MULTIPLE MIRROR TELESCOPE OBSERVATORY

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MMT UPGRADE/CONVERSION
TECHNICAL MEMORANDUM #88-1

Subject: An f/9 Optical Configuration for a 6.5 M MMT Conversion.

From: D. Blanco

Date: June 10, 1988

As part of the many design considerations towards converting the MMT to a single aperture telescope of maximum diameter, we should examine alternate optical designs. Epps presented a "first look" (MMT Technical Memorandum #18, 1986) at a configuration which derived from certain basic constraints and goals. Among others, these included:

1) The telescope must fit within the existing MMT building.

2) The focal field must be flat.

3) A field of at least 2 arcminute diameter must be provided at f/45 for IR use of the telescope.

Each of these constraints and requirements greatly effected the design. Subsequent studies (Hoffman, MMT Technical Report #22, 1987) have shown the feasibility of enlarging the MMT building, somewhat relaxing constraint 1). The use of MX type robotic fiber holders or the possibility of a curved mosaic of CCD's would relax requirement 2). Recent projections of the IR requirements of the future (Rieke '87) indicate the need for a faster IR focal ratio.

This memo presents a rough look at a possible optical configuration which is based on a different set of design goals. This design is not meant to be final; there are several areas where further research and optimization are needed. The goals chosen for this design are:

A) Compatibility with existing MMT instrumentation.

B) Use in the IR at a focal ratio f/15.

C) A wide field at f/9 using refractive correctors not requiring exotic glasses.

D) A modest field without refractive optics.

One design which meets this new set of design goals is a modified R-C with a Cassegrain focal ratio of f/9. This gives a reasonable field as a bare two mirror telescope and, with the addition of a single element field corrector, can cover 20 arcminutes with better than 0.14 arcsecond rms diameter images over a curved image surface.

The modification is a change in the primary and secondary conic sections away from the optimum R-C values. This sacrifices some performance in the bare telescope but enhances the performance when combined with a simple field corrector.

In this sample design, the primary focal ratio was chosen to be f/1.2, which is consistent with the present design for the Columbus and Magellan projects. This choice was primarily driven by use of the telescope with a chopping secondary which proved incompatible with a faster primary. A slower primary also relaxes the collimation error budget by a factor proportional to the cube of the primary focal ratio.

As an all reflecting, well collimated telescope, the usable field size is limited first by field curvature and second by field-dependent aberrations. Allowing 0.18 arcsecond rms maximum image diameter, a flat image field is limited to 5 arcminutes diameter, while a curved image surface reaches to 10 arcminutes diameter.

To increase the field size, a field corrector was added that is a single element meniscus with an asphere on the front surface. The design is similar to that of a Gascoyne type corrector plate. The chromatic aberrations of the Gascoyne plate are eliminated by bending the plate so that both surfaces are concentric about the focal plane. This makes the lens essentially achromatic. Since the glass is not used for color correction, the design can be tailored to use almost any glass which can be obtained in the 20" diameter needed.

