn (Electrical Engineer).

#### 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](mailto: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.

The consulting engineering firm of Simpson Gumpertz & Heger Inc. (SGH), which played a major design role in the original MMT, was contracted to assist in the design of the new optics support structure (OSS), the mirror cell, the aluminizing head, and modifications to the building and yoke.

The final design phase was completed in September 1992. The design incorporates thermal conditioning of the primary mirror, an inverted Serrurier truss for the support of the forward frame of the telescope, and provisions for *in situ* aluminization of the primary. In addition, the elevation drive motors will be moved from the elevation axis to the drive arcs near the observing floor. The elevation axis will be raised, and the azimuth axis better constrained. The contract for fabrication of the cell, OSS, and aluminizing head was awarded to TIW Fabrication & Machining, Inc. on September 30, 1993.

The mirror cell and drive arc assemblies were transported to the mountain and installed on the MMT yoke in the summer of 1998. Shortly thereafter, the 21,000 pound steel dummy mirror was installed in the mirror cell on the static primary mirror supports. Next, the forward structure was lifted into the building and attached to the cell. The hardpoints and mirror support actuators were then re-installed in the cell. The drive arc and elevation bearing alignment could then be completed. The active primary mirror support system was then tested with the dummy mirror to provide a degree-by-degree map of the actuator and hardpoint forces applied from zenith to horizon pointing, and for accelerations from 0 to the maximum slew speed.

Counterweight drive systems and the elevation brakes were installed and tested. The primary mirror support system, dummy mirror, and the telescope drives were operated simultaneously for the first time in late November. The servo loop for the telescope elevation drive was closed and both elevation motors have been run simultaneously at slew rates up to 1.5 degrees per second. The azimuth drives have been run at similar speeds. Controlled building/telescope collision tests were carried out to verify the safety of the primary mirror under rapid deceleration.

The vacuum head was transported to the mountain on November 17. On November 18, the vacuum head was test fitted to the mirror cell and stored on the roof of the support building. The large blower for the primary thermal control system was also lifted into place while the large crane was

on site. In early 1999, the vacuum head was re-installed on the cell. Large mechanical and turbo-molecular vacuum pumps were attached to the cell and the vacuum head. Then, the whole system was pumped down and deflections of the mirror cell under the pressure load were measured. Satisfactorily low pressures were achieved in the cell, and the cell deflection was within specification. The vacuum head was then removed along with the dummy mirror, and the telescope was prepared for installation of the primary mirror.

On March 22, the primary mirror was rolled out of the storage facility at the Whipple Observatory basecamp and lifted from its lowboy trailer. After mounting on the specially constructed transport trailer, it was rotated to near vertical in preparation for the trip to the summit, and bolted and chained into place. The mirror was driven up the mountain the following day, with the mirror convoy leaving the basecamp at about 9:00 AM. The convoy arrived at the summit at about noon. As in the moves of the other large components, a giant loader traveled behind the transport rig and pushed it up the steeper parts of the road. The whole trip went without a hitch. After arrival at the summit, the mirror box was off-loaded and the truck retreated back down the mountain.

Early on the morning of March 25, 1999, the primary mirror was readied for installation. Preparations of the previous day included the assembly of the lifting fixture, and vacuum tests of the suction pads and associated pumps. The lift had been planned for the afternoon of the 25th, but impending inclement weather forced a re-scheduling to the early morning to beat the incoming storm.

The joint MMTO/Steward Observatory crew assembled at about 6:00 AM for a pre-lift briefing by J.T. Williams, who directed the lift. At 7:10 AM, a 120-ton crane from Marco Crane & Rigging began to hoist the lifting spider holding the \$10 million primary over the top of the building, then gently lowered it into the optics support structure.

By 8:40 AM, observatory staffs were aligning the mirror very carefully to its cell, to within an accuracy of a couple of millimeters. At 10:26 AM, the mirror cell supported the entire 10-ton weight of the glass, with the crane holding only the 7-ton lifting fixture. Williams announced that the mirror was wholly free of crane support and cradled only by the cell. A half-hour later, celebratory rootbeer was popped and passed around among the staff. They still had a long day ahead, clearing the small, crowded summit of vehicles and equipment. But we'll never face this task again – the mirror has been installed for the life of the telescope. The MMT currently has the biggest single-piece primary mirror on the North American continent.

