CSWG Simulations
NIRCam Edition

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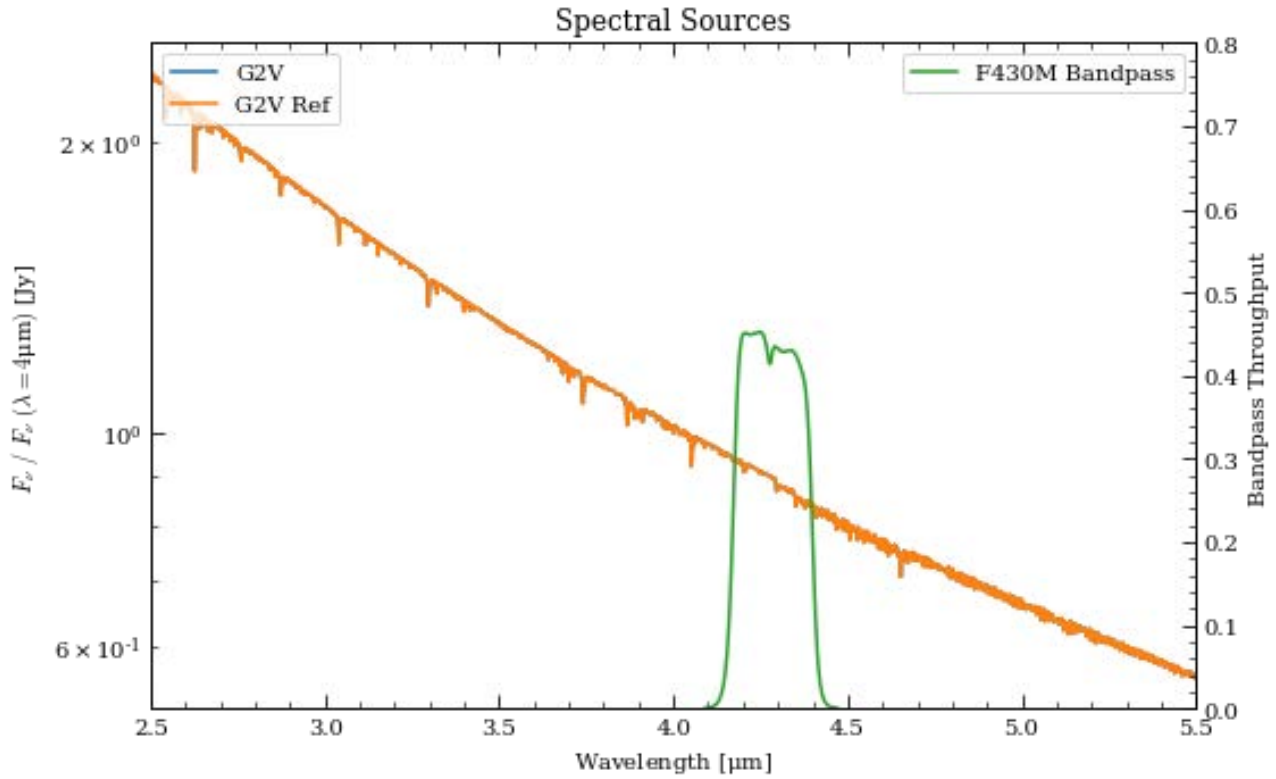
Comparison to WebbPSF Defaults