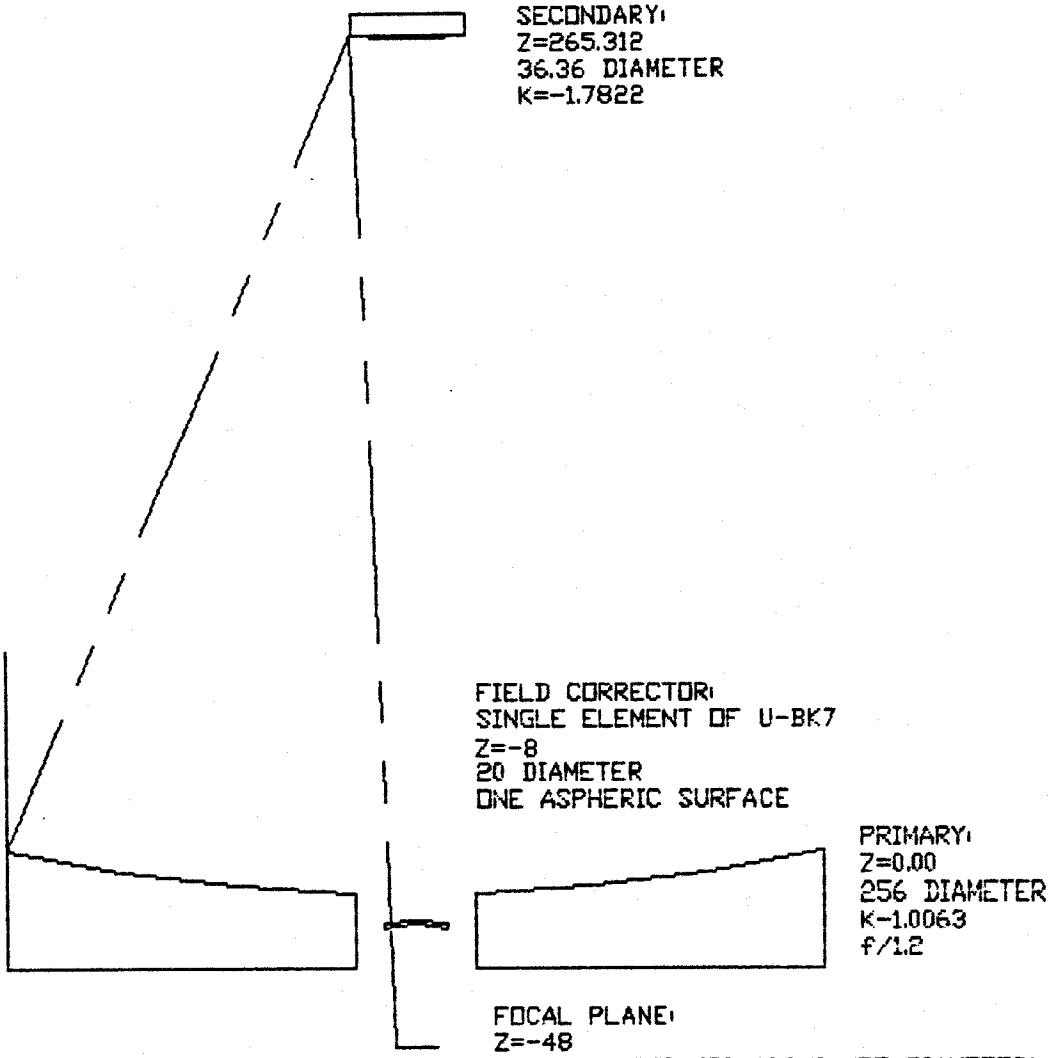
As in the Gascoyne plate, introducing an asphere on the front surface corrects for astigmatism but introduces coma and spherical aberration. Modifying the primary and secondary conic sections partially corrects these aberrations. In addition, the asphere introduces some "secondary" color separation which is corrected by giving the meniscus a slight positive power. The final focal ratio for the corrected field is f/8.98 with a platescale of 3.534 arcseconds/mm. The 20 arcminute diameter field is 13.39 inches in diameter.

A quick check shows that this kind of field corrector is relatively insensitive to tilts and decenters, and works well for modest miscollimation of the secondary mirror.

The f/15 IR focus gives a 2 arcminute diameter field with 0.16 arcsecond rms diameter images on a curved surface. The 2 arcminute field is 2.23 inches in diameter at a platescale of 2.12 arcseconds per millimeter. The field is limited by coma which is opposite in sign to the coma induced by chopping. This leads to the phenomenon of "coma compensation" which permits a greater chop throw for a given limiting image size on the optical axis. This effect is illustrated in the attached sheets.

The attached figures show the system layout, spot diagrams for both flat and curved image surfaces for both the bare configuration and for the corrected field. The tables include the system prescription, wave aberration sums, and estimates of the system sensitivity to tilts, decenters, and defocus.

