

CSWG Simulations

NIRCam Edition

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University of Arizona

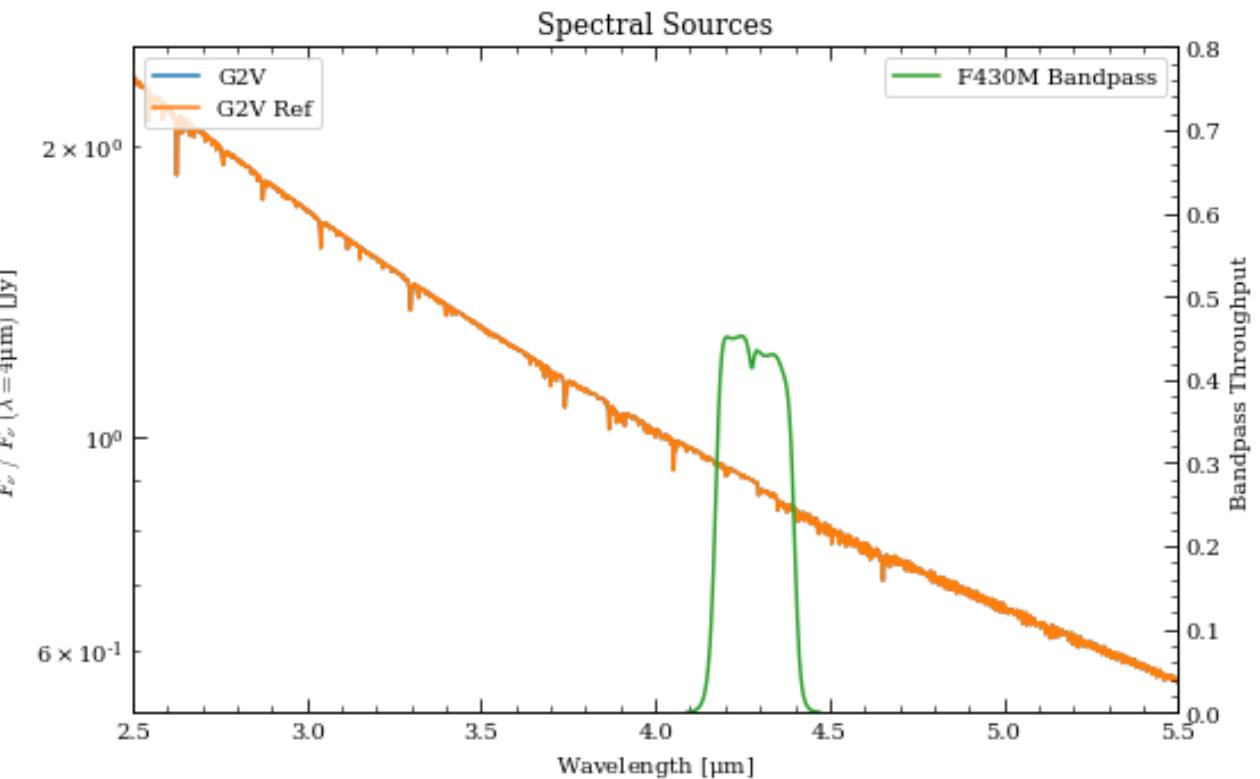
July 19, 2021

Comparison to WebbPSF Defaults

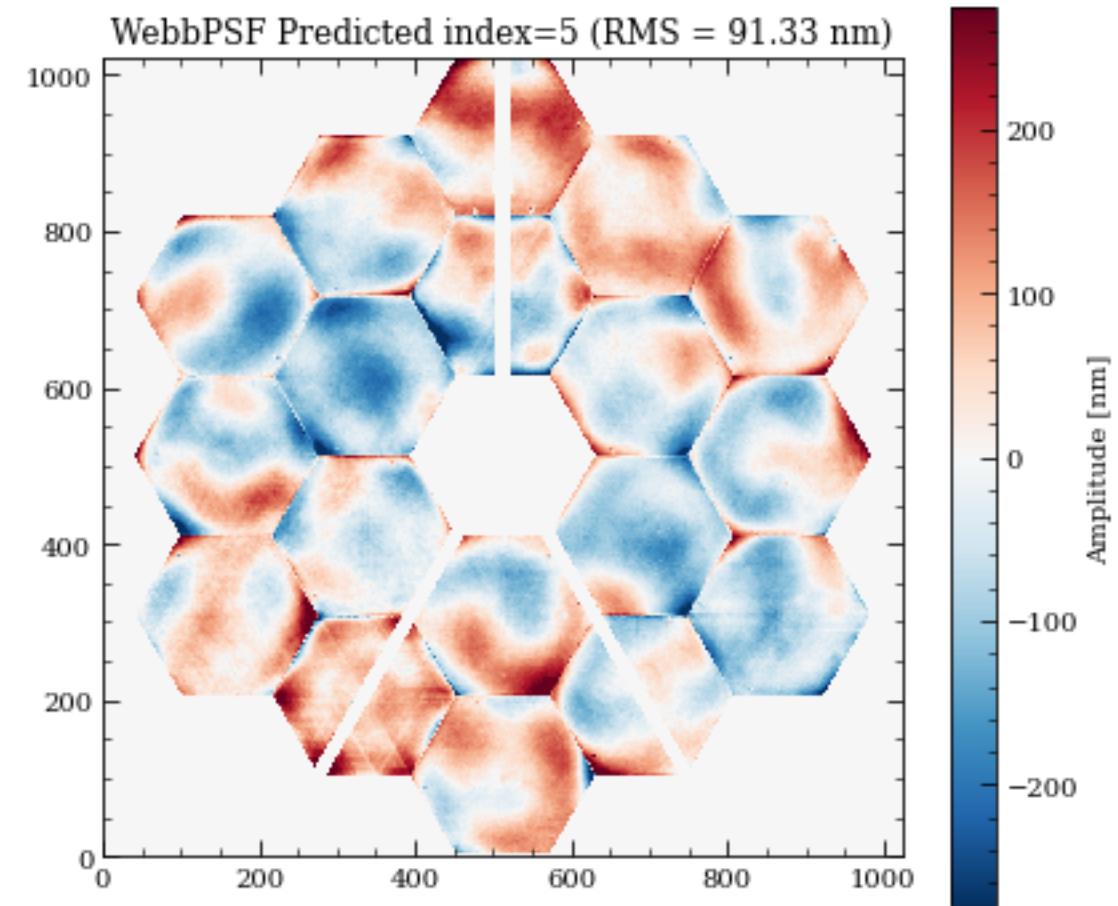
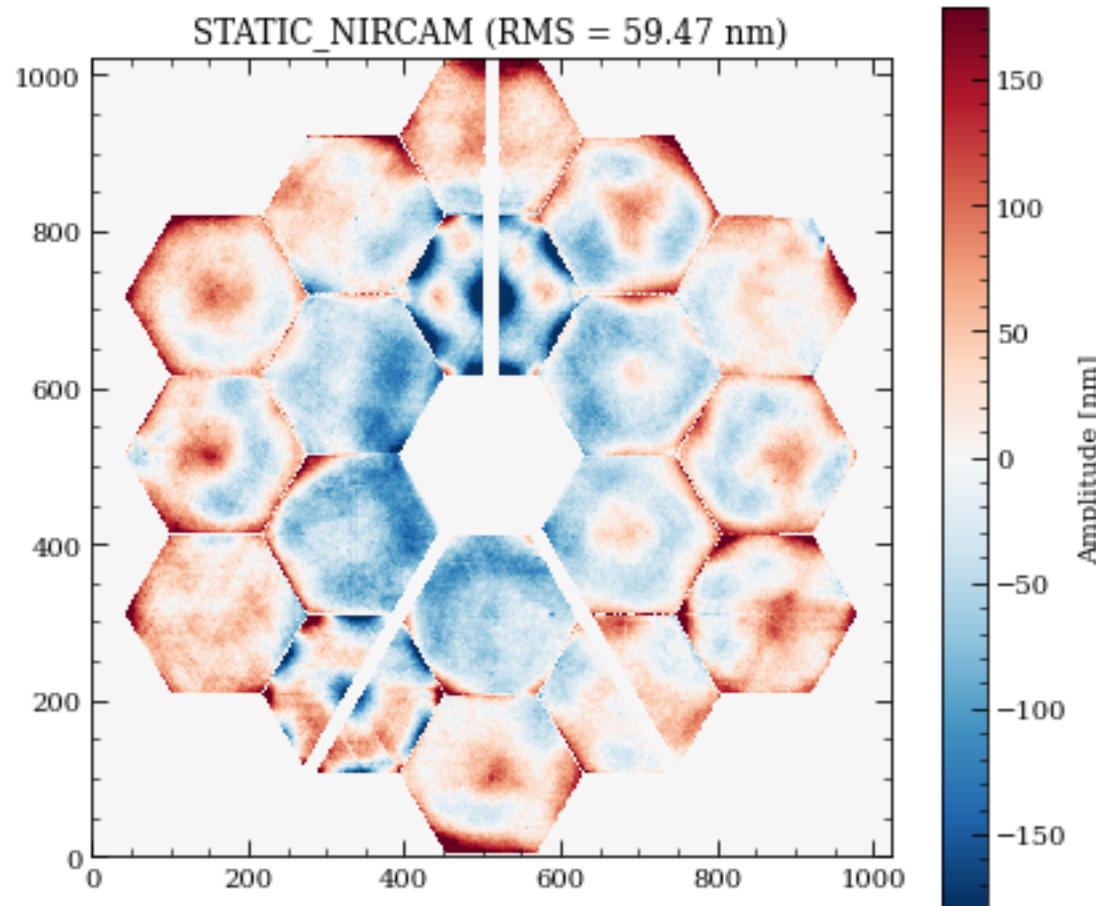
OTE OPDs and PSFs

