

MMT TECHNICAL REPORT NO. 1

THE FIELD OF VIEW OF THE MMT

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ABSTRACT

This report describes the procedures used to determine the unvignetted field of view of the MMT and the resulting observations. The unvignetted field of view has been determined for the MMT on March 5, 1980. The diameter of the equivalent area circle equals 35 arc seconds. Figure 5 shows the outline of the unvignetted area. It also shows the outline of the field at which 1, 2 and 3% vignetting occurs. The corresponding equivalent diameters are 59, 71 and 80 arc seconds.

## 1. INTRODUCTION

The field of view of the MMT is rather small as the result of the way the six images are combined optically. Vignetting at the edges of the field of view can be caused by either the telescope secondary, the tertiary mirror or the beamcombiner. When close to correct alignment and with the optical tertiary mirrors, the beamcombiner is the only cause for vignetting.

Appendix A to this report reproduces a memorandum by Carleton and Hoffmann on the F/9 beamcombiner for the MMT and of the associated optical parameters. It calculates the smallest diameter of the field of view to be 52 arc seconds which is achieved when all of the optics are in perfect alignment. In that case, the shape of the field of view is actually a hexagon with sides equal to 30 arc seconds and with two of the opposite sides horizontal. For the purpose of this report, I will define three different diameters of the field of view, in addition to giving its shape. They are:

1. The minimum diameter  $\emptyset_{\min}$  (52 arc seconds in the perfect case)
2. The maximum diameter  $\emptyset_{\max}$  (60 arc seconds in the perfect case)
3. The diameter of a hypothetical circle with an area equal to that of that unvignetted area  $\emptyset_{\text{area}}$  (54.6 arc seconds in the perfect case)

The perfect minimum vignetting is only achieved when all six telescopes are simultaneously in perfect optical alignment. This is, of course, never achieved. Especially the precise alignment of the tertiary mirrors is crucial. As they are mounted now this alignment is difficult. If, in the future, these tertiary mirrors become "articulated", such alignment becomes substantially easier. The purpose of this report

is solely to describe the present (March 5, 1980) status of the field of view vignetting with the optics as aligned in mid-1979 and not to determine the corrections to be made on the tertiary mirrors. In fact, using the procedures identified here, it should be possible to make the optimum adjustments in a straightforward manner (Appendix B).

## 2. PROCEDURES USED

The determination of the telescope vignetting was done by means of a camera system which was constructed with the aim of testing the MMT optics. Figure 1 shows a diagram of this simple camera system. It consists of a 508 mm focal length lens (removable) which, when placed in the quasi-cassegrain focus of the MMT, forms an image of the six pupils 540 mm behind the lens on polaroid film. There is a shutter just behind the lens and a removable, rotatable knife edge K in front of it. The camera is used for a number of optics tests:

- a) Knife edge tests of the six telescopes: A future report will discuss the results of these tests taken on March 4, 1980. Such tests show wavefront errors introduced by the optics.
- b) Out of Focus Images: Obtained by removing the lens L and knife edge K. Such tests were made also on March 4, 1980 and show wavefront errors in a different way.
- c) Images of the Pupils without a Knife Edge: Knife edge K is removed but not the lens L. They result in images of the six pupils as shown in Figure 2.

