



X-ray Evaluation of the MaGIXS Nickel-Replicated Mirrors

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August 15, 2019

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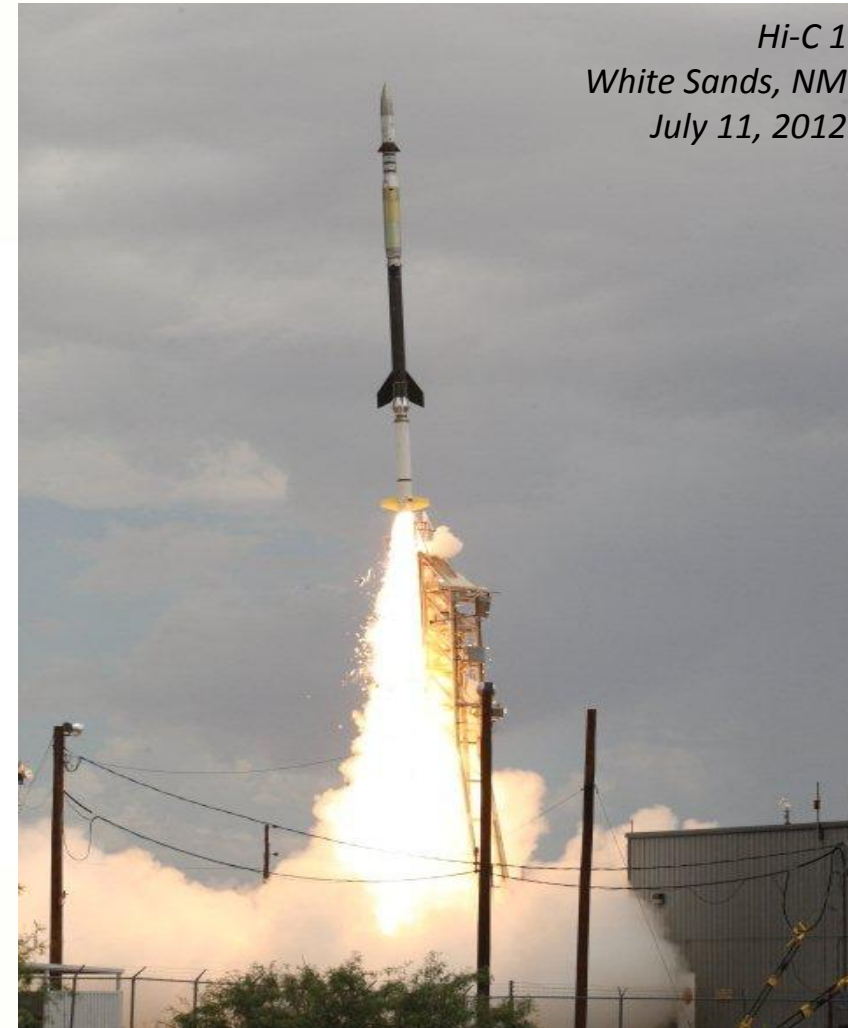


The Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)



Experiment Overview:

- Solar sounding rocket experiment
- 2020 Launch – WSMR, NM
 - Black Brandt - IX
- NASA MSFC developed optics, optical bench, detector
- Partner institutions:
 - SAO – mirror mounting and alignment
 - MIT & Izentis LLC. – grating design and fabrication



*Hi-C 1
White Sands, NM
July 11, 2012*



The Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)

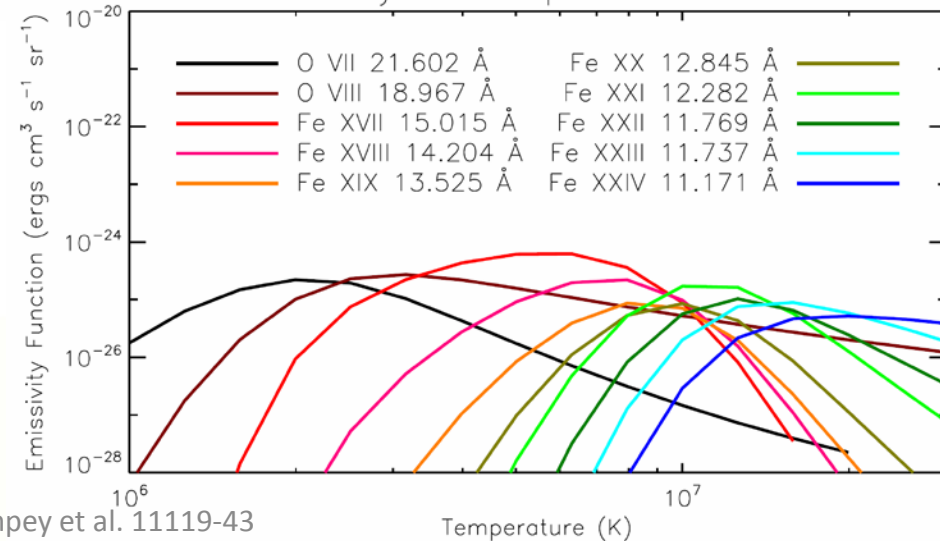
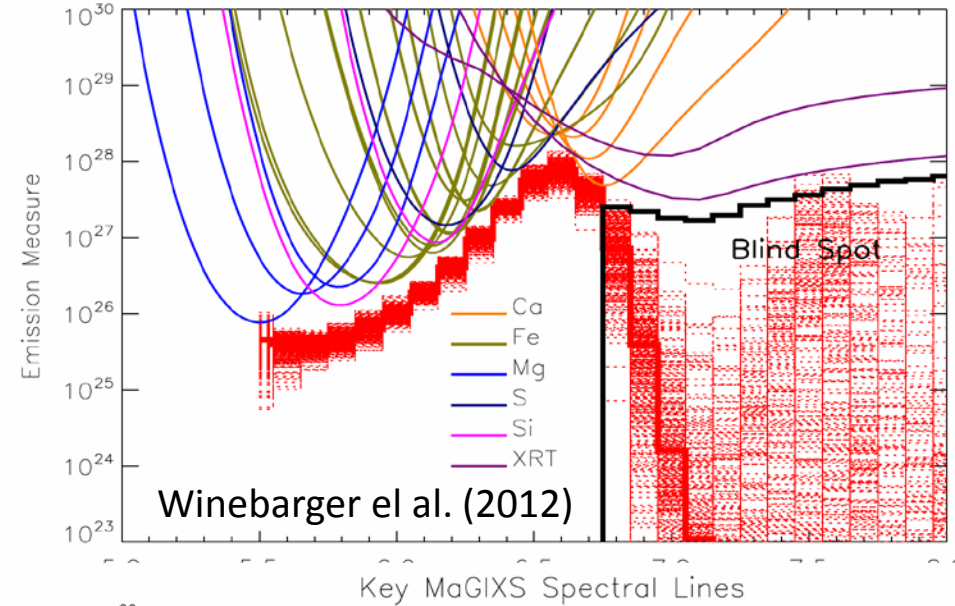


Science Goals: Probe Coronal Heating

- Measure the temperature distribution (Differential Emission Measure) of the solar corona
- Measure the elemental abundance in the solar corona

Observation Goals:

- Energy range: 0.57 – 1.3 keV (0.91 – 2.16 nm)
- Energy resolution: ~1 eV (0.005 nm)
- Slit spectrograph with 260" slit length
- 6" spatial resolution along slit



Wolter-I Telescope:

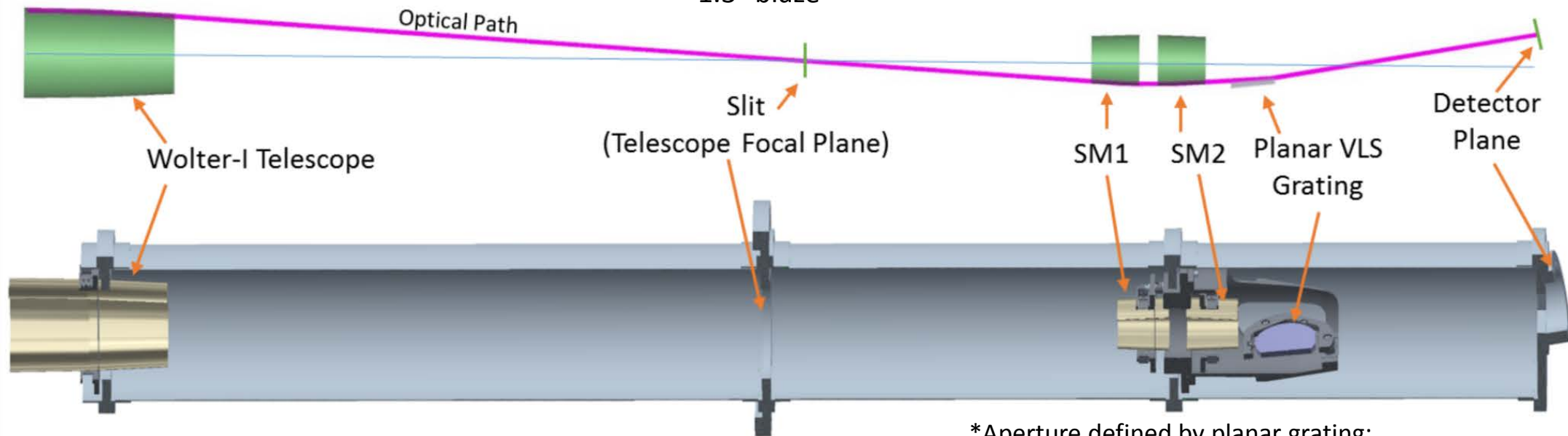
- Nickel Replicated
- Focal length = 1090 mm
- Diameter = 150 mm
- Graze angle = 1.0°

