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

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In collaboration with:
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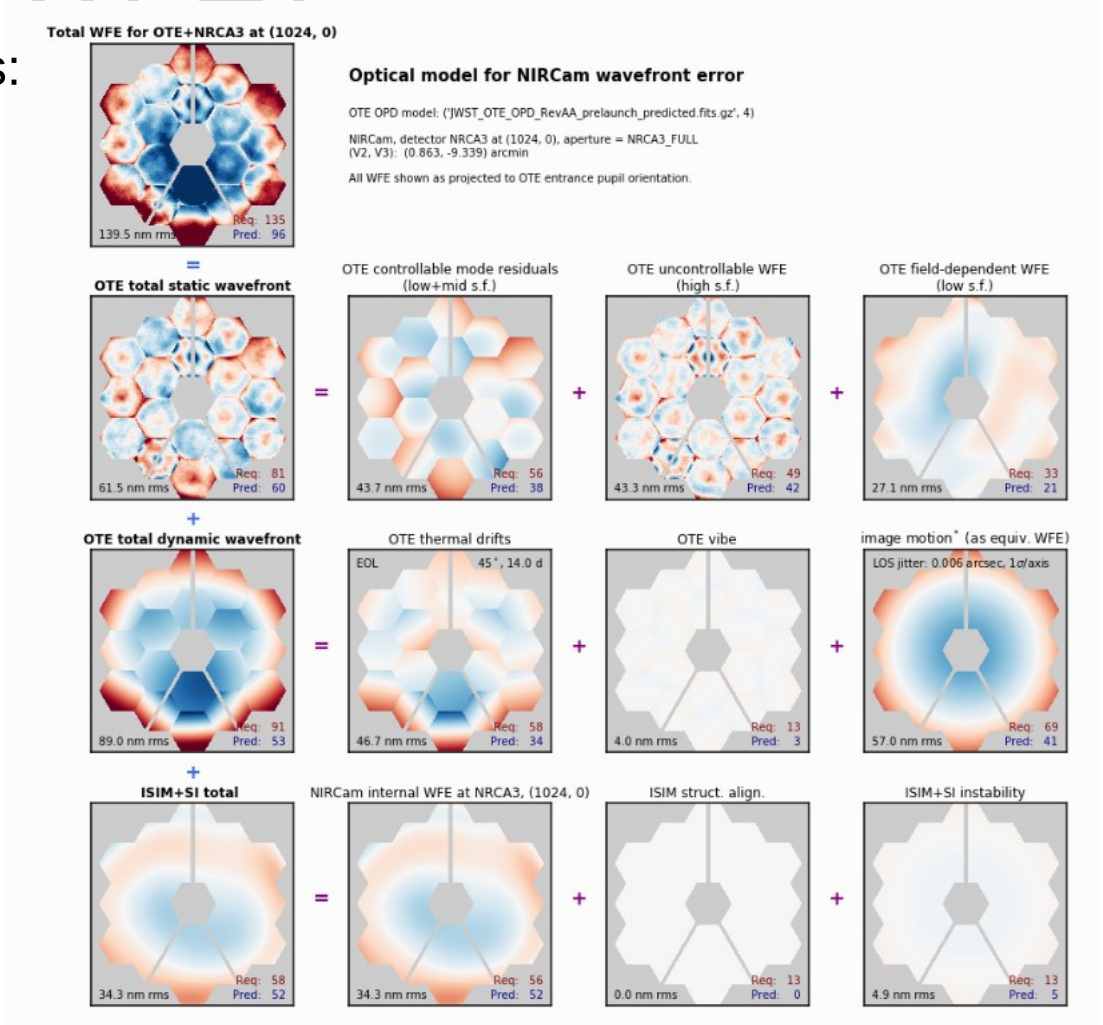
AMI + KPI Workshop
Montreal July 25-27

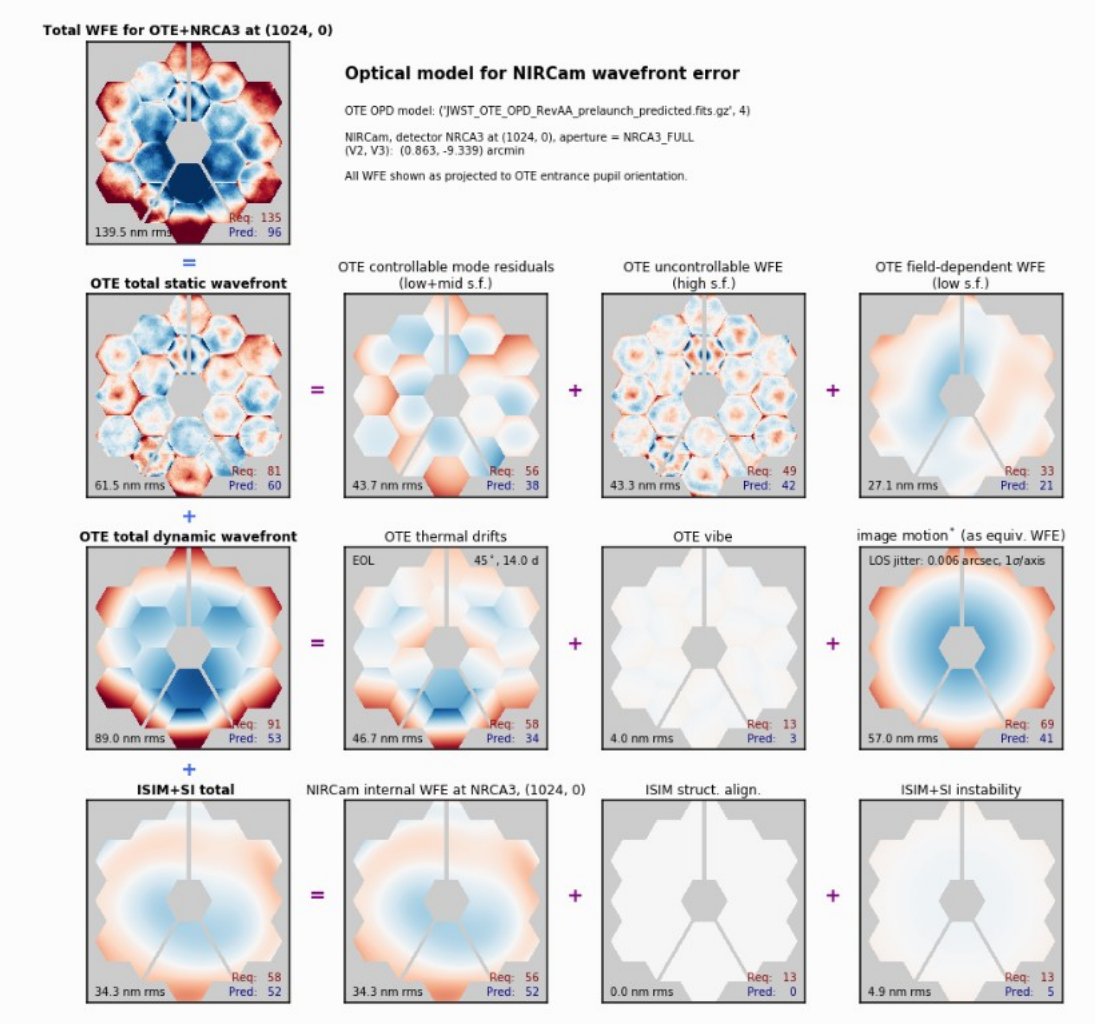
What makes up WFE?

