UNIVERSITY OF CALIFORNIA OBSERVATORIES
LICK OBSERVATORY

TECHNICAL REPORT

Analysis of Various Collimators for ESI

Brian M. Sutin

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University of California Observatories/Lick Observatory
University of California Santa Cruz
Santa Cruz, California, 95064

#84

This technical report compares three options for the collimating mirror and imaging field location of the ESI instrument on the Keck II telescope. Altering the location and shape of the imaging field of ESI effects the final image quality, the resolution along the slit in low-dispersion mode, and the TV guider system.

For each case, contour plots over the viewing region of various image spot diameters are shown. The ray tracing includes the effects of the non-axially symmetric Keck II primary, and the light losses from internal absorption of the refractive elements of the camera. The RMS image spot diameter, the 90% encircled energy image spot diameter, and the 100% encircled energy image spot diameter are each plotted. The spot diameters are all computed with 1000 rays, and are referenced to the centroid of the spot. Approximately 10^8 rays were traced for this technical report.

The first case is the on-axis field and off-axis collimator mirror which was assumed in previous reports. The field in this case is a disk centered on the telescope field-of-view, with a field radius of 1.5 arcmin. The total direct imaging area is 7.07 $arcmin^2$, and the maximum length of the slit for low-dispersion spectroscopy is 3.0 arcmin. The second case has an off-axis field with an on-axis collimator mirror. The field-of-view is the same size and shape, but shifted 5.5 arcmin away from the center of the telescope field-of-view. The third case also has an off-axis field and an on-axis collimator mirror, but the field shape is rectangular. The width is 2.0 arcmin, and the centerline is shifted 5.0 arcmin away from the center of the telescope field-of-view. The length of the rectangle may be up to 8.0 arcmin, giving an 8.0 arcmin low-dispersion slit and 16.0 $arcmin^2$ of direct imaging area. Figure-1 graphically shows the locations of these imaging areas relative the the total 10.0-arcmin radius of the Keck II telescope field-of-view.

Figure-2 through figure-6 show the case of the on-axis field. Figure-2 is a drawing of the configuration of the instrument within the Cassegrain module for direct imaging mode, and figure-3 is the equivalent drawing for the medium-dispersion echellette mode. Figure-4 through figure-6 are contours of the image spot diameters. In all three plots, the image size is roughly a function of radius. The images are sub-pixel in the center but rapidly become poor at the edges of the field. Any deviations from axial symmetry are due to the off-axis collimator and the beam from the collimator not being exactly centered on the camera mouth.

Figure-7 through figure-11 show the case of the round off-axis field. Figure-7 and figure-8 are the views of the instrument within the module for the direct imaging and echellette mode. Note that with the off-axis field, the location of the camera leaves more room behind the chip for the dewar compared to the on-axis field. Figure-9 through figure-11 are contours of the image spot diameters. The RMS and 90% spot diameters for this case are virtually constant throughout the field, and are always less than 0.25 arcsec. The 100% spot diameters for this case do not exceed those for the on-axis field.

Figure-12 through figure-14 are the contours for the rectangular off-axis field. The views of the instrument in the Cassegrain module are very similar to those for the off-axis round field for the previous case, and are not shown. The RMS, 90%, and 100% spot diameters are in this case virtually constant for a rectangle up to 6.0 arcmin in length, and are of equal quaility or better than the round off-axis field. The RMS and 90% spot diameters are again less than 0.25 arcsec over this region.

Figure-15 is a plot of the spot size along the low-dispersion slit for each of the three cases. The solid lines correspond to the on-axis round field, the shorter lines with the shorter dashes correspond to the round off-axis field, and the longer lines with the longer dashes correspond to the rectangular off-axis field. In each case, the (RMS spot diameter) < (90% spot diameter) < (100% spot diameter), just as in the contour plots. These spot sizes were computed assuming that the slit is extremely wide and no seeing effects blur the incoming light. These assumptions are not realistic, and a more accurate calculation, which would involve viewing images of the actual slit mask, might reveal different details. Nonetheless, this diagram reveals that the resolution along the slit is constant for the off-axis cases, and is not for the on-axis case.

One obvious conclusion is that the second case, with the round, off-axis field-of-view, is not worth consideration, since the rectangular field is superior in most respects.

In order to compare the two remaining cases, some criteria must be used. One practical assumption is that the instrument is essentially perfect when 90% of the encircled energy is within 0.25 arcsec (25.0 microns). Using this assumption, the on-axis field is perfect out to a radius of approximately 1.4 arcmin, or 6.2 arcmin^2, close to the total field-of-view. For the rectangular case, the field is perfect along 6.0 arcmin of slit length, or approximately 12.0 arcmin^2 of direct imaging field.

Another criterion is the amount of slit mask tilt required in order for the beam reflecting off of the slit mask towards the guide camera to clear the incoming light. For multi-slit mode, where slits are not necessarily at the center of the tilt-axis, this tilt may cause considerable de-focus. Since the rectangular field is narrower (2.0 arcmin, as opposed to 3.0 arcmin), this tilt is considerably less.

In conclusion, a comparison of the three collimator mirror configurations, the on-axis, off-axis, and off-axis rectangular fields, reveals that the off-axis rectangular field gives more viewing area, more uniform resolution both in direct imaging and in low-dispersion mode, and requires less slit mask tilt for slit viewing with the TV guider.