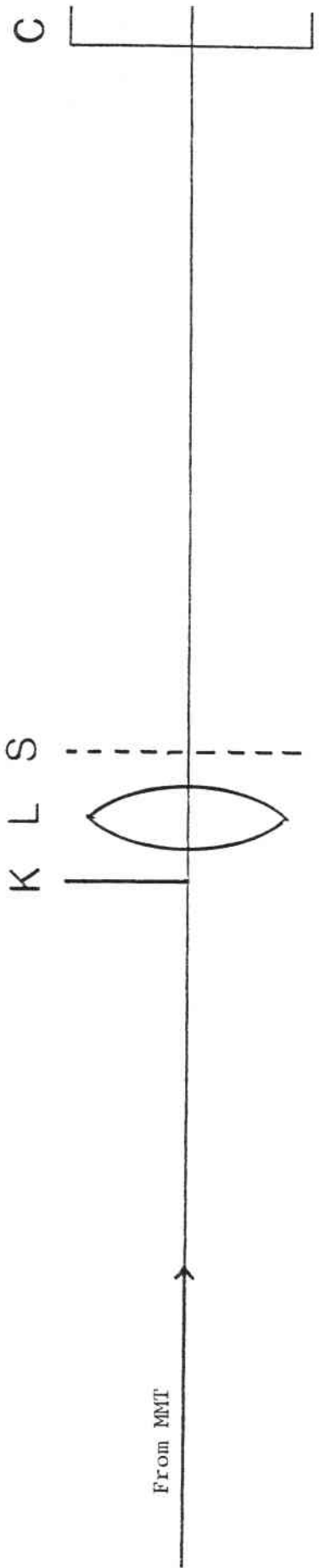


Figure 1: Focal Plane Camera. L = 504 mm Focal Length Lens, K = Knife Edge, S = Shutter, C = Polaroid Camera  
3.25 x 4.25 inch Format

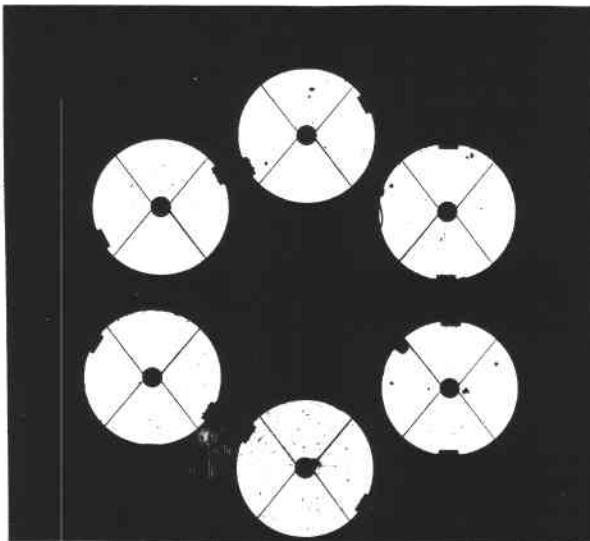


Figure 2: Unvignetted Images of 6 Pupils with MMT Optics Evaluation Camera (OEC) ( $m_v = 1.5$ , FO star at 5 second exposure on ASA 200 film).

Within the unvignetted field of view of the telescope, the six images show the full telescope apertures except for the obscuration caused by the secondaries, the spiders and the Risley prism boxes. If however the telescope is pointed so that the star images fall within a vignetted area, some of the pupil images show a cutoff caused by the edges of the beamcombiner. An example of this is shown in Figure 3.

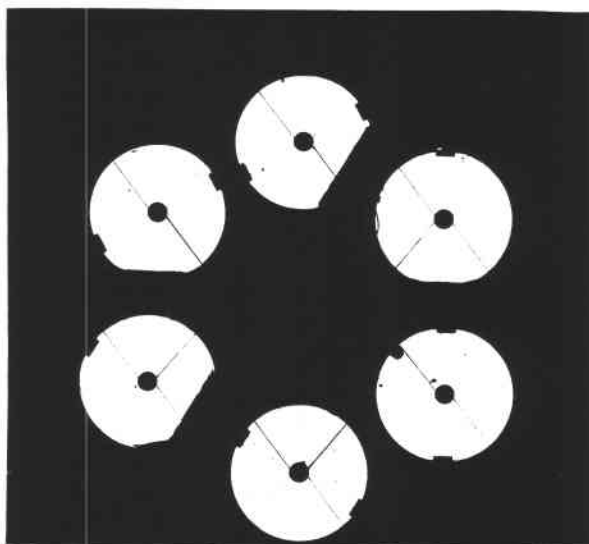


Figure 3: Images of 6 Pupils but with Vignetting by Beamcombiner on Pupil A (top left), B (top), C (top right) and F (bottom left).

