

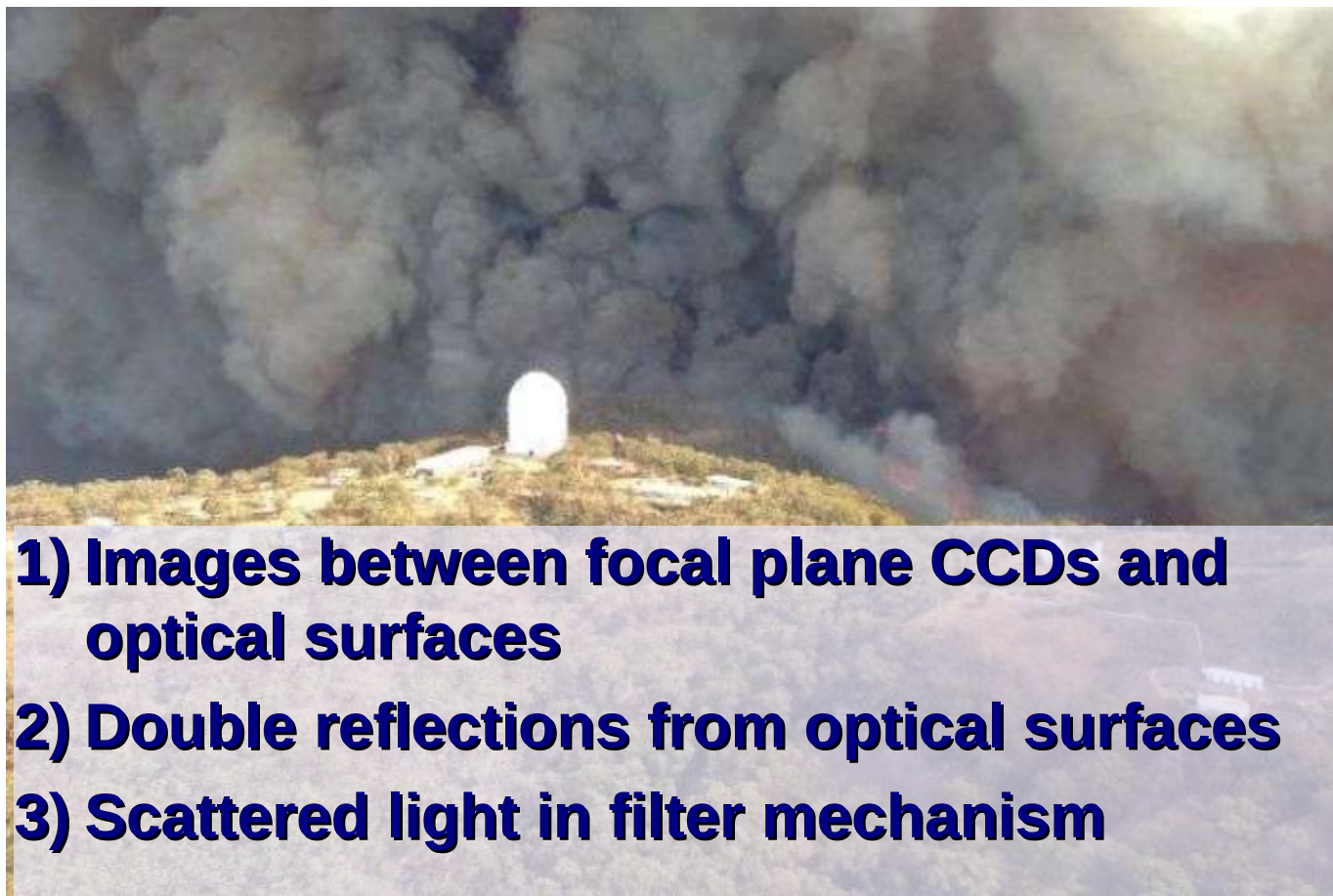


DARK ENERGY  
SURVEY

FERMILAB-SLIDES-20-114-SCD

# Ghost Images in DECam

with thanks to the Eyeball Squad

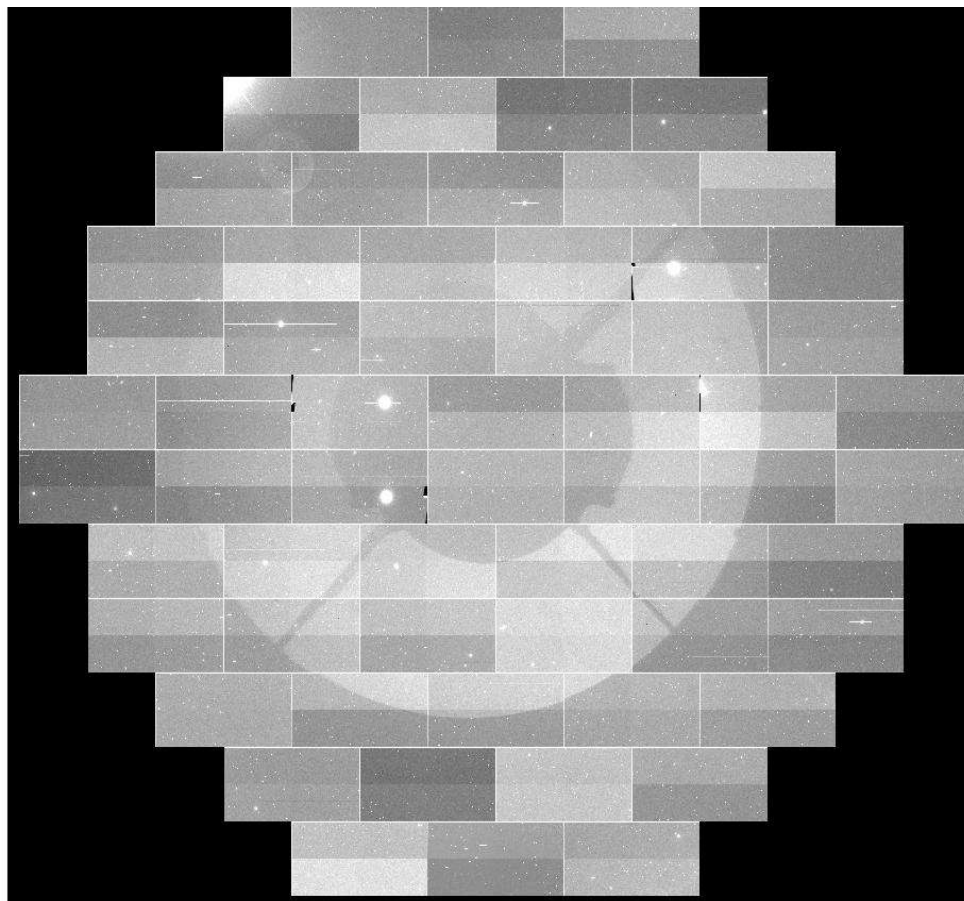
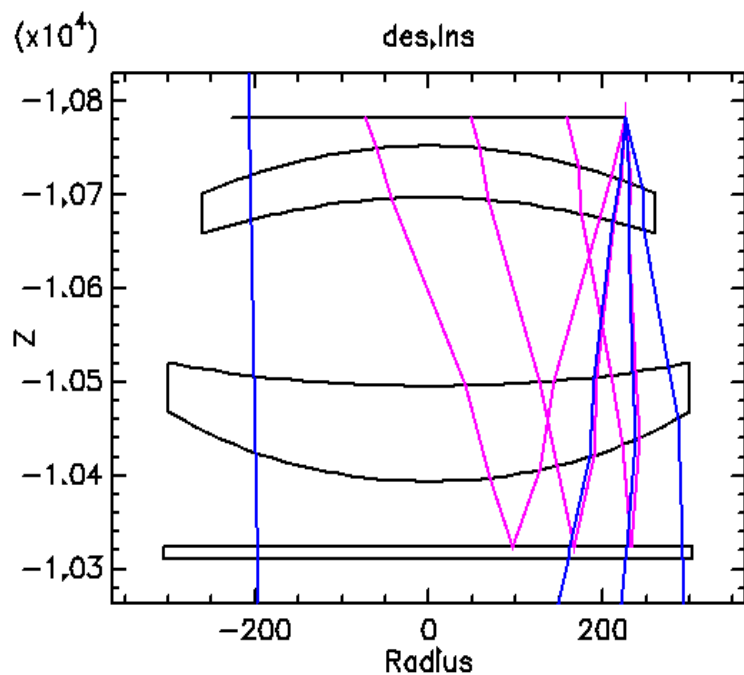


- 1) Images between focal plane CCDs and optical surfaces**
- 2) Double reflections from optical surfaces**
- 3) Scattered light in filter mechanism**



