The Coronagraph Instrument on WFIRST

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CGI Adjutant Scientist

The Science/Technology Teams

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DARK ENERGY • EXOPLANETS • ASTROPHYSICS

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Adjutant scientist: Jeremy Kasdin

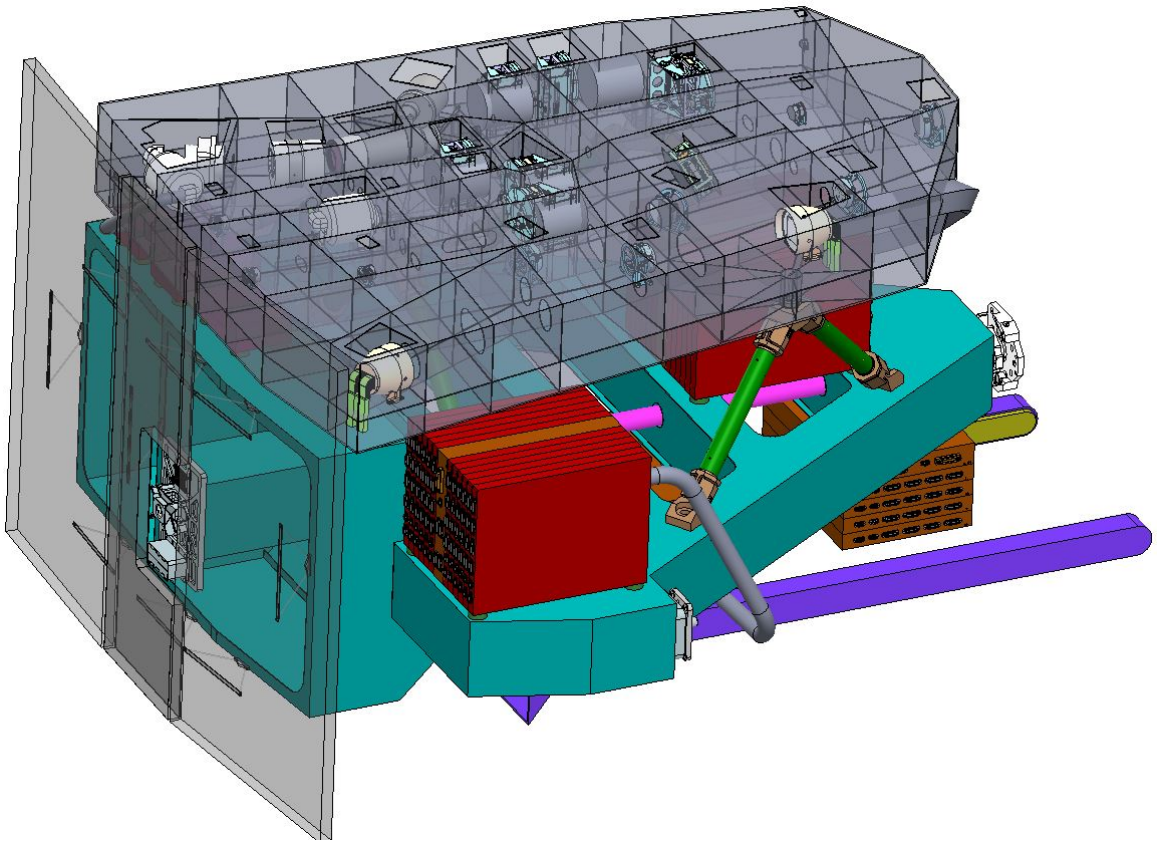
Post-WIETR CGI Status

- The Coronagraph Instrument is a technology demonstration only
- Requirements established using standard engineering practice
- Reduction in modes and science center role
- If successful, ”Participating Science Program” following tech demo
- Design to support possible starshade (pending Decadal recommendation)

<u>Notional CGI Program</u>

- 3 months of technology demonstration observing in first 1.5 years of WFIRST mission
- If meet success criteria, 1 year Participating Science Program
- If successful, follow-on 2.5 year science program

The Coronagraph Instrument (CGI)



- 2 Coronagraphs (SPLC & HLC)
- 2 Deformable Mirrors
- Low-Order Wavefront Sensing & Control
- Wide-band Imaging Camera
- Integral Field Spectrograph (R = 50)
- Photon-Counting EMCCD camera

The WFIRST CGI as a Technology Pathfinder

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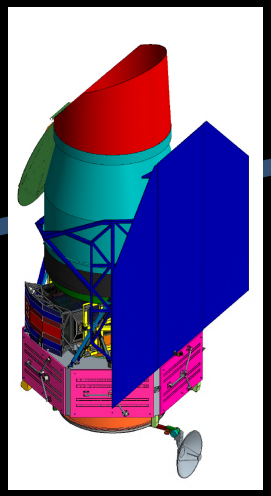
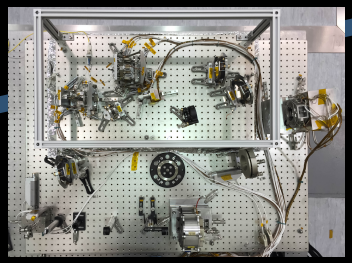
CGI is a direct predecessor to potential future flagship direct imaging missions aimed at *Earth-like* exoplanets (HabEx and LUVOIR)