NIRCam Obs Configuration

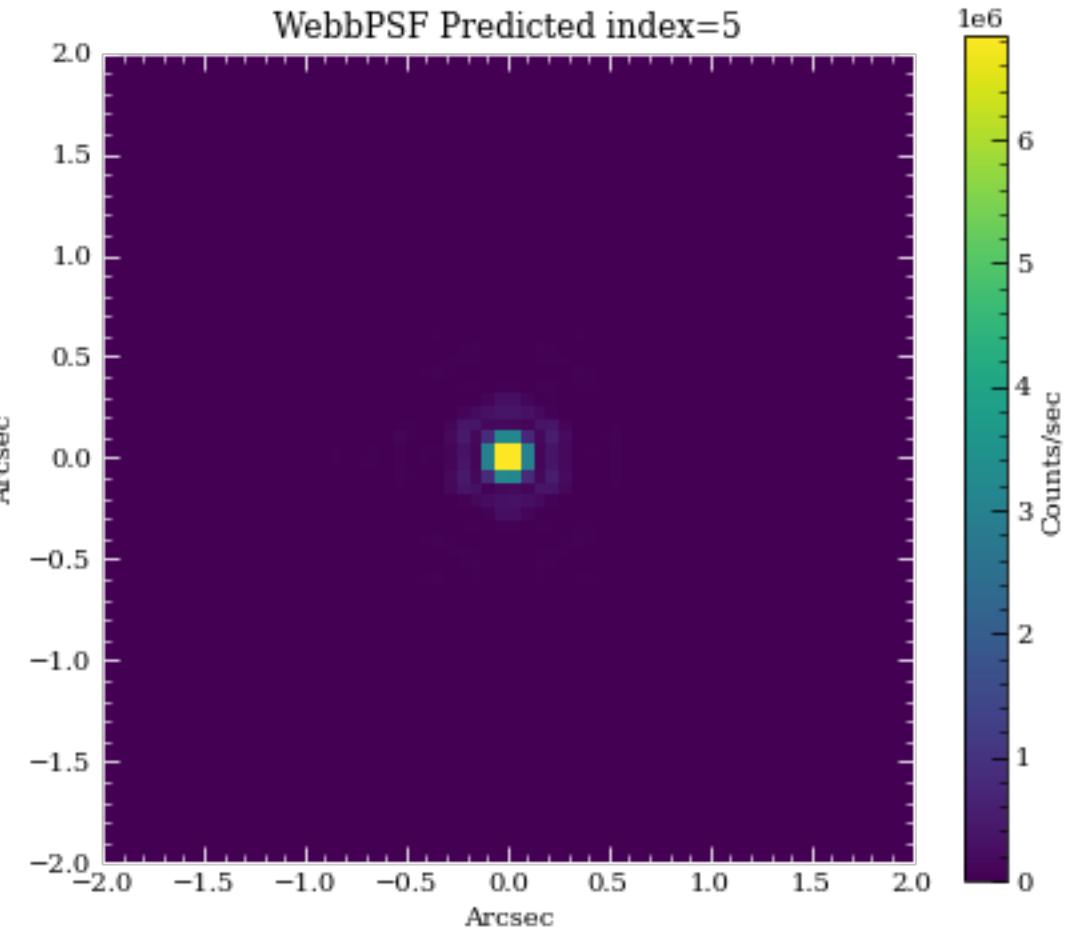
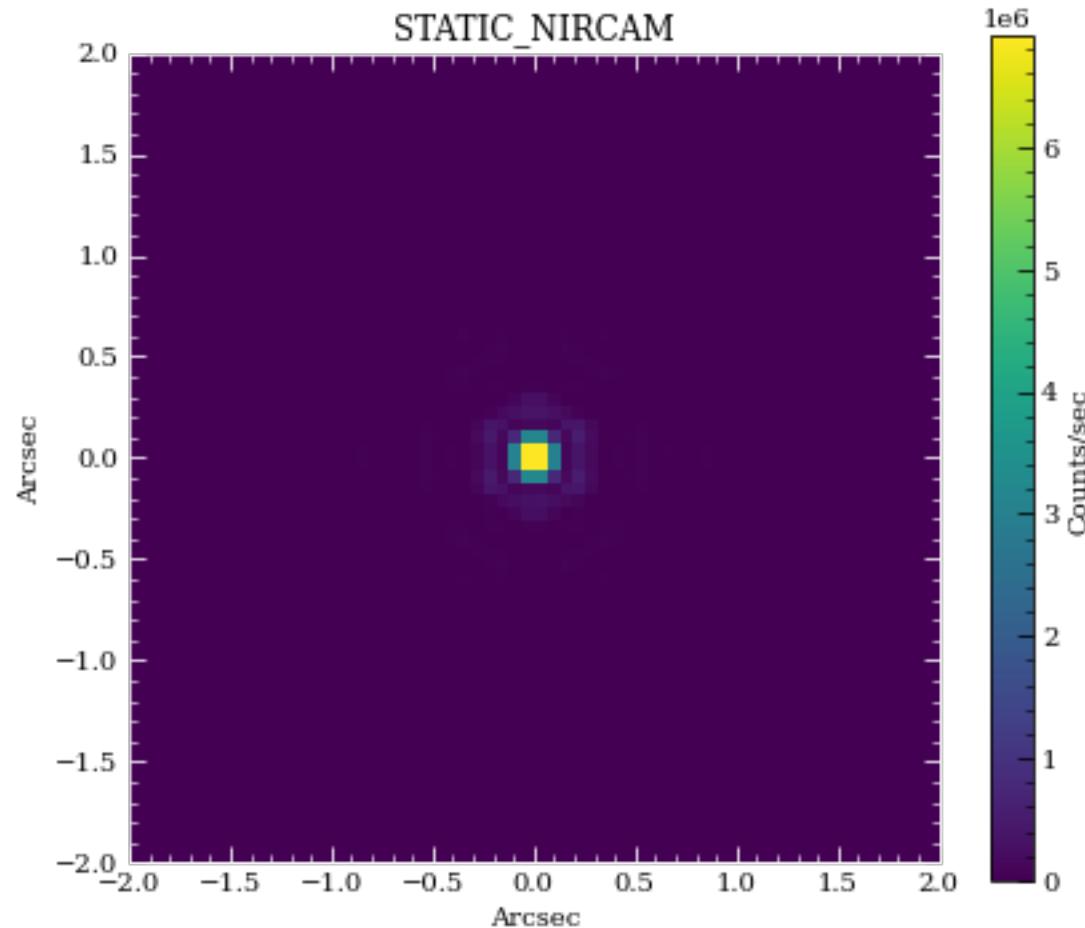
- NIRCam Coronagraphy
 - MASK430R + F430M
 - SUB320
 - MEDIUM8, NG=7, NINT=50
 - Exp time ~3600 sec
- G2V source from BOSZ models
 - $T_{\text{eff}} = 5777\text{K}$
 - $\log g = 4.43$
 - $[\text{Fe}/\text{H}] = 0$
 - 2MASS $K_s = 3.27$
- Corresponds to ~100 million ph/sec through F430M bandpass



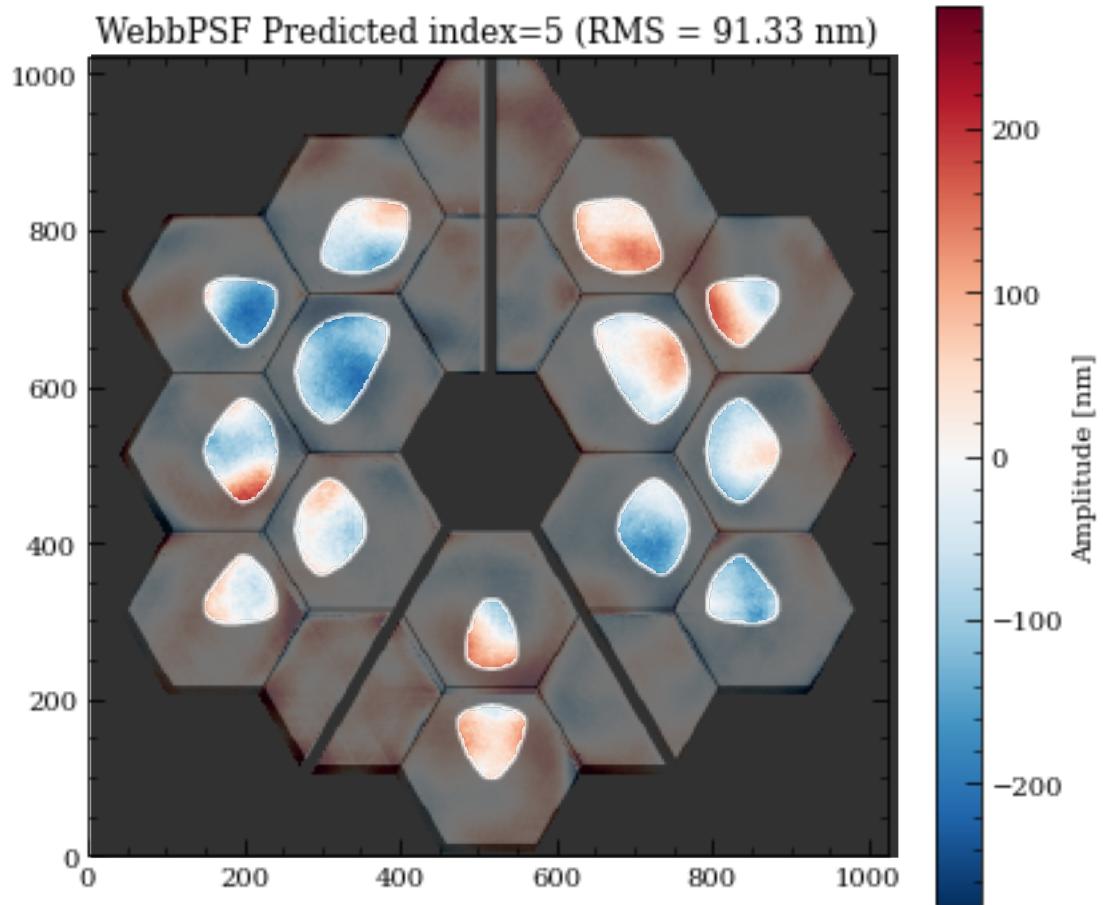
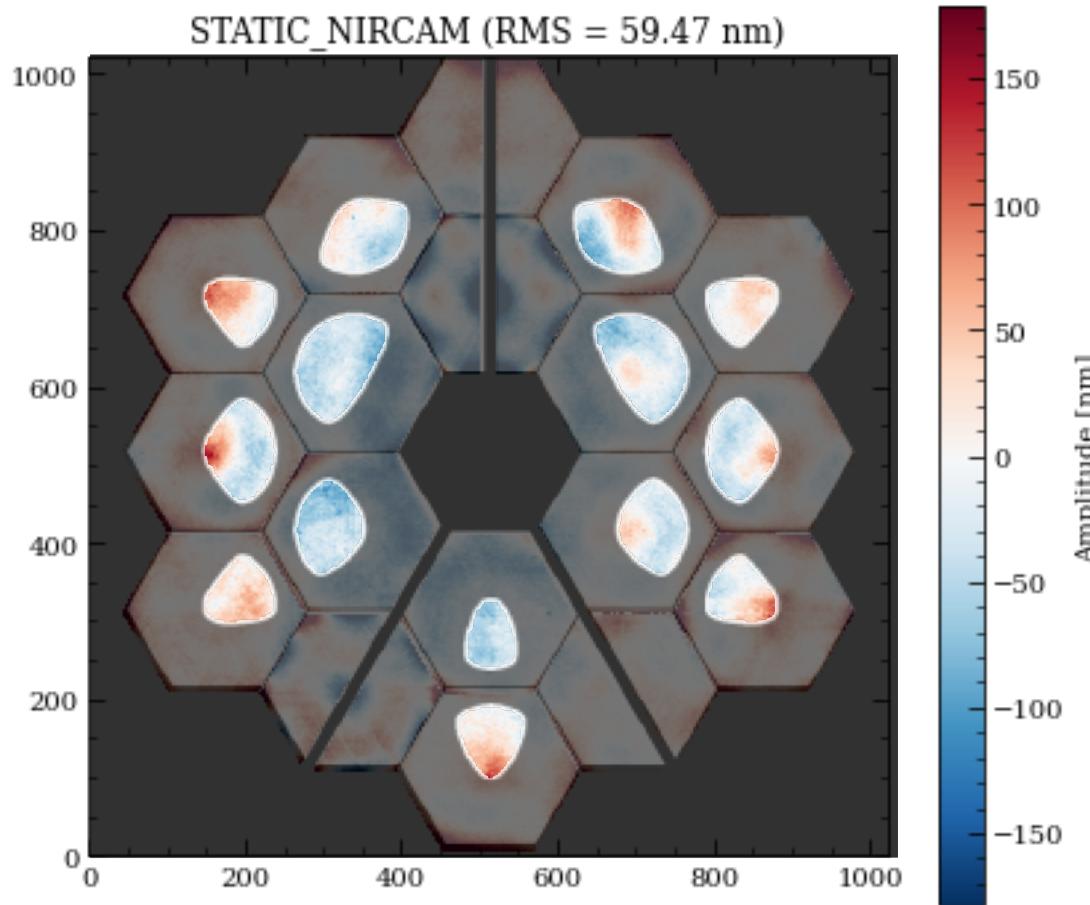
OTE WFE Comparisons