- 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



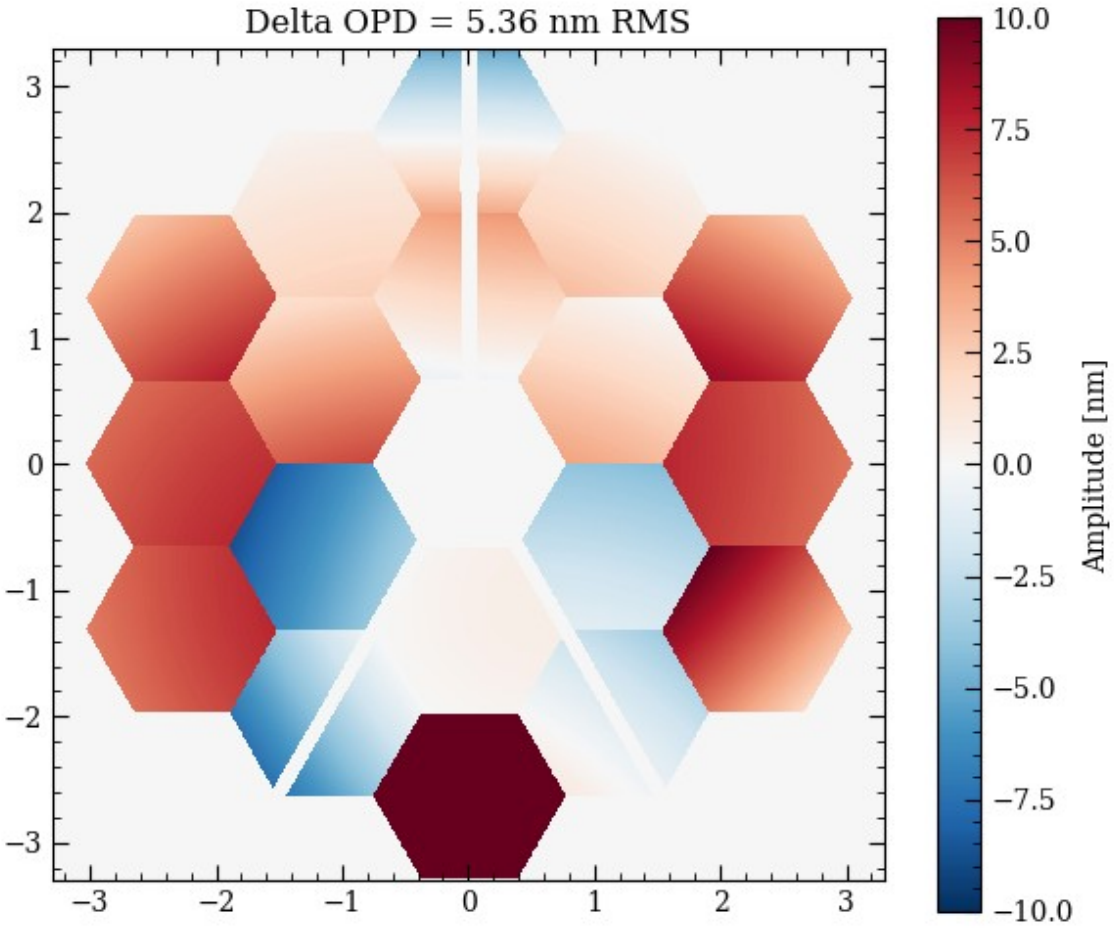
What makes up WFE?

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



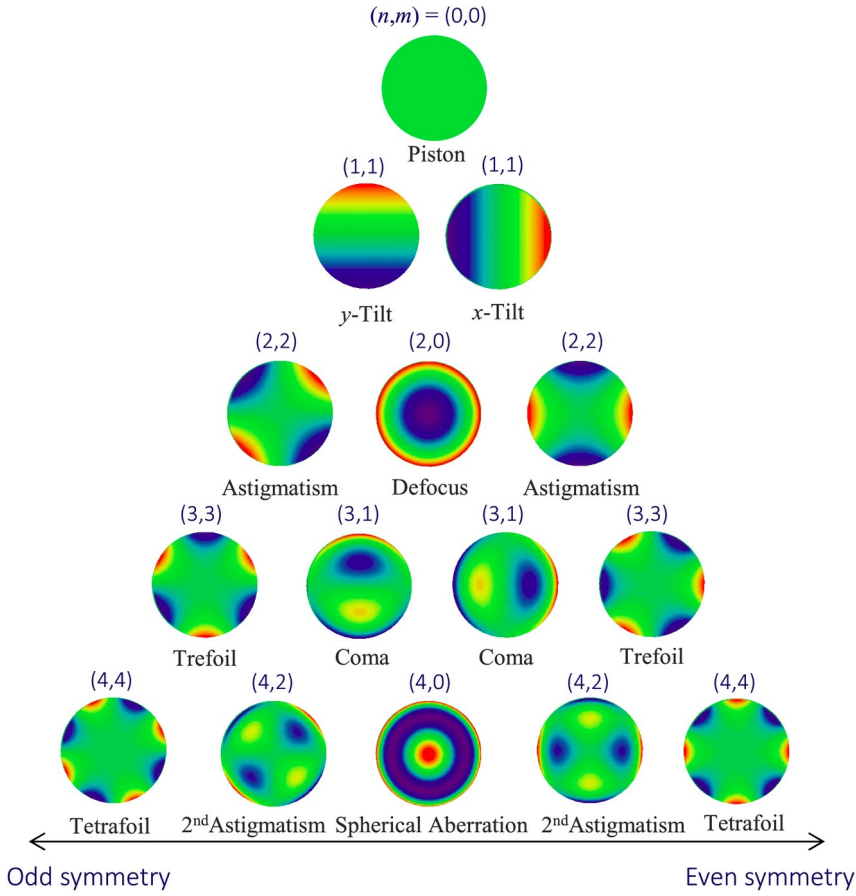
What makes up WFE?