Ultra-stable Space Telescope & Observatory

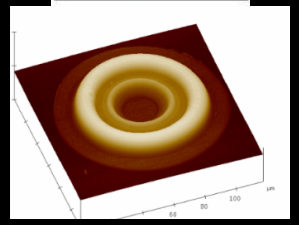


Autonomous Ultra-Precise Wavefront Sensing & Control System



First Use of Deformable Mirrors in Space

High Contrast Coronagraph Masks



Ultra-low noise photon counting Visible Detectors

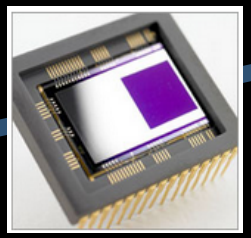
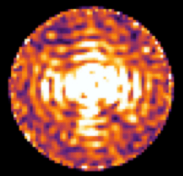


Image Processing at Unprecedented Contrast Levels



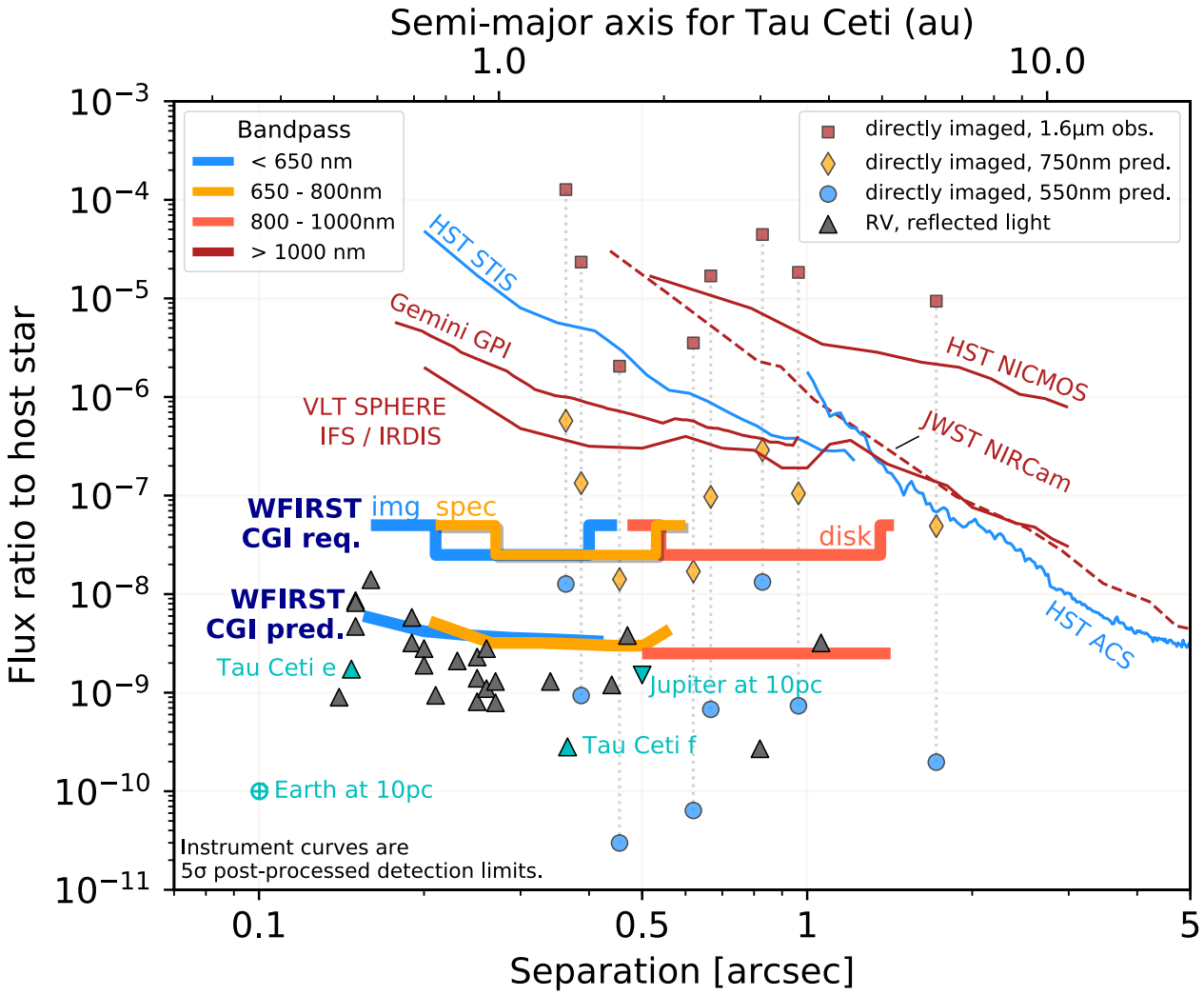
CGI will premiere in space many key technologies required for the characterization of rocky planets in the Habitable Zone, significantly reducing the risk and cost of future possible missions such as HabEx and LUVOIR

Technology Objectives

- **Demonstrate Coronagraphy with Active Wavefront Control**
- **Advance Engineering & Readiness of Coronagraph Elements**
- **Development and Demonstration of Advanced Coronagraph Algorithms**
- **Integrated Observatory Performance Characterization**
- **Demonstration of Advanced High-Contrast Data Processing**

Top level requirements on detectable flux ratio and angular range for both point sources and extended objects (disks) in both imaging and spectroscopic modes.

