

Technical Report No. 17

The Multiple Mirror Telescope Comparison
and Calibration Lamp Illumination System

Craig B. Foltz, David B. Ouellette,
Daniel R. Blanco, Frank H. Sharp,
and
Frederic H. Chaffee, Jr.

January 1986



ABSTRACT

We describe a recently implemented method of illuminating instruments attached to the Multiple Mirror Telescope (MMT) with light from comparison and calibration sources in a way which mimics the pupil of the MMT. The principle innovation is that the light is fed by 30-m lengths of fused-silica fibers to an integrating sphere from lamps located in a laboratory roughly 6 m from the telescope structure. This system has resulted in improved flexibility and serviceability over that previously used in which the lamps were located near the focal plane of the telescope. In addition, implementation of this scheme has removed a source of heat from the telescope chamber.



I. INTRODUCTION

The general instrument interface for the Multiple Mirror Telescope is the so-called Top Box. This device is located between the beam-combiner, the optical element which deflects the beams from the individual tertiary mirrors of the six telescopes of the MMT to a common focal plane, and the nominal MMT focal plane. (For a detailed description of the MMT optical path, see Beckers et al. 1981). The Top Box provides a mounting fixture for many of the instruments used on the MMT and houses various sub-systems which are essential for the operation of the MMT and its facility instruments. These include slit-viewing optics for television acquisition and guiding, and facilities for illuminating the full unvignetted field of the MMT with light from a set of calibration and comparison sources.

In the spring of 1985 the original MMT Top Box was replaced with a new one which includes the complex optical systems required to autoguide the MMT mount and determine the corrections necessary to coalign the six secondary mirrors in order to keep the images from the six telescopes coincident at the MMT focal plane. (For a detailed description of the new top box including description of the autoguiding techniques, see Blanco et al. 1986 and references therein.) The new top box contains an all new and redesigned comparison lamp illumination system. Design constraints on this system were: (1) the system should illuminate the focal plane

such that each point is presented with a beam which is identical to the MMT beam (see below); (2) the lamps should evolve as little heat in the telescope chamber as is possible; and (3) the lamps should be easily accessible for replacement and service. Furthermore, the diverse instrumental configurations of the MMT spectrographs requires that a large number of different types of sources be available at any time. The system which resulted from our design efforts meets all of these constraints and has proven itself to be flexible and serviceable, as well as to allow for future growth in response to changing illumination requirements.

II. ILLUMINATION SCHEME

Many of the observational programs carried out with the MMT Spectrograph and MMT Echelle Spectrograph are aimed at obtaining radial velocities with a precision of up to 0.5 km/sec. To minimize systematic velocity shifts, it is desirable to have the light from comparison sources and program objects to illuminate the spectrograph optics in an identical way. Therefore, the comparison light illumination system must simulate the incoming beam of the MMT as seen from the nominal focal plane. This consists of an unfilled beam produced by the six $f/31.6$ beams from each of the secondaries contained in an overall $f/9$ envelope.

To achieve this end, we use the illumination scheme shown in perspective in Figure 1. Light from a comparison source is fed to a 6-inch diameter integrating sphere (manufactured by Labsphere Inc.) where it can be

combined with light from any other lamps. The inside of the sphere is coated with Eastman 6080 white high-reflectance coating, which is suitable for use from 2000 Å to 2.5 μ and has a flat absolute reflectance versus wavelength over the visible spectrum. The coating is non-luminescent and is characterized by nearly perfect diffuse reflectance. The sphere has an exit port diameter of 2.0 inches. Light leaving the sphere then passes through two remotely-controllable, 8-position filter wheels. The first wheel contains a set of masks which simulate the MMT pupil and Hartmann masks used for focussing the spectrographs in their various configurations. The second wheel contains a set of neutral-density filters ranging from clear to 2.3 ND in steps of roughly 0.3 ND. The light is then directed toward the focal plane by a 45-degree flat which can be moved into the beam on a translating stage which registers repeatably to ~ 0.0001 inch. Finally, the light is relayed to the focal plane by a 3.4-inch diameter f/3 quartz lens. A virtual image of the pupil mask in the first filter wheel is formed at the same distance from the focal plane as the pupil of the MMT. This results in illumination of every point on the 4 arcmin field of the MMT with a beam that simulates that produced by the telescope.

