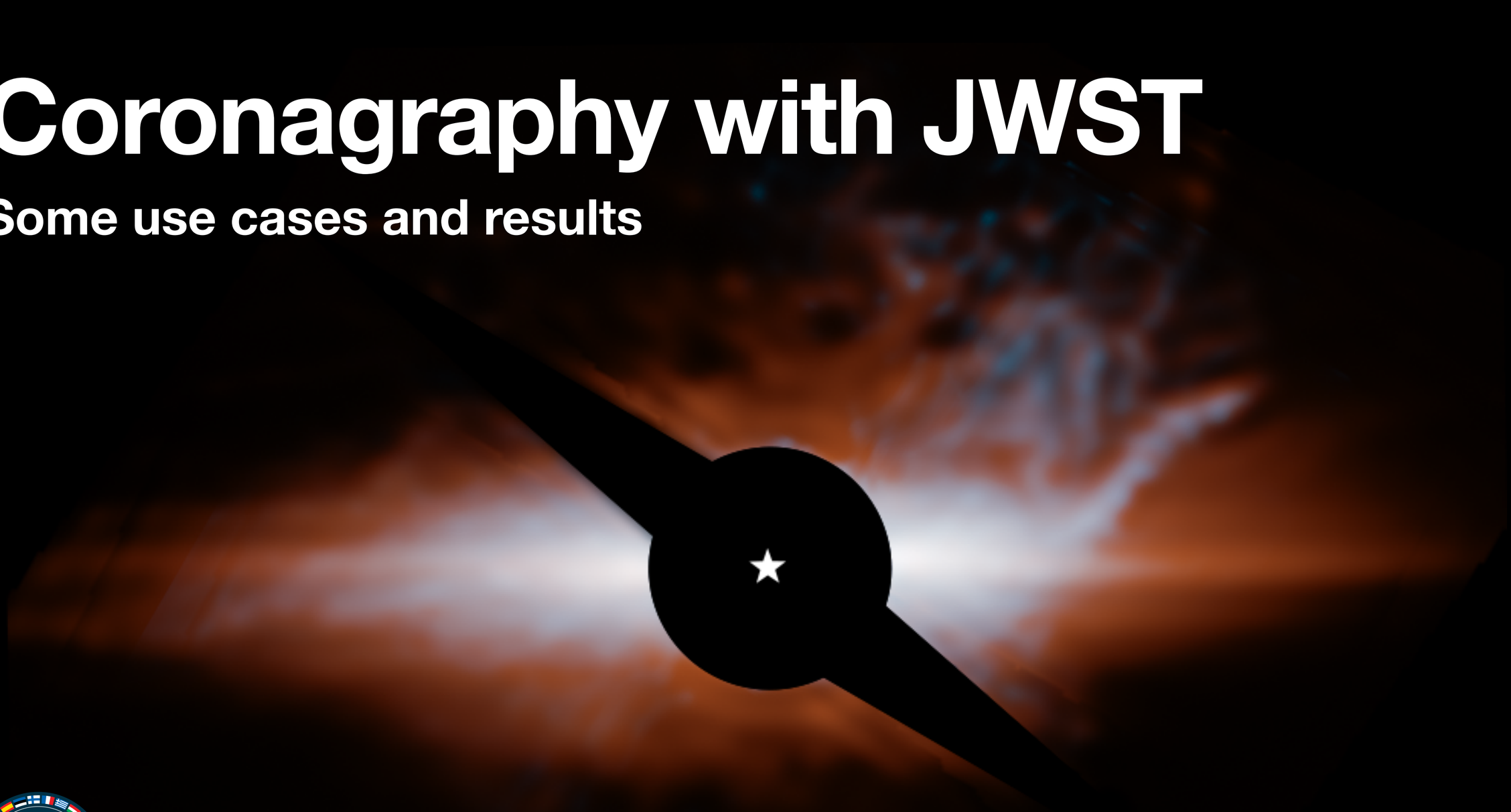
Coronagraphy with JWST

Some use cases and results

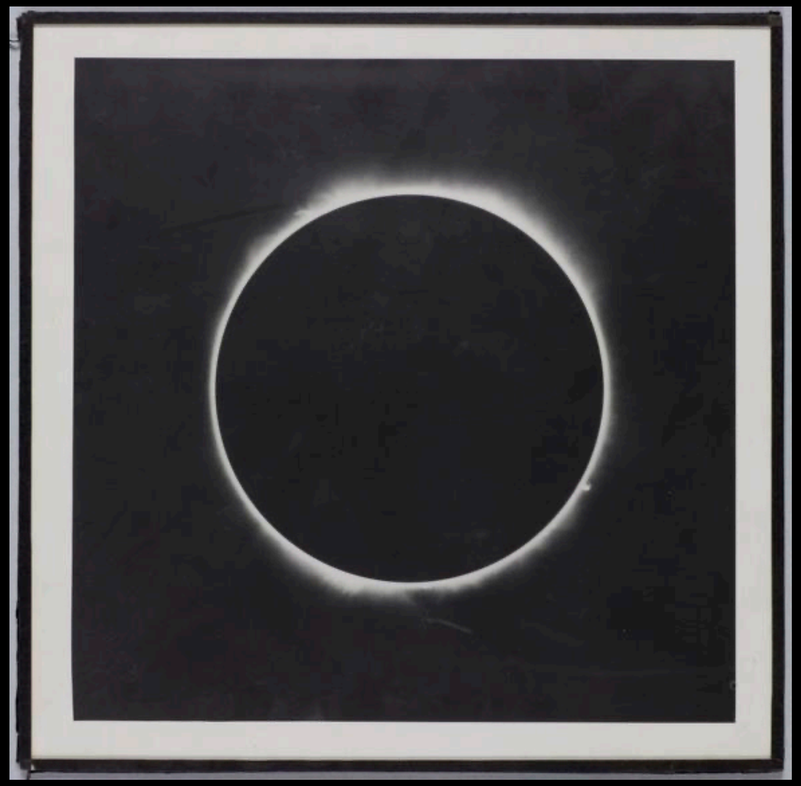


Isabel Rebollido

Bangalore, October 24th 2025

What is *coronagraphy*?

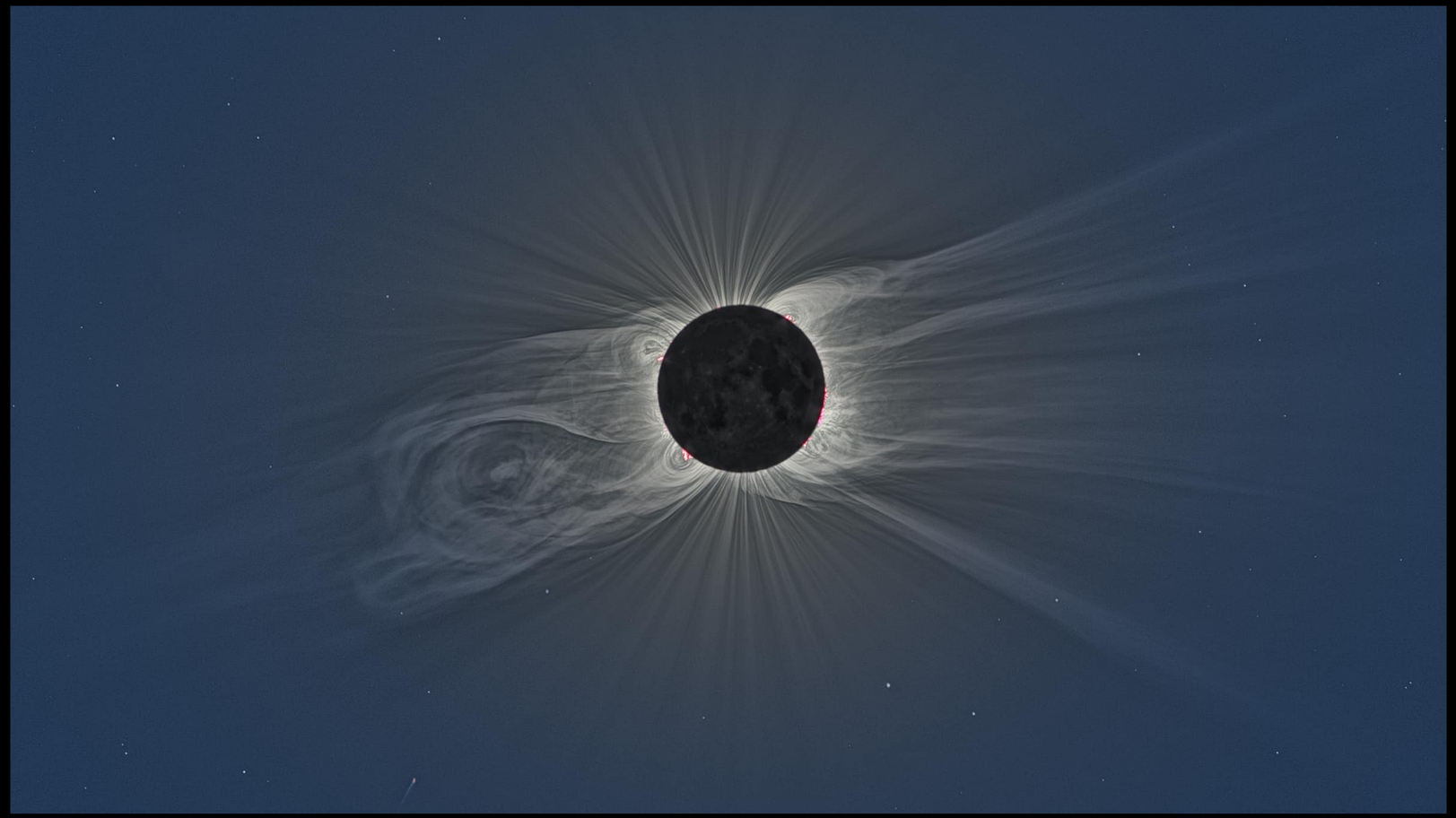
- Invented by Bernard Lyot to observe the Sun’s corona without the need for an eclipse
- Extremelly challenging from the ground due to the brightness of the sky (Rayleigh diffraction)
- Currently different types, but same principle: eliminate the light from the star



Sun’s corona from Pic du Midi
Bernard Lyot, 1930s

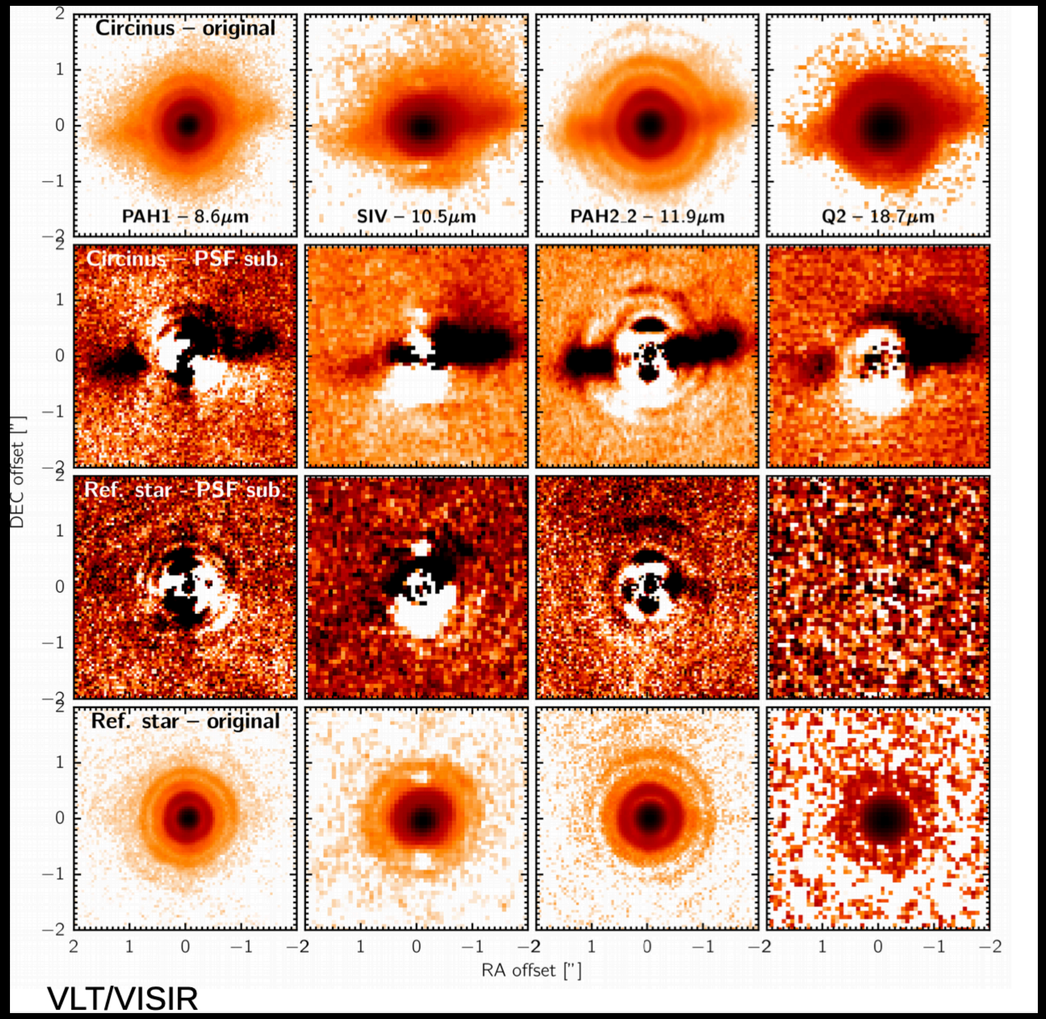
Use cases in astronomy: The Sun

- “Natural” coronagraphy -> discovery of the solar corona
- Flames/ejections
- Solar weather (impact to Earth)