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# CCD + Filter

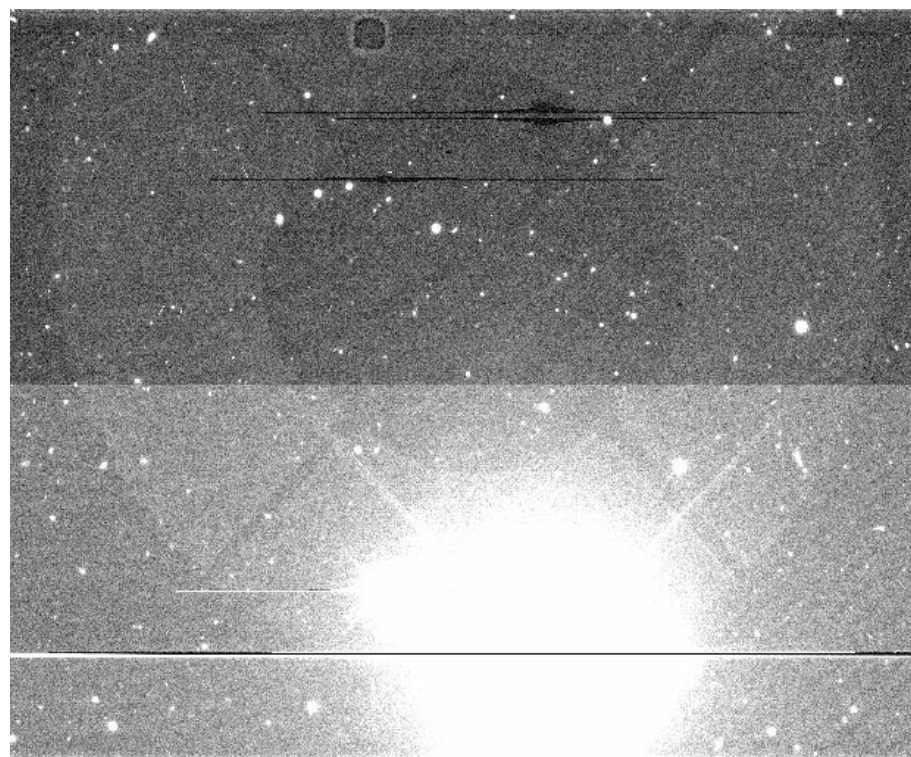
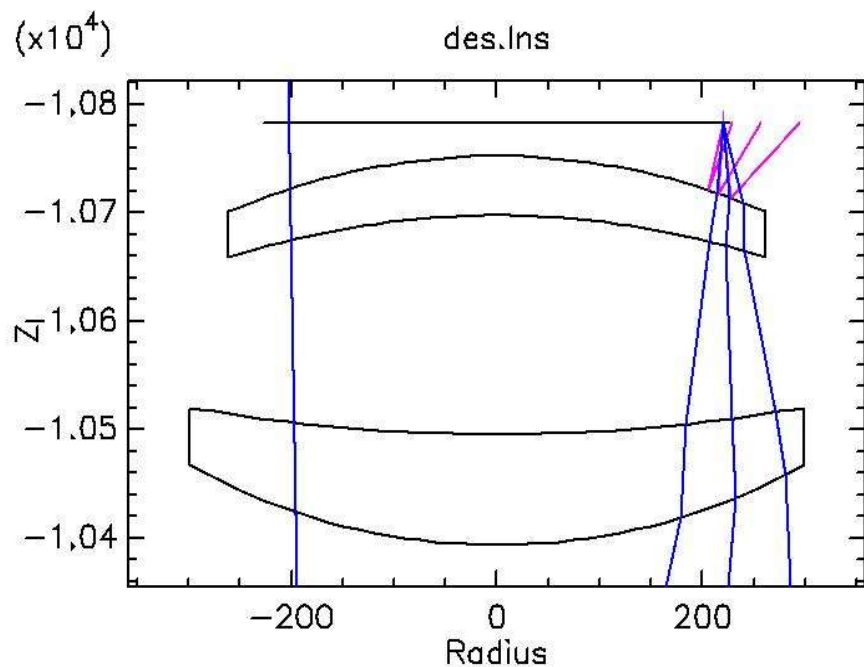


**Exit pupil ghost of R Doradus  
157555**



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# CCD + Rear C5

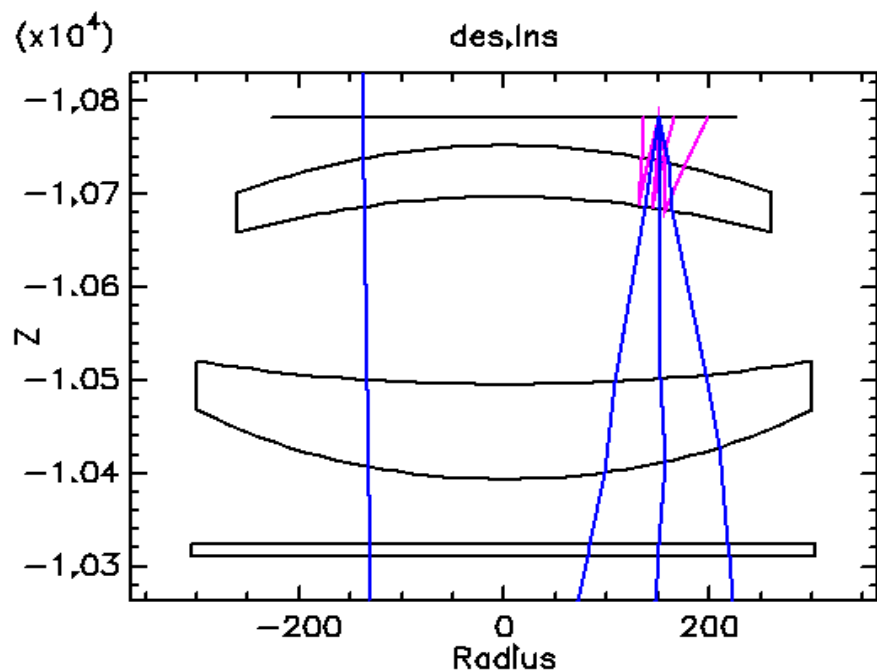


**Ghost of Mira 150983**



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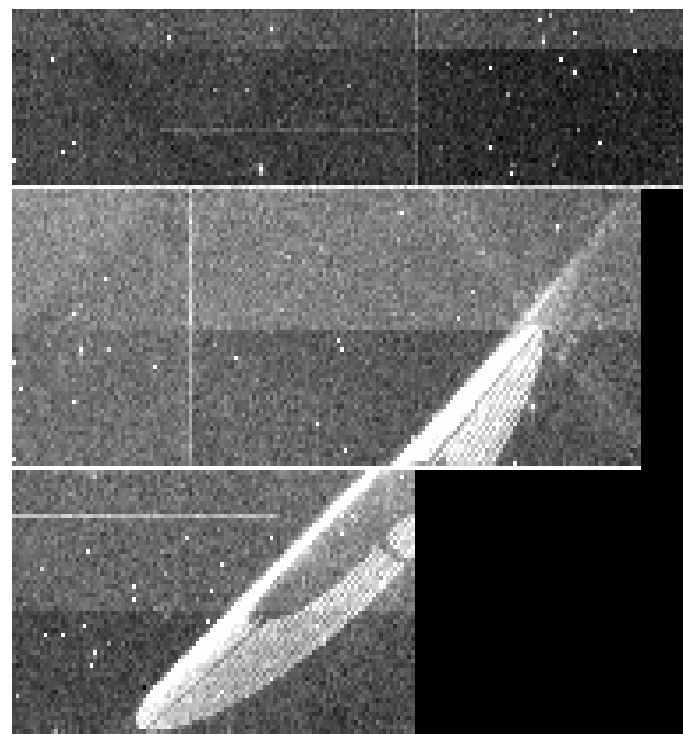
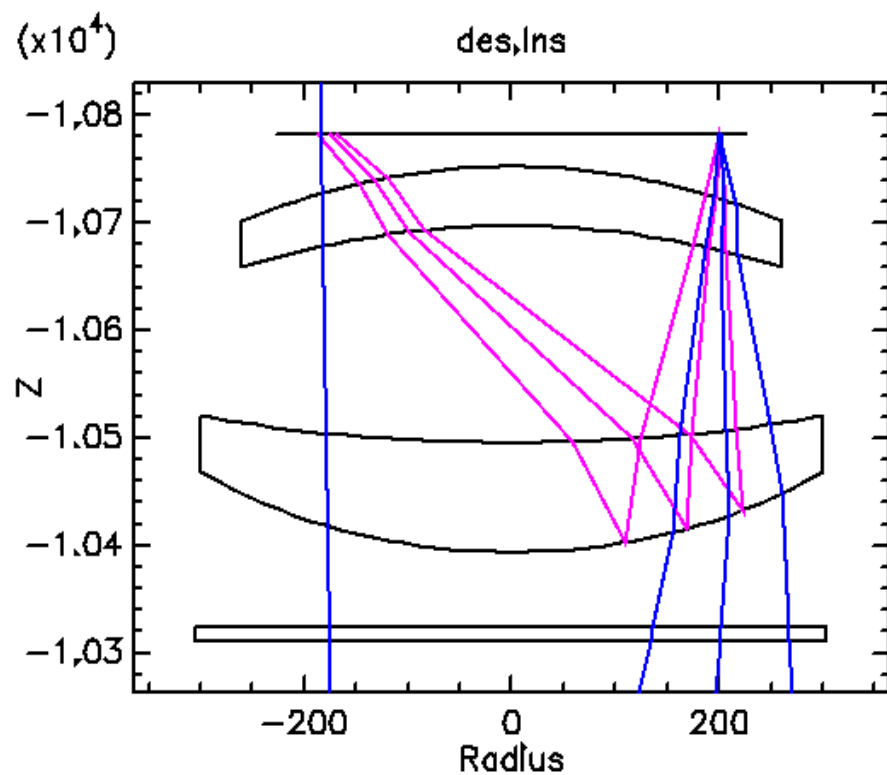
# CCD + Front C5



