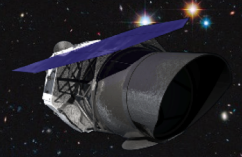


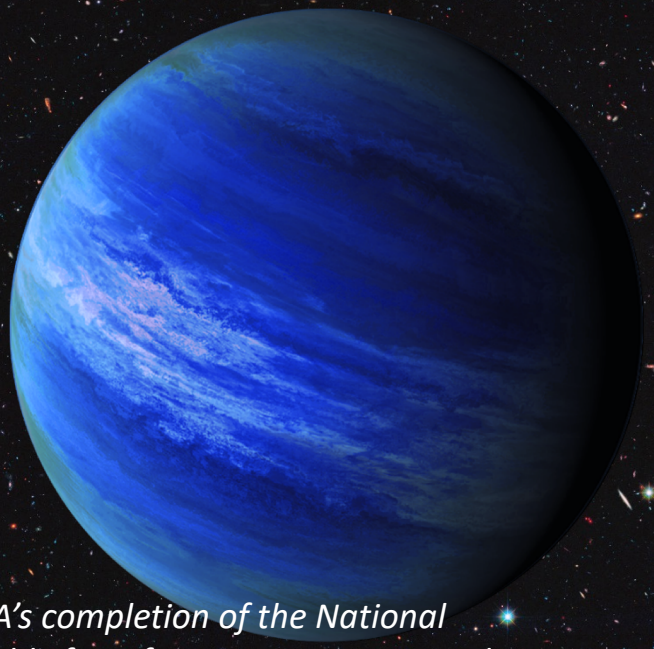
WFIRST CGI Virtual "Stanford" Meeting

Mask Design Updates

A.J. Riggs

Mask Design Lead

20 February 2019



The decision to implement the WFIRST mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

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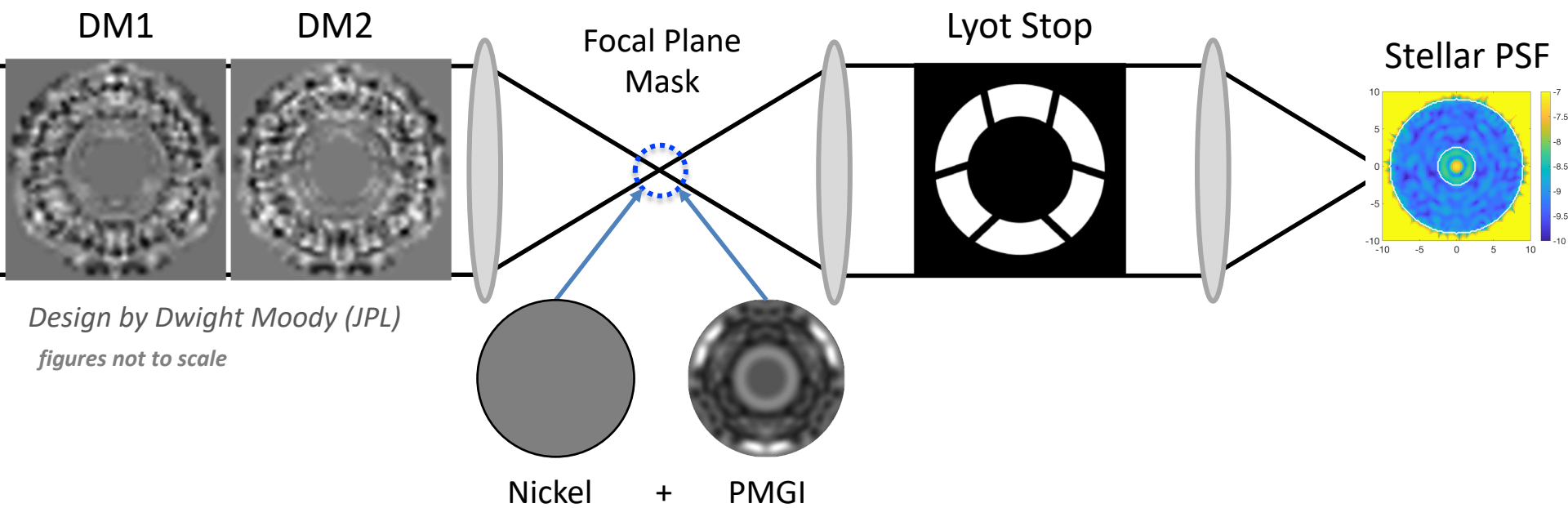
Overview

1) Recently baselined designs for Phase B

2) Same 3 coronagraph mode types as for SRR:
   a. (HLC) Narrow-FOV Imaging
   b. (SPC) Spectroscopy
   c. (SPC) Wide-FOV Imaging

3) Still researching higher performance designs

Narrow-FOV Imaging Mode: HLC-20190129



Design by Dwight Moody (JPL)

figures not to scale

- "Traditional" HLC chosen for PDR
  - Slightly better flux ratio noise (FRN)
    - 1.7 → 1.4 ppb (*req = 5.0 ppb*)
    - Lower throughput but better low-order aberration sensitivities
- Next: Lab test more advanced HLCs this summer.

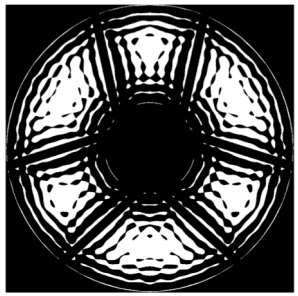
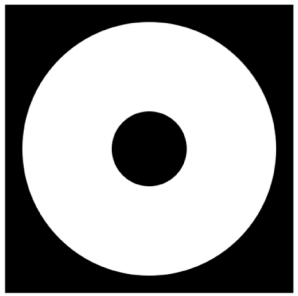
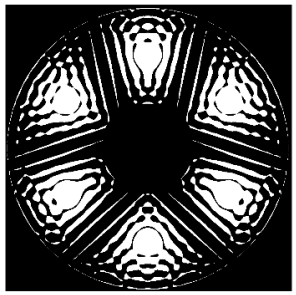
Spectroscopy Mode: SPC-20190130

