MMTO TECHNICAL REPORT NO. 2

# MMT-OPTICS
# FINAL DESIGN AND PREDICTED PERFORMANCE

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## INTRODUCTION

The purpose of this report is to summarize the final optical description of the Multiple Mirror Telescope optical system, review the optical quality of the major system components and predict, with approximations determined to be necessary, the final optical quality of the six individual 72 inch Cassegrain telescopes. In doing this study, many documents were found which we feel will be useful to support this work and which may answer from time to time questions which may arise about the fabrication, testing and verification of the optical system. Thus, at the end of this report is a Bibliography containing these pertinent documents.

## I. SYSTEMS DESIGN

This section summarizes the design parameters for the MMT optics and the image quality predicted for these at the edge of the field of view.

## I.1 72" CASSEGRAIN OPTICS

### Description of the First Order Parameters

The first order properties of the cassegrain optics are as follows:

| | |
|---|---|
| Diameter (Primary Mirror) | 71.7 inches |
| Effective Focal Length (EFL) | 2155.52 inches |
| Focal Ratio (F/#) | F/30.06 |
| Full Field of View (FFOV) | 5 arc-min |
| Image Plane Diameter | 3.13 inches |
| Image Plane Scale | 104 arcsec/inch<br>(0.01 in/arcsec) |

### Description of Components

| | Primary | Secondary |
|---|---|---|
| Diameter | 71.1 | 10.250 (9.25)* |
| Radius of Curvature | 388.8ccv | 58.435cvx |
| Conic Constant | -1.00 | -1.4358 |

For a complete description of the optical system, aberration analysis, diffraction analysis, etc., refer to the ACCOSV computer printout listed in Appendix I.

*Diameter of I.R. Secondary

## I.2 THE GUIDE SCOPE

### Description of the First Order Parameters

| | |
|---|---|
| Diameter (Primary Mirror) | 28.74 inches |
| Effective Focal Length (EFL) | 505.9 inches |
| Focal Ratio (F/#) | F/17.60 |
| Full Field of View (FFOV) | 1 degree |
| Image Plane Diameter | 8.83 inches |
| Image Plane Scale | 0.0025 inches/arcsec |
| Image Plane Radius of Curvature | 22.2 inches |

### Description of Components

| | Primary | Secondary | Corrector |
|---|---|---|---|
| Diameter | 30.0* | 9.0** | 10.0*** |
| Radius of Curvature | -166.122 | -35.809 | -736.4 (inches) |
| Conic Constant | -1.0145 | -2.0677 | -1.00 |
| 4th Order Deformation (AD) | --- | --- | $2.711 \times 10^{-5}$ |

*Actual diameter -- only 28.74 inches is actually used.

**Actual diameter -- only 6.4 inches is actually used.

***Actual diameter -- only 8.6 inches is actually used.

For a complete description of the optical system, aberration analysis, diffraction analysis, etc., refer to the ACCOSV computer printout listed in Appendix II.

## I.3 PREDICTION OF COMPOSITE IMAGE QUALITY AT EDGE OF FIELD

The presence of the beam combiner in the system causes each of the six Cassegrain image planes to tilt relative to the central optical axis. This does not effect the quality of an image at the center of the field, but, as this image moves towards the edge of the field, the six images begin to spread out. Furthermore, as this image moves azimuthally ($\Omega$) around the center of the field, this degraded pattern changes, repeating every $60^{\circ}$ in azimuth. Figure 1.1 a-g is a geometric composite spot diagram of the six images at increments of $\Delta\Omega = 10^{\circ}$ from $\Omega = 0^{\circ}$ to $\Omega = 60^{\circ}$. The degradation includes all of the telescope inherent properties (field curvature, coma, etc., as well as the errors due to image plane separation. The beam combiner configuration chosen was the F/9 beam combiner, used at a full-field of 52 arcsec. Also shown for comparison in Figure 1.2 is the composite image at $\Omega = 0^{\circ}$ for the F/5 beam combiner at a field of 150 arcsec.

A number of points are worth noting:

1. At $\Omega = 30^{\circ}$, the symmetry of the pattern is most pronounced. The reason for this is depicted in Figure 1.3
2. The largest out-of-focus spot for the F/5 Beam Combiner exhibits what is called keystone distortion. The spot pattern should be a perfectly retangular pattern. The tilt of the image plane, however, causes the pattern to wedge towards the center of the field - similar to the way the keystone in an arch is wedged.
3. The coma one expects the images to exhibit at the edge of the field is overpowered by the defocus blur. However, coma is evident, especially in the concentrated part of the image

at $\Omega = 0^\circ$, $30^\circ$ and $60^\circ$.