From images like those shown in Figure 3, one can determine which pupils have vignetting and how much.

The procedure followed to collect the data was (i) to select a bright ( $m_v = 1$ ) star, (ii) to superimpose and focus the images at the center of the field. This center was determined by theodolite. The centering of the star images to the telescope center could be done to an accuracy of  $\pm 2$  arc seconds. It had to be done directly by projection of a star image on a card. This centering could be improved upon. So could the coalignment and focussing of the images done again by direct projection on a card. (The addition of a beamsplitter and CID monitor of the focal plane, as was done on March 4, allows a much better focussing and superposition of the images. Because of the limited field of the beamsplitter causing vignetting itself, we could not use it for the field of view observations. In future observations, the CID monitoring system should definitely be added) (iii) to offset the MMT mount by  $\Delta EL$  arc seconds in elevation with  $\Delta EL$  ranging from -30 to +40 arc seconds, (iv) to offset at each  $\Delta EL$  value the MMT in azimuth by -35, -25, -15, -5, +5, +15, +25 and +35 arc seconds. Note that this offset is in true position on the sky. The offset  $\widetilde{\Delta AZ}$  equals therefore  $\Delta AZ / \cos(EL)$  with  $\Delta AZ$  being the mount offset, and (v) to photograph the six pupil images on polaroid film. These photographic records were then analysed as described in Section 4.

### 3. OBSERVING CONDITIONS

The observations were made in the evening of March 5, 1980, under good seeing conditions (approximately 1 arc seconds, relevant here only because of the precision of focussing and coalignment). We used a  $m_v = 1$  star at an elevation angle of approximately  $50^\circ$ . Wind velocities were moderate

( $\leq 20$  mph) and the MMT building was oriented such that the wind effects were small ( $< 1$  arc sec). Superposition of the images was done to about  $\pm 1$  arc seconds. For each  $\Delta EL$  run, the images were recentered and realigned to correct for telescope flexure effects. Each of the 8  $\Delta EL$  runs required an average of 20 minutes for pointing, coalignment, image photography and logging the images. The distance of the focal plane to the backplate of the beamcombiner equalled 50.6 inches which is 6 inches less than the distance of the nominal focus as given in the attached Carleton-Hoffmann memo. This error in setting of the camera was discovered after the fact and affects the results slightly in the sense that it decreases the theoretical  $\theta_{\min}$  to 49 arc seconds. The results in Section 4 are however valid for a position 6 inches ahead of the nominal focus. In future tests, care should be given to place the focal plane at the nominally correct position (56.7 inches from the beamcombiner backplate, 51.9 inches from the vertex of the beamcombiner or 51.7 inches from the flat screwhead which holds the beamcombiner to the backplate).

#### 4. RESULTS

For each set of eight images ( $\widetilde{\Delta AZ} = \pm 35''$ ,  $\pm 25''$ ,  $\pm 15''$  and  $\pm 5''$ ) at a given elevation offset ( $\Delta EL$ ), I determined the  $\Delta AZ / \cos(EL)$  value ( $= \widetilde{\Delta AZ}$ ) at which vignetting occurred by extrapolating backward from the images where clear vignetting was present to the point where the straight vignetting edge just touched each pupil circle. I ignored the vignetting by the Risley prism boxes in case this edge came in over it and I assumed a perfectly circular outline of the pupils. For each pupil one obtains that way, a set of ( $\widetilde{\Delta AZ}$ ,  $\Delta EL$ ) values which together fall on two lines intersecting at a  $60^\circ$  angle. Figure 4 shows the result of the determination of this angle for all six pupils. The unvignetted area corresponds to the deformed hexagon