	SPM	FPM	Lyot Stop	Flux Ratio Noise (FNR):	L3 Req: DNG 673799
SRR Design SPC-20170714				**2.9e-9**	
PDR Design SPC-20190130				TBR **< 2.2e-9**	

- *Traded contrast for higher throughput and sharper PSF*
- *Improved low-order aberration sensitivities algorithmically.*

- Incremental improvements from better algorithms and design trades.
  - More design trades will be possible once we streamline the evaluation process
- Next: Investigating 15%-BW HLC and hybrid SPC options

Wide-FOV Imaging Mode: SPC-20181220

	SPM	FPM	Lyot Stop
SRR Design SPC-20170130			
PDR Design SPC-20181220			

Main Differences

- 5.5% throughput
  (~5.2% with LS struts)
- IWA = **6.8** λ_c/D

- 4.6% throughput
- IWA = **5.7** λ_c/D

- Traded some throughput for smaller IWA
- Still easily meets all L5 requirements

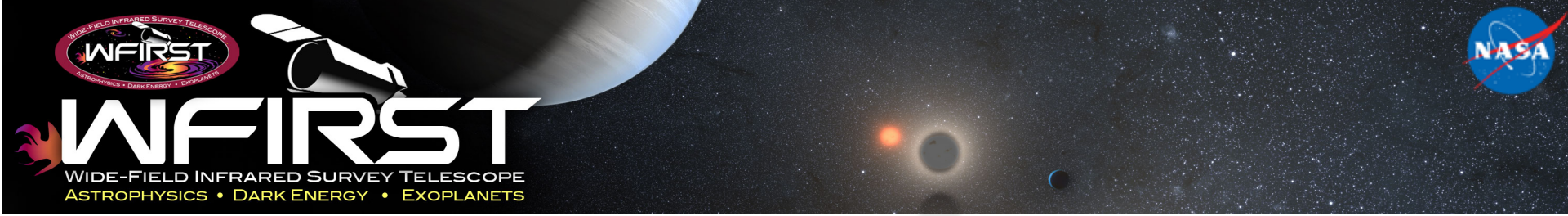
Next Steps (up to PDR)

1) Broader-bandwidth (15%) HLC designs for spectroscopy
   - Test in HCIT

1) Designs with BMC DMs
   - HLC trade survey
   - DMs+circularly-symmetric SPC might be possible

3) Utilize the new disk science figure of merit for Wide-FOV mode design feedback.

4) More streamlined coronagraph design evaluation
   - Designs → *WFSC and Sensitivity Calculator* → FRN Calculator
   - Needed for design feedback (Narrow-FOV and IFS)