Spectrometer:

- Nickel Replicated
- Finite conjugate pair
- Focal length = 594 mm
- Planar varied-line-space grating
- 1.3° blaze

Detector:

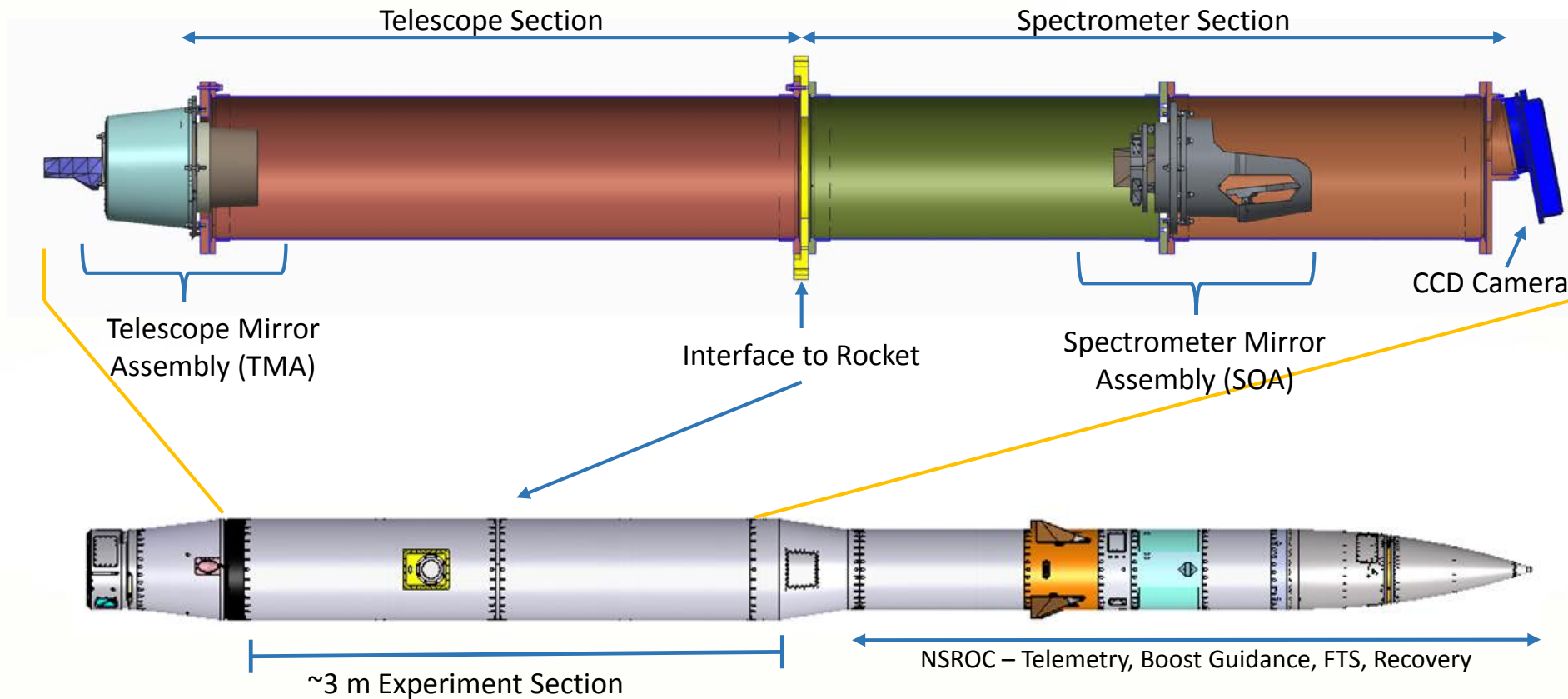
- CCD camera
- e2v 2k x 2k frame-transfer
- 2k x 1k active region
- $15 \mu\text{m}$ pixels



*Aperture defined by planar grating:
effective aperture $\sim 36^\circ$



Instrument Layout





Mirror Fabrication



*See paper 11119-30 by Jackie Davis, MSFC

- Mandrels diamond turned
- Lap polished
- Replicated engineering shells
- Deterministic polishing
- Lap polished for surface roughness
- Replicated flight shells

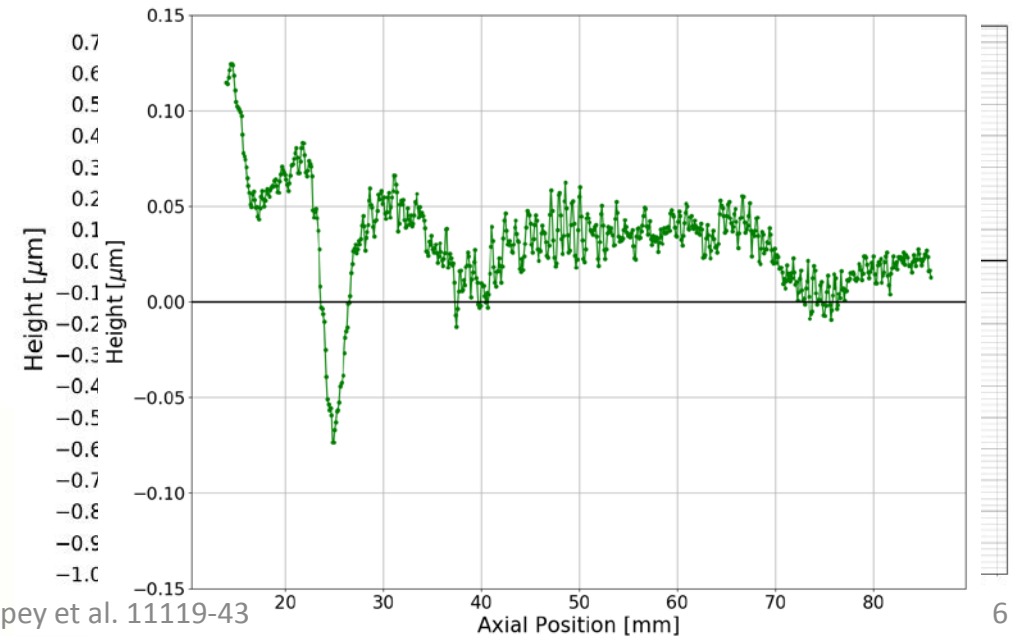


MaGIXS Mandrel on Zeeko IRP 600X

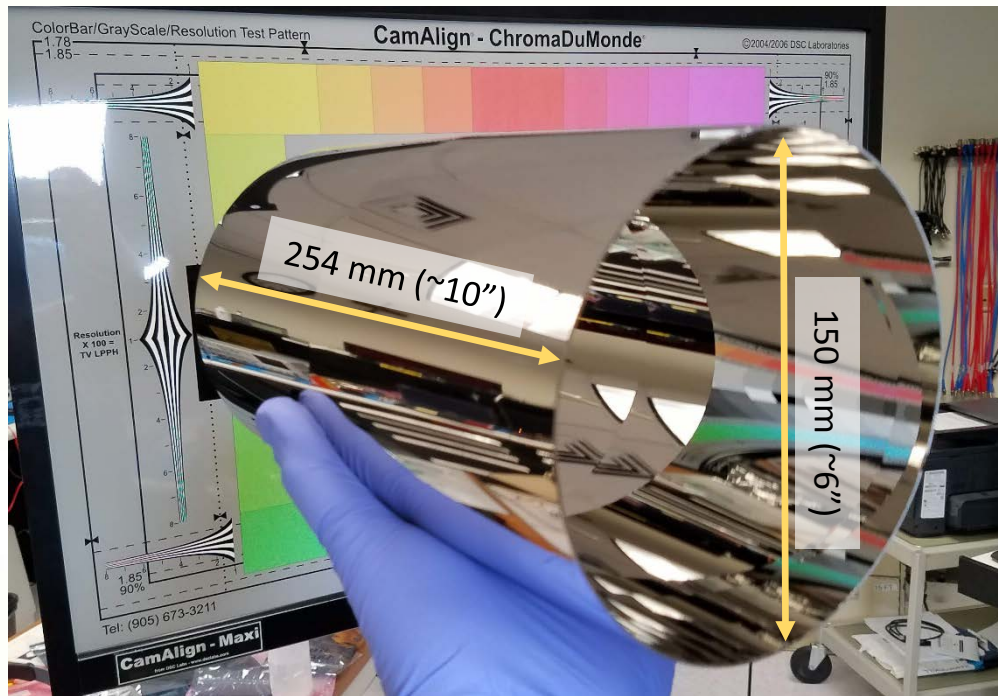
RMS slope error of mandrel figure

Mirror segment	Conventional	Predic. Mandrel HPD	Deterministic		Predic. Mandrel HPD
			Left:Axial,	Right:Axial+Az	
Wolter-I P	~4.0"	19.5"	0.72"	0.99"	6.4"
Wolter-I H	~6.0"		1.26"	1.51"	
Spec. P	~8.0"	22"	1.5"	-	4.0"