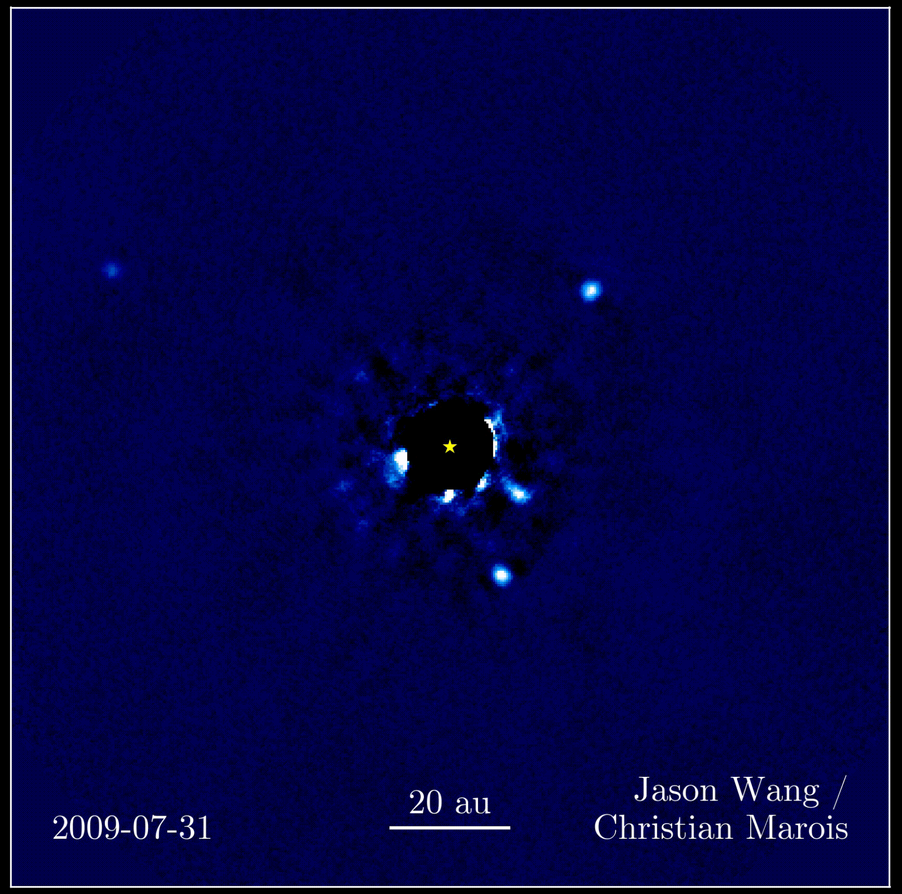
Use cases in astronomy: AGN and quasars

- Bright or active galactic nucleus
- Environments: dust, gas, morphology…



Use cases in astronomy: Exoplanets

- Detection
- Direct observation of their properties
- Orbit characterization



Use cases in astronomy: Exoplanets

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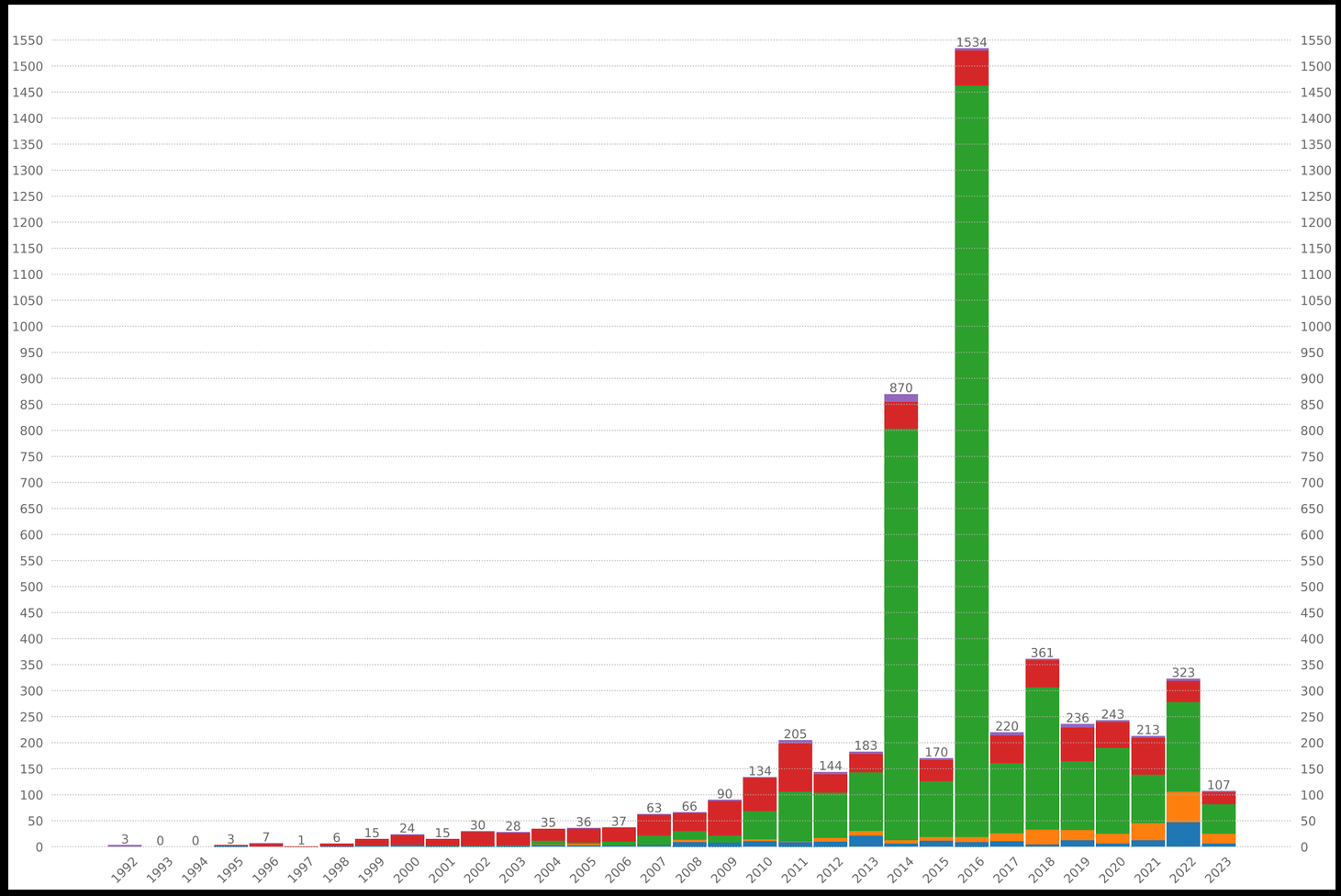

Use cases in astronomy: Exoplanets

- Detection
- Direct observation of their properties
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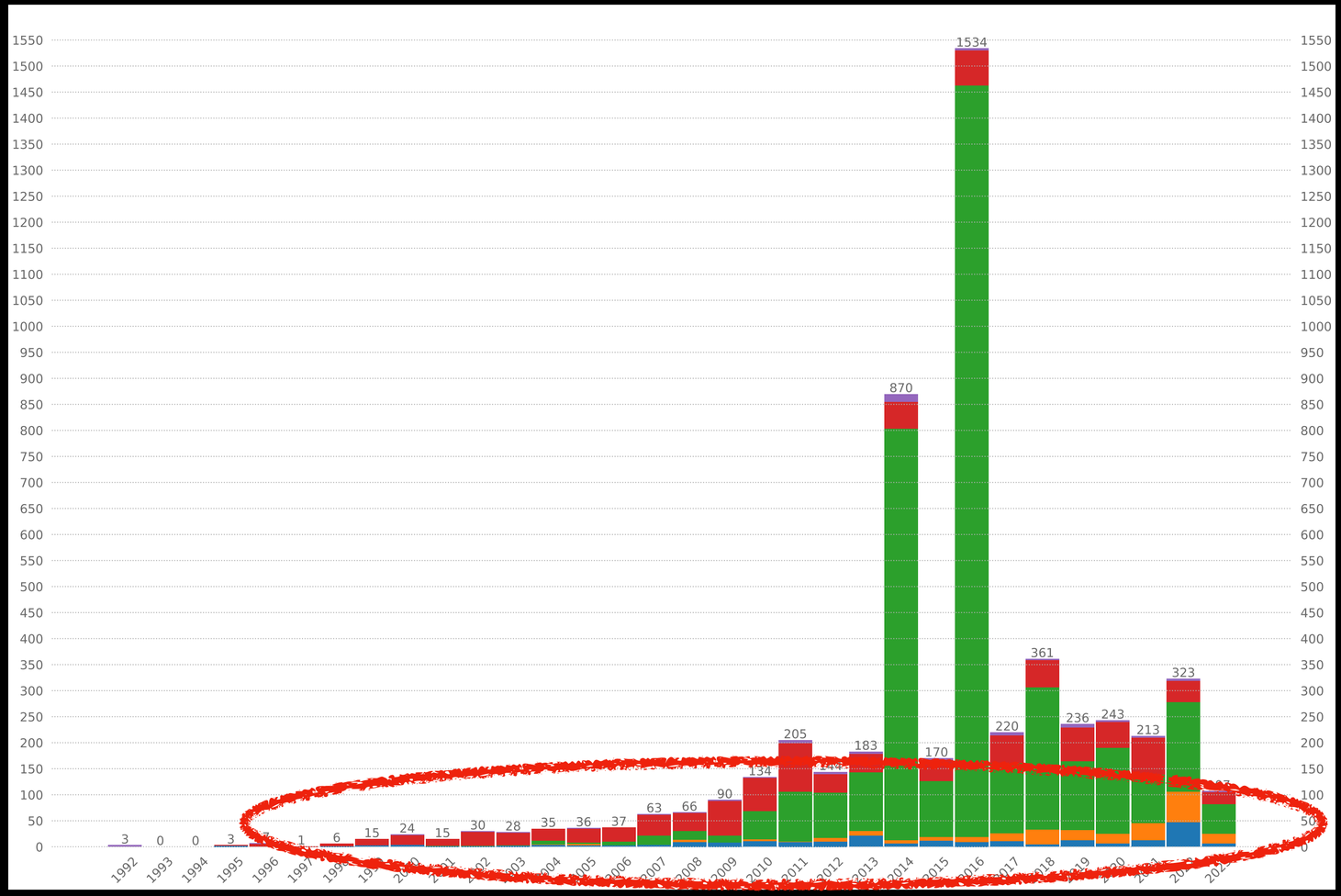
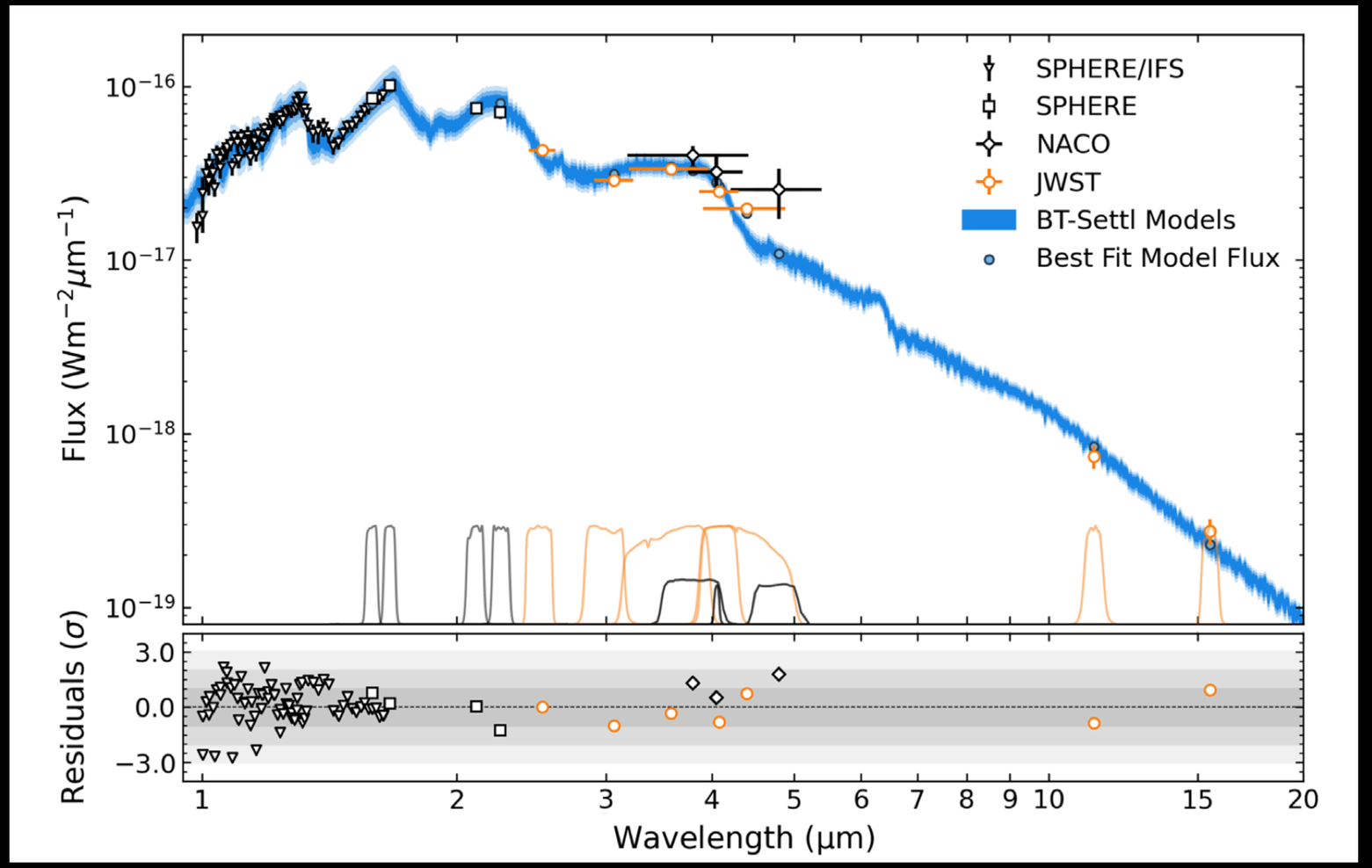


Very expensive technique!

Use cases in astronomy: Exoplanets

- Detection
- Direct observation of their properties
- Orbit characterization



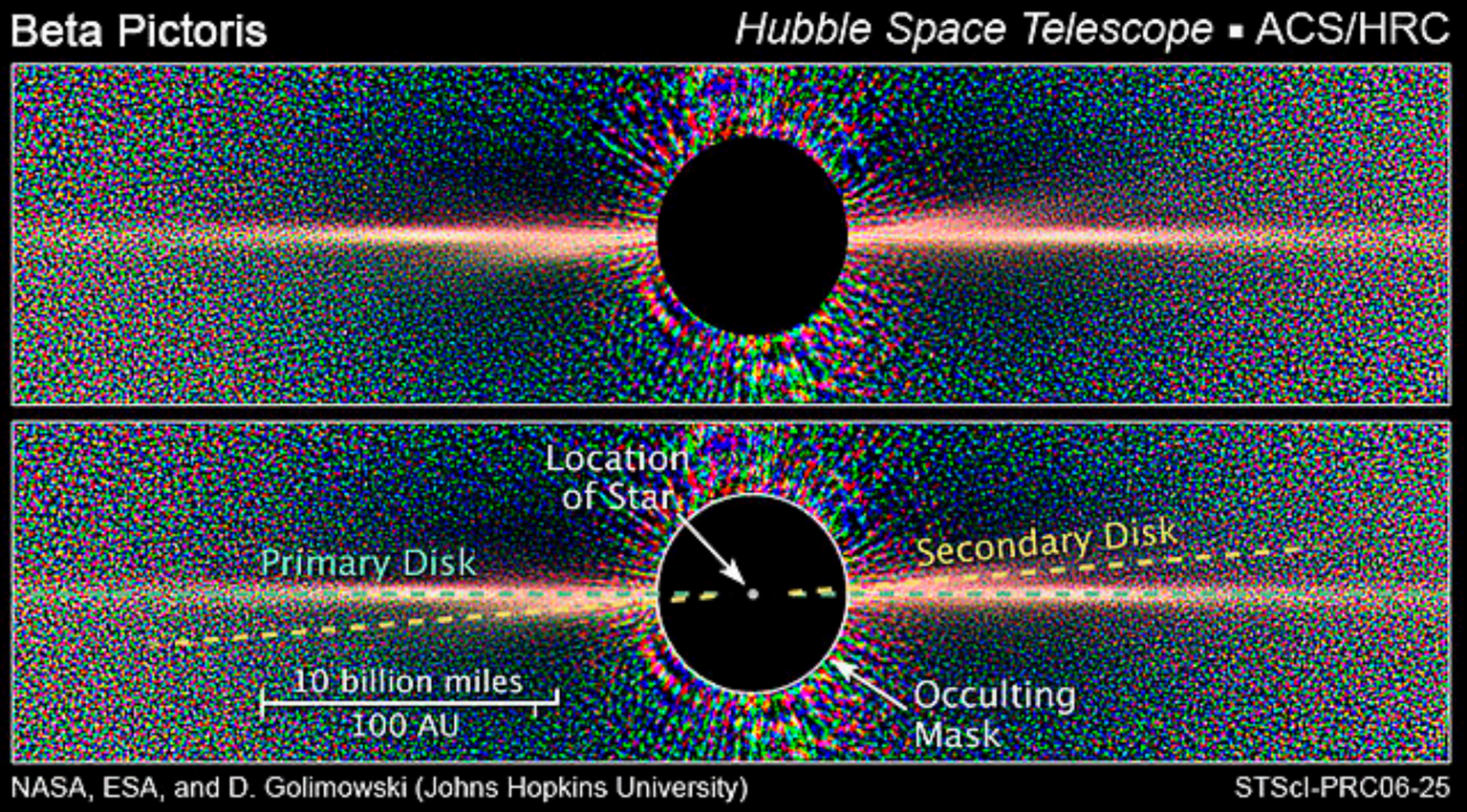
Very expensive technique!