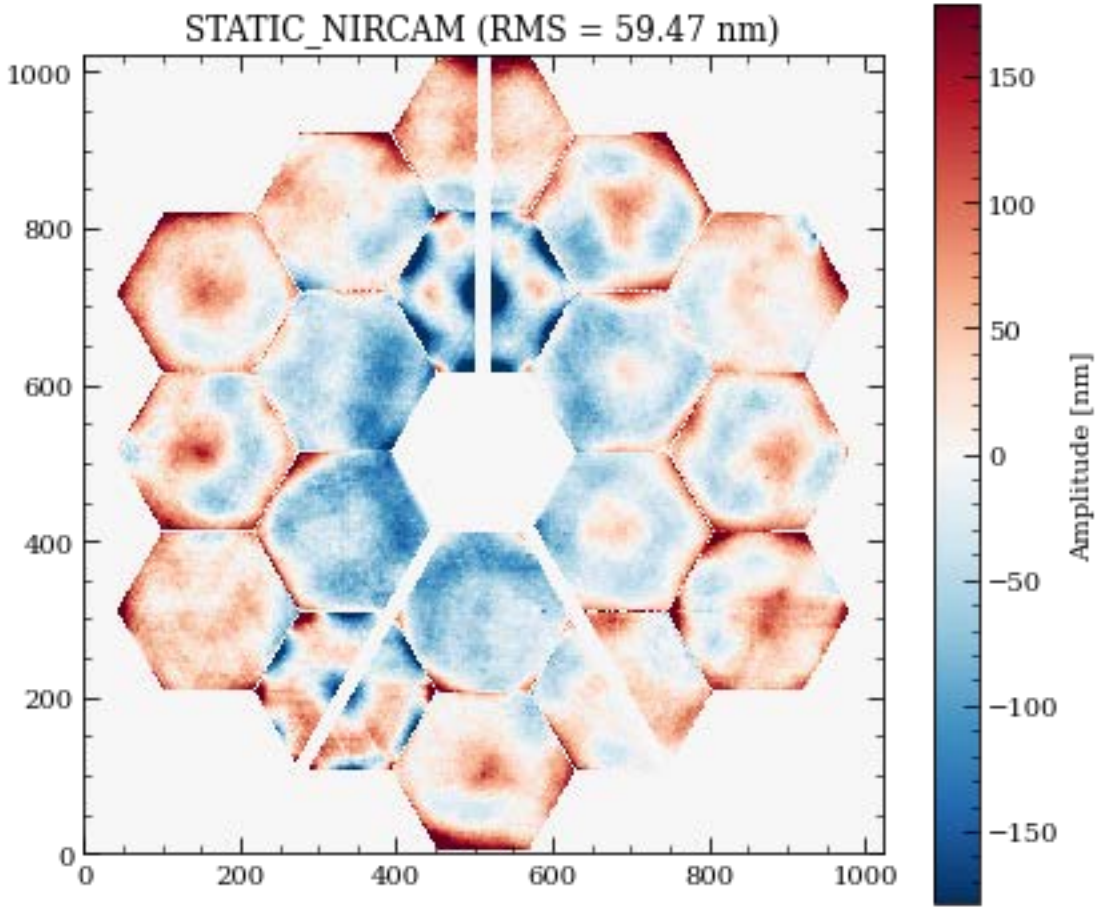
OTE OPDs and PSFs

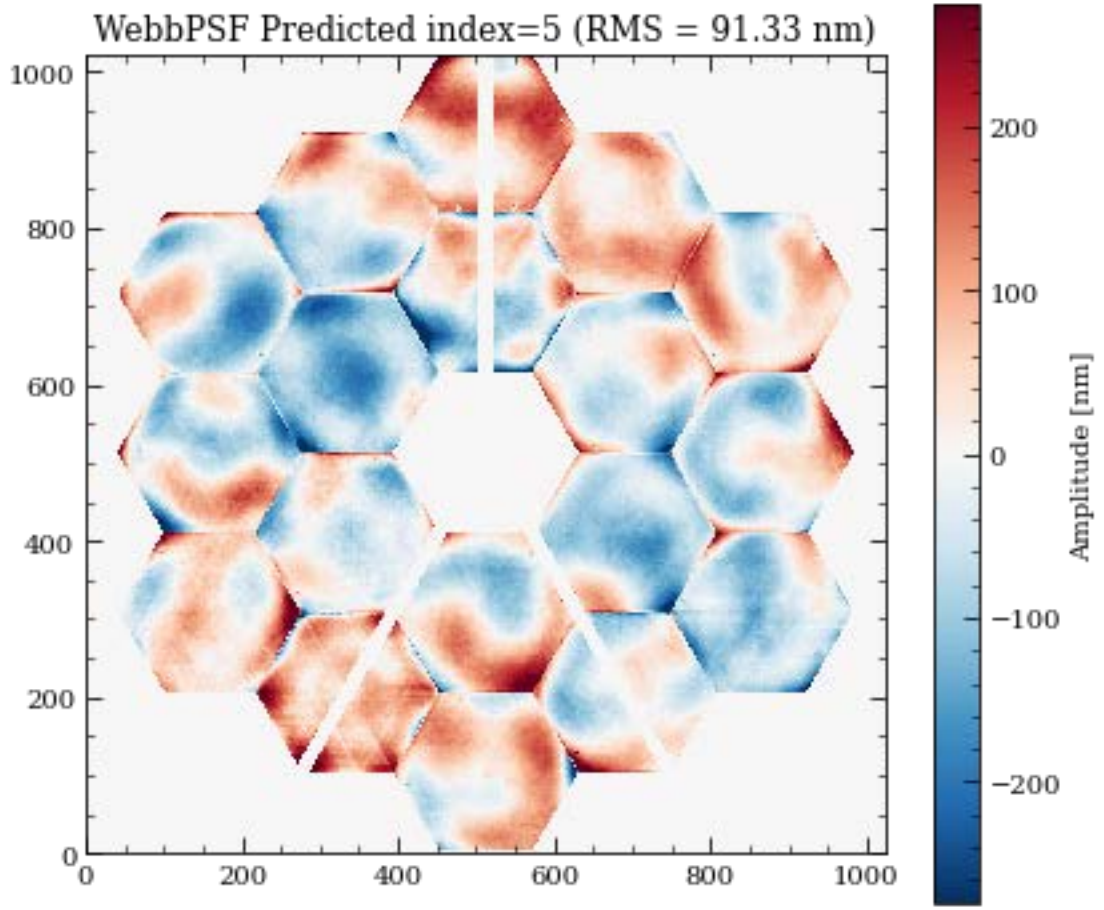
NIRCam Obs Configuration

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

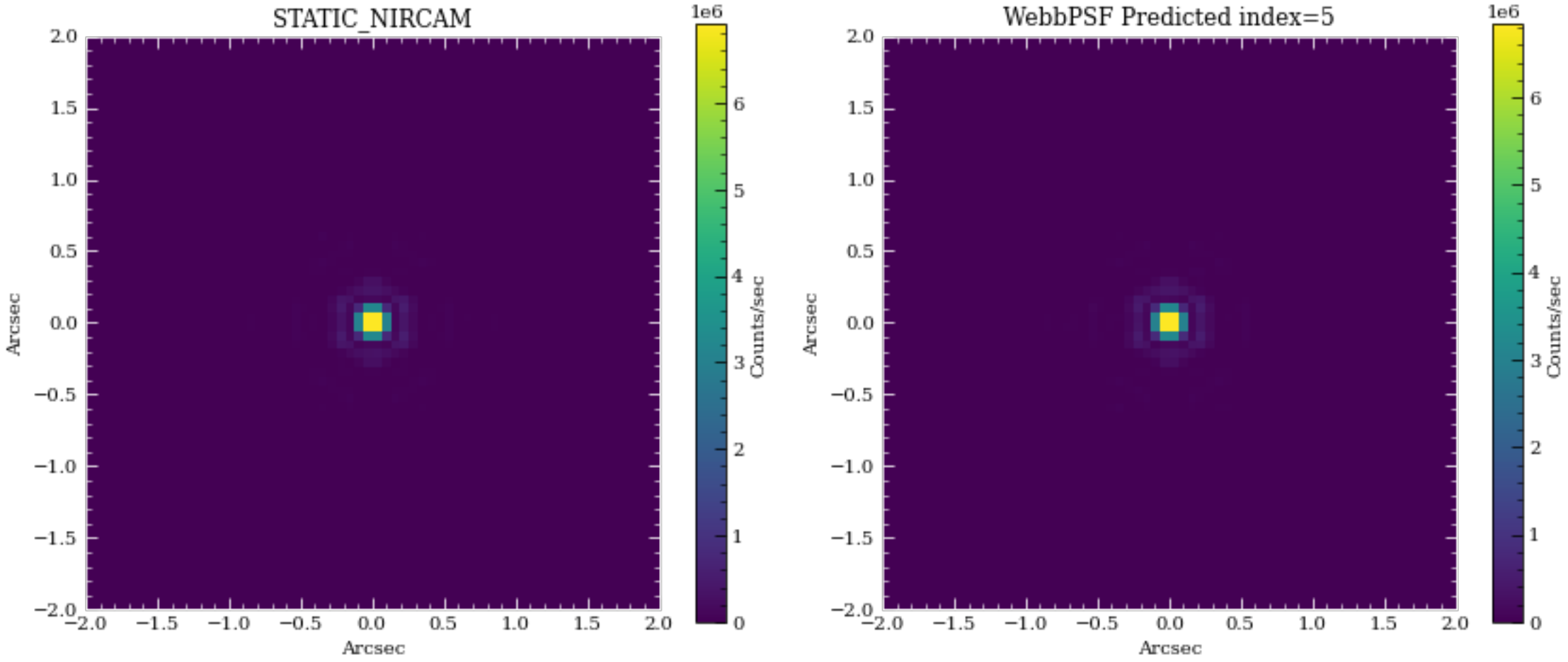


OTE WFE Comparisons

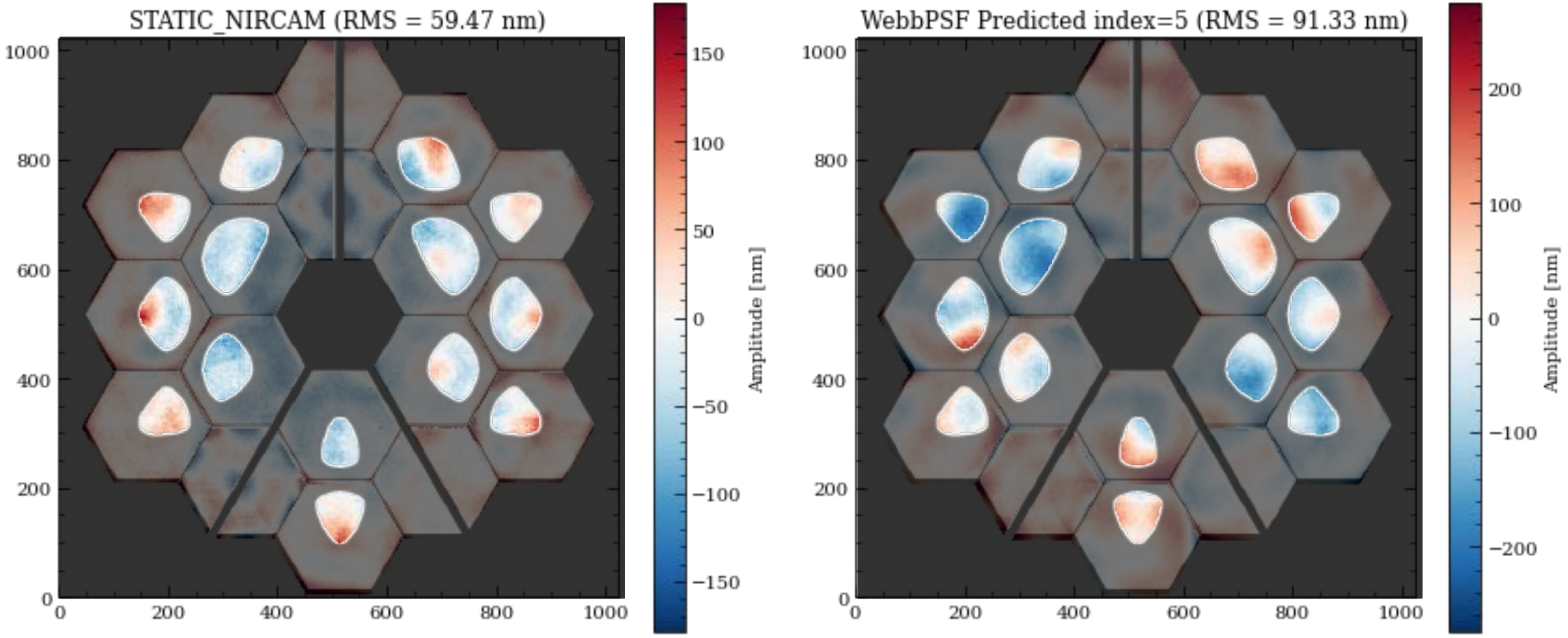




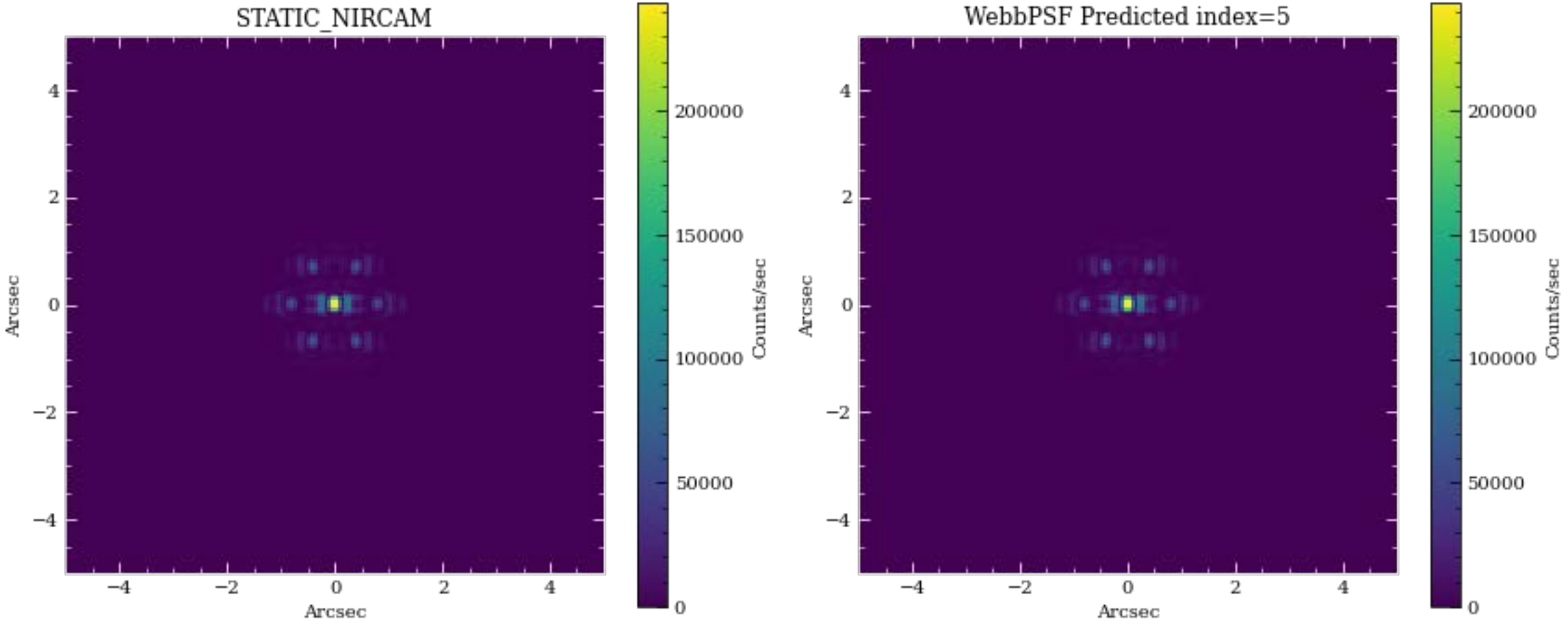
OTE WFE only – Direct Imaging PSF



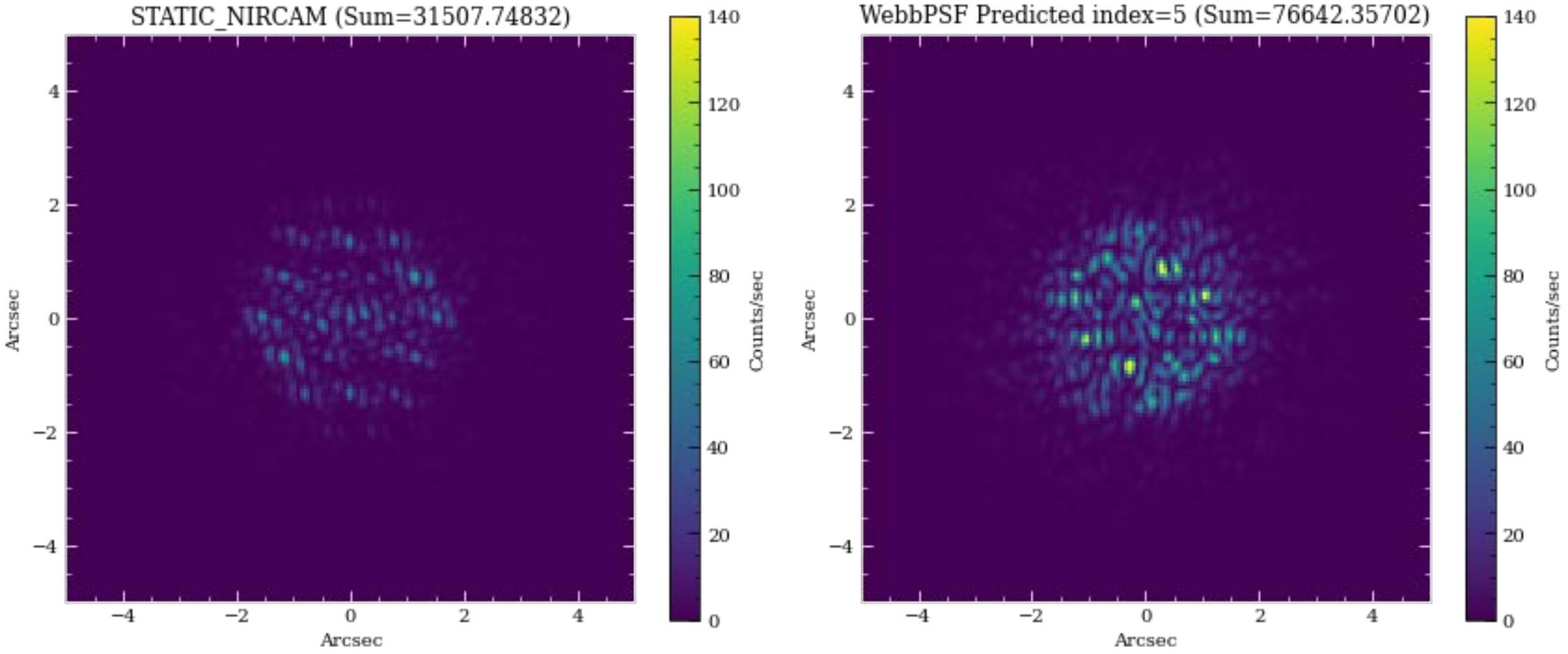
OTE WFE Comparisons + Lyot Mask