Exoplanet & Disk Direct Imaging Science Goals



Prepared by Vanessa Bailey, JPL

Participating Science Program Potential Objectives

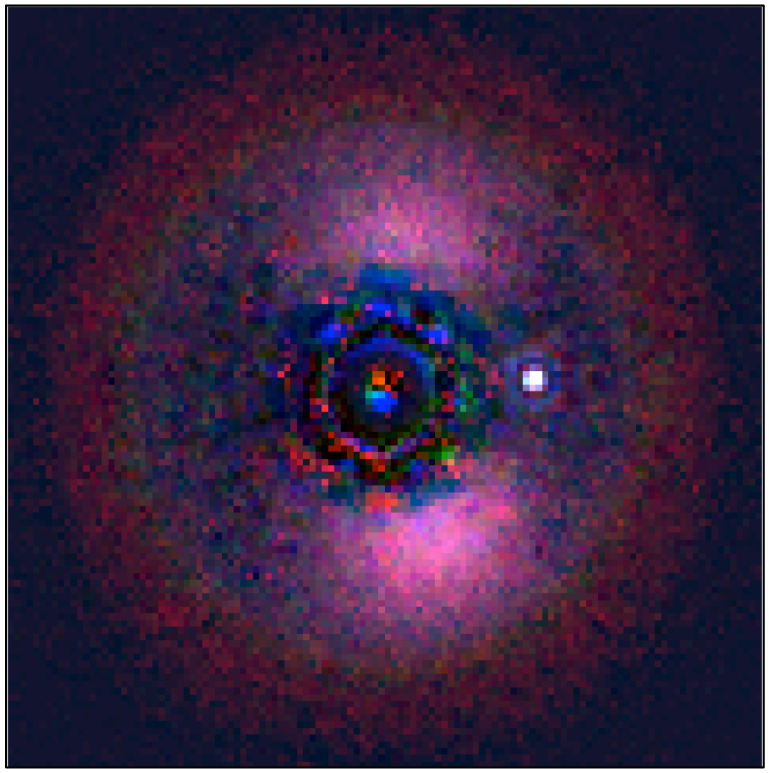
Imaging Photometry of Giant Planets (Imager)
- Methane and Water detection
- Clouds

Narrow-band Spectroscopy (IFS)
- Visible spectra of self-luminous planets
- Methane Abundance of a few known RVs
- Clues to metallicity and formation mechanism

Possible Giant planet discovery

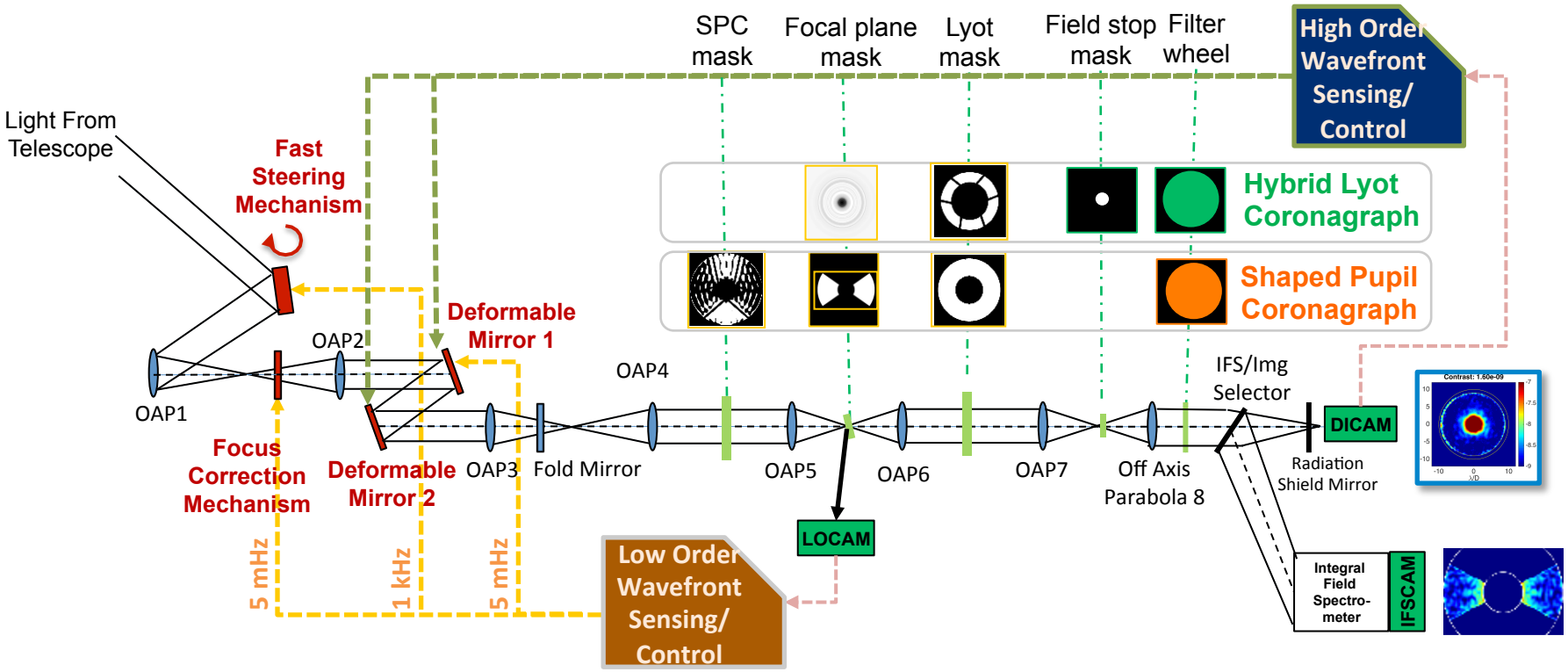
Exozodiacal Disk Imaging (~10x solar)
- Complementary to LBTI
- Determine frequency of occurrence
- Detect resonant clumps
- Inform future missions

