

# LICK OBSERVATORY

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TECHNICAL REPORT

## **Areal Parabolic Collimators for the Keck II Telescope**

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Santa Cruz, California  
April 28, 1995

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UNIVERSITY OF CALIFORNIA SANTA CRUZ

An imaging spectrograph optical design for the Cassegrain focus of the Keck II telescope has recently been proposed by H. Epps (April 1995). This technical report describes the optical performance of two alternative parabolic mirror collimators and the difficulties of physical packaging. The nominal design consists of a 90-inch focal length collimator followed by a 12.375-inch focal length camera, with a telescope field size of up to 5-arcmin on the sky. One difficulty with a mirror collimator is that the focal surface of the collimator and the exit pupil nearly coincide, so that either the focal surface or the exit pupil must be moved off axis to avoid vignetting. Another difficulty is the overall length of the package, both behind and in front of the focal surface of the telescope.

Four field points are shown for each collimator design case, one point in the center of the field imaged by the collimator and three points at the edges of the imaged field. The camera is assumed to have no aberrations when imaging the final spot diagrams. The box sizes for the spots are 0.5 arcsec, which is 50 microns at the CCD.

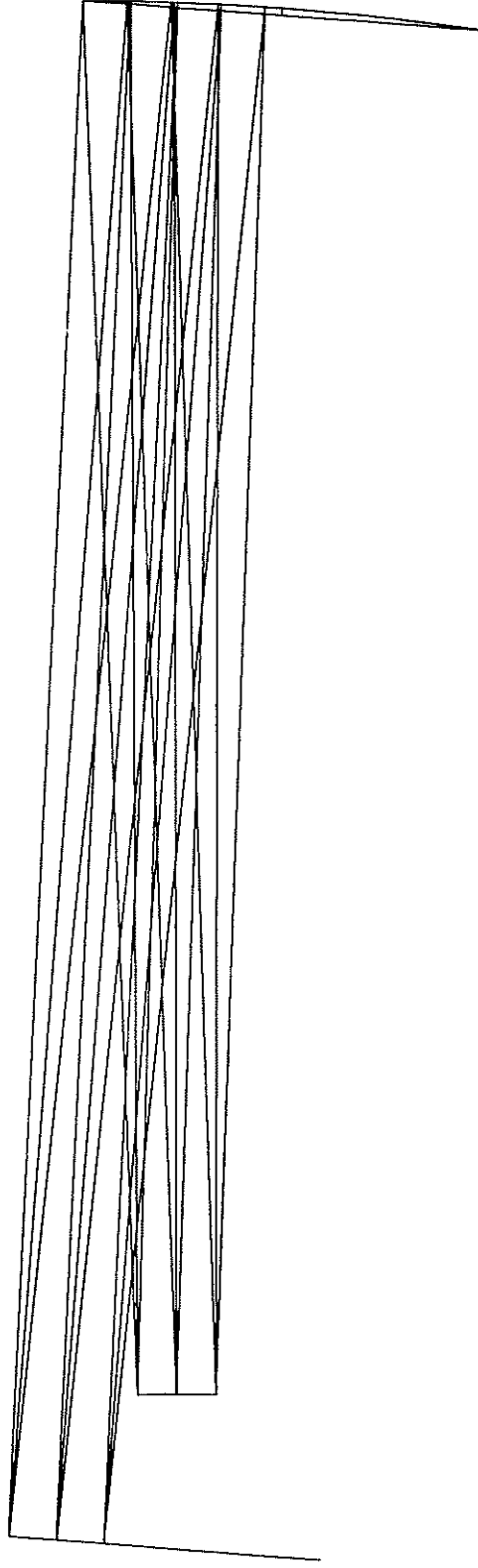
The off-axis mirror case is considered first, where the center of the telescope field is imaged and the collimator mirror is tilted to move the exit pupil away from the focal surface. Three different telescope field sizes are compared in Figures 1 through 6, which show the raytrace of the field points and the final spots. For the 3-, 4-, and 5-arcmin telescope field sizes, the rms spot diameters of the points at the edges of the field are 0.18, 0.26, and 0.36 arcsec, respectively.

Figures 7 through 10 show the opposite case, where the collimator mirror and exit pupil remain on axis while the imaged focal surface is off axis. Two telescope field sizes are shown, for 4- and 5-arcmin, which have worst case rms spot diameters of 0.21 and 0.25 arcsec, respectively.

For an equivalent telescope field size, a design with an on-axis collimator mirror and off-axis telescope field is clearly superior. For a 5-arcmin telescope field, the worst case rms spot diameter is 50 percent larger for the off-axis collimator mirror, and 20 percent worse for a 4-arcmin telescope field size.

The maximum envelope of the Cassegrain module for the Keck II telescope is shown in Figure 11, copied from an early drawing of the DEIMOS (formerly DEEP (formerly MBSS)) instrument. The module has a maximum axial length of 19.7 inches ahead of the focal surface of the telescope, and a maximum axial length of 98.4 inches behind the focal surface. Once a 90-inch collimator mirror is used, the remaining 8.4 inches is barely enough to contain the depth of the mirror and the mirror support structure. The current design of the dispersion section of the spectrograph shown in Figure 12 requires at least 16 inches ahead the focal surface, leaving a marginal 3.7 inches for the echellette grating support. If this space is not adequate, opening up the angle between the focal surface and the exit pupil would allow the imaging mirror to be moved closer to the collimator at the expense of some image quality.

In conclusion, a 90-inch mirror collimator used at the Cassegrain focus of the Keck II telescope with a 5-arcmin telescope field size would have 0.25 arcsec rms image diameters with an on-axis collimator mirror, superior to the 0.36 arcsec images from an off-axis mirror. A 90-inch mirror collimator design has only marginally adequate space in the Cassegrain module, both behind the collimator mirror and behind the echellette grating.



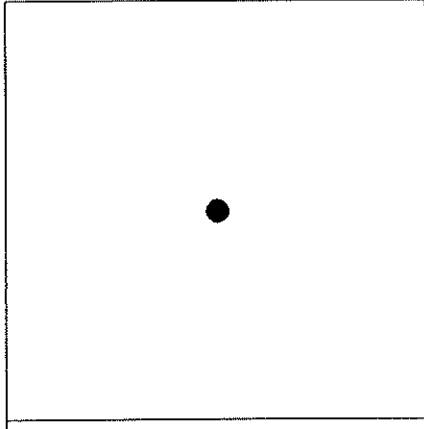
3D LAYOUT

3 ARCMIN FOV / 90" COLLIMATOR / 4.5 DEG OFF AXIS  
THU APR 27 1995

BRIAN SUTIN  
UCO/LICK OBSERVATORY  
SANTA CRUZ, CA 95064

Figure 1

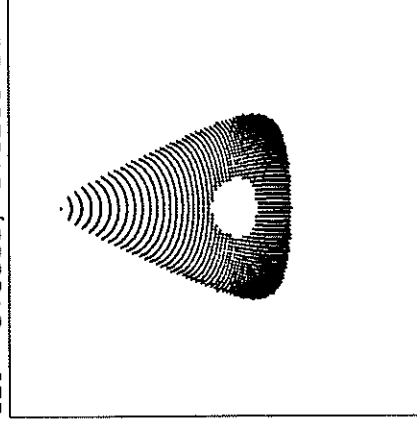
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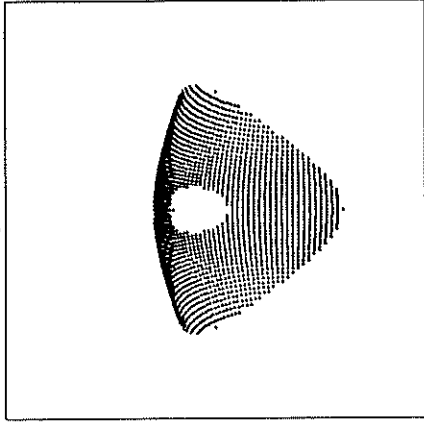
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OBJ: 0.0000, 0.0250 DEG



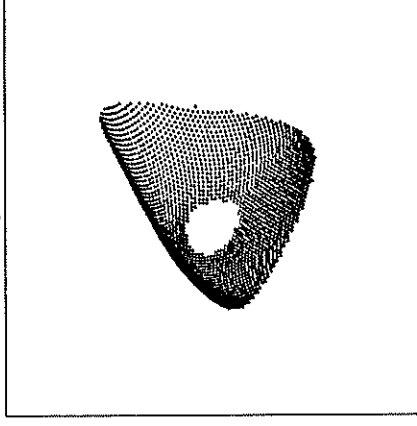
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IMA: 0.000, 0.353 IN