OTE WFE only – Off-axis Coronagraphic PSFs



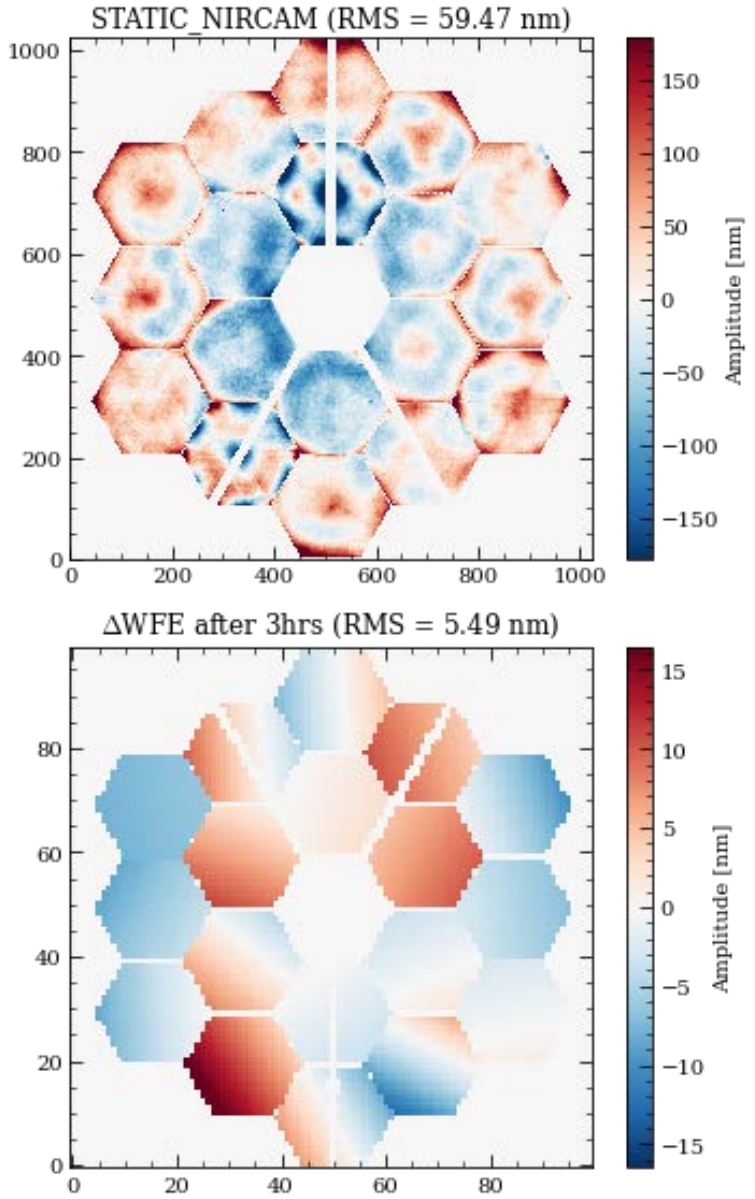
OTE WFE only – Occulted PSFs (MASK430R)



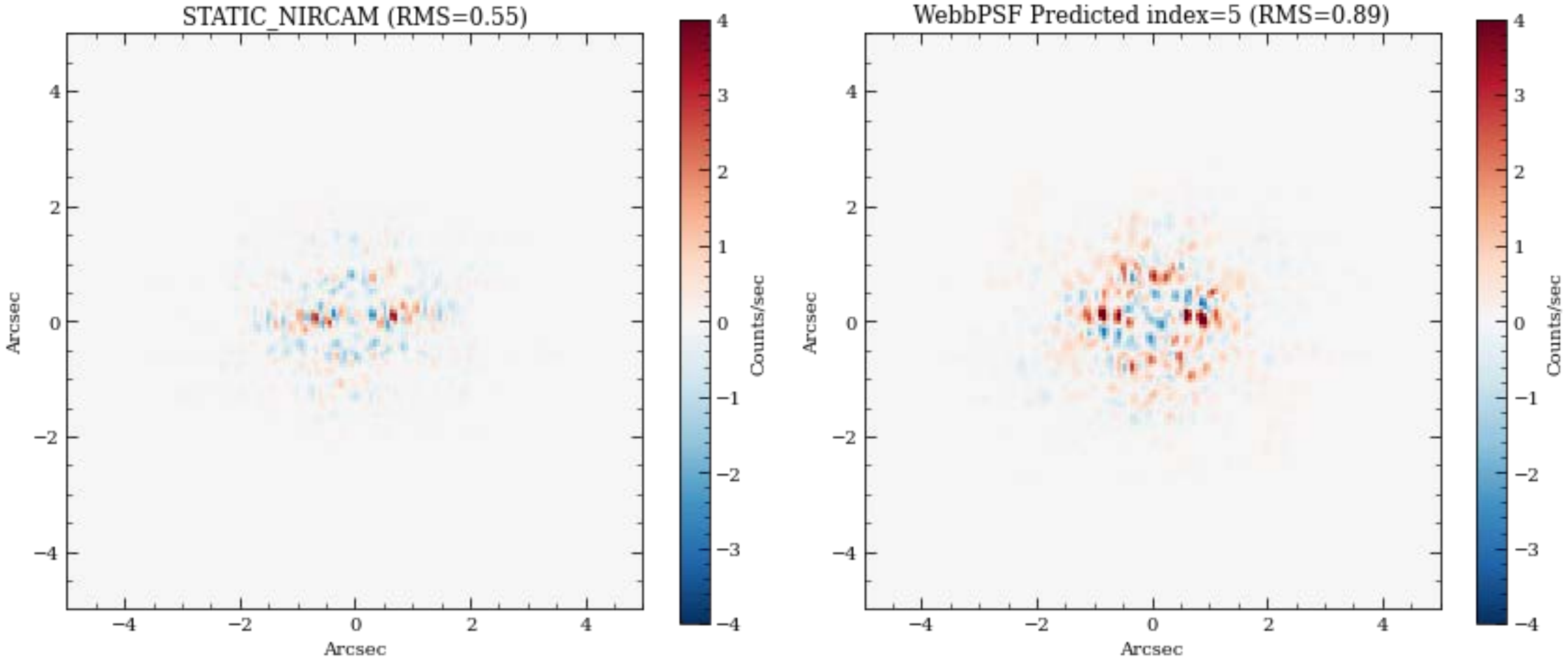
Delta WFE components

- The provided Thermal, Frill, and IEC maps are undersampled (100x100) and flipped compared to STATIC_***_INPUT.fits

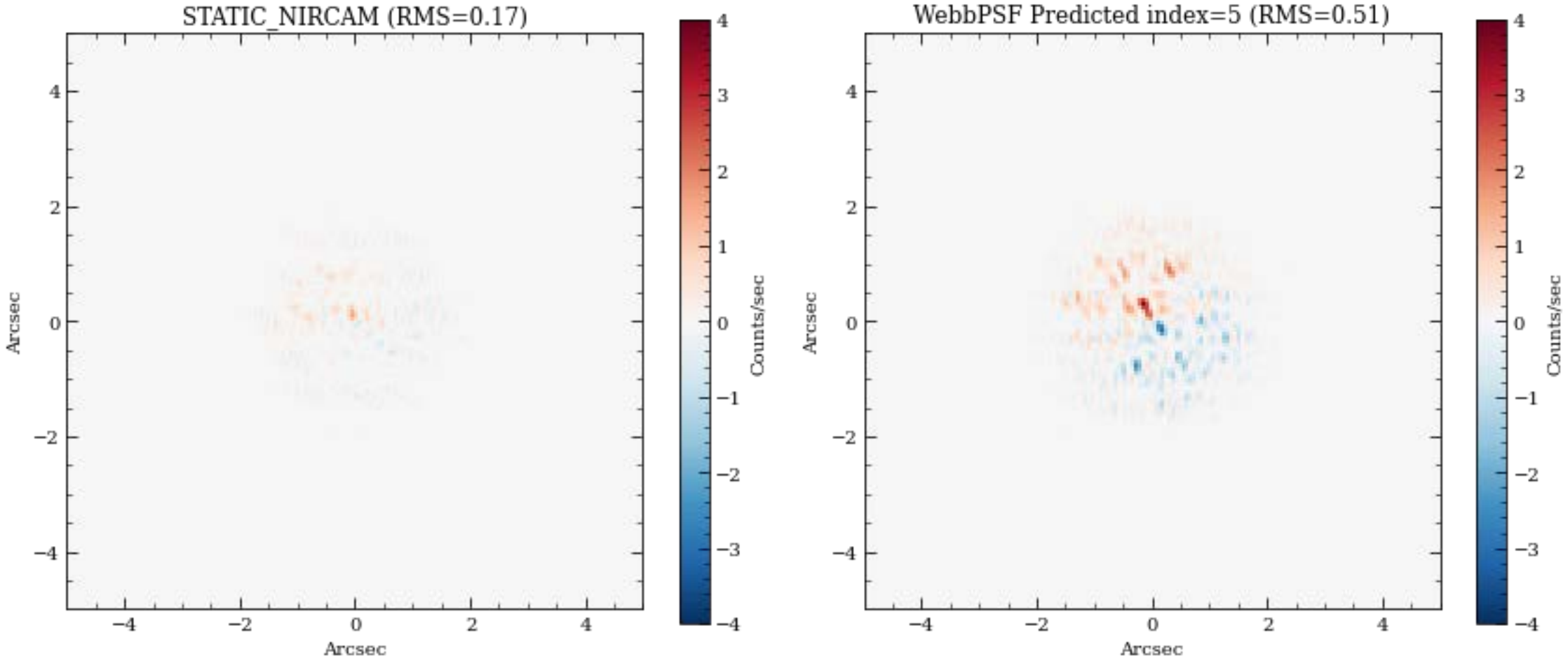
- Create new OPD at given time step
  - Flip drift components up-down
  - Rebin to 1024x1024
  - Add to static OPD