Visible light imaging of debris disks (within 10 AU)
- Wide field, Color, and Polarization



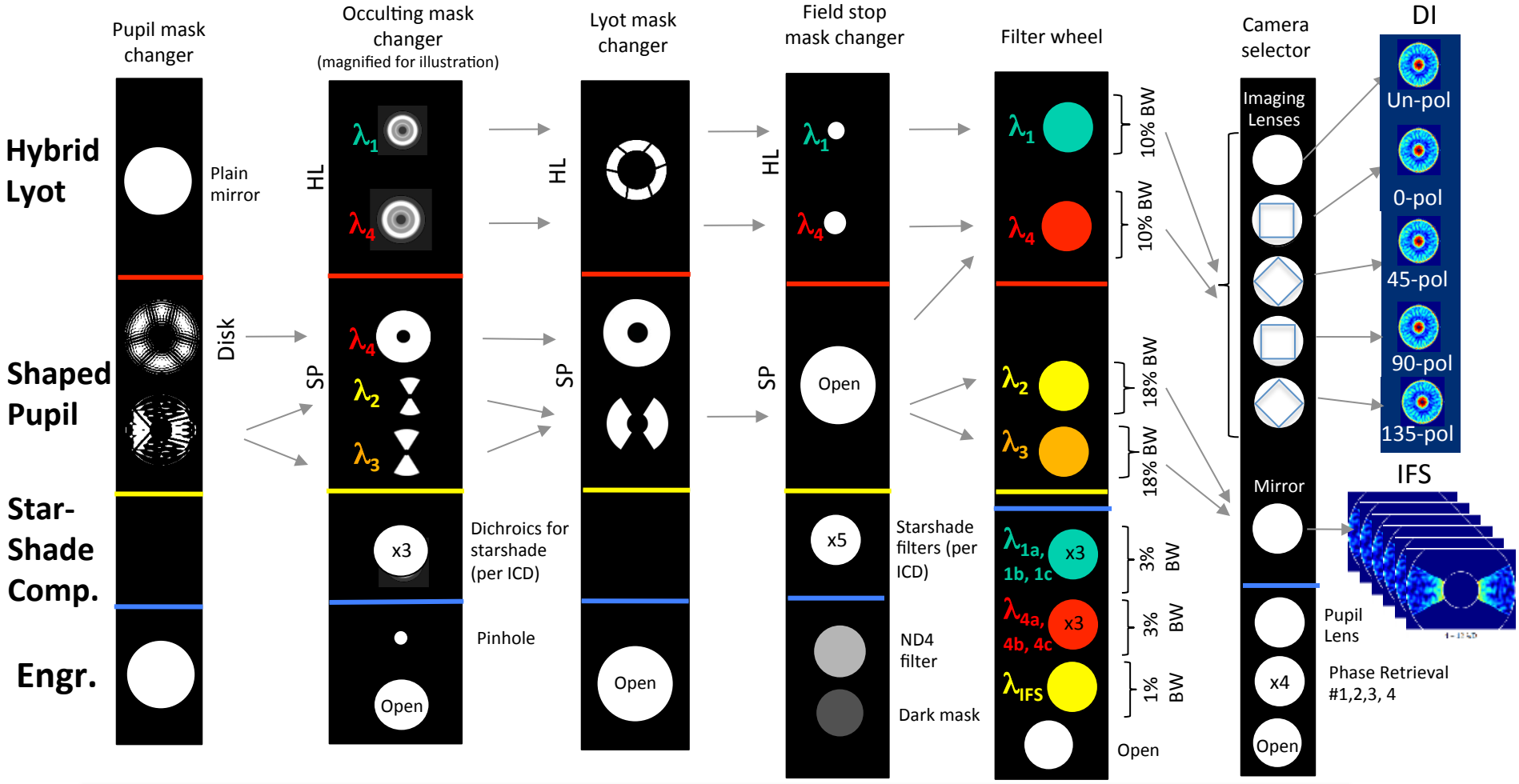
Credit: M. Rizzo, N. Zimmerman, A. Roberge (NASA GSFC), E. Douglas (MIT), L. Pueyo (STScI)