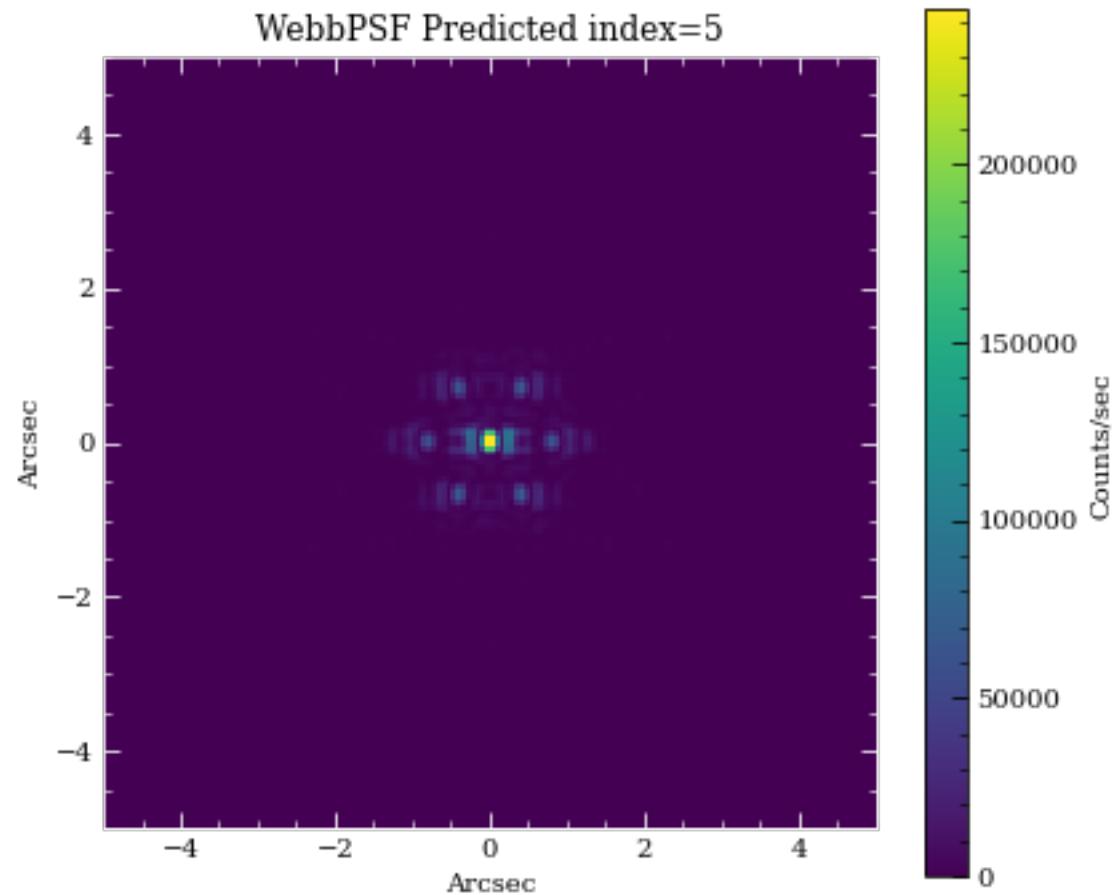
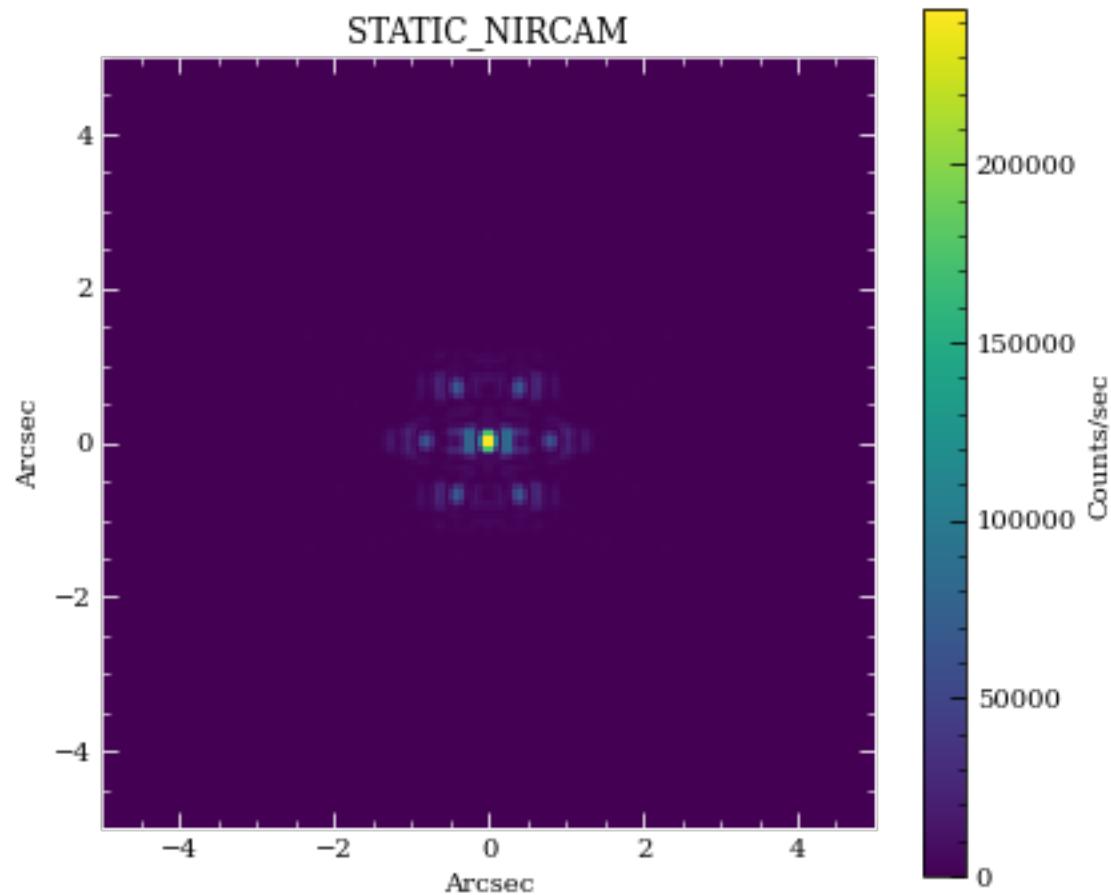
OTE WFE only – Direct Imaging PSF



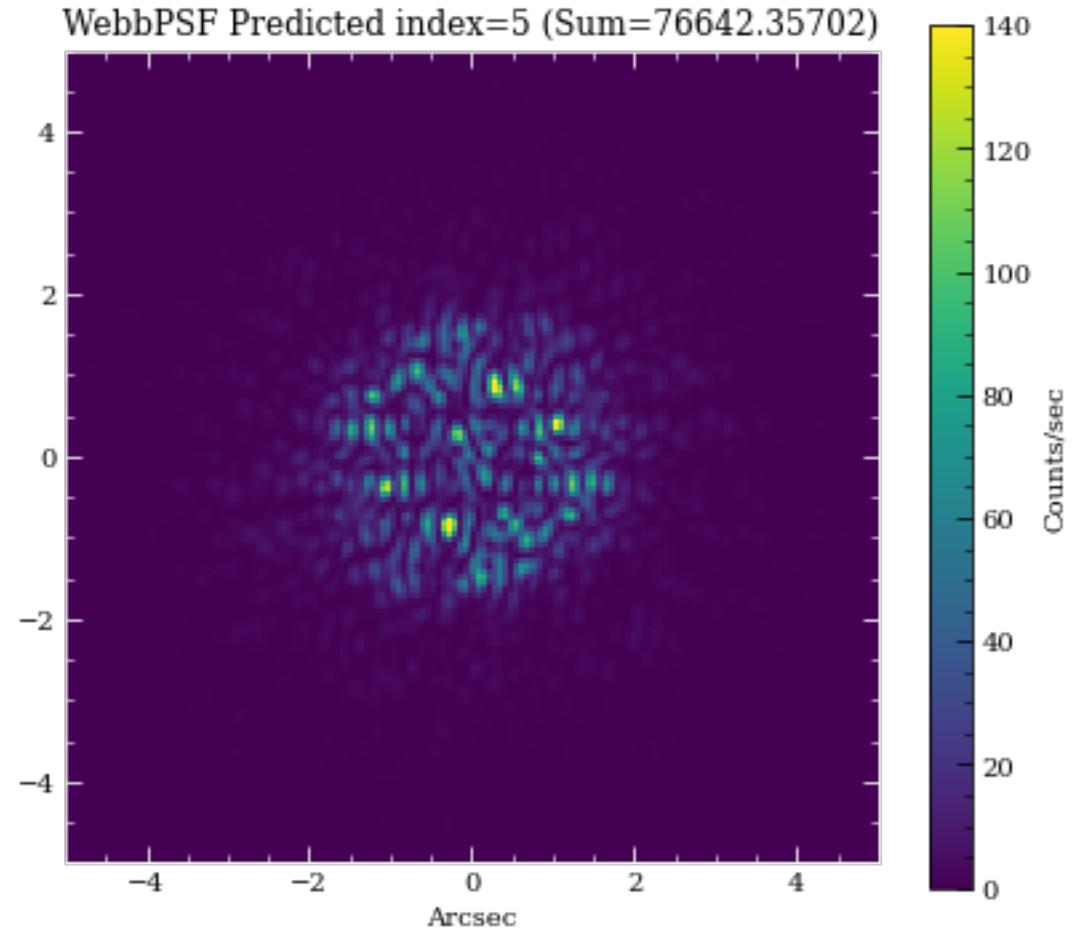
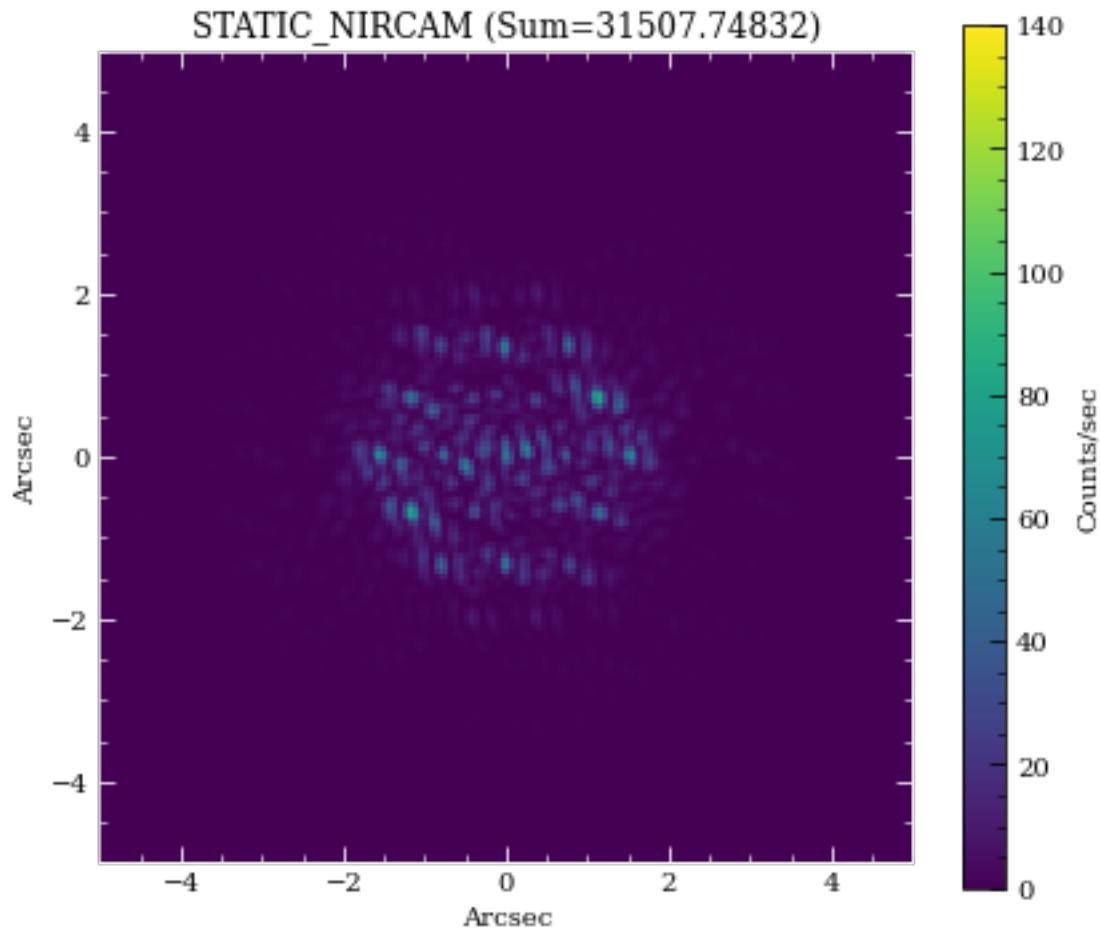
OTE WFE Comparisons + Lyot Mask