But very rewarding!

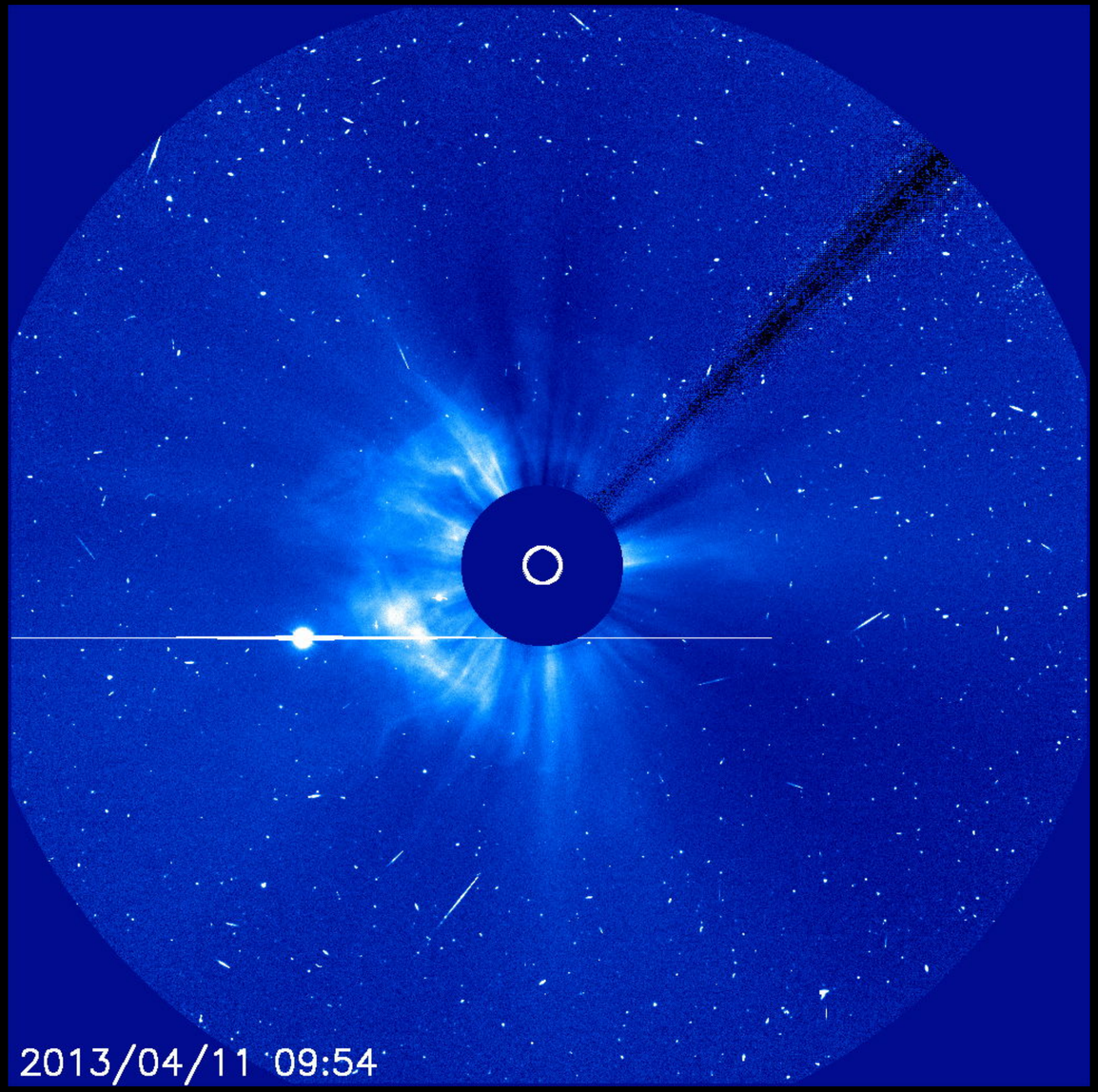
Carter+23

Use cases in astronomy: disks

- Detection
- Direct observation of their properties: dust distribution, composition, etc.



How does a coronagraph work?



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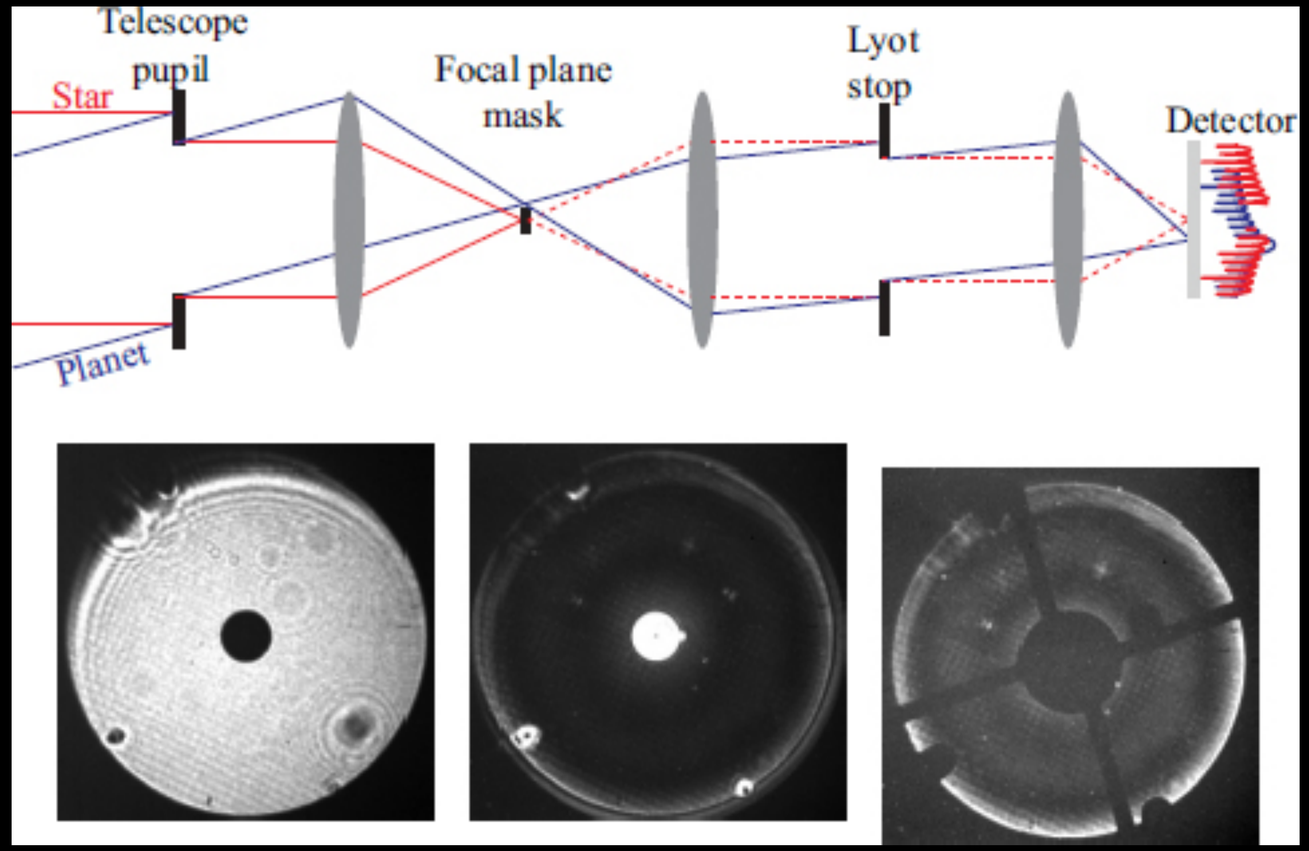
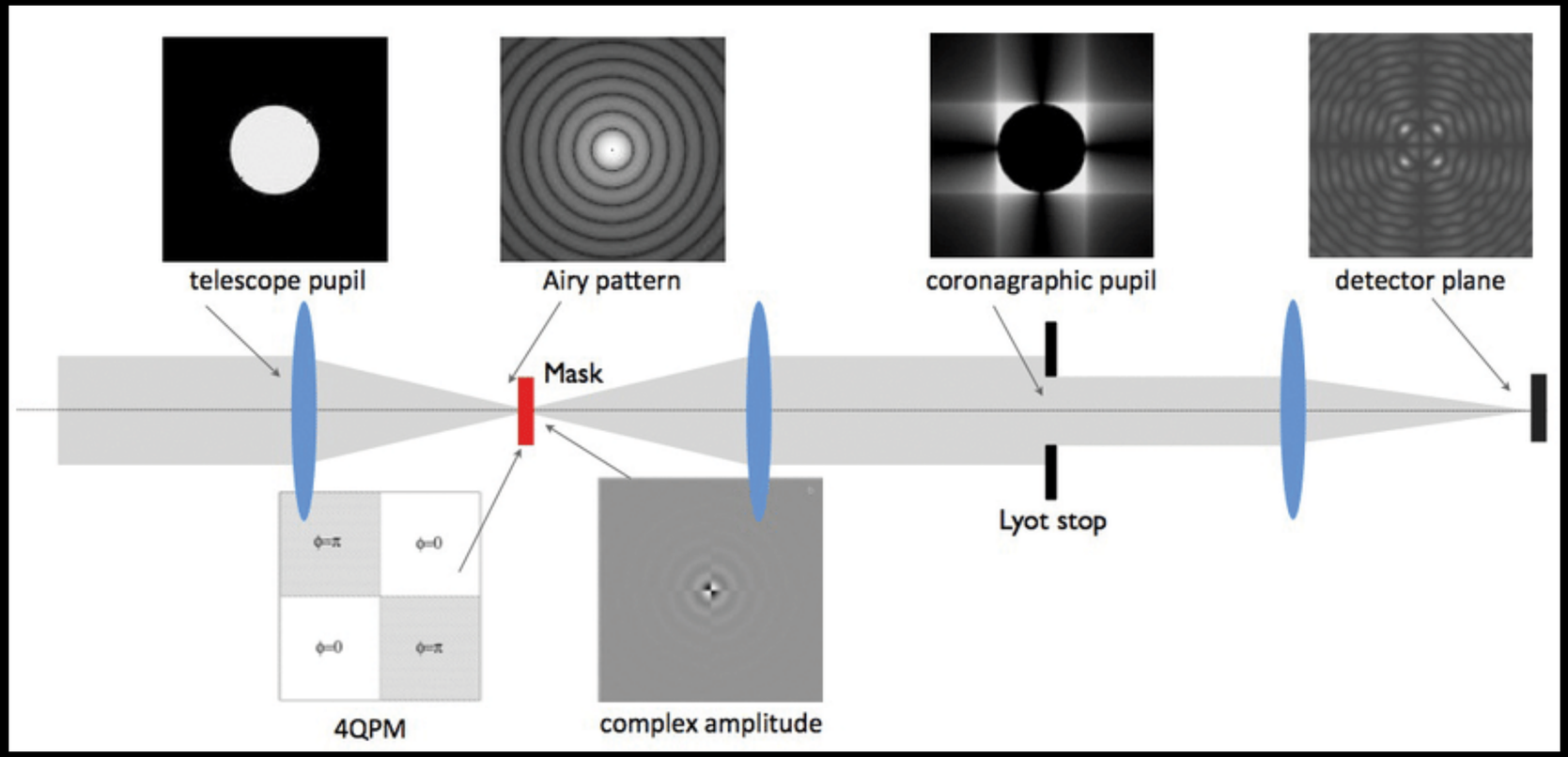


Full intensity distribution After coronagraph After Lyot stop

Lyot Coronagraph

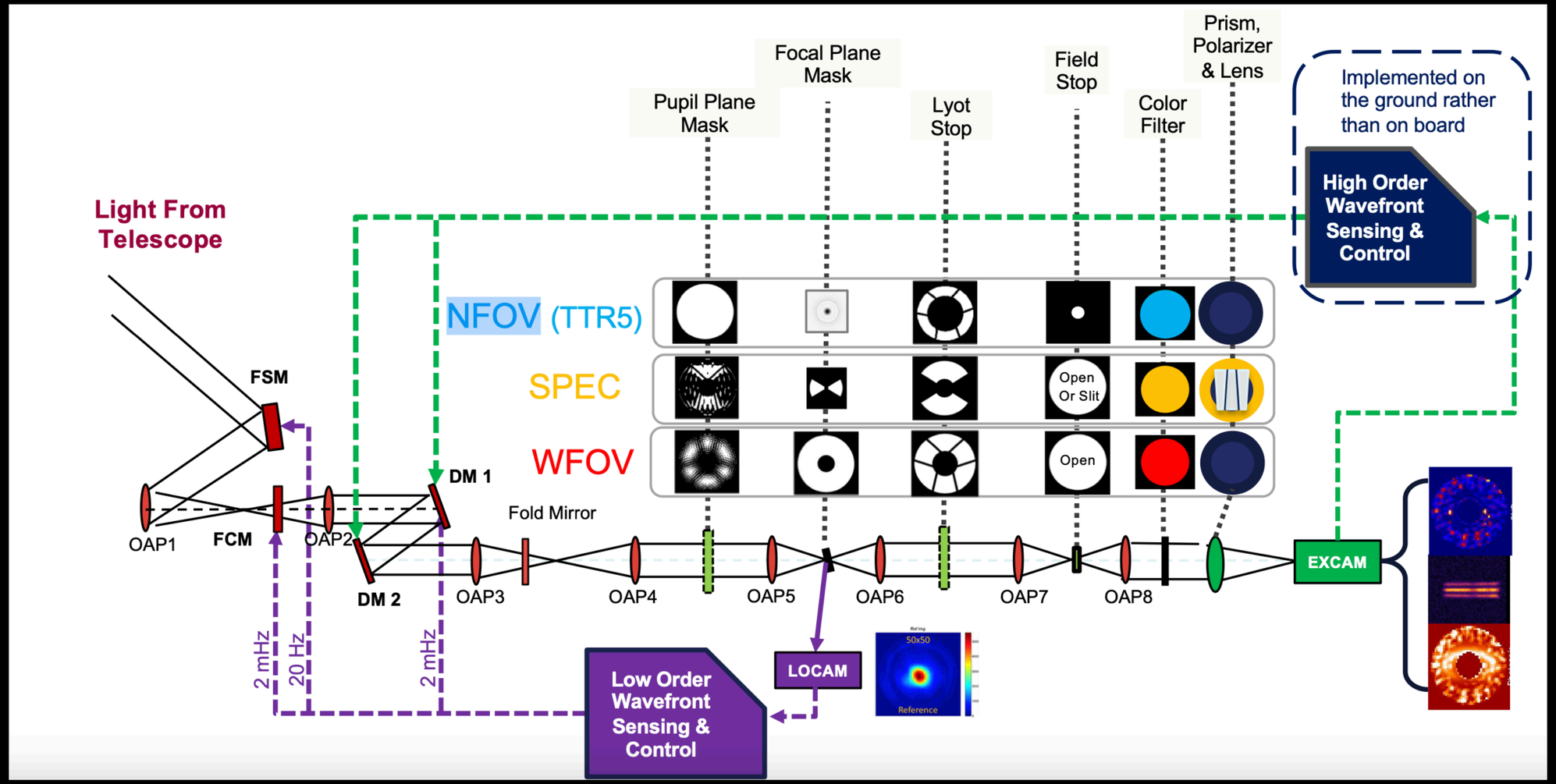
How does a coronagraph work?



