Vignetting with K1DM3 at the Cassegrain Focus, with ADC
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Introduction:

The original calculations for vignetting of the Cassegrain focus FOV showed no vignetting occurred within the LRIS FOV, defined by the corners (±4',4') and (±4',10'). (The extreme points (±4',10') are actually 10.77' from the telescope axis and suffer a very small amount of vignetting from M2.) However, this original calculation did not account for the re-pointing of the telescope to adjust for the displacement of the focal surface as the ADC is extended at lower elevations (see ADC Optical Design Report, Section 2). With the ADC fully extended, the maximum telescope offset is 0.817' toward lower elevation. This results in a larger effective FOV to lower elevations. The ADC itself was built with a displaced front prism so that no points in the full LRIS FOV were vignetted by the ADC. However, the inner drum of K1DM3 does not completely fill the ADC prism. This note explores vignetting by K1DM3 the ADC-extended effective LRIS FOV.

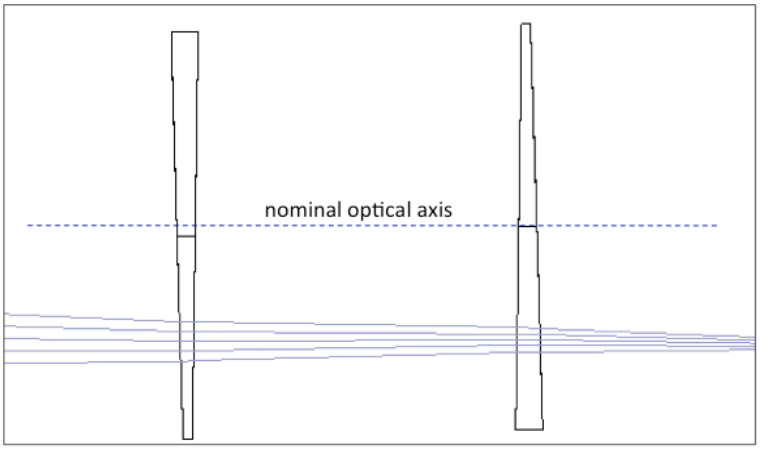

Figure 1: extended linear ADC, showing front prism slightly displaced, and how the bending of the rays effectively displaces the field. This must be compensated by re-pointing the telescope up to 0.817' when the ADC is fully extended.

Methodology:

A ZEMAX model ("K1DM3_drum_vign_working.ZMX") was constructed of the telescope, as-built ADC and LRIS Blue. The segmented shape outline of the primary was created with a User Define Aperture (UDA) file. To explore vignetting by the inner drum, we add circular apertures at appropriate z-distances (table). The difference between actual and required diameters determines which of the constraints is the limiting aperture.

	Actual diam (mm)	Distance from M1 vertex (mm)	Required diam. (mm)	Delta (mm)
Attachment ring	1104	3387.25	1136.1	-32.1
Upper ring	1100	3331.85	1134.8	-34.8
Lower ring	1075	2576.85	1117.2	-42.2

The limiting case is the drum lower ring, which would need to be 42.2mm larger to avoid vignetting.

Unvignetted thoughtput for the extreme field points is 76.88% (a combination of the secondary shadow and the missing parts of the segmented outline). Note that this is a very slight overestimate, as the M2 structure shadow is somewhat larger than M2 itself; this will have no significant effects on the results.

At the telescope focus, the extreme field points of LRIS are vignetted by 76.41% vs. 76.88% (0.61% decrease). The LRIS-B camera also vignettes, so adding LRIS-B into the model, we get 68.91% vs 69.37, or 0.66% decrease. Fig. 2a,b illustrates the complexity of the entire system.