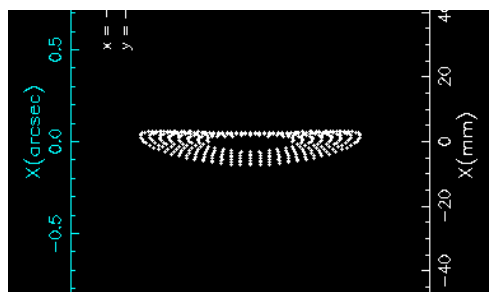


# CCD + Front C4

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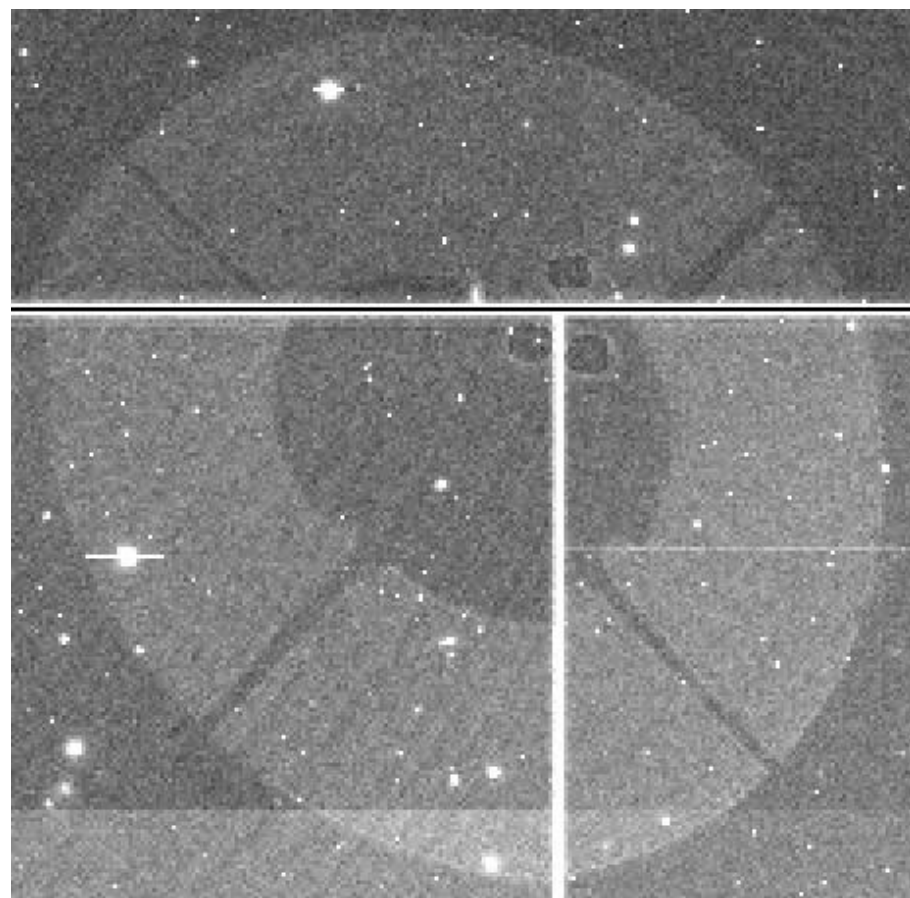
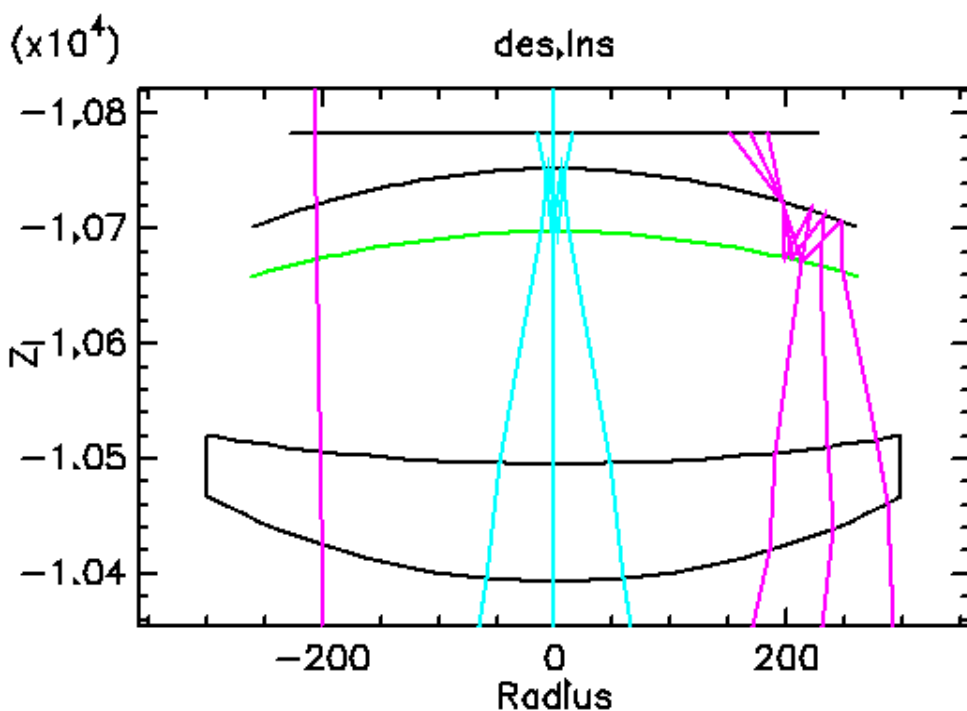
**Ghost of R Doradus 157556**





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# Internal Reflection - C5

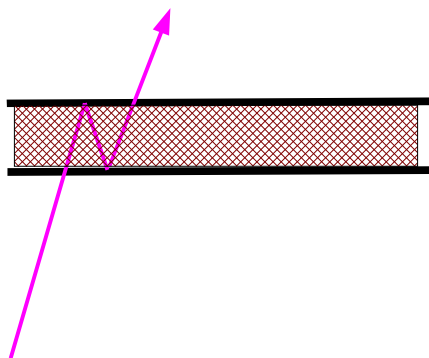


**Ghost of R Doradus 157554**

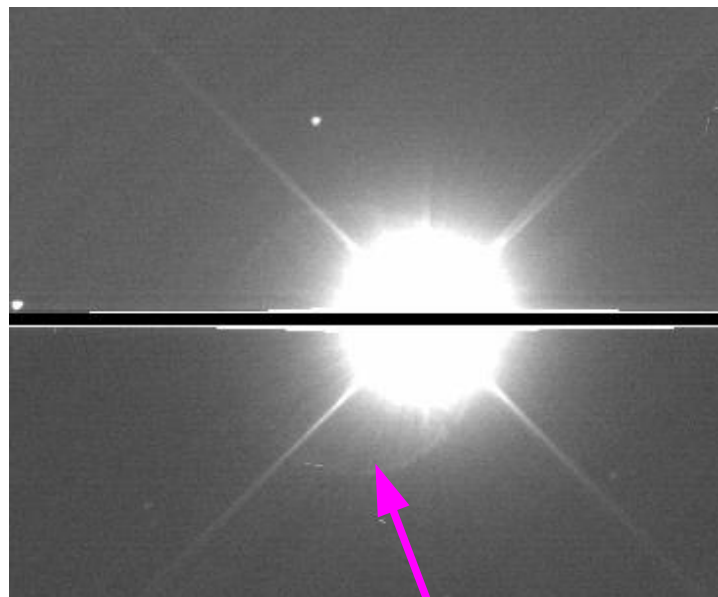


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# Double Internal Reflection - Filter