LIST OF ATTACHMENTS


SECONDARY:
Z=265.312
36.36 DIAMETER
K=-1.7822
FIELD CORRECTOR:
SINGLE ELEMENT OF U-BK7
Z=-8
20 DIAMETER
ONE ASPHERIC SURFACE
PRIMARY:
Z=0.00
256 DIAMETER
K=-1.0063
f/1.2
FOCAL PLANE:
Z=-48
13.4 DIAMETER (20 ARCMINUTE DIAMETER)
3.526 ARSECONDS PER MM
RADIUS OF CURVATURE:
42.55 FOR BARE TELESCOPE
57.16 WITH CORRECTOR

6.5 M f/1.2 TO f/9 R-C WITH FIELD CORRECTOR

SURF	RAD.	THICK	N1	N2	N3		GLASS
0	******	1E+12	1.00000	1.00000	1.00000		AIR
1	-15600	-6738.918	-1.00000	-1.00000	-1.00000	S*	REF
2	-2448.652	6942.11	1.00000	1.00000	1.00000	*	REF
3	1016	25.4	1.00000	1.00000	1.00000	*	~~AIR~~ BK7
4	995	989.3669	1.00000	1.00000	1.00000		AIR
5	-1452.3	0	1.00000	1.00000	1.00000		AIR

ASPHERIC COEFFICIENTS

SURF= 1	C =-6.410256E-05	K =-1.0063	A4 = 0
	A6= 0	A8= 0	A10= 0
SURF= 2	C =-4.083879E-04	K =-1.782218	A4 = 0
	A6= 0	A8= 0	A10= 0
SURF= 3	C = 9.84252E-04	K =-.2608388	A4 = 0
	A6= 0	A8= 0	A10= 0

6.5 M f/1.2 TO f/9 R-C WITH FIELD CORRECTOR
THIRD ORDER

SURF	SPH	COMA	ASTI	DIST	PETZ	LONC	LATC
1	-46.28	-410.32	2.86	0.00	-2.86	0.00	0.00
2	46.94	411.36	-0.20	-0.84	18.25	0.00	0.00
3	-0.16	-1.71	-9.70	-17.22	7.41	-0.00	156.82
4	0.00	-0.03	7.56	4.96	-7.56	0.17	-155.90
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUMS	0.50	-0.72	0.53	-13.10	15.23	0.17	0.92

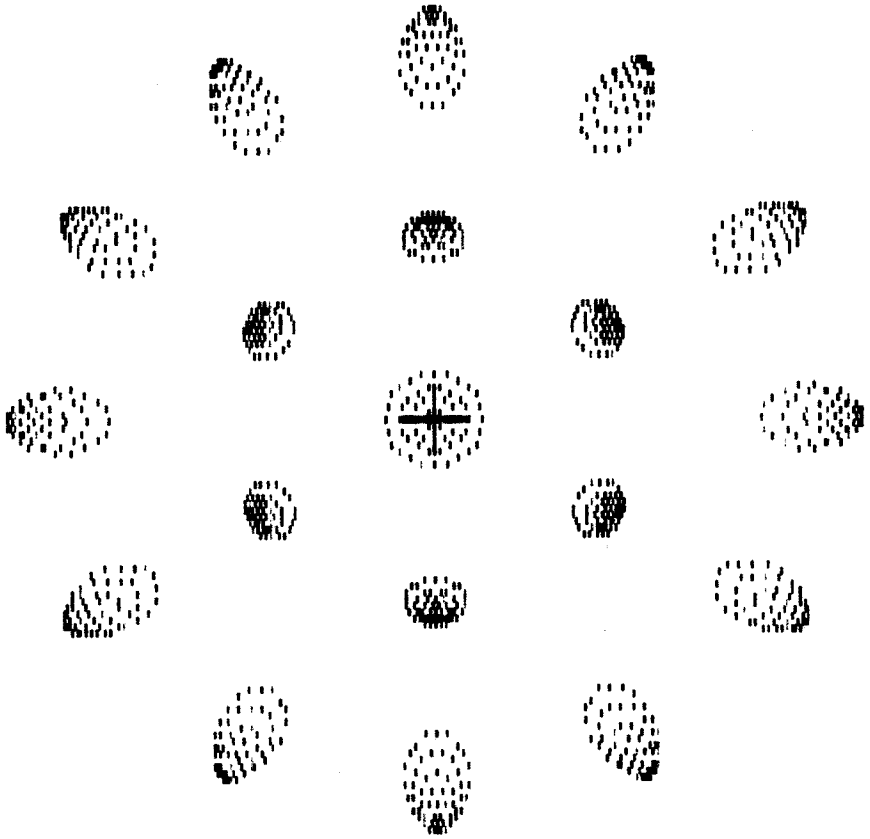
IN MICRONS ~ 20' FIELD DIA

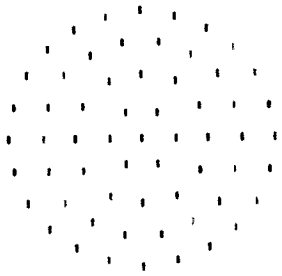
6.5 M f/1.2 TO f/9 R-C WITH FIELD CORRECTOR
THIRD ORDER

