

Wavefront Error Reconstruction and Companion Detection for Full Pupil and AMI Imaging

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University of Michigan

In collaboration with:

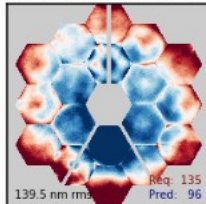
Marie Ygouf, Graca Rocha, Alexandra Greenbaum, Michael Meyer, Charles Beichman

AMI + KPI Workshop
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What makes up WFE?

- Total WFE of a given observation includes:
 - Contribution from optical telescope element (OTE) → will drift
 - SI WFE → will be stable
- Information for simulations:
 - WebbPSF predicted OTE OPD (multiple realizations)
 - WebbPSF predicted SI WFE: set of 37 Zernikes based on detector position
- Information for real data:
 - OTE wavefront measurement about every 2 days
 - SI wavefront measurement
 - WFE drift realization

Total WFE for OTE+NRCA3 at (1024, 0)



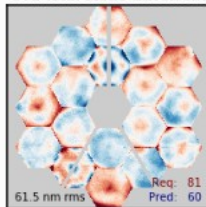
Optical model for NIRCam wavefront error

OTE OPD model: (JWST_OTE_OPD_RevAA_prelaunch_predicted.fits.gz, 4)

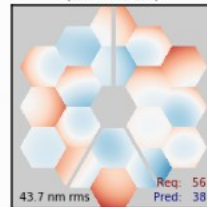
NIRCam, detector NRCA3 at (1024, 0), aperture = NRCA3_FULL (V2, V3): (0.863, -9.339) arcmin

All WFE shown as projected to OTE entrance pupil orientation.

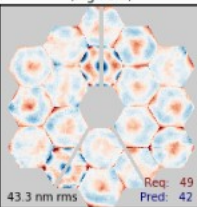
OTE total static wavefront



OTE controllable mode residuals (low+mid s.f.)



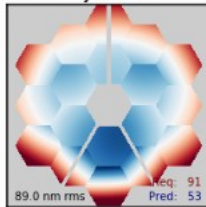
OTE uncontrollable WFE (high s.f.)



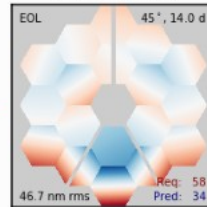
OTE field-dependent WFE (low s.f.)



OTE total dynamic wavefront



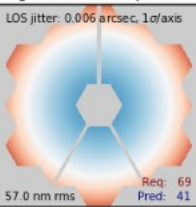
OTE thermal drifts



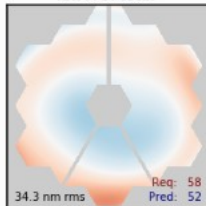
OTE vibrate



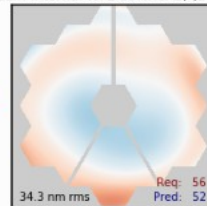
image motion* (as equiv. WFE)



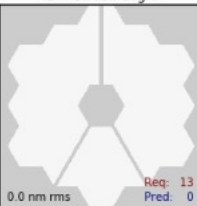
ISIM+SI total



NIRCam internal WFE at NRCA3, (1024, 0)



ISIM struct. align.