IMAGING FIELDS OF THE THREE CASES

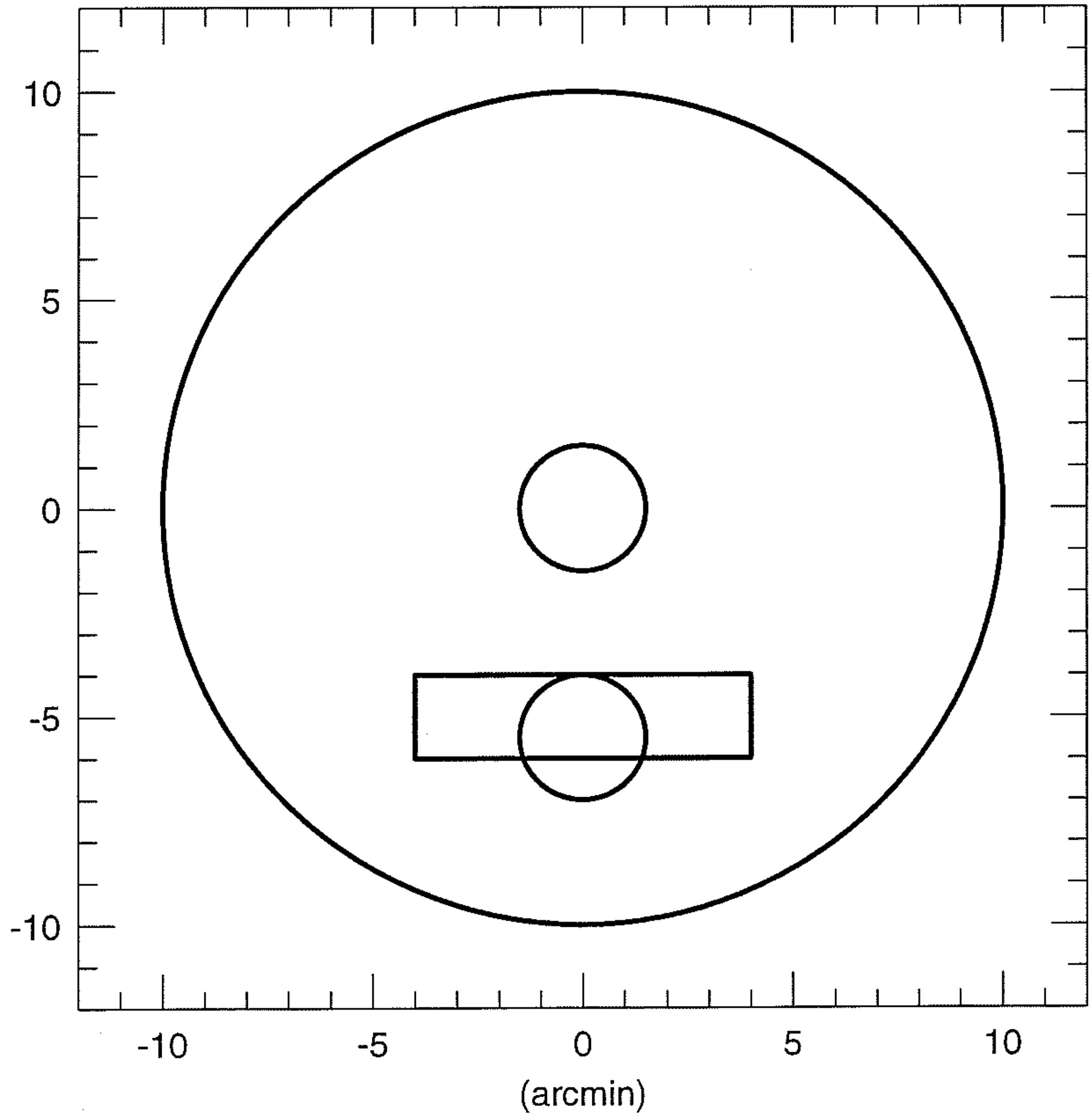


figure 1

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

ON-AXIS FIELD IN IMAGING MODE

ESI (04/17/96)

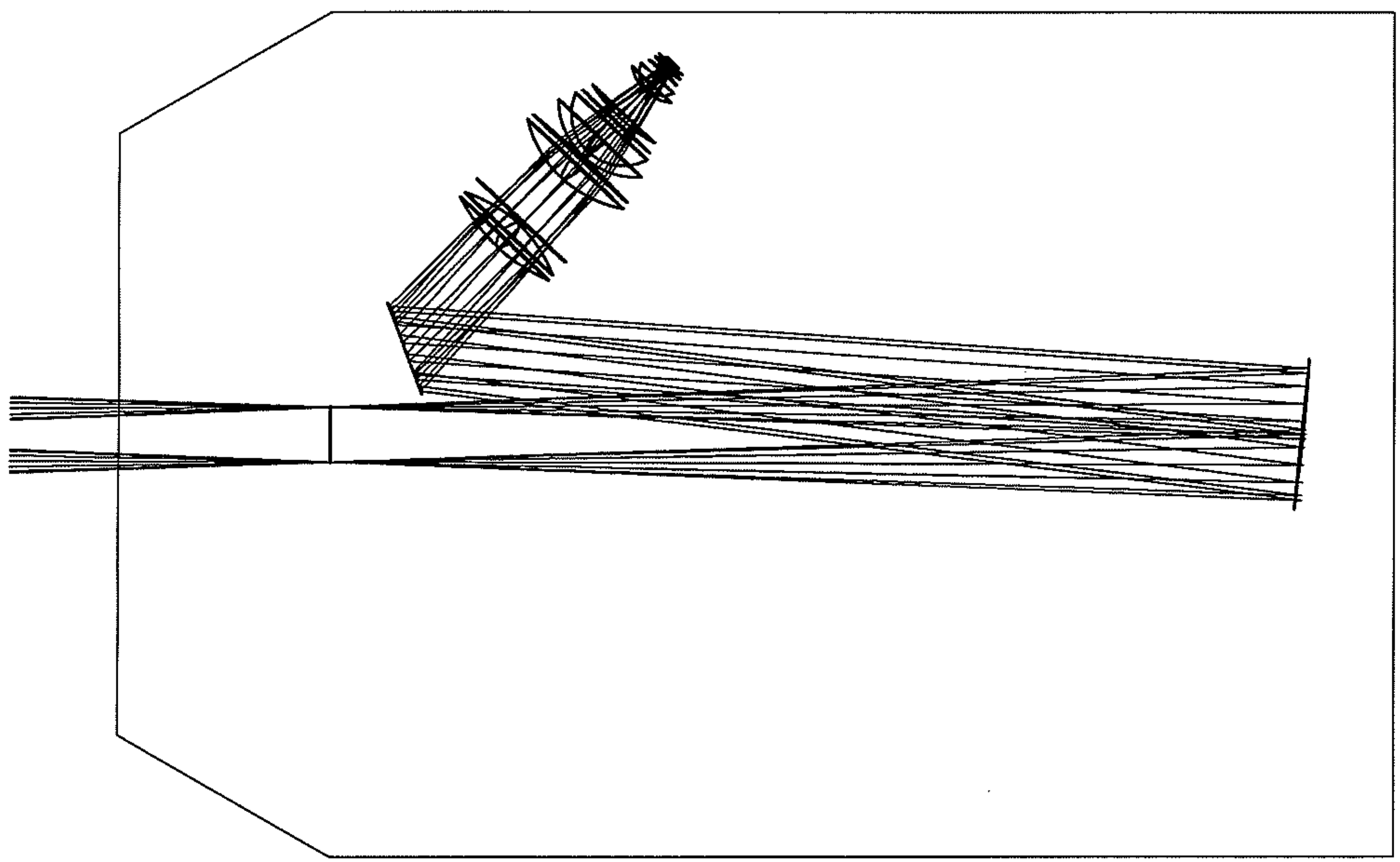


figure 2

Brian M. Sutin (408)459-3840 sutin@ucolick.org
UCO/Lick Observatory Santa Cruz, CA 95064