SURF	SPH	COMA	ASTI	DIST	PETZ	LONC	LATC
1	-46.28	-205.16	0.72	0.00	-0.72	0.00	0.00
2	46.94	205.68	-0.05	-0.11	4.56	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUMS	0.66	0.52	0.67	-0.11	3.85	0.00	0.00

FIELD CORRECTOR REMOVED IN MICRONS - 10° FIELD DIA

SPOT DIAGRAMS FOR AN f/ 1.2 TO f/ 9 MISMATCHED CASSEGRAIN
FLAT IMAGE FIELD WELL COLLIMATED
IMAGE SHIFT = 0 ARCSECONDS 5 ARCMINUTE DIAMETER FIELD





.5 ARCSECOND

IMAGE SIZES IN ARCSECONDS RMS FOR AN f/ 1.2 TO f/ 9 MISMATCHED CASSEGRAIN
FLAT IMAGE FIELD FOR CX = 0 CY = 0 , VX = 0 VY = 0
SKY CHOP ANGLE = 0 ARCSECONDS 5 ARCMINUTE DIAMETER FIELD
?

.1753389

.1753389 .1753389

.1753389 8.102125E-02 .1753389

8.102125E-02 8.102125E-02

.1753389 .1604424 .1753389

8.102125E-02 8.102125E-02

.1753389 8.102125E-02 .1753389

.175339 .1753389

.1753389

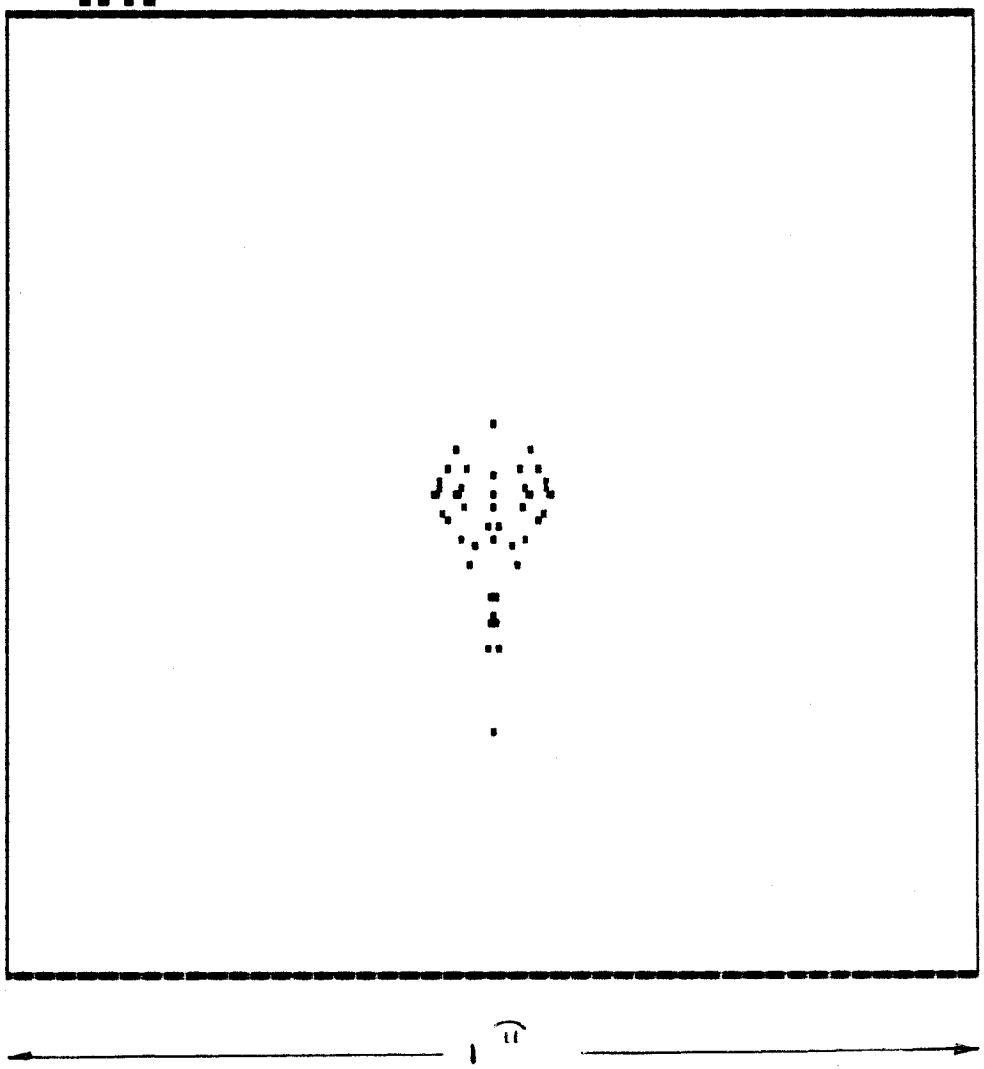
6.5 M f/1.2 TO f/9 R-C WITH FIELD CORRECTOR D