OTE WFE only – Off-axis Coronagraphic PSFs

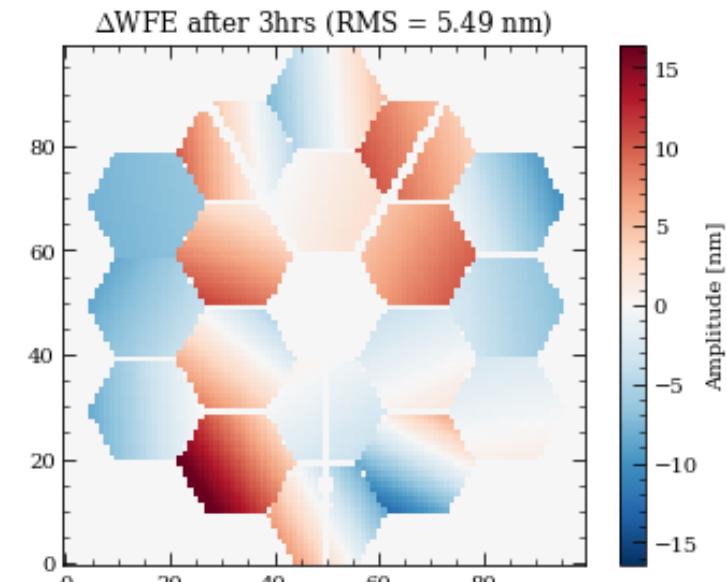
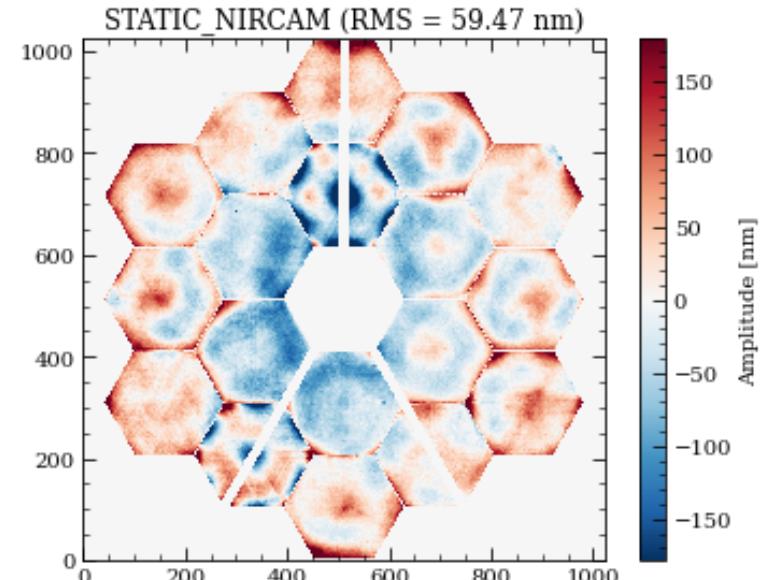


OTE WFE only – Occulted PSFs (MASK430R)

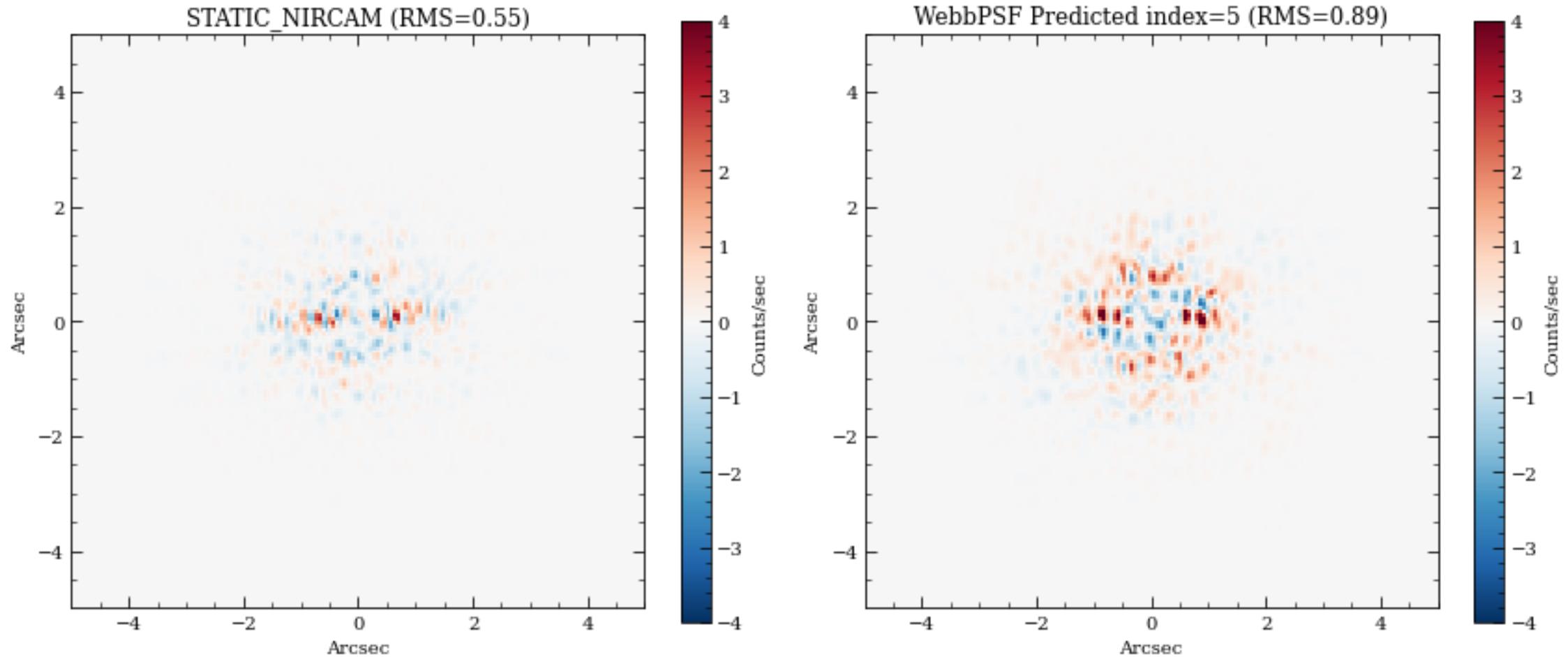


Delta WFE components

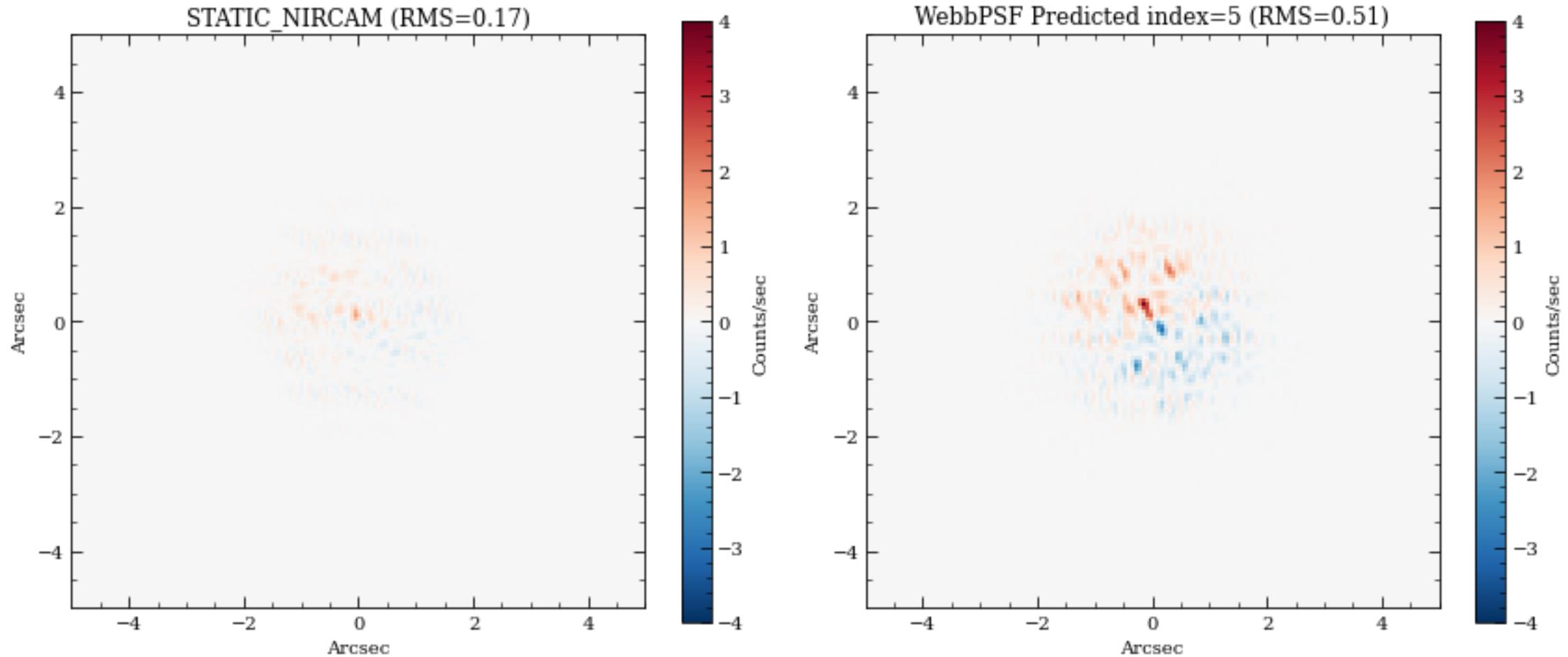
- The provided Thermal, Frill, and IEC maps are undersampled (100x100) and flipped compared to STATIC_***_INPUT.fits
- Create new OPD at given time step
 - Flip drift components up-down
 - Rebin to 1024x1024
 - Add to static OPD



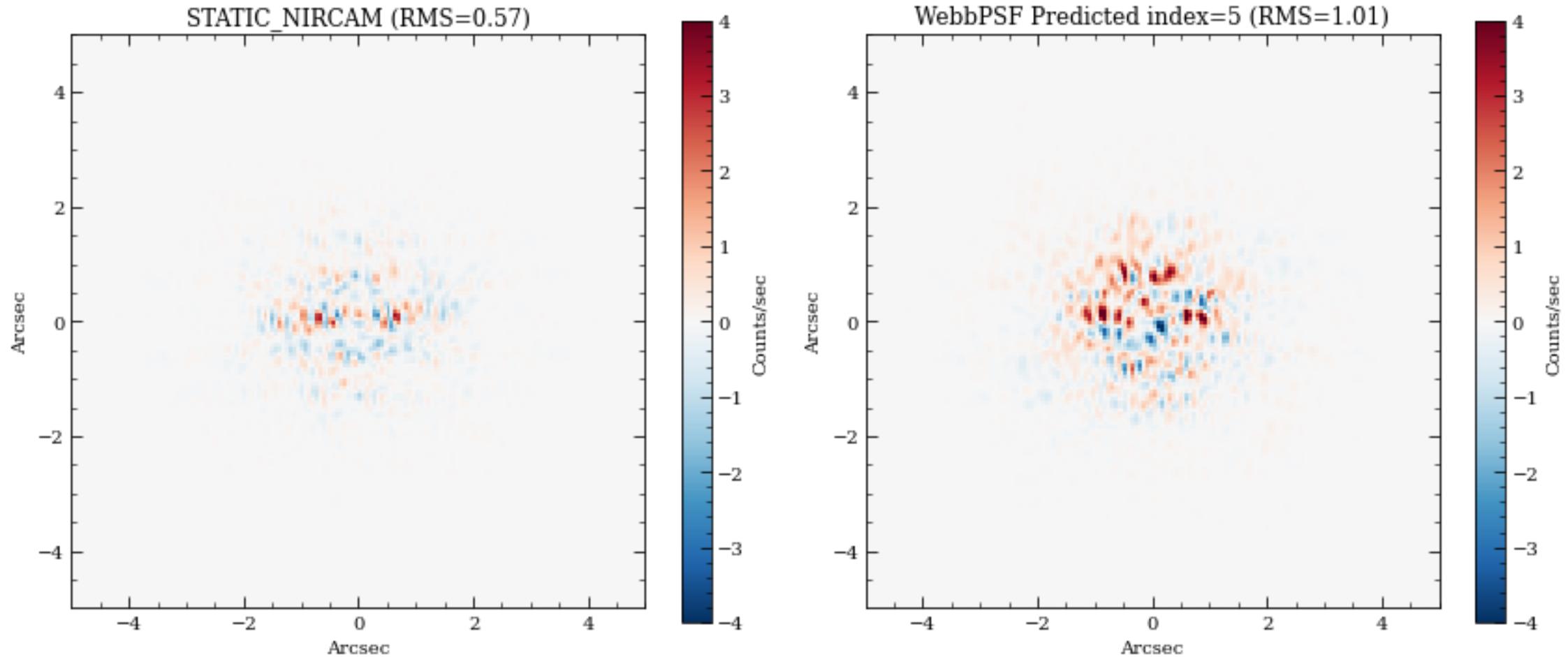
PSF Differences (WFE Drift of 5.5 nm)



PSF Differences (TA offset of 10 mas)



PSF Differences (TA + WFE drift)



Intermediate Conclusions (MASK430R)

- Delivered OPD maps produce better coronagraphic suppression compared to WebbPSF's *_predicted.fits and *_requirements.fits
 - Should result in improved contrast at <2" by almost a factor of 2 (???)
- WFE Drift vs Target Acquisition offsets
 - TA offsets of 10 mas produce small residual speckle noise compared to WFE Drift of 5.5 nm RMS
 - TA offsets may dominate for small WFE drifts, though
 - Likely depends on mask and filter
- Effects from jitter considered later...