- WFE drift appears to be segment specific
- Figure shows ΔWFE 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



Hsieh et al. (2020)

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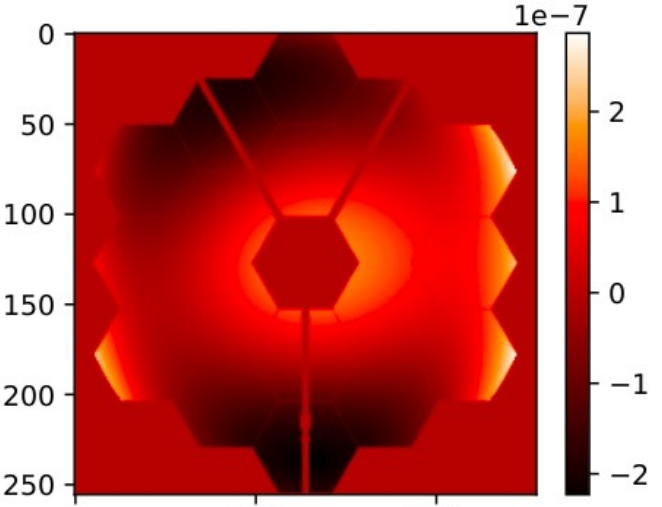
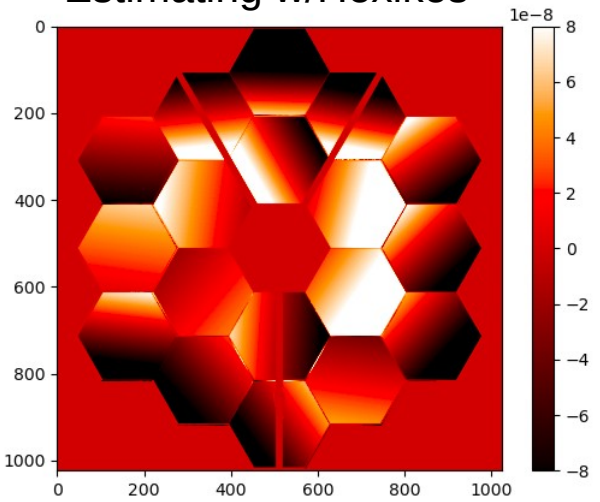
Estimating w/Zernikes

