Engineering Report
May 18 and 22, 2016

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Abstract

We had previously showed that the pupil is vignetted on the internal pupil stop in Smokey. I re-mapped the XY stage offset and POM tilt versus telescope offset to resolve the current pupil vignetting in Smokey. I present new equations for the POM tilt and XY stage position versus telescope offset. I later measured the emissivity (5.1%), and took pupil images near Jupiter to characterize the source of the scattered light that makes finding a guide star difficult. I also found that the primary mirror hole causes significant vignetting of the pupil for much of the off-axis guide regions.

Background

Over the years, I had noticed that out-of-focus images with the off-axis guider (a.k.a. Smokey) were not round, but rather appeared to be vignetted on one side. Only recently did I realize that this could be due to a misalignment of the pupil image made by Smokey's camera lens relative to the internal pupil stop. The pick-off mirror (POM) needs to tilt as the XY stage is moved to keep the pupil image on the pupil stop. Should the mapping of POM tilt vs. XY stage position be incorrect, vignetting would result. During a previous engineering night, I verified that tilting the POM would remedy the vignetting issue.

May 18, 2016

Procedure

We pointed to Epsilon Virginis (V=2.8), starting one hour east of zenith. The overall approach was to move the star to various points within the Smokey patrol area, then tilt the POM and offset the XY stage until the image was round and centered. The vfocus of Smokey was changed from +0.34 (nominal vfocus for SpeX) to +1.00 to create a big out-of-focus donut. A total of 14 field positions were measured. We used t3remote to offset the telescope in 122 arcsecond steps. The telescope was tracking open loop during each measurement. The star was frequently returned to the (0,0) offset position to check that it remained in the middle of the SpeX/Guidedog field of view. We also checked that the POM tilt and XY stage offsets for the center position were repeatable during each visit back to the center position (they were).

Results

We found that the POM tilt offsets were significantly different from the current model. The POM tilt and XY stage offsets were repeatable during several visits to the center position. The POM tilt in the E/W direction only depended on the E/W telescope offset, and vice versa. This is also true of the XY stage offsets. We were not able to use the POM in the fully 'out' position to the south due to vignetting of the beam by the primary mirror central hole. Rather than offset by -293", we found that the farthest we could go without vignetting was with the telescope offset to -269".

Figure 1 illustrates the locations of the positions that we measured, and the XY stage offset and the POM tilt for each location.