CGI Architecture



- Little has changed in CGI architecture over past year
- Some modes removed and some modes not tested to meet new cost targets

CGI Baseline



λ_1=575 nm, 10% (annular, 3-9 λ/D)
λ_2=660 nm, 18% (bow-tie / IFS, 3-9 λ/D)
λ_3=760 nm, 18% (bow-tie / IFS, 3-9 λ/D)
λ_4=825 nm, 10% (annular, 3-19 λ/D)

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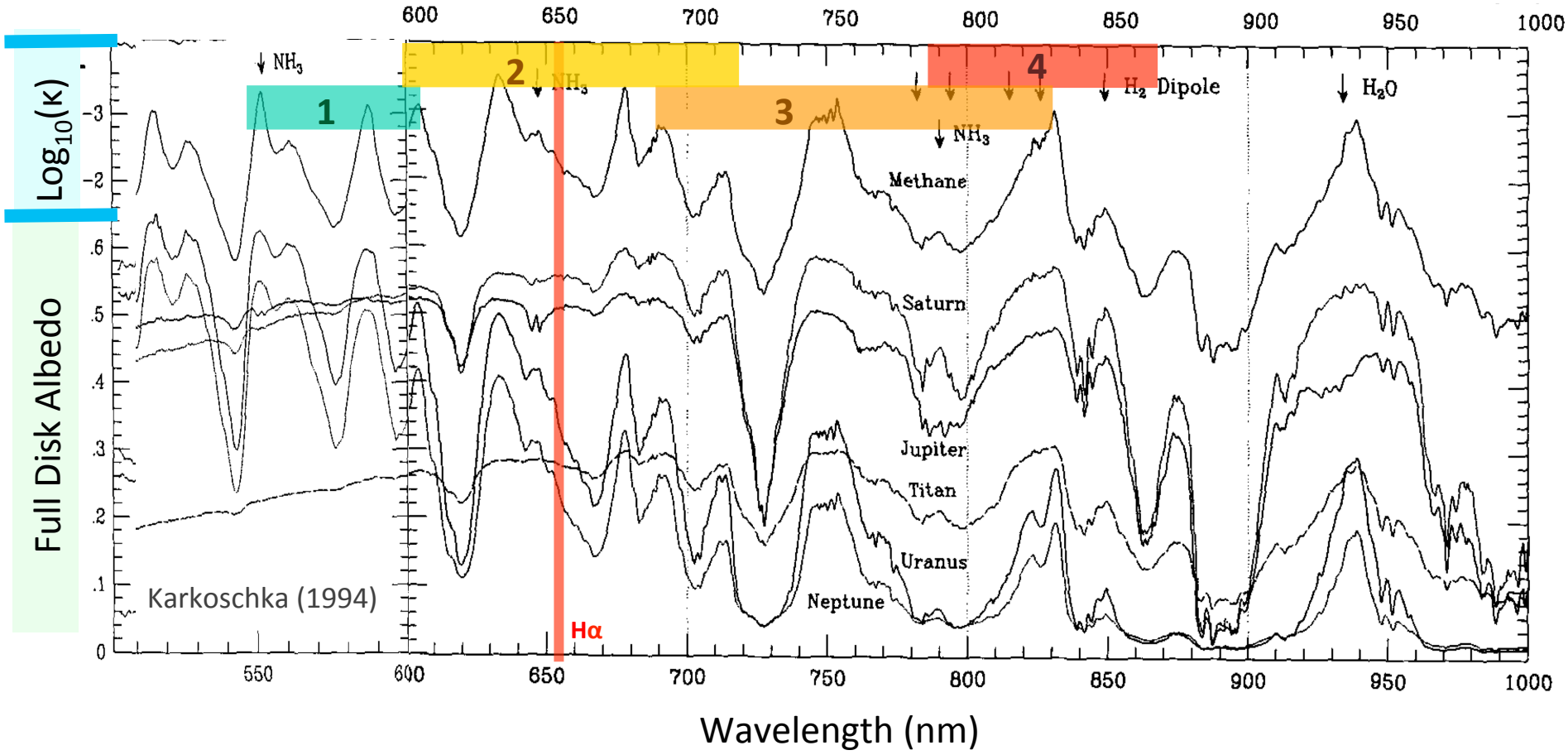
CGI Science Filters