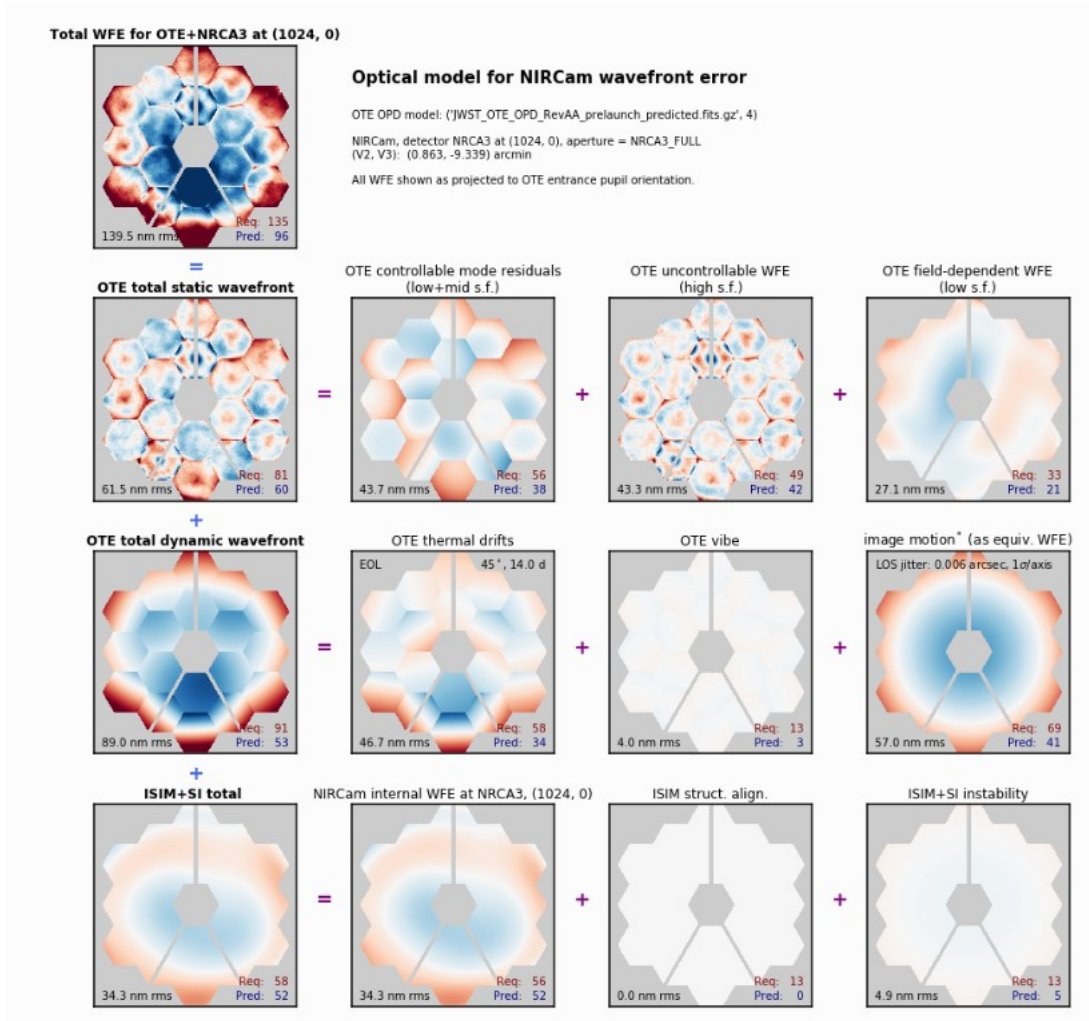


ISIM+SI instability



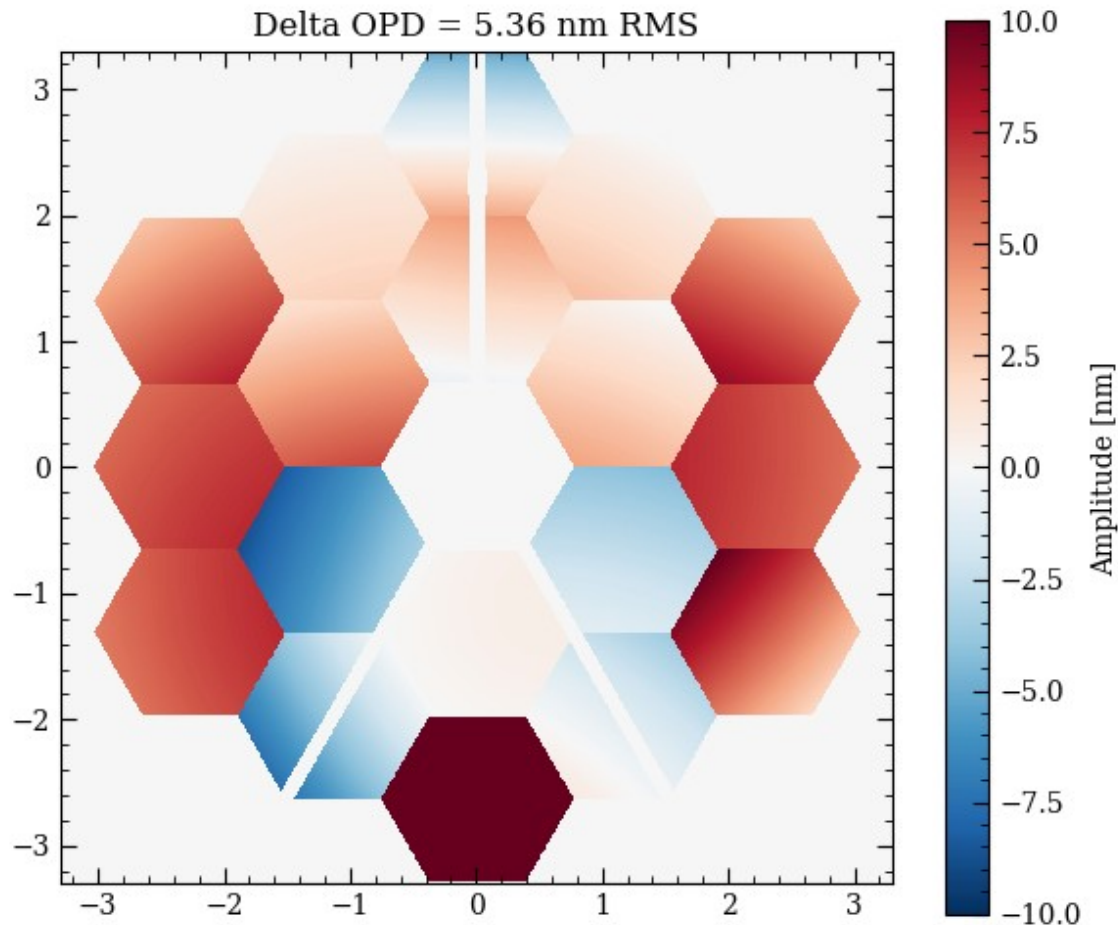
What makes up WFE?

- High frequency errors are static
- Low frequency errors are expected to be small + well understood
- WFE drift appears to be segment specific



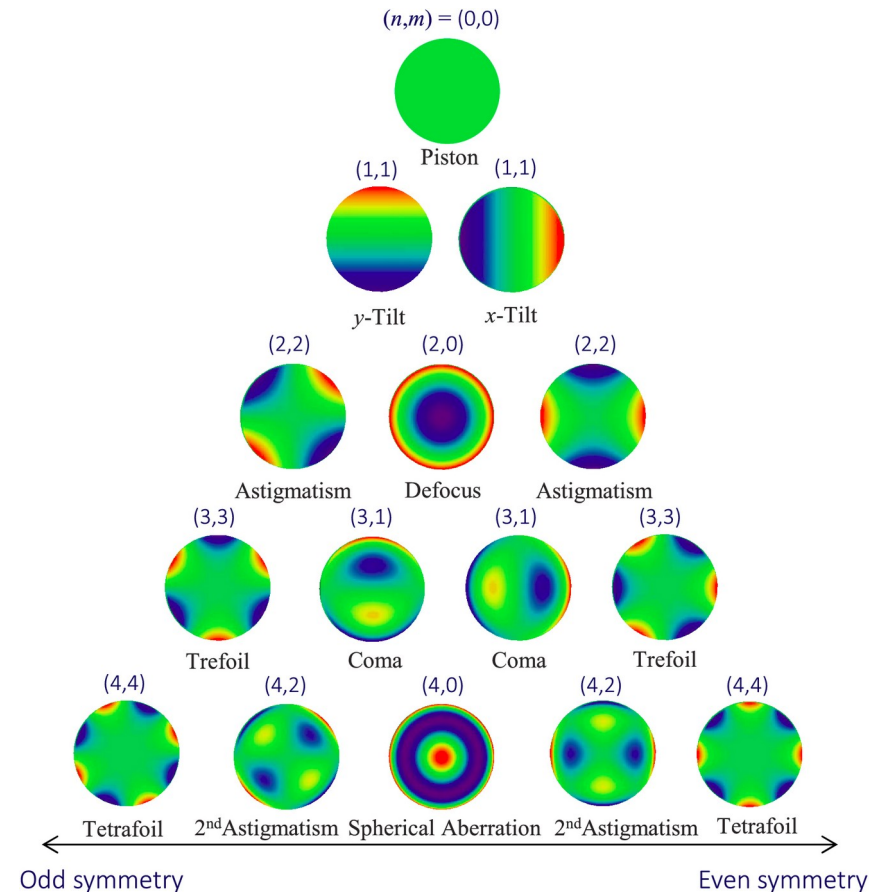
What makes up WFE?