Progress was made on the three secondary mirrors. The first to be installed will be the 1 m diameter f/9 secondary. Polishing of this optic is complete and its cell is nearing completion. The f/15 secondary, a 1.7 mm thick, 70 mm diameter glass membrane, was polished in the Steward Observatory Mirror Lab and currently awaits installation on its bed of the 320 actuators that will apply the adaptive correction. The 1.7 m diameter f/5 wide-field secondary has been aspherized to a surface error of about 3 micrometers using fixed tools. It will soon be mounted on the stressed lap polisher at SOML for loose abrasive grinding and stressed lap

polishing. Design of its cell is nearly complete.

Figuring of all the f/5 wide field corrector optics was completed at Raytheon Optical Systems. The surfaces are very smooth and the metrology gives us high confidence that the correct surface radii were achieved. The tricky task of bonding the ADC prism elements went very well in the end, with only a few tiny bubbles in the epoxy adhesive. Raytheon's attention to quality has been outstanding. The corrector cell is complete and has been delivered to the Porter Exchange laboratory in Cambridge. All parts fit well. The large fixture to dip the corrector lenses into a Sol-gel solution, to produce antireflection coatings, was completed and tested. 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 first attempt at aluminizing the primary *in situ*, i.e., in the telescope cell, was carried out in mid-July. The results were mixed: The mechanical pumps worked very well, as did the large cryopump during pre-fire testing. The latter was probably saturated and not properly purged before the actual deposition event, so pressures during the deposition were a little high. Good deposition rates were achieved, and about 900 Å of Al were deposited on the primary with very good adhesion. The major problem was that some of the filaments ran dry of Al during the attempt, and tungsten was deposited on the mirror on top of the aluminum. This resulted in reflectance that is below the acceptable level. The problems have been diagnosed and corrected, and a second attempt will be made in late 1999. The surface is perfectly adequate for engineering tests however.

A CCD camera has been mounted at prime focus for pointing and tracking tests. Using a 6-term pointing model, the first pointing run of 52 stars gave a pointing accuracy of 8 arcsec rms. This is a tribute to the stiffness of the new telescope's structure. Additional pointing tests will be run at Cassegrain following the installation of the first secondary. We expect to reduce the pointing error by roughly an order of magnitude.

The prototype wavefront sensor for the MMT was again taken to the Vatican Advanced Technology Telescope for proof of its operation in an extremely fast (f/1) beam. The main issues being investigated were the sensitivity to aberrations and the dynamic range of a high-resolution interferometric Hartmann wavefront sensor. The results of the run have shown that this type of instrument will work very well at the f/1.25 prime focus of the new telescope as well as at the f/9 and f/5.4 Cassegrain foci. Using this technique, we can solve for phases and/or wavefront gradients. All least squares fitting is done with singular value decomposition. After phases are solved for, Zernike polynomials are fit. Alternatively, wavefront gradients are fitted directly to the differentiated Zernike terms. Comparison of the two methods with the same starting CCD frames yielded high repeatability. The final wavefront sensor was designed and constructed along with a complete software package for reduction of the interferograms. The device will be mounted first at the prime

focus in the fall of 1999 to optimize the forces applied to the active primary mirror support actuators.

With all the various pieces of the telescope coming together quickly, first light at Cassegrain is expected to occur near the turn of the Millennium.

## 5. SEEING MONITORING PROGRAM

No seeing data were taken during this reporting period. Seeing monitoring will be re-instated following the commissioning of the 6.5 m telescope in early 2000.

## 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 will be made available to the astronomical community, starting in March 2000, 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 will begin in March 2000. Proposals should be submitted through NOAO using the standard NOAO proposal form. The NOAO TAC will review proposals, and those approved will be forwarded to the MMT for scheduling.

Procedures and forms to apply for telescope time can be found at [http://www.noao.edu/noaoprop/noao\\_prop.html](http://www.noao.edu/noaoprop/noao_prop.html).

## PUBLICATIONS

Antebi, J., Dusenberry, D. O., Liepins, A. A. (1998). "Conversion of the MMT to a 6.5-m Telescope: the Optics Support Structure and the Enclosure," *SPIE*, **3352**, 513.

Barton, E. J., Bromley, B. C., Geller, M. J. (1999). "Kinematic Effects of Tidal Interaction on Galaxy Rotation Curves," *ApJ Letters*, **511**, L25.