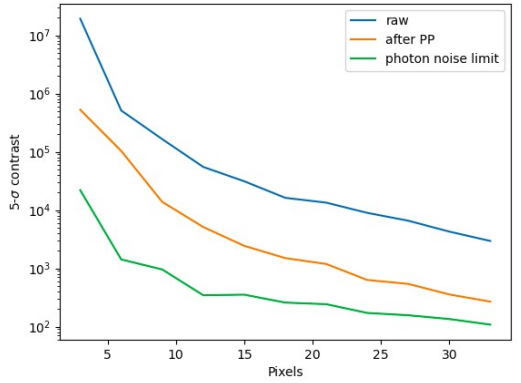


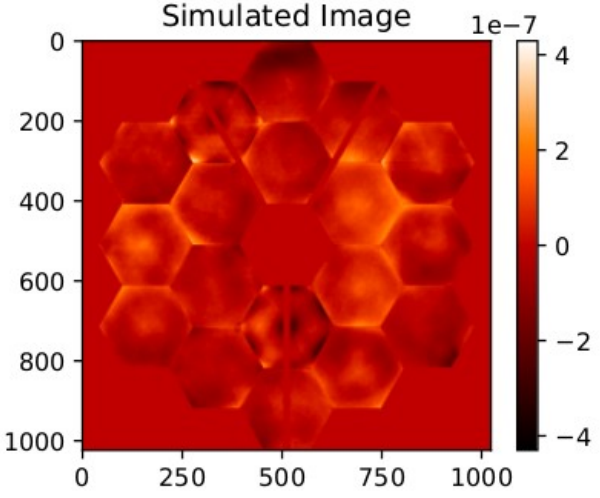
Estimating w/Hexikes

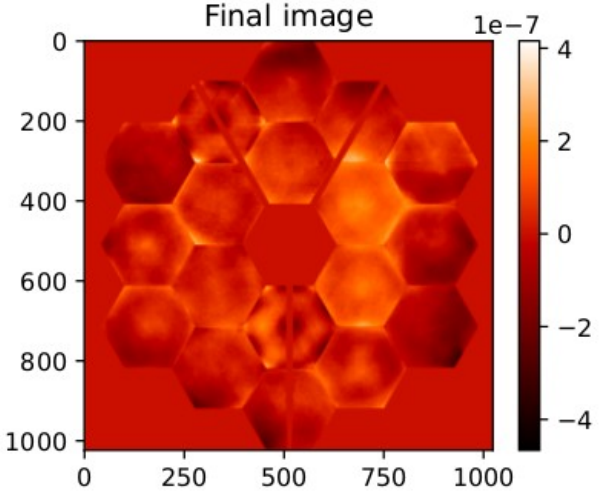


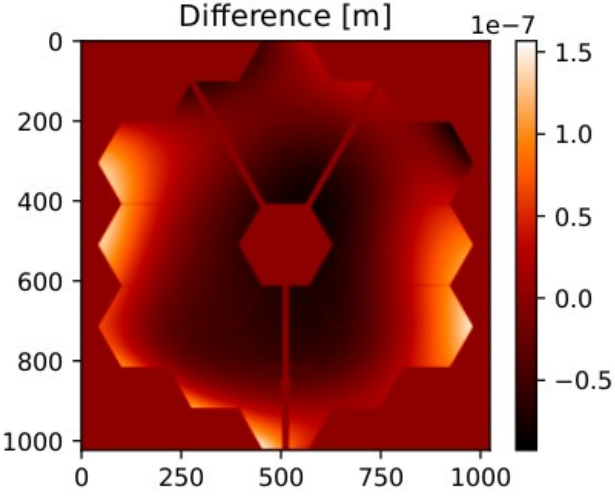
Zernike Basis – Full Pupil Imaging

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

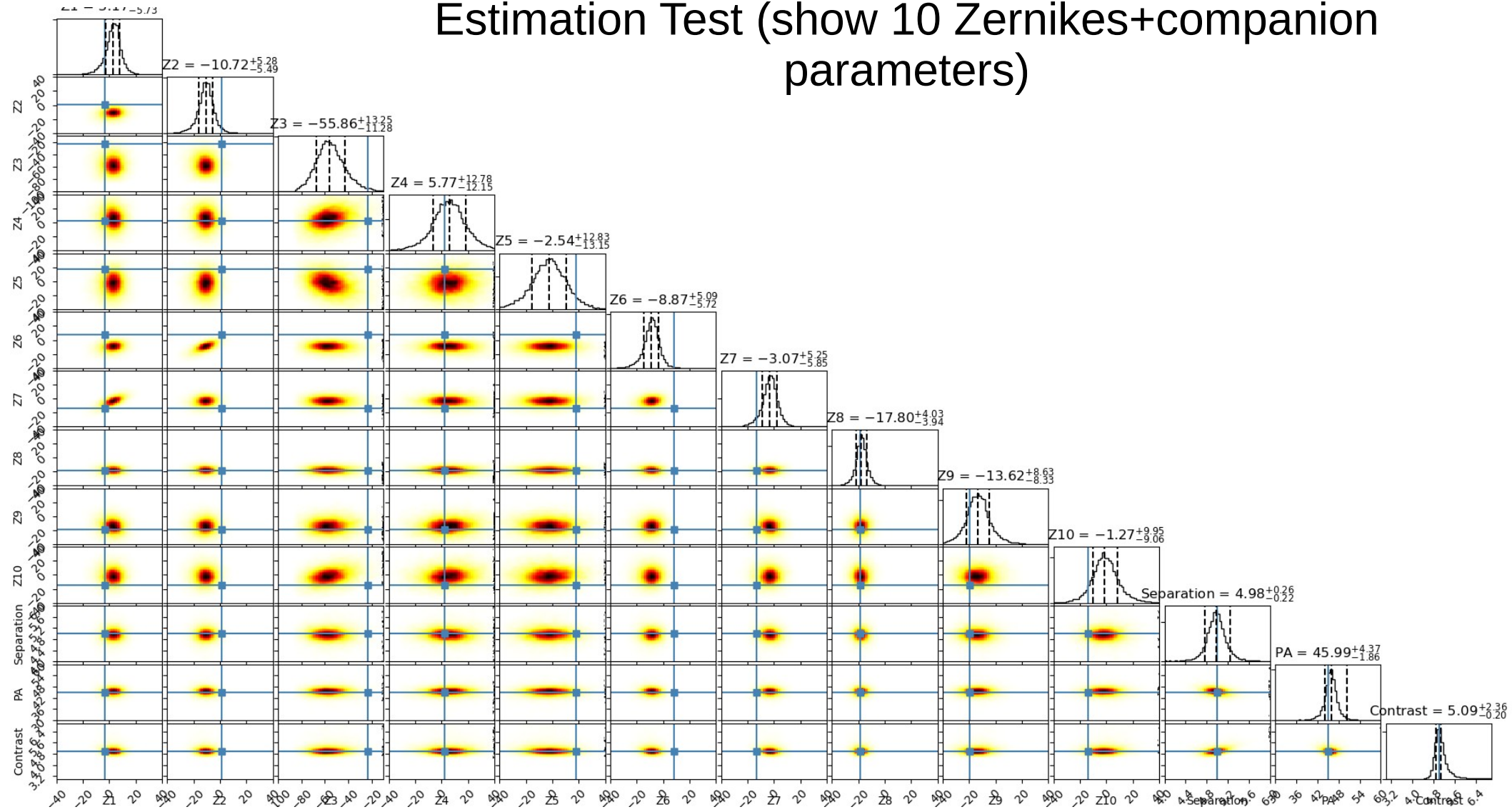






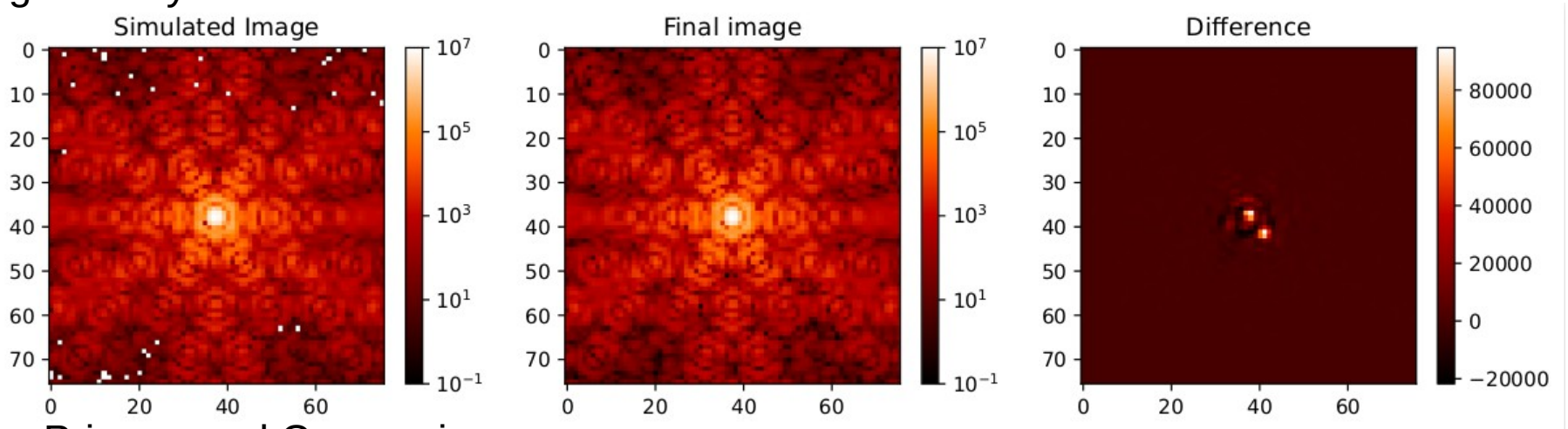


Estimation Test (show 10 Zernikes+companion parameters)

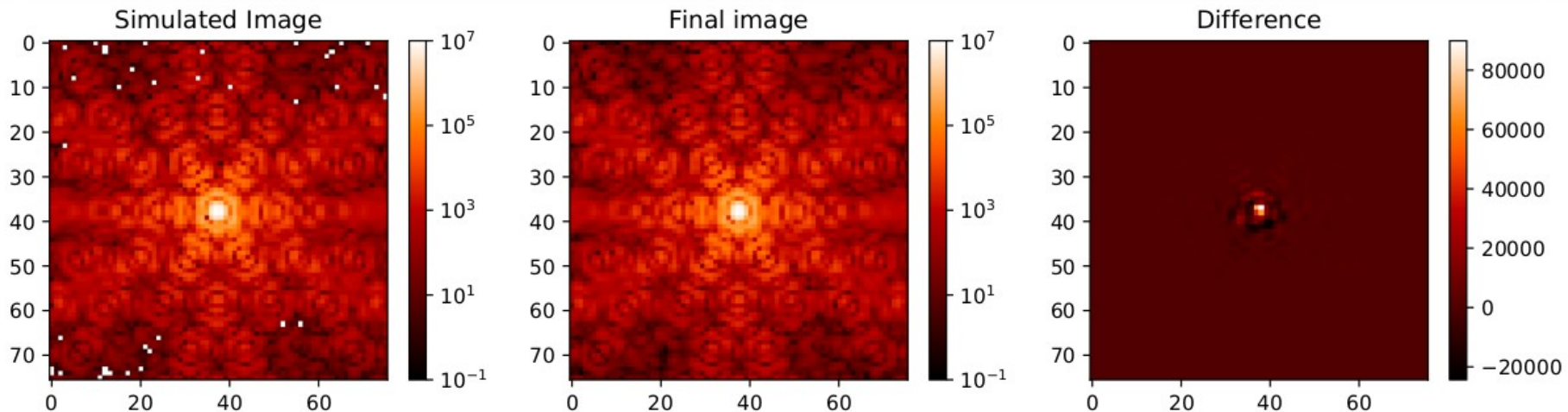


How well does it work?