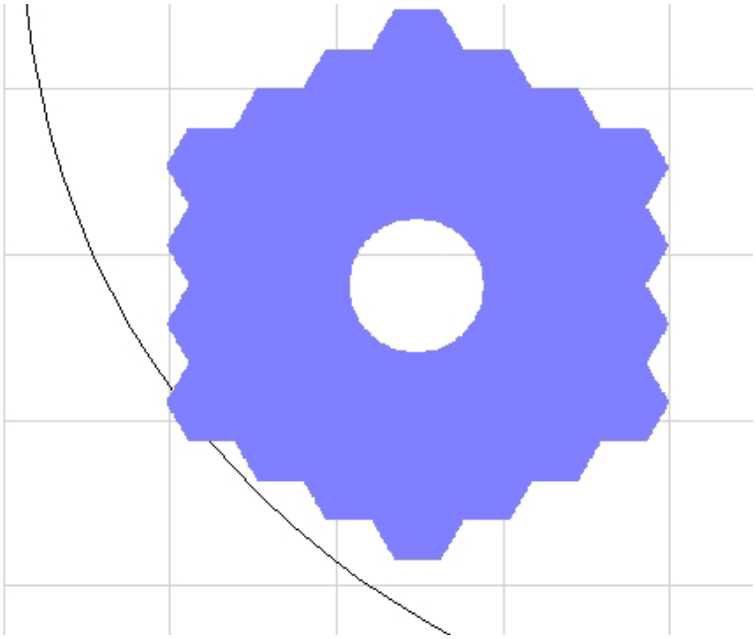

Figure 2a: Footprint of an extreme field point at the lower drum ring (indicated by black line), assuming no vignetting by LRIS (at this rotator angle, vignetting by the extended ADC is just avoided). At this rotator angle, there is apparent albeit slight vignetting by the K1DM3 drum.

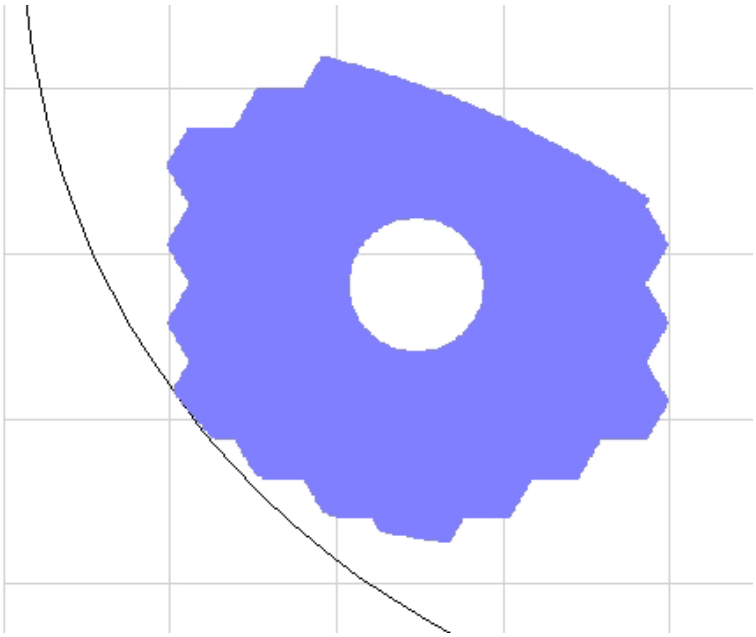

Figure 2b: Same as Fig. 2a, except that rays vignetted by LRIS are now removed. The upper arc is produced by the undersized collimator (only for field points beyond 10' radius), whereas the ears of some segments are vignetted by the camera.

Discussion and Conclusions:
The K1DM3 drum does result in some vignetting at the corners of the LRIS FOV when the ADC fully extended, but the 10' FOV is never vignetted (see Fig. 2). We have explored this vignetting and have deduced the following parameters:

K1DM3 does not vignette anywhere at all for 0>Z>32. At greater zenith distances, the extreme corners start to vignette.

At Z=60 and LRIS rotated to the worst-case rotator angle, the approximate unvignetted FOV radius for LRIS is 10.15'. The extreme corners of the LRIS FOV see an additional 0.66% of vignetting. The line of no vignetting is given in the following table.

X-distance from tel. axis (arcminutes)	Y-distance from tel. axis (arcminutes)	Radial-distance from tel. axis (arcminutes)
±1.74	10	10.150
±2.0	9.96	10.155
±2.5	9.88	10.191
±3.0	9.78	10.230
±3.5	9.67	10.282
±4.0	9.53	10.335

At Z=60° (ADC fully extended) and at the telescope focus, slight vignetting would occur even to ±90-deg LRIS rotation on one extreme corner. However, including the

LRIS camera vignetting, no points are vignetted if the rotator is ±74° from the lowest positions (±106° from the highest position).