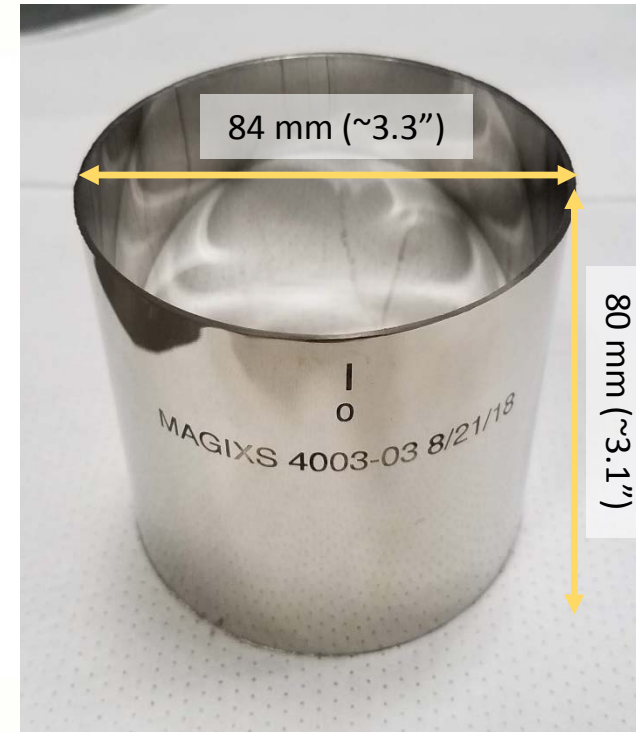
MaGIXS Spectrometer Mandrel



Wolter-I Telescope

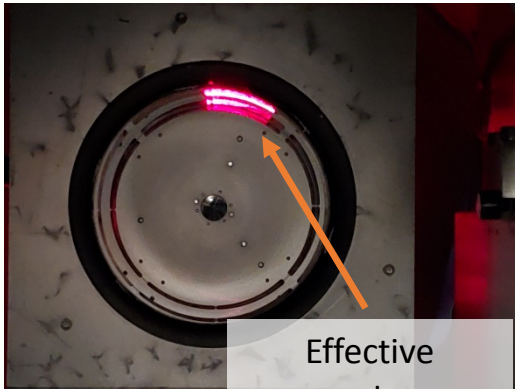
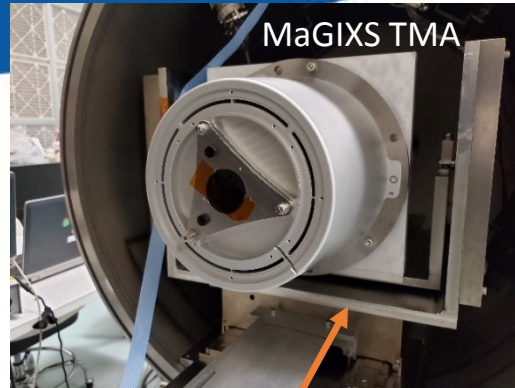


Spectrometer Mirrors - Single Paraboloid



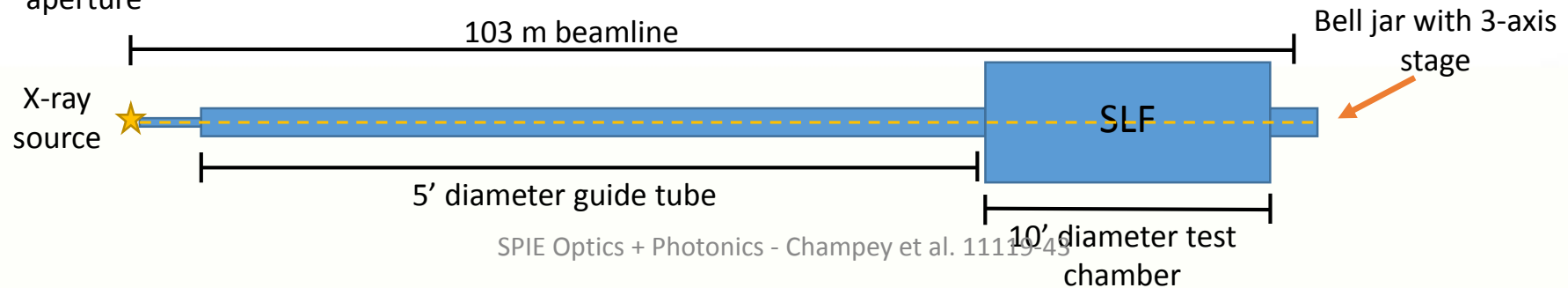
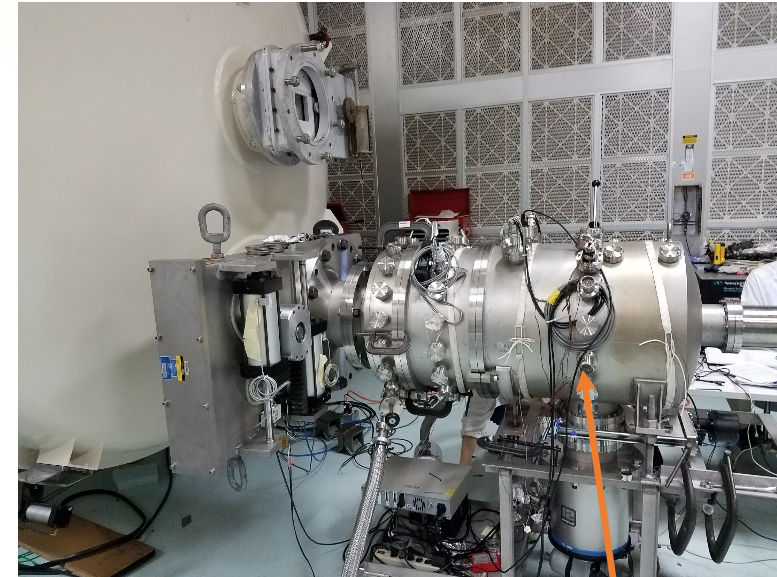