- WFE drift appears to be segment specific
- Figure shows Δ WFE over 30 hrs w/40 degree pitch angle motion



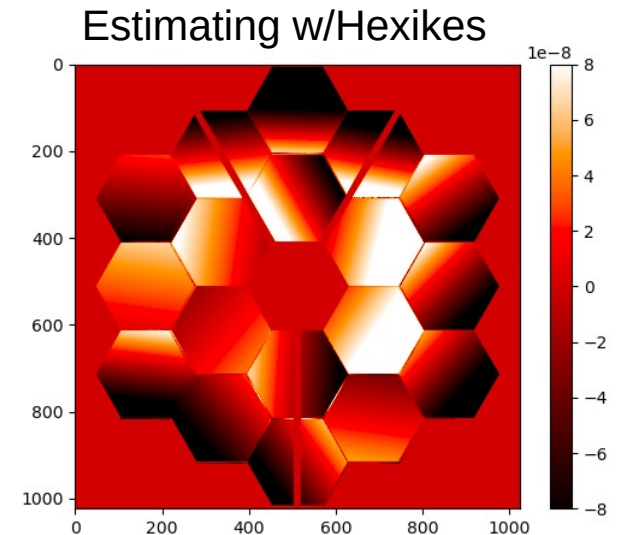
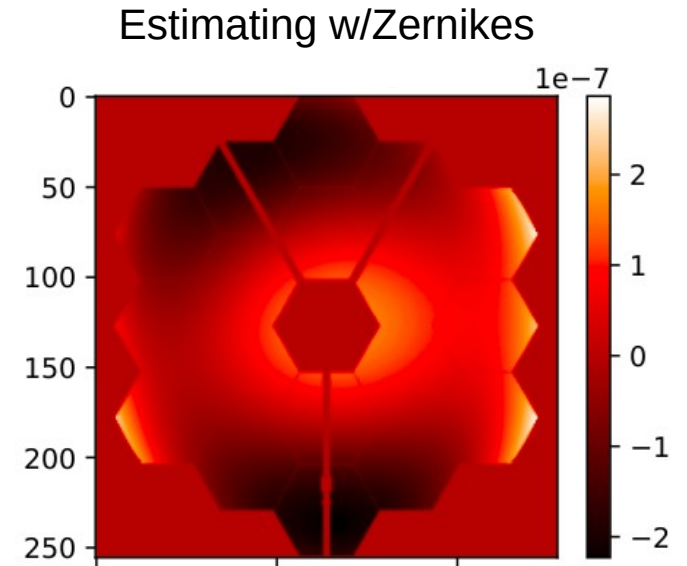
Estimating WFE

- WebbPSF/Poppy model optical system of JWST
- Use Zernike/Hexike basis to reconstruct image
- Zernike basis addresses global WFE
- Hexike basis is same as Zernike but specific to each hexagonal segment



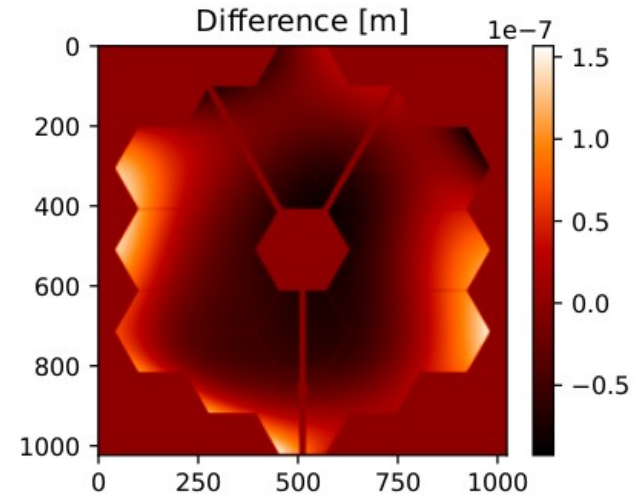
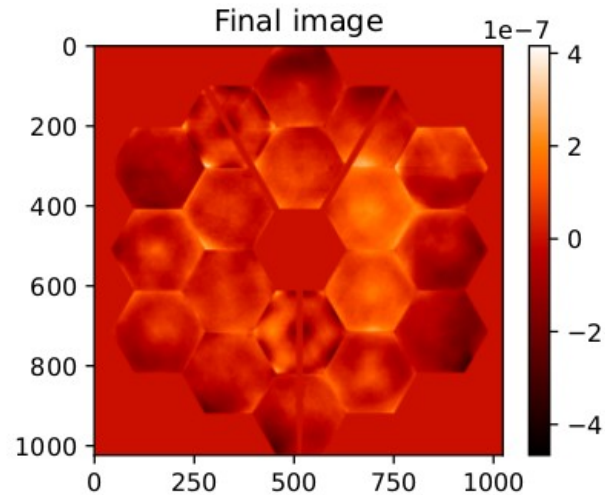
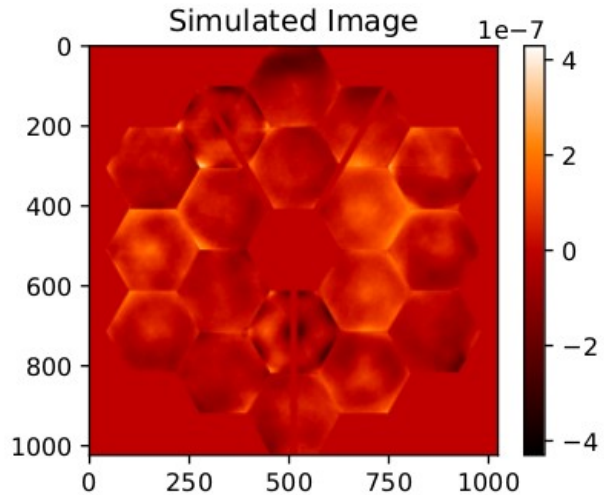
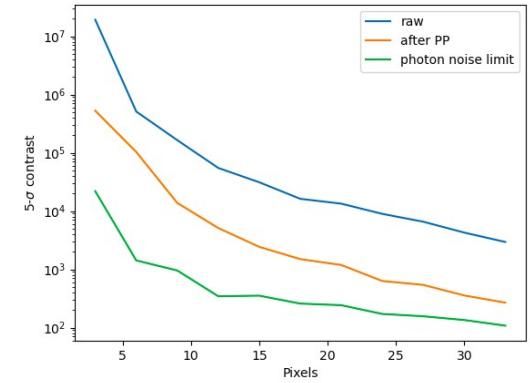
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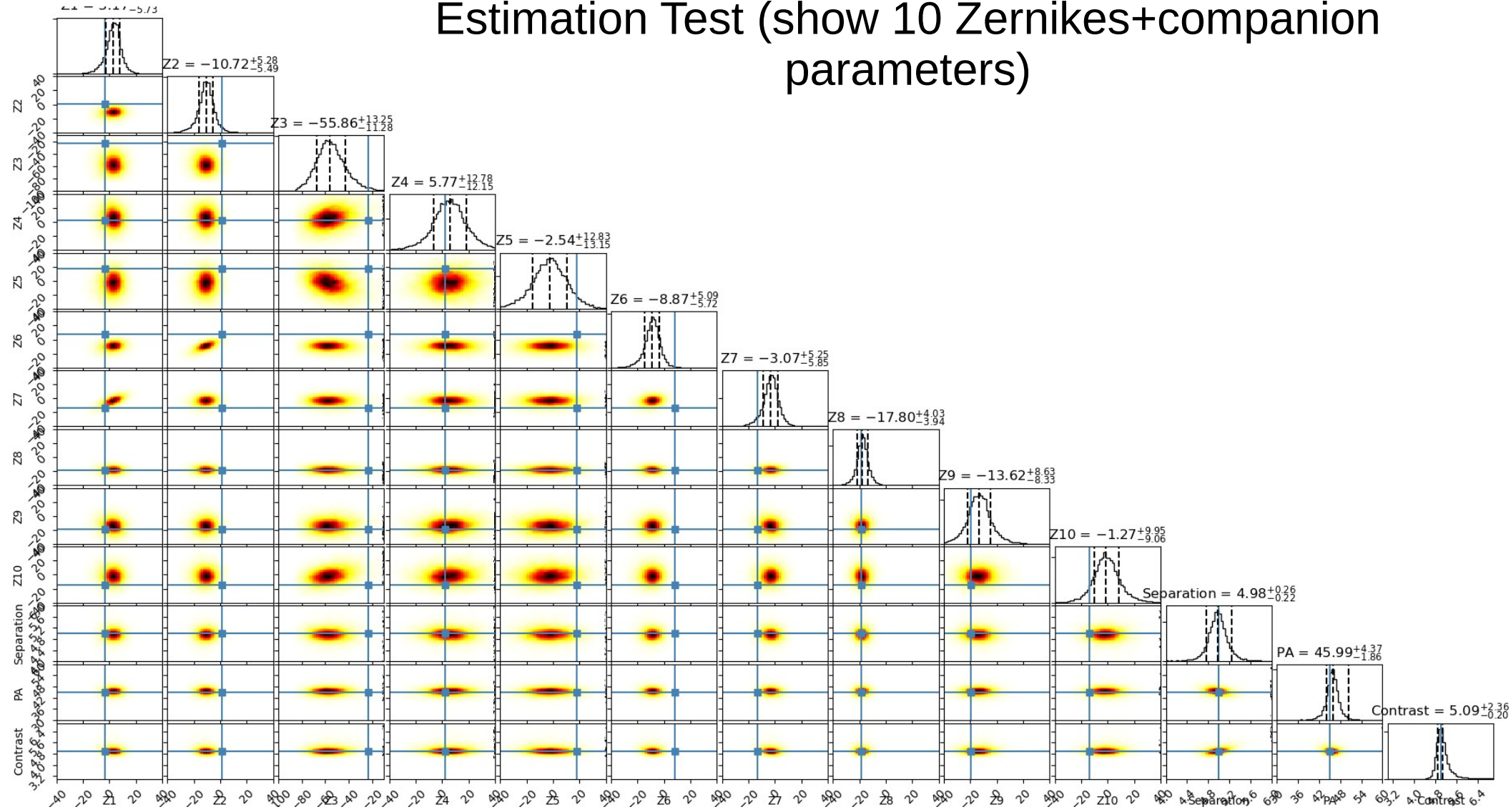