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IMA: -0.353, 0.000 IN

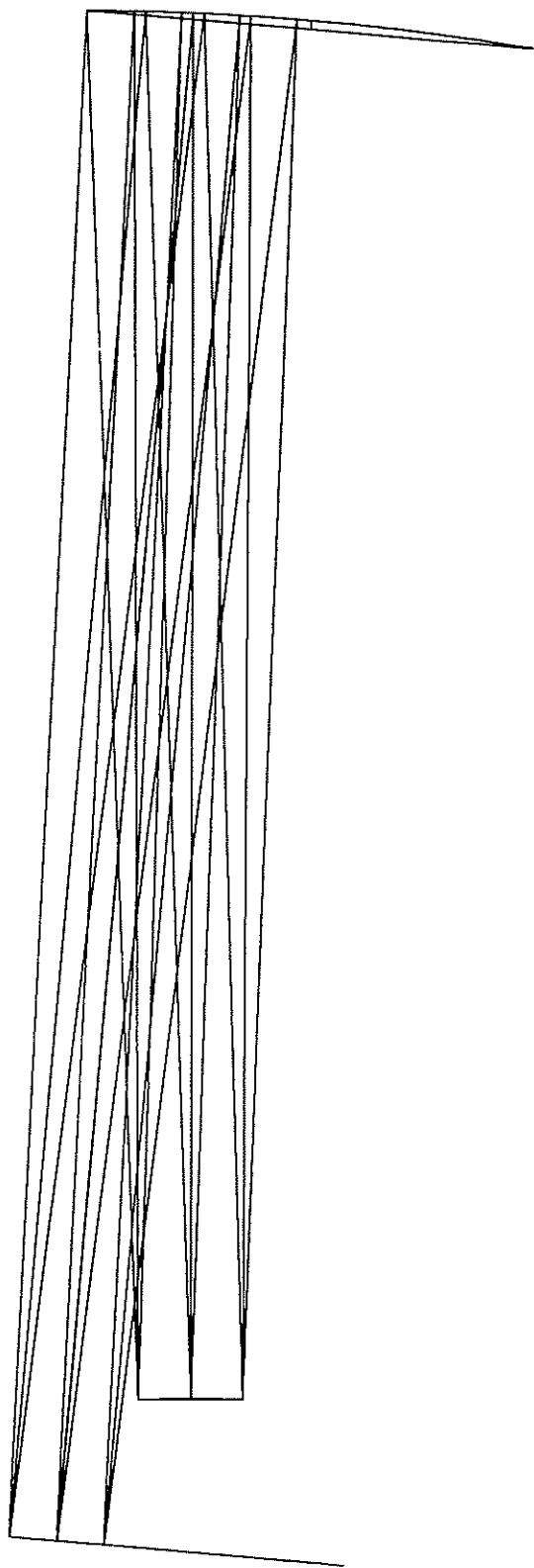
SPOT DIAGRAM

3 ARCMIN FOV / 90" COLLIMATOR / 4.5 DEG OFF AXIS  
THU APR 27 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.644	9.070	9.007	9.038
GEO RADIUS	1.269	15.039	18.782	17.480
BOX WIDTH	50			
			REFERENCE	: CENTROID

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Figure 2



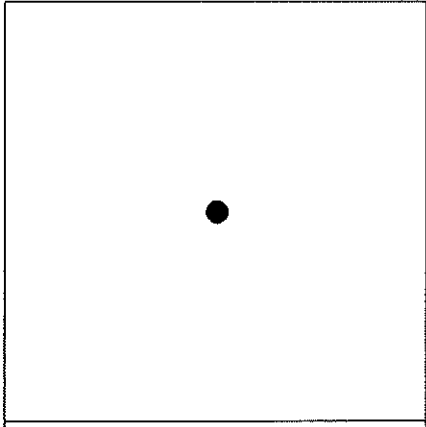
3D LAYOUT

4 ARCMIN FOV / 90" COLLIMATOR / 5 DEG OFF AXIS  
THU APR 27 1995

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Figure 3

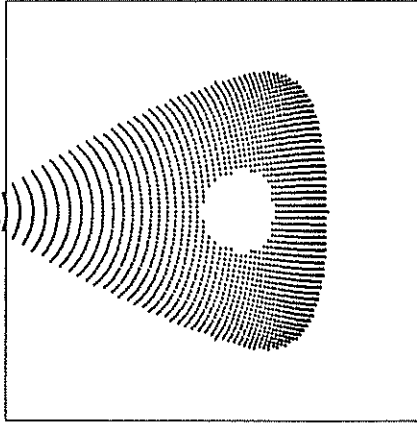
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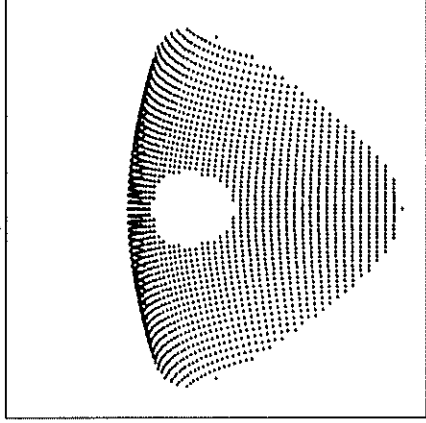
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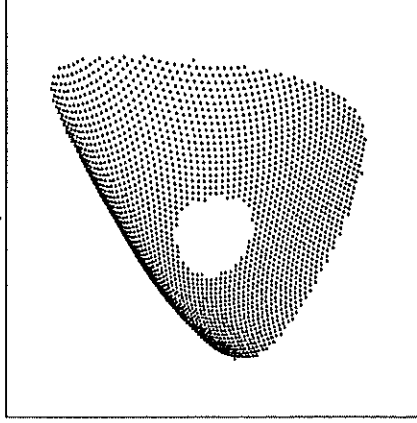
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IMA: 0.000, 0.471 IN

OBJ: 0.0333, 0.0000 DEG



IMA: -0.470, 0.001 IN

SPOT DIAGRAM

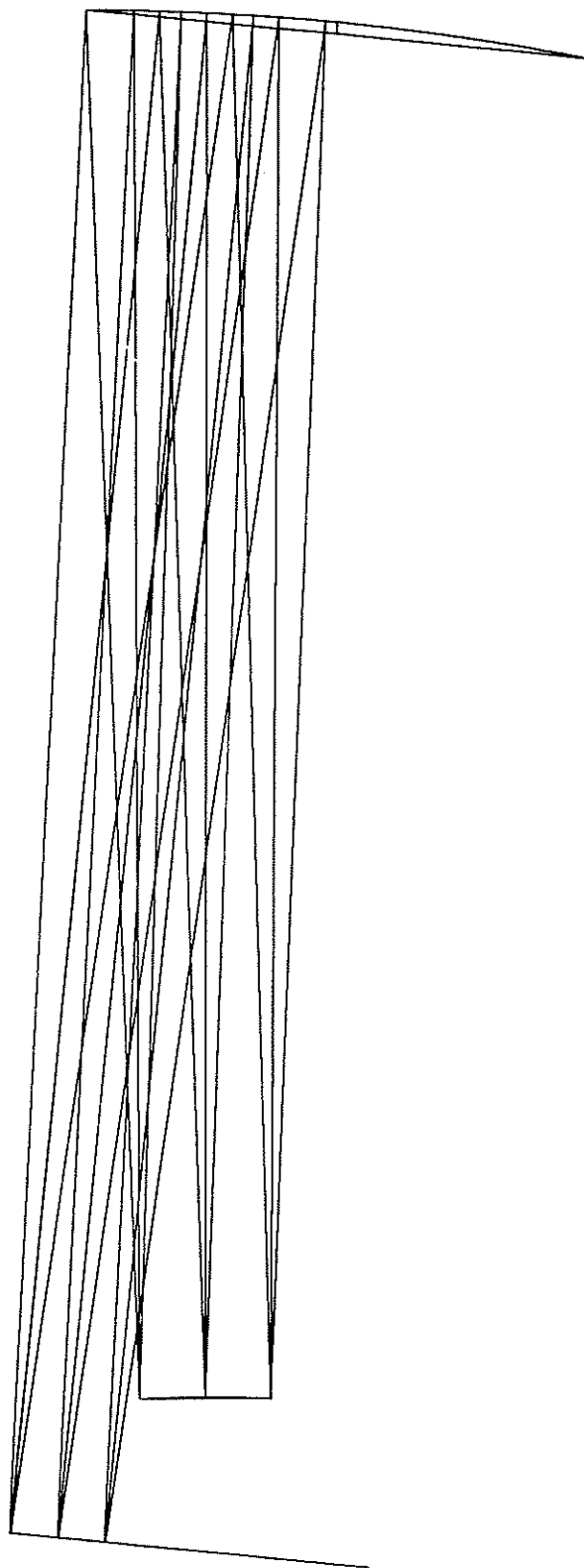
4 ARCMIN FOV / 90" COLLIMATOR / 5 DEG OFF AXIS

THU APR 27 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.644	13.378	13.257	13.317
GEO RADIUS	1.269	21.994	26.648	24.952
BOX WIDTH	50			
REFERENCE	: CENTROID			

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Figure 4



3D LAYOUT

5 ARCMIN FOV / 90" COLLIMATOR / 5.5 DEG OFF AXIS

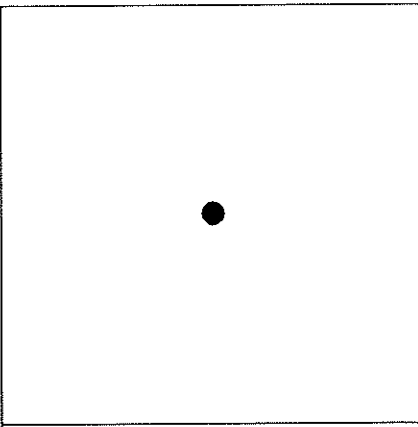
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THU APR 27 1995