SPOT (FIELD CORRECTOR REMOVED)

DATE: 11-22-1987
TIME: 19:07:47
FIELD ANG .0833333 (5°)
HALF SIZE = .142
X= 0
Y= 85.05138
LAMBDA = 656.27
LAMBDA = 1000
LAMBDA = 350

RMS DIA = 4.206062E-02

= .148"



6.5 M f/1.2 TO f/9 R-C WITH FIELD CORRECTOR

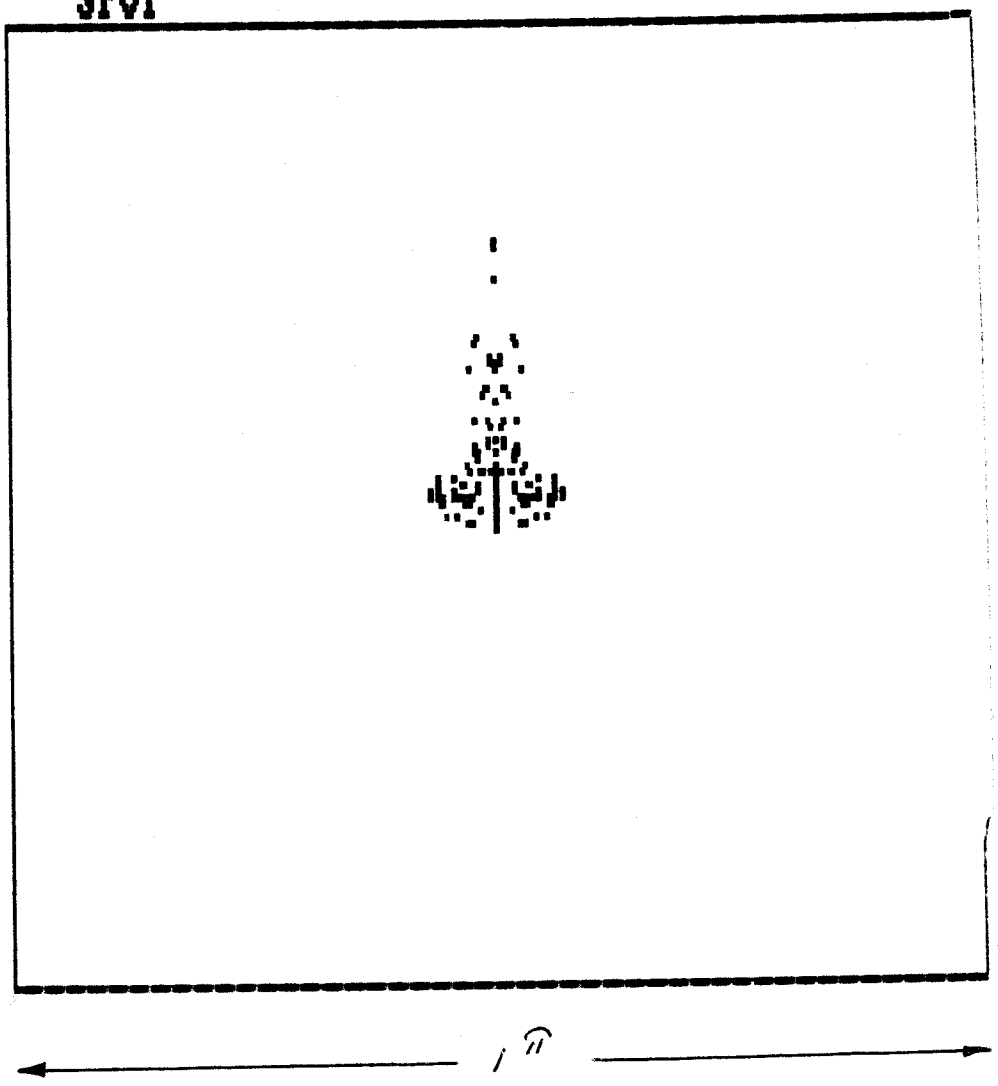
D

SPOT

DATE: 11-22-1987
TIME: 19:04:55
FIELD ANG .166666 (10 ′)
HALF SIZE = .142
X= 0
Y= 169.8086
LAMBDA = 656.27
LAMBDA = 1000
LAMBDA = 350
} (IN 3 COLORS)

RMS DIA = 3.952026E-02

= .139 ″



6.5 M f/1.2 TO f/9 RITCHEY CHRETIEN

6.5 M f/ 1.2 to f/ 9 TELESCOPE

CURVATURE AND ECCENTRICITIES
15.6 M1 VERTEX RADIUS
2.448653 M2 VERTEX RADIUS
-1.005598 , -1.773279 M1 AND M2 CONIC SECTIONS FOR RC
-1 , -1.710059 M1 AND M2 CONIC SECTIONS FOR PURE CASSEGRAIN
-1.452284 PETZVAL RADIUS OF CURVATURE
-1.080961 MEDIONAL (BEST IMAGE FIELD) RADIUS OF CURVATURE

DISTANCES AND DIAMETERS
6.5 M1 DIAMETER
6.738917 M1 TO M2
7.958122 M2 TO FOCAL PLANE