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CGI Modes Table

CGI Filters	λ_{center} (nm)	BW	Channel	Masks	Working Angle	Can use w/ linear polarizers	Starlight Suppression Region	Tested before launch?
1	575	10%	Imager	HLC	3-9 λ/D	Y	360°	Y
2	660	18%	IFS	SPC	3-9 λ/D		130°	
2	660	18%	Imager	SPC	3-9 λ/D	Y	130°	
3	760	18%	IFS	SPC	3-9 λ/D		130°	Y
3	760	18%	Imager	SPC	3-9 λ/D	Y	130°	
4	825	10%	Imager	HLC	3-9 λ/D	Y	360°	
4	825	10%	IFS	HLC	3-9 λ/D		360°	
4	825	10%	Imager	SPC disk	6.5-20 λ/D	Y	360°	Y

λ_1=575 nm, 10% (annular, 3-9 λ/D)
λ_2=660 nm, 18% (bow-tie / IFS, 3-9 λ/D)
λ_3=760 nm, 18% (bow-tie / IFS, 3-9 λ/D)
λ_4=825 nm, 10% (annular, 3-19 λ/D)

Starshade Filter List

	λ (nm)	BW	Δλ	λ_{min} (nm)	λ_{max} (nm)
Starshade Science Bands	488.5	26.0%	127	425	552
	707.5	26.1%	185	615	800
	728	19.8%	144	656	800
	884.5	26.1%	231	769	1000
	910	19.8%	180	820	1000