Figure 5



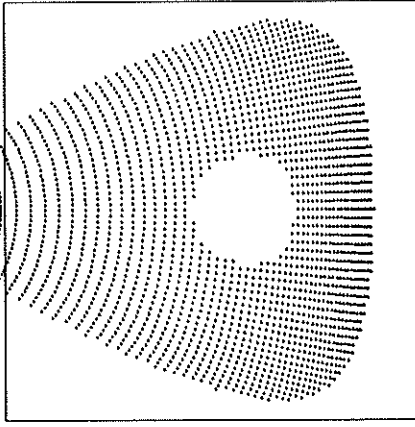
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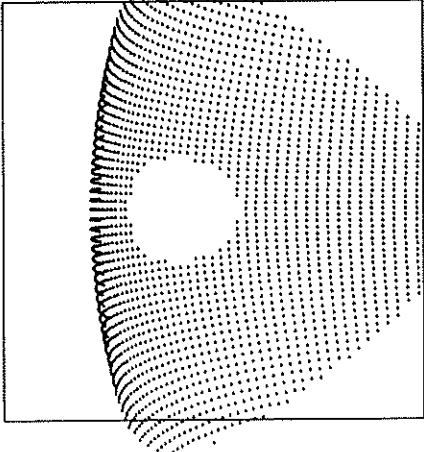
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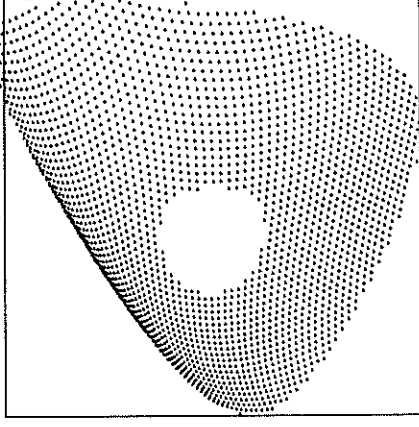
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IMA: 0.000, 0.589 IN

OBJ: 0.0417, 0.0000 DEG



IMA: -0.588, 0.001 IN

SPOT DIAGRAM

5 ARCMIN FOV / 90" COLLIMATOR / 5.5 DEG OFF AXIS  
THU APR 27 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.644	18.353	18.148	18.251
GEO RADIUS	1.268	29.719	35.520	33.442
BOX WIDTH	50			
			REFERENCE	: CENTROID

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Figure 6

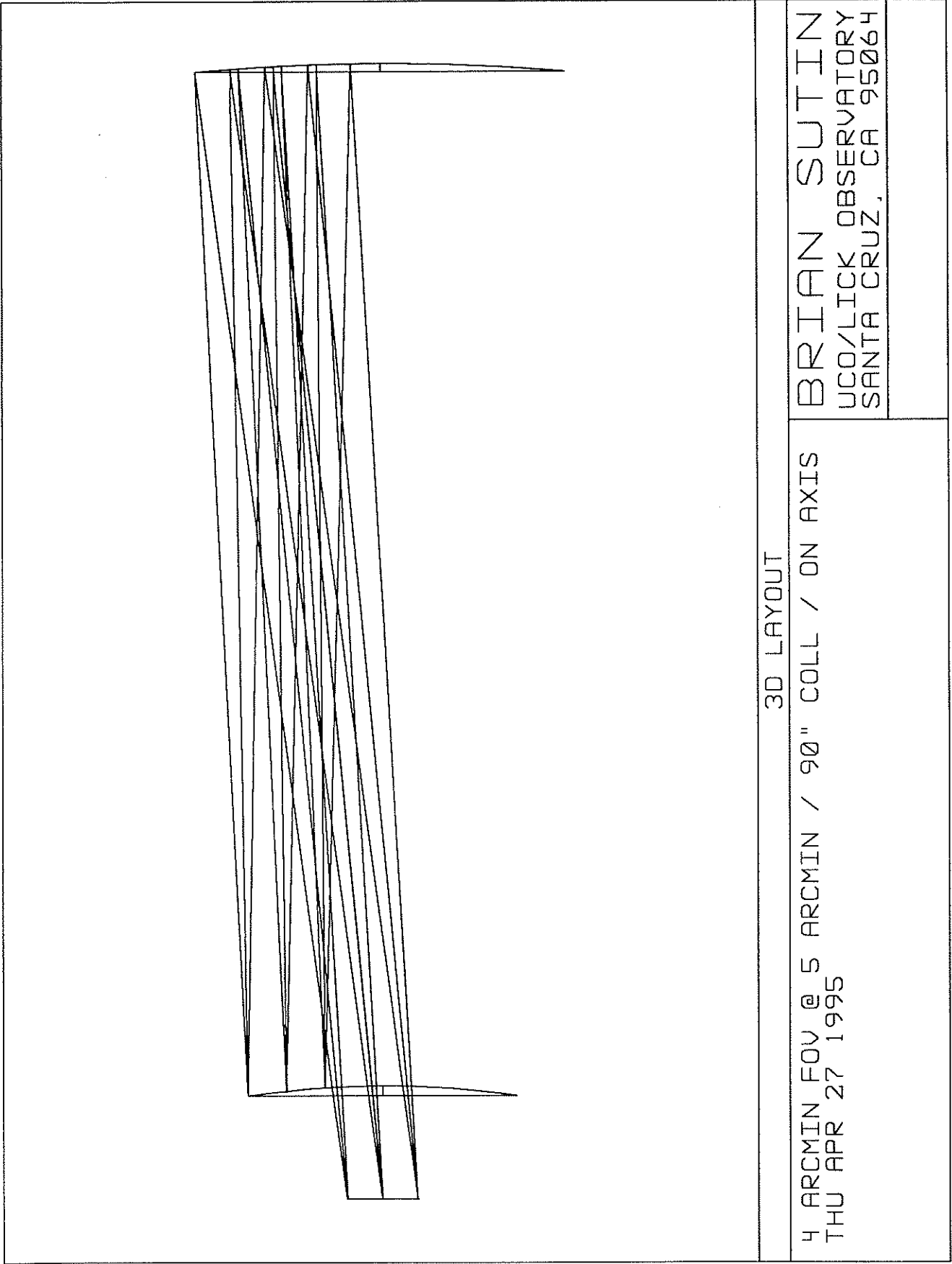
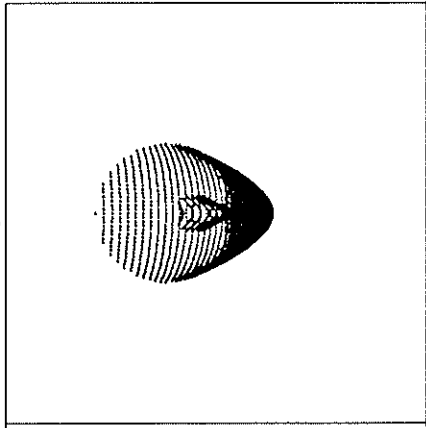


Figure 7

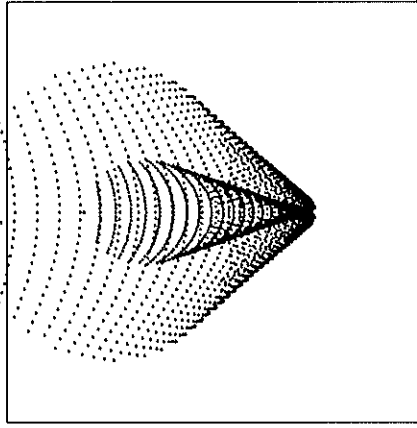
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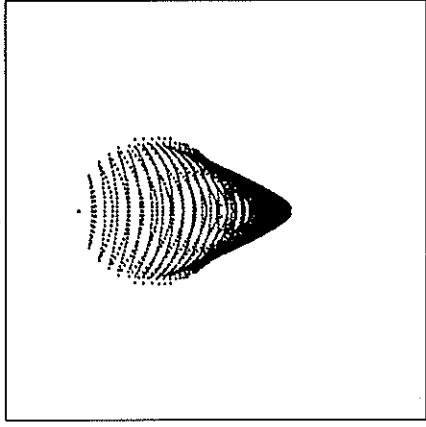
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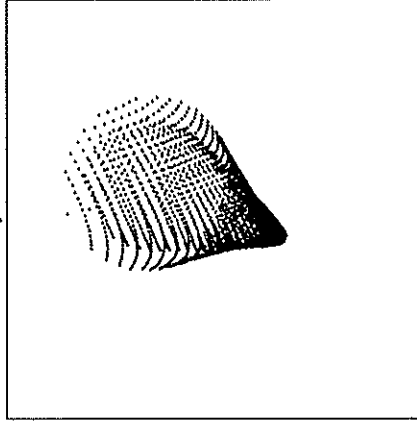
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IMA: 0.000, -1.179 IN