Bresolin, F., Kennicutt, Jr., R. C., Garnett, D. R. (1999). "The Ionizing Stars of Extragalactic H II Regions," *ApJ*, **510**, 104.

Campos, A., Yahil, A., Windhorst, R. A., Richards, E. A., Pascarelle, S., Impey, C., Petry, C. (1998). "A Cluster or Filament of Galaxies at Redshift  $z = 2.5?$ ," *ApJ Letters*, **511**, L1.

Davison, W. B., Williams, J. T., Hill, J. M. (1998). "Handling 20 Tons of Honeycomb Mirror with a Very Gentle Touch," *SPIE*, **3352**, 216.

Ellison, S. L., Lewis, G. F., Pettini, M., Sargent, W. L. W., Chaffee, F. H., Foltz, C. B., Rauch, M., Irwin, M. J. (1999). "KECK HIRES Spectroscopy of APM 08279+5255," *PASP*, **111**, 946.

Foltz, C. B. (1998). "AAS Annual Report," *BAAS*, **31**, 268.

Foltz, C. B., Williams, J. T., West, S. C., Fabricant, D. G., Martin, H. M. (1999). "The Rebirth of the MMT," *Measurements for the New Millennium*, Proceedings of the 16th IEEE Instrumentation and Measurement Technology Conference, eds. V. Piuri and M. Savino, p. 633.

Hines, D. C., Schmidt, G. D., Wills, B. J., Smith, P. S., Sowinski, L. G. (1999). "The Misdirected Central Engine of the Hyperluminous Infrared Galaxy and Type 2 QSO IRAS P09104+4109," *ApJ*, **512**, 145.

Holberg, J. B., Barstow, M. A., Bruhweiler, F. C., Hubeny, I., Green E. M. (1999). "Far-Ultraviolet Space Telescope Imaging Spectrograph Spectra of the White Dwarf REJ 1032+532. II. Stellar Spectrum," *ApJ*, **517**, 850.

Huchra, J. P., Vogeley, M. S., Geller, M. J. (1999). "The CfA Redshift Survey: Data for the South Galactic Cap," *ApJ Supp*, **121**, 287.

Izotov, Y. I., Chaffee, F. H., Foltz, C. B., Green, R. F., Guseva, N. G., Thuan, T. X. (1999). "Helium Abundance in the Most Metal-Deficient Blue Compact Galaxies: I ZW 18 and SBS 0335-052," *ApJ*, in press.

Izotov, Y. I., Papaderos, P., Thuan, T. X., Fricke, K. J., Foltz, C. B., Guseva, N. G. (1999). "Is I Zw 18 a Young Galaxy?," *A&A*, submitted.

Latham, D. W., Stefanik, R. P., Mazeh, T., Torres, G., Carney, B. W. (1998). "Low-Mass Companions Found in a Large Radial-Velocity Survey," *Brown Dwarfs and Extrasolar Planets*, eds. R. Rebolo, E. L. Martin, and M. R. Zapatero Osorio, *Astronomical Society of the Pacific Conference Series*, **134**, 178.

Latham, D. W., Stefanik, R. P., Mazeh, T., Goldberg, D., Torres, G., Carney, B. W. (1998). "A Survey for Spectroscopic Binaries in a Large Proper-Motion Sample," *The 10th Cambridge Workshop: Cool Stars, Stellar Systems, and the Sun*, eds. R.A. Donahue and J.A. Bookbinder, *Astronomical Society of the Pacific Conference Series*, **154**, 2129.

Liu, C. T., Petry, C. E., Impey, C. D., Foltz, C. B. (1999). "Quasars as Absorption Probes of the Hubble Deep Field," *AJ*, **118**.

Luhman, K. L., Rieke, G. H., Lada, C. J., Lada, E. A. (1998). "Low-Mass Star Formation and the Initial Mass Function in IC 348," *ApJ*, **508**, 347.

Martin, H. M., Callahan, S. P., Cuerden, B., Davison, W. B., DeRigne, S. T., Dettmann, L. R., Parodi, G., Trebisky, T. J., West, S. C., Williams, J. T. (1998). "Active Supports and Force Optimization for the MMT Primary Mirror," *SPIE*, **3352**, 412.

Martin, H. M., Allen, R. G., Angel, J. R. P., Burge, J. H., Davison, W. B., DeRigne, S. T., Dettmann, L. R., Ketelsen, D. A., Kittrell, W. C., Miller, S. M., Strittmatter, P. A., West, S. C. (1998). "Fabrication and Measured Quality of the MMT Primary Mirror," *SPIE*, **3352**, 194.