Removing Primary

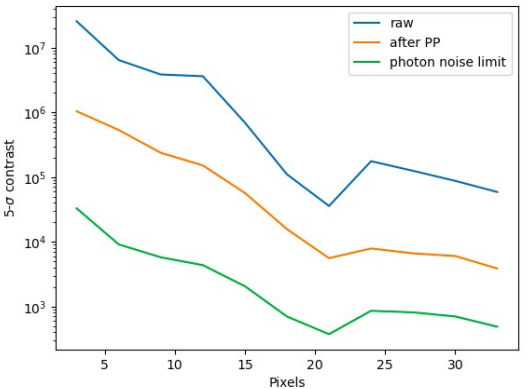


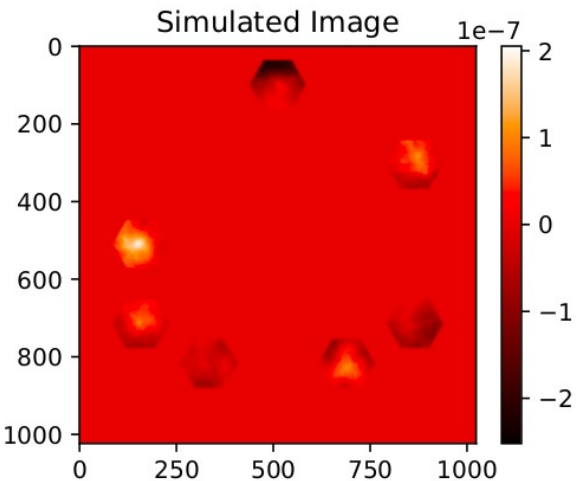
Removing Primary and Companion

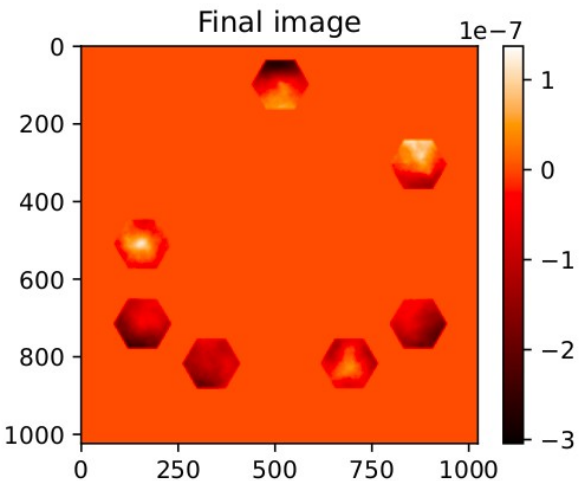


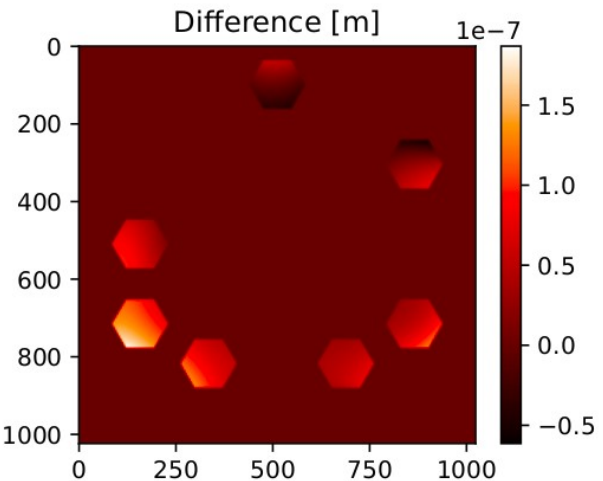
Zernike Basis – AMI Imaging

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



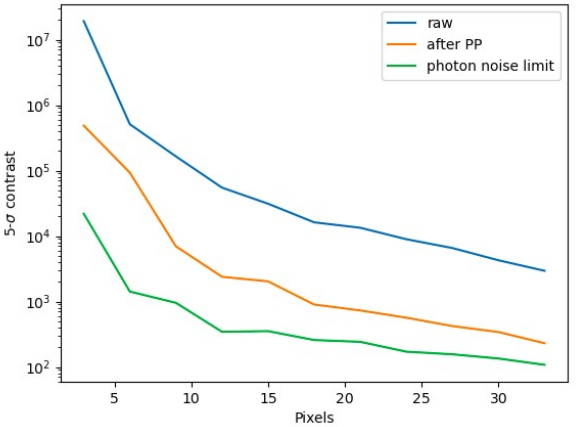


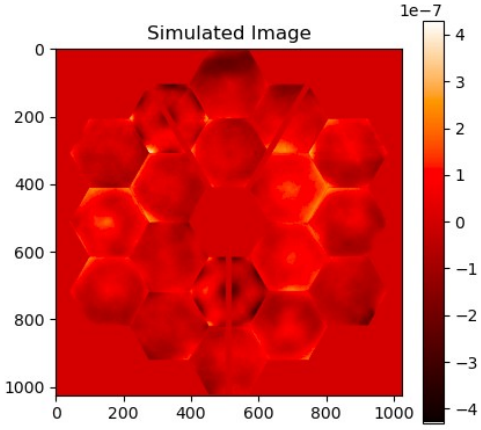


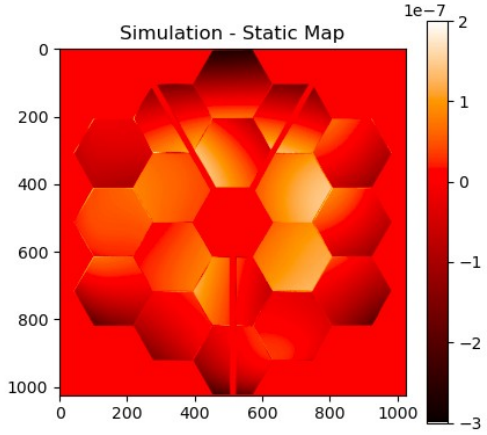


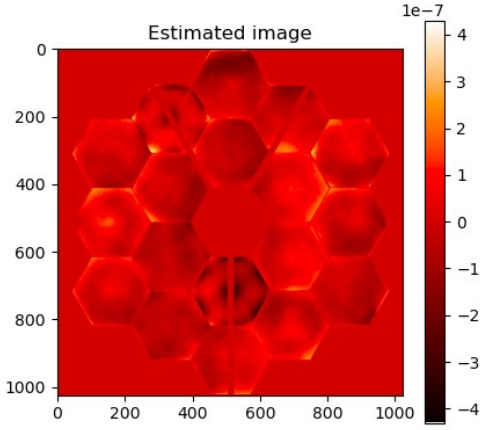
Hexike Basis – Full Pupil Imaging

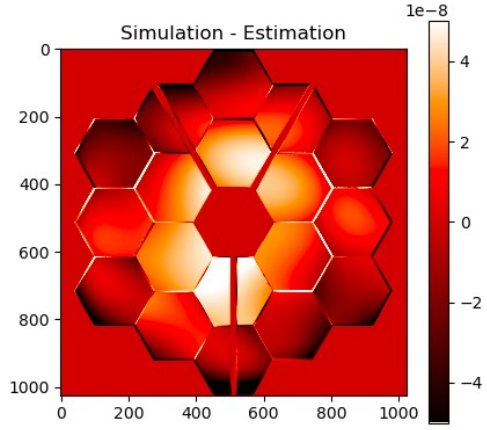
- Fit three Hexikes per segment: Piston+tip+tilt