Note that vignetting by the K1DM3 drum can always be avoided by observing with LRIS in the upper angles of rotation.

The retracted M3 is to be parked at an upper-elevation position. Since the displacement of the effective FOV as the ADC extends is toward lower elevation, any vignetting done by the retracted mirror structure will be *reduced* as the ADC is extended. The hope is that we can fully clear the LRIS FOV with the retracted K1DM3 with no ADC, and the presence/operation of the ADC would thus have no impact. Only the inner diameter of the bearing causes vignetting.

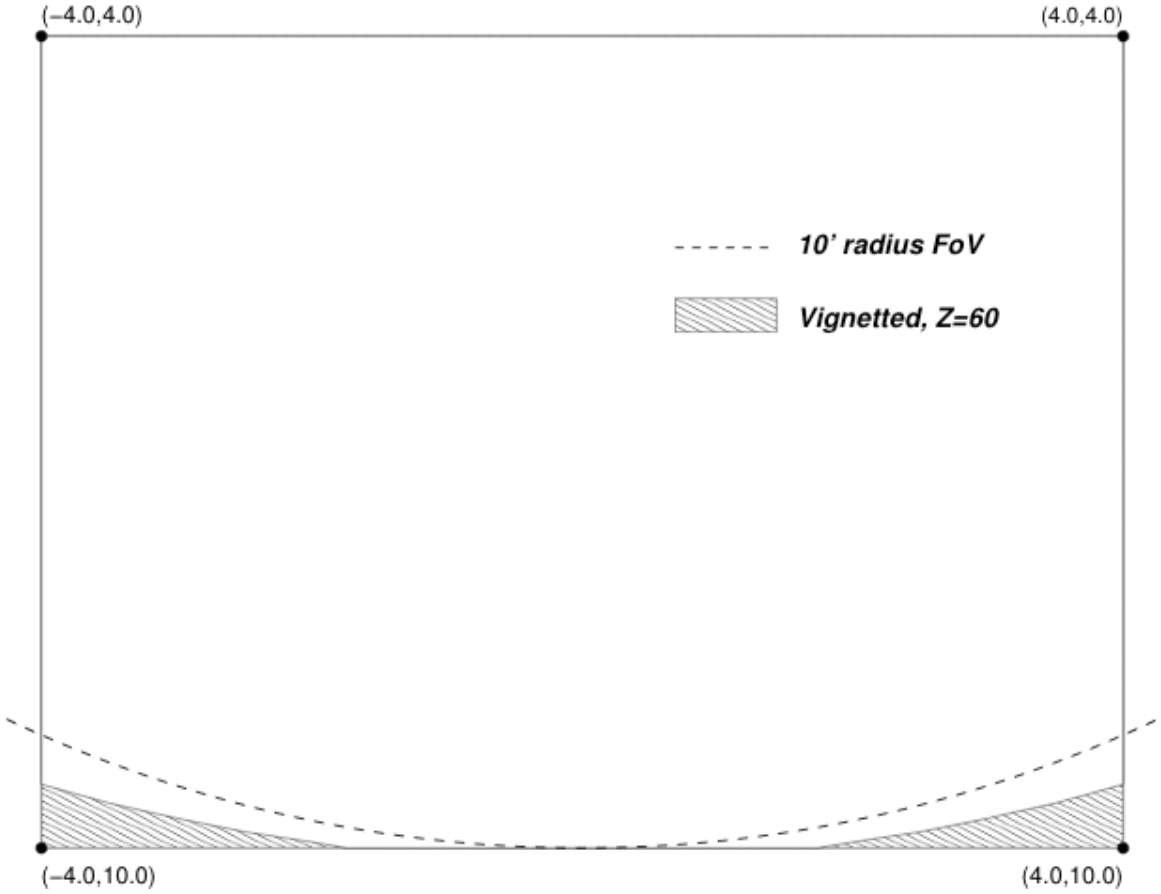

Figure 2: A map of the LRIS field, showing the maximum vignetted regions (shaded), which occurs with the ADC fully extended and LRIS at the bottom of its rotation. The worst vignetting in the corners is only 0.66%. Note that all vignetted regions lie outside the 10' radius FOV (dashed line). No vignetting occurs at elevations above 58°, nor with LRIS rotated within ±106° of its highest position.