OBJ: 0.0333, 0.0833 DEG



IMA: -0.472, -1.180 IN

SPOT DIAGRAM

4 ARCMIN FOV @ 5 ARCMIN / 90" COLL / ON AXIS  
THU APR 27 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	5.873	6.844	10.569	7.333
GEO RADIUS	14.399	16.440	30.043	18.543
BOX WIDTH	50			
				REFERENCE : CENTROID

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Figure 8

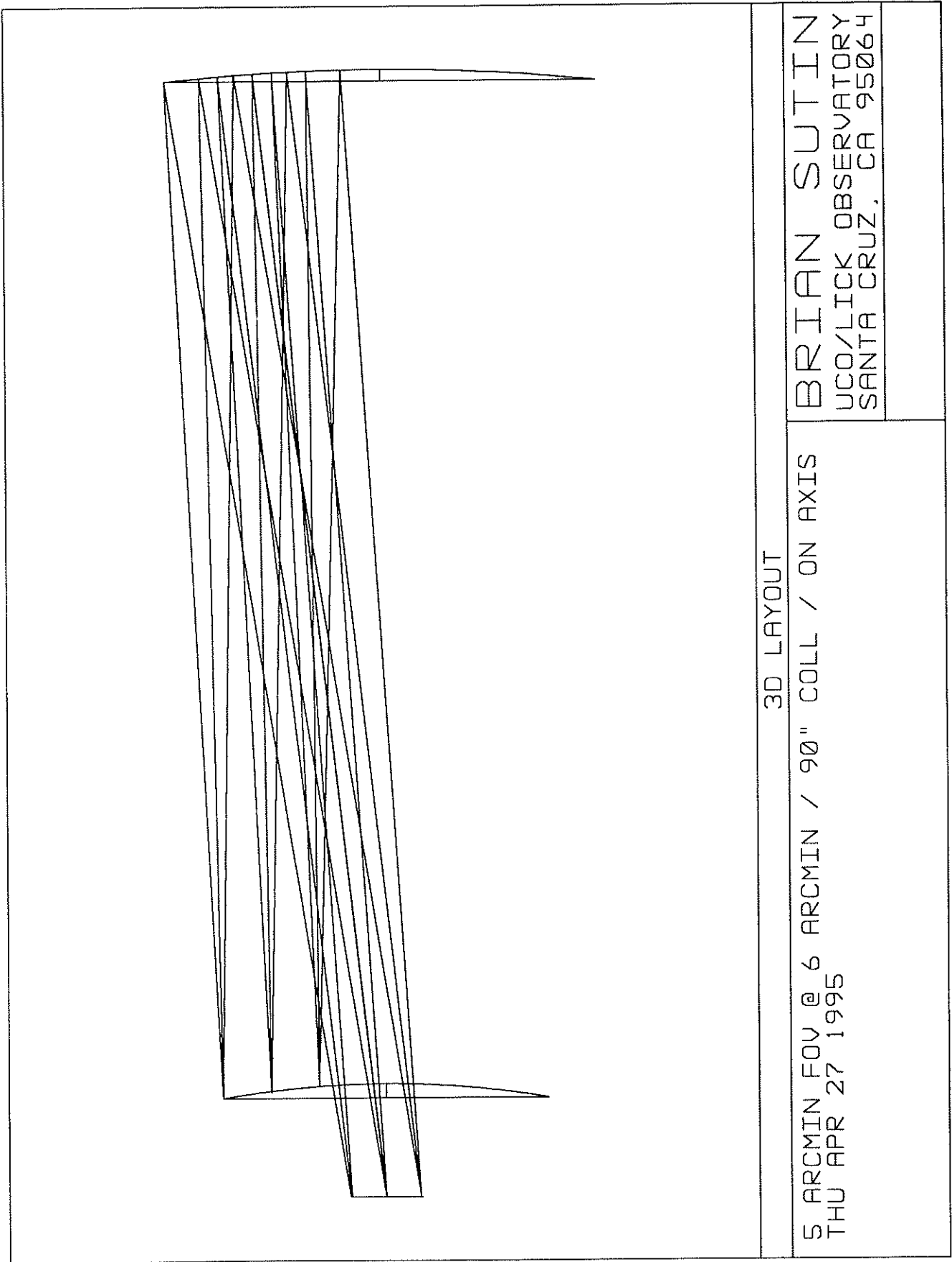
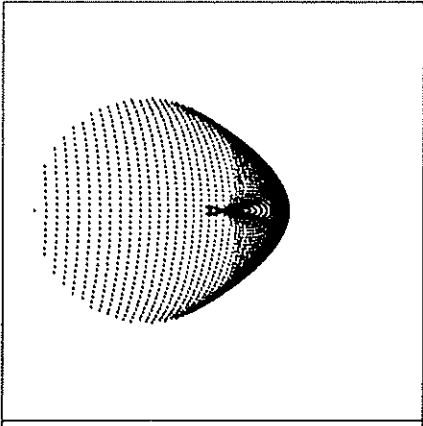


Figure 9

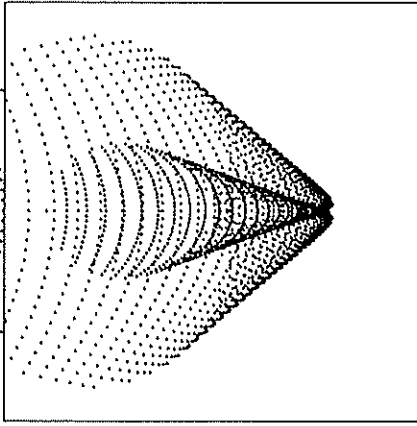
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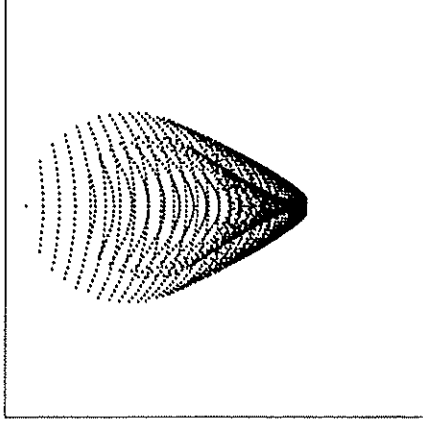
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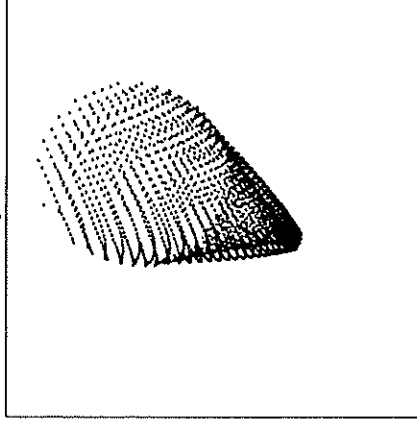
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IMA: 0.0000, -1.417 IN

OBJ: 0.0417, 0.1000 DEG



IMA: -0.590, -1.417 IN

SPOT DIAGRAM

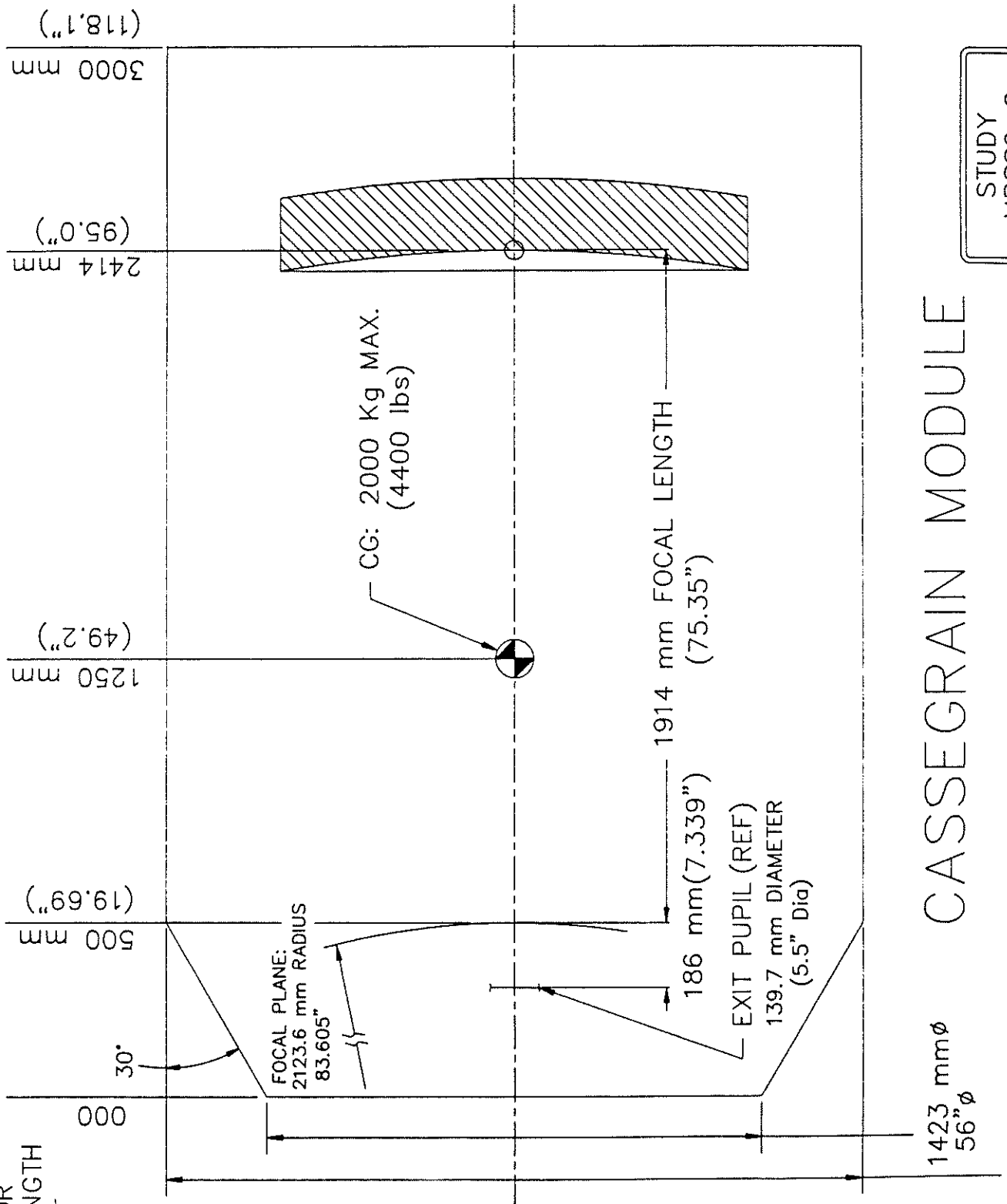
5 ARCMIN FOV @ 6 ARCMIN / 90" COLL / ON AXIS  
 THU APR 27 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	9.299	8.617	12.654	8.942
GEO RADIUS	21.267	22.558	35.591	22.050
BOX WIDTH	50			
			REFERENCE	: CENTROID