1.219205 M1 VERTEX TO FOCAL PLANE
1.03609 M2 TO ENTRANCE PUPIL
1.03931 M2 VERTEX TO ZCP FOR RC
1.061083 M2 VERTEX TO ZCP FOR CASS
.9993569 PUPIL DIAMETER
.9234412 M2 DIAMETER FOR 20 MINUTE FIELD
.4296717 MINIMUM CASSEGRAIN HOLE DIAMETER FOR 20 MINUTE FIELD

PLATESCALE AND FOCAL LENGTH
58.5 EFFECTIVE FOCAL LENGTH
3.525898 PLATESCALE (ARCSEC PER MM)
340.3389 20 MINUTE FIELD SIZE (MM)

M2 FOCUS TOLERANCES
.2148923 MICRONS dS FOR SPECKLE AT 3.1525 MICRON WAVELENGTH
4.5396 MICRONS dS FOR .1 ARCSEC SEEING
45.396 MICRONS dS FOR ONE ARCSEC SEEING

M2 CENTRATION TOLERANCES
27.9422 MICRONS DECENTER AT ZCP FOR .1 SEC COMA, RC
28.52757 MICRONS DECENTER AT ZCP FOR .1 SEC COMA, CASS
2.1825 MICRONS DECENTER AT M2 C OF C FOR .05 ARCSEC IMAGE MOTION

M1 TILT TOLERANCES
2.041682 IMAGE MOTION TO M1 TILT RATIO (SEC PER SEC)
.1561708 COMA FROM M1 TILT (SEC COMA PER SEC SKY), RC
.1533364 COMA FROM M1 TILT (SEC COMA PER SEC SKY), CASS