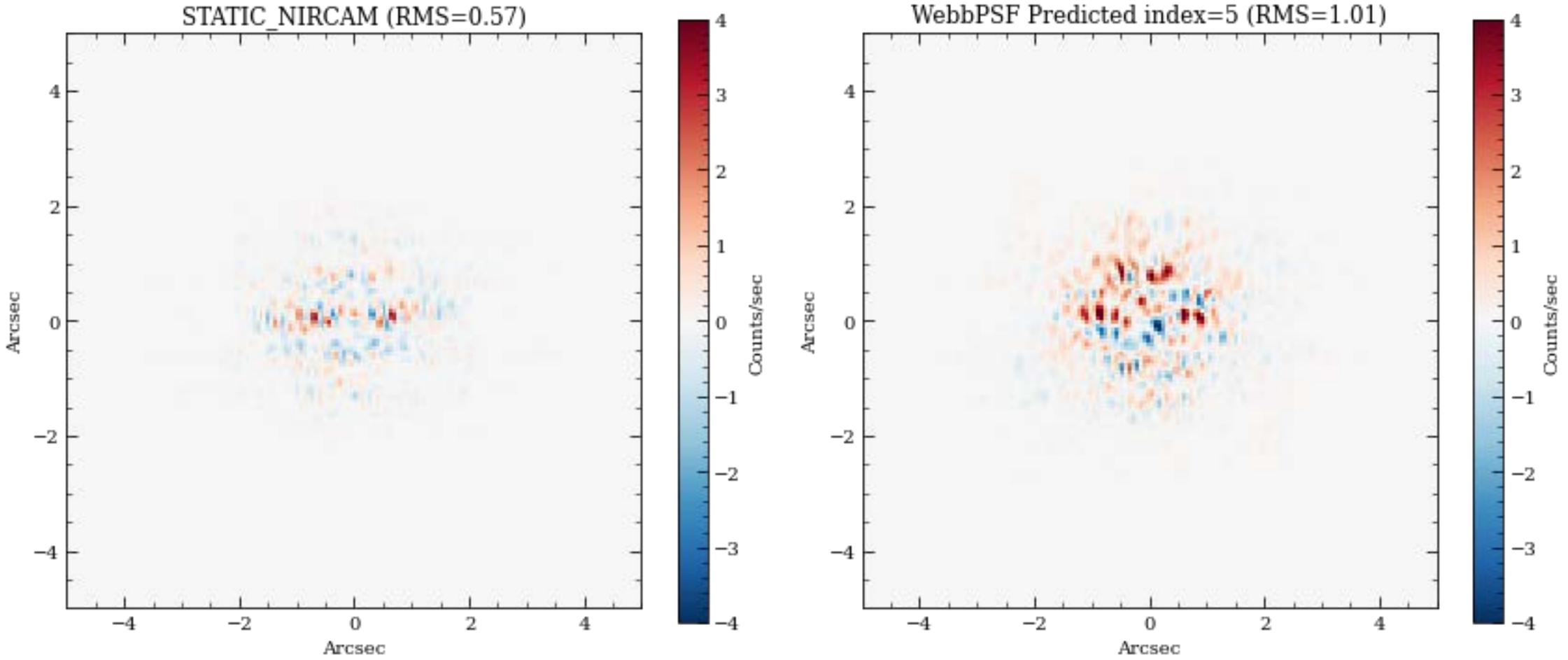
PSF Differences (WFE Drift of 5.5 nm)



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 x 50 x 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)

NIRCam Obs Configuration

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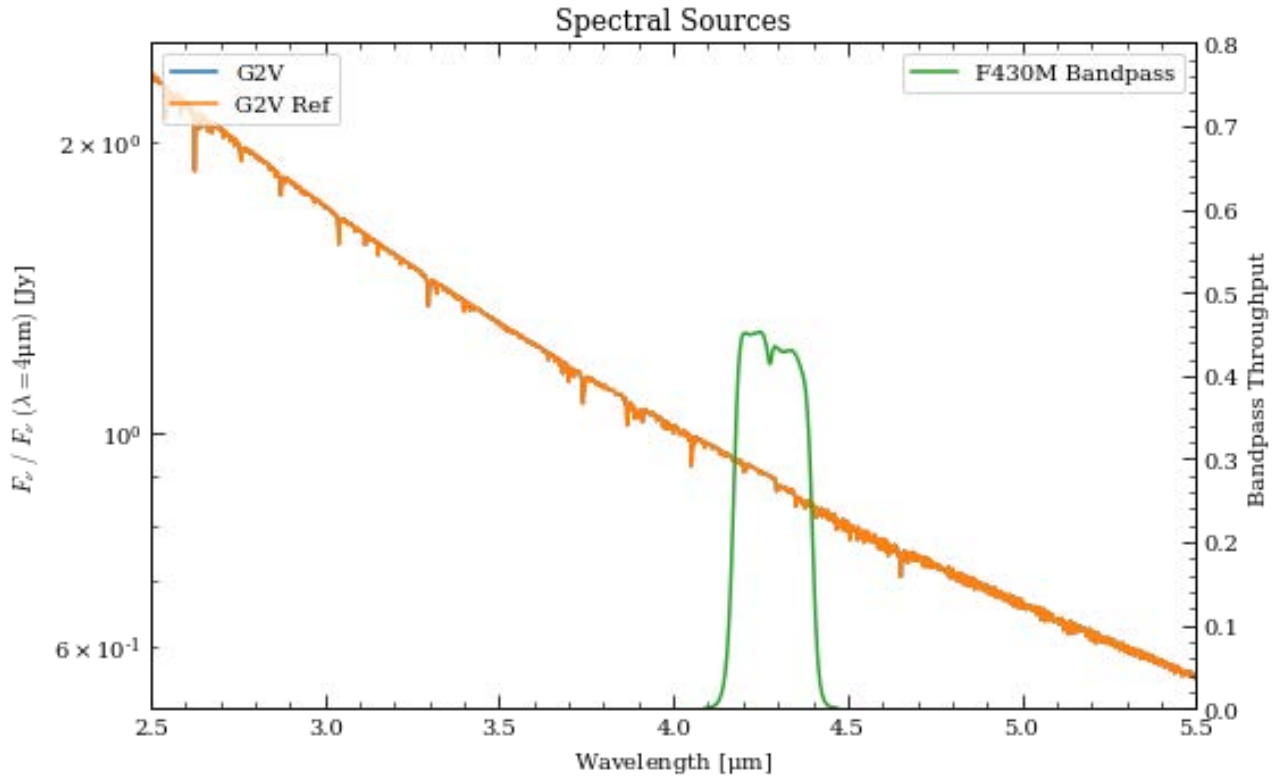