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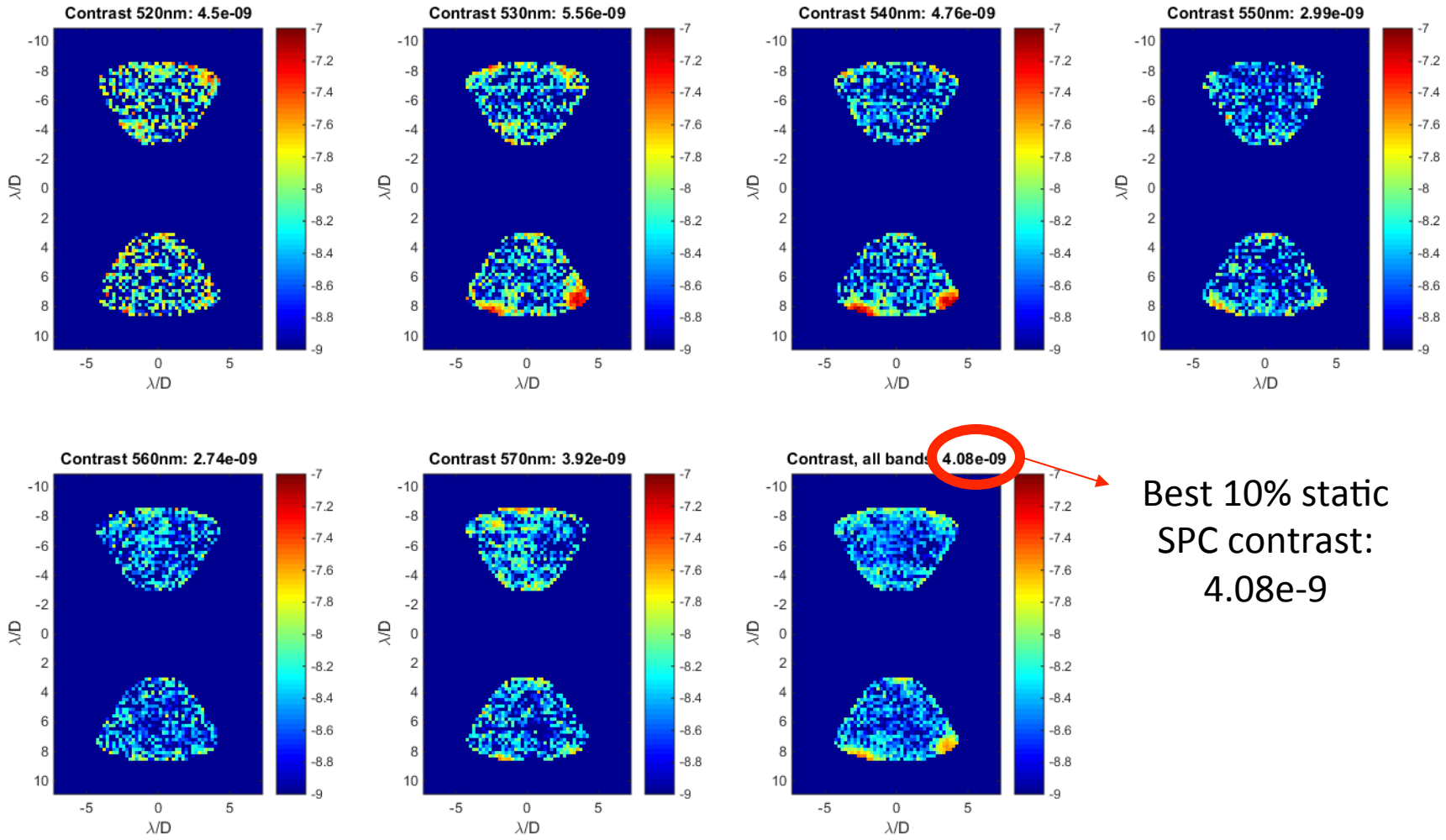
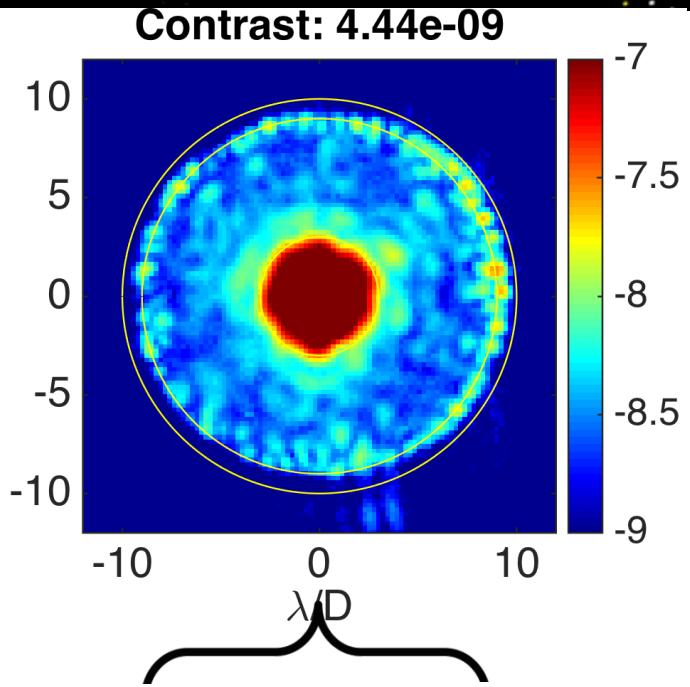
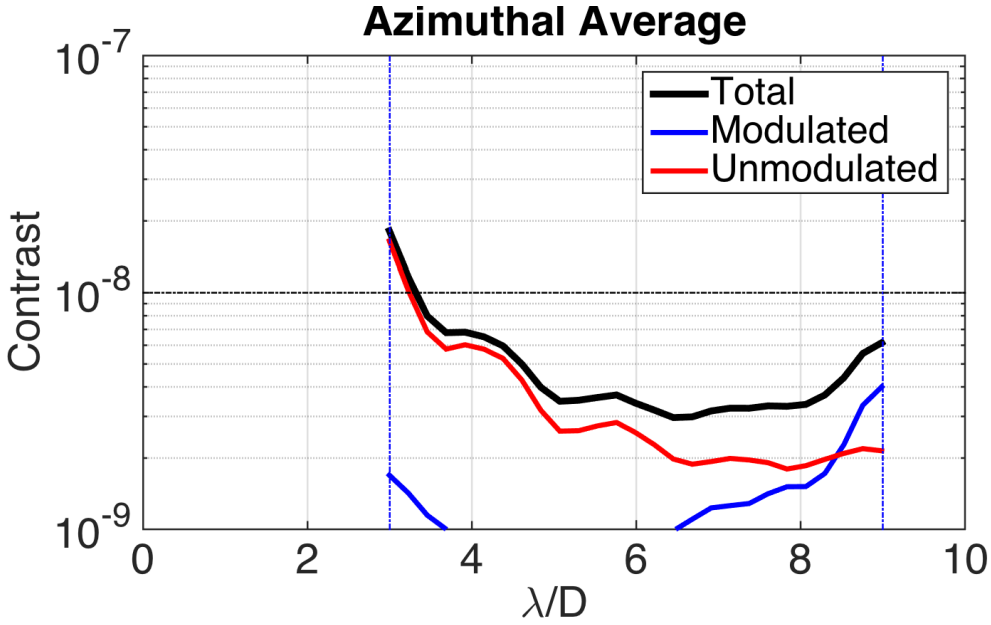
Static Testbed Results



Best 10% static SPC contrast: 4.08e-9

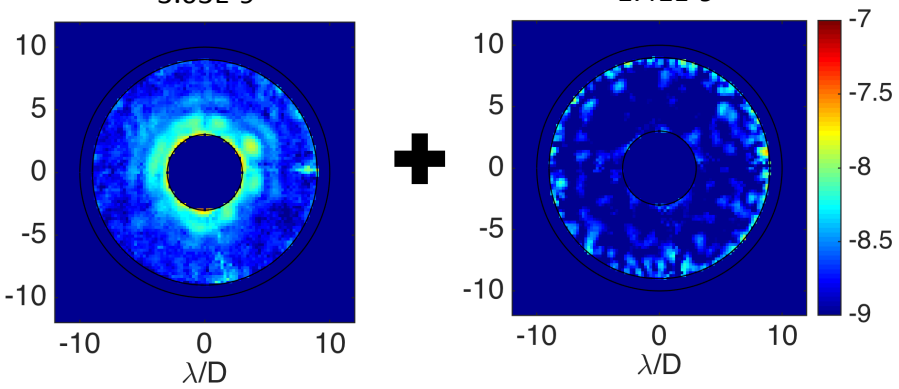
HLC DynamicTestbed Result





Unmodulated light
3.03E-9

Modulated light
1.41E-9



- **Contrast consisted of two terms:**
  - **Unmodulated light dominated by the LoS Jitter.**
  - **Modulated light dominated by calibration error.**