McIntosh, D. H., Rix, H.-W., Rieke, M. J., Foltz, C. B. (1998). "Redshifted and Blueshifted Broad Lines in Luminous Quasars," *ApJ Letters*, **517**, L73.

Mermilliod, J.-C., Mathieu, R. D., Latham, D. W., Mayor, M. (1998). "Red Giants in Open Clusters. VIII. NGC 752," *A&A*, **339**, 423.

Napiwotki, R., Green, P. J., Saffer, R. A. (1999). "A Com-

- parative Study of the Mass Distribution of Extreme-Ultraviolet-Selected White Dwarfs,” *ApJ*, **517**, 399.
- Pickering, T. E., Van Gorkom, J. H., Impey, C. D., Quillen, A. C. (1999). “Kinematics and Neutral Hydrogen Properties of the Giant Low Surface Brightness Galaxy UGC 2936,” *AJ*, **118**, 765.
- Rector, T. A., Stocke, J. T., Perlman, E. S. (1999). “A Search for Low-Luminosity BL Lacertae Objects,” *ApJ*, **516**, 145.
- Riess, A. G., Kirshner, R. P., Schmidt, B. P., Jha, S., Challis, P., Garnavich, P. M., Esin, A. A., Carpenter, C., Grashius, R., Schild, R. E., Berlind, P. L., Huchra, J. P., Prosser, C. F., Falco, E. E., Benson, P. J., Briceo, C., Brown, W. R., Caldwell, N., Dell’Antonio, I. P., Filippenko, A. V., Goodman, A. A., Grogan, N. A., Groner, T., Hughes, J. P., Green, P. J., Jansen, R. A., Kleyna, J. T., Luu, J. X., Macri, L. M., McLeod, B. A., McLeod, K. K., McNamara, B. R., McLean, B., Milone, A. A. E., Mohr, J. J., Moraru, D., Peng, C., Peters, J., Prestwich, A. H., Stanek, K. Z., Szentgyorgyi, A., Zhao, P. (1999). “BV RI Light Curves for 22 Type Ia Supernovae,” *AJ*, **117**, 707.
- Sartoretti, P., Brown, R. A., Latham, D. W., Torres, G. (1998). “A Search for Substellar Companions Around Nine Weak-Lined T-Tauri Stars with the Planetary Camera 2 of the Hubble Space Telescope,” *A&A*, **334**, 592.
- Statler, T. S., Smecker-Hane, T. (1999). “The Stellar Kinematic Fields of NGC 3379,” *AJ*, **117**, 839.
- Statler, T. S., Dejonghe, H., Smecker-Hane, T. (1999). “The Three-Dimensional Mass Distribution in NGC 1700,” *AJ*, **117**, 126.
- Thuan, T. X., Izotov, Y. I., Foltz, C. B. (1998). “The Young Age of the Extremely Metal-Deficient Blue Compact Dwarf Galaxy SBS 1415+437,” *ApJ*, **525**, 105.
- Udry, S., Mayor, M., Latham, D. W., Stefanik, R. P., Torres, G., Mazeh, T., Goldberg, D., Andersen, J., Nordström, B. (1998). “A Survey for Spectroscopic Binaries in a Sample of G Dwarfs,” *The 10th Cambridge Workshop: Cool Stars, Stellar Systems, and the Sun*, eds. R.A. Donahue and J.A. Bookbinder, *Astronomical Society of the Pacific Conference Series*, **154**, 2148.
- Wegner, G., Colless, M., Saglia, R. P., McMahan, R. K., Jr., Davies, R. L., Burstein, D., Baggley, G. (1999). “The Peculiar Motions of Early-Type Galaxies in Two Distant Regions – II. The Spectroscopic Data,” *MNRAS*, **305**, 259.
- White, R. L., Becker, R. H., Gregg, M. D., Laurent-Muehleisen, S. A., Brotherton, M. S., Impey, C. D., Petry, C. E., Foltz, C. B., Chaffee, F. H., Richards, G. T., Oegerle, W. R., Helfand, D. J., McMahan, R. G., Cabanella, J. E. (1999). “The First Bright Quasar Survey. II. 60 Nights and 1200 Spectra Later,” *ApJ Supp*, submitted.