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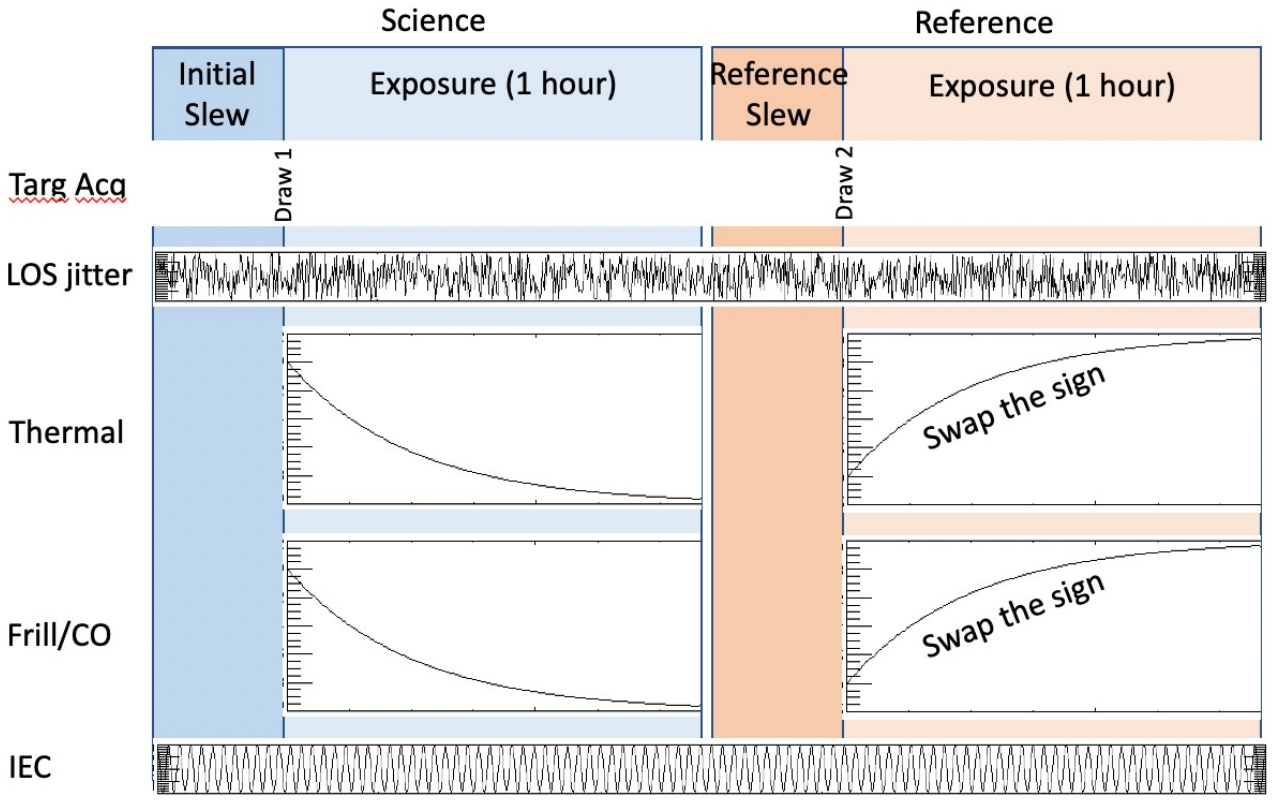
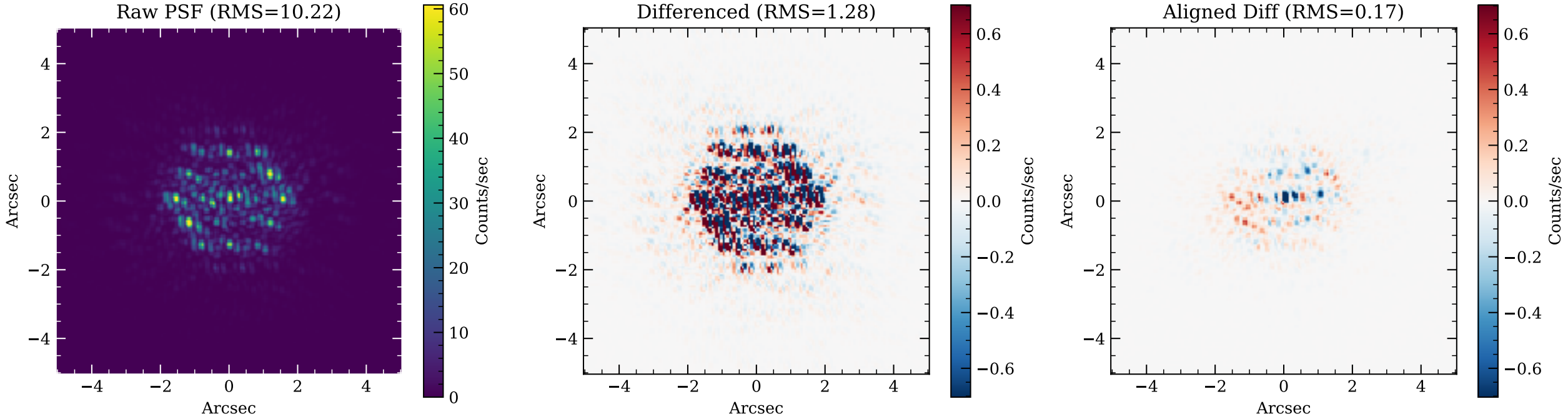
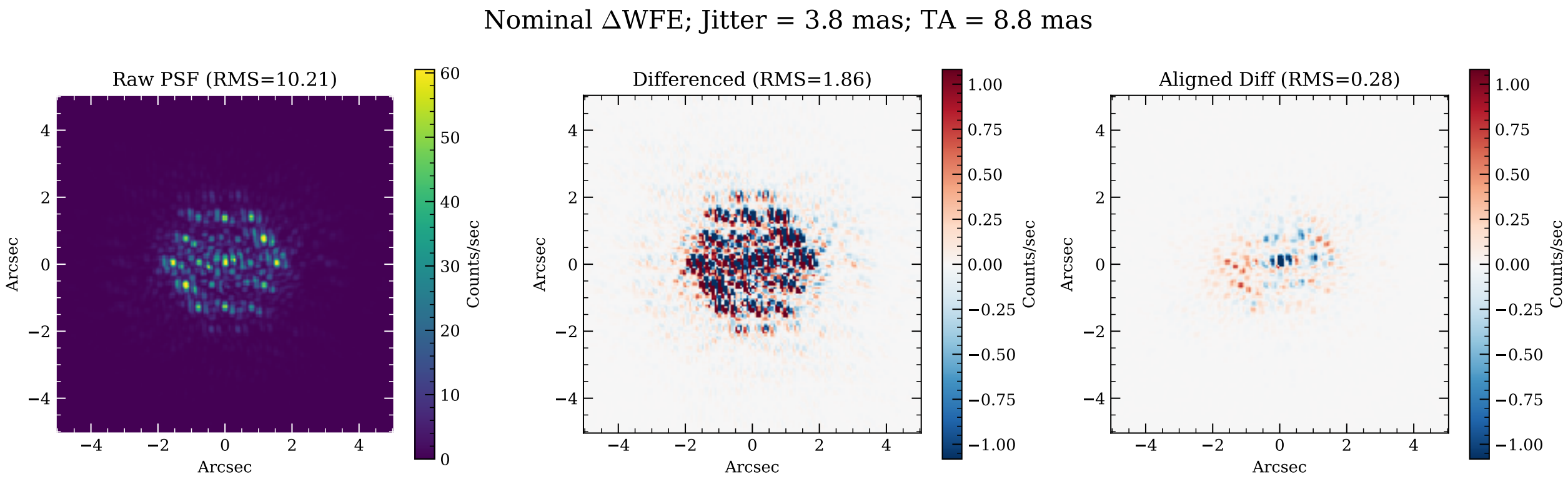


Results – Base Case (<dWFE> = 0.7 nm)

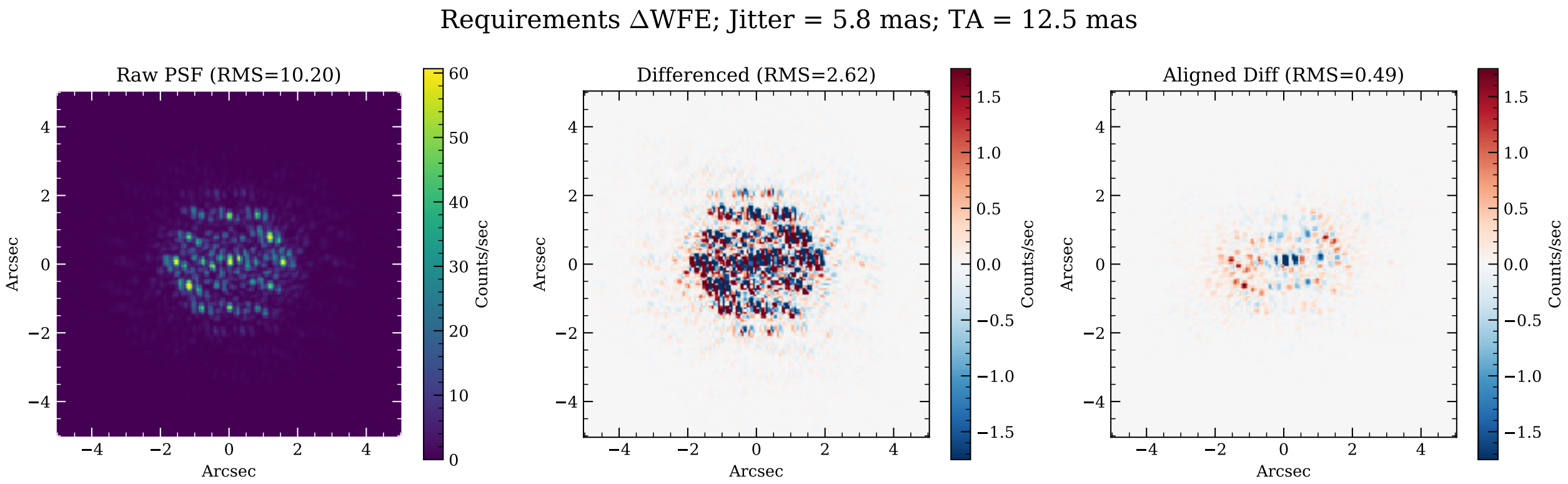
Best Case ΔWFE; Jitter = 2.5 mas; TA = 6.3 mas



Results – Nominal (<dWFE> = 1.3 nm)