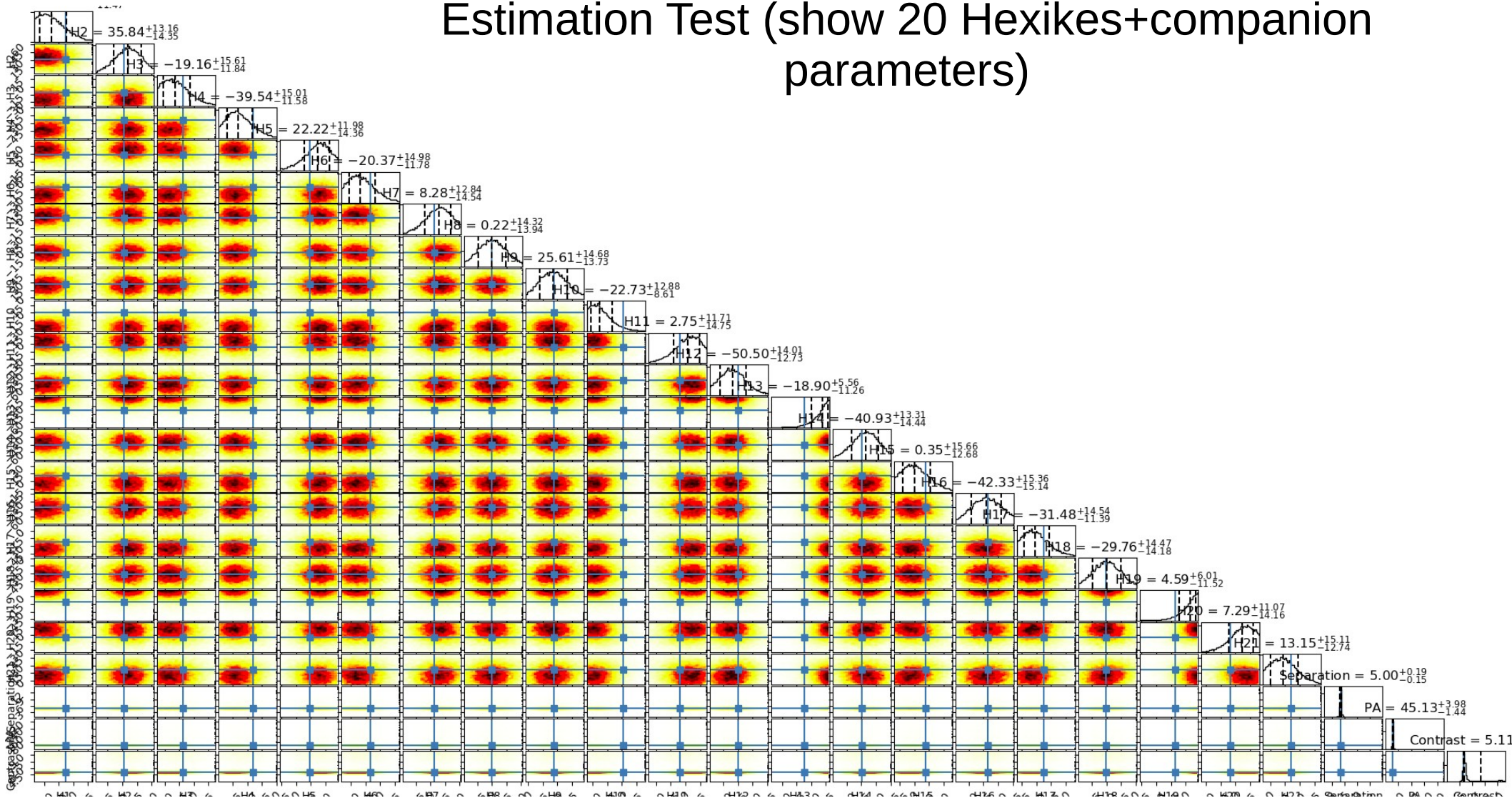








Estimation Test (show 20 Hexikes+companion parameters)



How well does it work?