Zernike Basis – Full Pupil Imaging

- Simulate image with OTE + SI WFE and photon noise
- Fit 20 Zernike coefficients + scene parameters (position and flux of primary and companion)

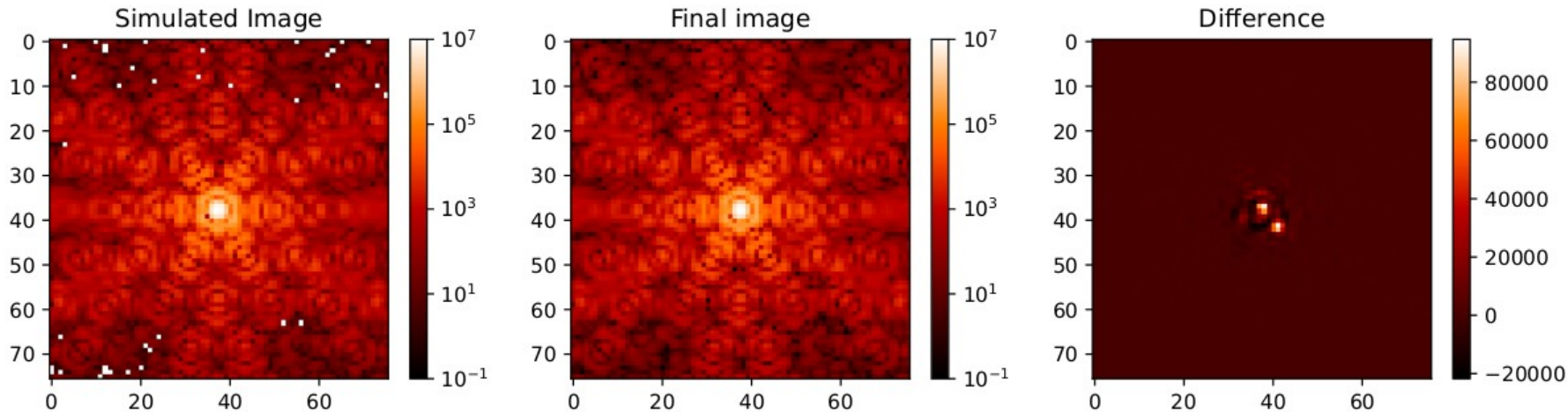


Estimation Test (show 10 Zernikes+companion parameters)

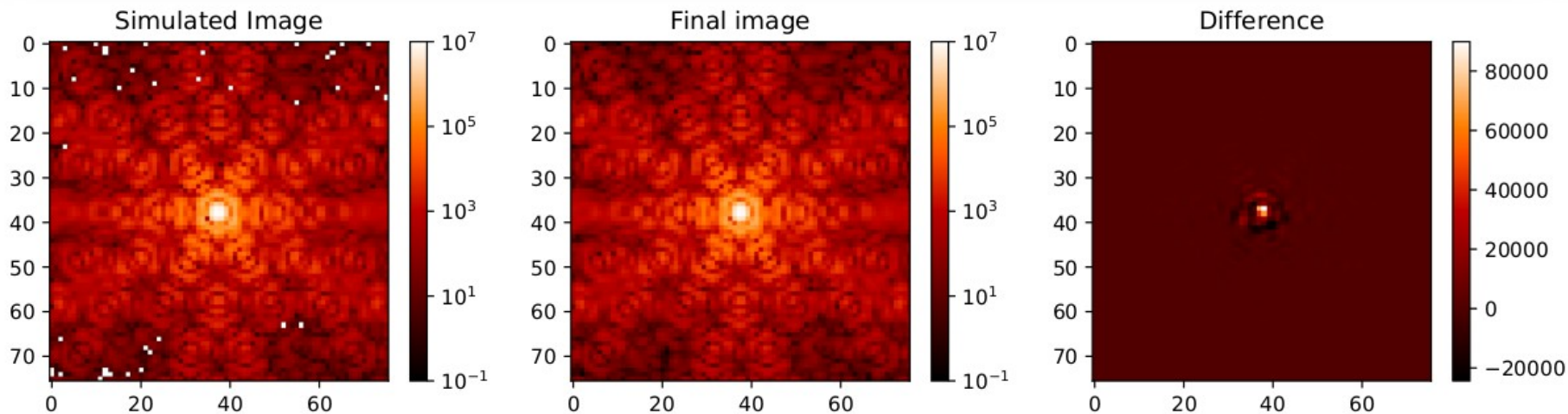


How well does it work?