X-ray Tests in Stray Light Facility (SLF), MSFC



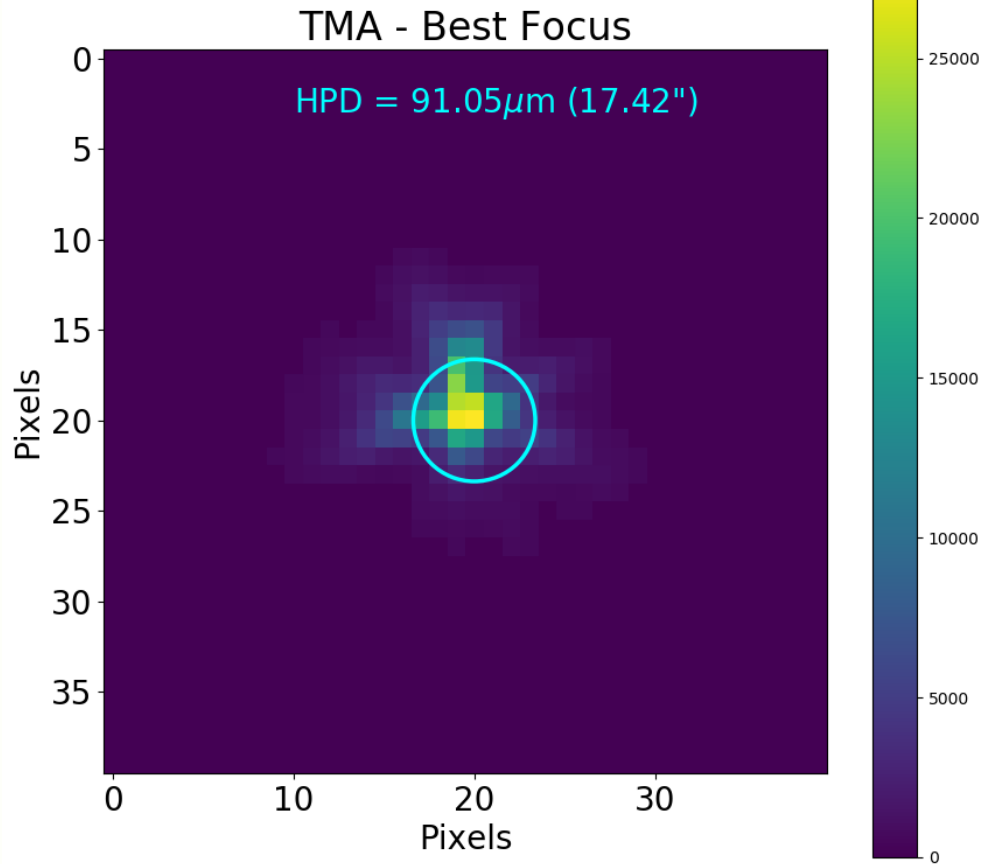
Detector: Andor Ikon-L

- 2k x 2k CCD
- 13.5 μm pixels

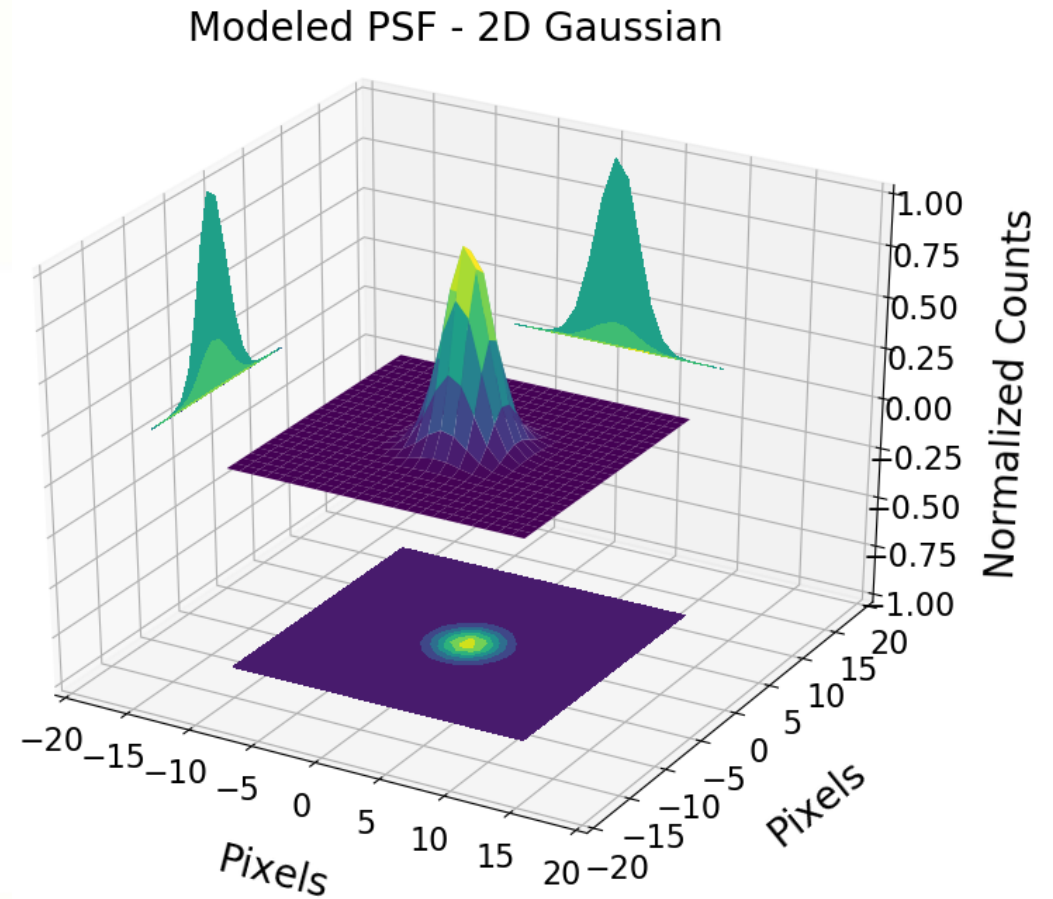




TMA Best Focus Image



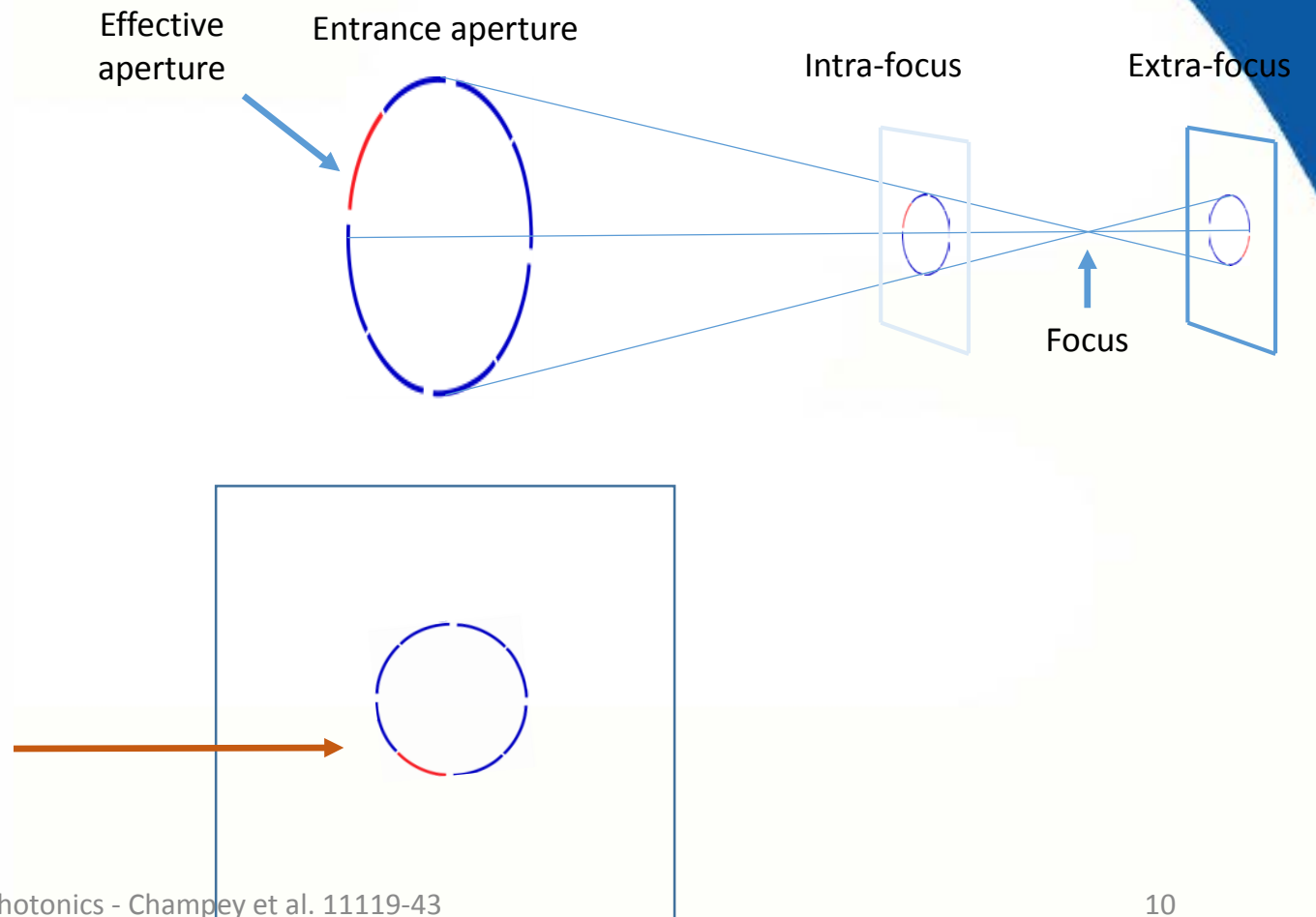
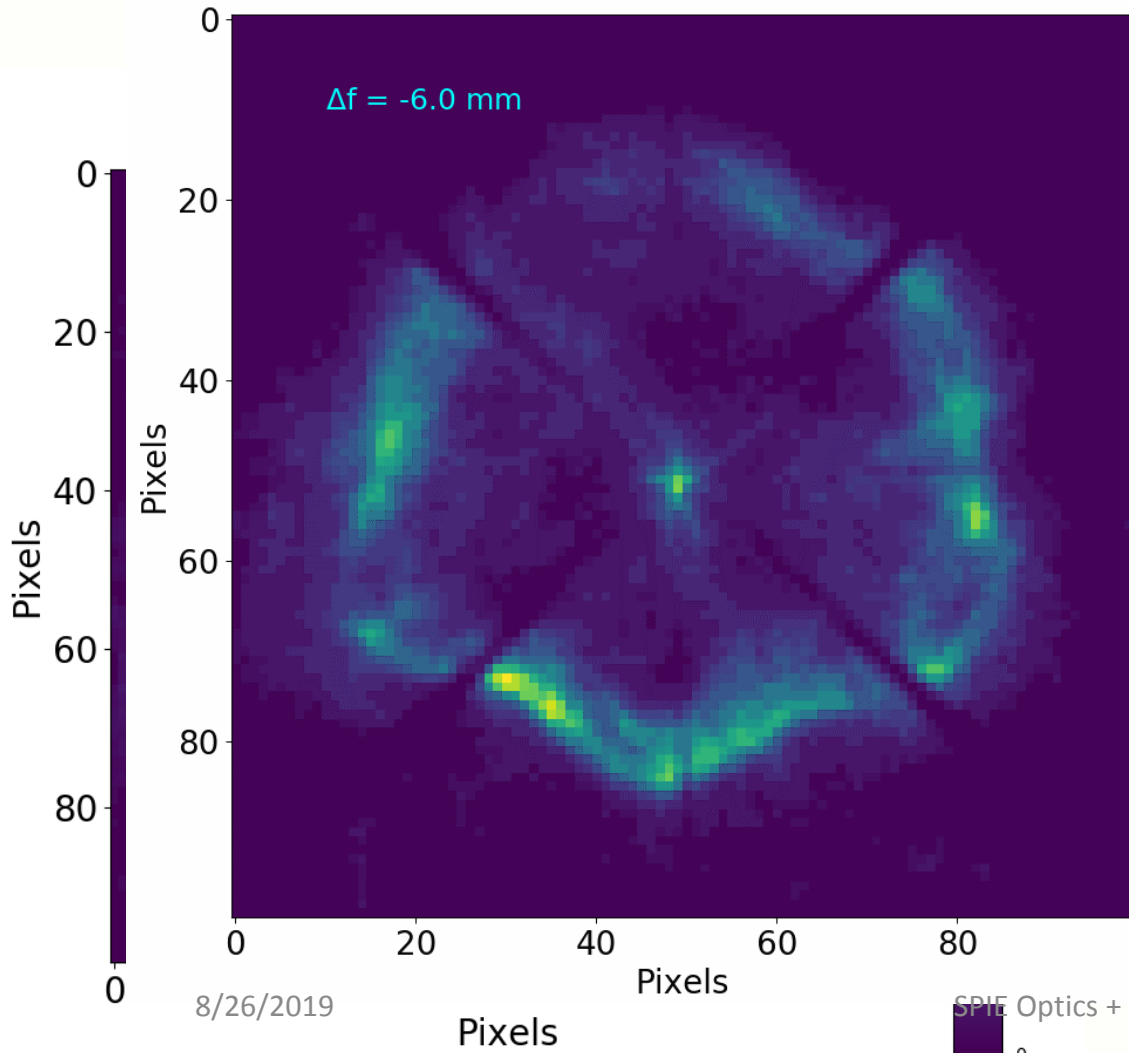
- plate scale = 2.5 arcsec/pix
- Pixel size = 13.5 μm