LOS Jitter

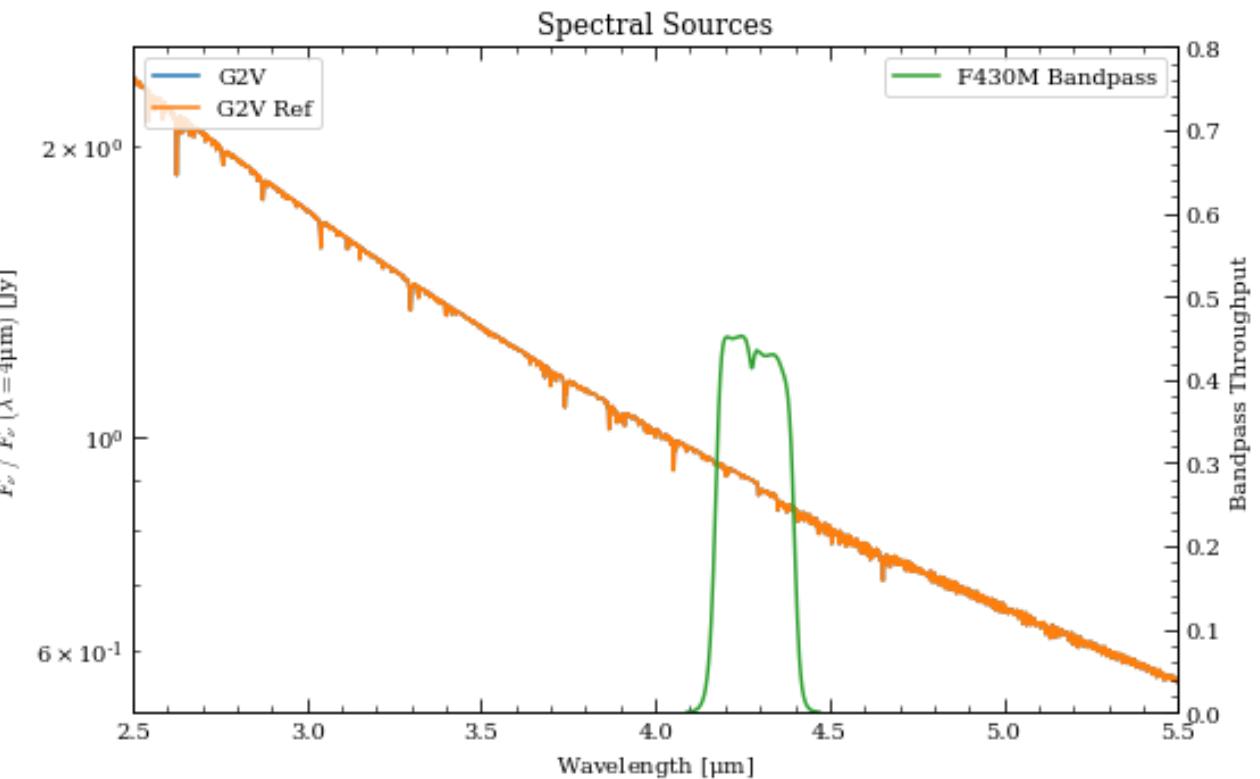
- LOS Jitter values correspond to time steps every 37.7 sec
- Jitter should be higher frequency (>1 Hz)
 - Will blur PSFs over an integration time
 - Enough samples over an exposure should also work
- Adopt random jitter draws for each group (1.4 sec)
 - Need $2 \times 50 \times 7 = 700$
 - Delivered LOS_JITTER.fits file does not provide enough independent values
 - Generated appropriately sized random arrays using [2.5, 3.8, 5.8] mas per axis

Observation Simulations

Using delivered OPD files (e.g., STATIC_***_INPUT.fits)

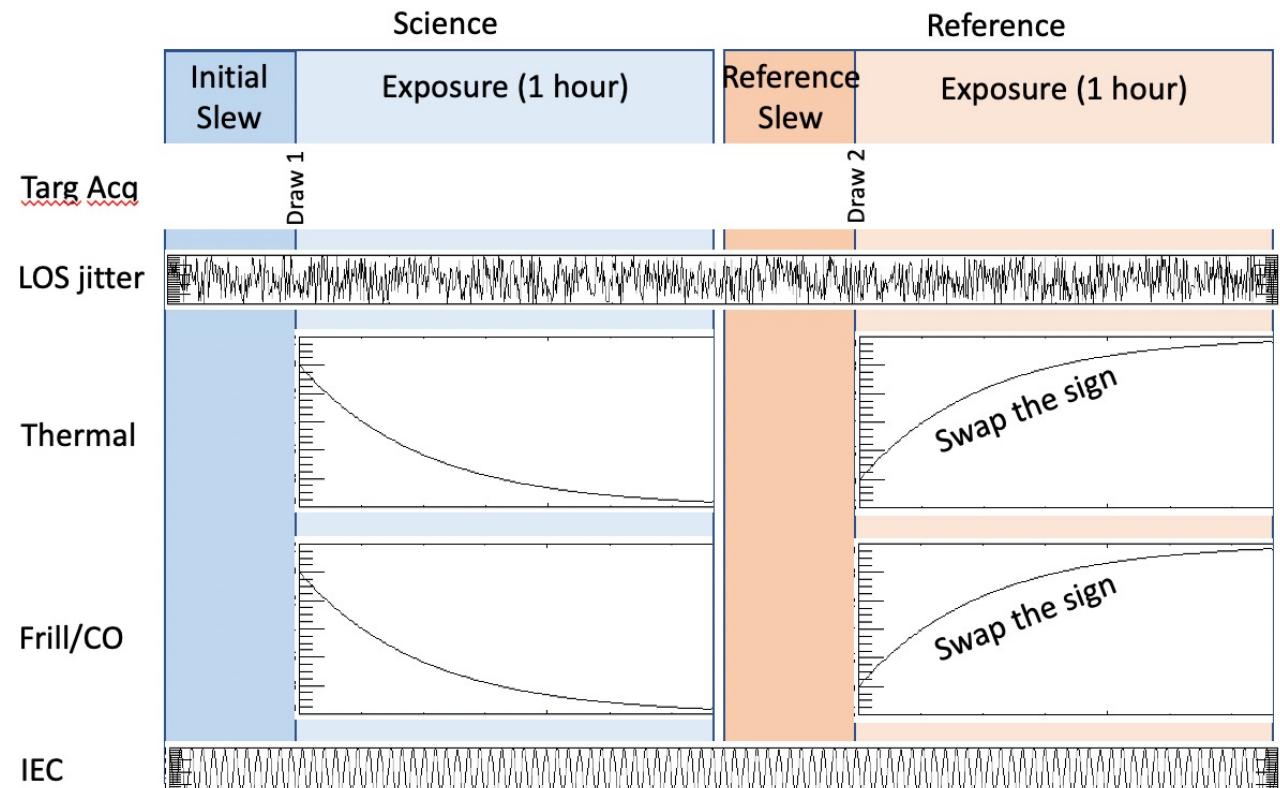
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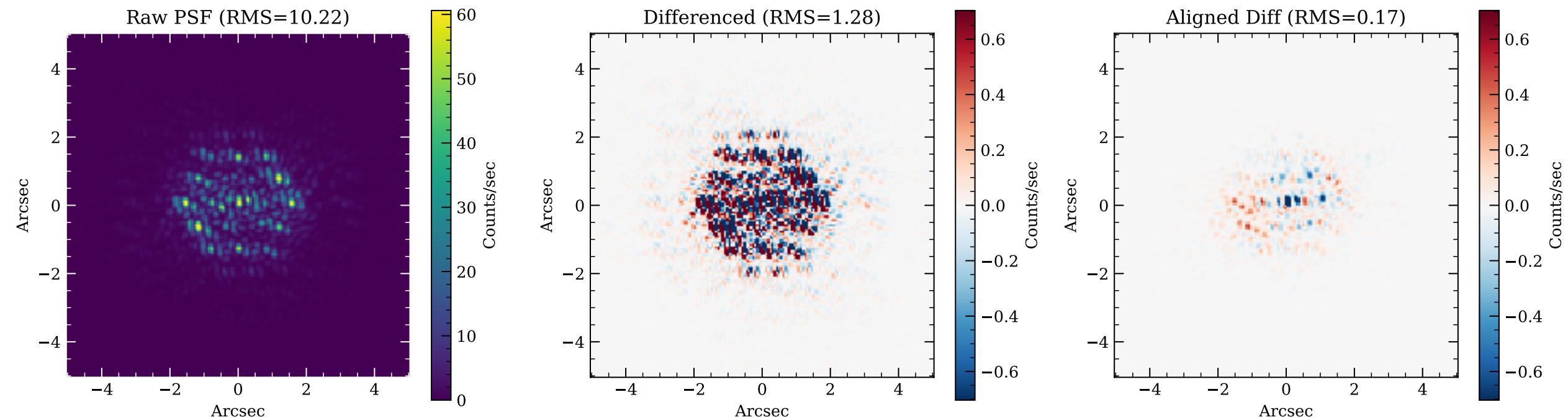
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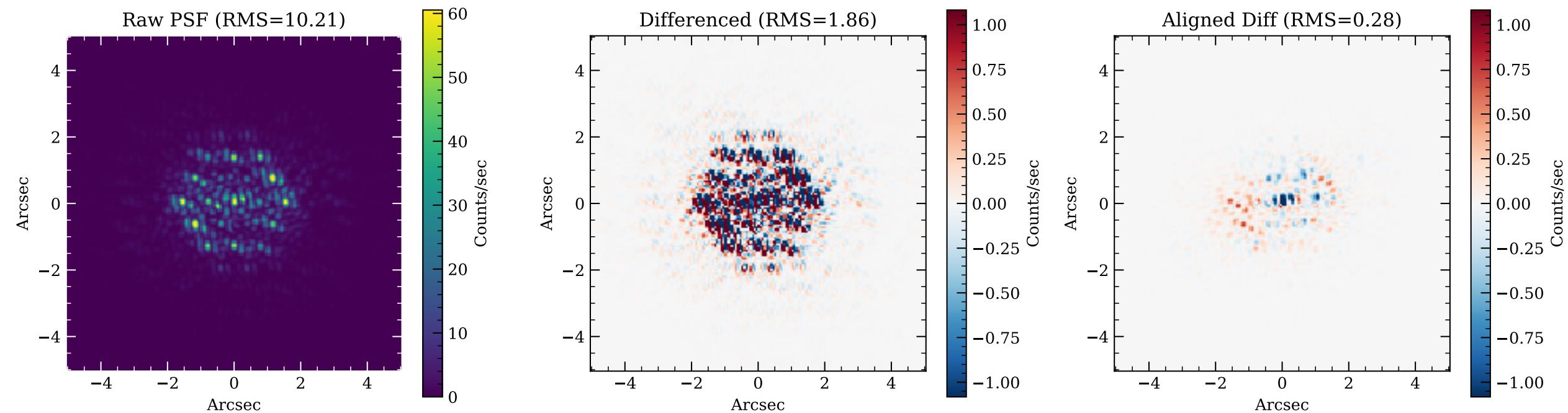
Results – Base Case ($\langle dWFE \rangle = 0.7$ nm)

Best Case ΔWFE ; Jitter = 2.5 mas; TA = 6.3 mas



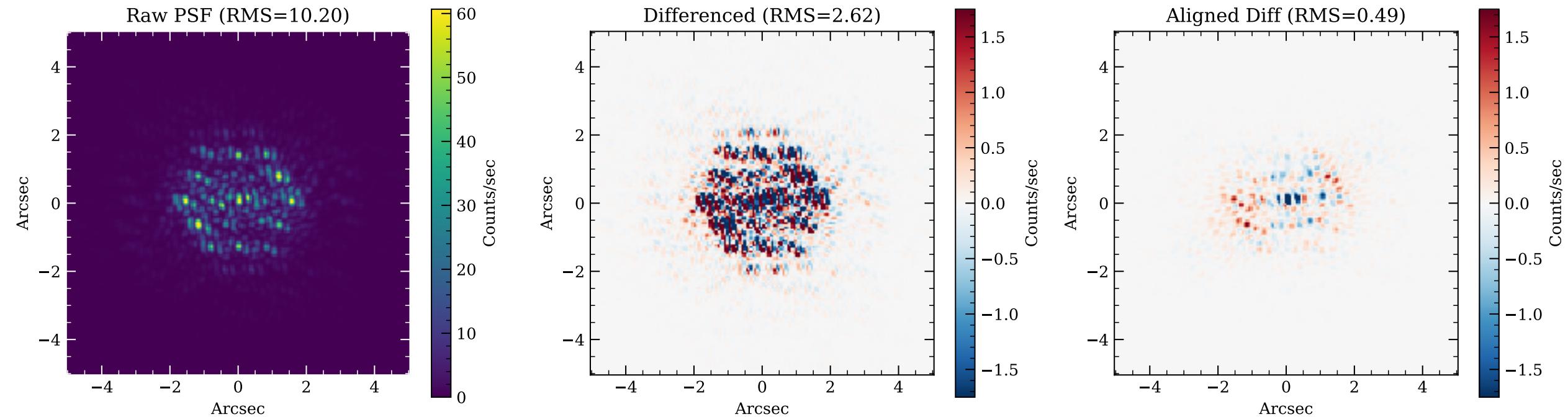
Results – Nominal ($\langle dWFE \rangle = 1.3$ nm)