Boccaletti+2015

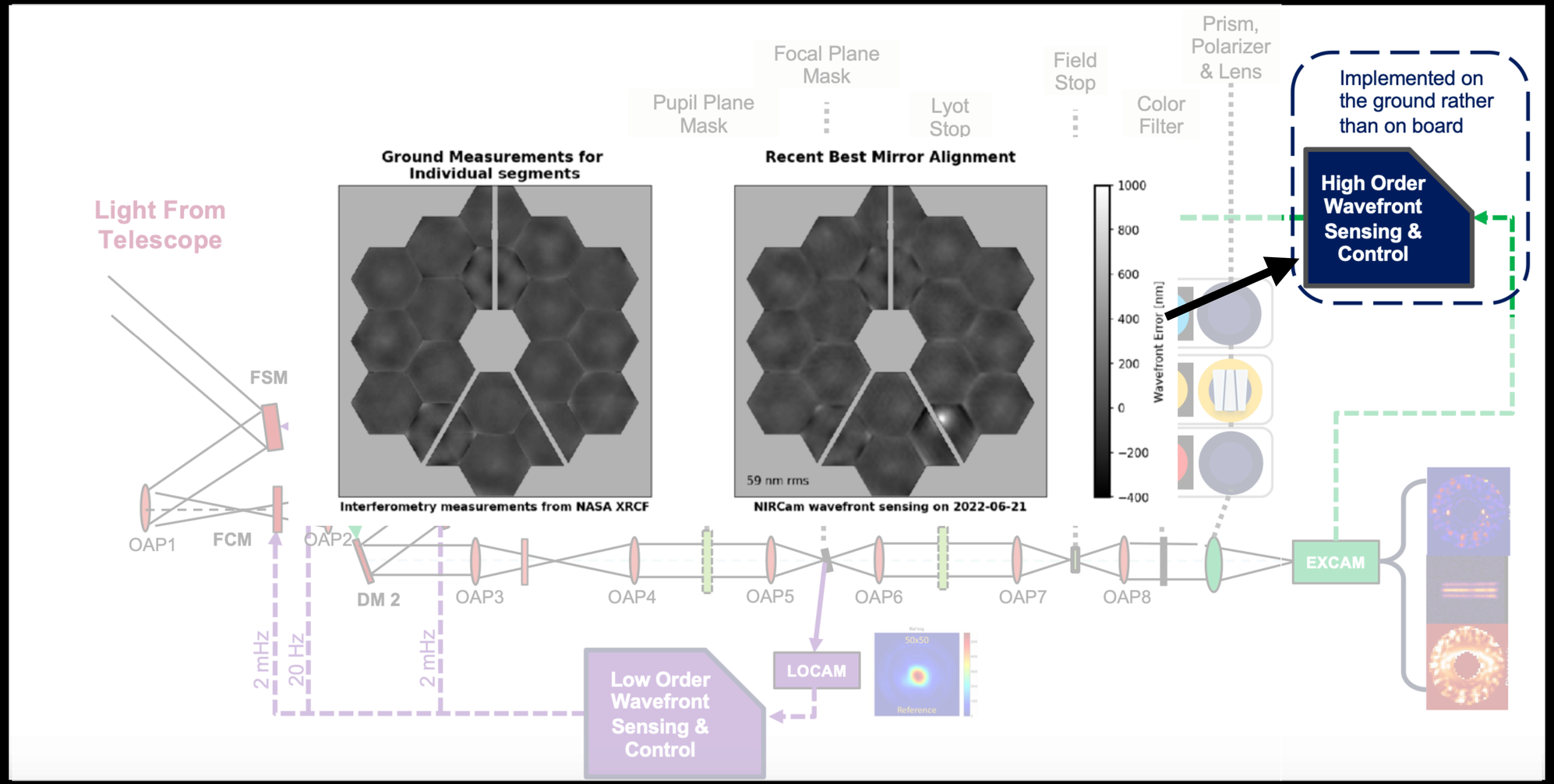
Phase Mask Coronagraph

How does a coronagraph work?



Roman Space Telescope coronagraph

How does a coronagraph work?



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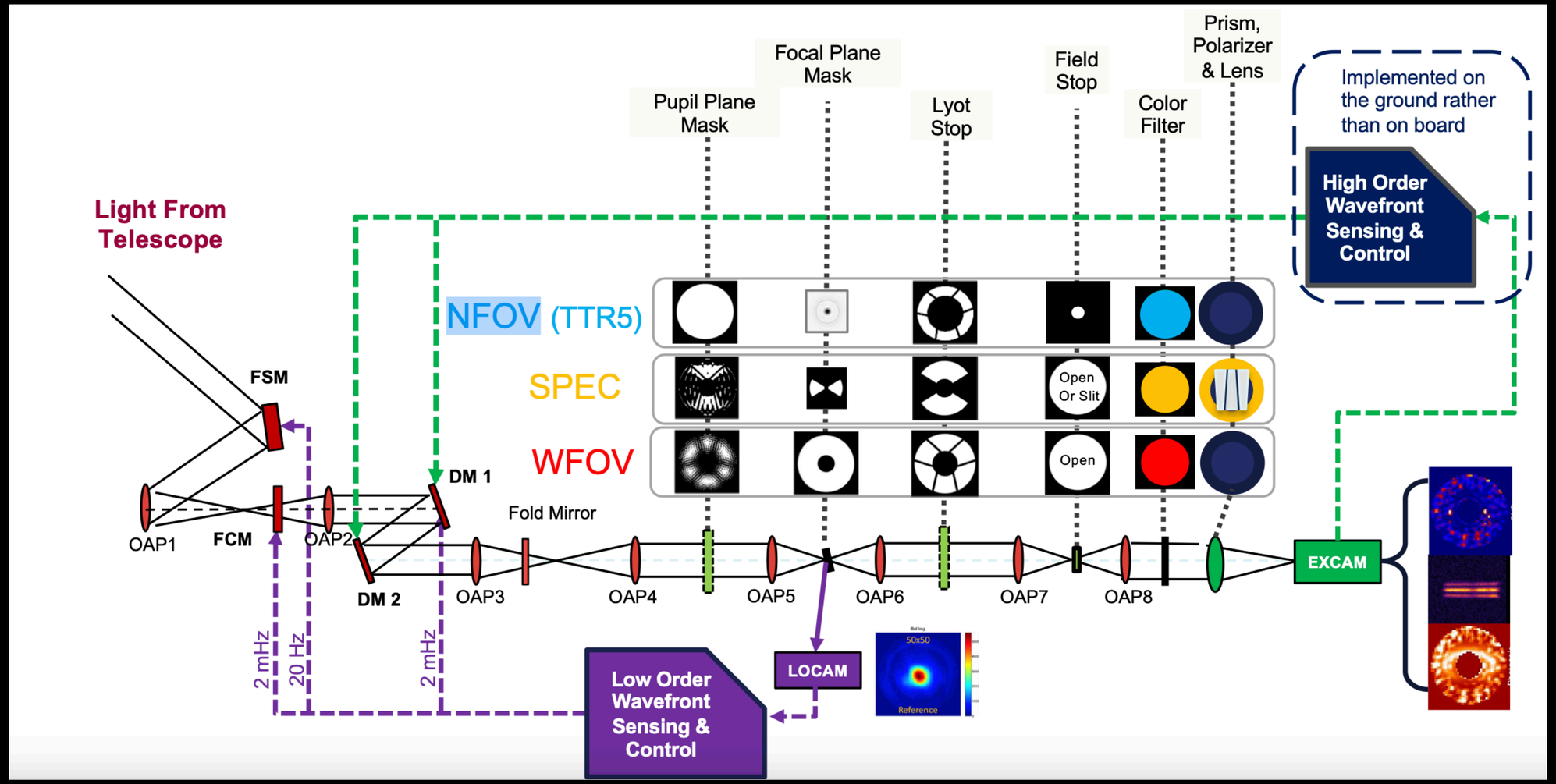

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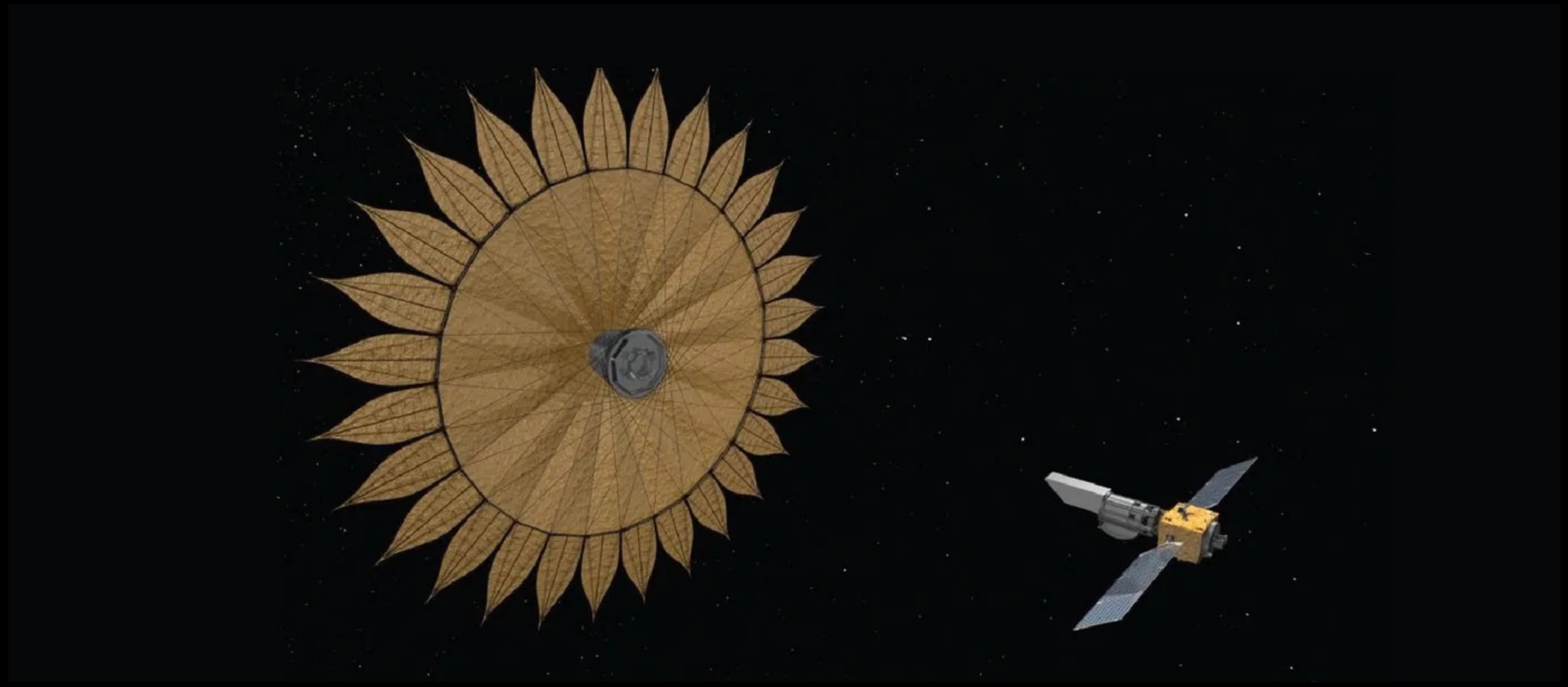

Starshade concept

How does a coronagraph work?

How does a coronagraph work?

Proba-3

The coronagraphs in JWST

Cycle 2

Instrument	Mode	Prime %	Coordinated Parallel %	Total (Prime + Coordinated parallels)	Instrument Prime Usage (all modes)	Instrument Prime + Coordinated Parallel Usage (all modes)	Pure Parallels
MIRI	MIRI Coronography MIRI Imaging MIRI LRS MIRI MRS	0.9% 8.6% 6.1% 17.6%	2%	0.8% 7.8% 5.4% 15.6%	33.1%	29.6%	
NIRCam	NIRCam Coronography NIRCam GrismTimeSeries NIRCam Imaging NIRCAM TimeSeries NIRCam WFSS	2.1% 0% 11.5% 0% 3.4%	24.2% 19.6%	1.8% 0% 12.9% 0% 5.2%	16.9%	19.9%	49.4%
NIRISS	NIRISS Imaging NIRISS AMI NIRISS SOSS NIRISS WFSS	0% 0% 2.1% 1.3%	9.6%	0% 0% 1.9% 2.2%	3.4%	4.1%	50.6%
NIRSpec	NIRSpec BrightObjectTimeSeries NIRSpec FixedSlitSpectroscopy NIRSpec IFUSpectroscopy NIRSpec MOS	17% 4.2% 17.6% 7.9%	44.6%	15.1% 3.7% 15.6% 12%	46.6%	46.4%	

Imaging 23.4% vs 76.6% Spectroscopy

The coronagraphs in JWST

Cycle 2

Instrument	Mode	Prime %	Coordinated Parallel %	Total (Prime + Coordinated parallels)	Instrument Prime Usage (all modes)	Instrument Prime + Coordinated Parallel Usage (all modes)	Pure Parallels
MIRI	MIRI Coronography	0.9%	2%	0.8%	33.1%	29.6%	
	MIRI Imaging	8.6%		7.8%			
	MIRI LRS	6.1%		5.4%			
	MIRI MRS	17.6%		15.6%			
NIRCam	NIRCam Coronography	2.1%	24.2%	1.8%	16.9%	19.9%	49.4%
	NIRCam GrismTimeSeries	0%		0%			
	NIRCam Imaging	11.5%		12.9%			
	NIRCAM TimeSeries	0%		0%			
	NIRCam WFSS	3.4%	19.6%	5.2%			
NIRISS	NIRISS Imaging	0%	9.6%	0%	3.4%	4.1%	50.6%
	NIRISS AMI	0%		0%			
	NIRISS SOSS	2.1%		1.9%			
	NIRISS WFSS	1.3%		2.2%			
NIRSpec	NIRSpec BrightObjectTimeSeries	17%	44.6%	15.1%	46.6%	46.4%	
	NIRSpec FixedSlitSpectroscopy	4.2%		3.7%			
	NIRSpec IFUSpectroscopy	17.6%		15.6%			
	NIRSpec MOS	7.9%		12%			