- FWHM (x,y) = 10.02", 10.55"
- Symmetric Gaussian PSF



Through-focus Images

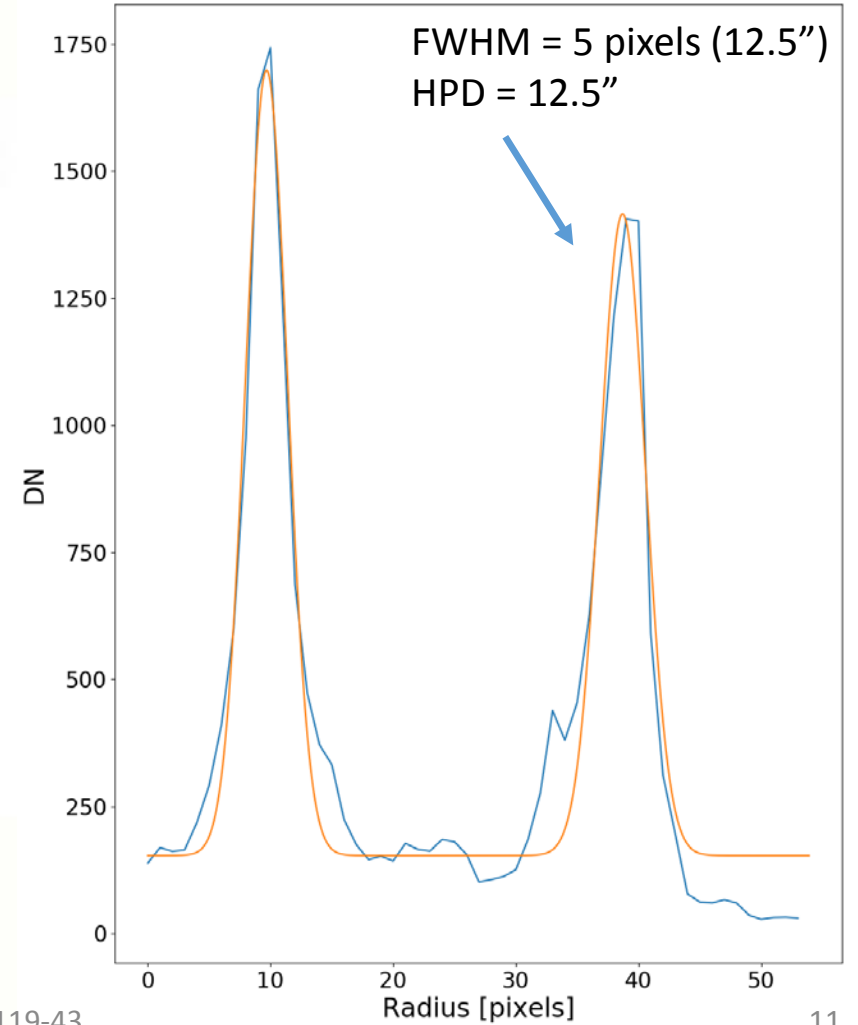
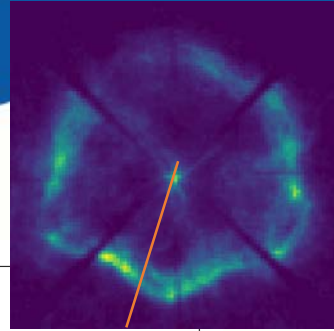
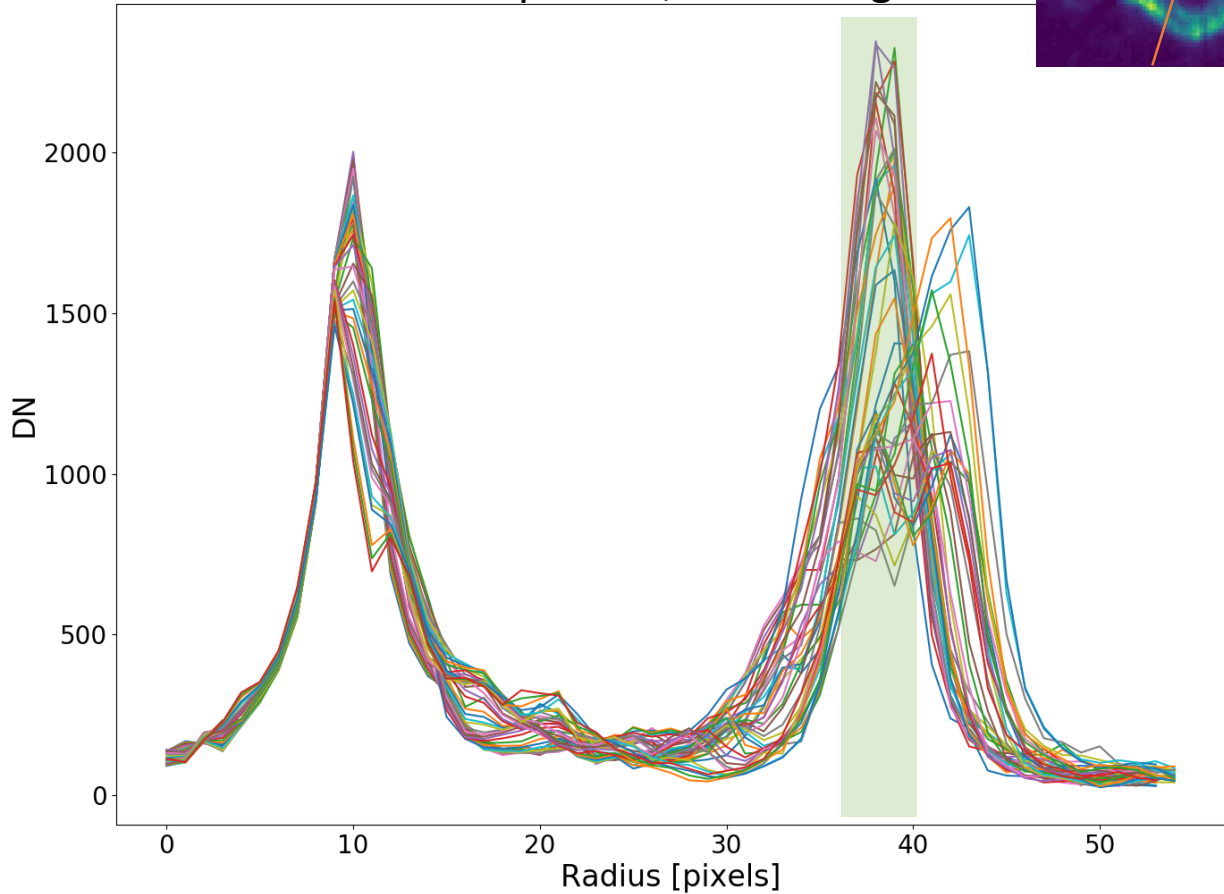