Removing Primary

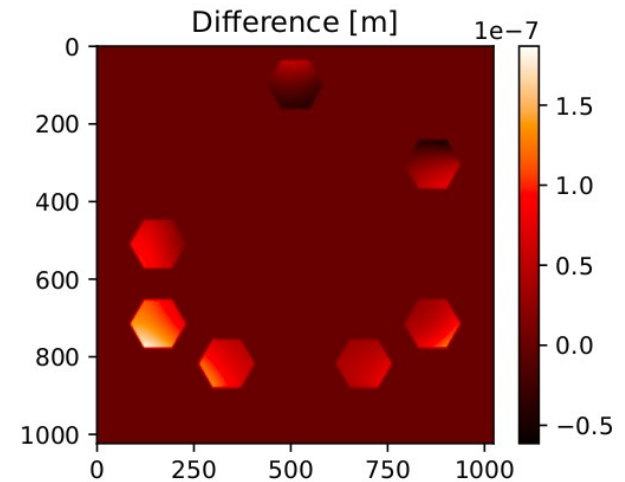
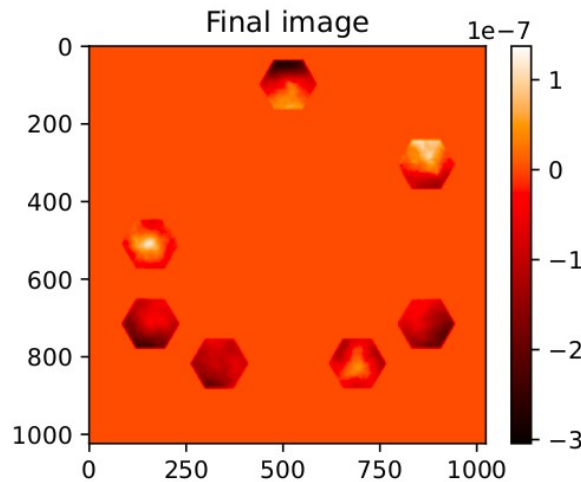
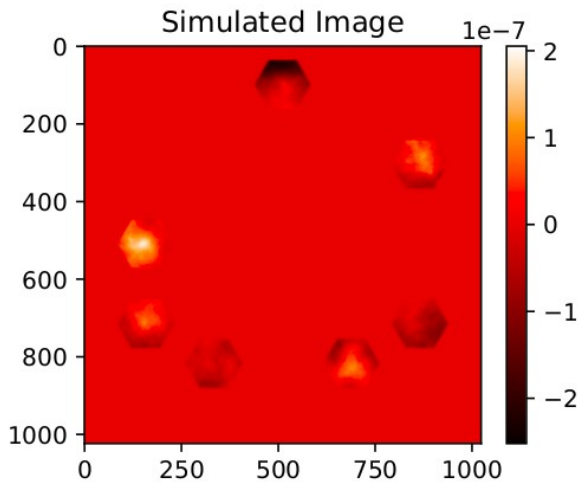
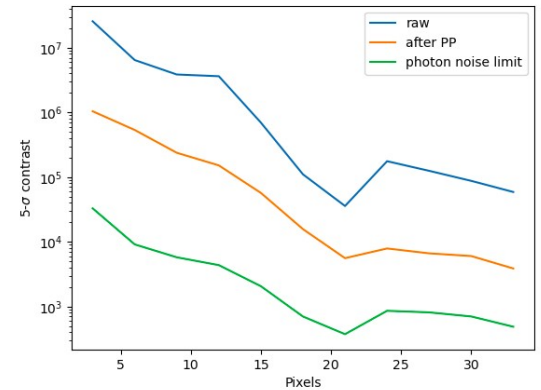


Removing Primary and Companion



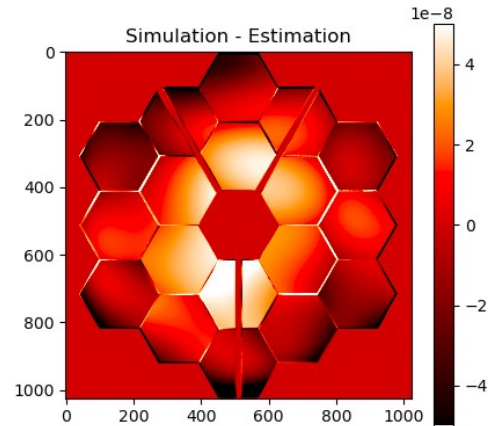
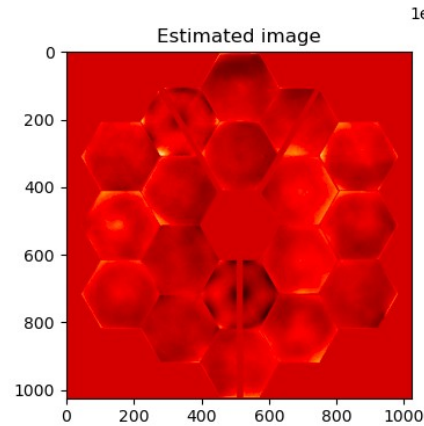
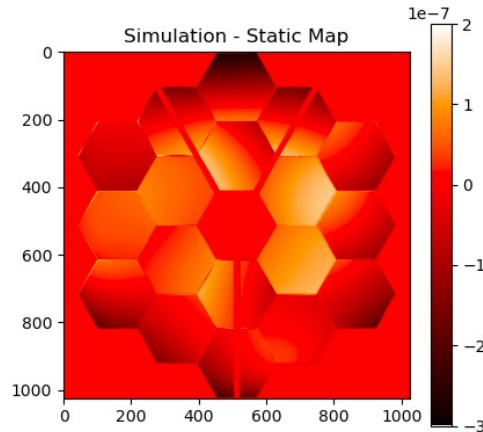
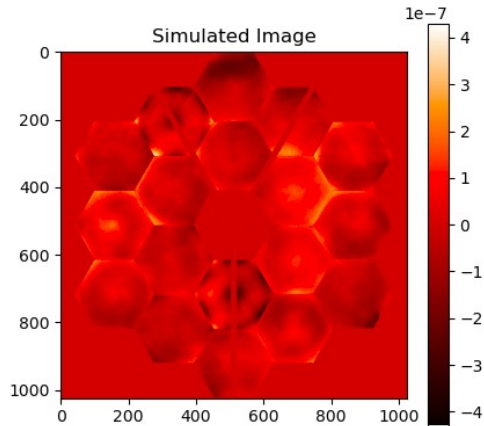
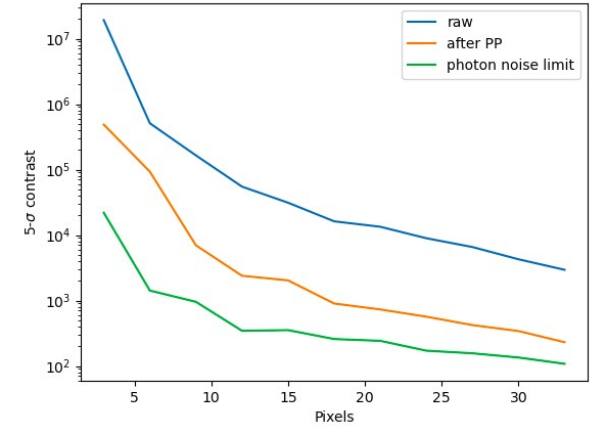
Zernike Basis – AMI Imaging