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Figure 10

TEK LIGHTWEIGHT  
 ABOLIC MIRROR  
 15" FOCAL LENGTH  
 7" RADIUS)  
 DIAMETER



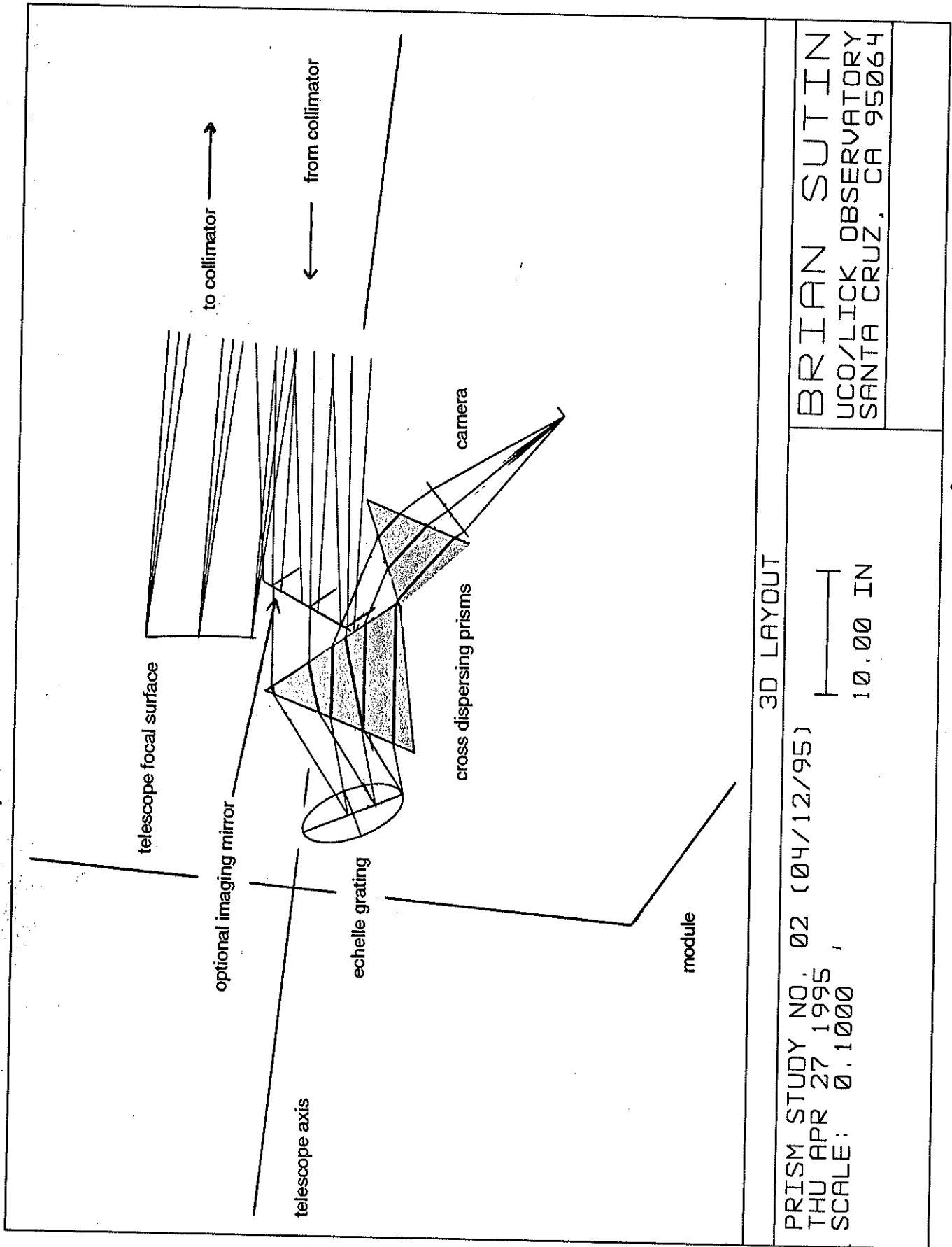
*Handwritten note:* H... for... (10)

STUDY  
 MBSS6-C  
 j.o. 2-23-92

# CASSEGRAIN MODULE

Figure 11

1423 mm φ  
 56" φ  
 2000 mm φ  
 78.74" φ



3D LAYOUT

PRISM STUDY NO. 02 (04/12/95)  
 THU APR 27 1995  
 SCALE: 0.1000

10.00 IN

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Figure 12

UNIVERSITY OF CALIFORNIA OBSERVATORIES

LICK OBSERVATORY TECHNICAL REPORTS

No. 87A

**ADDENDUM TO**

**AREAL PARABOLIC COLLIMETERS  
FOR THE KECK II TELESCOPE**

Brian M. Sutin

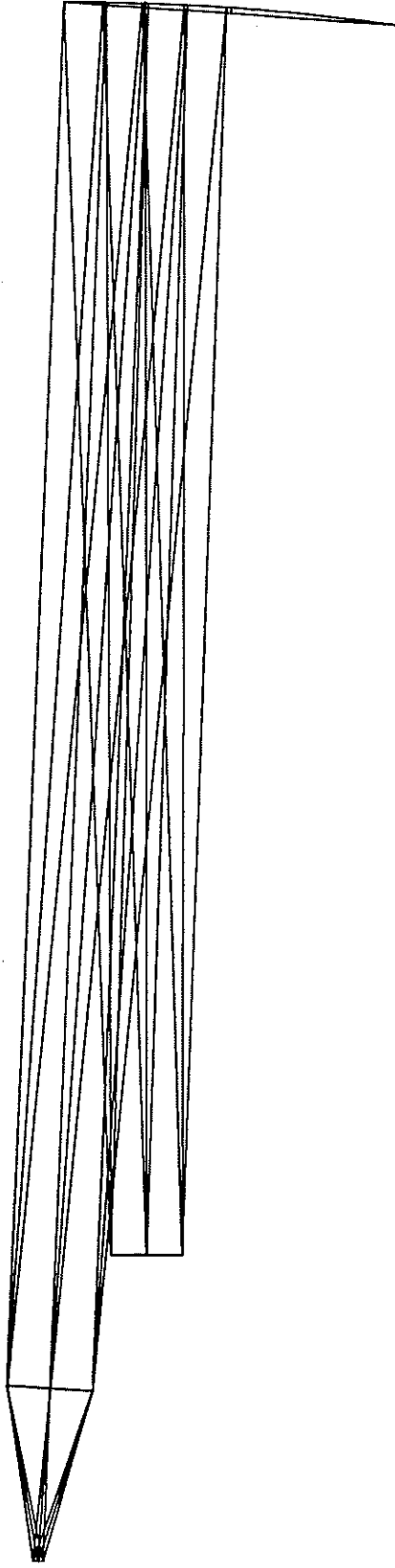
Santa Cruz, California  
August 15, 1995



The collimator for the ESI instrument for the Keck II telescope is a 3.0-arcmin on-axis field of view off-axis parabolic mirror. The collimator angle between the entrance and exit pupil changes the maximum distance from the focal surface of the telescope to the pick-off mirror for direct imaging, which intercepts the collimated light returning from the collimator without blocking the 3.0-arcmin field of view. Although careful engineering has not been done to find the minimum distance required to prevent the grating inside the module, a pick-off mirror distance of about 2.0 inches seems minimally adequate for a single mounted grating. With any of the collimator angles except the 4.0-degree choice, a exit-pupil moving curved entrance window is required to move the exit pupil back to the save location relative to the result of the spectrograph and camera.