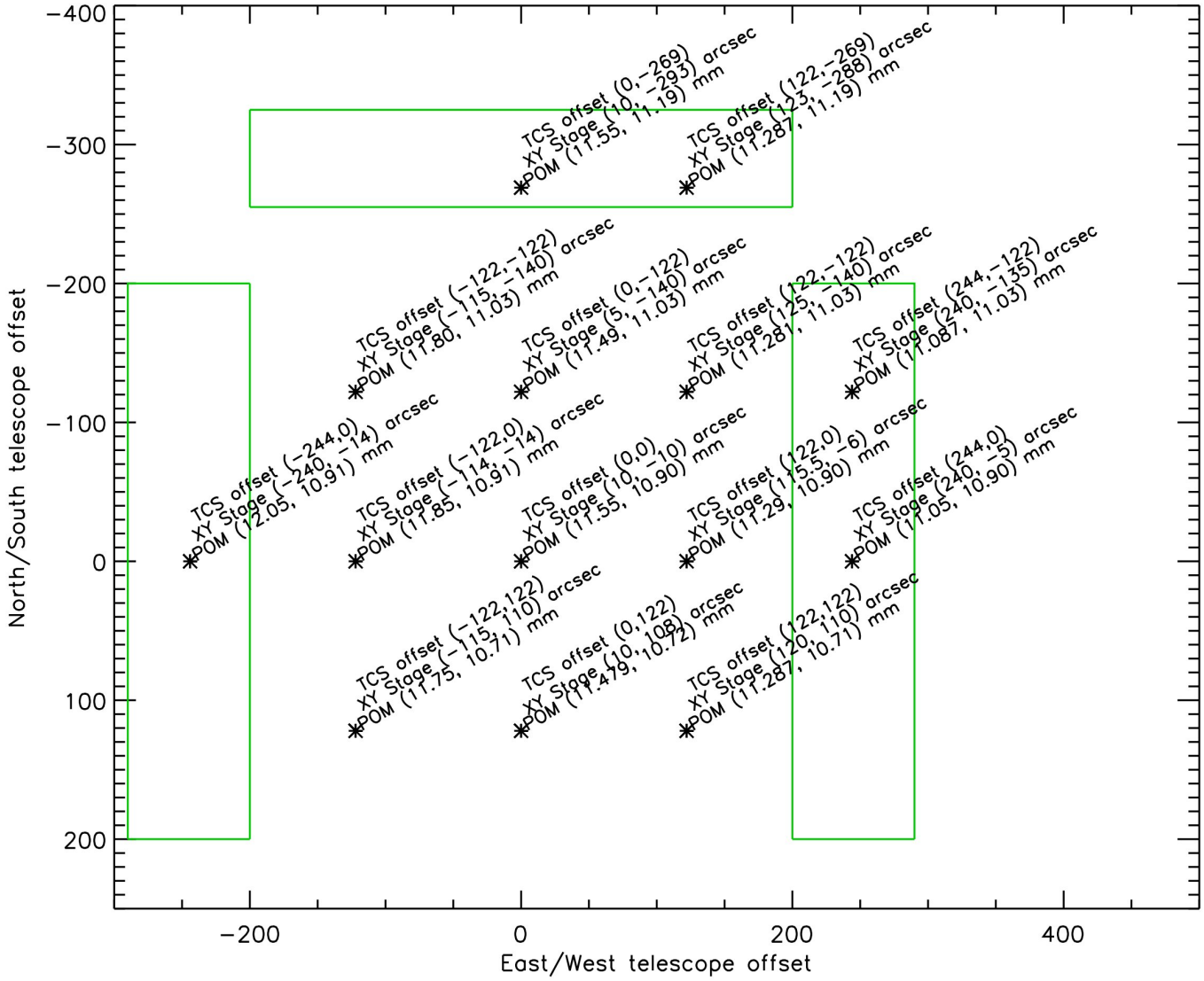

Figure 1: The XY stage and POM offsets for each position that was measured. The off-axis guide boxes are overlaid in green, in the same orientation as shown in Starcat.