- Simulate image with OTE + SI WFE and photon noise
- Fit 20 Zernike coefficients + scene parameters (position and flux of primary and companion)

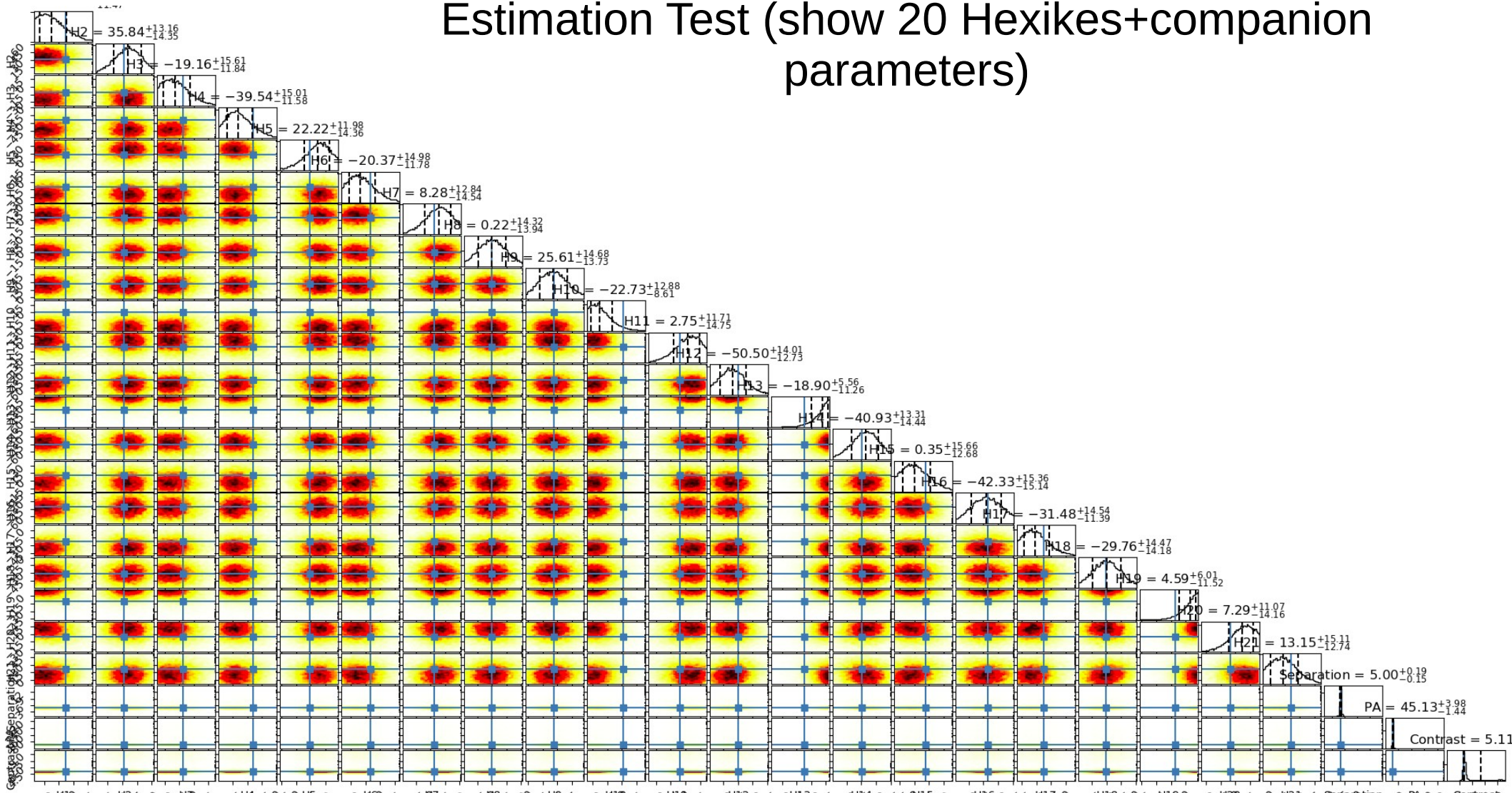


Hexike Basis – Full Pupil Imaging

- Fit three Hexikes per segment: Piston+tip+tilt



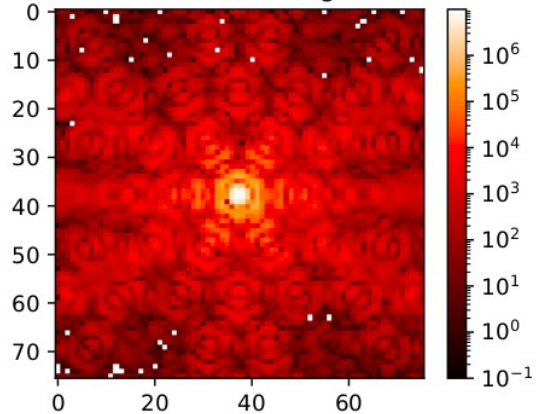
Estimation Test (show 20 Hexikes+companion parameters)



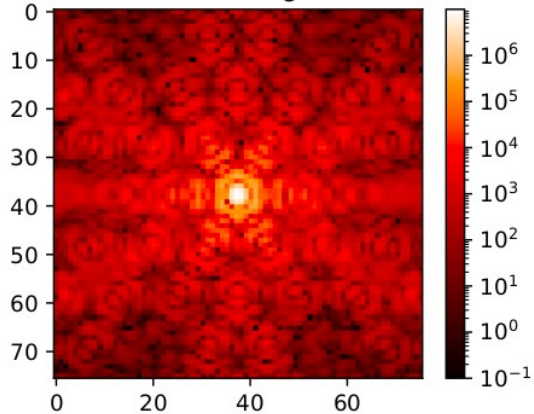
How well does it work?