ON-AXIS FIELD IN ECHELLETTE MODE

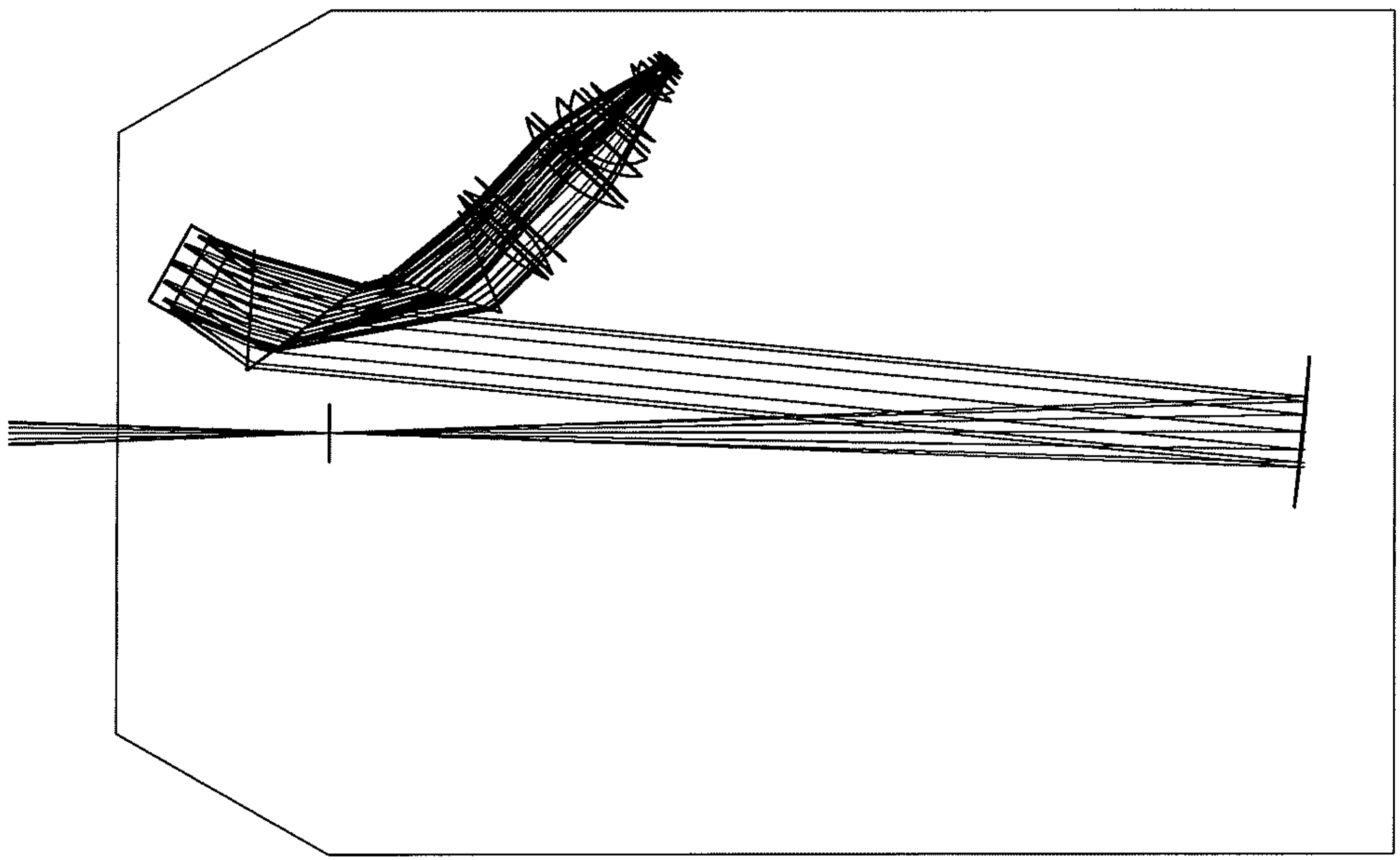


figure 3

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

ON-AXIS FIELD IMAGING RMS SPOT DIAMETER

ESI (04/17/96)

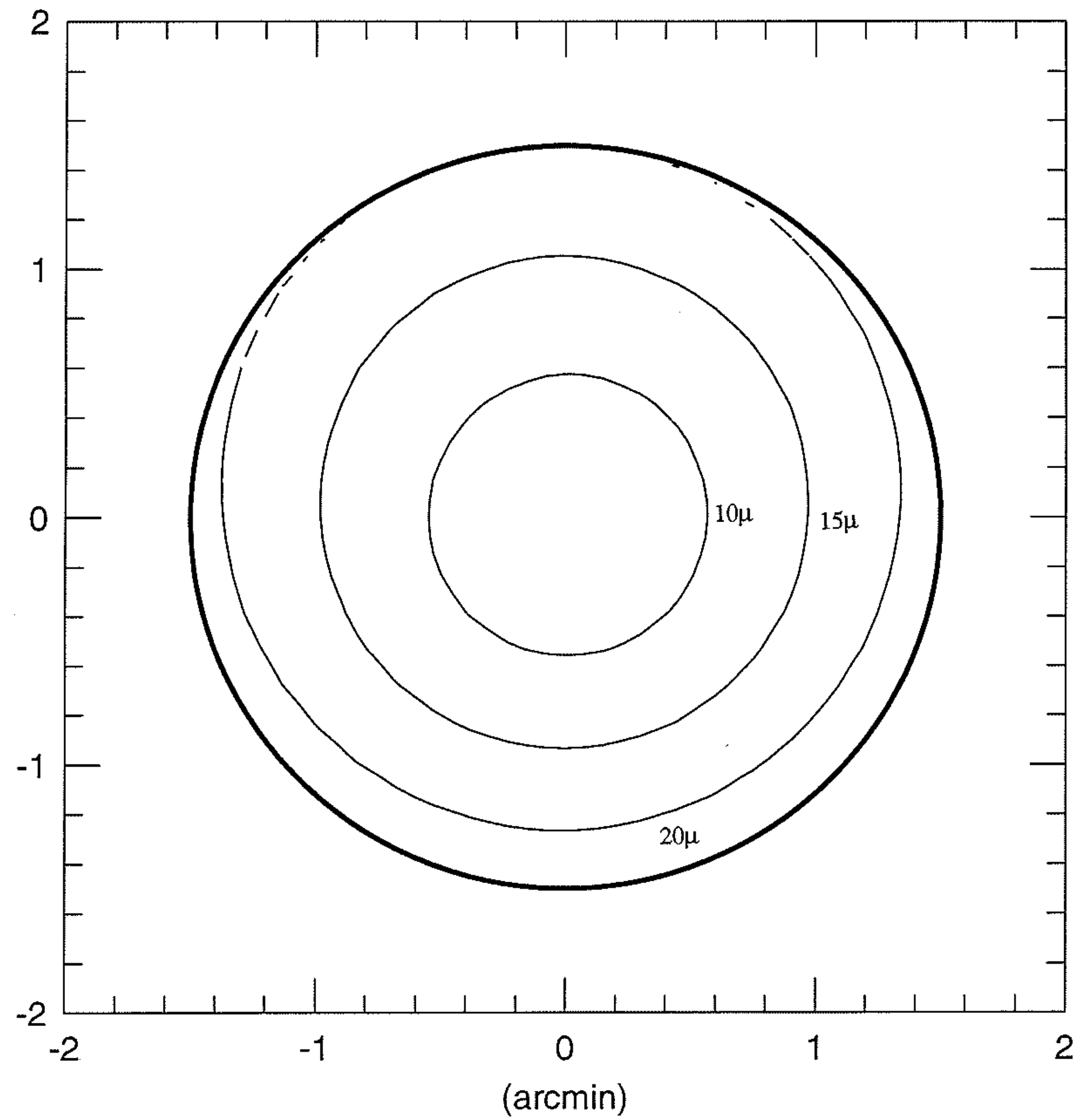
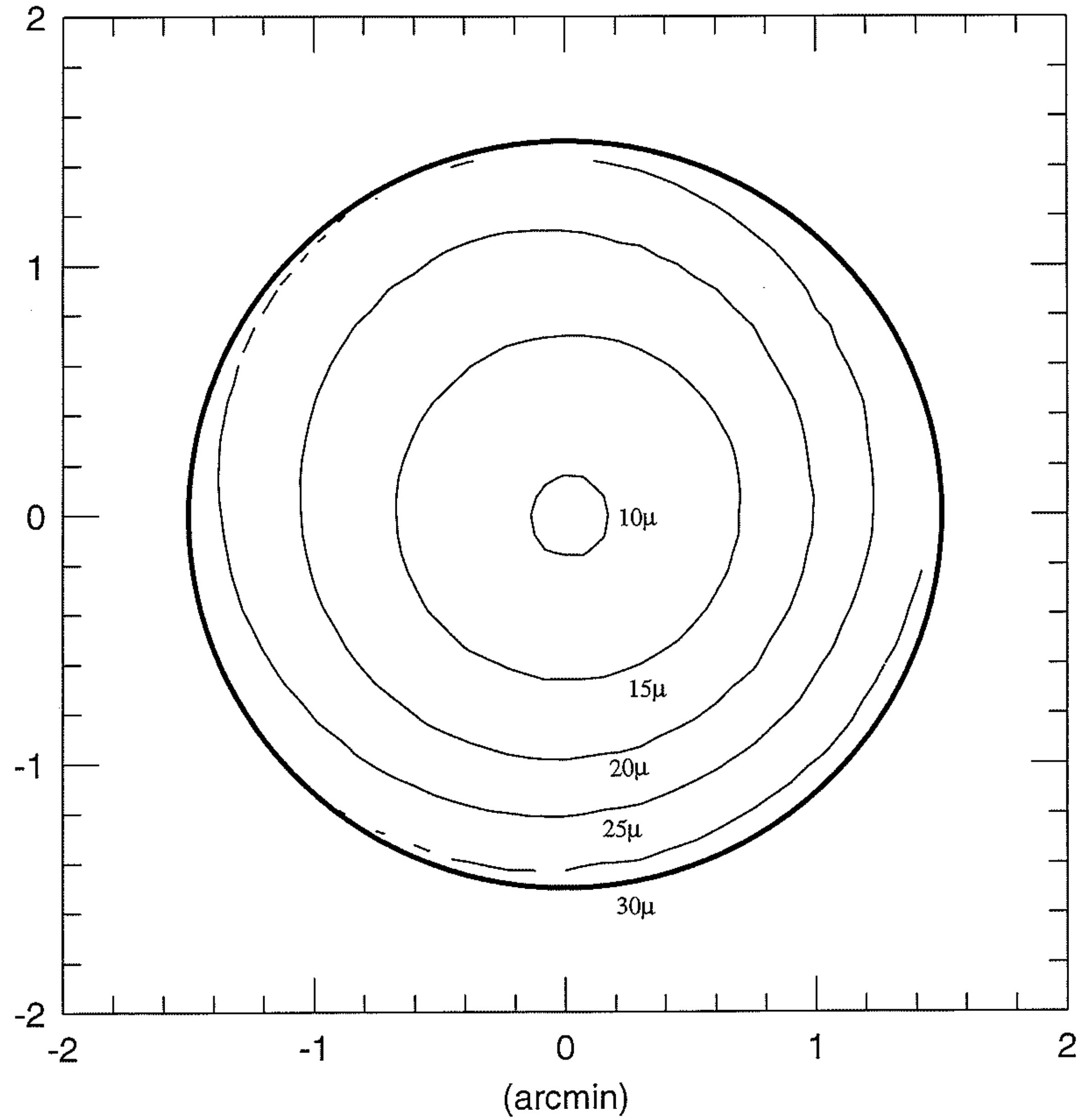