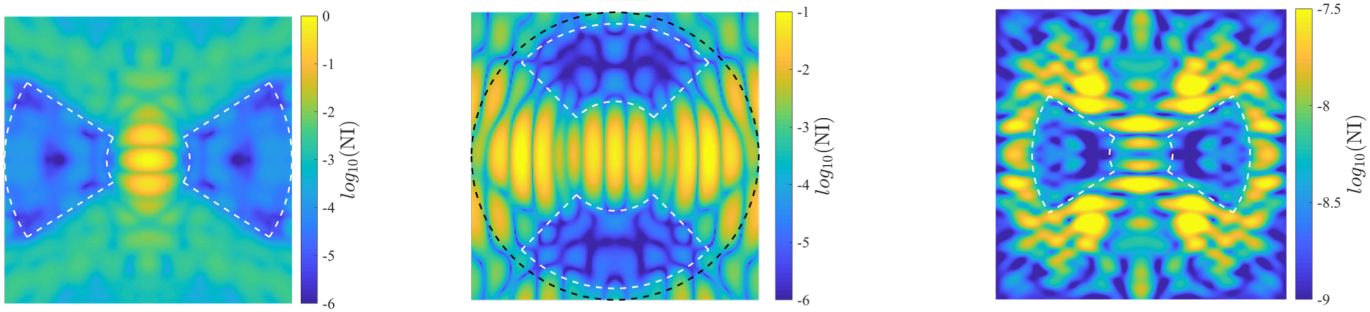


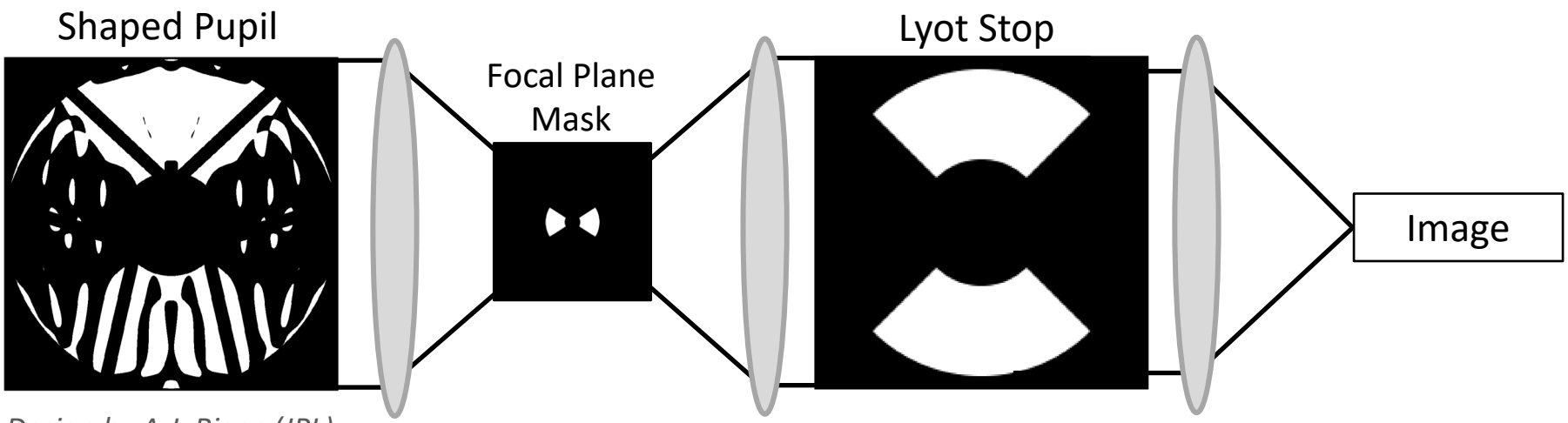
Backup Slides

Spectroscopy Mode: SPC-20190130

figures not to scale

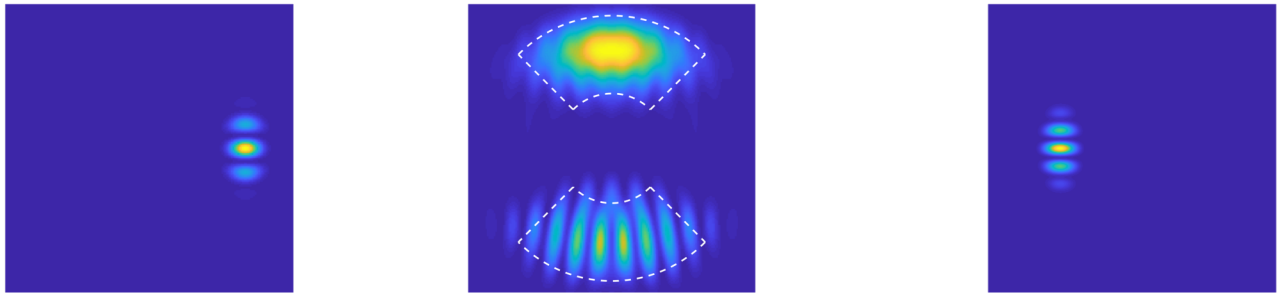
On-Axis Starlight
($\log_{10}$ scale)





Design by A.J. Riggs (JPL)

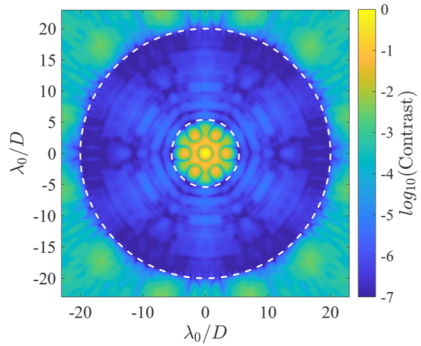
Off-Axis Point Source
(linear scale)

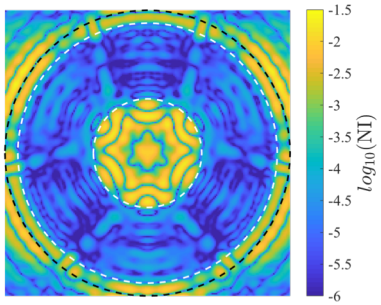


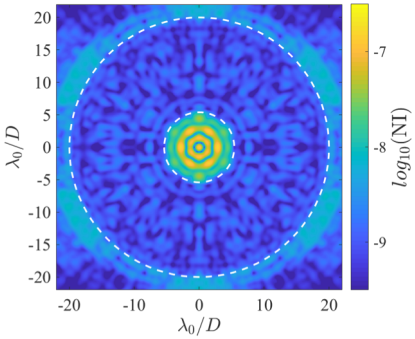
Wide-FOV Imaging Mode: SPC-20181220

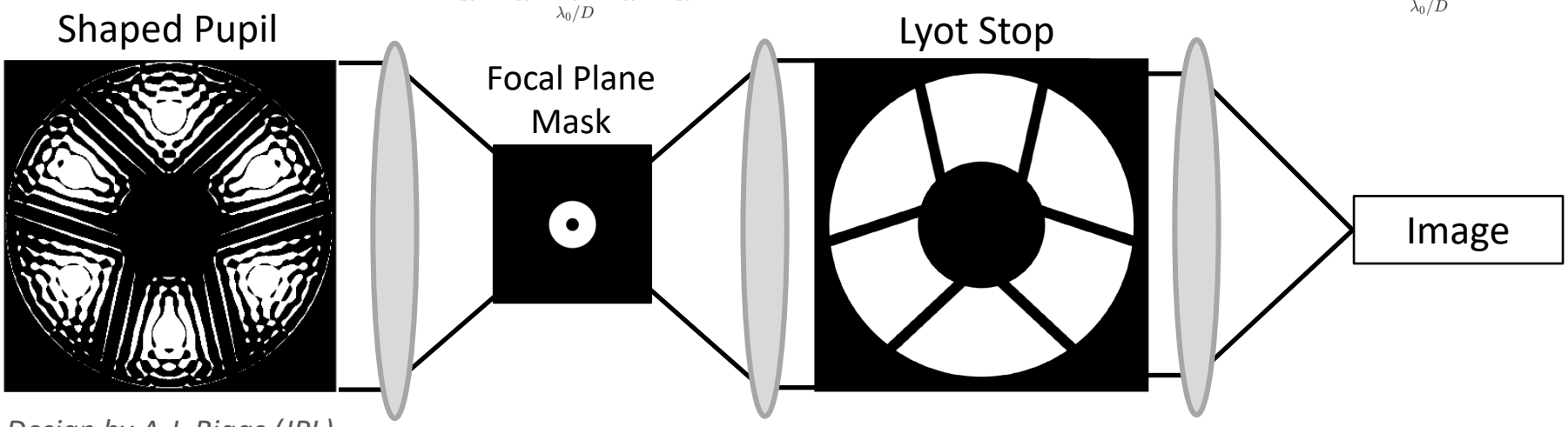
figures not to scale

On-Axis Starlight
($\log_{10}$ scale)