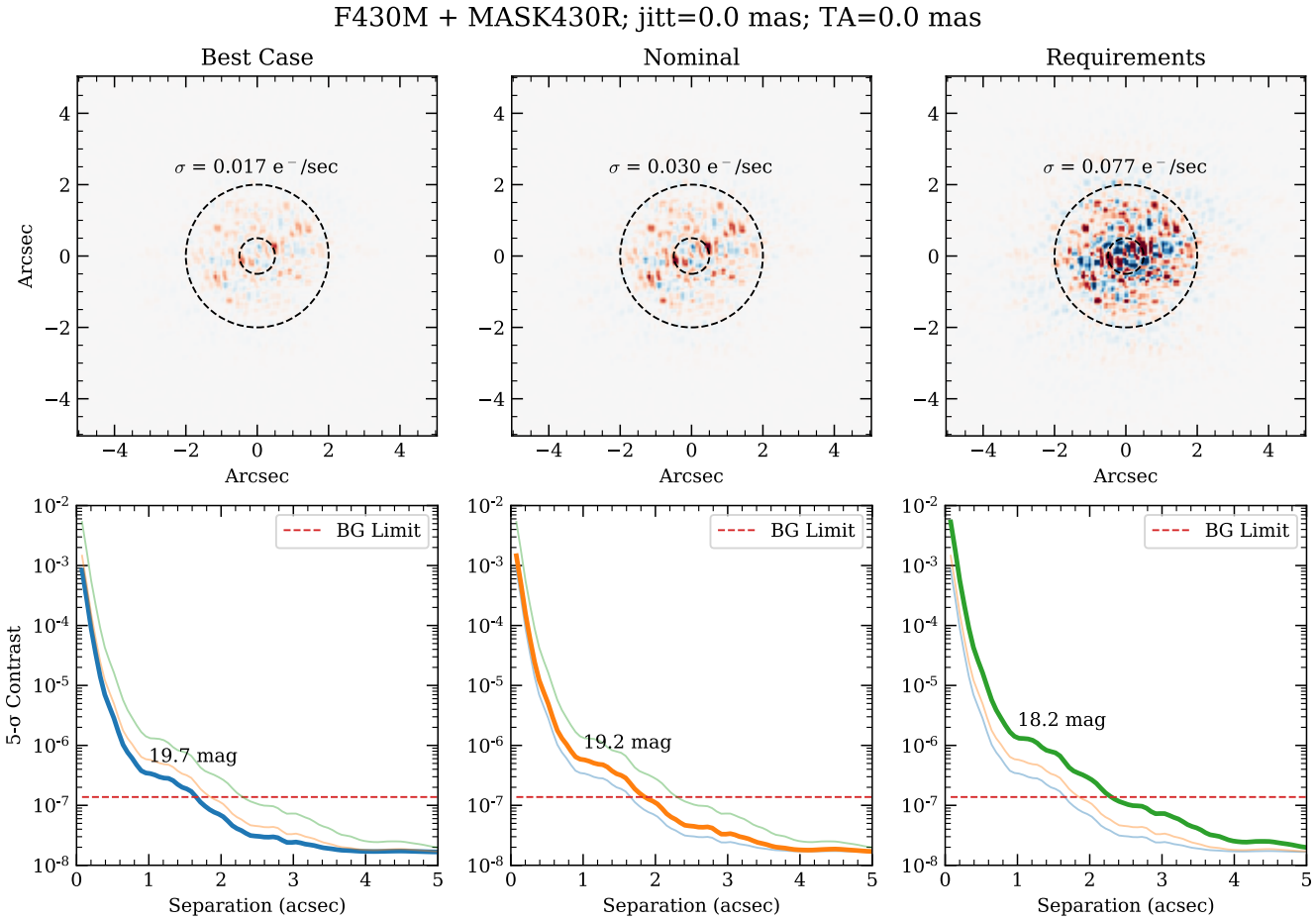


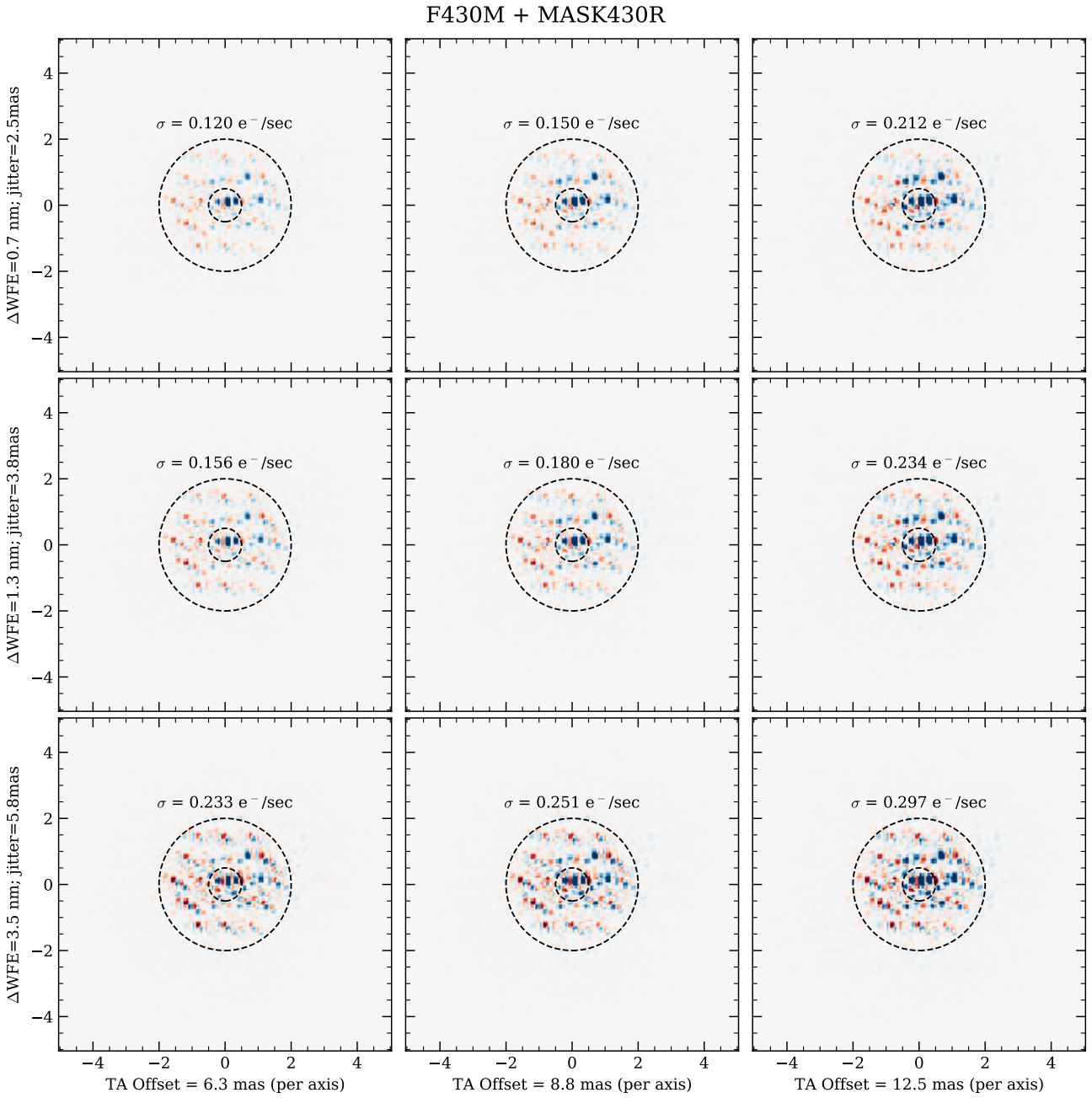
Results – Requirements (<dWFE> = 3.5 nm)



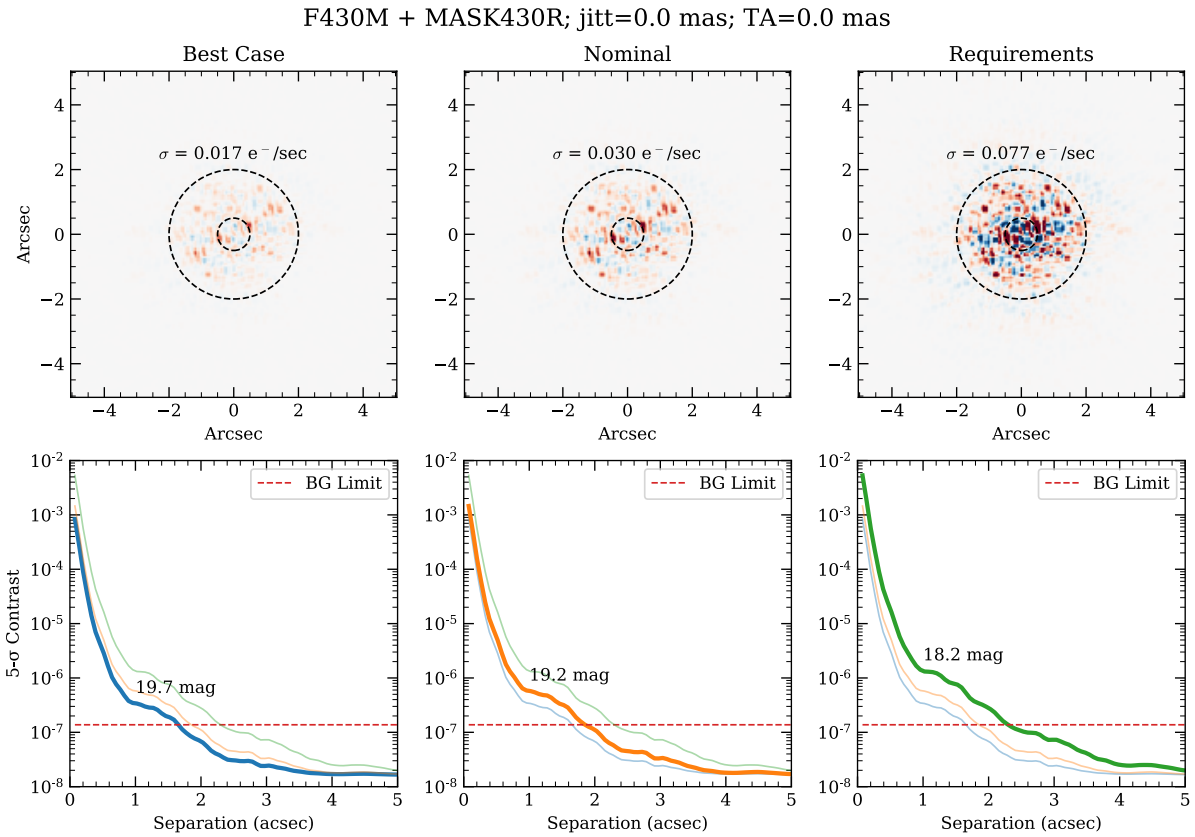
Noise Components

- 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.