figure 4

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

ON-AXIS FIELD 90% ENERGY DIAMETER ESI (04/17/96)



Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

figure 5

ON-AXIS FIELD 100% ENERGY DIAMETER

ESI (04/17/96)

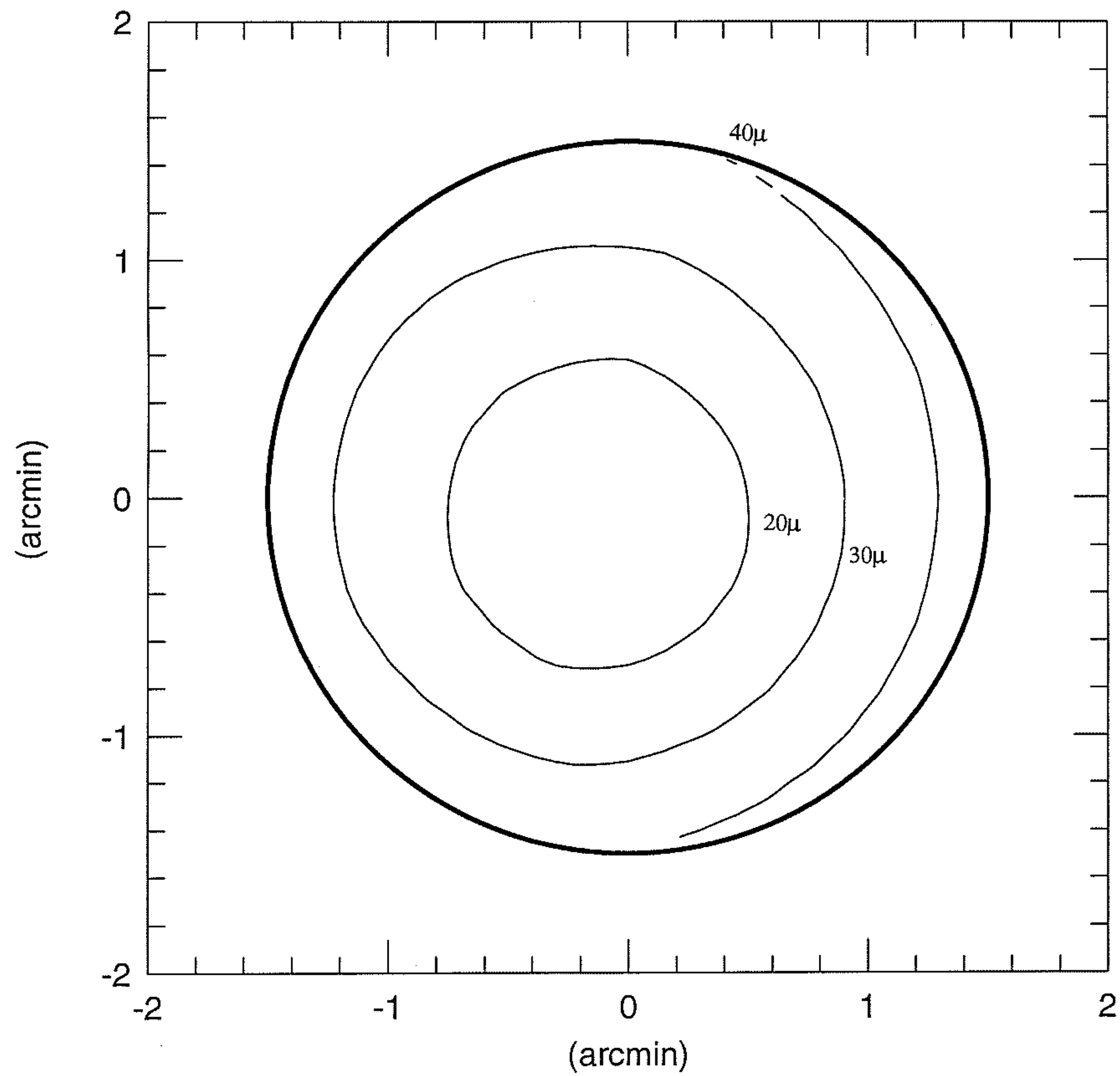


figure 6

Brian M. Sutin (408)459-3840 sutin@ucolick.org