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The coronagraphs in JWST

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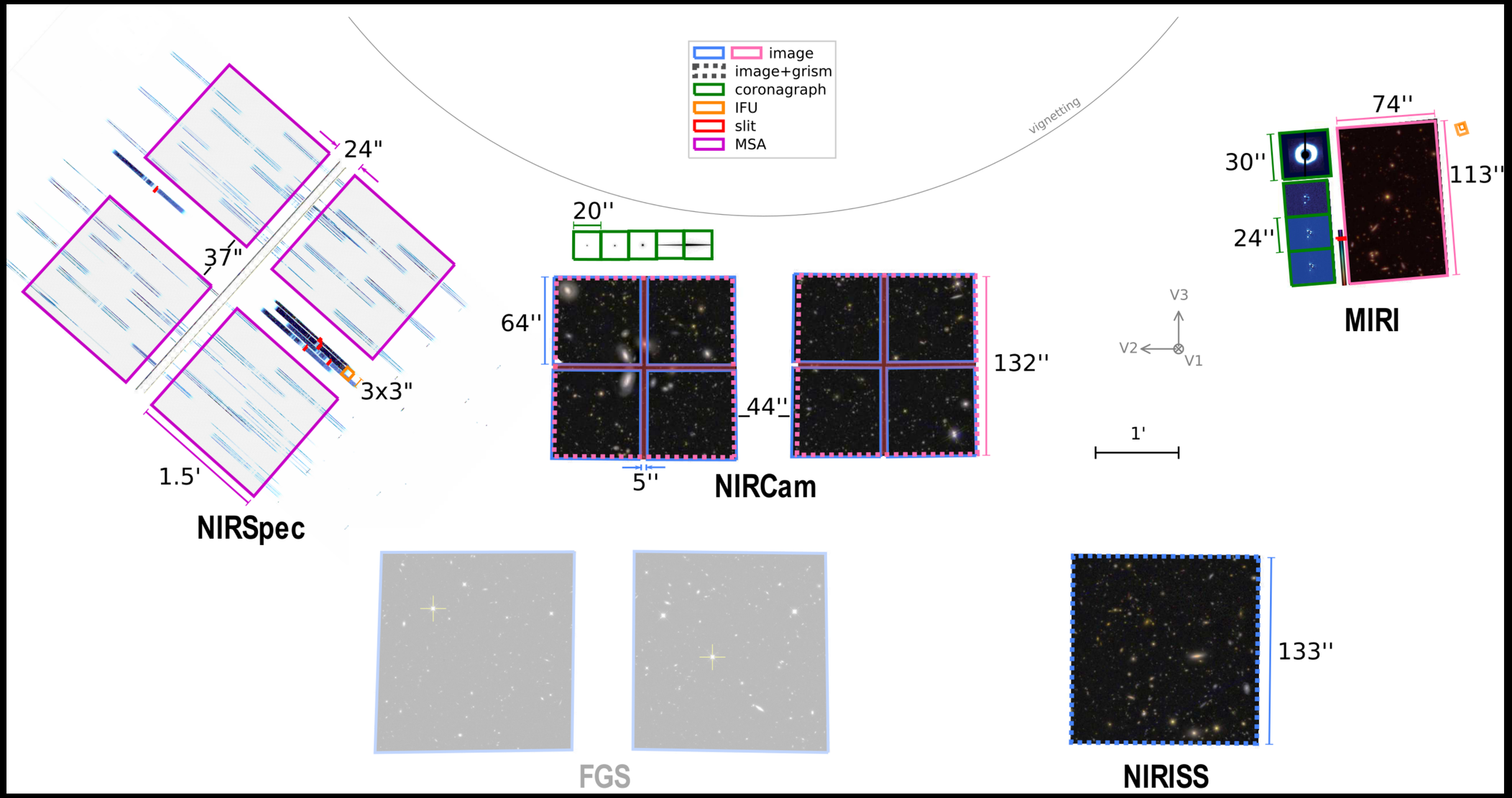
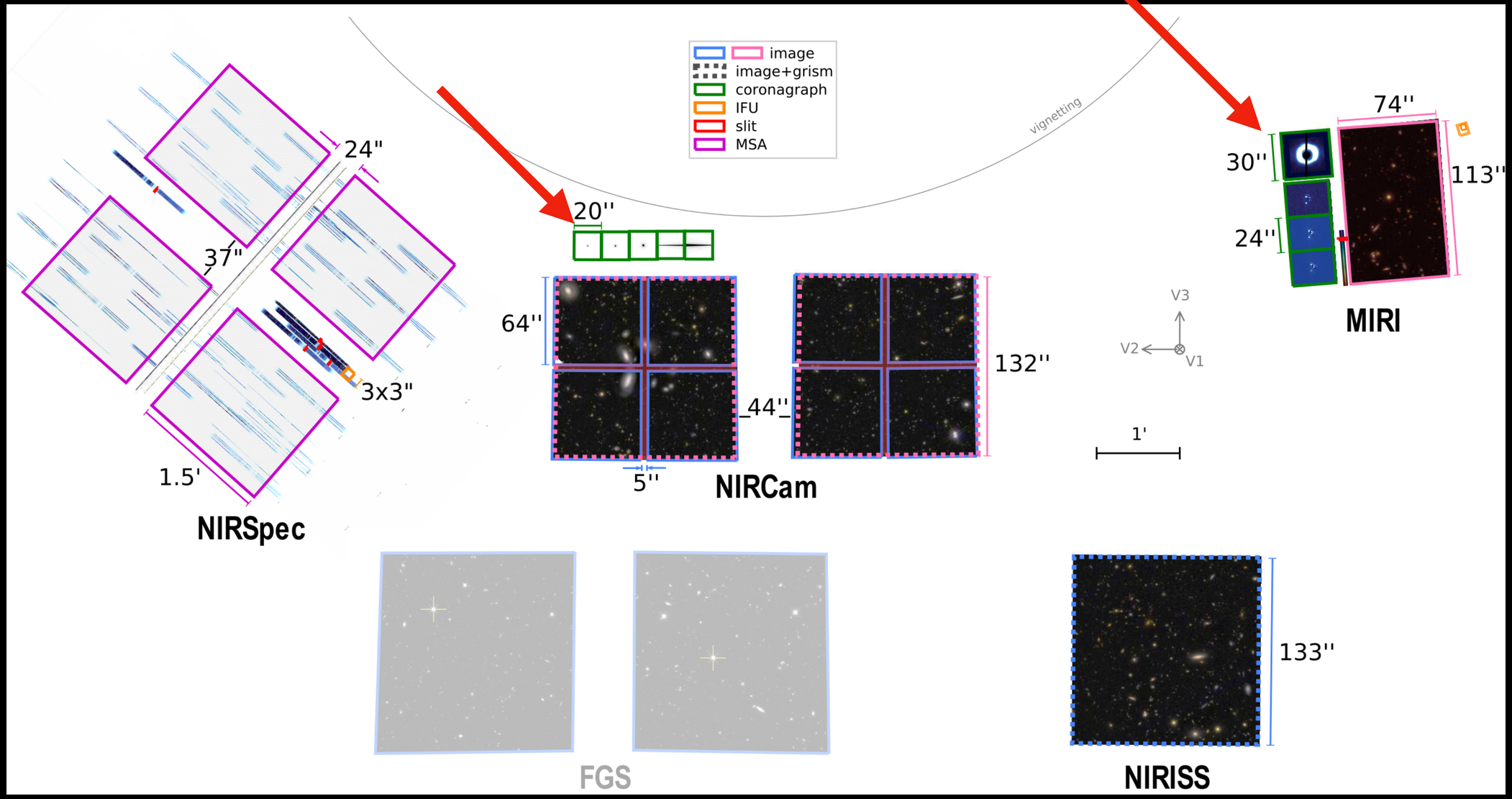
	MIRI MRS	17.6%		15.6%			
NIRCam	NIRCam Coronography	2.1%	24.2%	1.8%	16.9%	19.9%	49.4%
	NIRCam GrismTimeSeries	0%		0%			
	NIRCam Imaging	11.5%		12.9%			
	NIRCAM TimeSeries	0%		0%			
	NIRCam WFSS	3.4%	19.6%	5.2%			
NIRISS	NIRISS Imaging	0%	9.6%	0%	3.4%	4.1%	50.6%
	NIRISS AMI	0%		0%			
	NIRISS SOSS	2.1%		1.9%			
	NIRISS WFSS	1.3%		2.2%			
NIRSpec	NIRSpec BrightObjectTimeSeries	17%	44.6%	15.1%	46.6%	46.4%	
	NIRSpec FixedSlitSpectroscopy	4.2%		3.7%			
	NIRSpec IFUSpectroscopy	17.6%		15.6%			
	NIRSpec MOS	7.9%		12%			