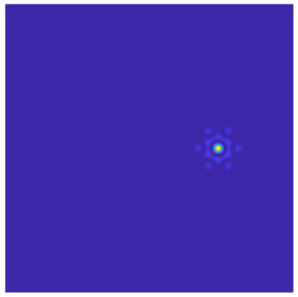


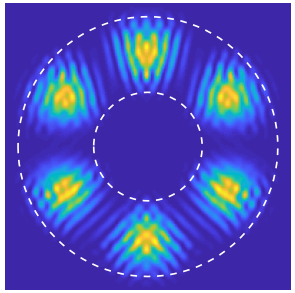


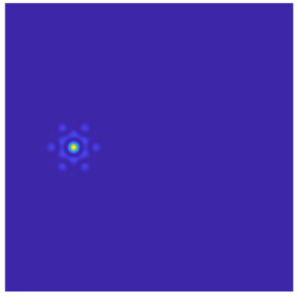


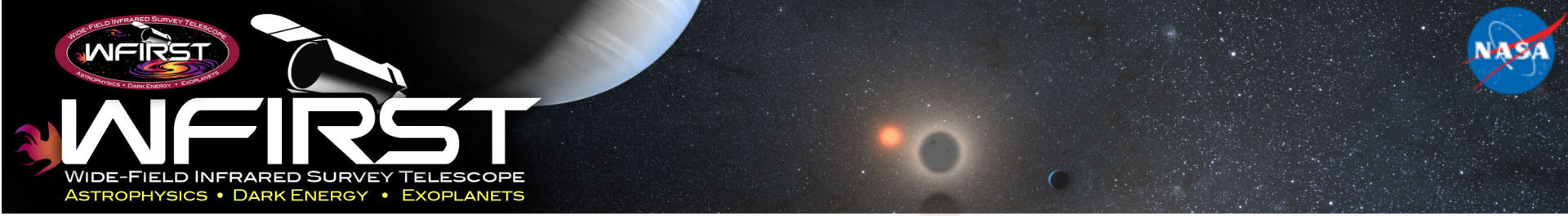
Design by A.J. Riggs (JPL)

Off-Axis Point Source
(linear scale)









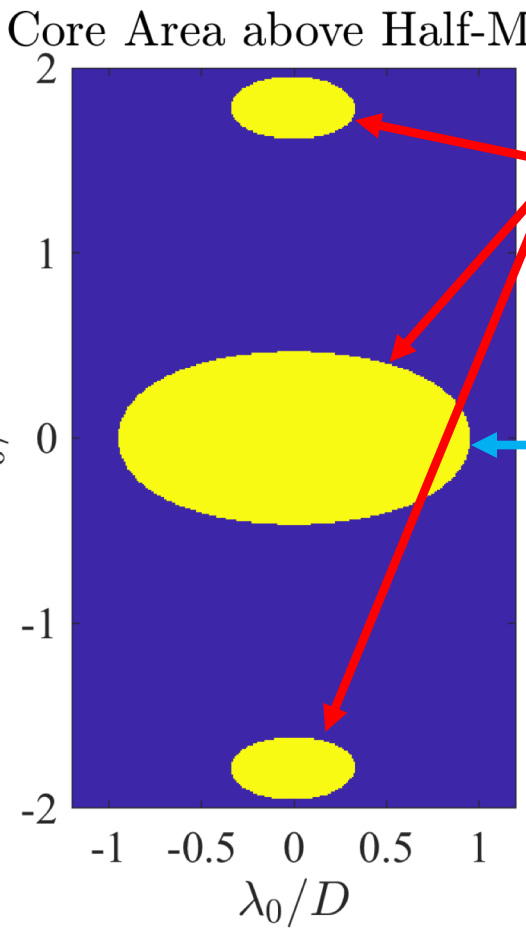
Spectroscopy Mode Mask Design Comparisons: Phase A vs Phase B

Spectroscopy Mode Designs: Descriptions

Phase A (SPC-20170714)	**Phase B** (SPC-20190130)
SPM • Input pupil: 2014, symmetric • 1000x1000 resolution • Pixel-centered 	SPM • Input pupil CGI180718 • 1000x1000 resolution • Pixel-centered
FPM • 2.6 – 9.0 λ/D • 2 x 65° • 0 radius of curvature at corners 	FPM • 2.6 – 9.0 λ/D • 2 x 65° • 0.25 λ/D radius of curvature at corners
LS • 25% - 82% beam diameter • 2 x 115° • 0 radius of curvature at corners 	LS • 38% - 92% beam diameter • 2 x 90° • 0 radius of curvature at corners

IFS Mode Design Comparisons : Core Area and Throughput

Phase A (SPC-20170714)



All 3 Lobes:

- **4.56% throughput**
- 1.77 $(\lambda/D)^2$
- 3.43% thput/(λ/D)

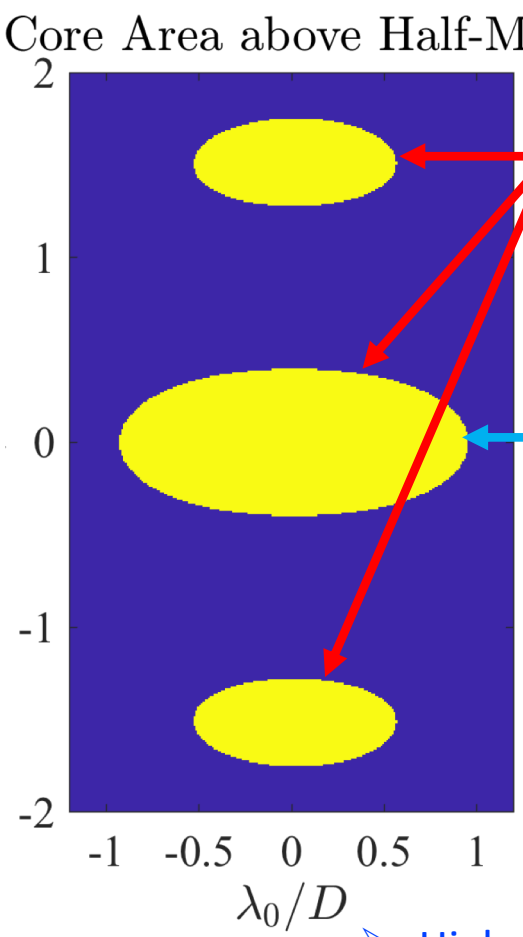
Main-lobe only:

- **3.86% throughput**
- 1.42 $(\lambda/D)^2$
- 3.24% thput/(λ/D)

Background-limited throughput [= throughput/sqrt(area)] is given in blue.

(source offset by 6 λ/D)

Phase B (SPC-20190130)



All 3 Lobes:

- **6.21% throughput**
- 2.02 $(\lambda/D)^2$
- 4.37% thput/(λ/D)

Main-lobe only:

- **4.05% throughput**
- 1.20 $(\lambda/D)^2$
- 3.70% thput/(λ/D)

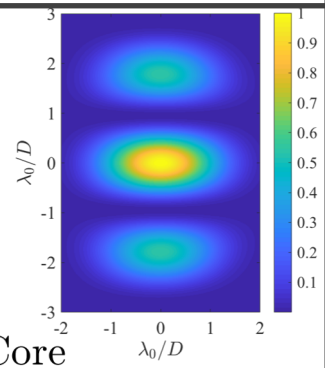
Background-limited throughput [= throughput/sqrt(area)] is given in blue.