Removing Primary

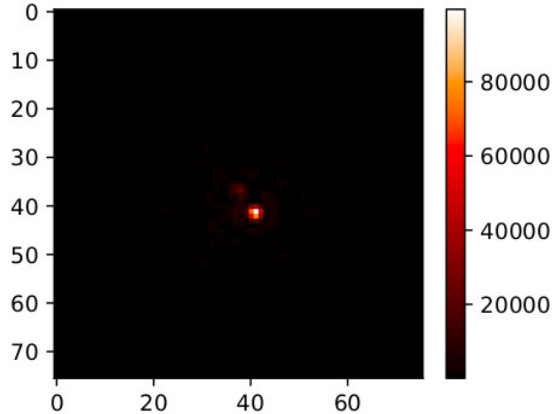
Simulated Image



Final image

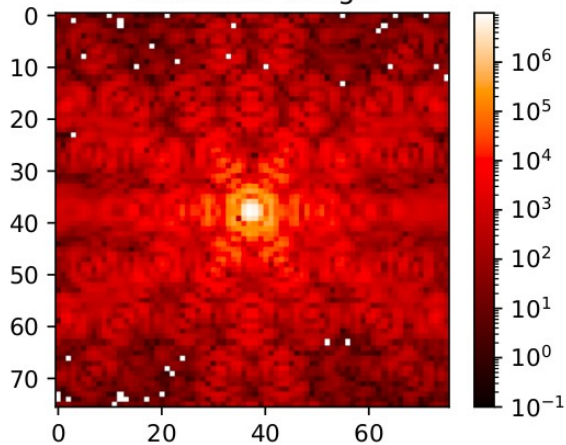


Difference

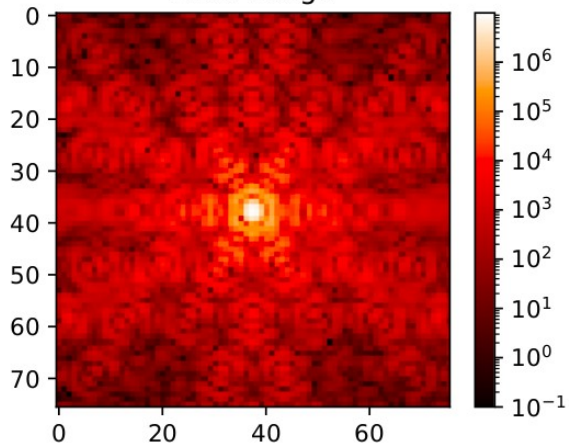


Removing Primary and Companion

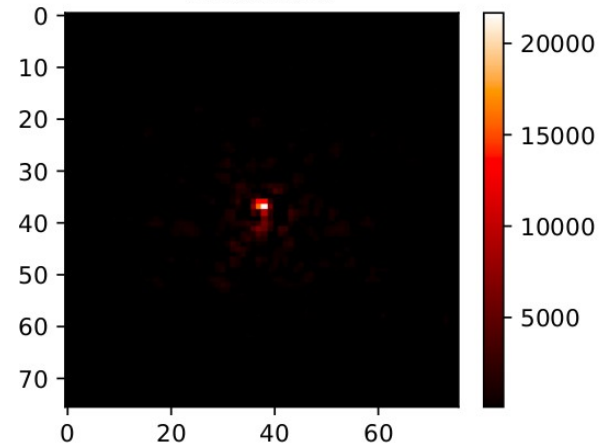
Simulated Image



Final image

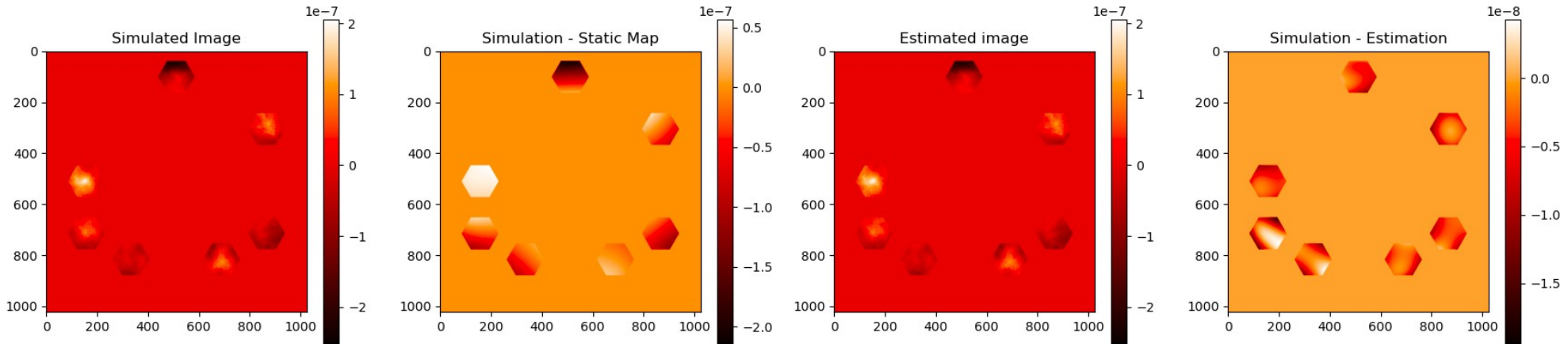
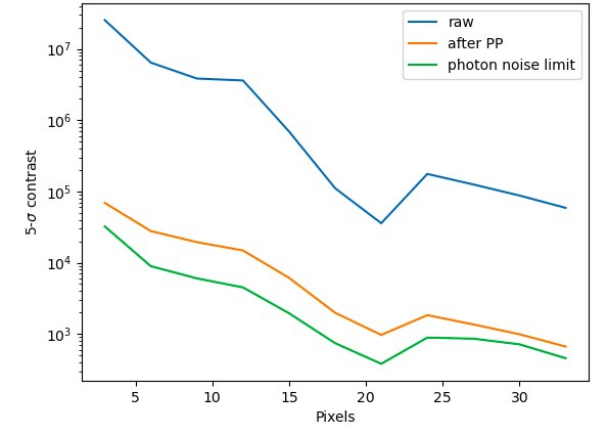