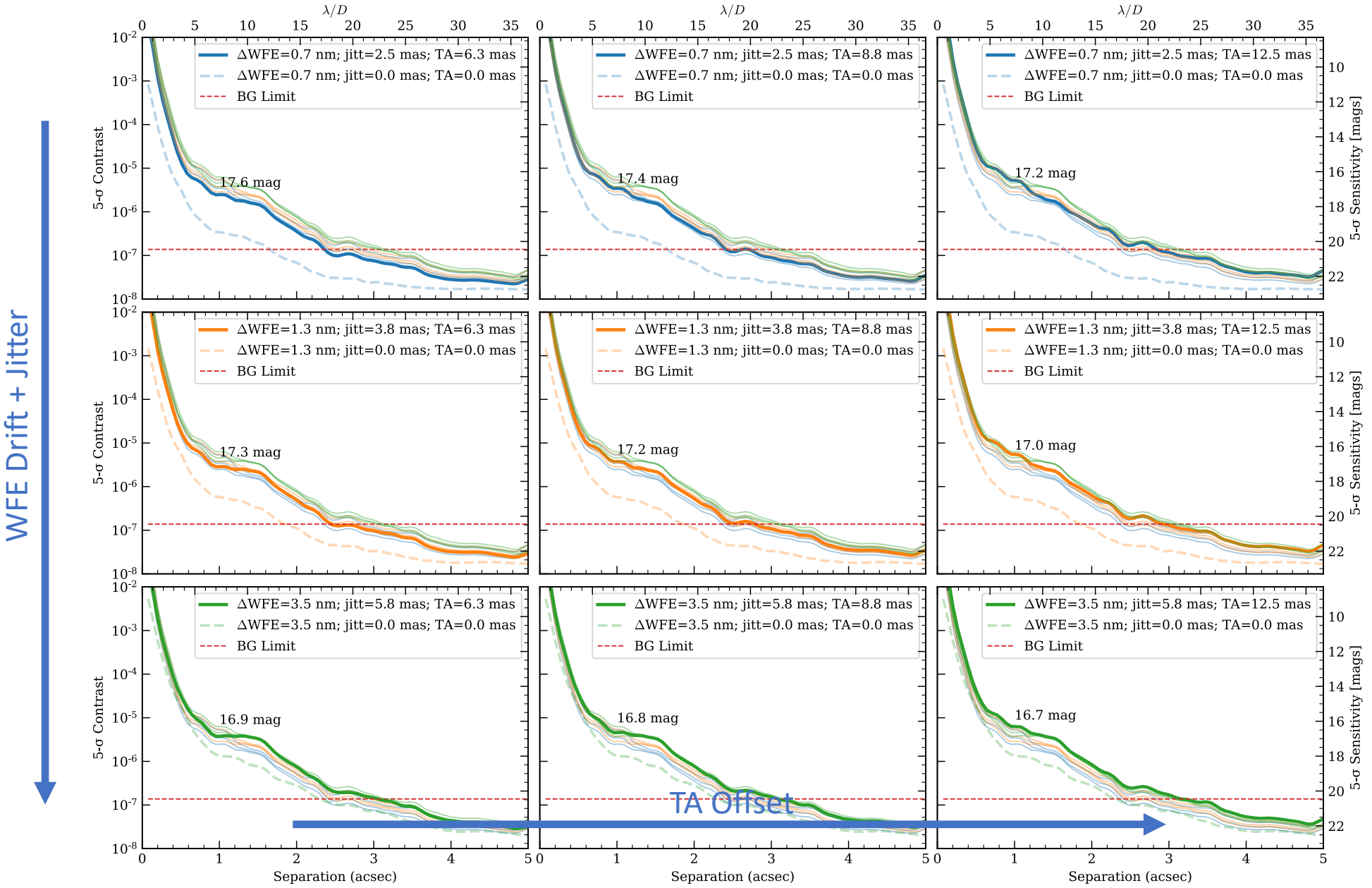




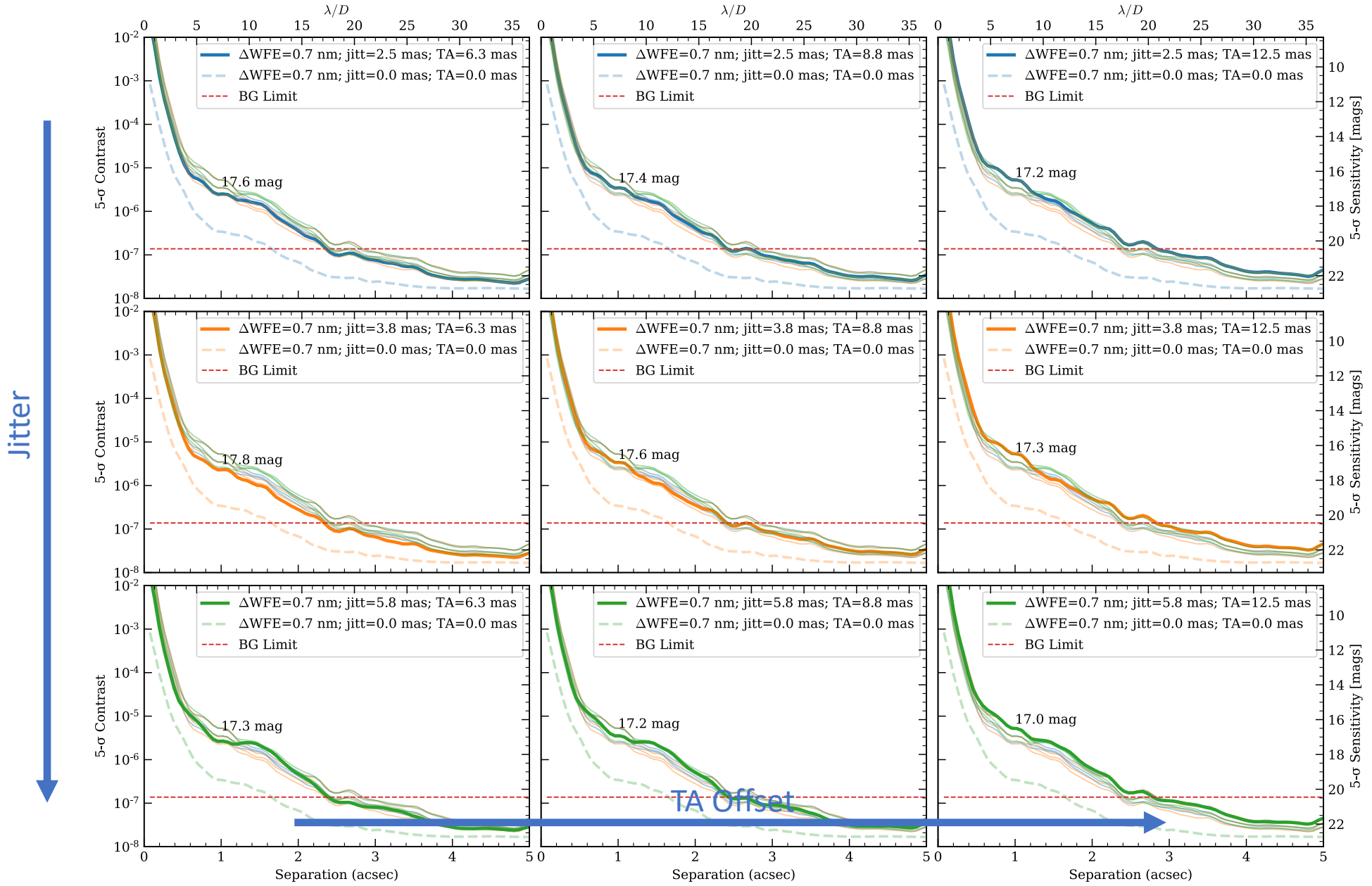
- Average OPD drifts (nm RMS)
  - Best, Nom, Req = (0.7, 1.3, 3.5)
- Jitter & TA dominate residual speckle noise and contrast