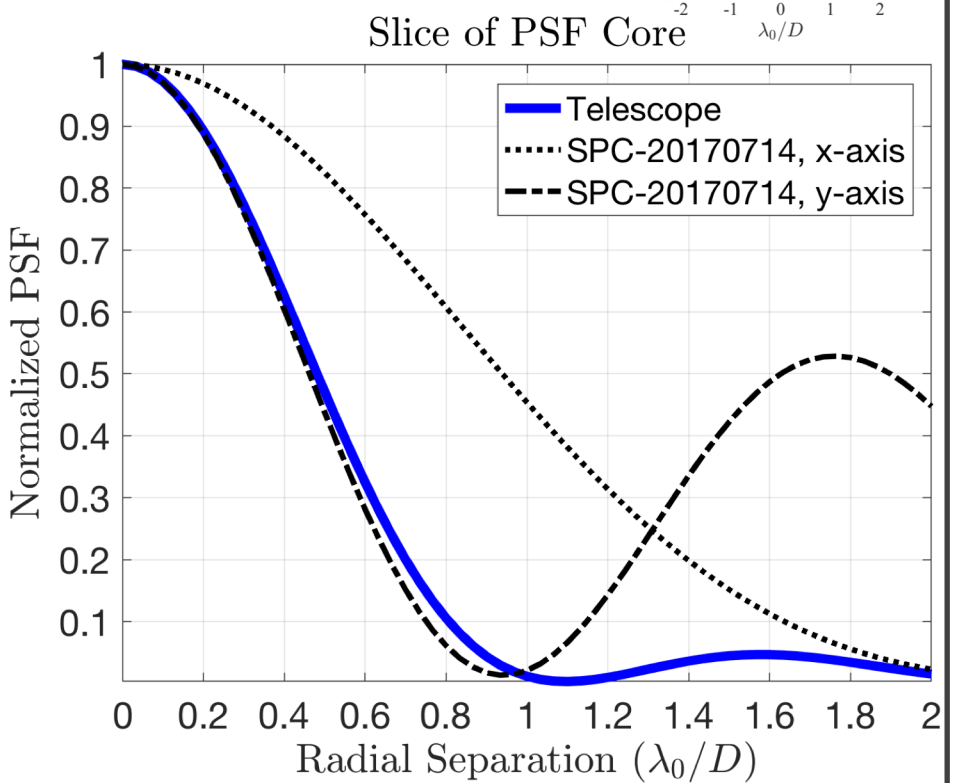
(source offset by 6 λ/D)

- Higher throughput
- Smaller core area

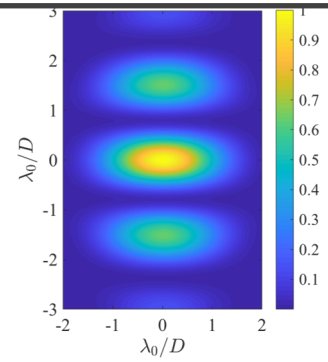
IFS Mode Design Comparisons : PSF Morphology

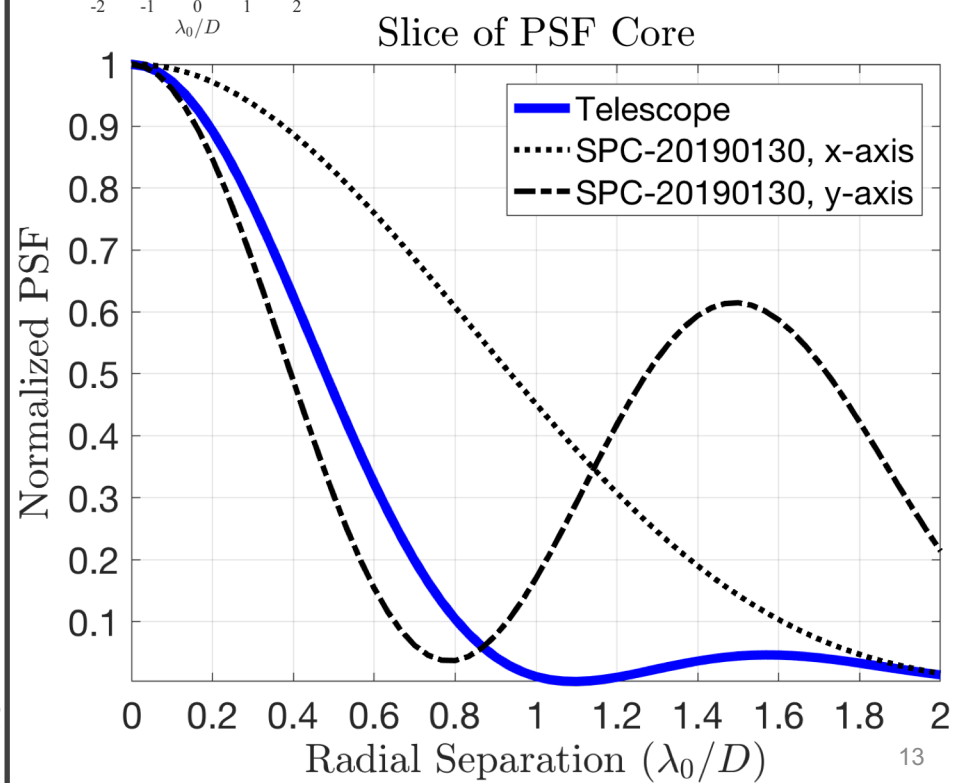
Phase A (SPC-20170714)