UCO/Lick Observatory Santa Cruz, CA 95064

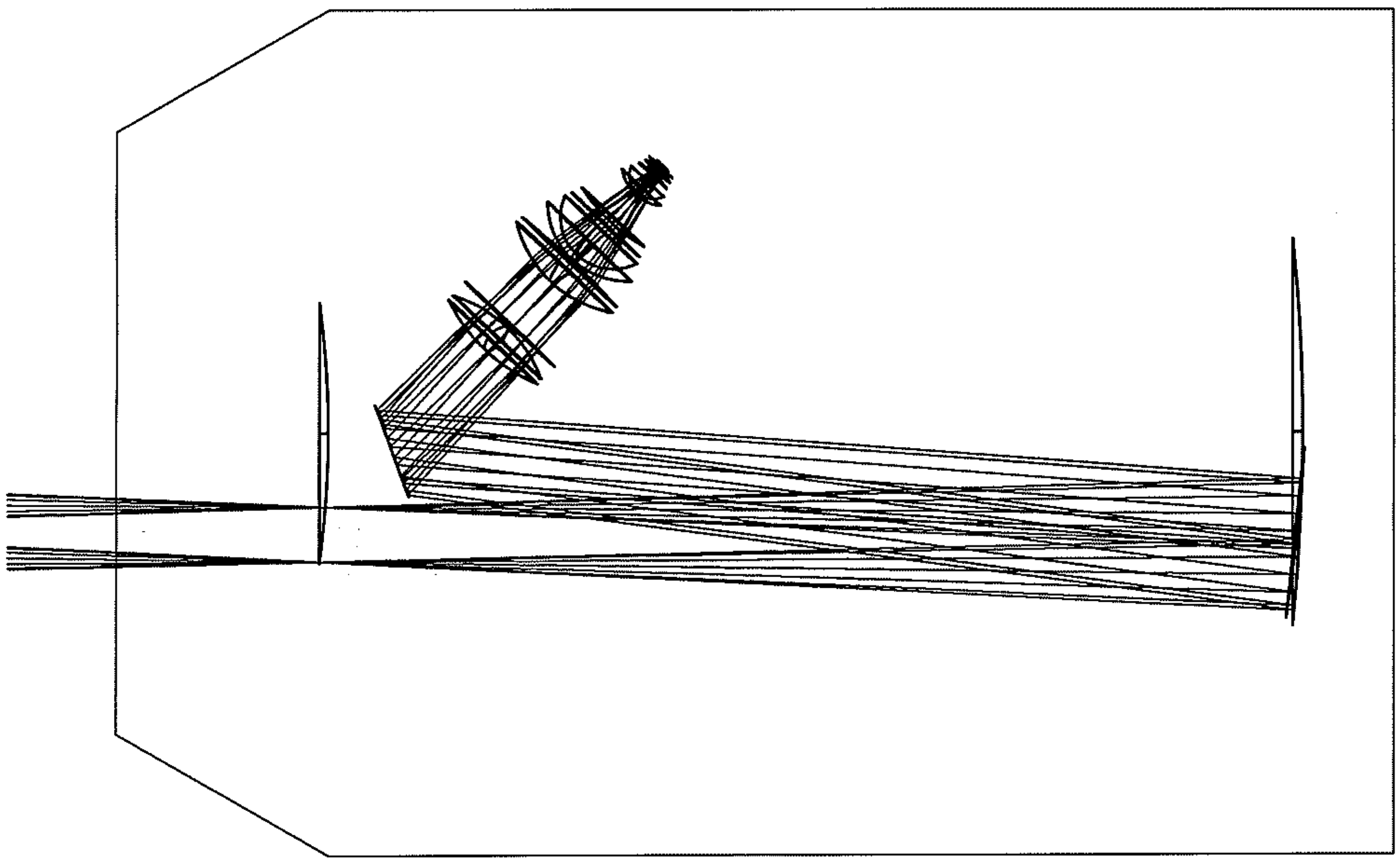


figure 7

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

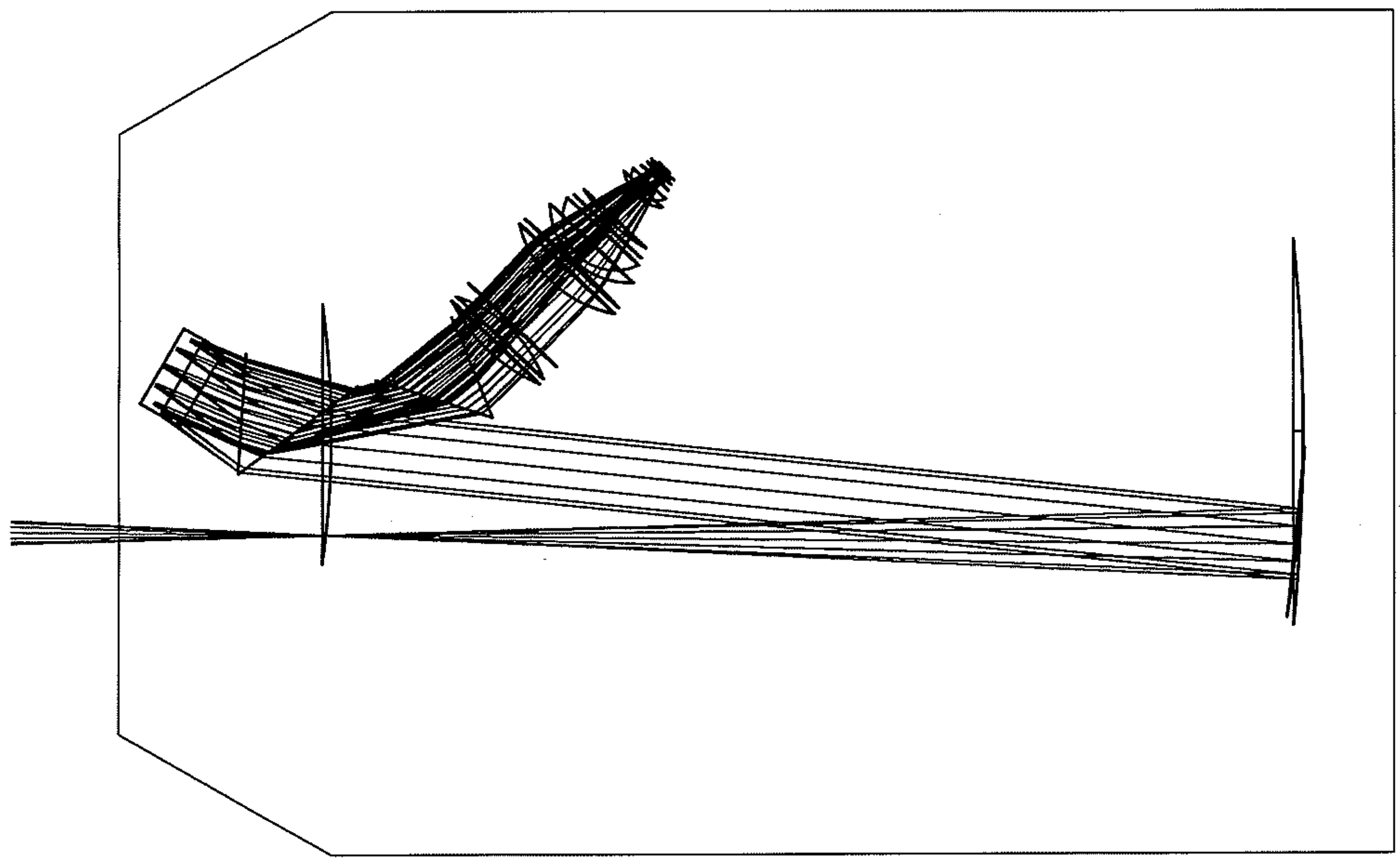


figure 8

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

OFF-AXIS FIELD IMAGING RMS SPOT DIAMETER

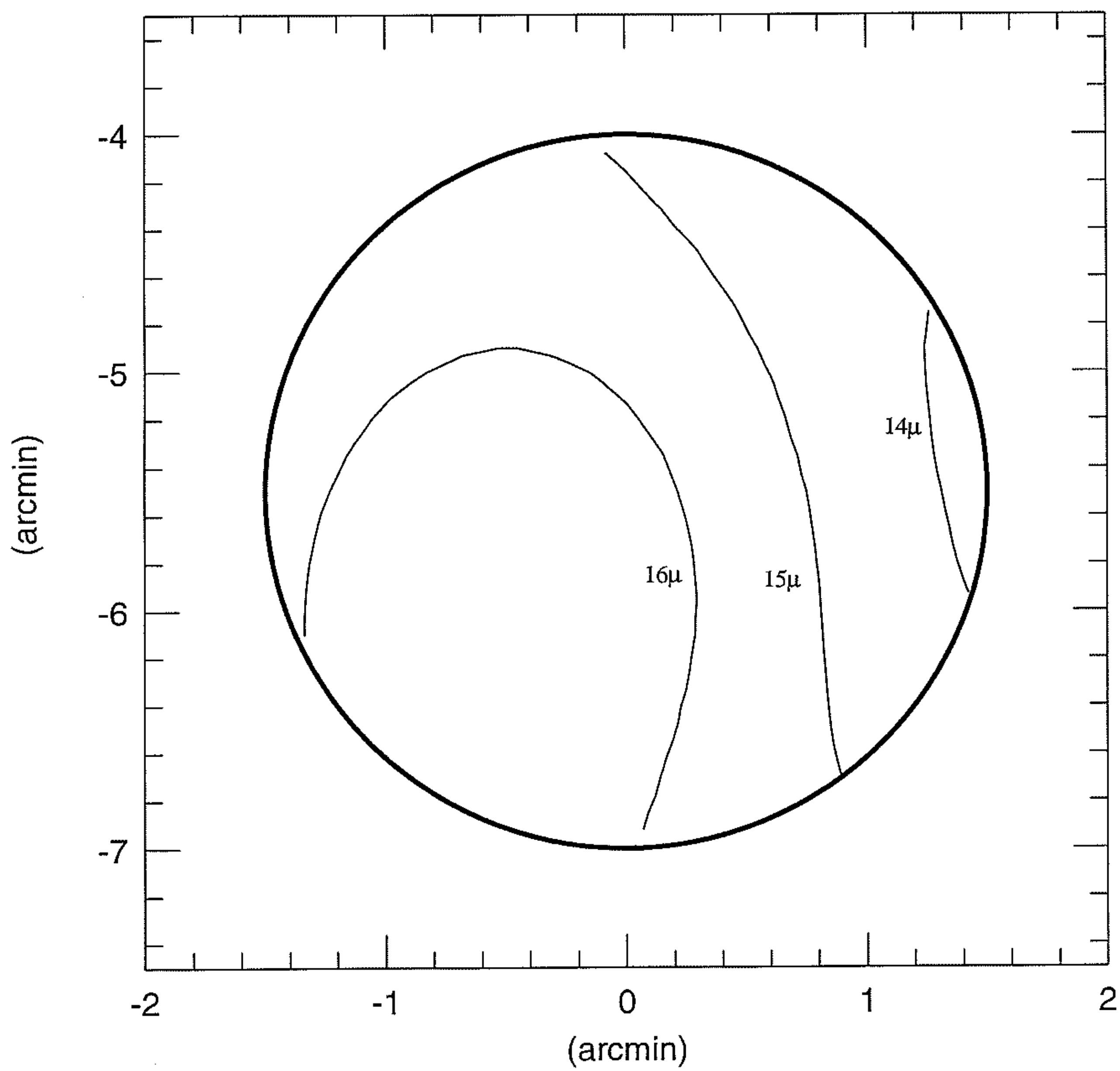