Nominal ΔWFE ; Jitter = 3.8 mas; TA = 8.8 mas



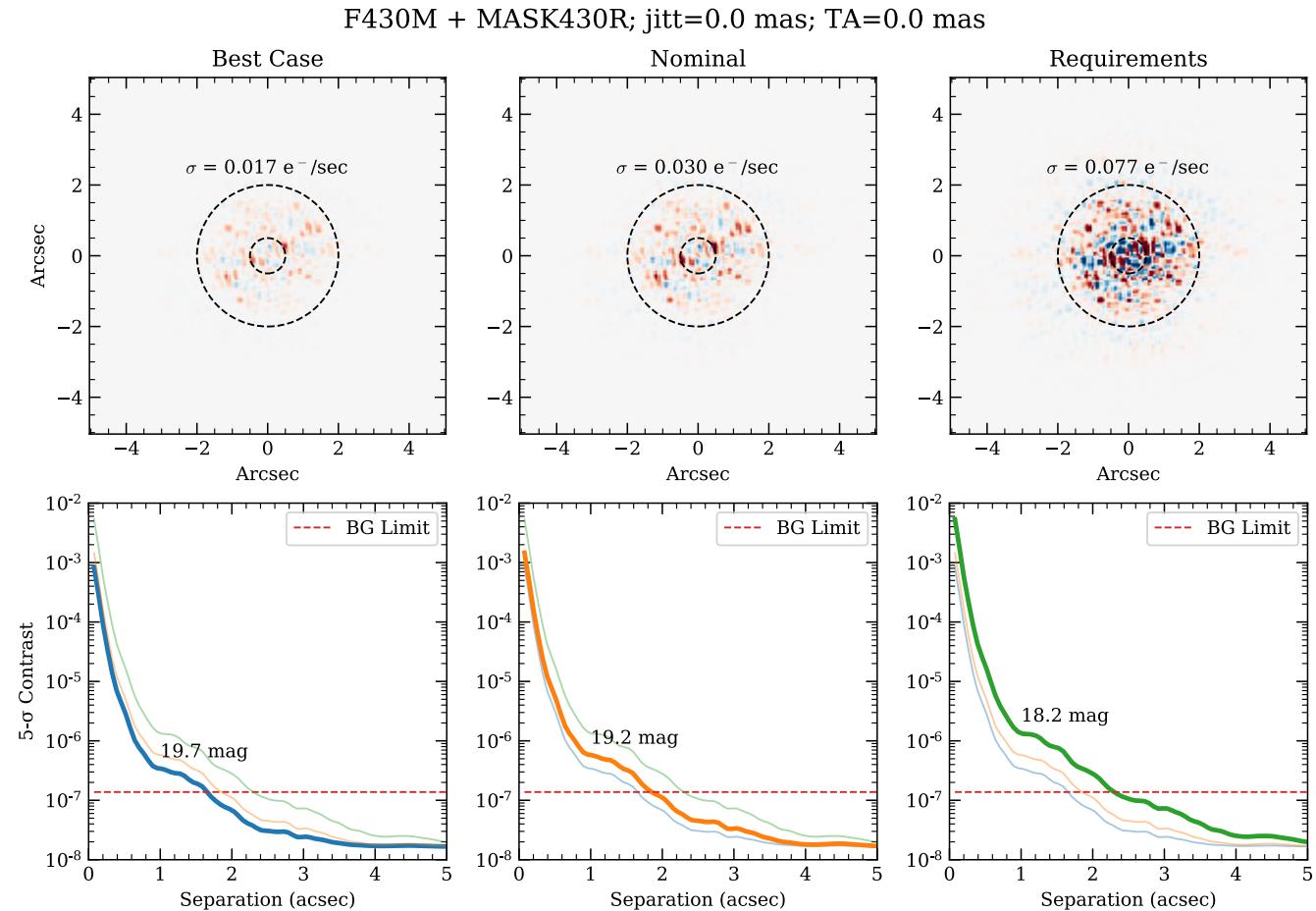
Results – Requirements ($\langle dWFE \rangle = 3.5$ nm)

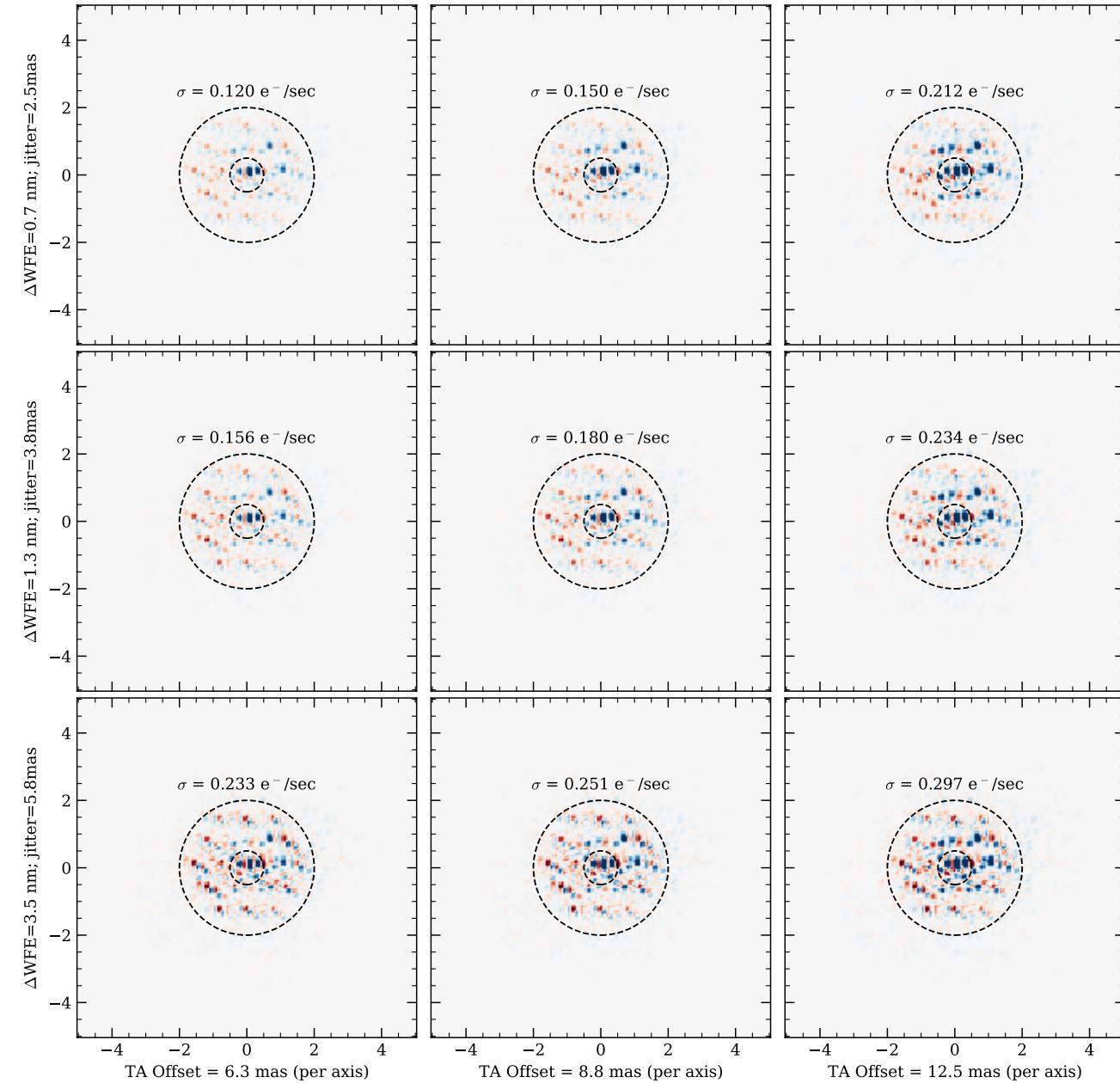
Requirements ΔWFE ; Jitter = 5.8 mas; TA = 12.5 mas



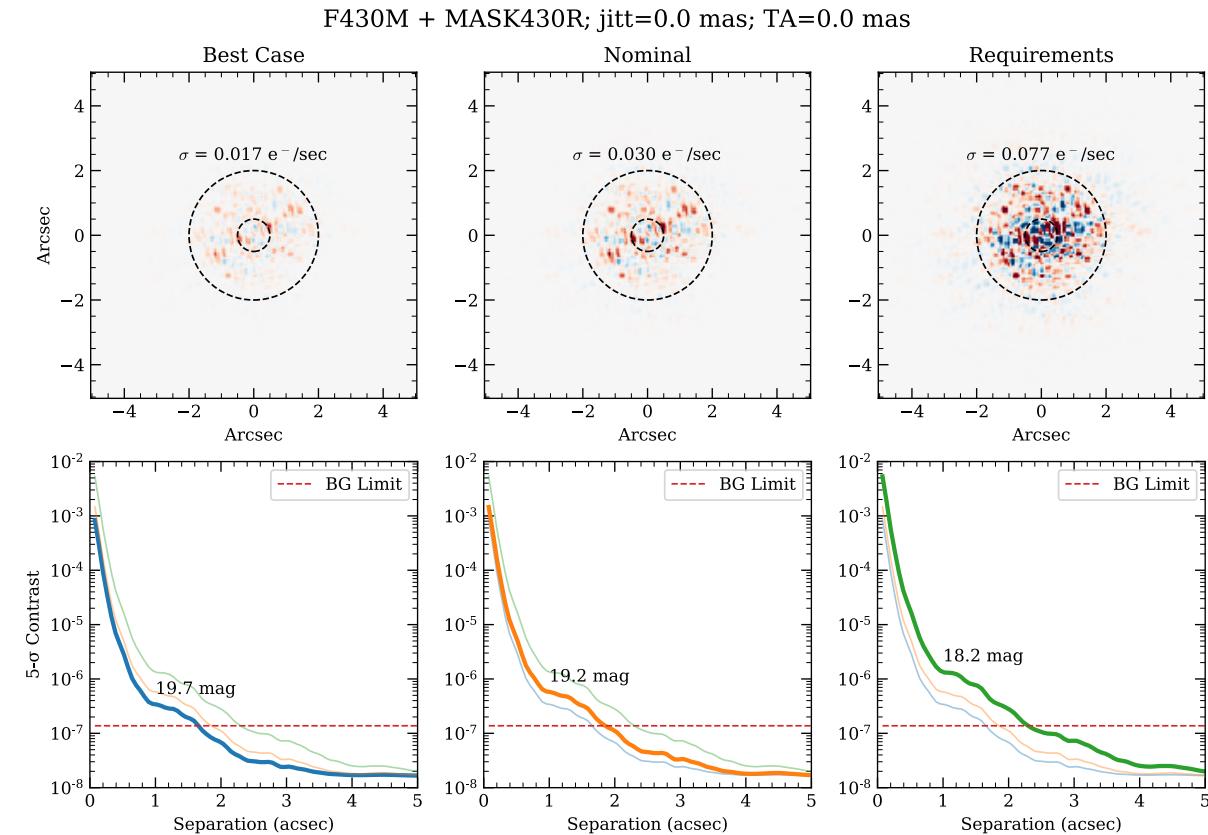
Noise Components

- Want to disentangle contributions from:
 - WFE drift noise
 - Jitter
 - TA offsets
- Calculate RMS of sci-ref differenced images
- Generate contrast curves
- Right: Case of jitter=0, TA=0.