Ray bouncing inside  
a filter



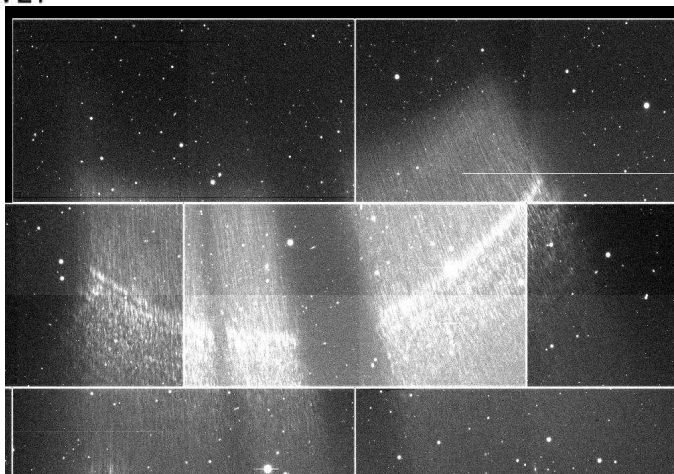
Ghost

Bright star in Orion Region, z filter 150720

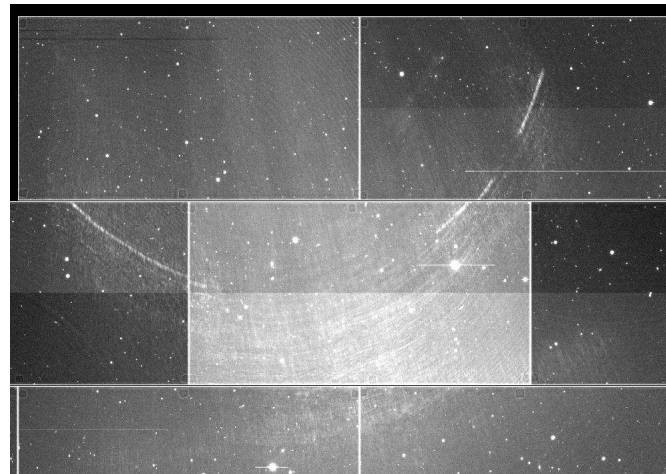


# Scattered Light from Filters/Shutter

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Mira g-band 149251

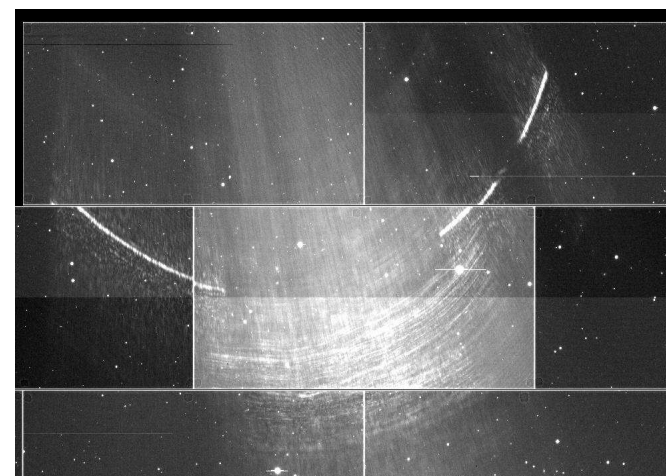


Mira i-band 149251

Mira 1.67  
Degrees  
off-axis



S. Kent, Jan 16, 2013 Mira r-band 149252

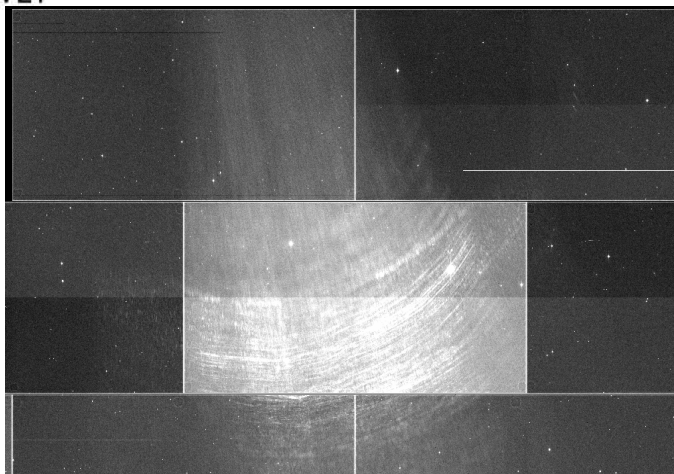


Mira z-band 149251

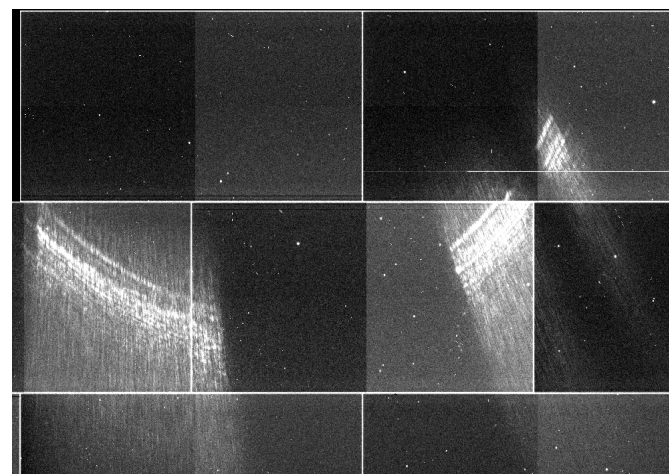


# Scattered Light from Filters/Shutter

DARK ENERGY  
SURVEY

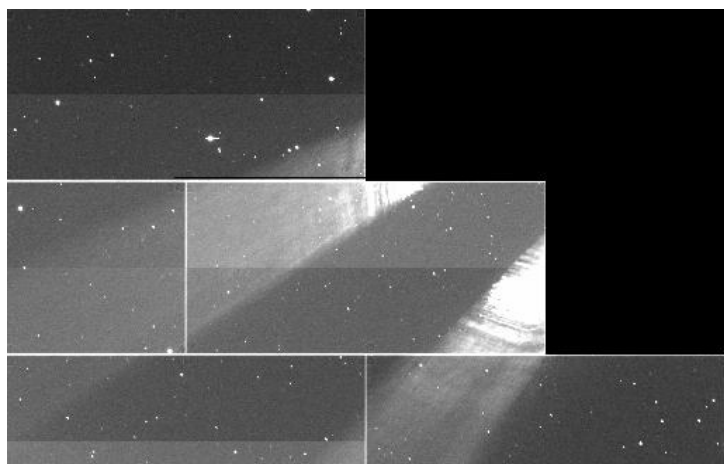


Mira Y-band 149713

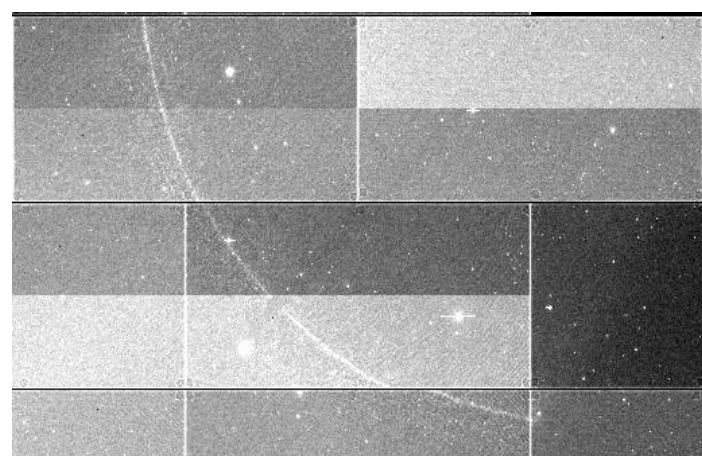


Mira u-band 149710

Mira 1.67  
Degrees  
off-axis



Mira  
1.45  
Deg.  
off-  
axis



Mira 1.79  
Degrees  
off-axis



# Puzzles - partially solved

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- **Three types of scattered light:**
  - **Spray (Type I)** Y filter is prototype
  - **Spray (Type II)** g filter is prototype
  - **Arc** z filter is prototype
- Raytrace of light reflected from side of filter has correct location, shape in focal plane BUT specular reflected rays should be blocked by filter frame rim.  
**Rays pass in through uncoated portion of filter**
- Unclear what blocks portions of arc **Fins and Central “chimney”**
- Origin of “spray” **(Type I)** is unclear **Inside shutter wall**
- **Origin of “arc” still unclear**



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# Central “chimney”