Light is fed to the integrating sphere by a fiber optic bundle from an instrument laboratory located roughly 6 m from the telescope structure. In order to run through the standard cable drape and the instrument rotator the total fiber length is 30 m. The fibers are Fibropsil QSFW-600 fused-silica from Quartz Products Corporation which were chosen for their large core size (600 μ m) and their high UV transmission. The bundle consists of eight individual fibers contained

in a protective sheath (a rubber air hose). They accept light within a 31 degree apex angle cone and have a numerical aperture of 0.27. The fibers were prepared by cleaving the appropriate lengths and polishing the cleaved ends with successive grades of diamond abrasive compound to 0.5 micron (50,000 mesh).

The manufacturer's specification on these fibers is that their losses do not exceed 6 dB/km at 8200 Å, 10 dB/km at 6300 Å, and have a typical attenuation of 50 dB/km at 4000 Å. Our measurements are consistent with the latter estimate. In addition, we routinely see emission lines in the spectrum of a Mercury-Cadmium source at 3131 Å which have been transmitted by the fiber.

The comparison sources are, with two exceptions (see below), located in a 42 x 30 inch NEMA (National Electrical Manufacturers Association) box which is mounted on the wall in the instrument laboratory (Figure 2). The lamps are mounted on a piece of 36" x 24" x 0.25" thick aluminum plate which has 1/4-20 holes on 1.0 inch centers. Lamp holders, imaging optics, filter holders, etc. are secured on standard commercially-available pin mounts. This facilitates the installation of new sources and the modification of existing lamp configurations (i.e. custom filtering). Under typical observing conditions, the following lamps are available: Mercury-Cadmium discharge source, Iron-Neon hollow cathode lamp, Neon glow lamp, a bright quartz-halogen source (used for correction of the flatfield response of the MMT Echelle Spectrograph and direct and spectroscopic CCD detectors), and a faint quartz-halogen source (used with the MMT Spectrograph). Only a Helium-Argon source and a Thorium-Argon hollow cathode lamp are currently located in the new top box itself.

The emitting regions of the lamps are imaged onto the fiber ends with fast (typically $f/2$) lenses, quartz or glass depending on the UV requirements of the source. In some cases cylindrical lenses and cylindrical or spherical reflectors are used to increase the flux at the end of the fiber. Each lamp generally has a color-balancing and/or neutral density filter associated with it. Additional spatial filtering is available, as required, by defocussing or purposefully misaligning the image on the fiber end.

In addition to the sources mentioned above, the NEMA box contains optics for the illumination of an etalon with collimated white light. The resulting Edser-Butler bands are ideal for wavelength calibration since they are unblended, roughly uniformly spaced, and of nearly constant brightness. The etalons currently in use are from the PEPSIOS triplets (Hegyfi, Traub, and Carleton 1972) under loan from Dr. Carleton. These have spacings of roughly 1 mm and, in the configuration used here, yield fringe spacings of 1-3 Å with a finesse of about 5. A sample spectrum obtained with the MMT Echelle Spectrograph is shown in Figure 3. The etalon support is a kinematic mount -- a design which completely constrains all six degrees of freedom without overconstraints. The support provides a stable mount for the etalon while allowing it to be removed and replaced with excellent registration within seconds.

Power to the lamps is controlled remotely either by manual or computer control as arbitrated by the new top box controller. Power to individual lamps can be disabled in the NEMA box to protect certain instruments from illumination by lamps that could potentially damage the