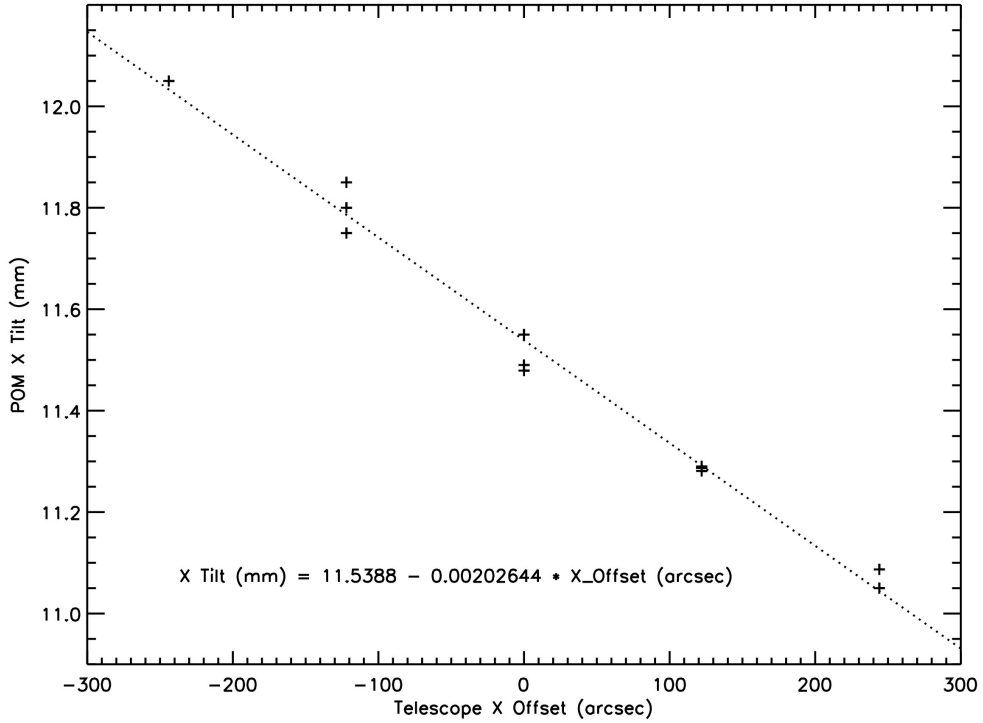

Figure 2: The POM X-axis tilt vs. telescope east/west offset. The best-fit linear regression line is overlaid, and its equation is shown.

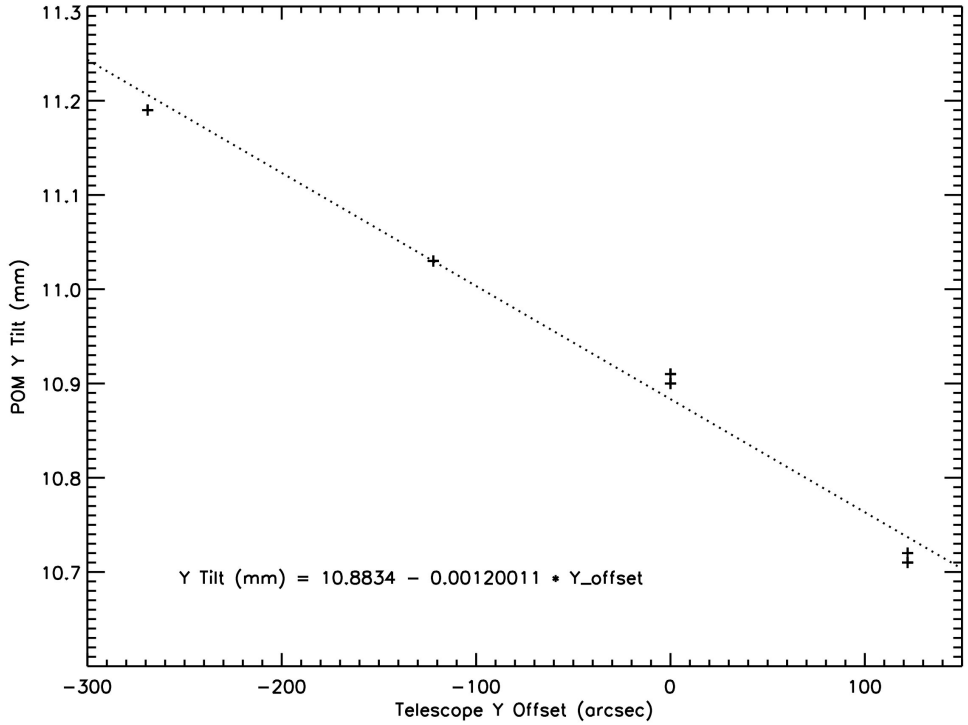

Figure 3: The POM Y-axis tilt vs. telescope north/south offset.