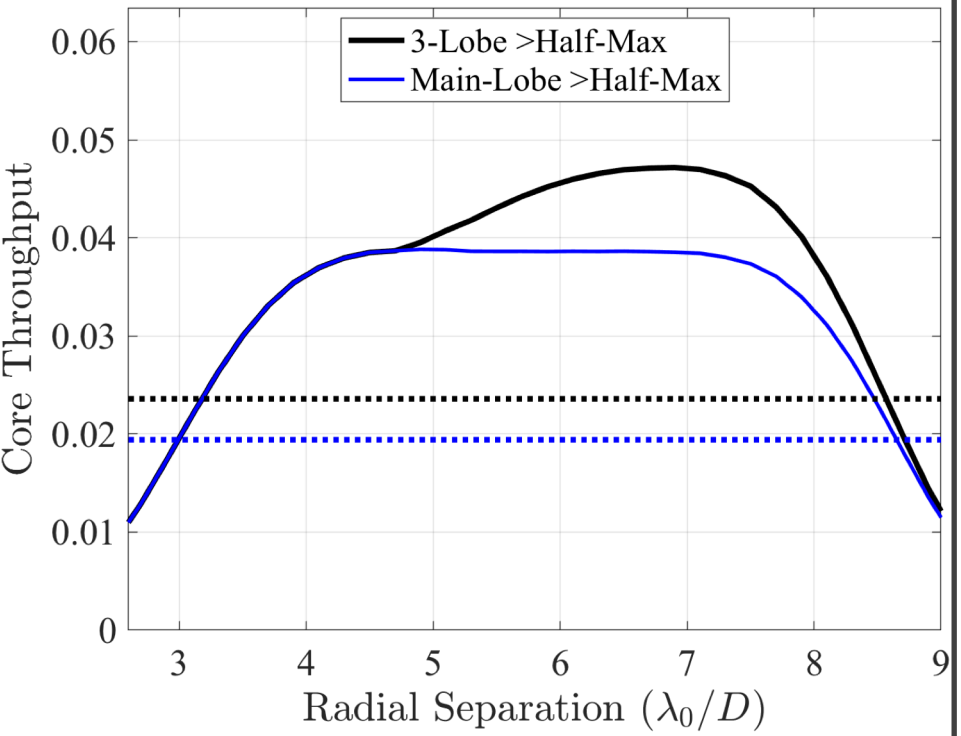
Phase B (SPC-20190130)



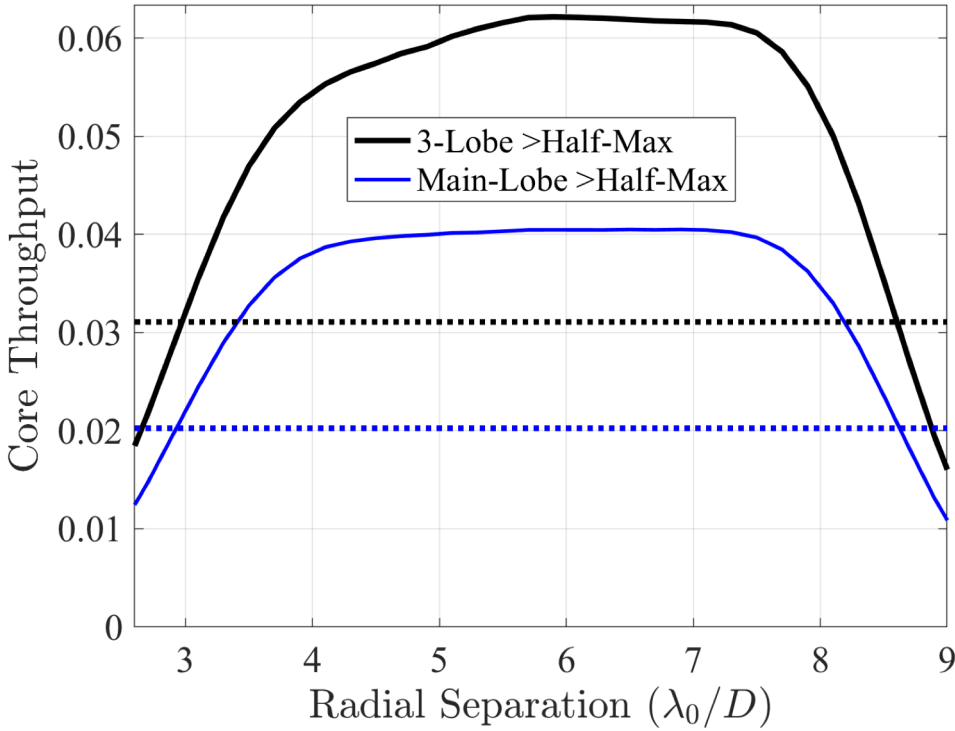


IFS Mode Design Comparisons : Throughput vs Separation

Phase A (SPC-20170714)



Phase B (SPC-20190130)