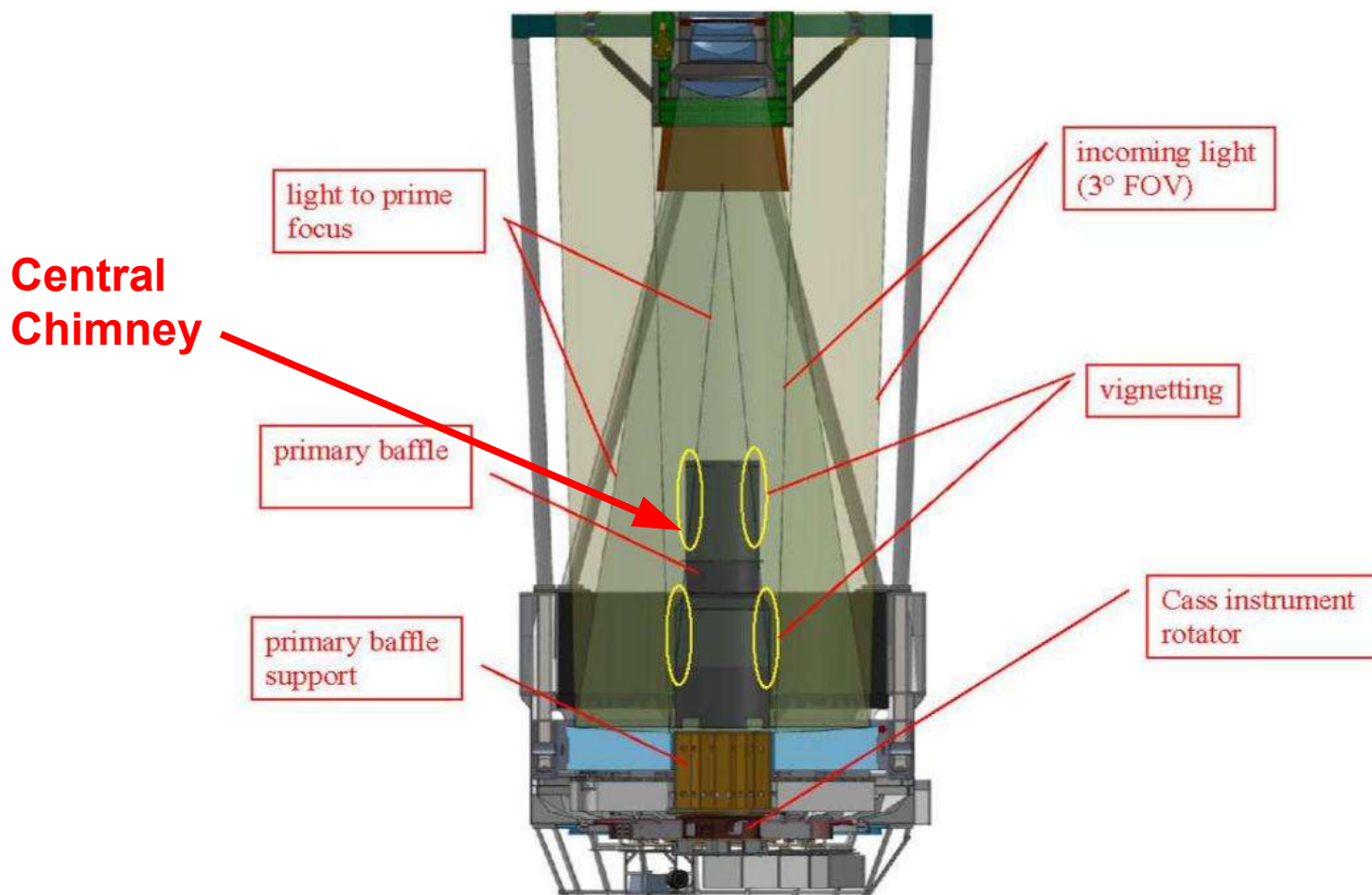
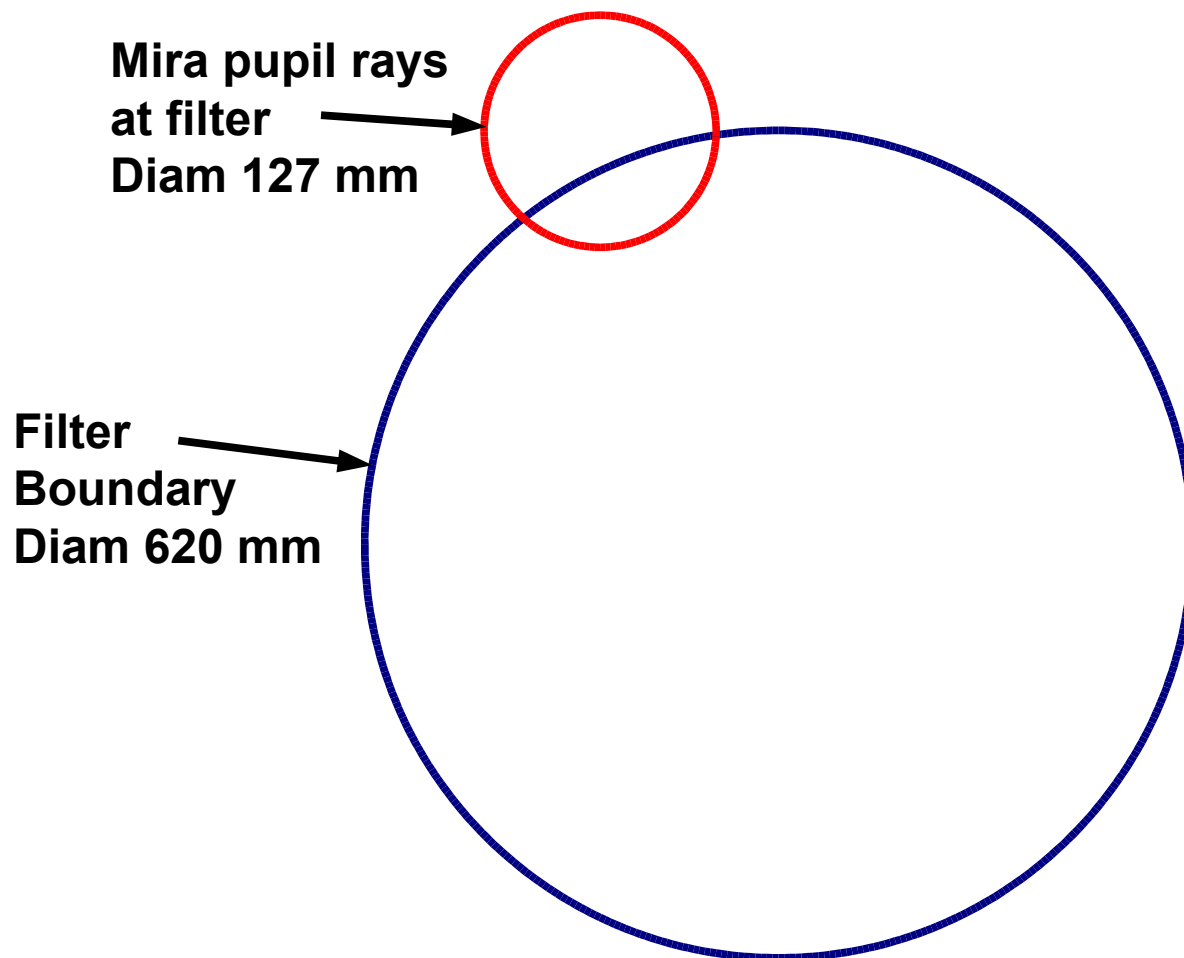


Figure 11: Vignetting of reflected light by the current Mayall primary baffle for the BigBOSS 3° FOV.



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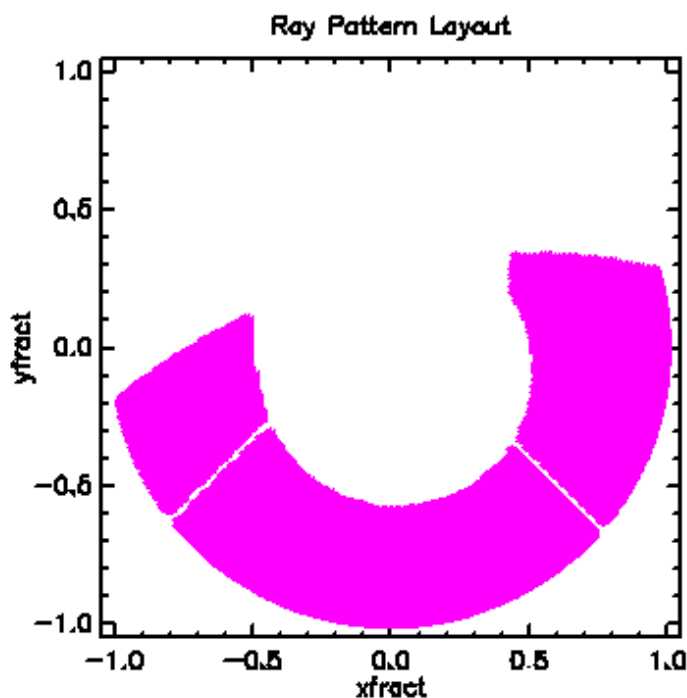
# Geometry at Filter



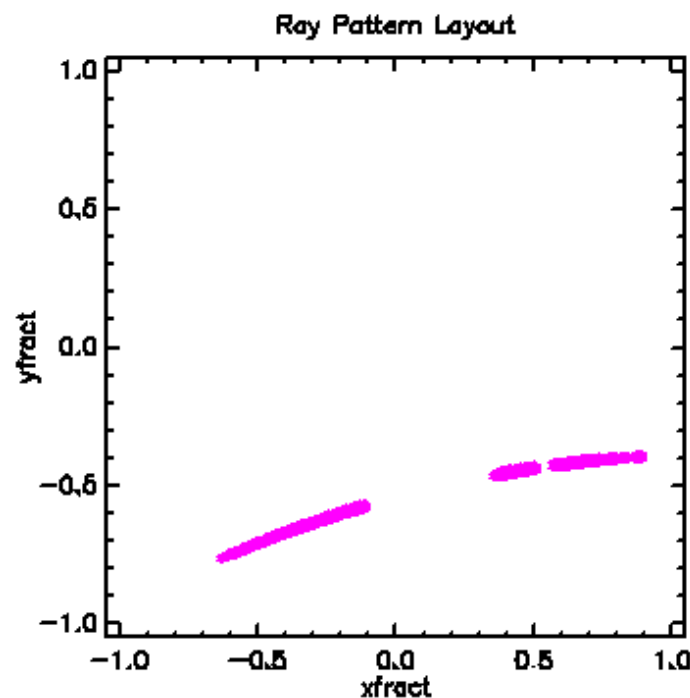


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# Rays from beam that strike filter edge