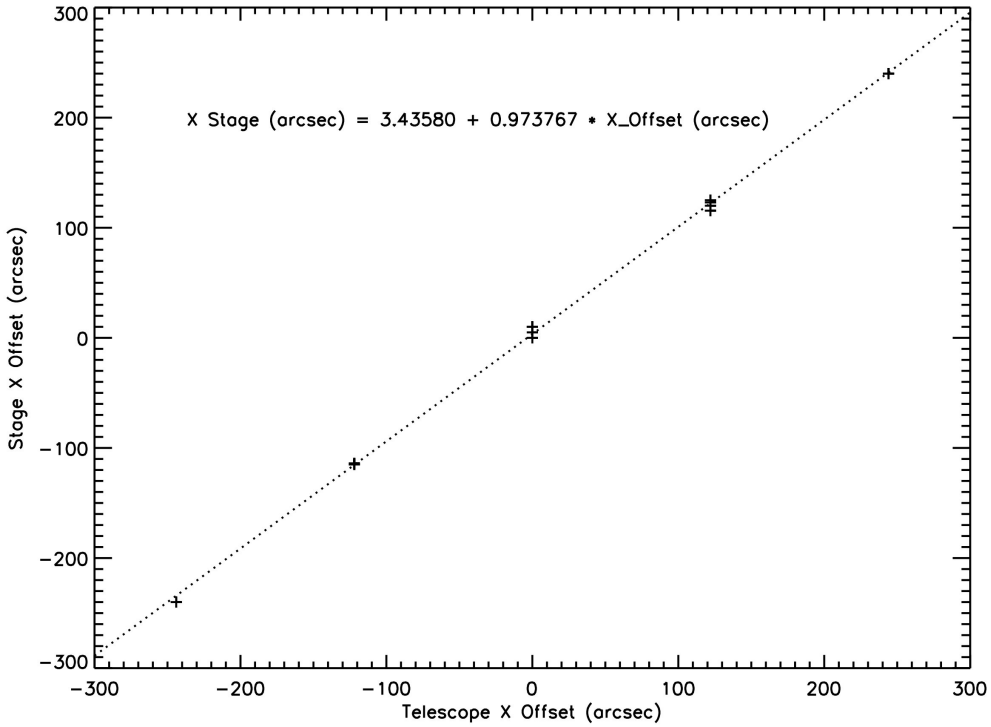

Figure 4: The XY stage X-axis offset vs. telescope east/west offset.

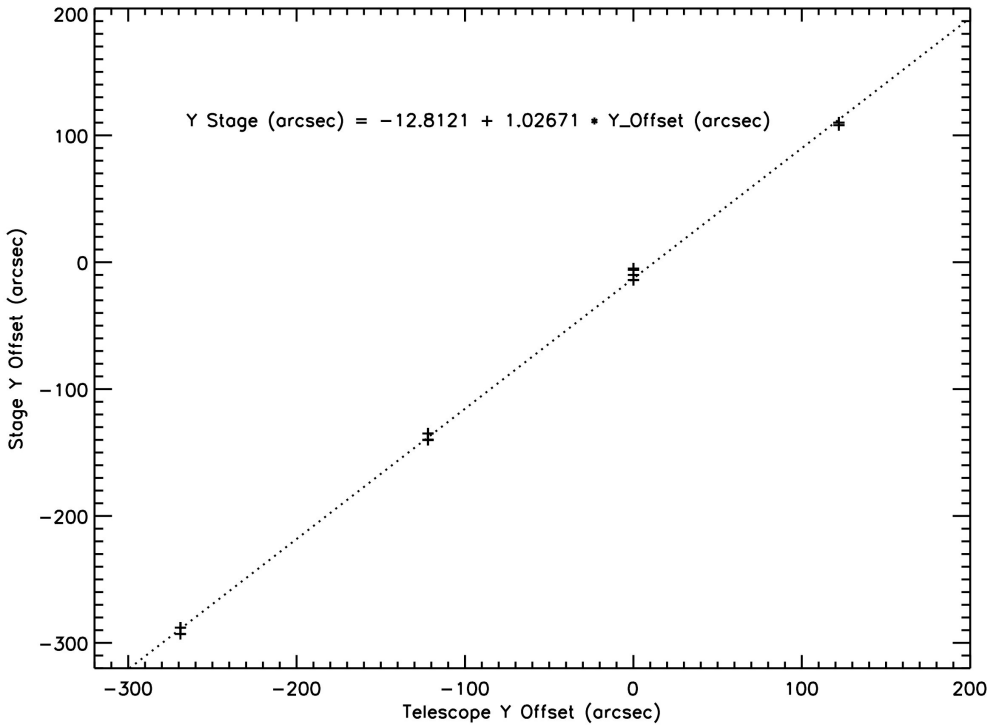

Figure 5: The XY stage Y-axis offset vs. telescope north/south offset.