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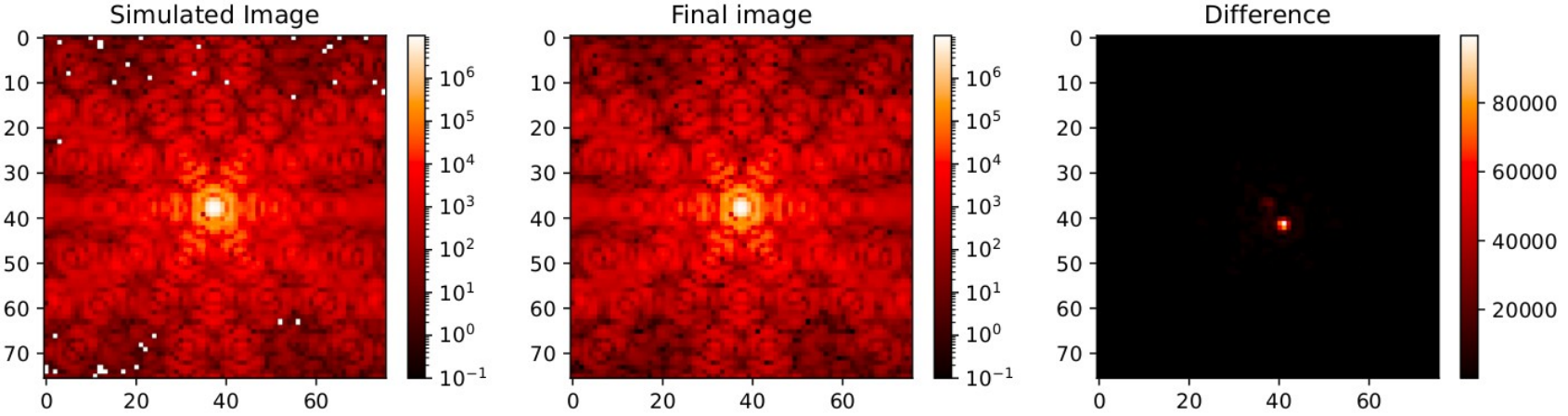
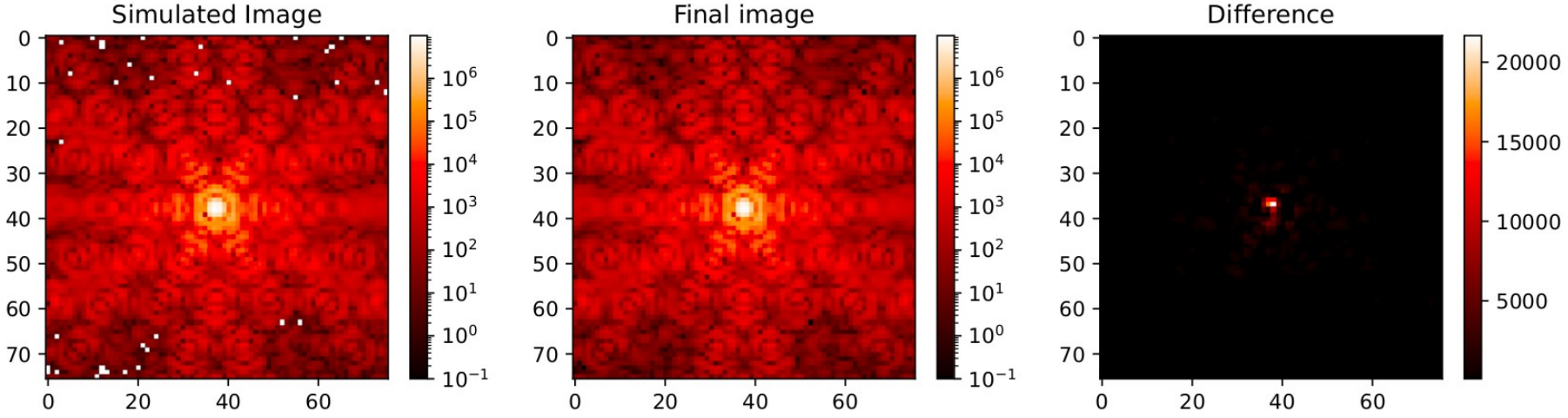
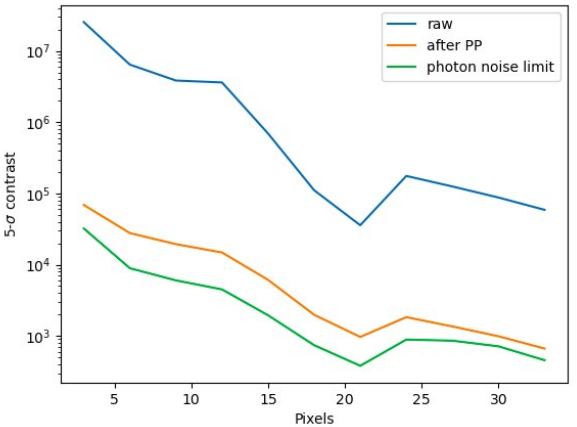


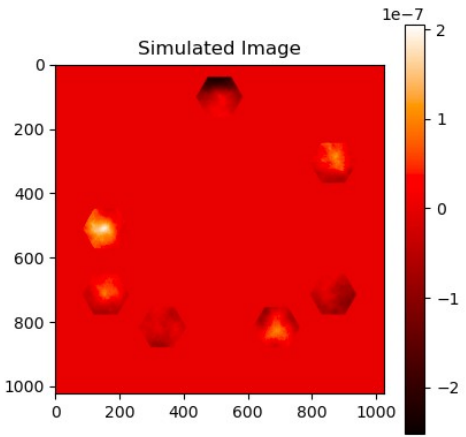
Removing Primary and Companion

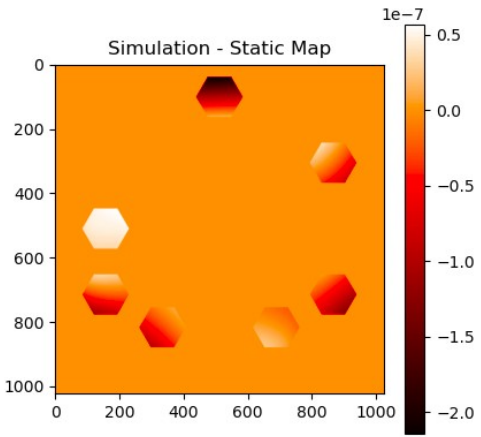


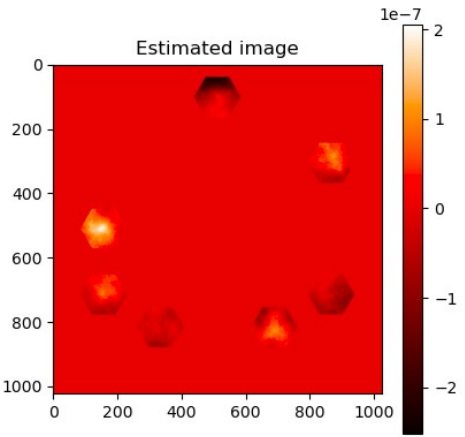
Hexike Basis – AMI Imaging

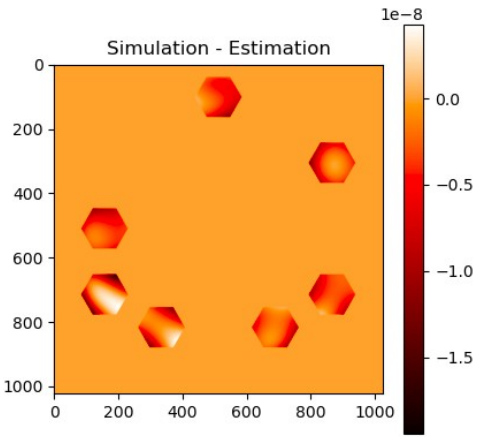
- Fit three Hexikes per segment: Piston+tip+tilt