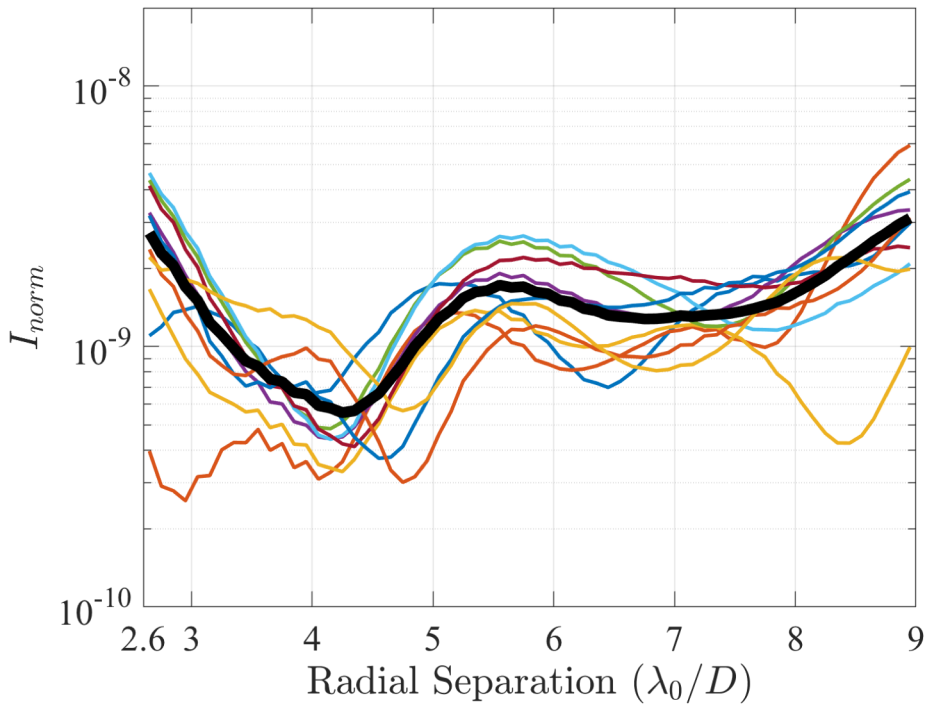


- Slightly higher throughput for main lobe
- Much higher throughput for 3 lobes

Spectroscopy Mode Designs: Stellar PSF

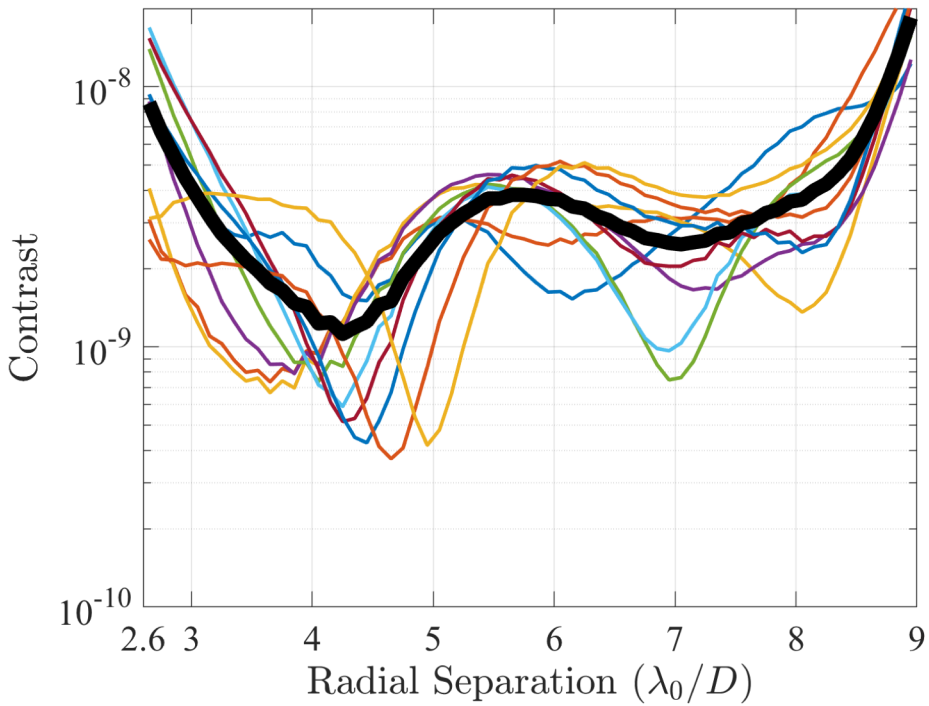
Phase A (SPC-20170714)

Stellar PSF by Wavelength



Phase B (SPC-20190130)

Stellar PSF by Wavelength



Spectroscopy Mode Designs: Low-Order Sensitivities

Phase A (SPC-20170714)

Zernike Sensitivities (|dE/dZ|^2):

Z2 sens	= 1.1e-11 (3-4 l/D)	= 4.4e-12 (4-8 l/D)
Z3 sens	= 2.4e-11 (3-4 l/D)	= 1.0e-11 (4-8 l/D)
Z4 sens	= 2.8e-10 (3-4 l/D)	= 1.1e-10 (4-8 l/D)
Z5 sens	= 1.0e-10 (3-4 l/D)	= 3.8e-11 (4-8 l/D)
Z6 sens	= 4.6e-11 (3-4 l/D)	= 2.8e-11 (4-8 l/D)

Phase B (SPC-20190130)

Zernike Sensitivities (|dE/dZ|^2):

Z2 sens	= 7.5e-12 (3-4 l/D)	= 7.7e-12 (4-8 l/D)
Z3 sens	= 1.2e-11 (3-4 l/D)	= 1.3e-11 (4-8 l/D)
Z4 sens	= 1.8e-10 (3-4 l/D)	= 2.1e-10 (4-8 l/D)
Z5 sens	= 7.1e-11 (3-4 l/D)	= 1.0e-10 (4-8 l/D)
Z6 sens	= 2.8e-11 (3-4 l/D)	= 3.0e-11 (4-8 l/D)

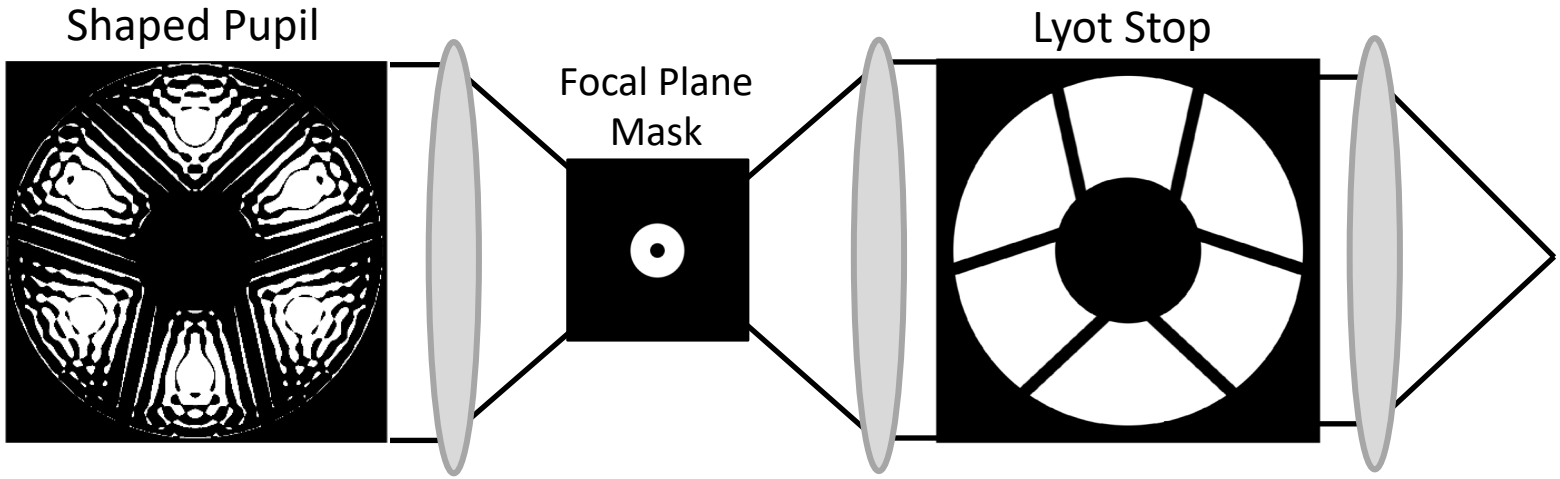
Better L.O. sensitivities from 3-4 λ/D.