Full pupil, 1.67 deg. off-axis

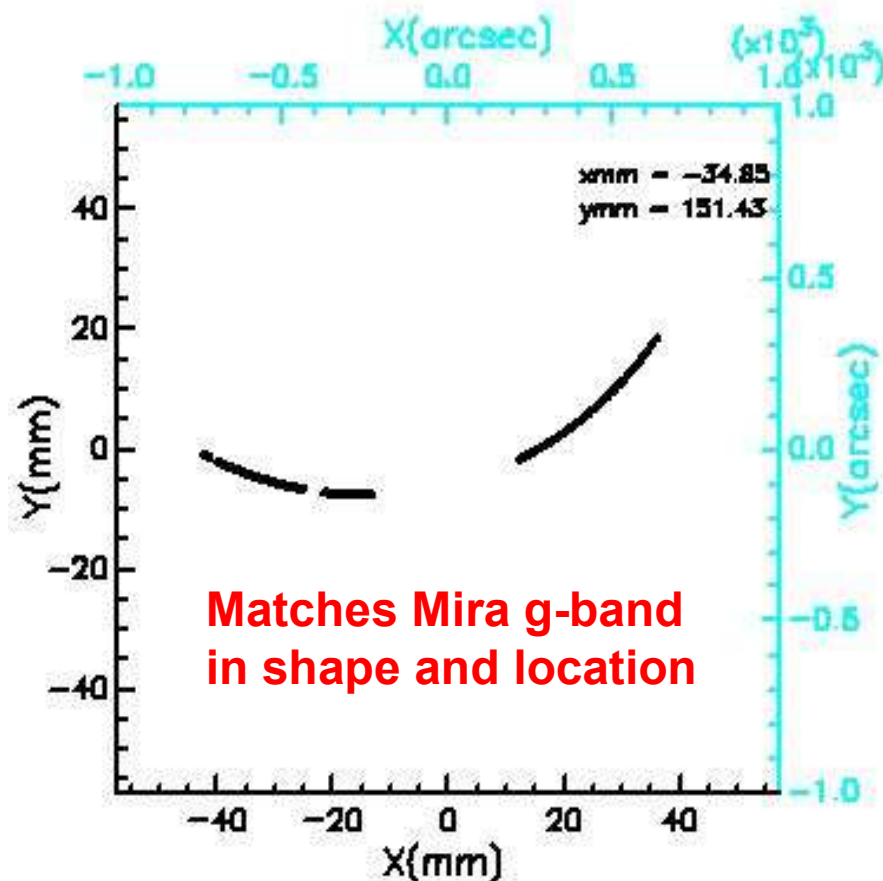
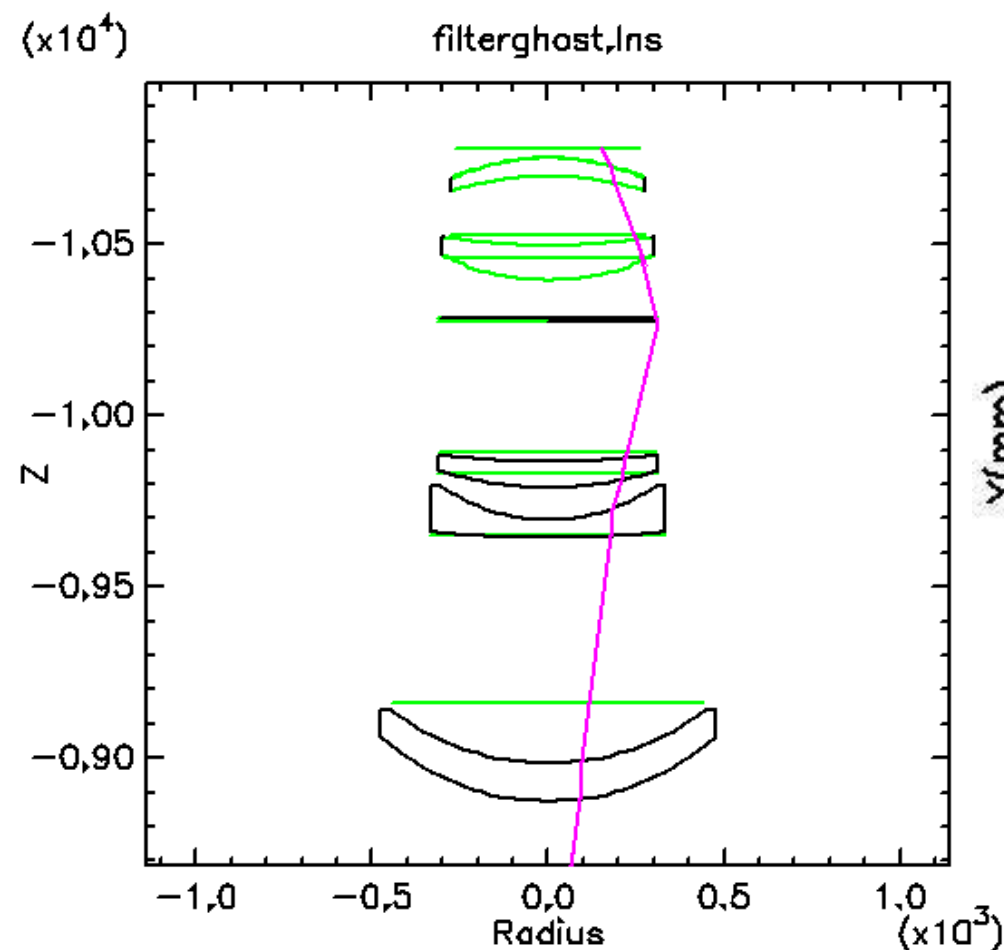


Intersection with edge of g filter



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# Raytrace of Mira - 1.67 degrees from field center, light reflected from filter side



Mira position: X = -81 mm  
Y = 334 mm



# Filter Changer Mechanism

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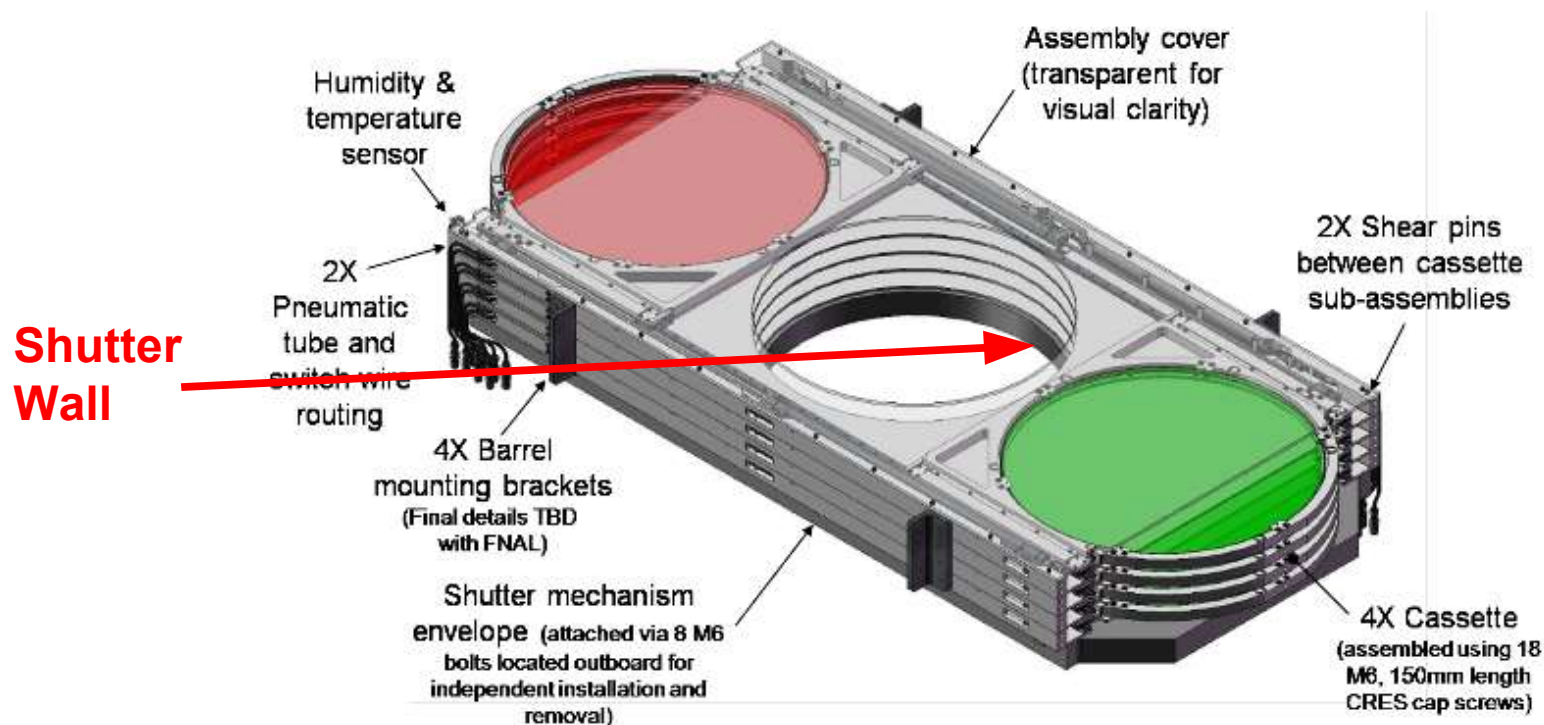
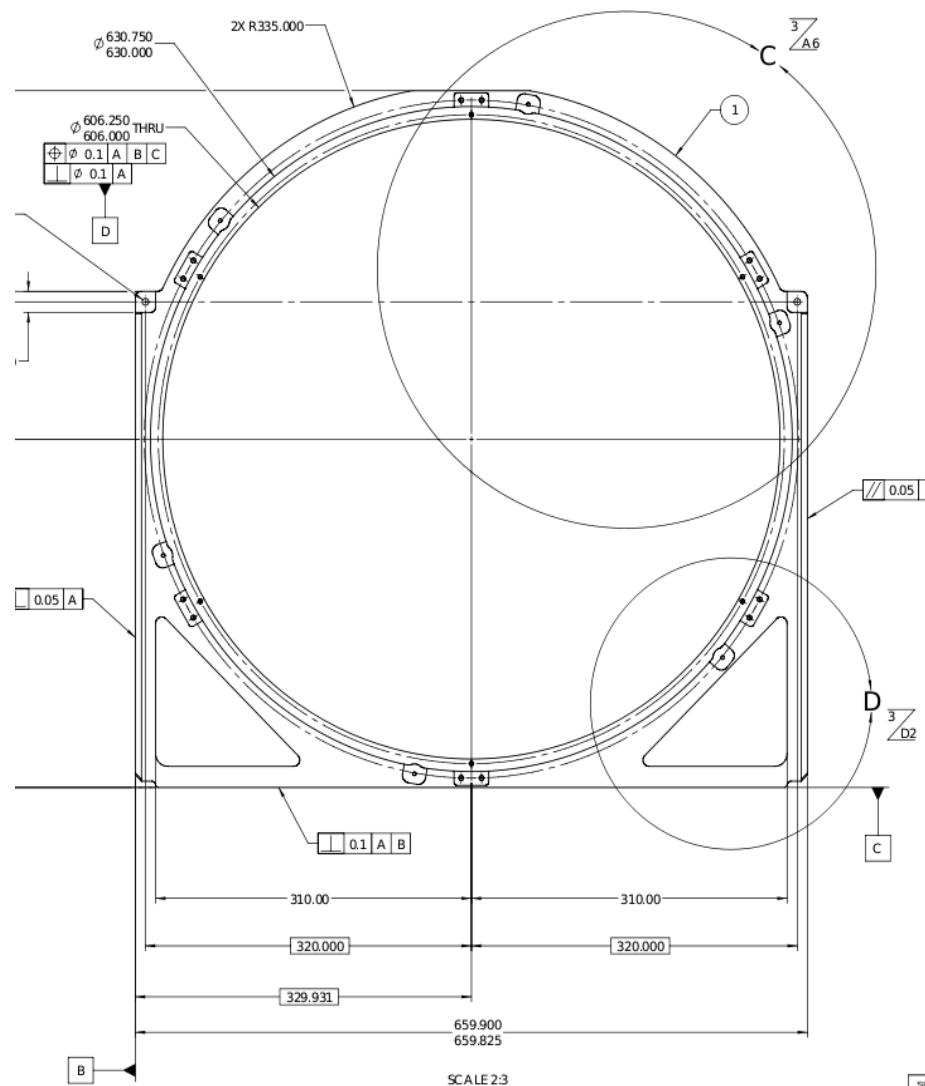