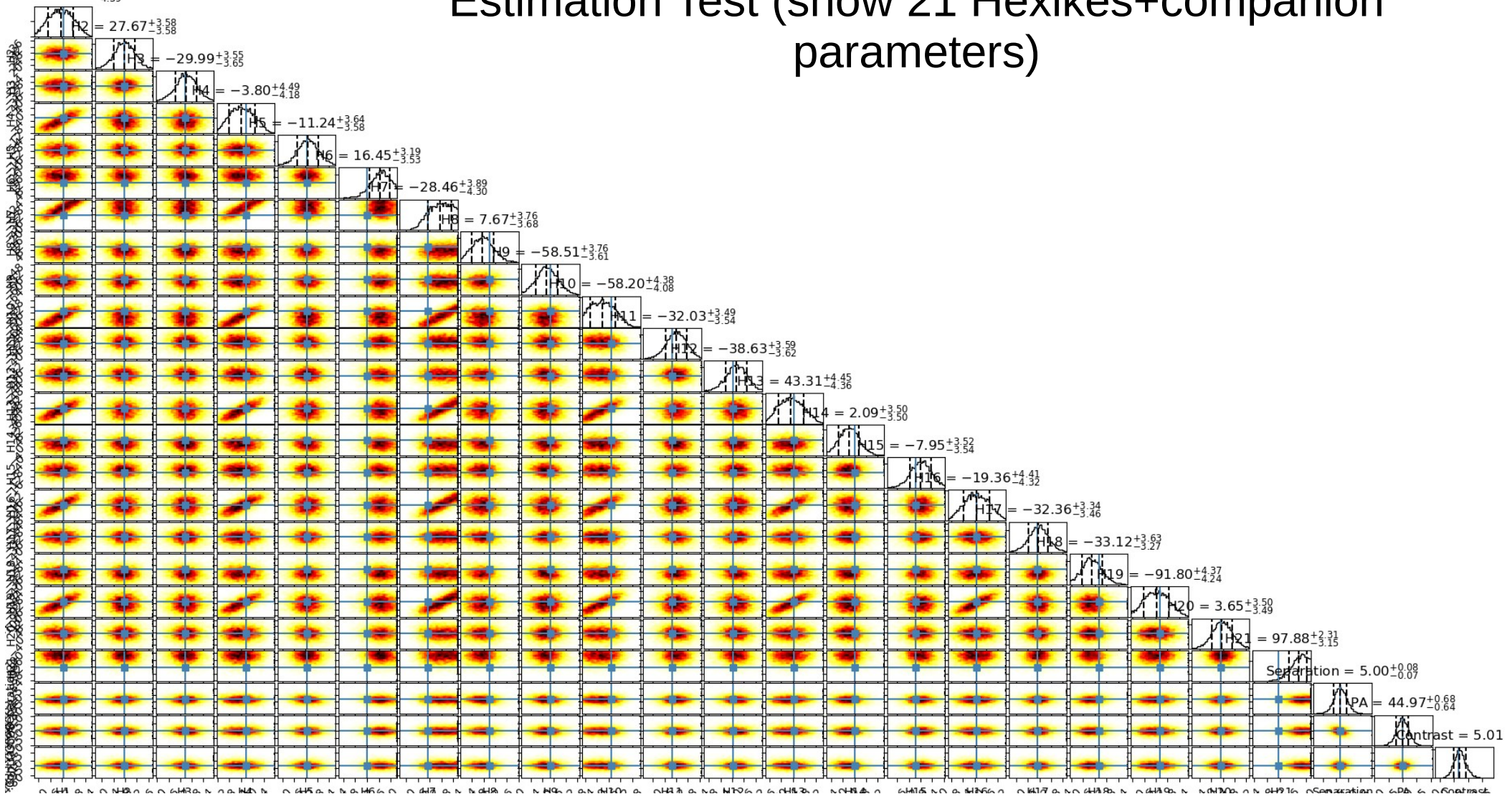








Estimation Test (show 21 Hexikes+companion parameters)



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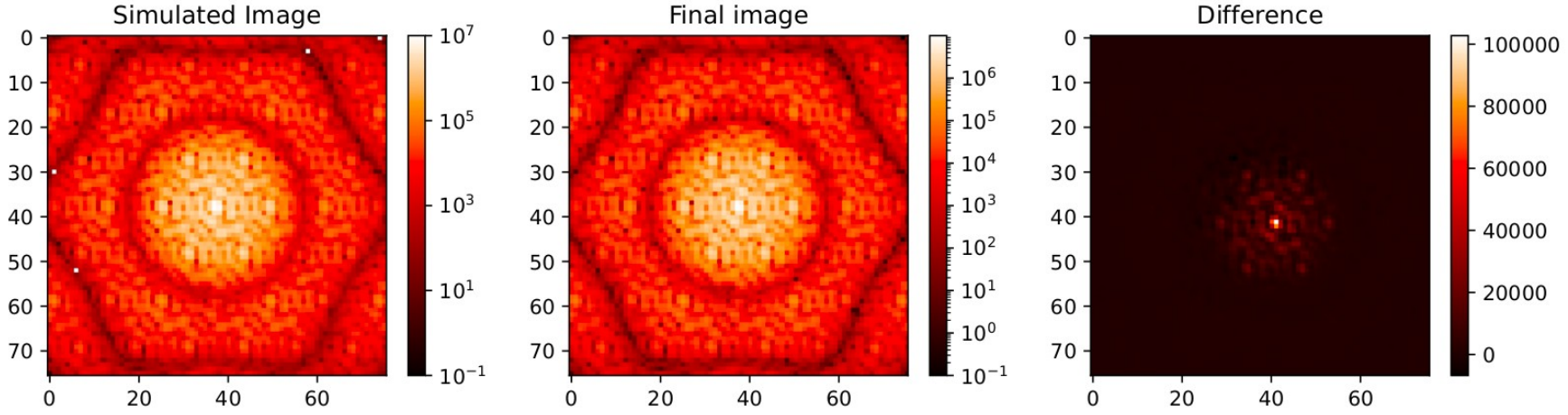

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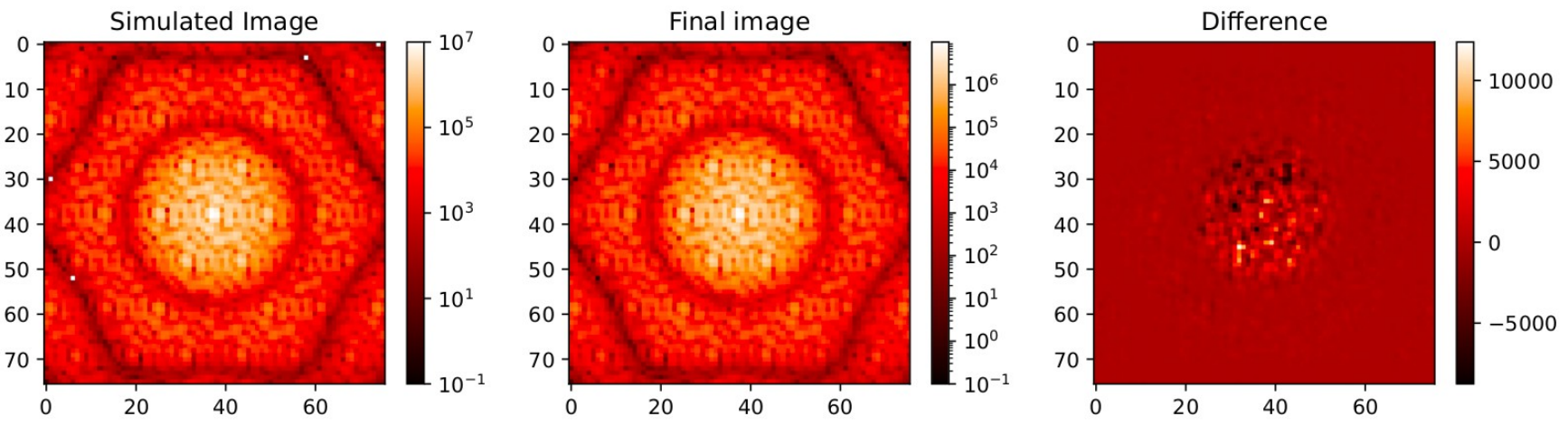

Summary

- 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)