figure 9

Brian M. Sutin (408)459-3840 sutin@ucolick.org
UCO/Lick Observatory Santa Cruz, CA 95064

OFF-AXIS FIELD 90% ENERGY DIAMETER ESI (04/17/96)

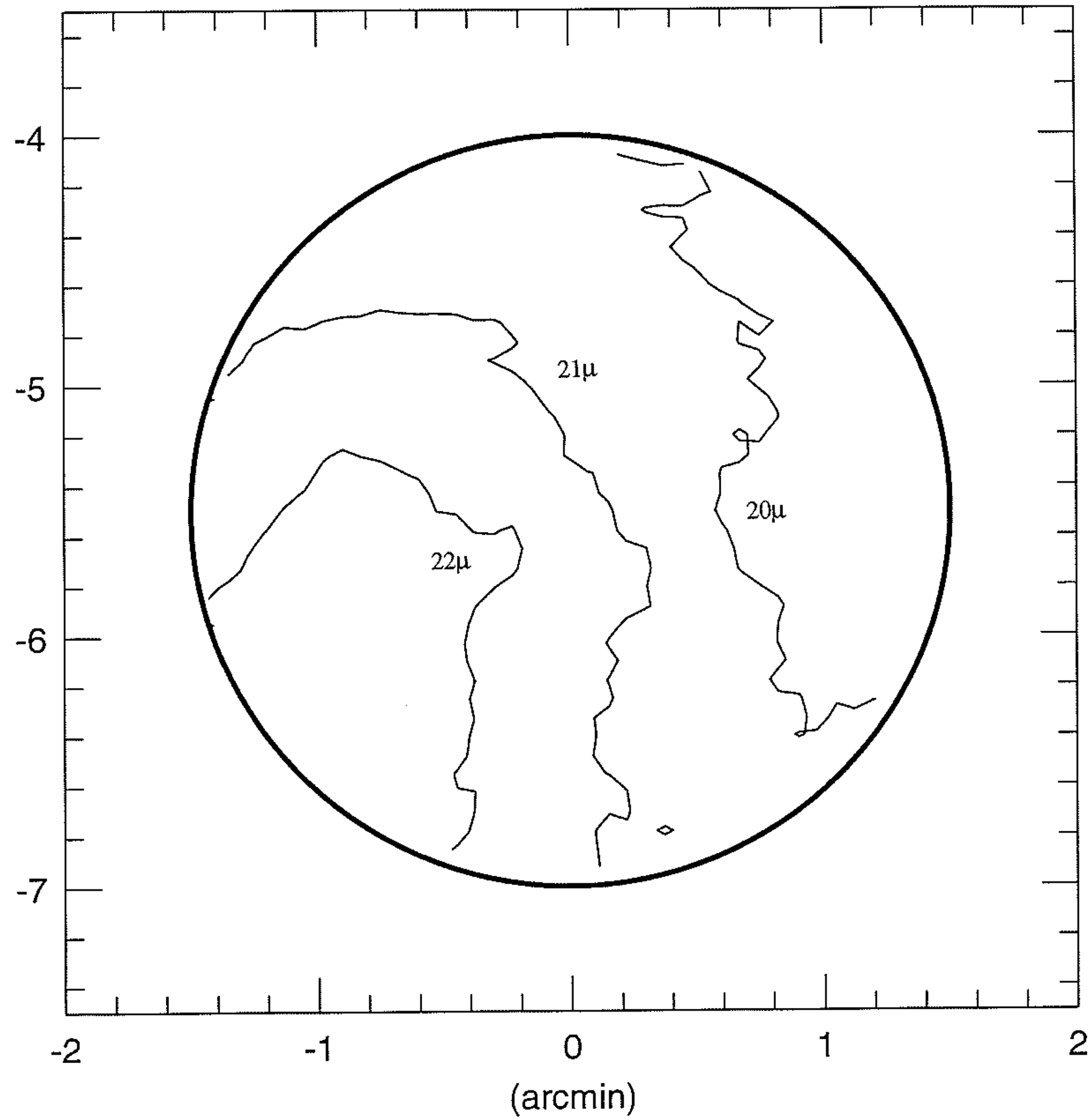


figure 10

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064

OFF-AXIS FIELD 100% ENERGY DIAMETER

ESI (04/17/96)