The following figures show raytraces various cases of collimator angles, as well as spot diagrams for each, assuming a perfect camera. The spots are for points at the center and at 1.0 arcmin and 1.5 arcmin angular radii from the center of the field. All boxes are 0.5 arcsec, or 50 microns at the CCD chip. The following Table summarizes the pupil-mirror distance, and the maximum rms diameter spot size for a 3.0-arcmin field.

Collimator Angle degrees	Pupil-Mirror Distance inches	Maximum Spot Diameter arcsec
4.0	1.5	0.16
4.5	7.2	0.18
5.0	11.9	0.20
5.5	16.0	0.22
6.0	20.2	0.24



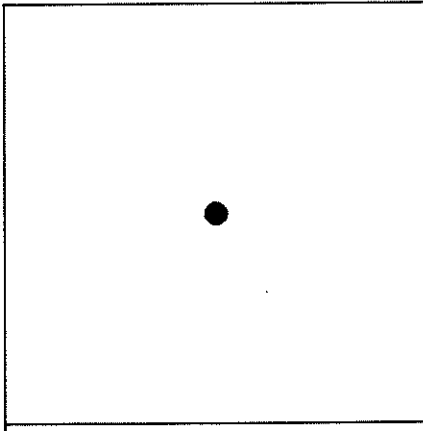
3D LAYOUT

3 ARCMIN FOV / 90" COLLIMATOR /  
 TUE AUG 15 1995  
 SCALE: 0.0833

4.0 DEG OFF AX  
 12.00 IN

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 SANTA CRUZ, CA 95064

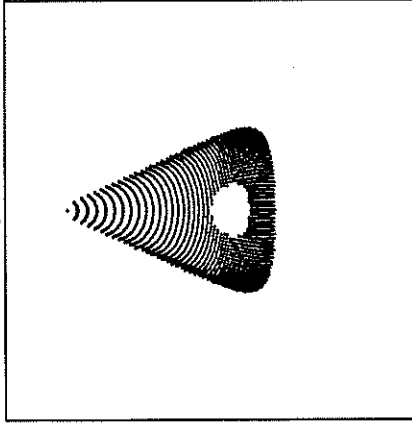
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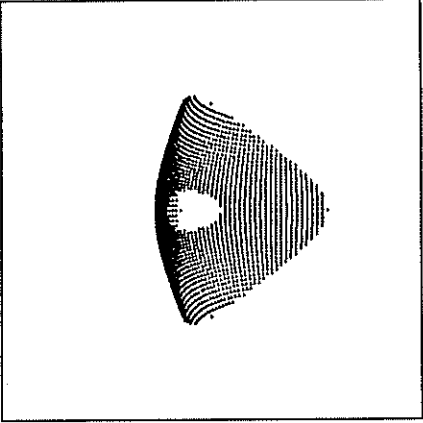
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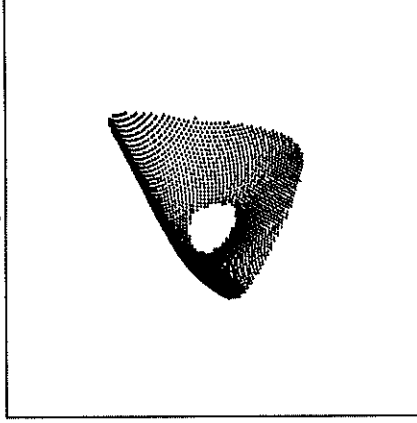
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IMA: 0.000, 0.353 IN

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IMA: -0.353, 0.000 IN

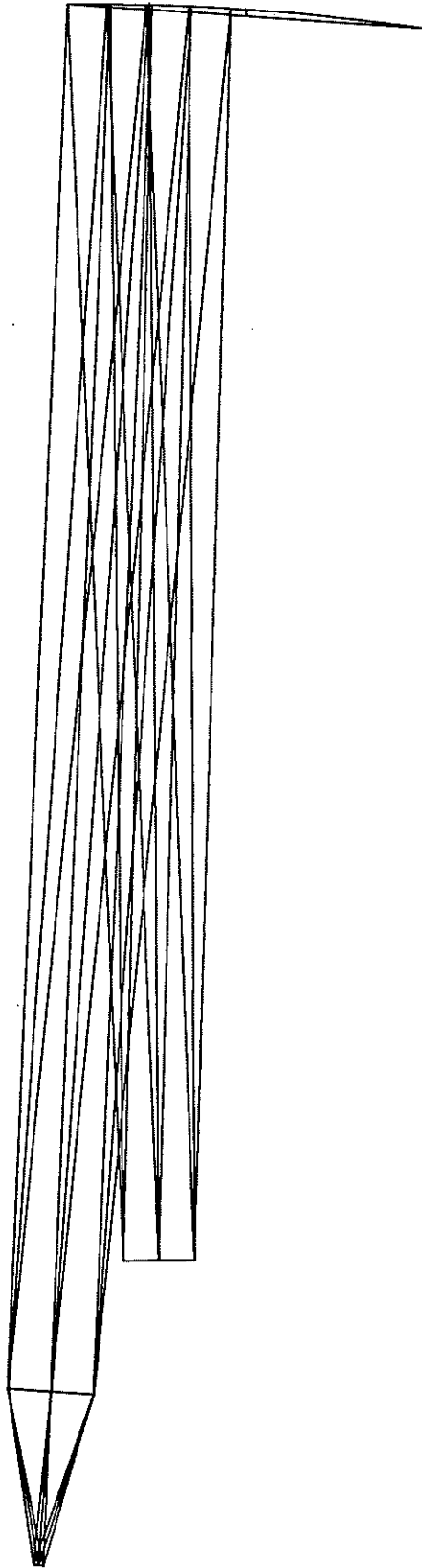
SPOT DIAGRAM

3 ARCMIN FOV / 90" COLLIMATOR / 4.0 DEG OFF AXIS

TUE AUG 15 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.645	8.128	8.069	8.098
GEO RADIUS	1.269	13.700	17.461	16.166
BOX WIDTH	50			
	REFERENCE : CENTROID			

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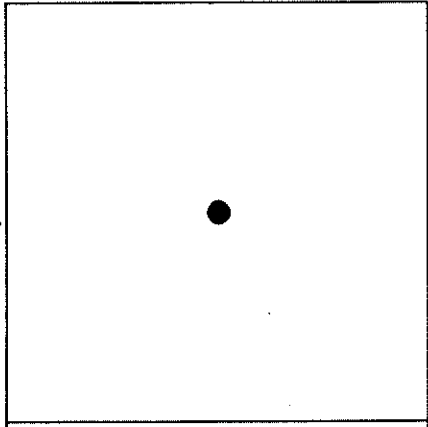


3D LAYOUT

3 ARCMIN FOV / 90" COLLIMATOR / 4.5 DEG OFF AXIS  
TUE AUG 15 1995  
SCALE: 0.0833

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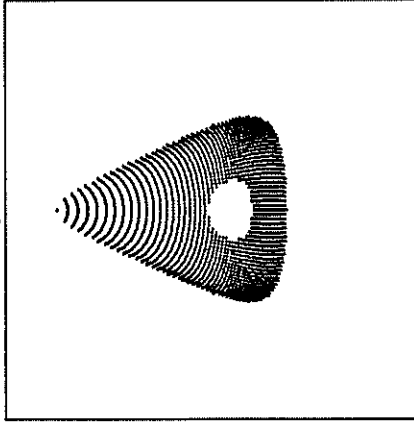
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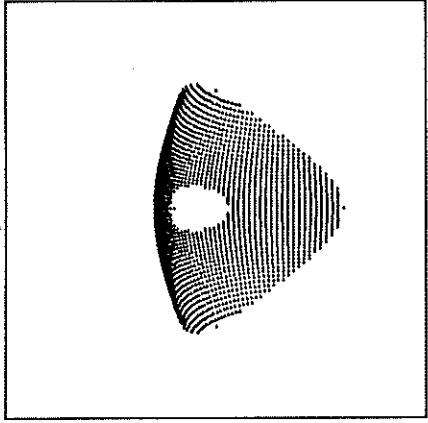
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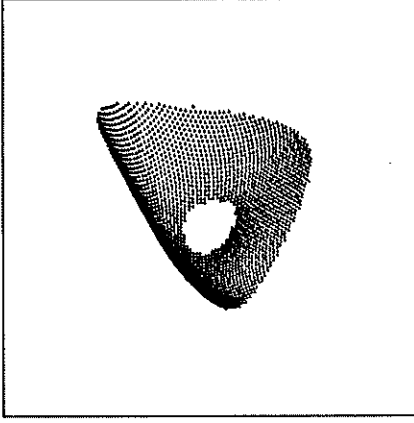
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OBJ: 0.0000, -0.0250 DEG