4. Note that the spot diagrams of $\Omega = 0^\circ$ and $\Omega = 60^\circ$ are identical -- except for a relative rotation of $60^\circ$.

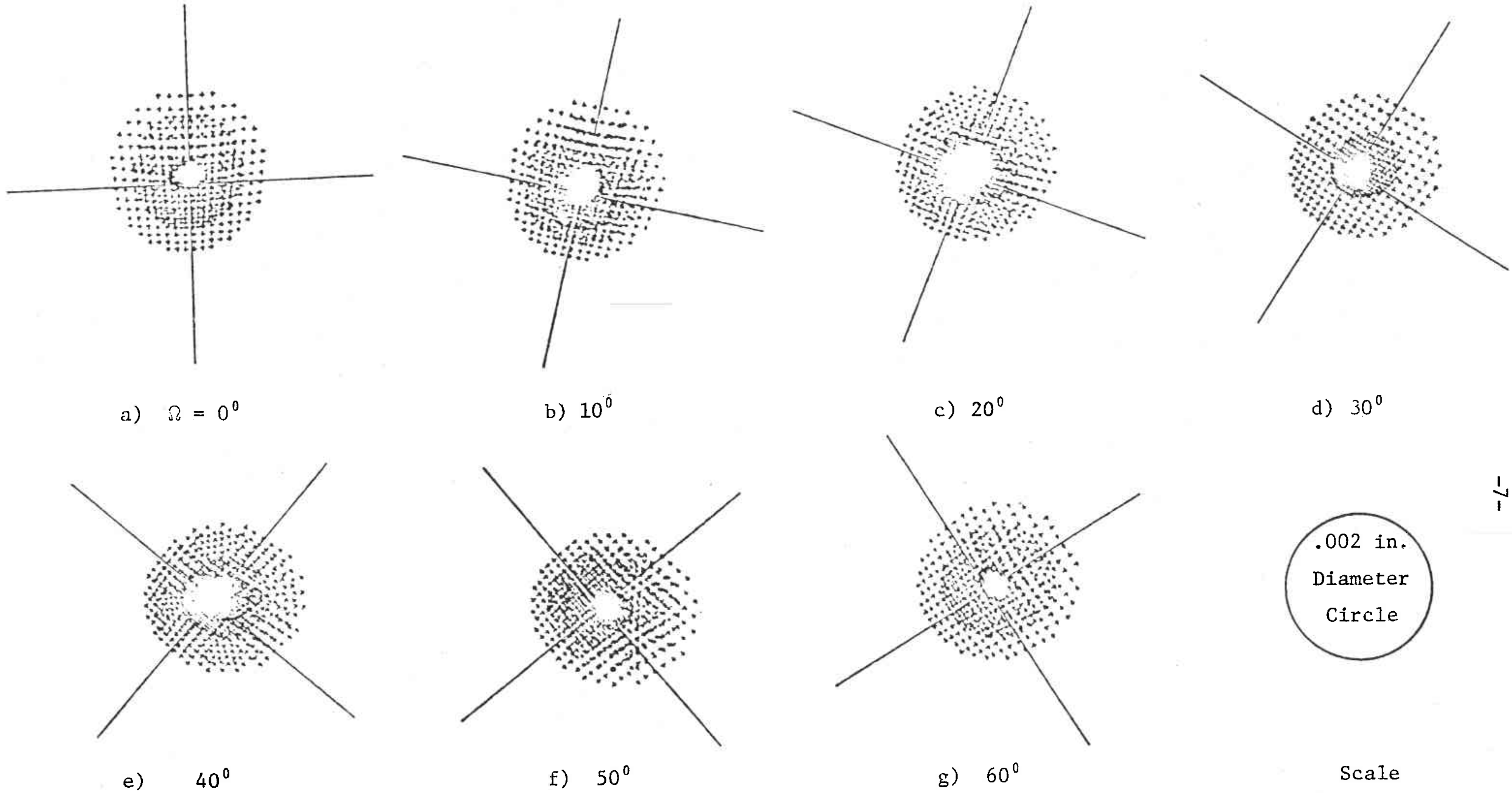


Figure 1.1

Composite Spot Diagrams at Edge of Field
Intermediate Focal Mode; F/9 Beam Combiner 52 Arc-Sec Full-Field