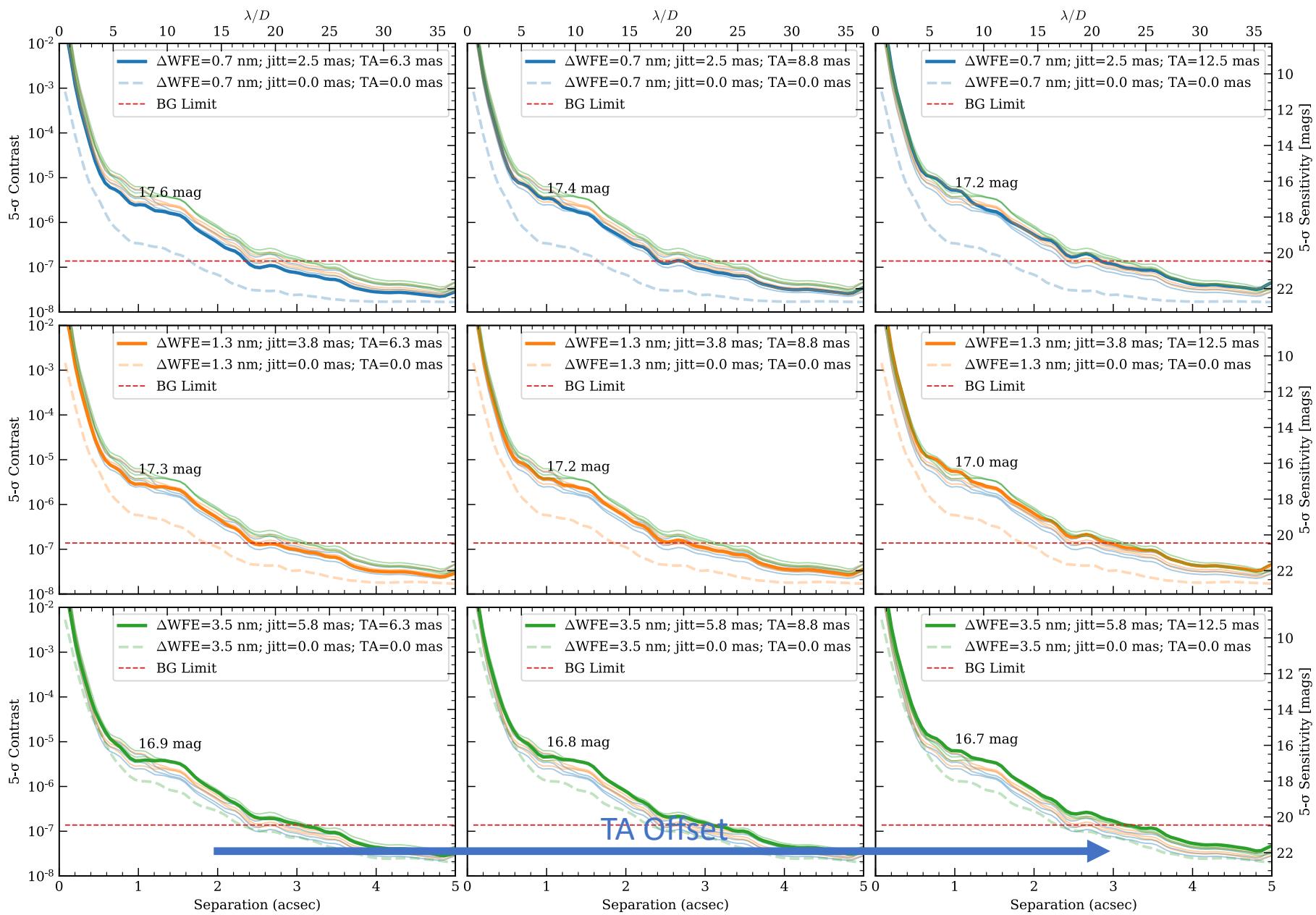


- Average OPD drifts (nm RMS)
 - Best, Nom, Req = (0.7, 1.3, 3.5)
- Jitter & TA dominate residual speckle noise and contrast