IMA: 0.000, 0.353 IN

OBJ: 0.0250, 0.0000 DEG



IMA: -0.353, 0.000 IN

SPOT DIAGRAM

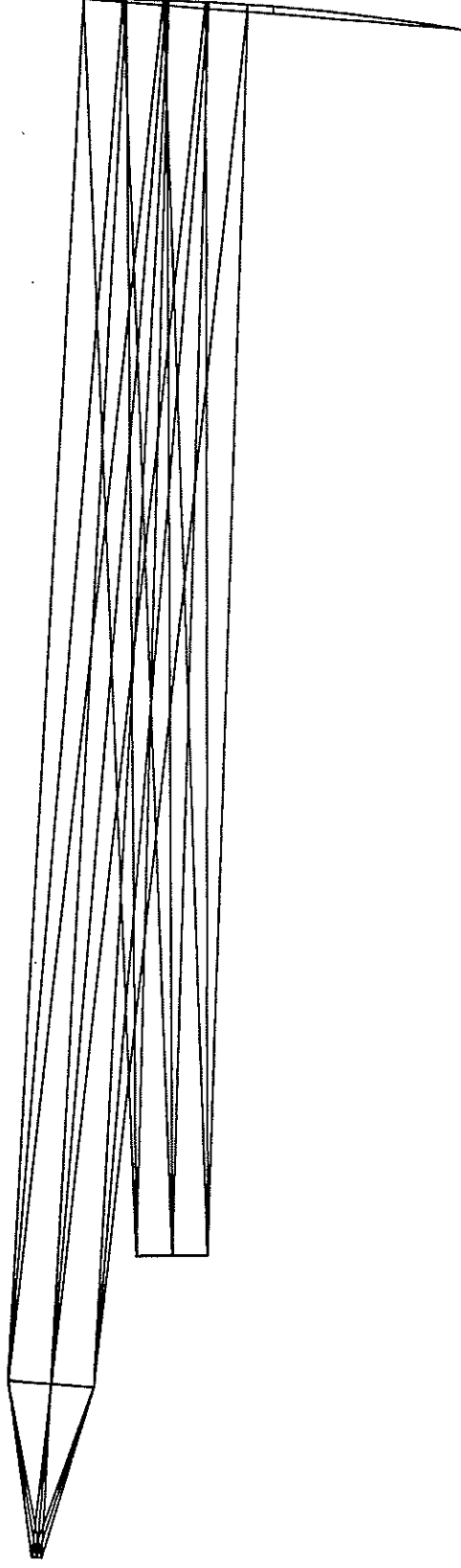
3 ARCMIN FOV / 90" COLLIMATOR / 4.5 DEG OFF AXIS

TUE AUG 15 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.644	9.070	9.007	9.038
GEO RADIUS	1.269	15.039	18.782	17.480
BOX WIDTH	50			

REFERENCE : CENTROID

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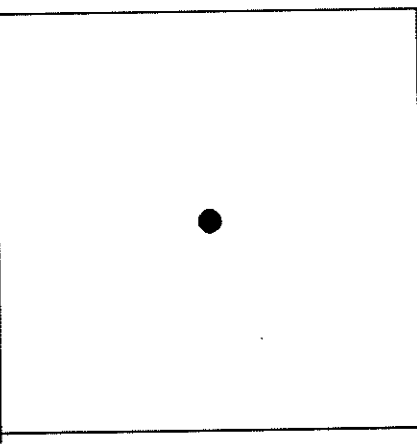


3D LAYOUT

3 ARCMIN FOV / 90" COLLIMATOR / 5.0 DEG OFF AXIS  
TUE AUG 15 1995  
SCALE: 0.0833

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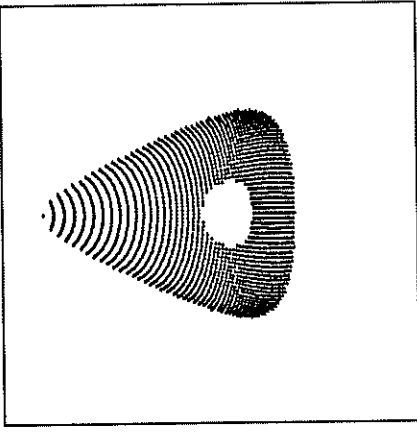
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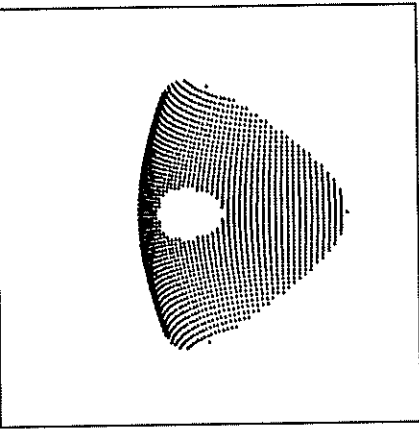
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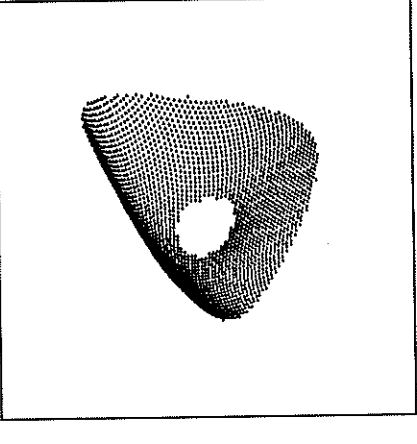
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OBJ: 0.0000, -0.0250 DEG



IMA: 0.000, 0.353 IN

OBJ: 0.0250, 0.0000 DEG



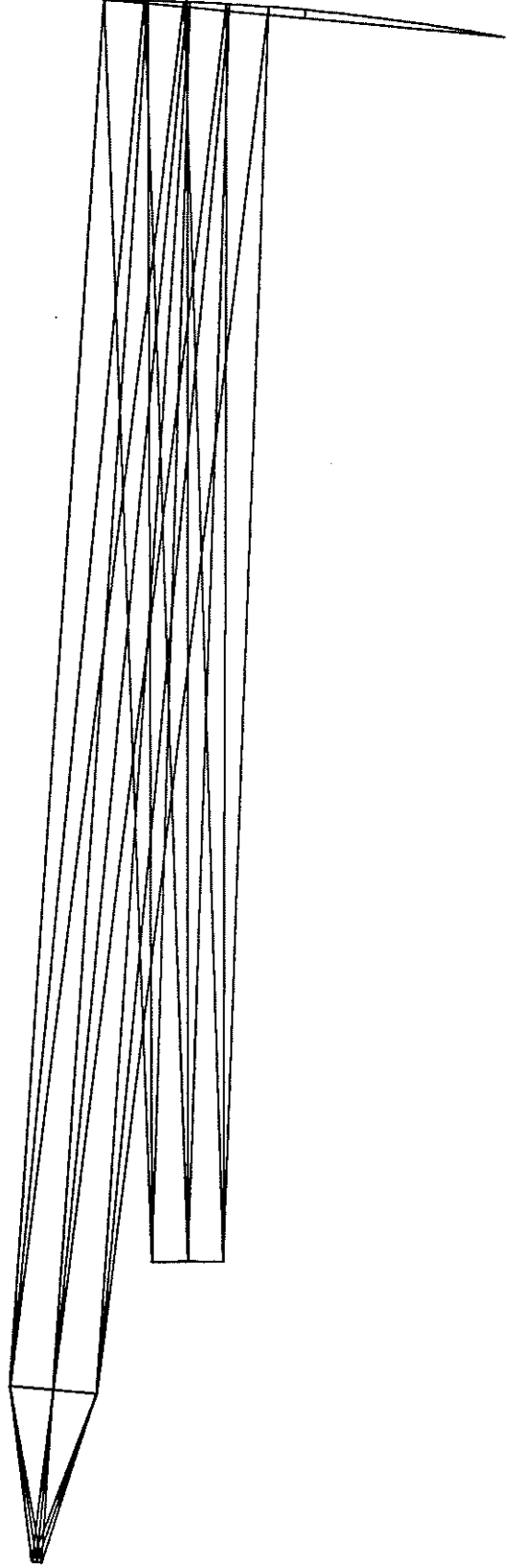
IMA: -0.353, 0.000 IN

SPOT DIAGRAM

3 ARCMIN FOV / 90" COLLIMATOR / 5.0 DEG OFF AXIS  
TUE AUG 15 1995 UNITS ARE MICRONS.

FIELD :	1	2	3	4
RMS RADIUS :	0.644	10.018	9.950	9.984
GEO RADIUS :	1.269	16.376	20.102	18.793
BOX WIDTH :	50			
			REFERENCE :	CENTROID

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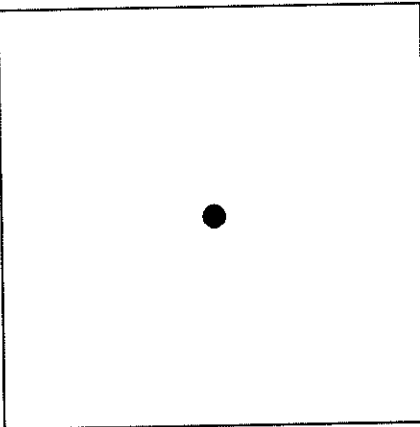
3D LAYOUT