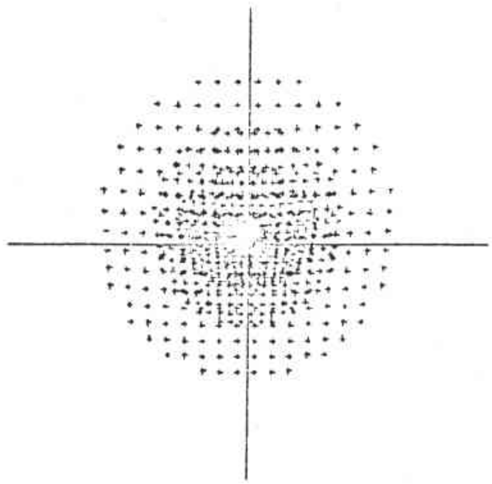

Figure 1.2 Spot Diagram at the edge of the field for the F/5 beam combiner ( $\Omega = 0^0$). Note how the spots of the most out of focus star image seem to converge towards the bottom of the paper, rather than being a rectangular pattern. This effect - Keystone Distortion - is due to the tilt of the image plane. Scale is the same as for Figure 1.1.

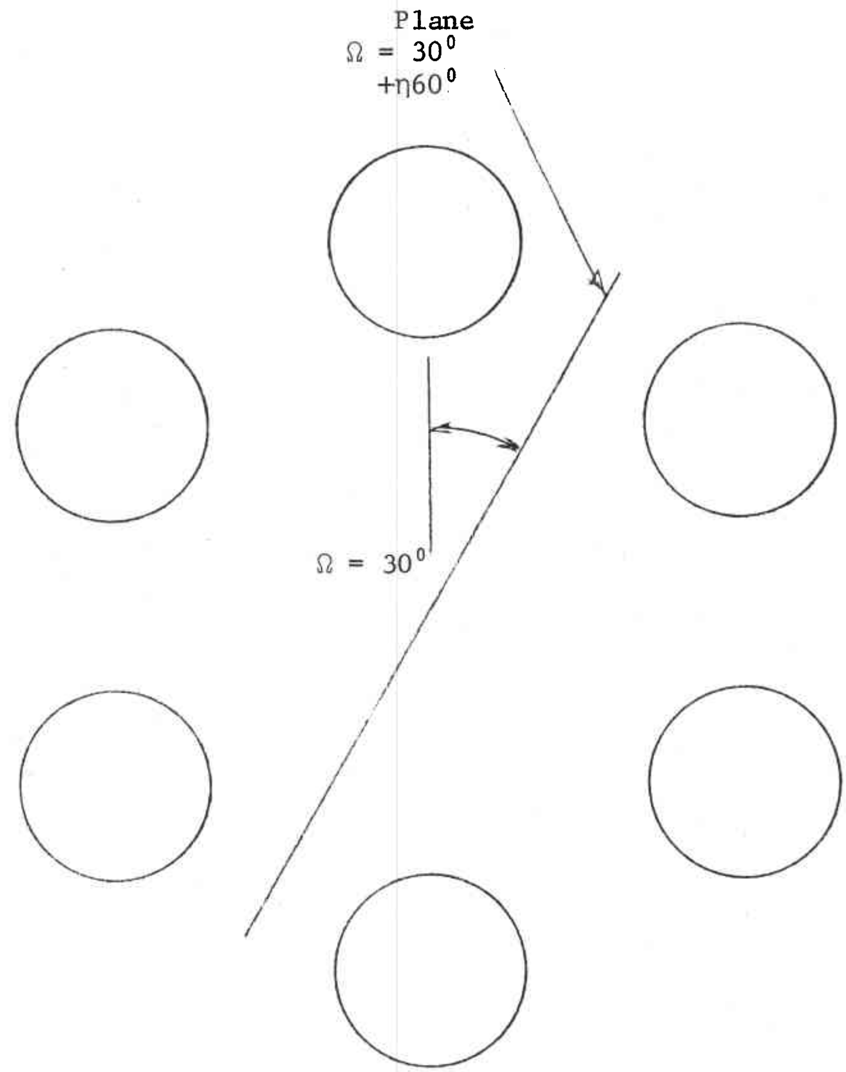


Figure 1.3

When an object lies in a plane, $30^0 + \eta 60^0$ ($\eta$ = 0, 1 ..., 5) to the vertical (altitude) axis, it sees a unique symmetry pattern. In addition, no aperture lies in this plane.