Pupil Vignetting

While aligning the POM, I noticed that the pupil was vignetted by the primary mirror hole (or the top of the AO spool, which is about the same size). The pupil was badly vignetted at the XY stage "out" position (0,-293"), which is why the POM alignment was done with an offset of (0,-269"). However, offsetting by +122" in hour angle resulted in the vignetting shown in Figure 6. About half of the pupil is obscured. To the east or west of the field center (-244,0) or (+244,0) there was no vignetting. However, an offset to (+244,-122) resulted in the vignetting shown in Figure 7. Moving the XY stage to the ends of the guide boxes would have resulted in more severe vignetting.

The immediate effect of the vignetting is to make off-axis guide stars appear fainter when they are not due north, east, or west of the field center. Perhaps more importantly, our future plans to do wavefront sensing with off-axis guider will be strongly affected by this vignetting problem. It will be much less likely that we would be able to find a suitable guide star if we can only look due north, east, or west of the field center. It will be very difficult, if not impossible, to reconstruct the wavefront with this much of the pupil missing.

A solution to this problem is to make the POM head smaller. It is currently approximately 6" wide and 7" long to house a 3" mirror. The extra size allows the tip/tilt mechanism for the mirror. We should be able to buy a small tip/tilt mechanism that fits behind the mirror and thus wouldn't expand the profile of the POM mirror. This would allow the POM to be moved closer to the field center, increasing the non-vignetted patrol area and thus increasing the chance of finding an off-axis guide star. Removing the extra 1.5 inches of width around the POM should increase the width of the guide fields by 67 arcseconds.

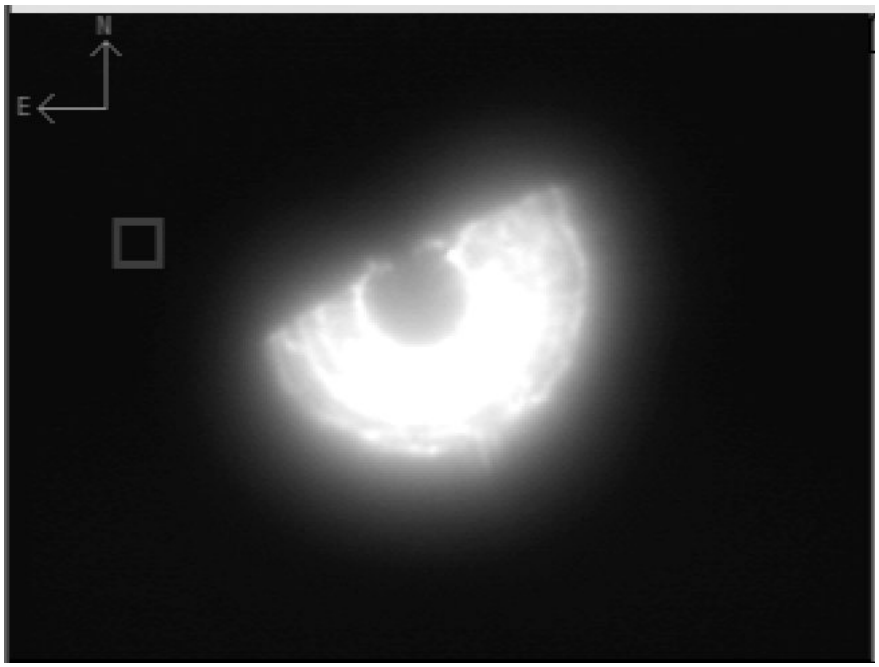

Figure 6: The image of the star taken with Smokey, out of focus, with the telescope offset by (+122,-269) arcseconds (top guide box, towards the right). The image was taken after tilting the POM and adjusting the XY stage.