Figure 1: Filter changer mechanism and shutter attached.



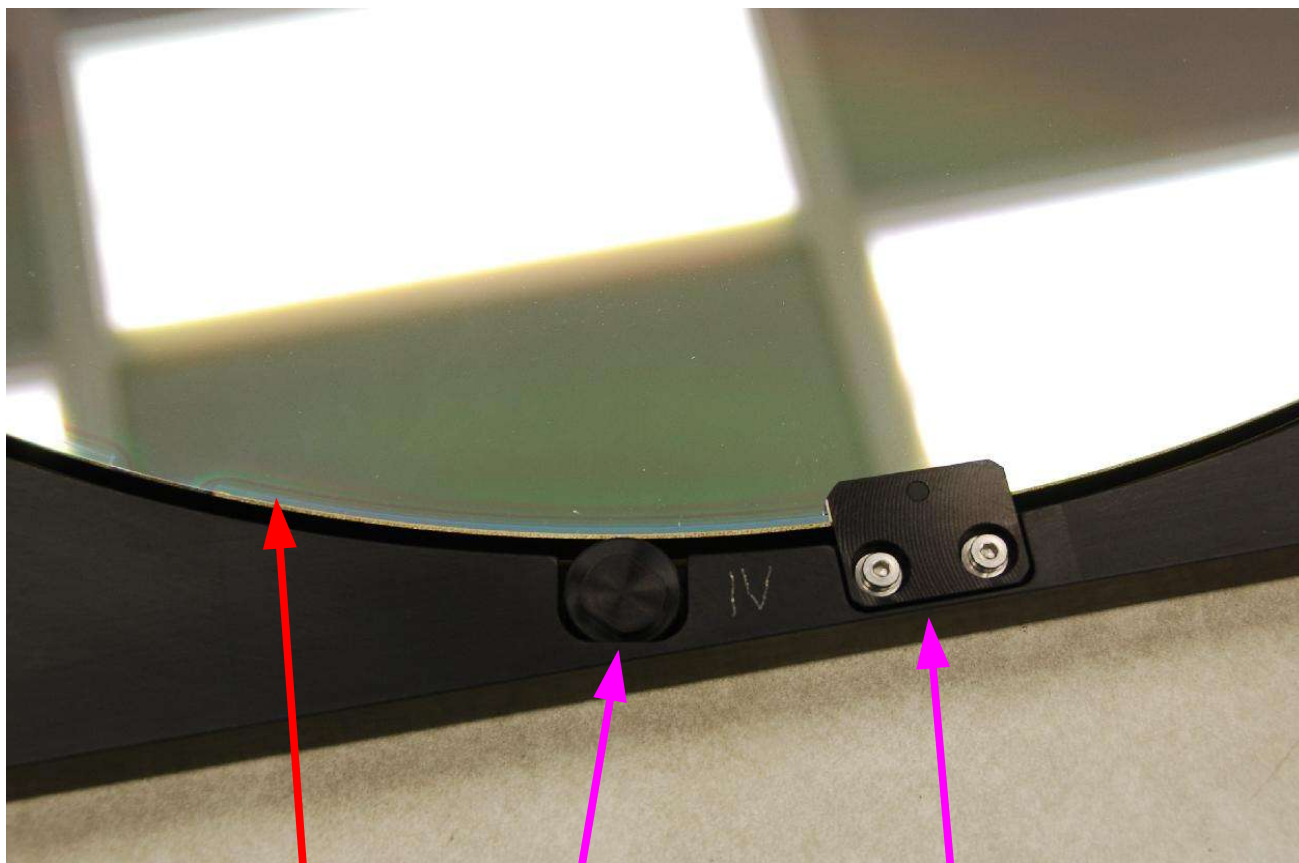
**DARK ENERGY:  
SURVEY**





# Filter Holder Geometry

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Radial spacer

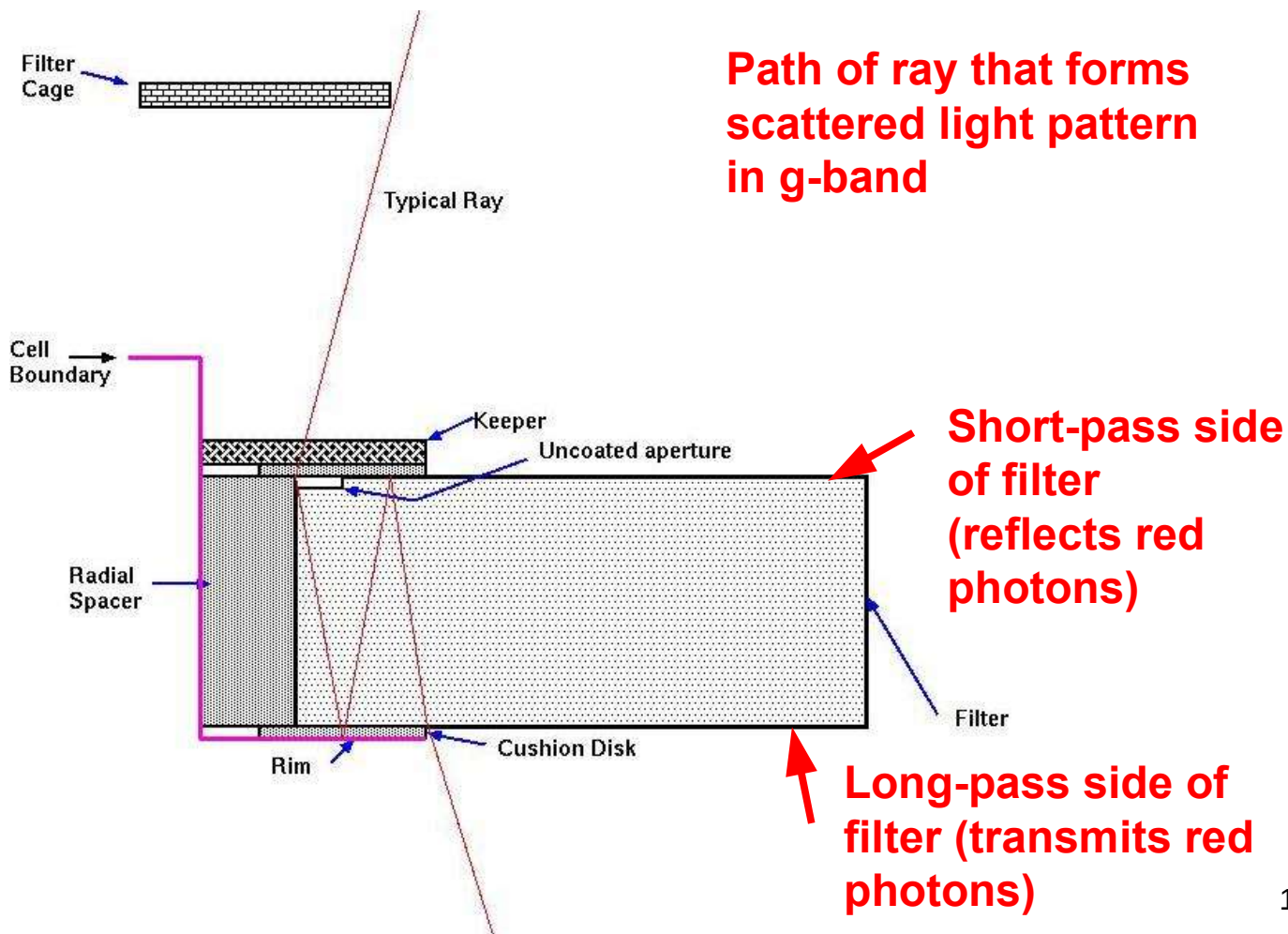
Keeper

Filter coating does not extend to edge **Unwanted light enters here**



# Side View - Spray (Type II)

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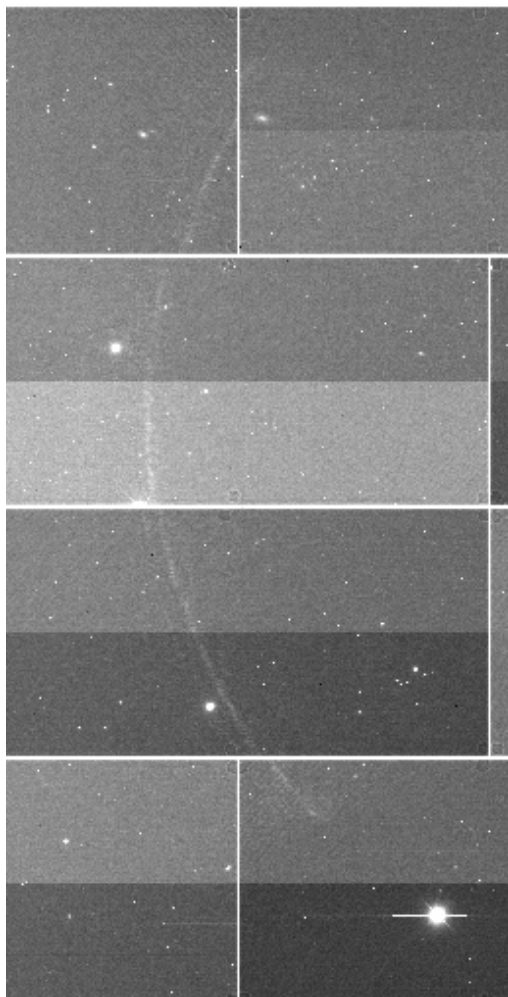
# Origin of Arcs - smoking gun

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**154500**

**Z band**

**1.82 deg.  
off axis**

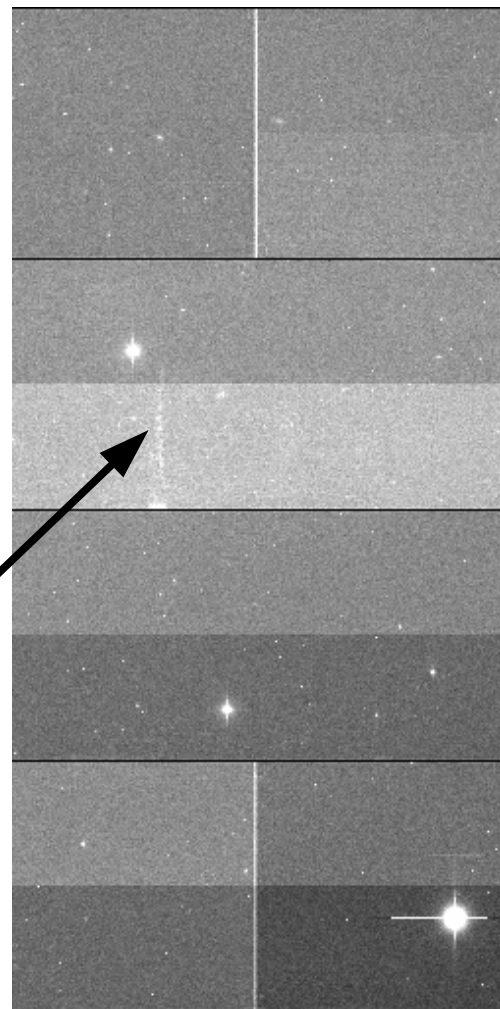


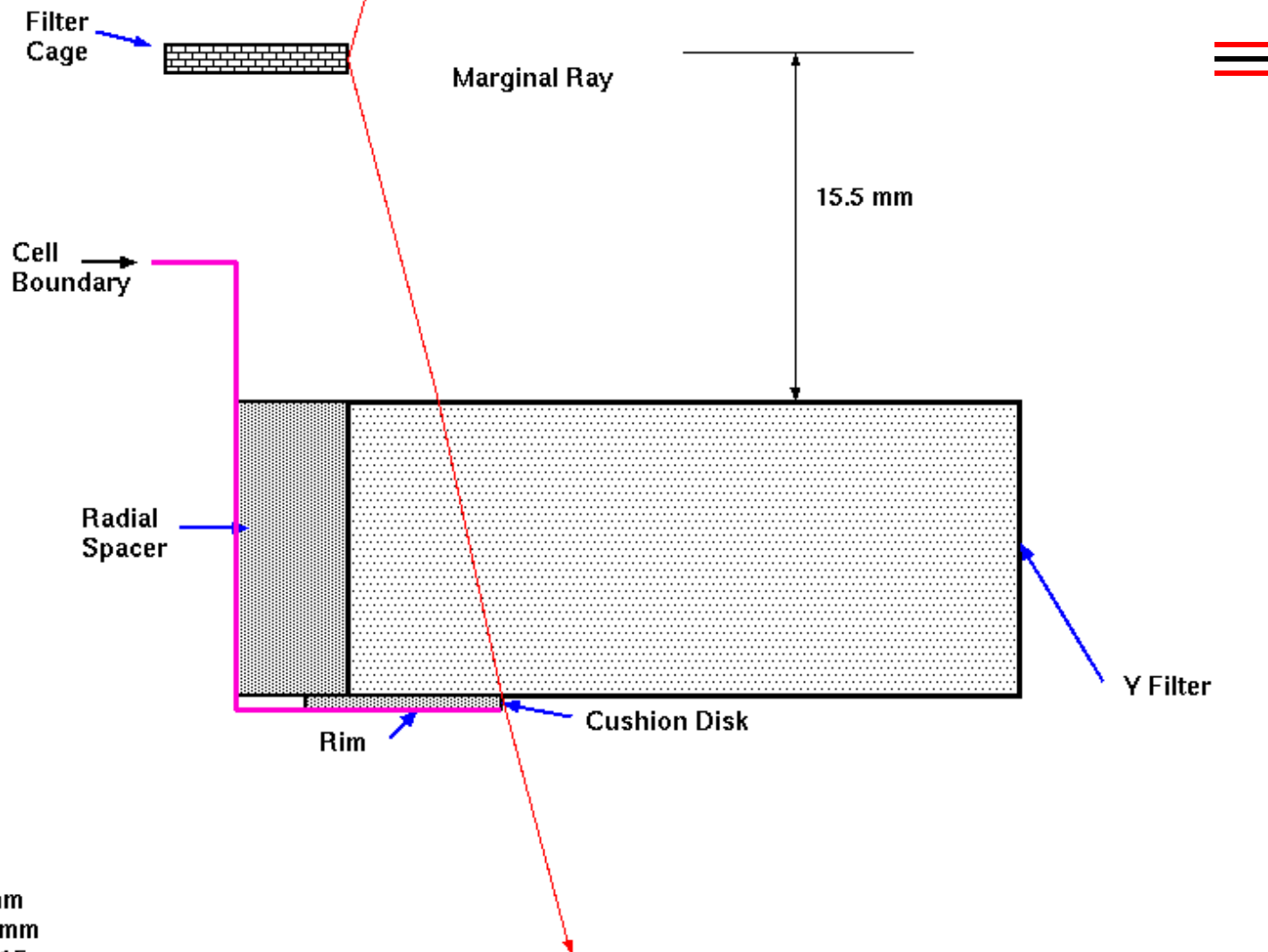
**154501**

**Y band**

**1.82 deg.  
off axis**

**Faint arc**





Radius:

Rim 303 mm

Filter 310 mm

Cell wall 315 mm

Filter cage: 310 mm (???)

Shutter: 300 mm

**Side View of Filter Cell, Cage, and related  
showing arc rays for Y filter**



# Conclusions

- **Ghost images are all understood. Amplitude is about what is expected for CCDs with 10%-15% reflectivity, filters with 1%-1.5% reflectivity.**
- **Scattered light from bright stars off the field has multiple causes:**
  - a) Unblocked edges of filters. We definitely want to add baffles to all filters to block light around edges.
  - b) Inside shutter wall. We want to either paint the wall with aeroglaze black (or equivalent) or add some baffles
  - c) filter cage or some other surface located above u/Y filter cassette. Probably need to examine visually before deciding on a course of action.