Difference

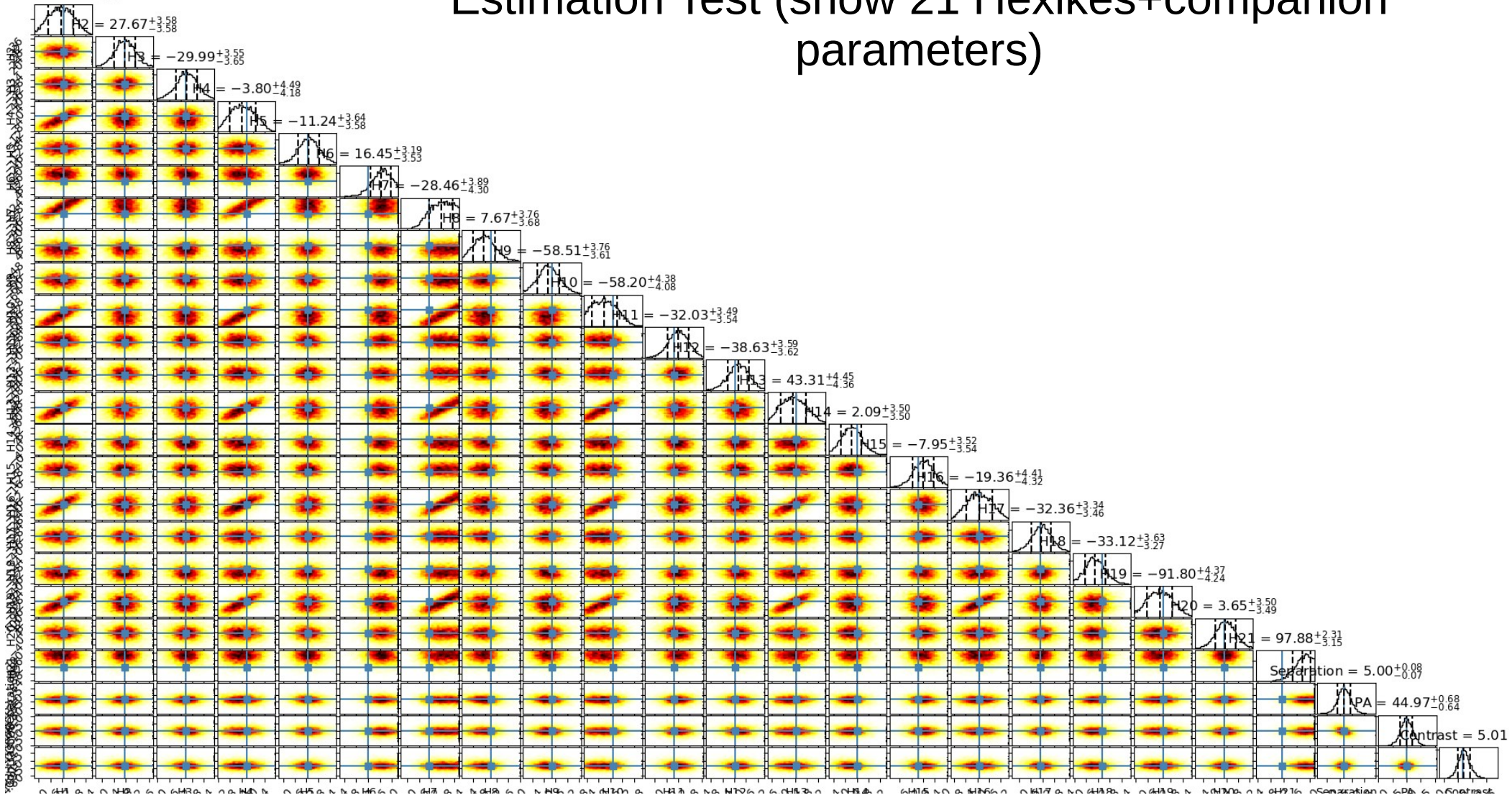


Hexike Basis – AMI Imaging

- Fit three Hexikes per segment:
Piston+tip+tilt

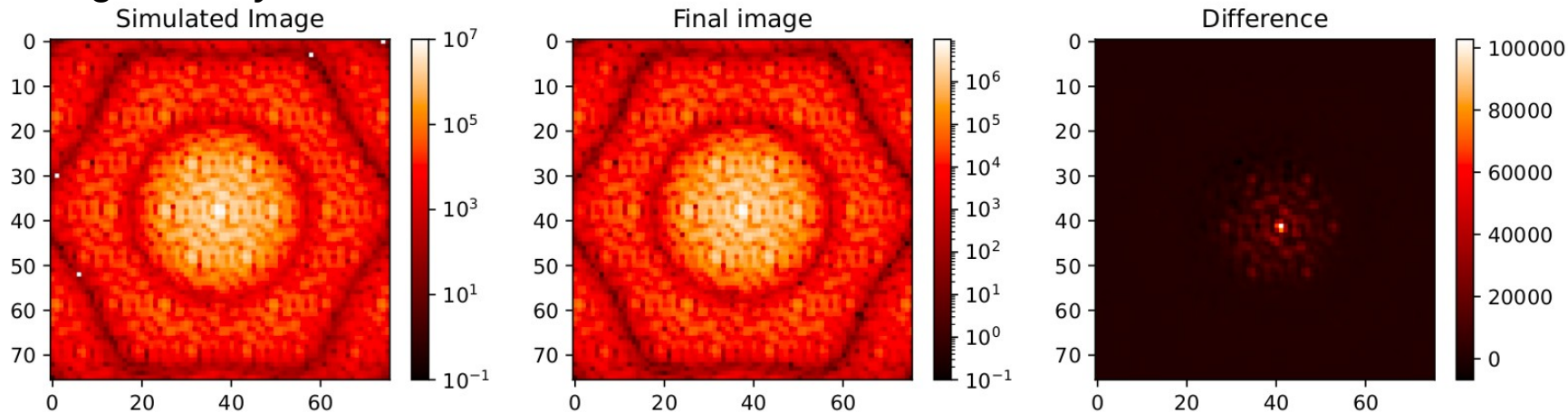


Estimation Test (show 21 Hexikes+companion parameters)

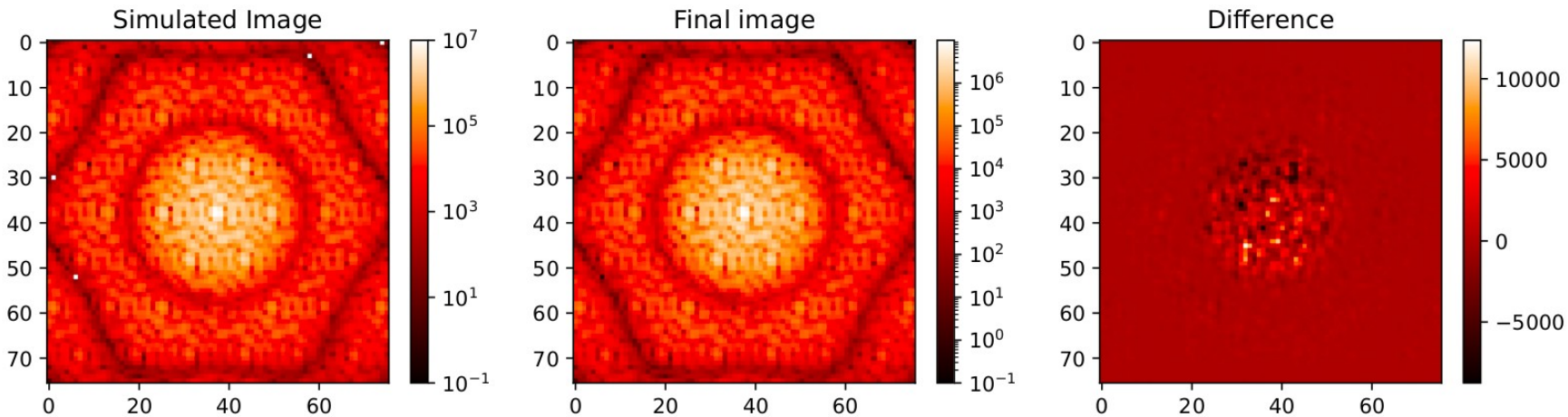


How well does it work?

Removing Primary



Removing Primary and Companion



Summary

- Developed routine to simultaneously recover WFE and companion
- Implemented estimation routine in full pupil and AMI observing modes with a Zernike and Hexike basis
- Successfully recovered 5mag contrast companion
- Working to improve WFE recovery with combination of Zernike + Hexikes bases
- Apply technique to more realistic simulations (e.g. ami_sim)