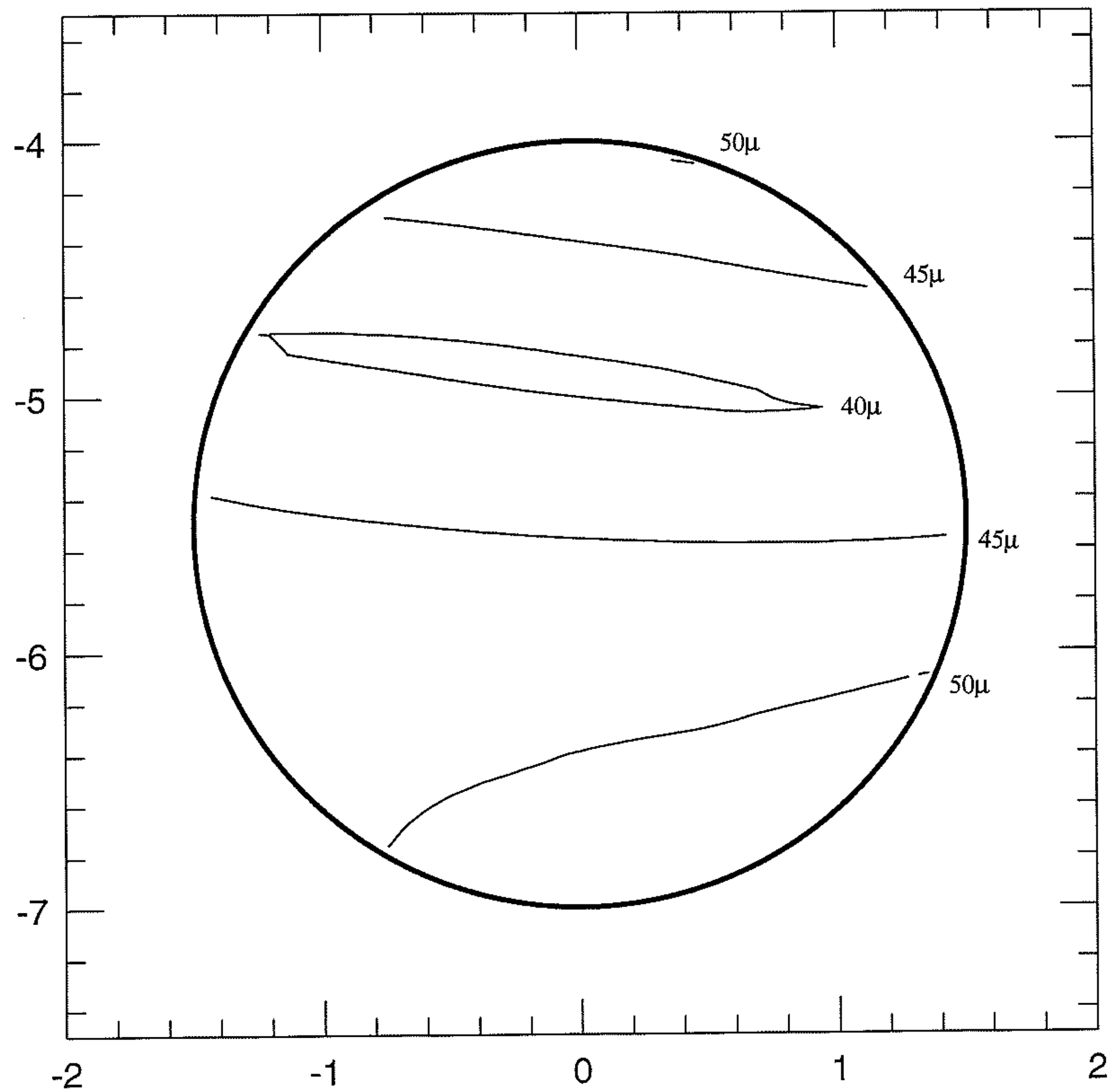


figure 11

Brian M. Sutin (408)459-3840 sutin@ucolick.org
UCO/Lick Observatory Santa Cruz, CA 95064