M2 TILT TOLERANCES
3.67549 M2 TILT TO SKY ANGLE RATIO (VERTEX CHOP)
6.626156E-02 COMA FROM VERTEX CHOP (SEC/SEC SKY ANGLE)
6.385955 M2 TILT TO SKY ANGLE RATIO (ZERO COMA CHOP, RC)
6.48616 M2 TILT TO SKY ANGLE RATIO (ZERO COMA CHOP, CASS)
1.064894 FIELD ANGLE (ARCMIN) FOR .1 ARCSEC ASTIGMATISM ON AXIS
.1133394 CORRESPONDING M2 ZCP TILT IN DEGREES FOR RC
.1151179 CORRESPONDING M2 ZCP IN DEGREES FOR CASS

PRESCRIPTION FOR A 6500 DIAMETER f/ 1.2 TO f/ 15 MISMATCHED CASSEGRAIN

R1	-15600
T1	-7131.912
R2	-1452.367
T2	8351.111
Q1	-1.0063
Q2	-1.472529

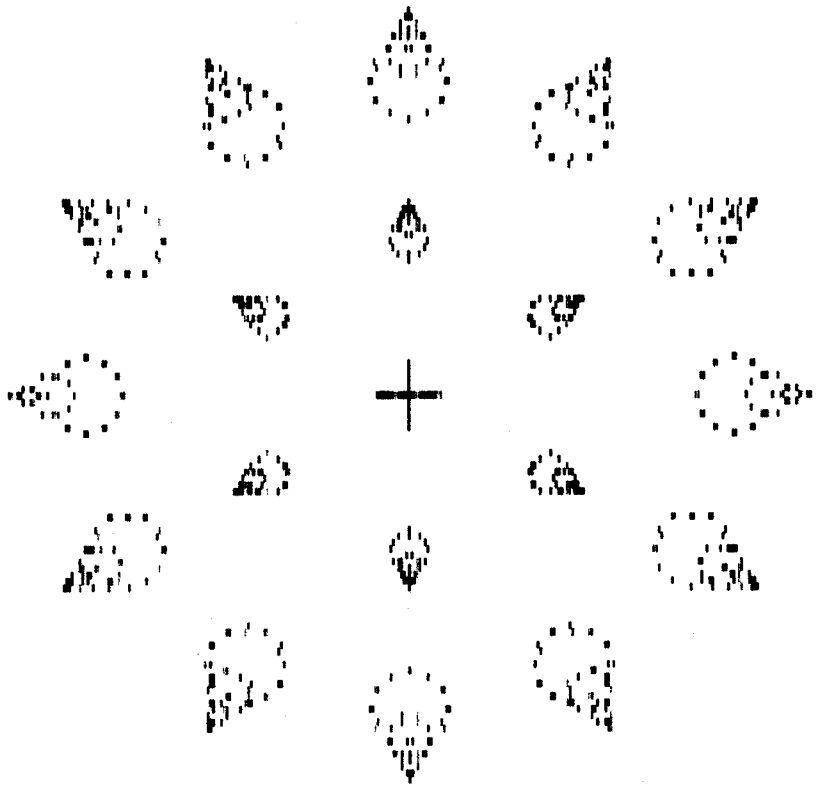
?

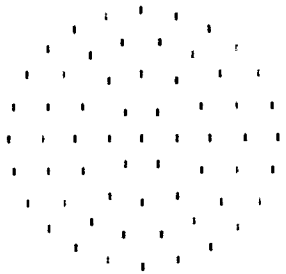
THIRD ORDER WAVE ABERRATIONS FOR AN ALIGNED f/ 1.2 TO f/ 15
MISMATCHED CASSEGRAIN 2 ARCMINUTE FIELD DIAMETER

SPHR	-4.591766E-04	(WAVES AT 999.9999 NM)
COMA	1.117171	
ASTI	4.322814E-02	
PETZ	.2790428	
DIST	-7.614307E-03	

SPOT DIAGRAMS FOR AN f/ 1.2 TO f/ 15 MISMATCHED CASSEGRAIN
MEDIAL IMAGE FIELD
IMAGE SHIFT = 0 ARCSECONDS

WELL COLLIMATED
2 ARCMINUTE DIAMETER FIELD





.5 ARCSECOND

01

IMAGE SIZES IN ARCSECONDS RMS FOR AN f/ 1.2 TO f/ 15 MISMATCHED CASSEGRAIN
MEDIAL IMAGE FIELD FOR CX = 0 CY = 0 , VX = 0 VY = 0
SKY CHOP ANGLE = 0 ARCSECONDS 2 ARCMINUTE DIAMETER FIELD