6 mm Intra-Focus

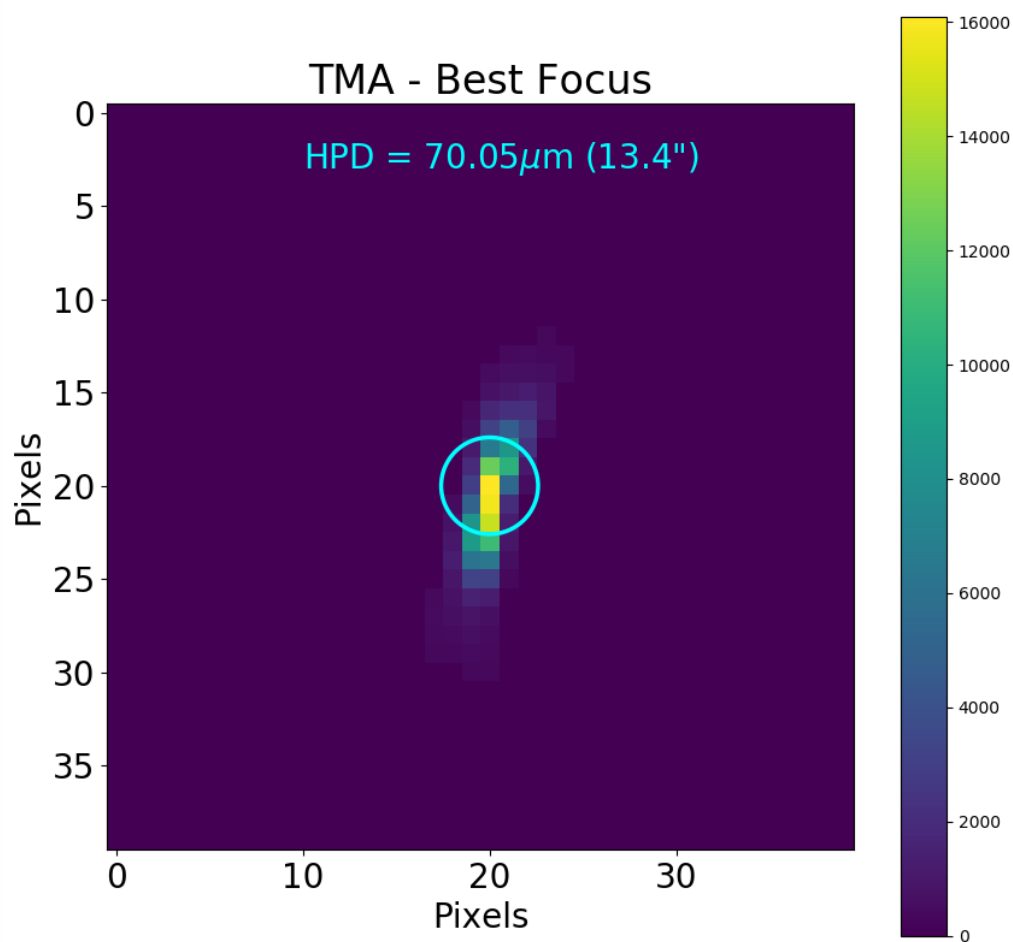


Radial profiles, $\Delta\theta = 1$ degree

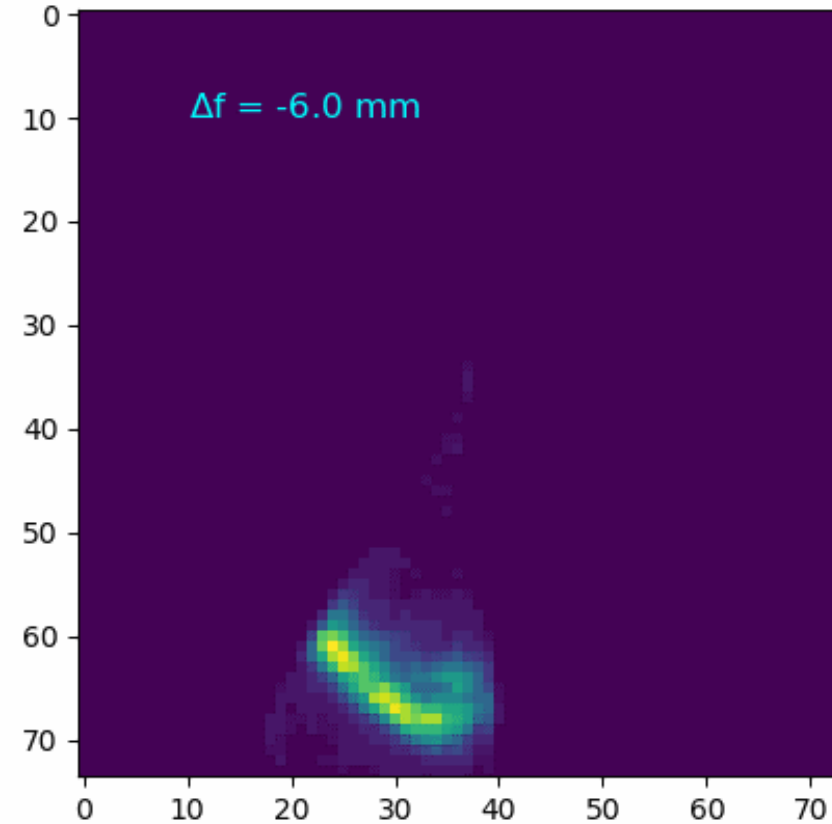




Effective Aperture



Through-focus effective aperture



- PSF yields “bowtie” shape
- Spatial along bowtie
- Spectral dispersion across bowtie

- Effective aperture has “S” shaped curvature
- Contributes to PSF

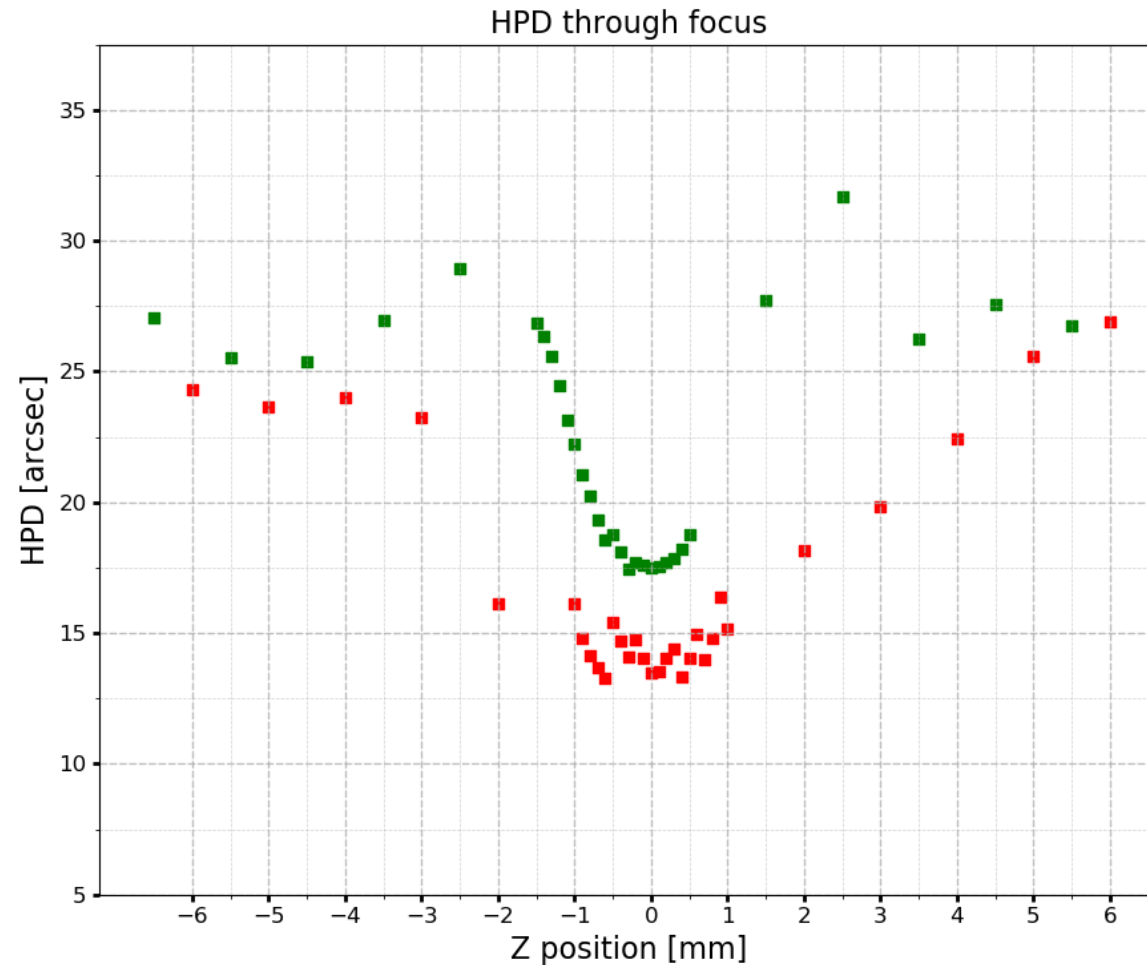
8/26/2019



Through Focus HPD



- Half power diameter (HPD) measured at each focal position
- Green = Full aperture
- Red = Masked aperture
- Similar depth of focus ~ 1 mm

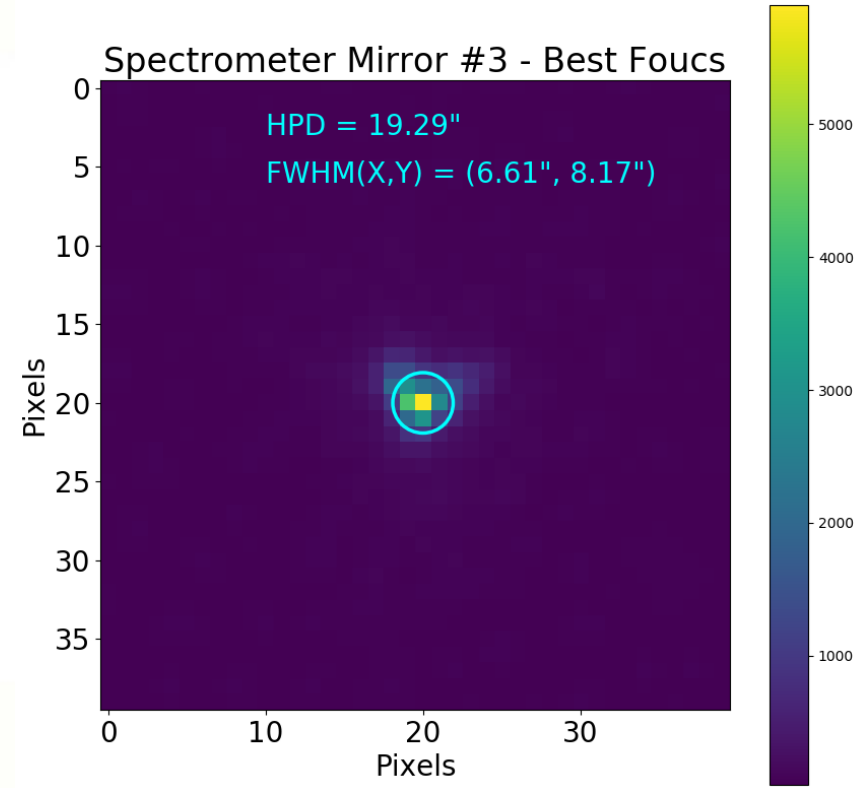
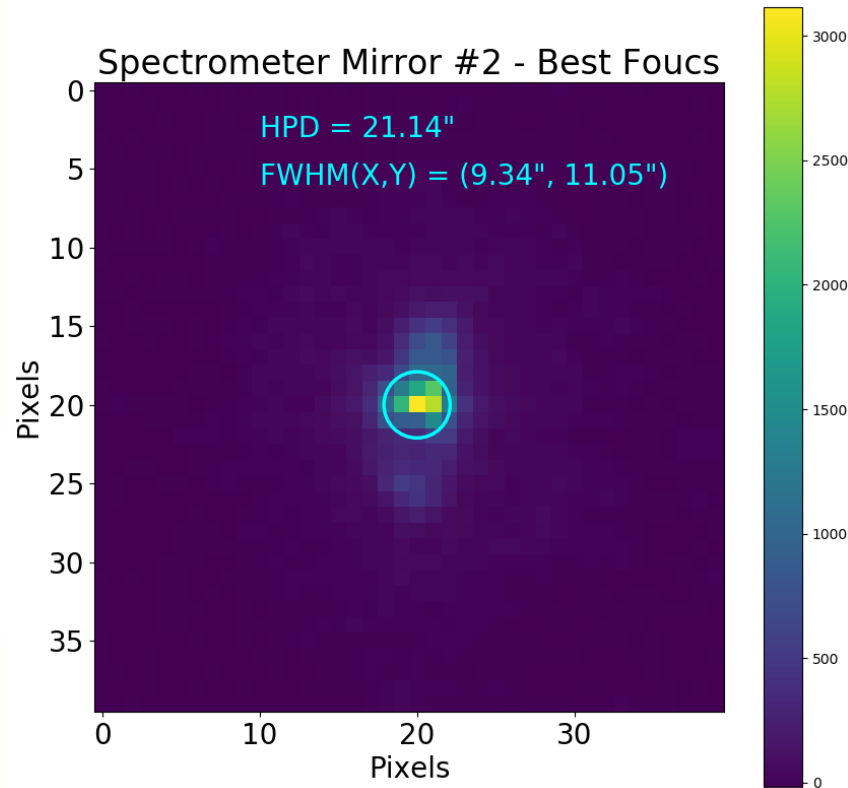