Imaging 23.4% vs 76.6% Spectroscopy

The coronagraphs in JWST



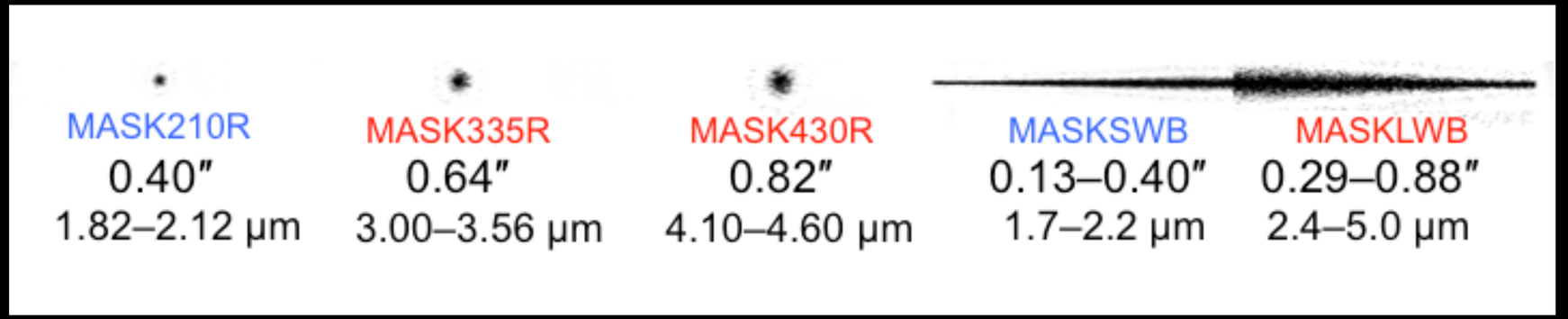
The coronagraphs in JWST



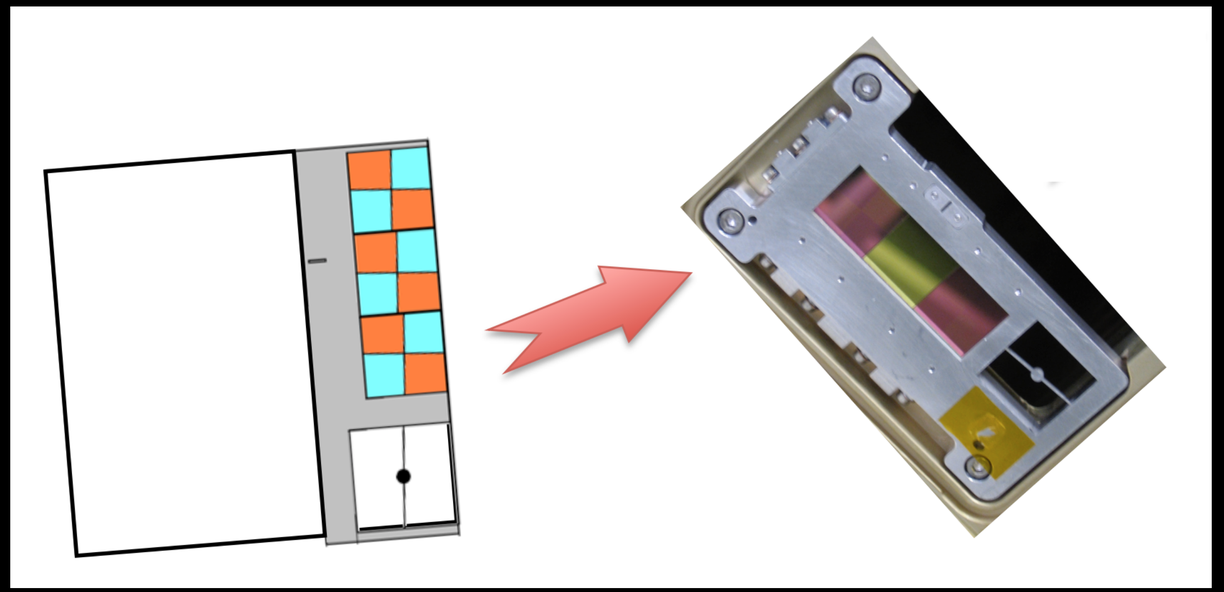
The coronagraphs in JWST

NIRCam coronagraphs

The coronagraphs in JWST

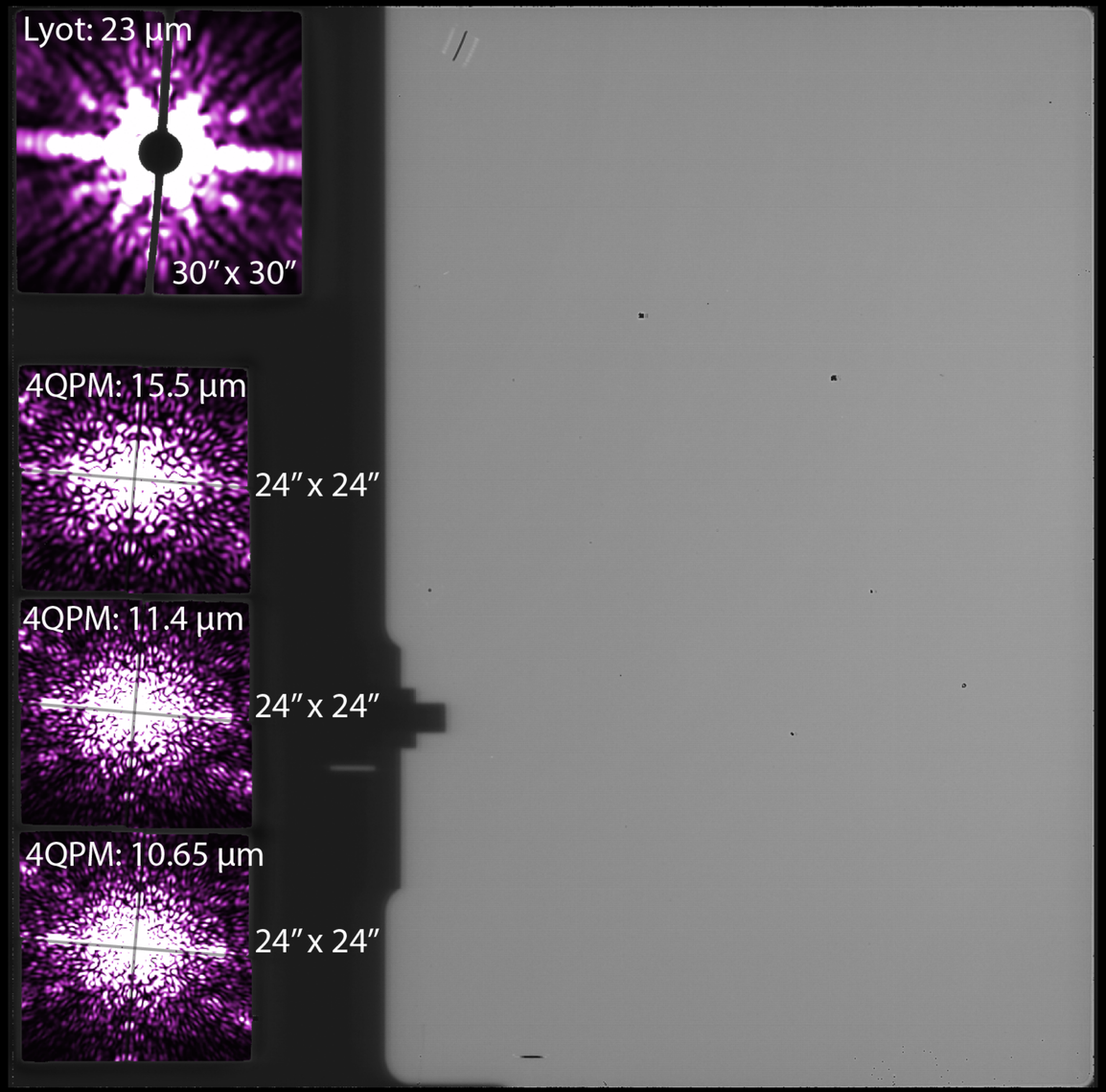


NIRCam coronagraphs

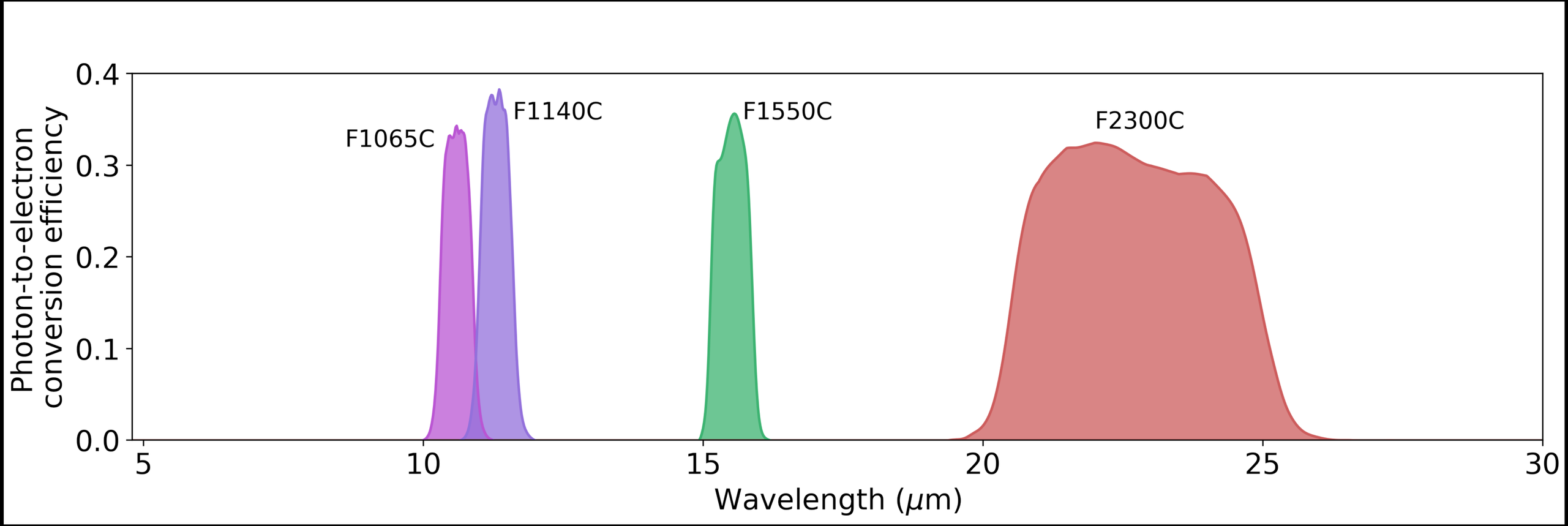


MIRI coronagraphs

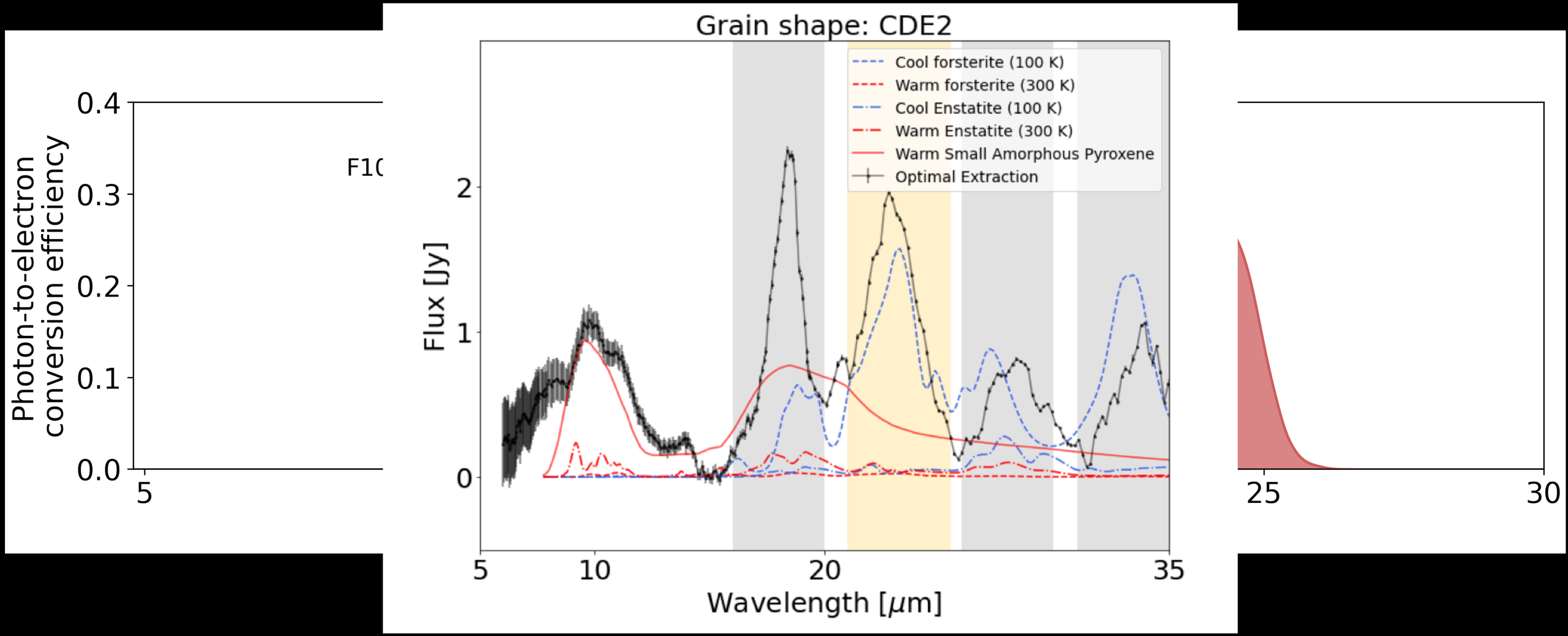
The coronagraphs in JWST: MIRI