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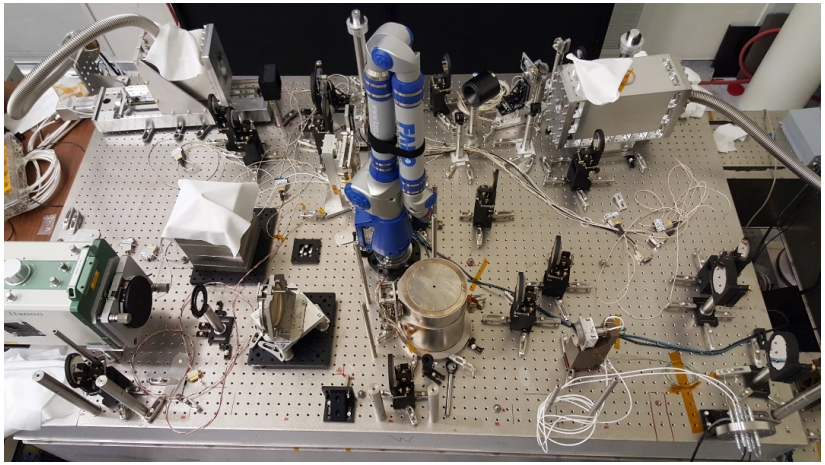
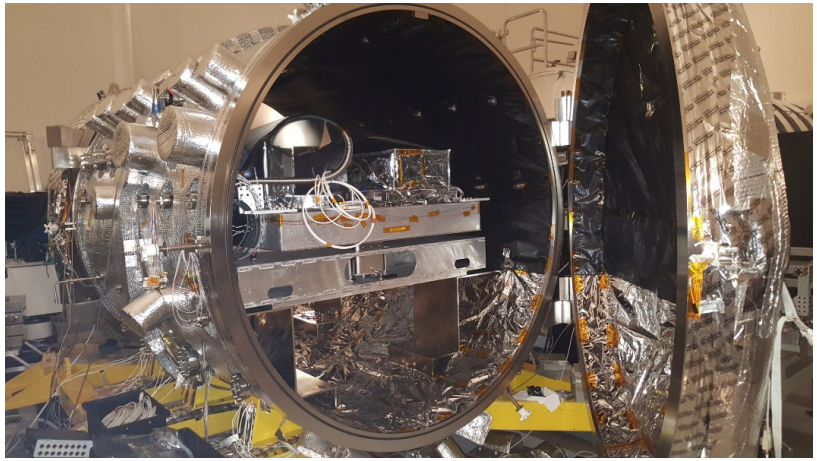
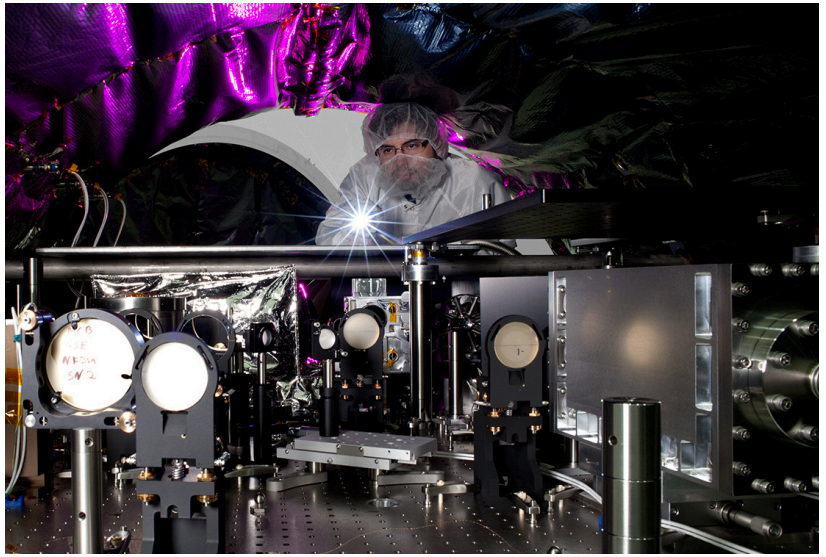
OMC Dynamic Testbed







Summary

- WFIRST will carry the first active coronagraph in space
  - Combines multiple technologies and modes
  - Demonstrates new technology in space critical to future missions
- Coronagraph has potential for a participating science program bearing on the questions of planetary system formation
  - Spectroscopy of a small number of known RV and self-luminous planets
  - Photometry of additional systems
  - Possible iscovery of unknown lower-mass planets, potential targets for future missions
  - Characterization of zodiacal dust and debris disks
- Progress in the design and in the laboratory is on schedule and achieving significant successes.