Spectrometer Mirror PSFs



- 594 mm focal length
- plate scale = 5 arcsec/pix
- Pixel size = 13.5 μm

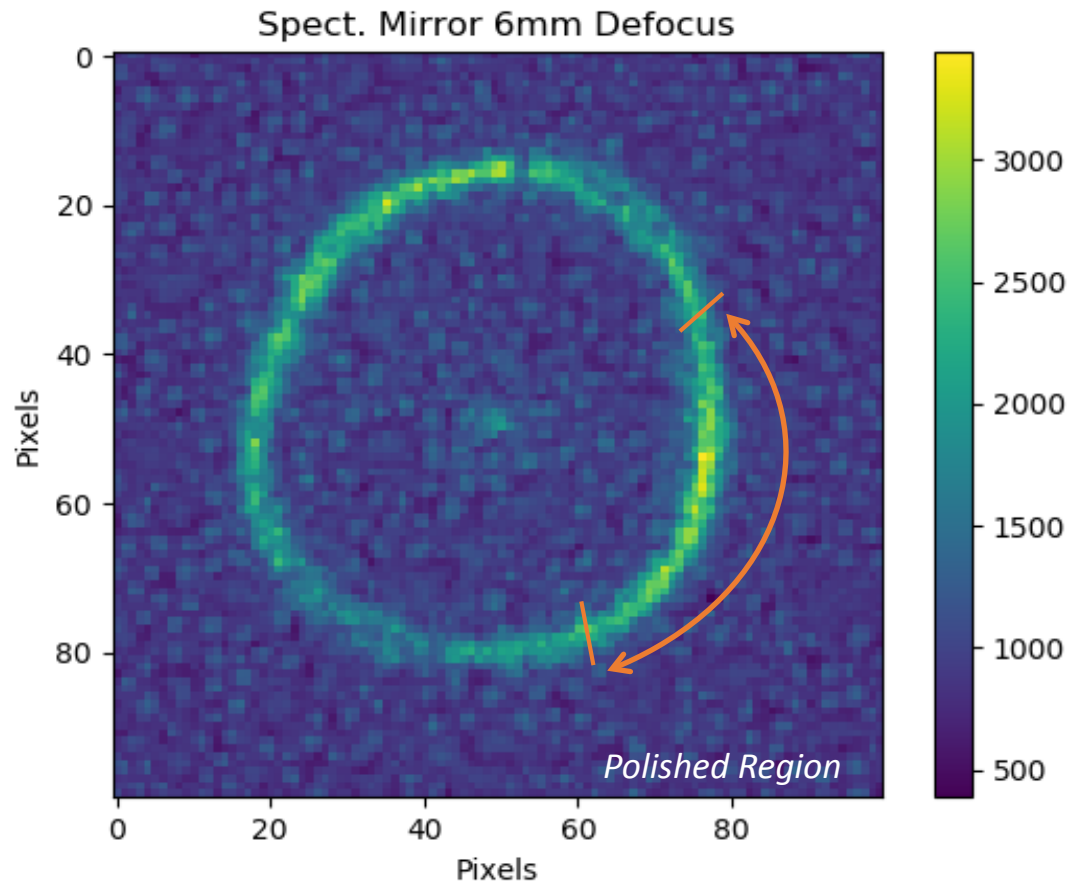




Defocused Spec. Mirror



- Deterministic polishing over 100 degree region
- Qualitative improvement in figure (annulus) over polished region
- Measurements with aperture mask not completed



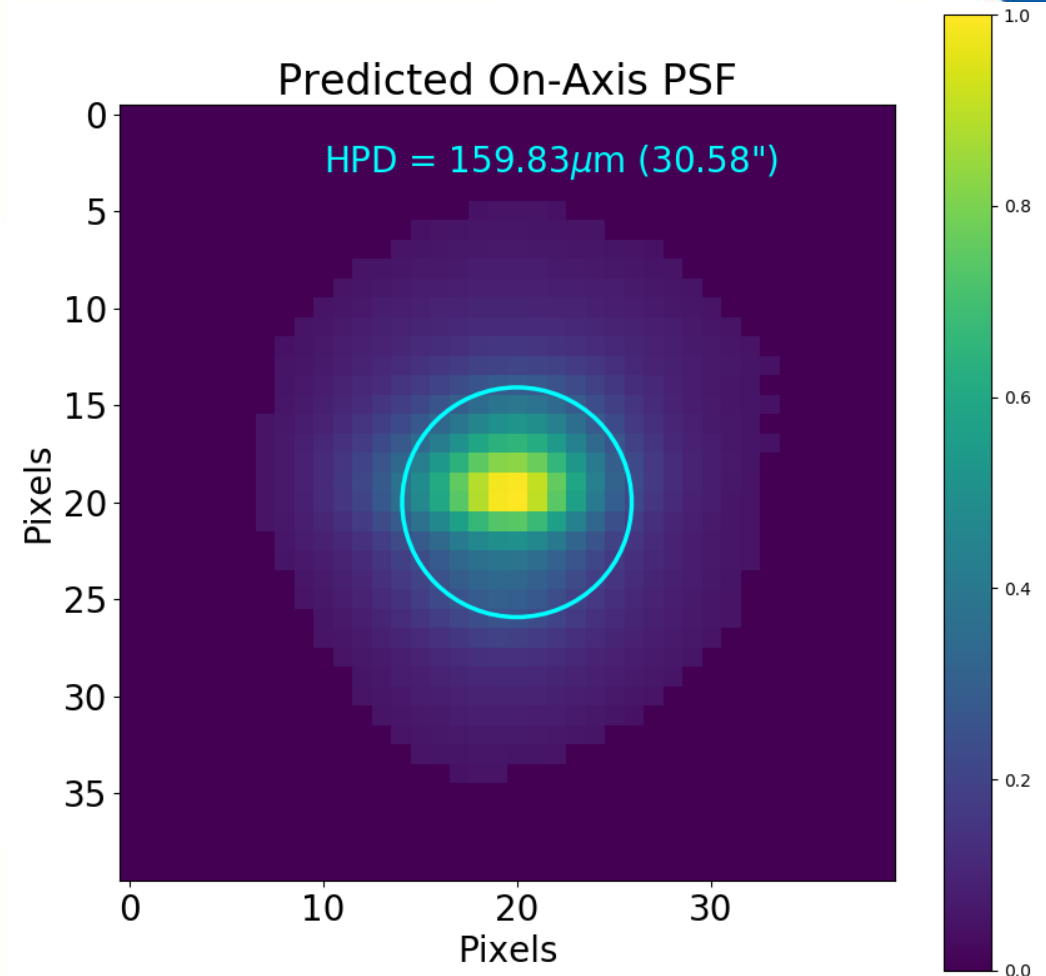


Predicted On-Axis Performance



- Multiplied TMA full aperture PSF with a mask representing slit
- Convolved SM1 and SM2 images
- Convolved SM1, SM2 and TMA sub-aperture image

	W-I	SM1	SM2	RSS
HPD	13"	21"	20"	31"