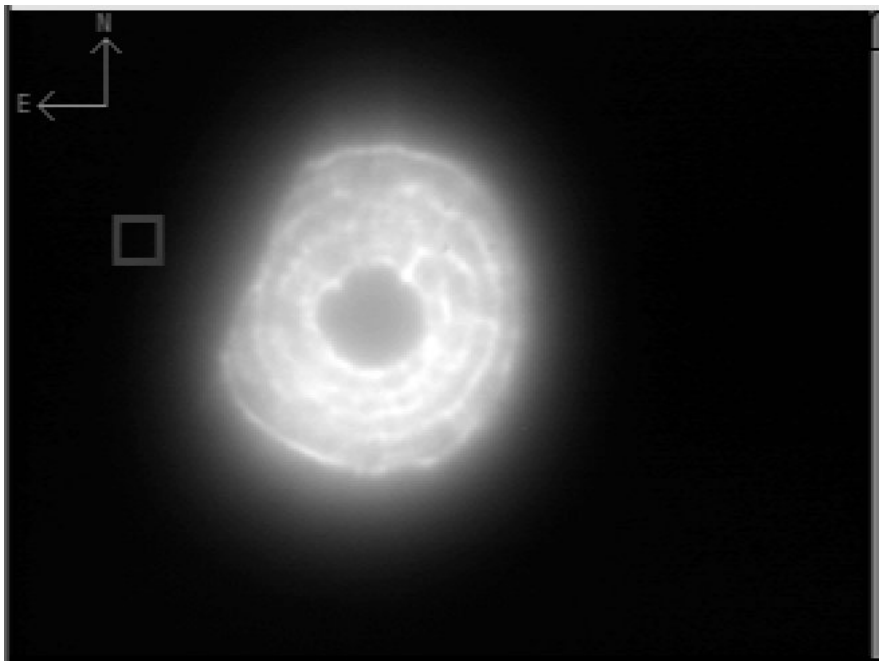

Figure 7: The image of the star taken with Smokey, out of focus, with the telescope offset by (+244,-122) arcseconds (right guide box, towards the top). The image was also taken after tilting the POM and adjusting the XY stage.

May 22, 2016

During this engineering time, I updated the collimation, measured emissivity, determined how close the POM could be to the field center, and tried to determine the source of scattered light near Jupiter.

Emissivity

The emissivity was measured to be 5.1%. I used the back of the POM arm as the high emissivity reference rather than the usual foam. The day crew reports that the mirror looks a bit "milky" or "foggy". I suspect it's time to get it recoated.

POM Clearance

If the POM could be moved in, then more guide stars would be accessible. For this test, I compared L-band images with the POM near the field to an L-band image taken with the POM in the 'out' position. To the north guide field, Smokey needs to be as far south as the 'out' position. For the right guide field, Smokey needs to be at +244" offset. However, for the left guide field, the POM could be moved in 25" towards the center of the field, from the default of -244" to -220".

Scattered Light from Jupiter

TOs often have a hard time finding an off-axis guide star with Smokey due to scattered light. To try to determine the source of the light, we looked at the secondary mirror with SpeX/guidedog in pupil viewing mode with Jupiter offset by 244 arcseconds. This was to put Jupiter as far away from guidedog as when Smokey is trying to find a guide star with Jupiter on-axis. Images with guidedog were taken at J-band as that as close as possible to the Smokey wavelength range.

Figure 6 shows the J-band pupil image in the east/west direction by -241". The bright glint at the edge of the secondary mirror follows the direction that Jupiter is offset. We also see a grazing incidence reflection from the spider reflected in the secondary, but not directly from the spider itself.

A possible solution to this problem is to install an 890 nm methane filter into the Smokey filter wheel. It'll effectively block light from Jupiter while letting ~18 nm of star light to pass through. Stars will look fainter than without the filter, but hopefully it'll be an overall improvement as it should suppress the scattered light.