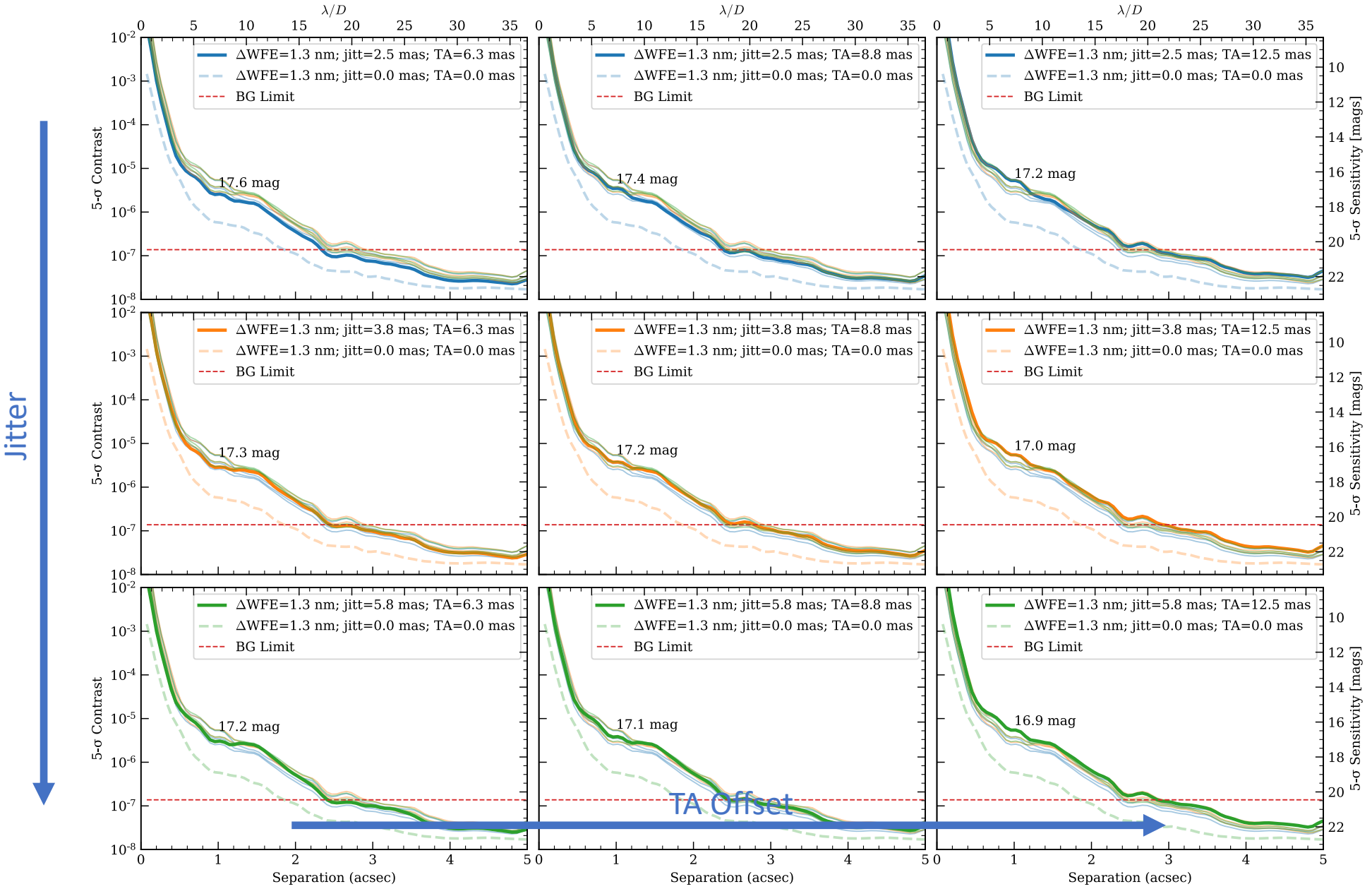
F430M + MASK430R



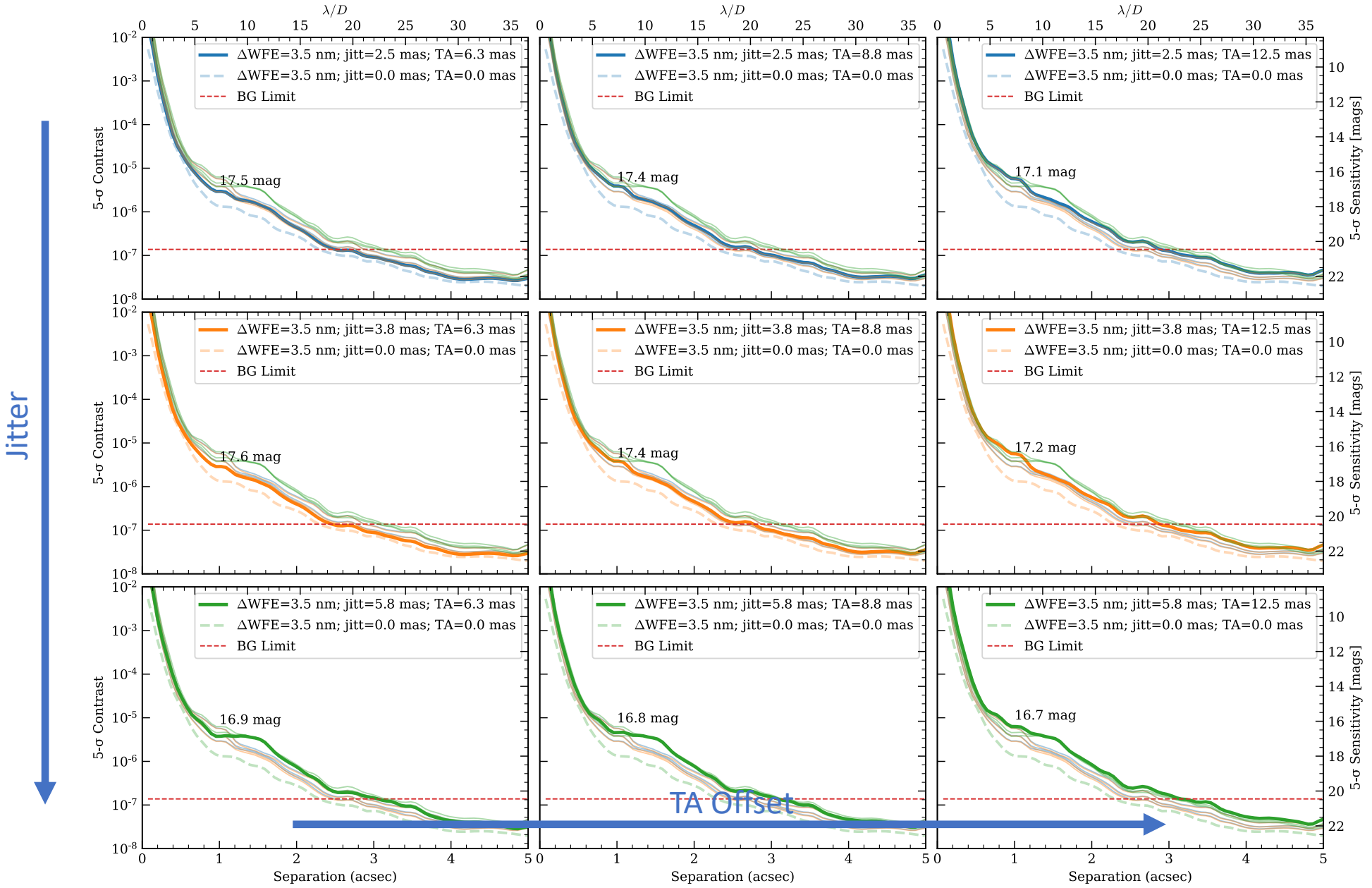
F430M + MASK430R -- Best Case Scenario



F430M + MASK430R -- Nominal Scenario

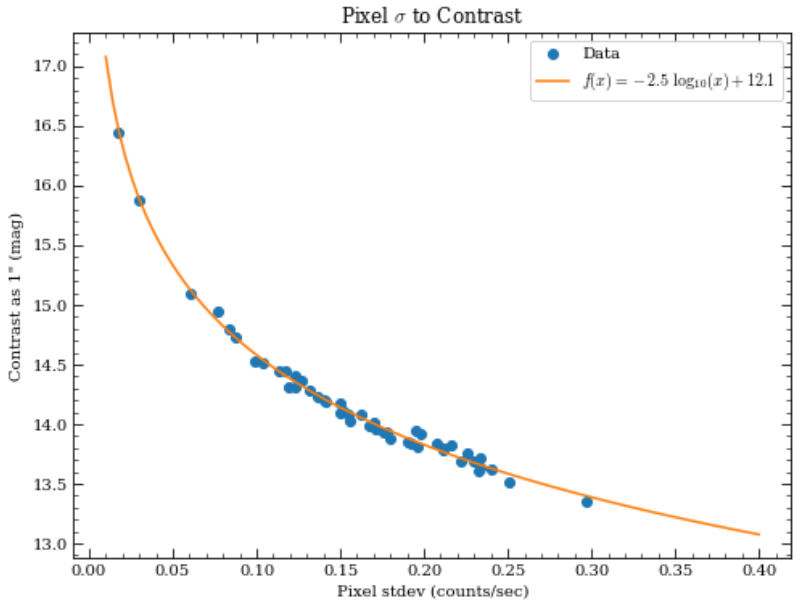


F430M + MASK430R -- Requirements Scenario



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)				
	Jitter	TA Offset (mas)			
	(mas)	0	6.3	8.8	12.5
Best Case	**0**	0.02	0.08	0.12	0.20
0.7 nm RMS	**2.5**	0.06	0.12	0.15	0.21
	3.8	0.15	0.15	0.16	0.21
	5.8	0.17	0.17	0.18	0.23
Nominal	**0**	0.03	0.09	0.13	0.20
1.3 nm RMS	**2.5**	0.10	0.12	0.15	0.21
	3.8	0.16	0.17	0.18	0.23
	5.8	0.17	0.18	0.19	0.24
Requirements	**0**	0.08	0.12	0.15	0.22
3.5 nm RMS	**2.5**	0.11	0.14	0.17	0.23
	3.8	0.16	0.17	0.18	0.23
	5.8	0.22	0.23	0.25	0.30

	Contrast at 1" (mags)				
	Jitter	TA Offset (mas)			
	(mas)	0	6.3	8.8	12.5
Best Case	**0**	16.3	14.8	14.4	13.8
0.7 nm RMS	**2.5**	15.2	14.4	14.2	13.8
	3.8	14.2	14.2	14.1	13.8
	5.8	14.0	14.0	14.0	13.7
Nominal	**0**	15.9	14.7	14.3	13.8
1.3 nm RMS	**2.5**	14.6	14.4	14.2	13.8
	3.8	14.1	14.0	14.0	13.7
	5.8	14.0	14.0	13.9	13.6
Requirements	**0**	14.8	14.4	14.2	13.7
3.5 nm RMS	**2.5**	14.5	14.2	14.0	13.7
	3.8	14.1	14.0	14.0	13.7
	5.8	13.7	13.7	13.6	13.4

	Contrast loss (relative to best) at 1"				
	Jitter	TA Offset (mas)			
	(mas)	0	6.3	8.8	12.5
Best Case	**0**	-1.95	-0.44	0.00	0.55
0.7 nm RMS	**2.5**	-0.75	0.00	0.24	0.61
	3.8	0.24	0.24	0.31	0.61
	5.8	0.38	0.38	0.44	0.71
Nominal	**0**	-1.51	-0.31	0.09	0.55
1.3 nm RMS	**2.5**	-0.20	0.00	0.24	0.61
	3.8	0.31	0.38	0.44	0.71
	5.8	0.38	0.44	0.50	0.75
Requirements	**0**	-0.44	0.00	0.24	0.66
3.5 nm RMS	**2.5**	-0.09	0.17	0.38	0.71
	3.8	0.31	0.38	0.44	0.71
	5.8	0.66	0.71	0.80	0.99

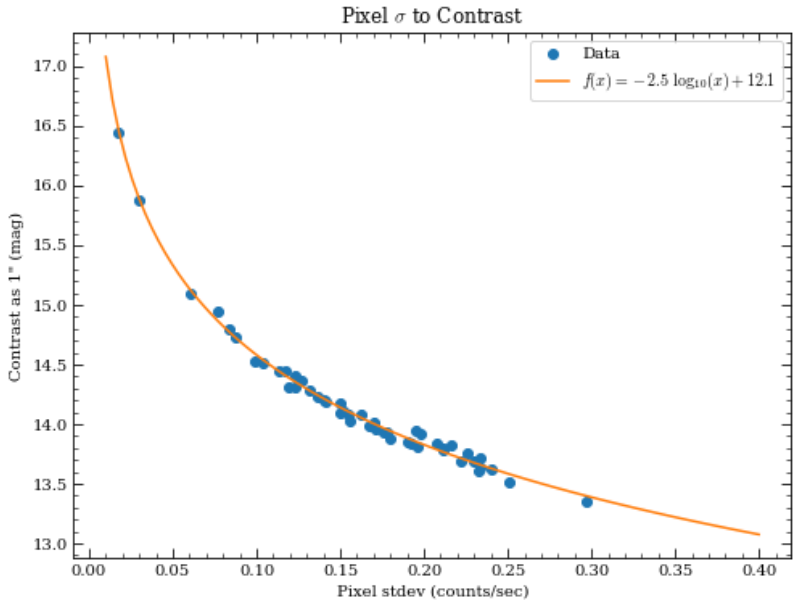
Performance Metrics

- V
- 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 acqusition are per axis, relative offset between a single sci obs and ref obs



	pixel std at 0.5"<r<2" (counts/sec)				
	Jitter (mas)	TA Offset (mas) 0	6.3	8.8	12.5
Best Case 0.7 nm RMS	**0**	0.02	0.08	0.12	0.20
	2.5	0.06	0.12	0.15	0.21
	3.8	0.15	0.15	0.16	0.21
	5.8	0.17	0.17	0.18	0.23
Nominal 1.3 nm RMS	**0**	0.03	0.09	0.13	0.20
	2.5	0.10	0.12	0.15	0.21
	3.8	0.16	0.17	0.18	0.23
	5.8	0.17	0.18	0.19	0.24
Requirements 3.5 nm RMS	**0**	0.08	0.12	0.15	0.22
	2.5	0.11	0.14	0.17	0.23
	3.8	0.16	0.17	0.18	0.23
	5.8	0.22	0.23	0.25	0.30

	Contrast at 1" (mags)				
	Jitter (mas)	TA Offset (mas) 0	6.3	8.8	12.5
Best Case 0.7 nm RMS	**0**	16.3	14.8	14.4	13.8
	2.5	15.2	14.4	14.2	13.8
	3.8	14.2	14.2	14.1	13.8
	5.8	14.0	14.0	14.0	13.7
Nominal 1.3 nm RMS	**0**	15.9	14.7	14.3	13.8
	2.5	14.6	14.4	14.2	13.8
	3.8	14.1	14.0	14.0	13.7
	5.8	14.0	14.0	13.9	13.6
Requirements 3.5 nm RMS	**0**	14.8	14.4	14.2	13.7
	2.5	14.5	14.2	14.0	13.7
	3.8	14.1	14.0	14.0	13.7
	5.8	13.7	13.7	13.6	13.4

	Contrast loss (relative to best) at 1"				
	Jitter (mas)	TA Offset (mas) 0	6.3	8.8	12.5
Best Case 0.7 nm RMS	**0**	-1.95	-0.44	0.00	0.55
	2.5	-0.75	0.00	0.24	0.61
	3.8	0.24	0.24	0.31	0.61
	5.8	0.38	0.38	0.44	0.71
Nominal 1.3 nm RMS	**0**	-1.51	-0.31	0.09	0.55
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	3.8	0.31	0.38	0.44	0.71
	5.8	0.38	0.44	0.50	0.75
Requirements 3.5 nm RMS	**0**	-0.44	0.00	0.24	0.66
	2.5	-0.09	0.17	0.38	0.71
	3.8	0.31	0.38	0.44	0.71
	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