The coronagraphs in JWST: MIRI

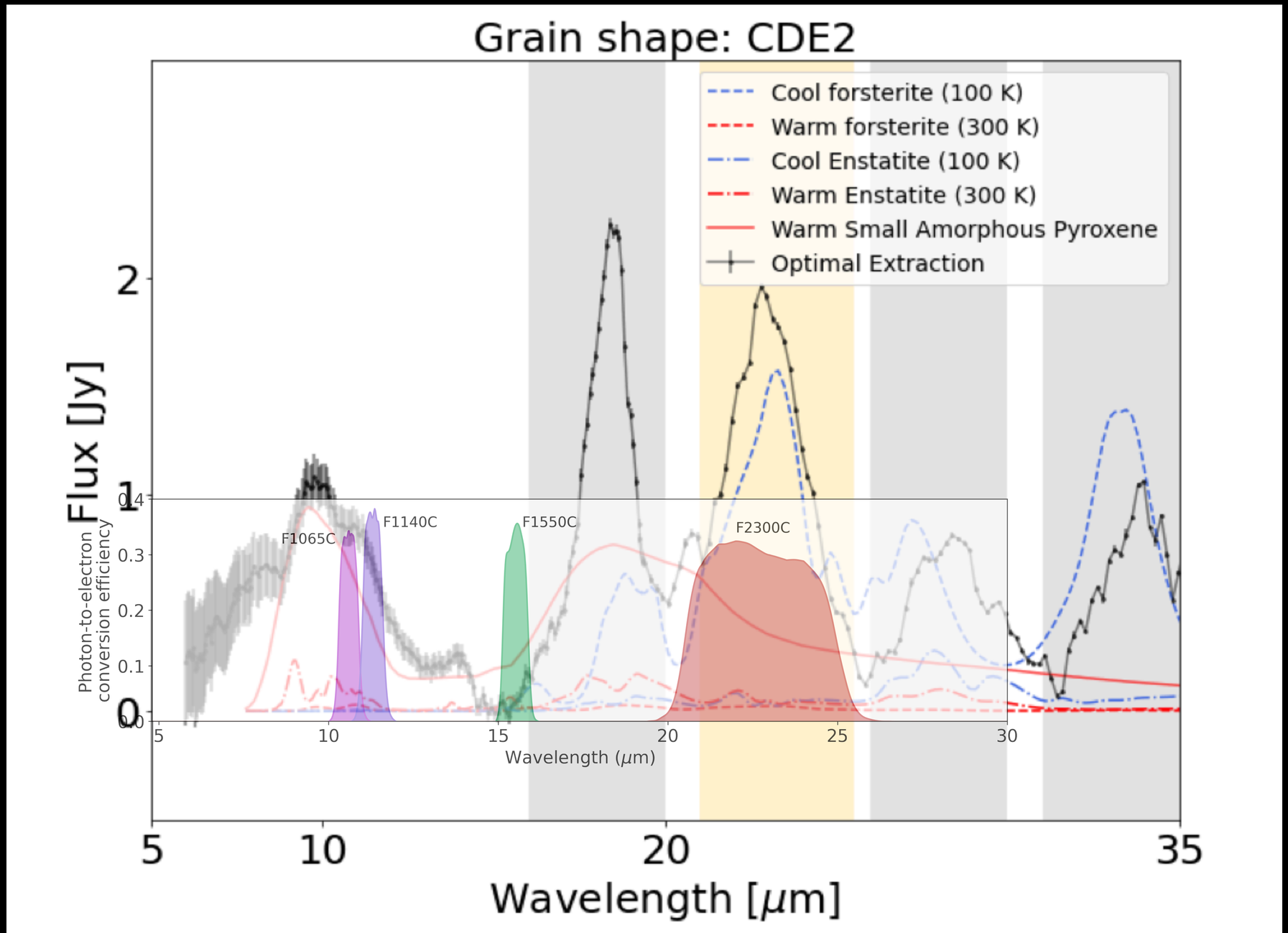


The coronagraphs in JWST: MIRI

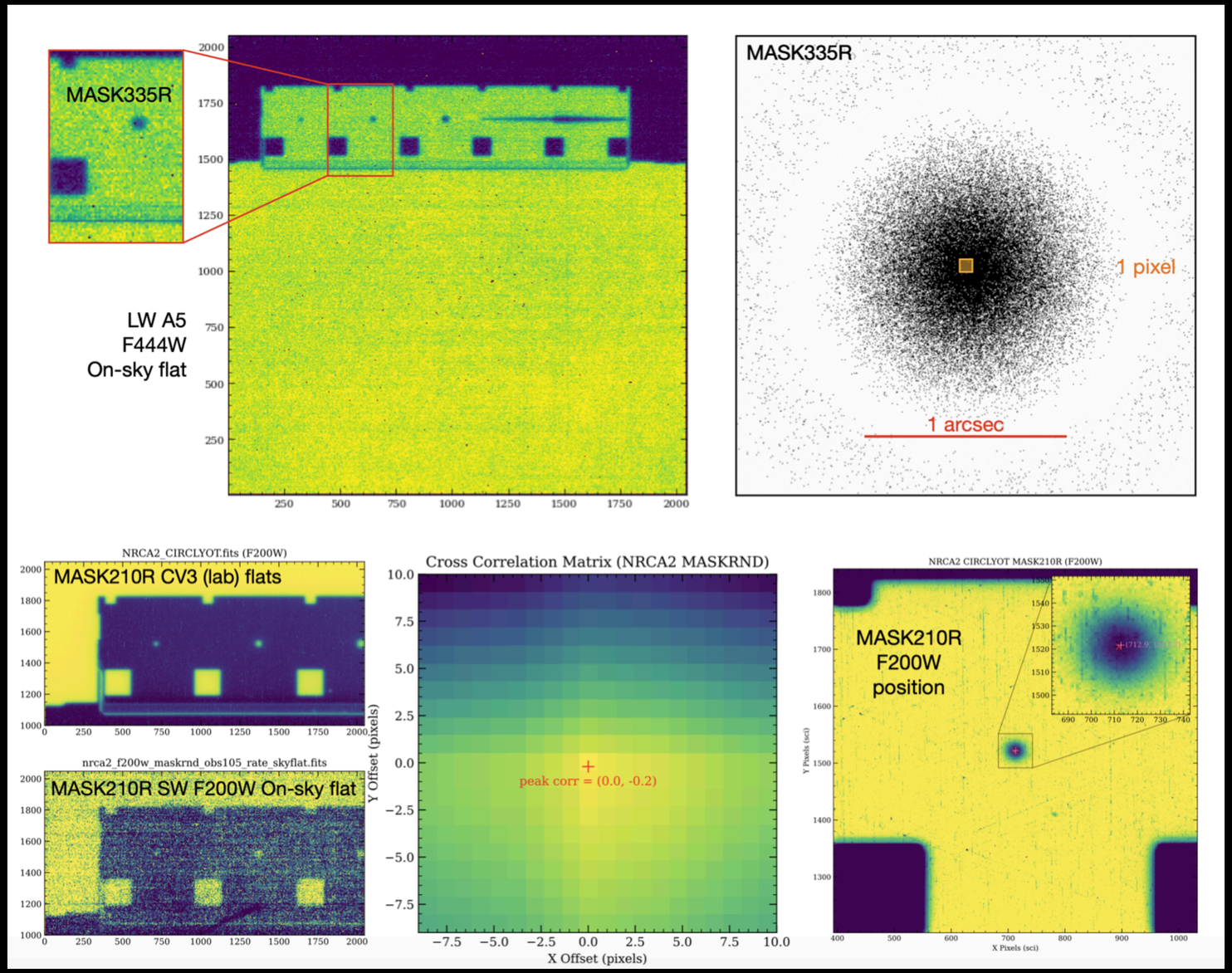


C. Lu+22

The coronagraphs in JWST: MIRI



The coronagraphs in JWST: NIRCam



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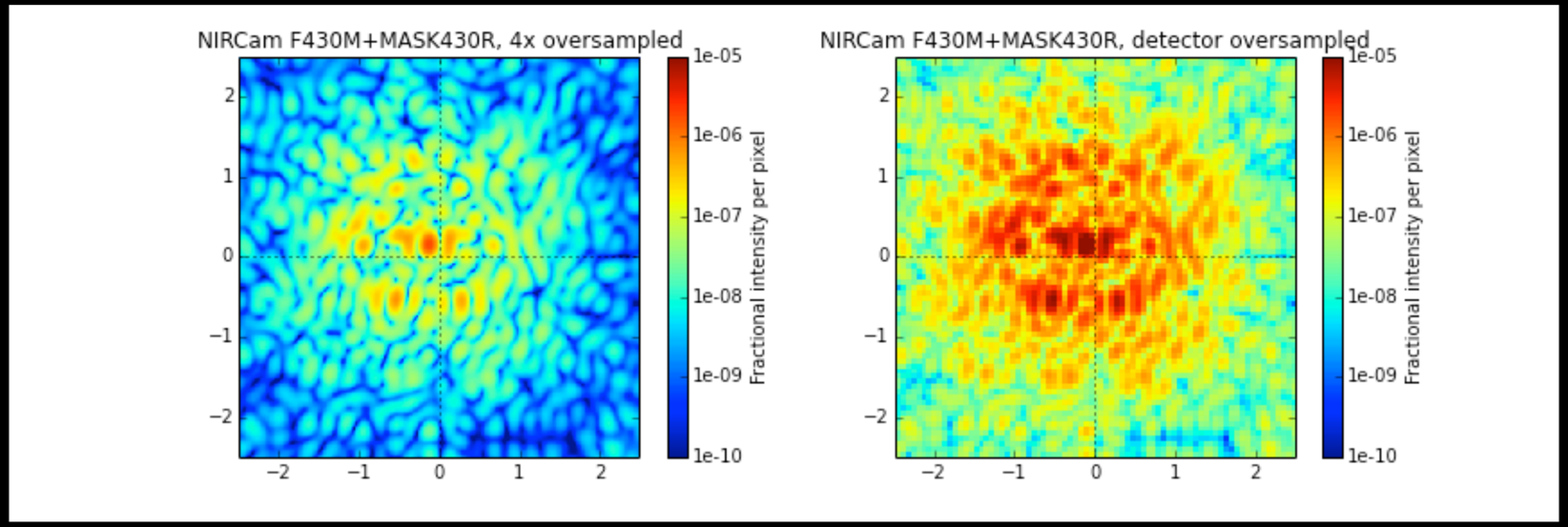
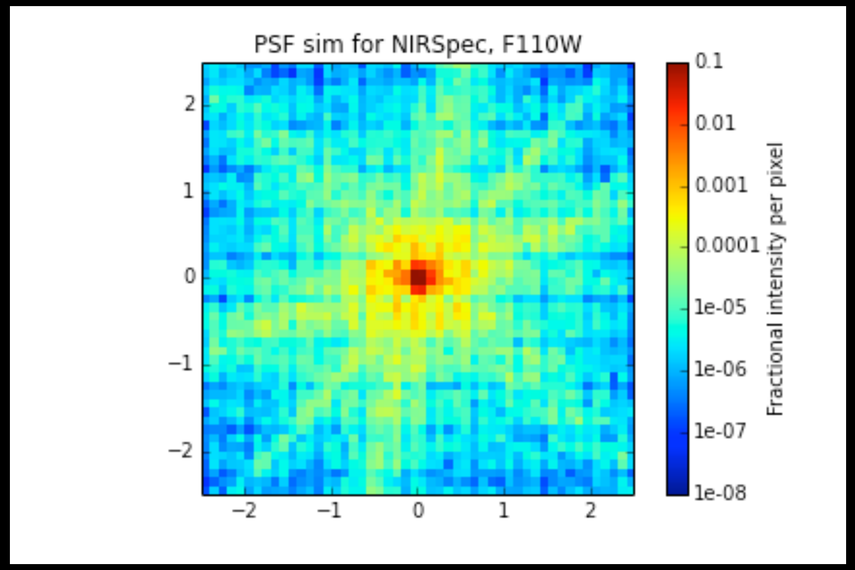
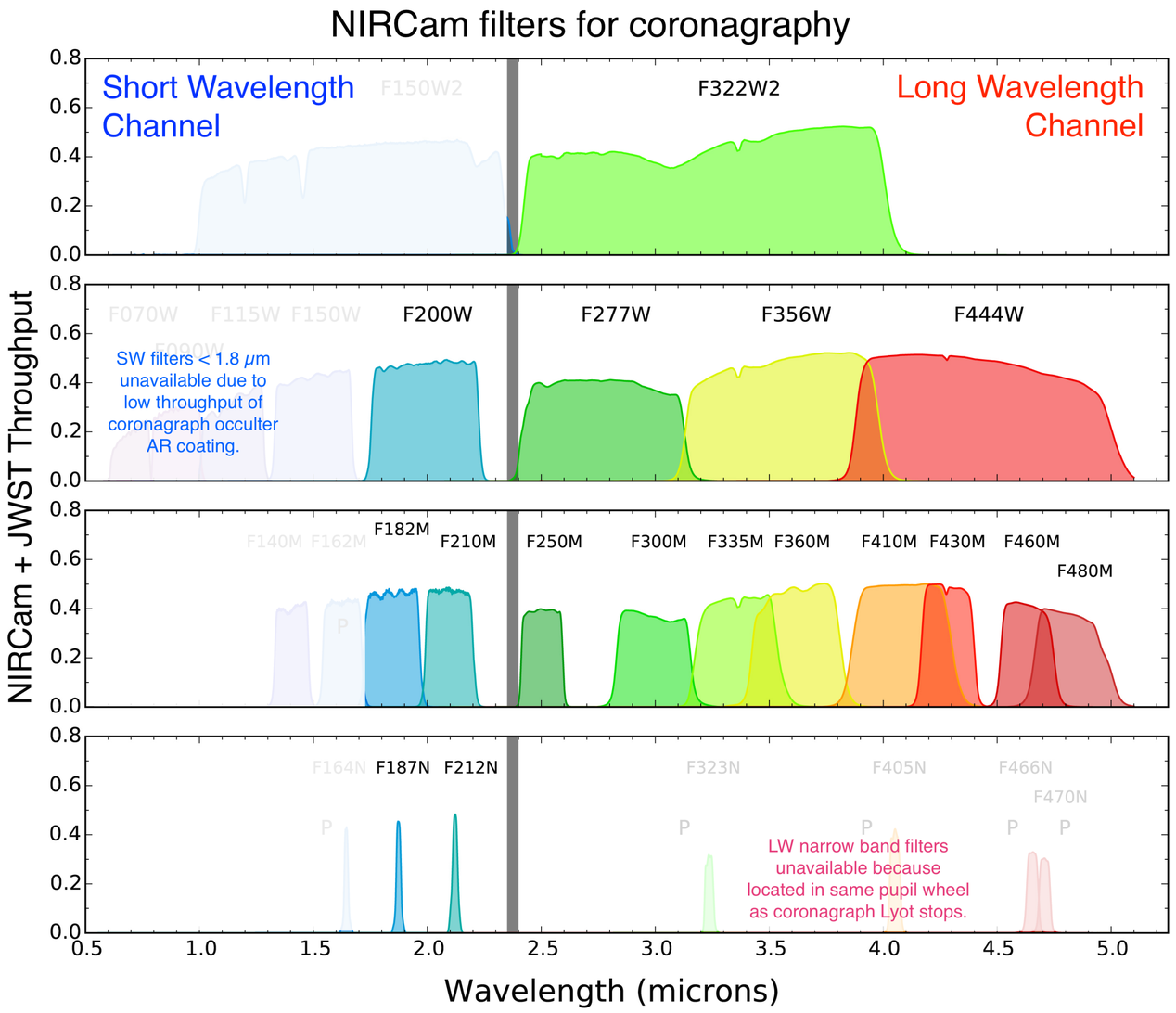
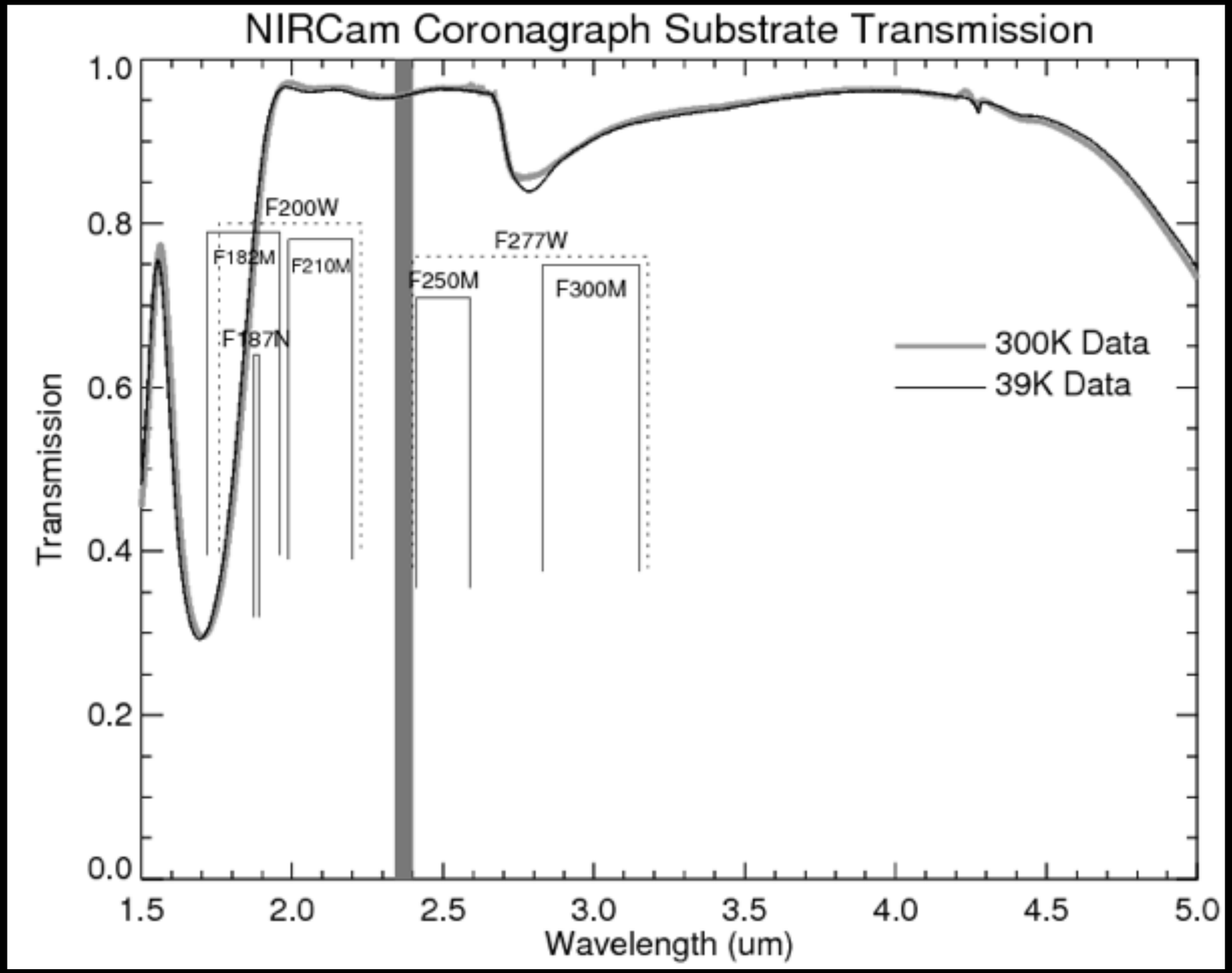