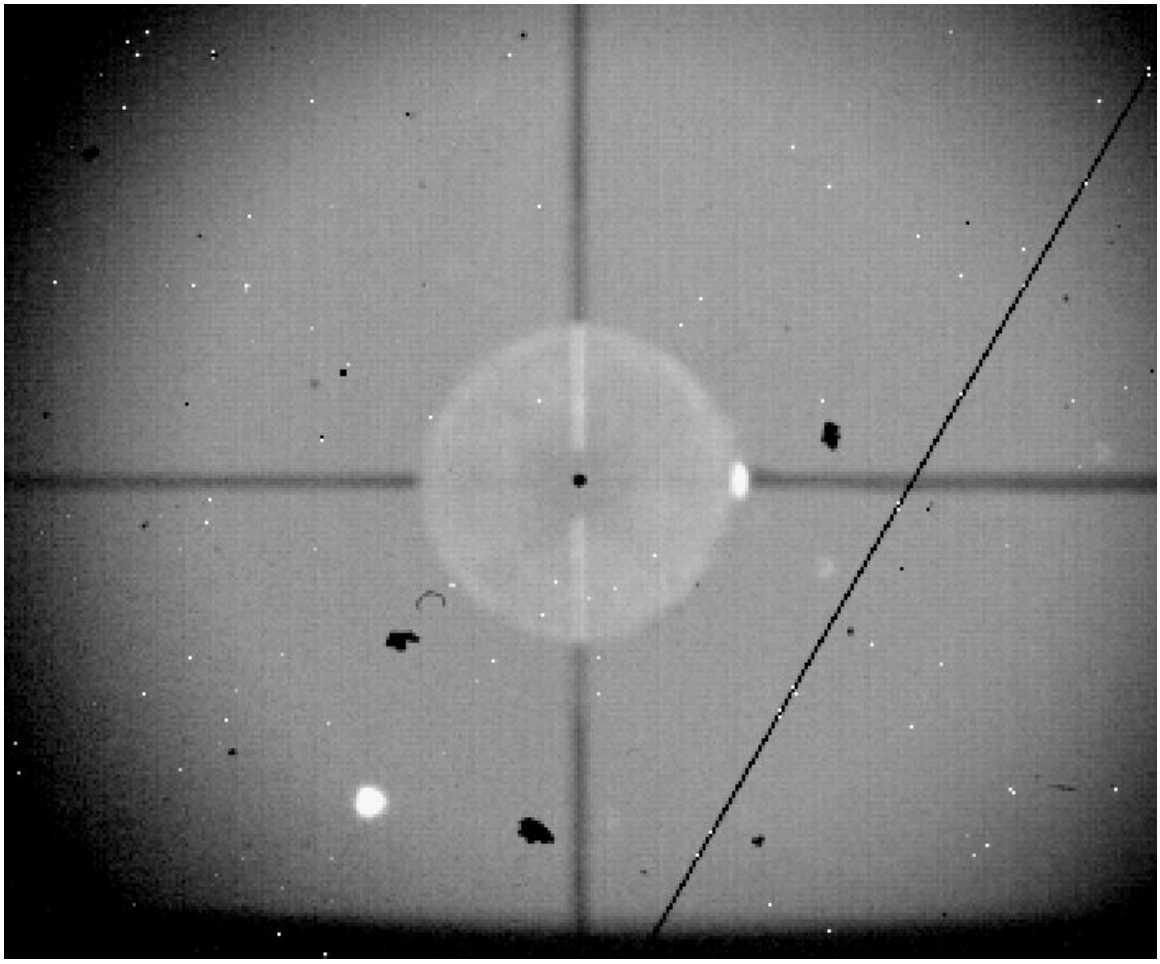

Figure 8: J-band pupil image taken by Guidedog with Jupiter offset by 244". The bright glint at the edge of the secondary follows direction of the offset of Jupiter. Note the reflection off of the spider as seen in the secondary, but not directly from the spider itself. The secondary mirror itself is brighter than the sky; another source of scattered light for the off-axis guider.