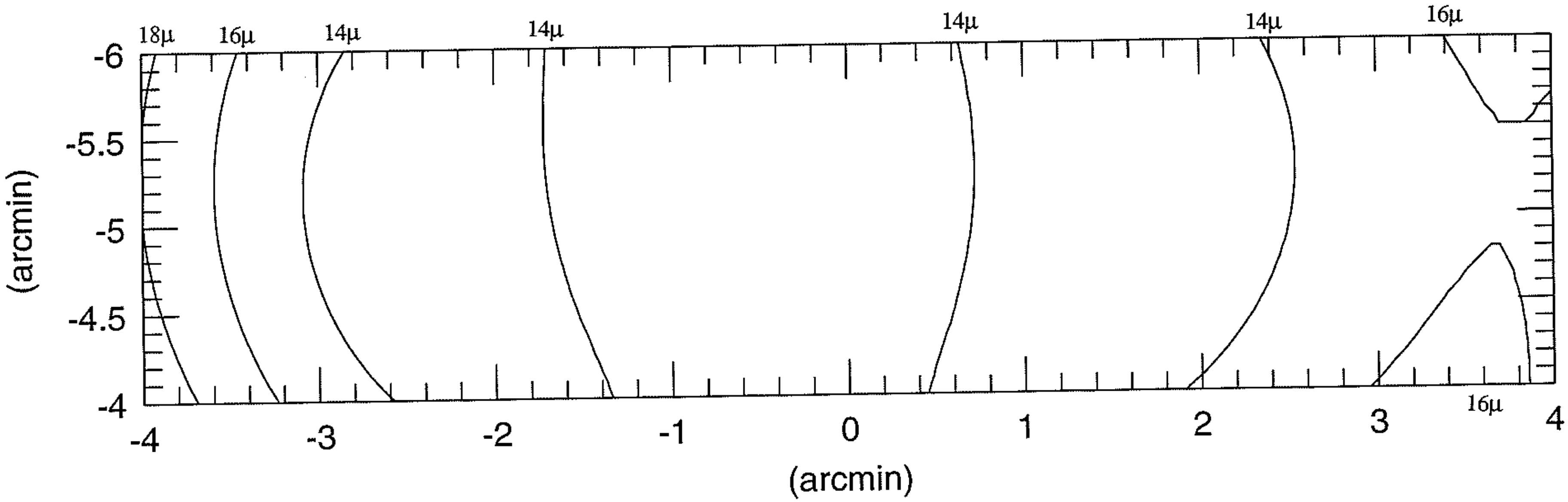

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figure 12

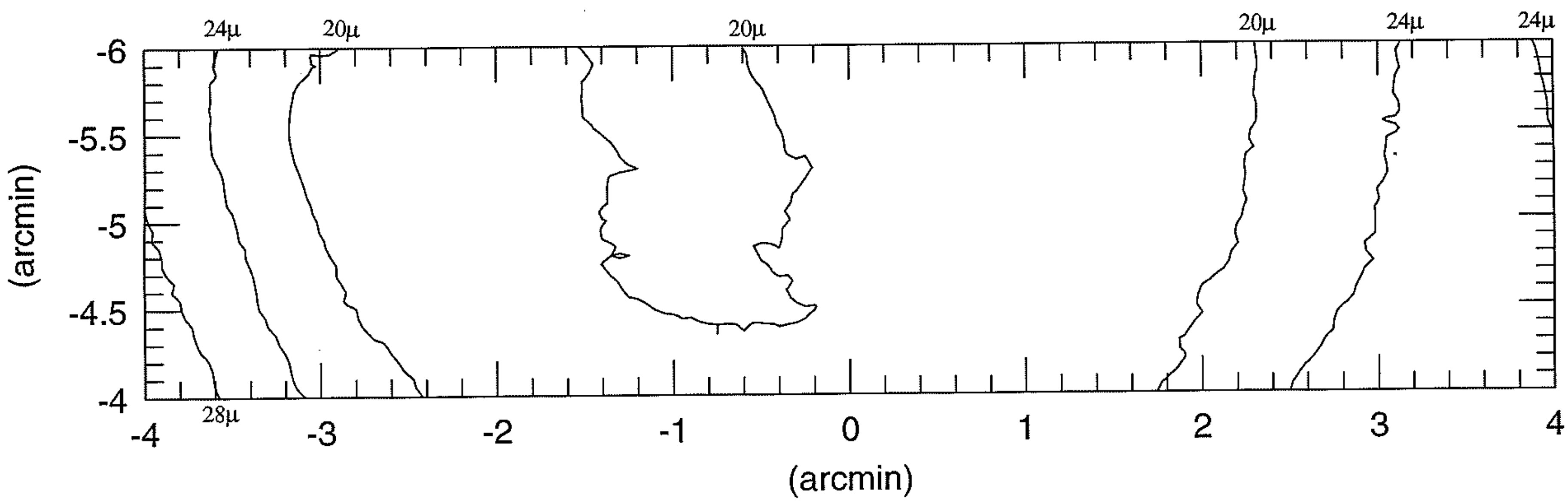

figure 13

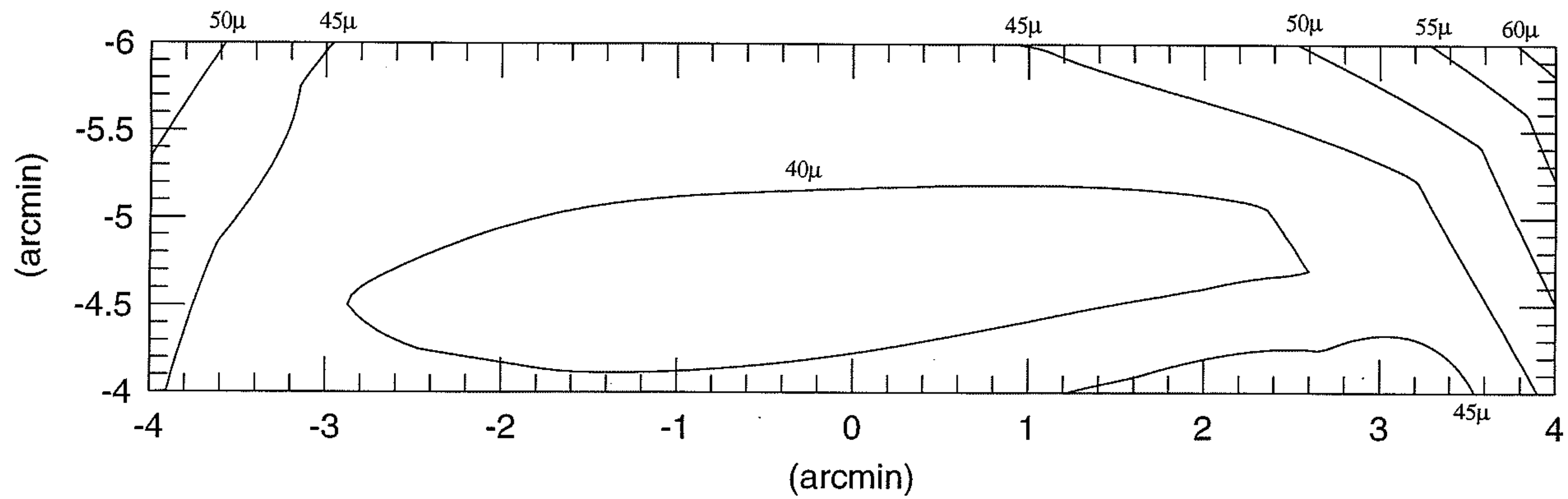
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figure 14

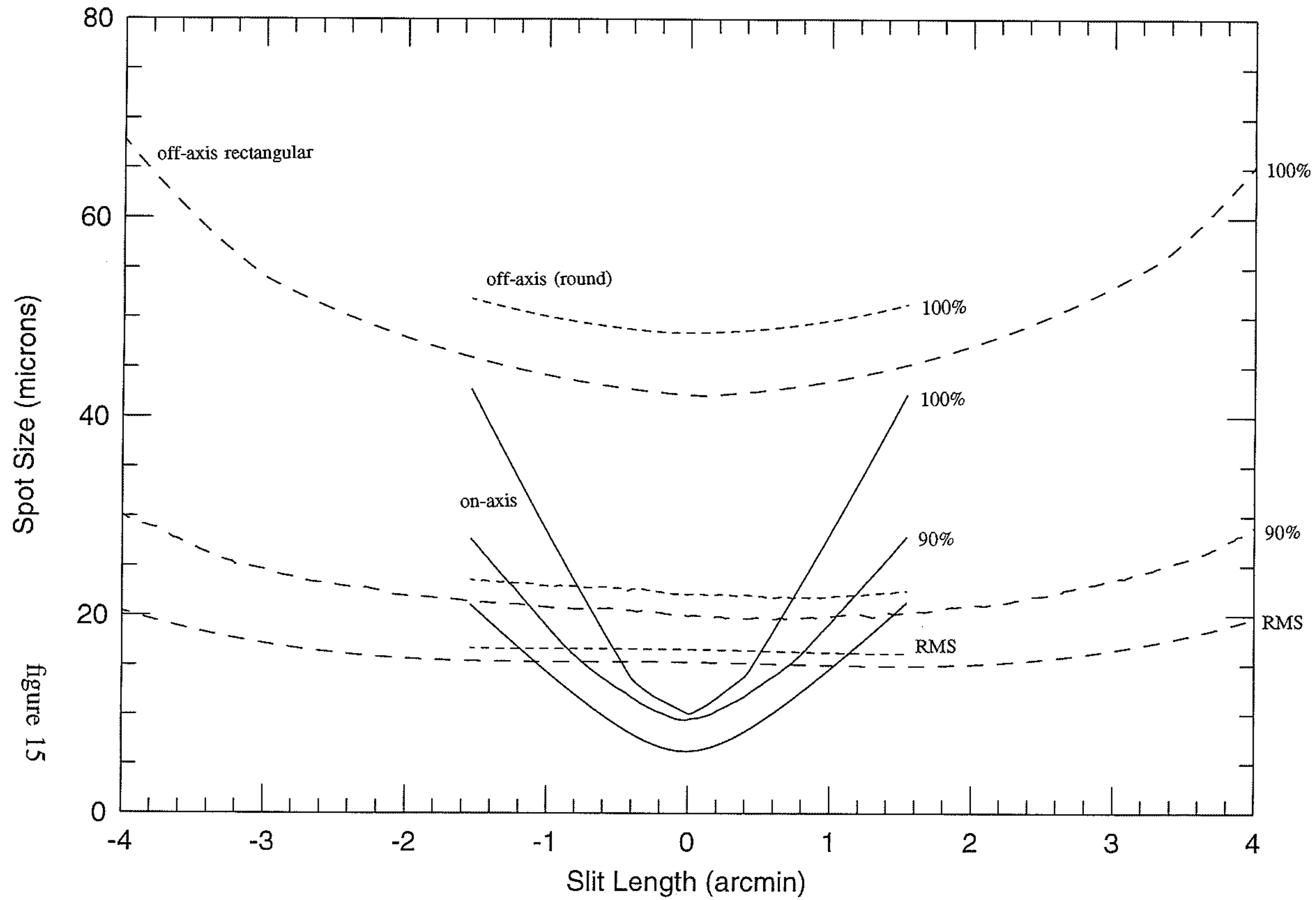

figure 15

Brian M. Sutin (408)459-3840 sutin@ucolick.org UCO/Lick Observatory Santa Cruz, CA 95064