3 ARCMIN FOV / 90" COLLIMATOR / 5.5 DEG OFF AX  
TUE AUG 15 1995  
SCALE: 0.0833

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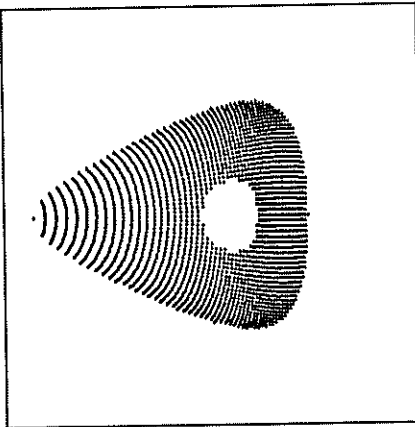
OBJ: 0.0000, 0.0000 DEG



50.00

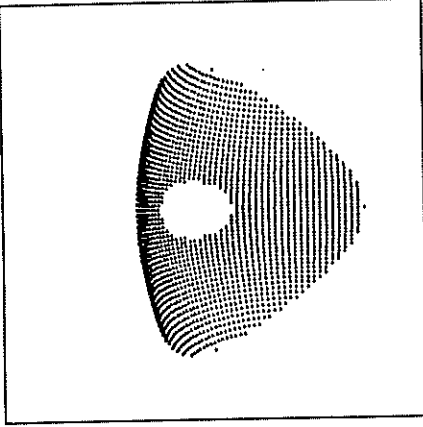
IMA: 0.000, -0.000 IN

OBJ: 0.0000, 0.0250 DEG



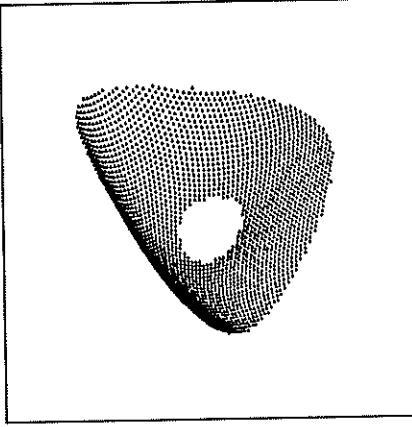
IMA: 0.000, -0.352 IN

OBJ: 0.0000, -0.0250 DEG



IMA: 0.000, 0.353 IN

OBJ: 0.0250, 0.0000 DEG



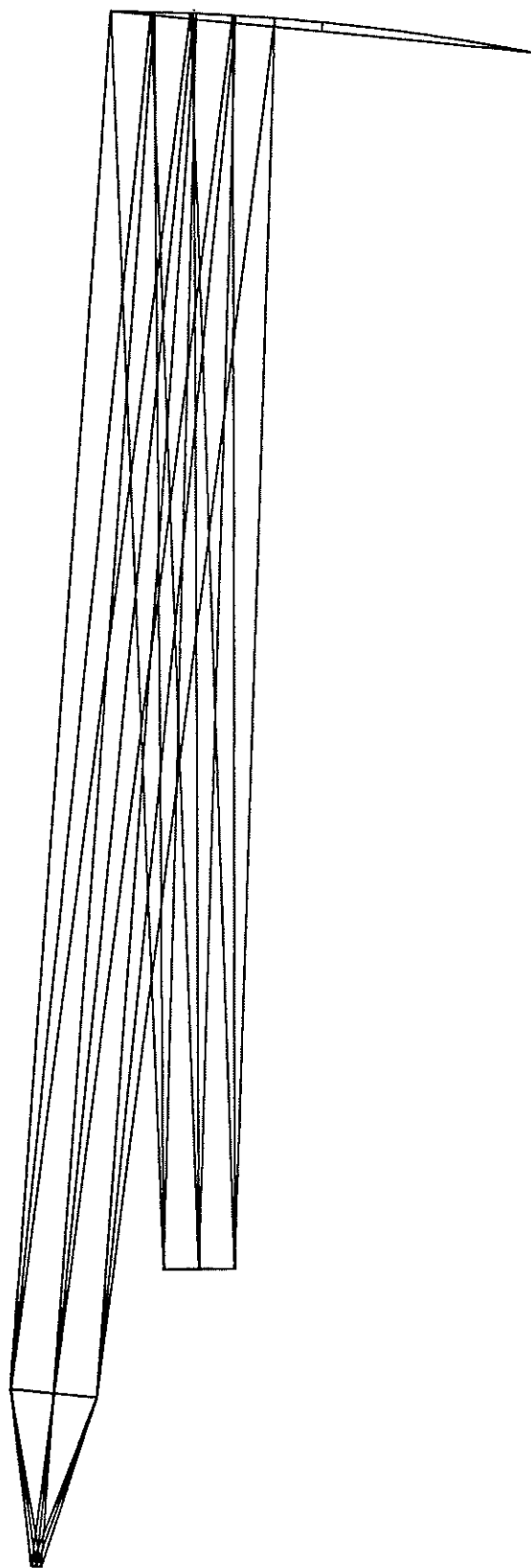
IMA: -0.352, 0.001 IN

SPOT DIAGRAM

3 ARCMIN FOV / 90" COLLIMATOR / 5.5 DEG OFF AXIS  
TUE AUG 15 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.644	10.971	10.897	10.934
GEO RADIUS	1.268	17.714	21.419	20.104
BOX WIDTH	50			
			REFERENCE	: CENTROID

BRIAN SUTIN  
UCO/LICK OBSERVATORY  
SANTA CRUZ, CA 95064

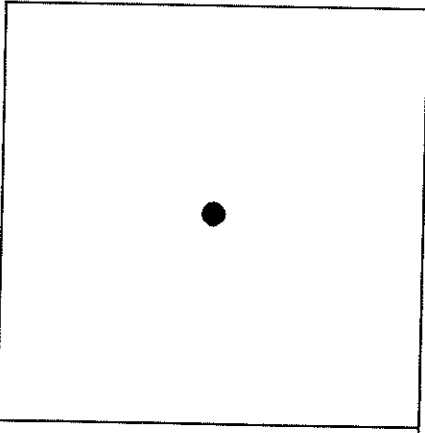


3D LAYOUT

3 ARCMIN FOV / 90" COLLIMATOR / 6.0 DEG OFF AX  
TUE AUG 15 1995  
SCALE: 0.0833

ABRIAN SUTIN  
UCO/LICK OBSERVATORY  
SANTA CRUZ, CA 95064

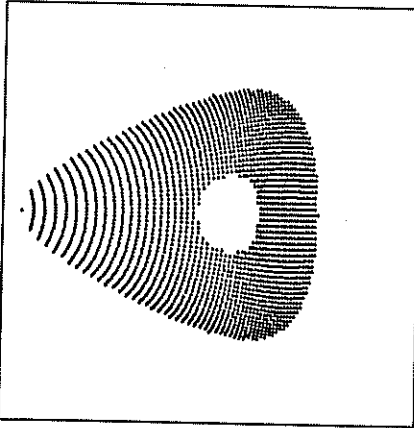
OBJ: 0.0000, 0.0000 DEG



50.00

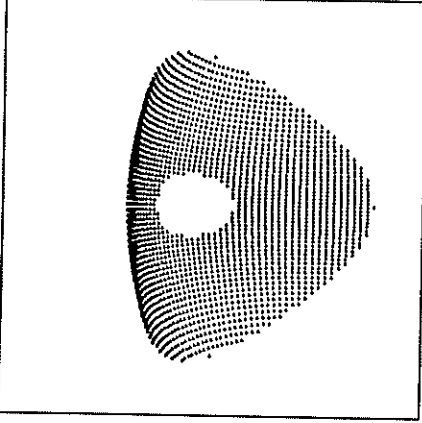
IMA: 0.000, -0.000 IN

OBJ: 0.0000, 0.0250 DEG



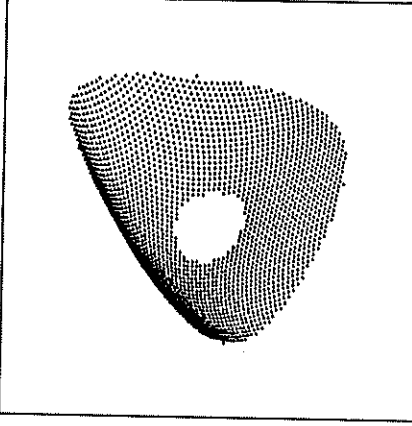
IMA: 0.000, -0.352 IN

OBJ: 0.0000, -0.0250 DEG



IMA: 0.000, 0.353 IN

OBJ: 0.0250, 0.0000 DEG



IMA: -0.352, 0.001 IN

SPOT DIAGRAM

3 ARCMIN FOV / 90" COLLIMATOR / 6.0 DEG OFF AXIS  
TUE AUG 15 1995 UNITS ARE MICRONS.

FIELD	1	2	3	4
RMS RADIUS	0.644	11.926	11.846	11.886
GEO RADIUS	1.268	19.050	22.733	21.414
BOX WIDTH	50			
			REFERENCE	: CENTROID

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UCO/LICK OBSERVATORY  
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