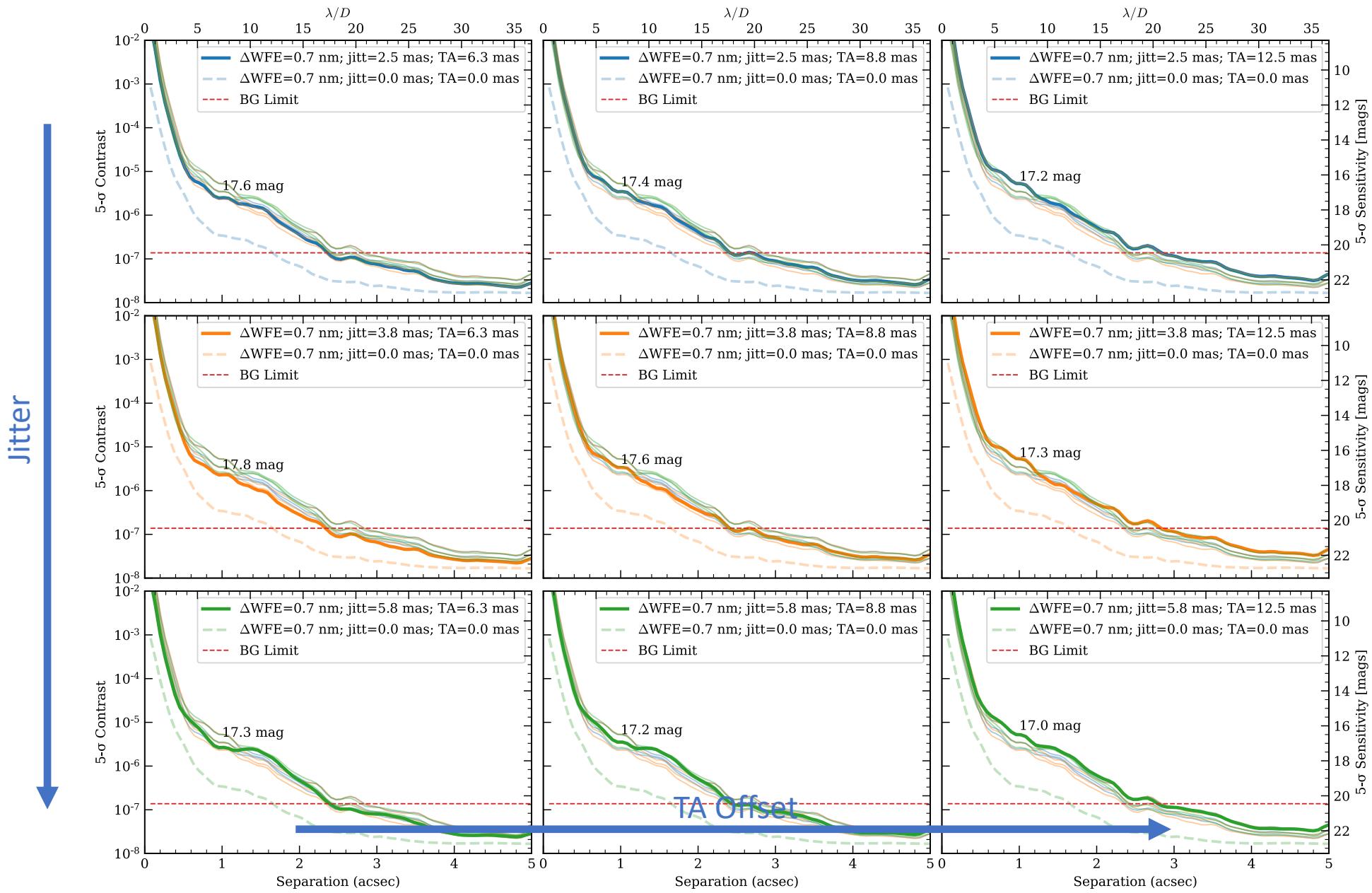


F430M + MASK430R

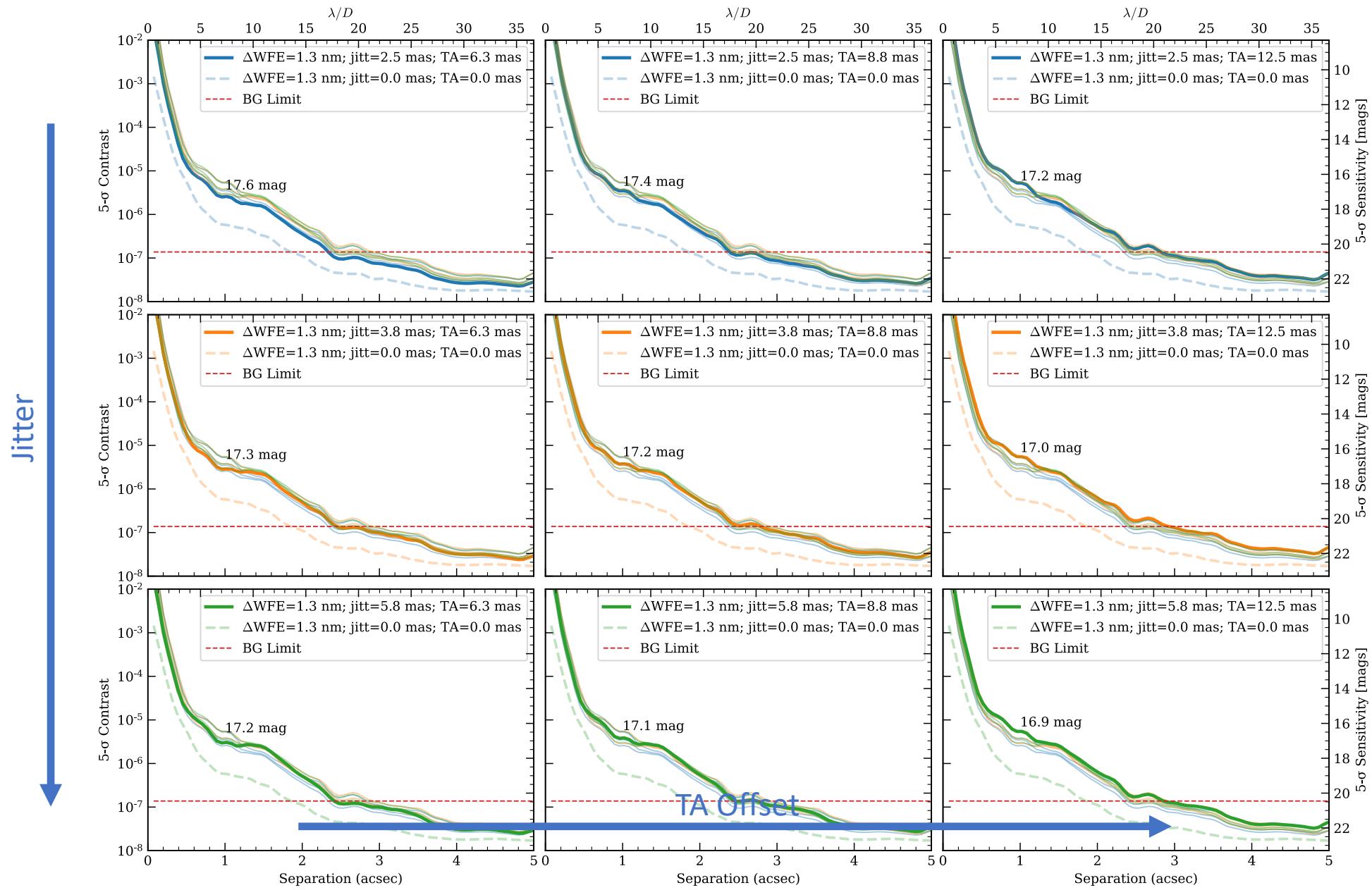
WFE Drift + Jitter ↓



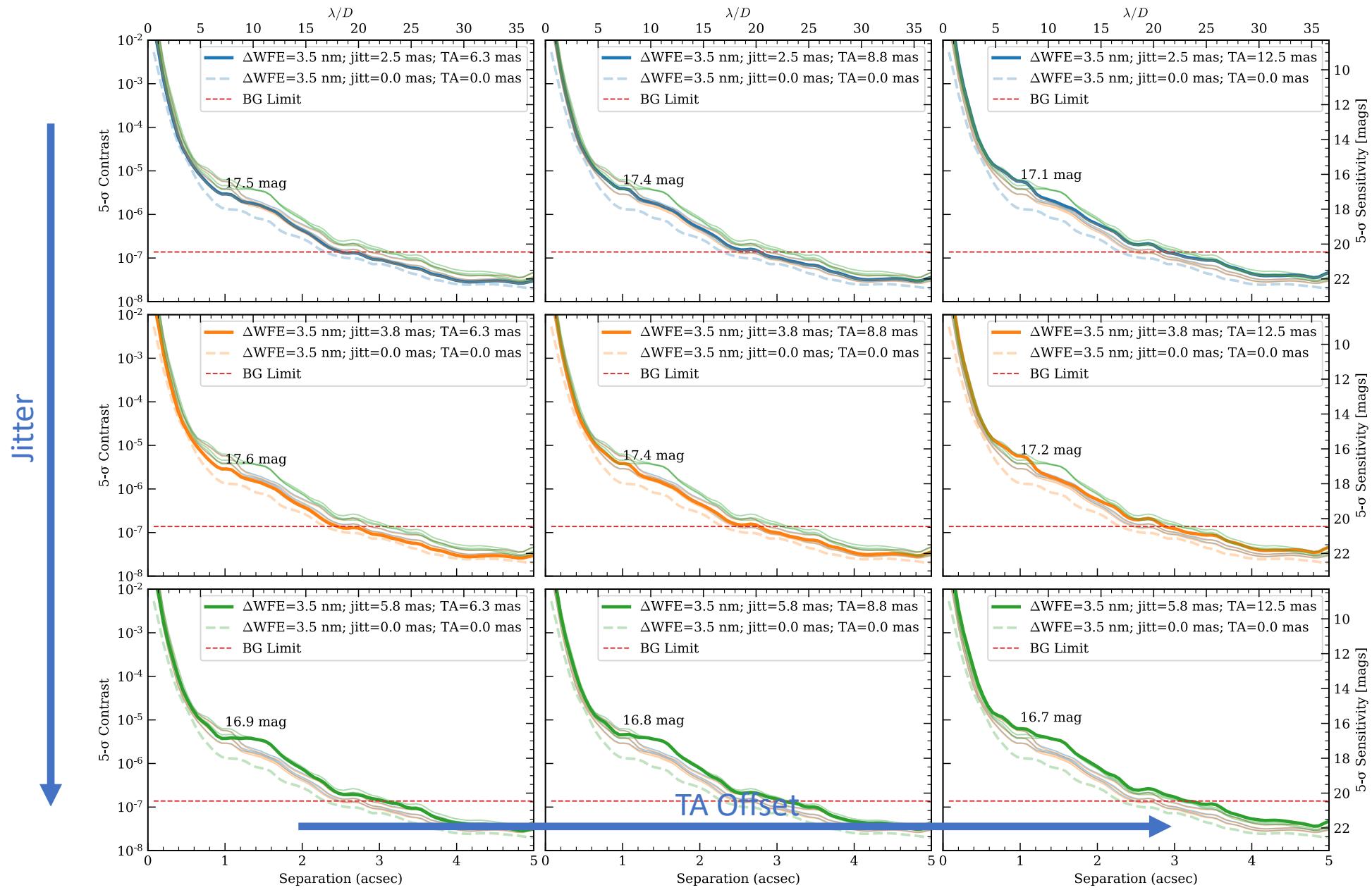
F430M + MASK430R -- Best Case Scenario



F430M + MASK430R -- Nominal Scenario

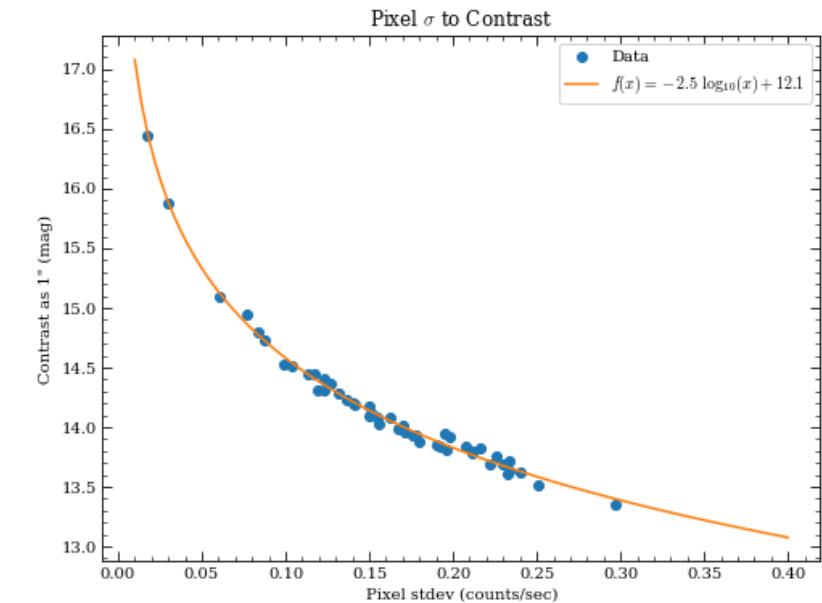


F430M + MASK430R -- Requirements Scenario



Performance Metrics

- WFE drift, jitter, and TA offset each contribute towards residual speckle noise.
- Add contributions in quadrature.
- Convert noise to contrast.



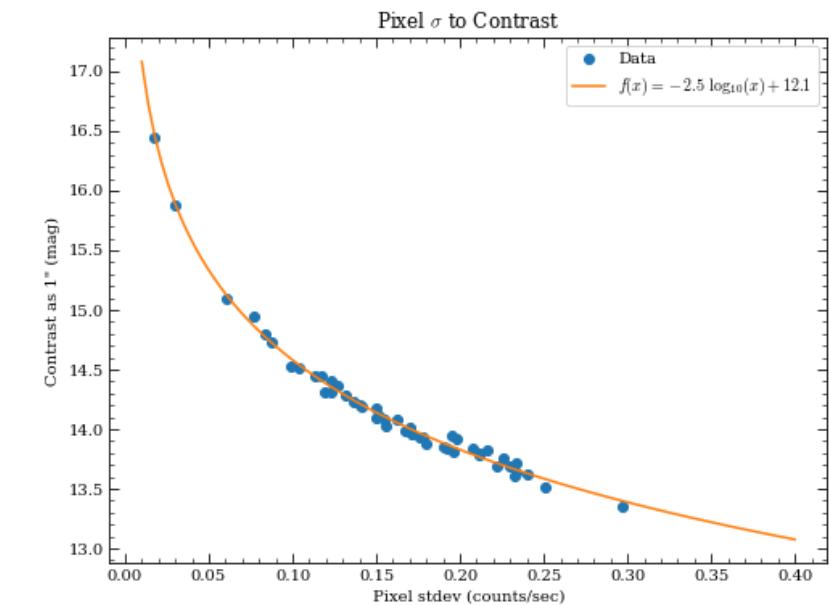
		pixel std at 0.5" <r<2" (counts/sec)						Contrast at 1" (mags)						Contrast loss (relative to best) at 1"						
		Jitter (mas)	TA Offset (mas)					Jitter (mas)	TA Offset (mas)					Jitter (mas)	TA Offset (mas)					
			0	6.3	8.8	12.5				0	6.3	8.8	12.5				0	6.3	8.8	12.5
Best Case	0	0.02	0.08	0.12	0.20	Best Case	0	16.3	14.8	14.4	13.8	Best Case	0	-1.95	-0.44	0.00	0.55			
	2.5	0.06	0.12	0.15	0.21		2.5	15.2	14.4	14.2	13.8		2.5	-0.75	0.00	0.24	0.61			
	3.8	0.15	0.15	0.16	0.21		3.8	14.2	14.2	14.1	13.8		3.8	0.24	0.24	0.31	0.61			
	5.8	0.17	0.17	0.18	0.23		5.8	14.0	14.0	14.0	13.7		5.8	0.38	0.38	0.44	0.71			
Nominal	0	0.03	0.09	0.13	0.20	Nominal	0	15.9	14.7	14.3	13.8	Nominal	0	-1.51	-0.31	0.09	0.55			
	2.5	0.10	0.12	0.15	0.21		2.5	14.6	14.4	14.2	13.8		2.5	-0.20	0.00	0.24	0.61			
	3.8	0.16	0.17	0.18	0.23		3.8	14.1	14.0	14.0	13.7		3.8	0.31	0.38	0.44	0.71			
	5.8	0.17	0.18	0.19	0.24		5.8	14.0	14.0	13.9	13.6		5.8	0.38	0.44	0.50	0.75			
Requirements	0	0.08	0.12	0.15	0.22	Requirements	0	14.8	14.4	14.2	13.7	Requirements	0	-0.44	0.00	0.24	0.66			
	2.5	0.11	0.14	0.17	0.23		2.5	14.5	14.2	14.0	13.7		2.5	-0.09	0.17	0.38	0.71			
	3.8	0.16	0.17	0.18	0.23		3.8	14.1	14.0	14.0	13.7		3.8	0.31	0.38	0.44	0.71			
	5.8	0.22	0.23	0.25	0.30		5.8	13.7	13.7	13.6	13.4		5.8	0.66	0.71	0.80	0.99			

Performance Metrics

- V
- C
- A
- C

Estimate contrast at 1"			
dWFE (nm):	2.5	RMS:	0.06
Jitter (mas):	3	RMS:	0.09
TA (mas):	7	RMS:	0.09
			Total RMS: 0.14
			Contrast: 14.2 mags (at 1")
			Sensitivity: 17.5 mags (at 1") assuming stellar mag of 3.26

Notes: Jitter values are per axis per target
Target acquisition are per axis, relative offset between a single sci obs and ref obs



	pixel std at 0.5" <r<2" (counts/sec)					Contrast at 1" (mags)					Contrast loss (relative to best) at 1"						
	Jitter (mas)	TA Offset (mas)				(mas)	TA Offset (mas)				Best Case	0.7 nm RMS	3.8	5.8			
		0	6.3	8.8			0	6.3	8.8								
Best Case	0	0.02	0.08	0.12	0.20	Best Case	0	16.3	14.8	14.4	13.8	Best Case	0	-1.95	-0.44	0.00	0.55
0.7 nm RMS	2.5	0.06	0.12	0.15	0.21	0.7 nm RMS	2.5	15.2	14.4	14.2	13.8	0.7 nm RMS	2.5	-0.75	0.00	0.24	0.61
	3.8	0.15	0.15	0.16	0.21		3.8	14.2	14.2	14.1	13.8		3.8	0.24	0.24	0.31	0.61
	5.8	0.17	0.17	0.18	0.23		5.8	14.0	14.0	14.0	13.7		5.8	0.38	0.38	0.44	0.71
Nominal	0	0.03	0.09	0.13	0.20	Nominal	0	15.9	14.7	14.3	13.8	Nominal	0	-1.51	-0.31	0.09	0.55
1.3 nm RMS	2.5	0.10	0.12	0.15	0.21	1.3 nm RMS	2.5	14.6	14.4	14.2	13.8	1.3 nm RMS	2.5	-0.20	0.00	0.24	0.61
	3.8	0.16	0.17	0.18	0.23		3.8	14.1	14.0	14.0	13.7		3.8	0.31	0.38	0.44	0.71
	5.8	0.17	0.18	0.19	0.24		5.8	14.0	14.0	13.9	13.6		5.8	0.38	0.44	0.50	0.75
Requirements	0	0.08	0.12	0.15	0.22	Requirements	0	14.8	14.4	14.2	13.7	Requirements	0	-0.44	0.00	0.24	0.66
3.5 nm RMS	2.5	0.11	0.14	0.17	0.23	3.5 nm RMS	2.5	14.5	14.2	14.0	13.7	3.5 nm RMS	2.5	-0.09	0.17	0.38	0.71
	3.8	0.16	0.17	0.18	0.23		3.8	14.1	14.0	14.0	13.7		3.8	0.31	0.38	0.44	0.71
	5.8	0.22	0.23	0.25	0.30		5.8	13.7	13.7	13.6	13.4		5.8	0.66	0.71	0.80	0.99

Conclusions (MASK430R)

- The simulated WFE drifts ([0.7, 1.3, 3.5] nm RMS) have a minimal impact on the contrast relative to jitter and TA offsets.
 - Low RMS of static OPD (compared to WebbPSF defaults)
 - Small timescales probed (sci=1hr, ref=1hr)
 - Assumed symmetric pitch angles for sci and ref slew (eg., +10 deg then -10 deg), which minimizes average drifts between the two observations.
- Jitter
 - For Nominal TA pointing, the range of jitter values (2.5-5.8 mas) produces a contrast difference of ~0.25 mag at 1''.
- Target Acquisition Offsets
 - For Nominal Jitter, contrast difference across TA: TA[12.5] – TA[6.3] = 0.4 mag

To-Do

- Same analysis for different M210R and M335R
- Try the WebbPSF OPDs
- Distribute TA offsets between science and reference
- Implement SGD and PCA analysis
- Same output between simulations
 - Run both NIRCam and MIRI sims through something like pyKLIP
 - Same visualizations