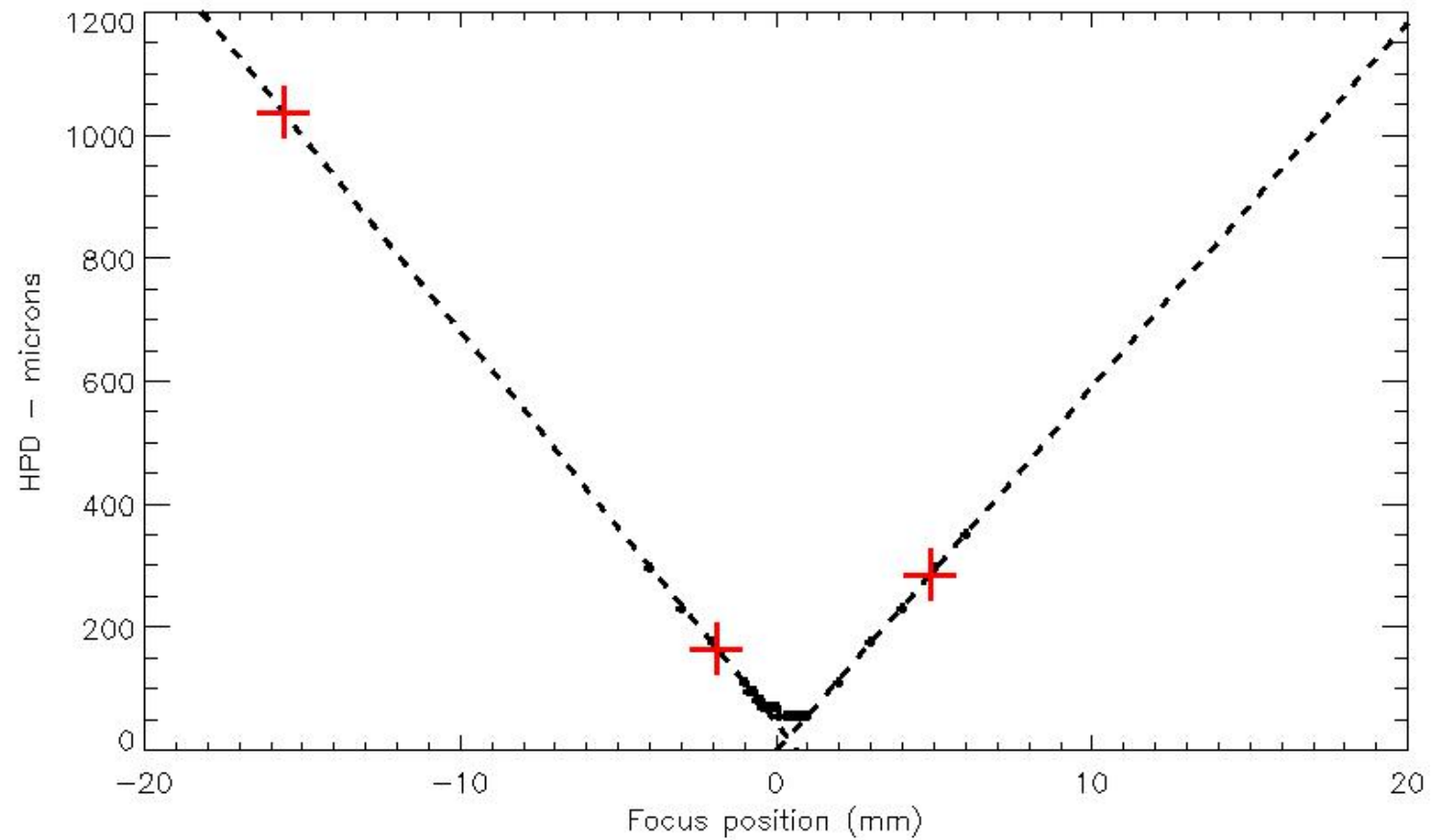




Current Progress – TMA Focusing

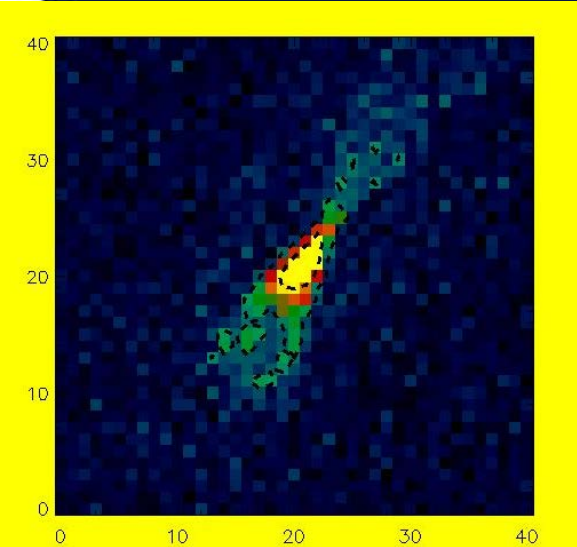


- SLF HPD measurements
- Dotted line is a fit to SLF HPDs
- + = XRCF measured HPD

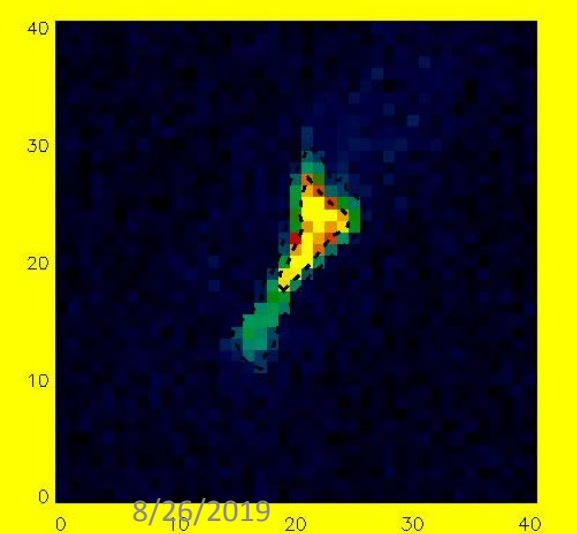




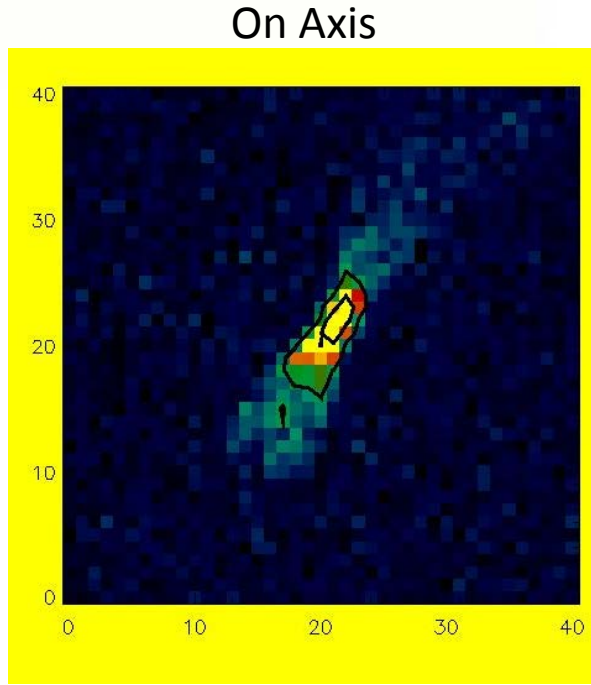
On-Axis Focus Check



Third off axis pointing
"seq3"

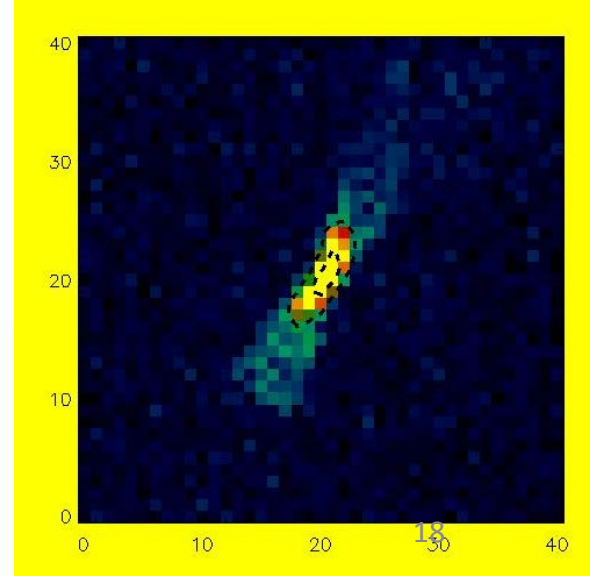
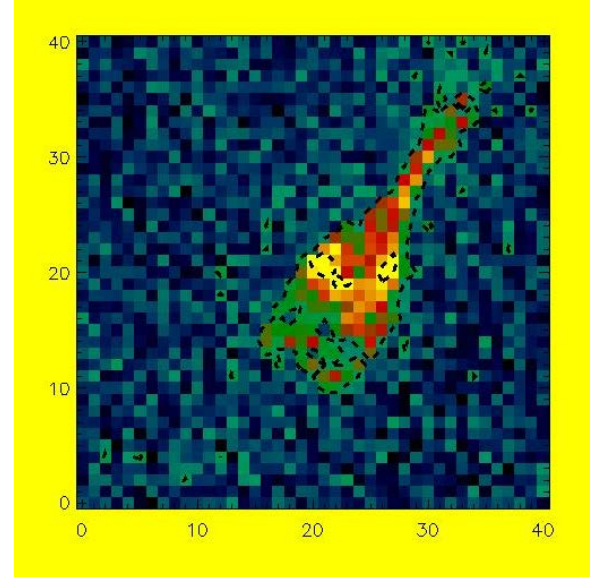


Final off axis pointing
"seq4"



On Axis

Second off axis pointing
Also labeled "seq2", but
after 17:15



First off axis pointing
"seq2"



Summary



- MaGIXS is a high-resolution imaging spectrometer – solar sounding rocket mission
 - Solar active region
 - 0.57 – 1.3 keV (~ 1 eV resolution)
- Mandrels polished using deterministic technique
- Replicated shells tested at the MSFC SLF
- Predicted on-axis HPD $\sim 30''$
- Future work includes continued development for image analysis techniques
 - Envision these types X-ray image data to supplement metrology