.1638342

.1638342 .1638342

.1638342 8.188266E-02 .1638342

8.188266E-02 8.188266E-02

.1638342 0 .1638342

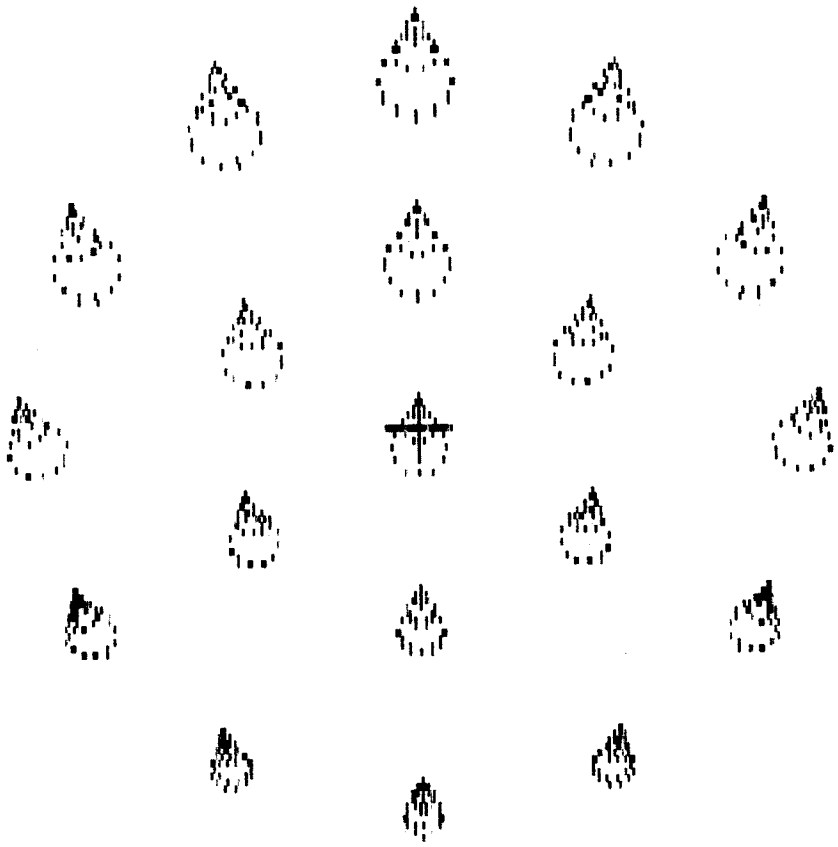
8.188266E-02 8.188266E-02

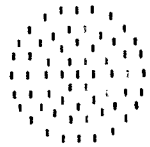
.1638342 8.188266E-02 .1638342

.1638343 .1638342

.1638342

SPOT DIAGRAMS FOR AN f/ 1.2 TO f/ 15 MISMATCHED CASSEGRAIN
MEDIAL IMAGE FIELD FOR Cx = 0 Cy =-.4110374 , CSx = 0 CSy =-.1766302
IMAGE SHIFT = 10 ARCSECONDS 2 ARCMINUTE DIAMETER FIELD





1 ARCSECOND

IMAGE SIZES IN ARCSECONDS RMS FOR AN f/ 1.2 TO f/ 15 MISMATCHED CASSEGRAIN
MEDIAL IMAGE FIELD FOR CX = 0 CY =-.4110374 , VX = 0 VY = 0
SKY CHOP ANGLE = 10 ARCSECONDS 2 ARCMINUTE DIAMETER FIELD
?

.6350001

.6183861 .6183863

.5706826 .5526774 .5706828

.5165474 .5165474

.4985908 .4706912 .4985909

.4357802 .4357802

.4146893 .3893824 .4146894

.3408304 .3408305

.3095193