Wide-FOV Mode Details

Wide-FOV Mode (SPC-20181220): Mask Descriptions

figures not to scale

Design by A.J. Riggs (JPL)

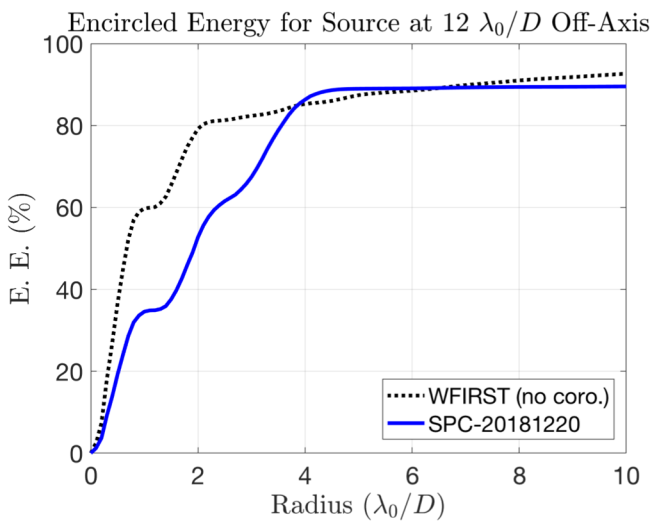


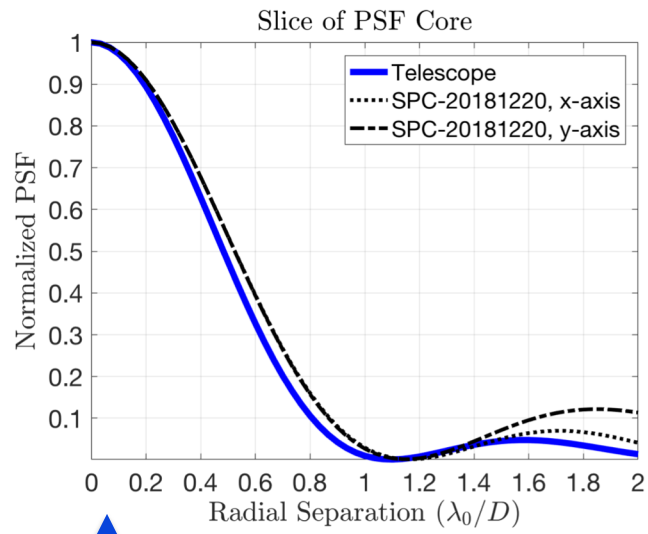
- Input pupil CGI180718, symmetrized about vertical axis
- Resolution
  - 1000x1000 for modeling
  - 3000x3000 for manufacturing
- Pixel-centered

- 5.4 – 20.0 λ/D
- 360°

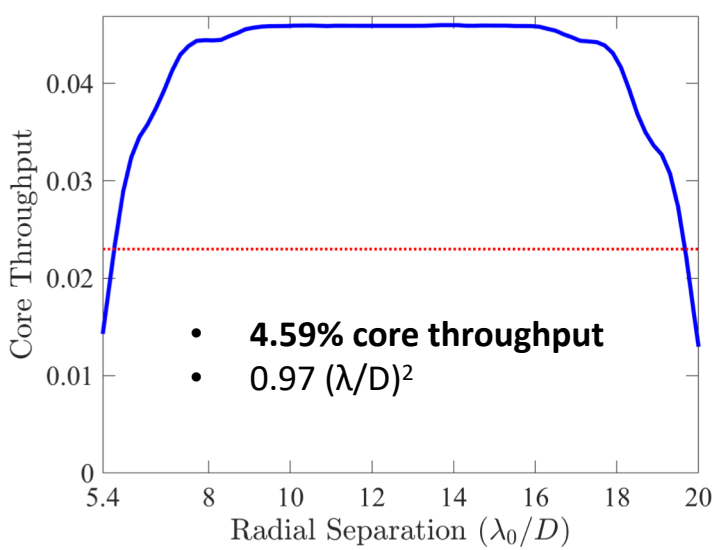
- 38% - **91**% beam diameter, concentric
- Input pupil CGI180718, symmetrized about vertical axis
- 3.2% D struts

Wide-FOV Imaging Mode SPC-20181220, Off-axis Performance

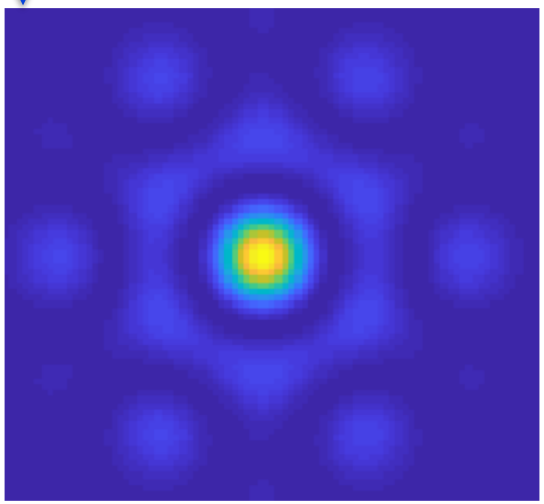




(source offset by 12 λ/D)



- **4.59% core throughput**
- 0.97 $(\lambda/D)^2$



Linear scale from 0 to 1