The coronagraphs in JWST: NIRCam

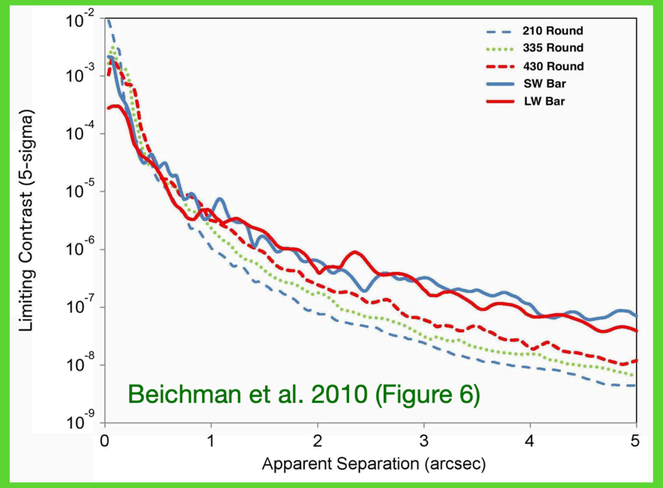


The coronagraphs in JWST: NIRCam

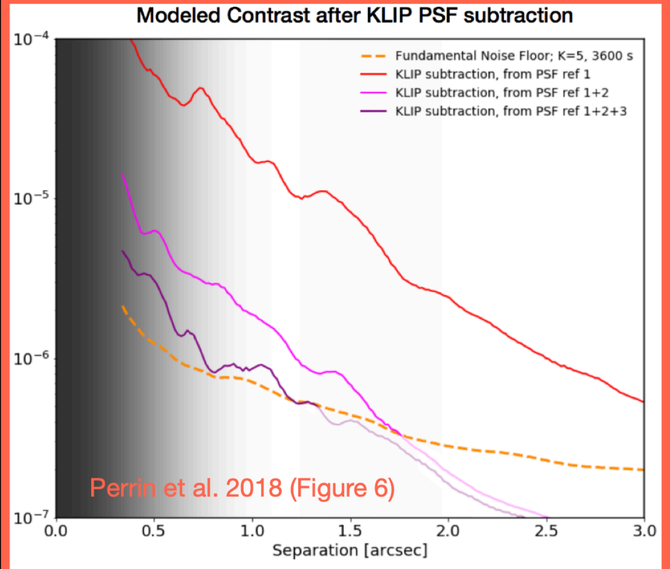


The coronagraphs in JWST: NIRCam

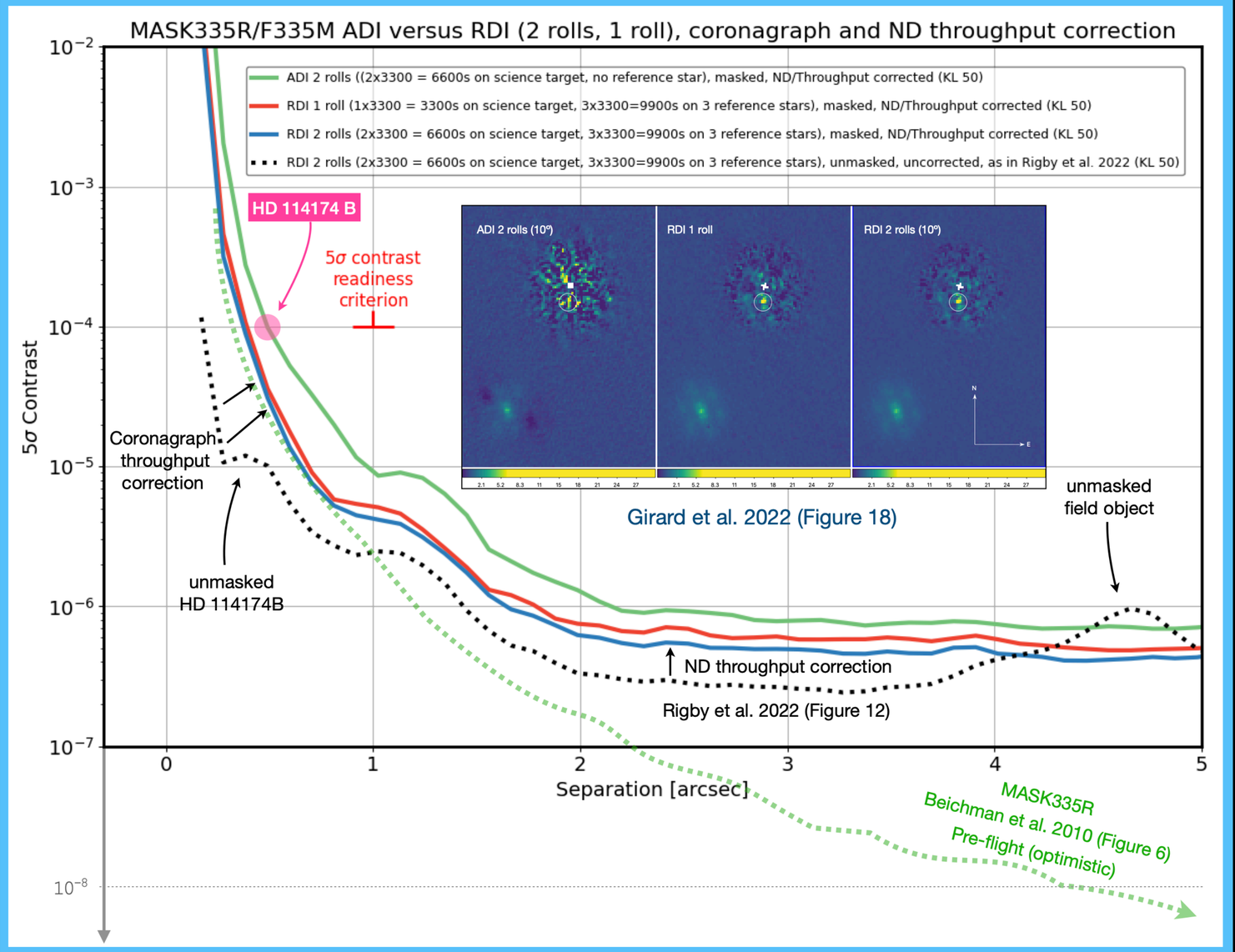
Pre-flight contrast curves



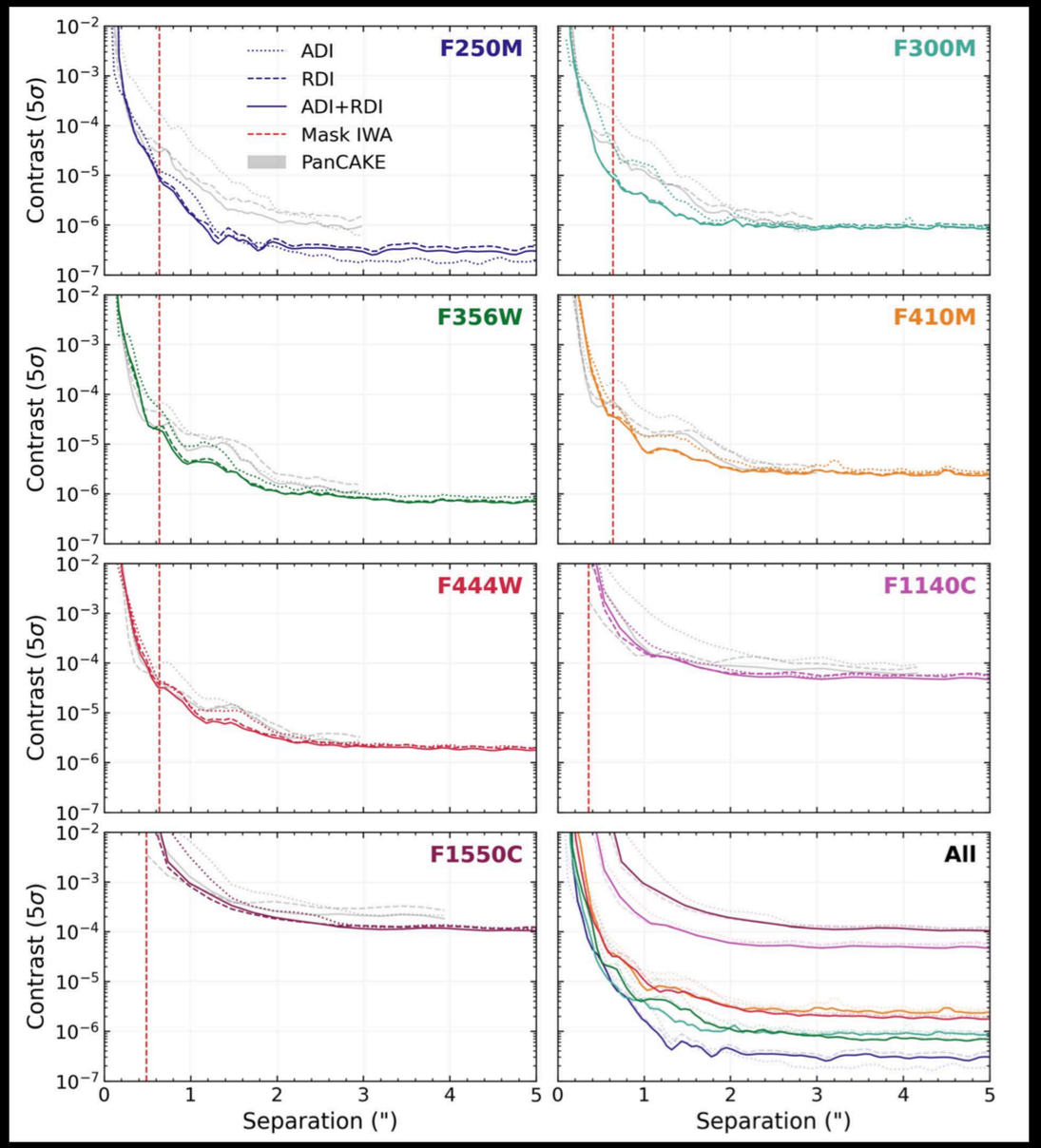
Pre-flight contrast curves



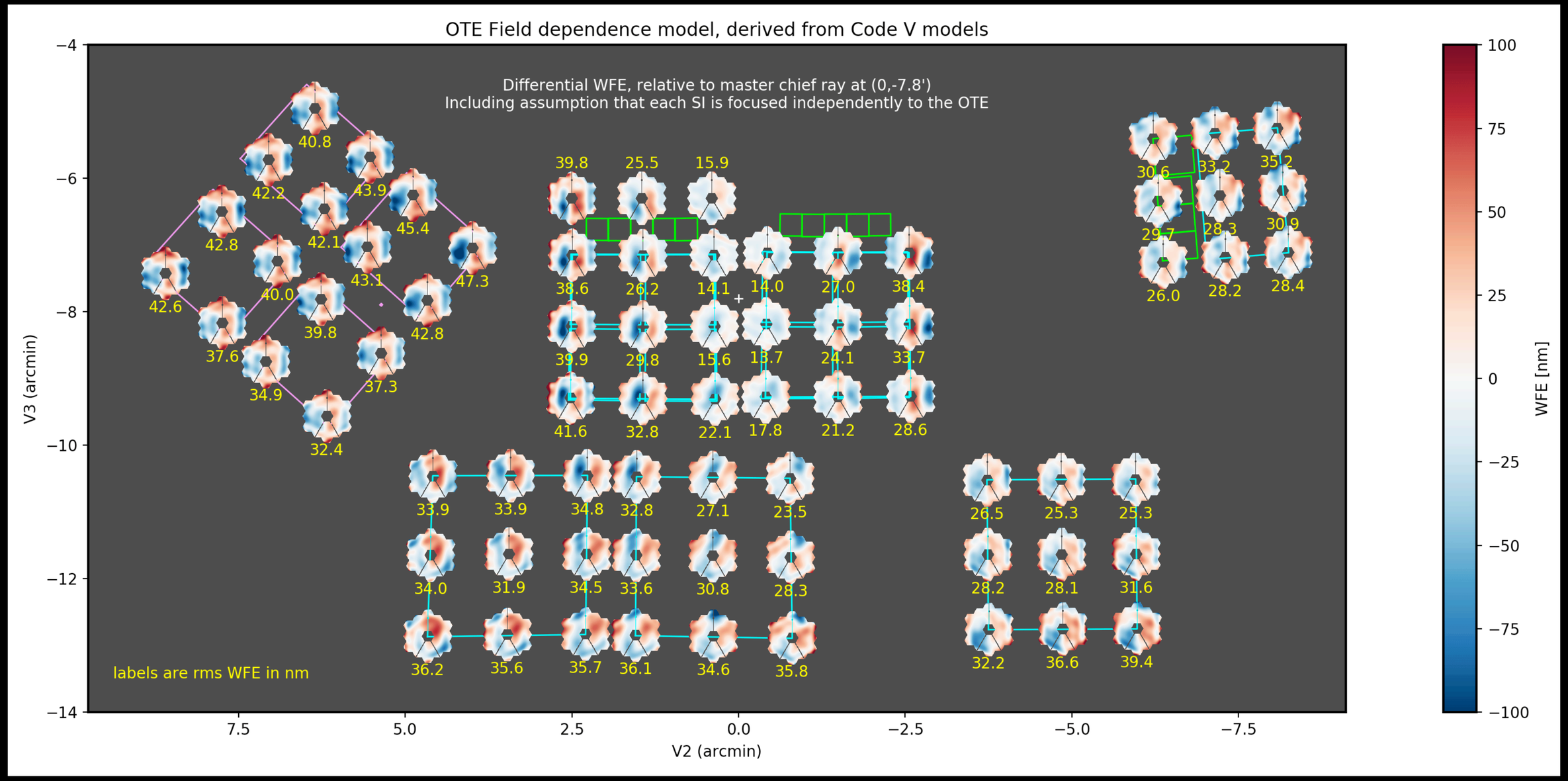
Flight (commissioning) contrast curve



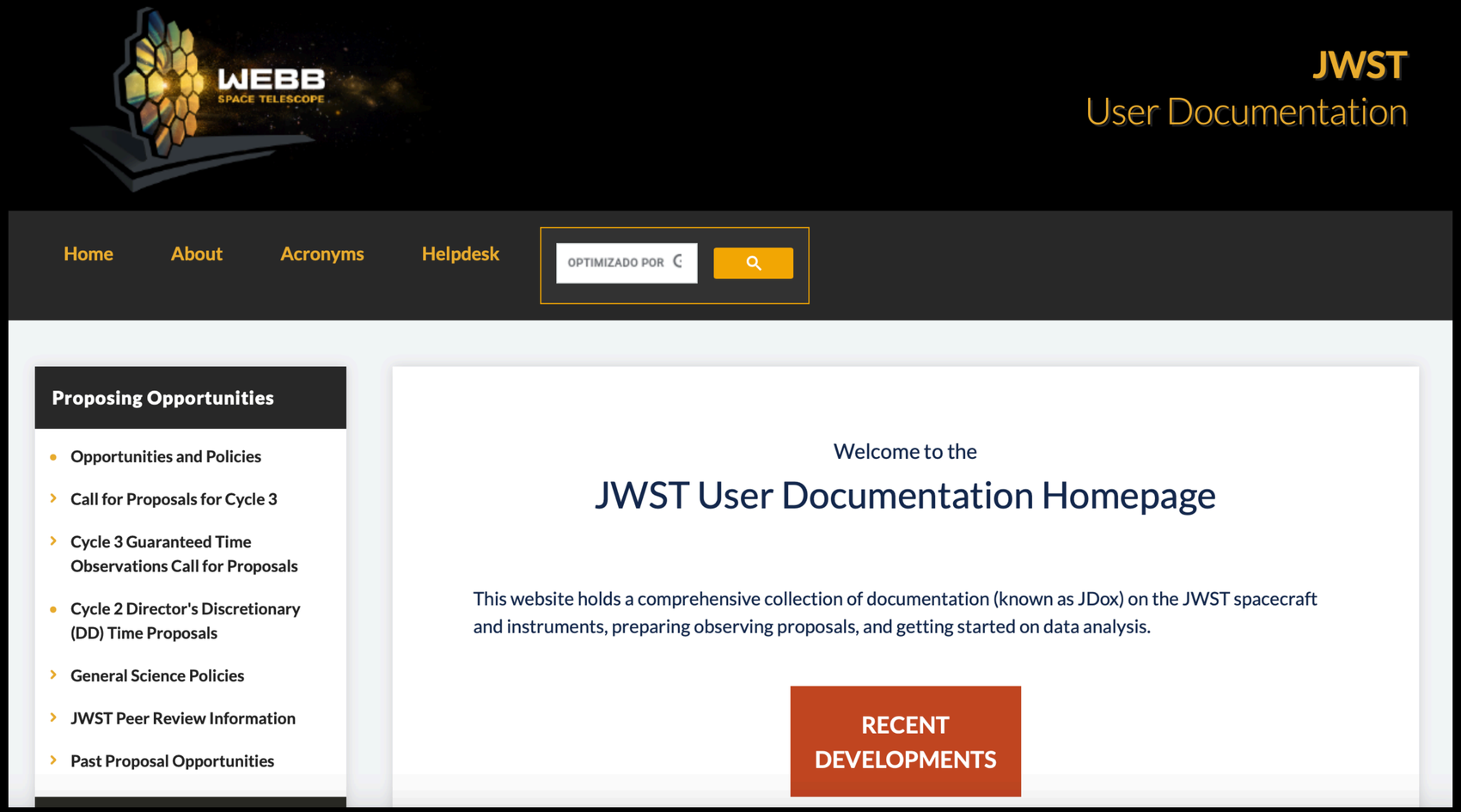
The coronagraphs in JWST: NIRCam



The coronagraphs in JWST: Wavefront control



How the data reduction works



https://jwst-docs.stsci.edu/

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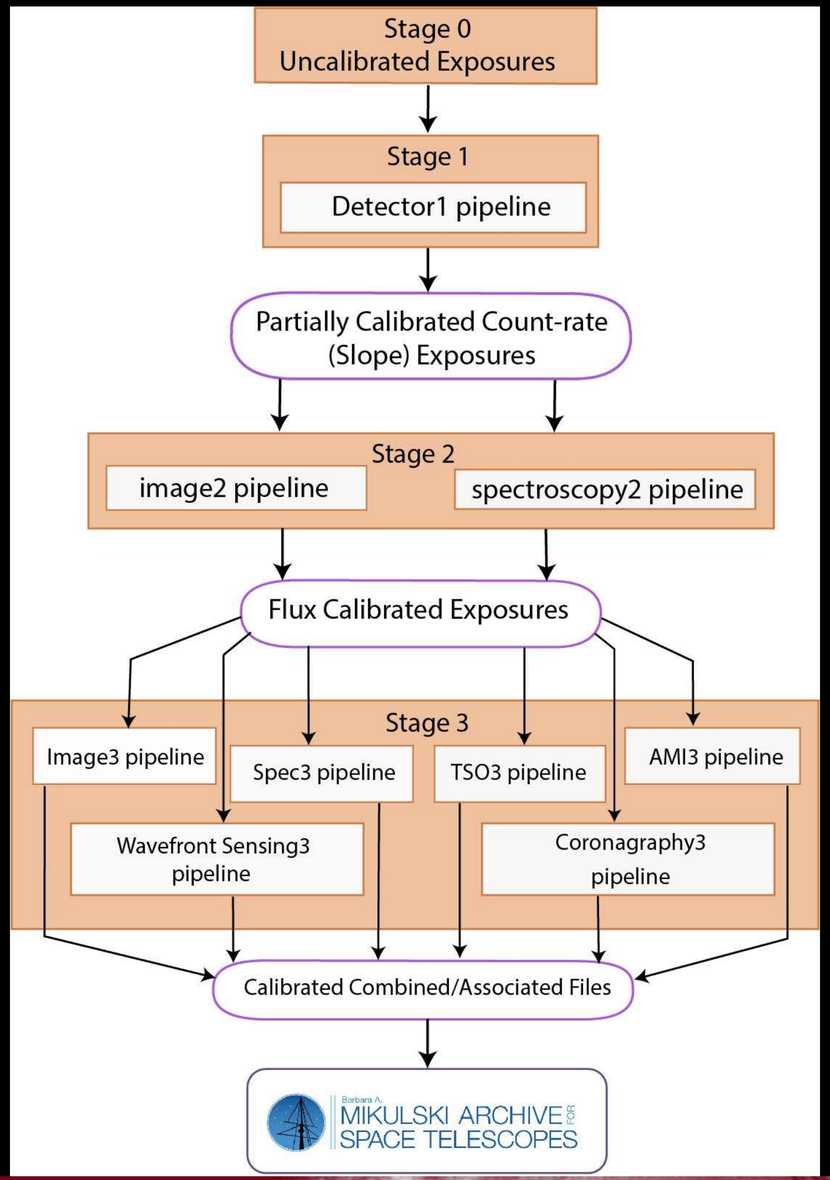

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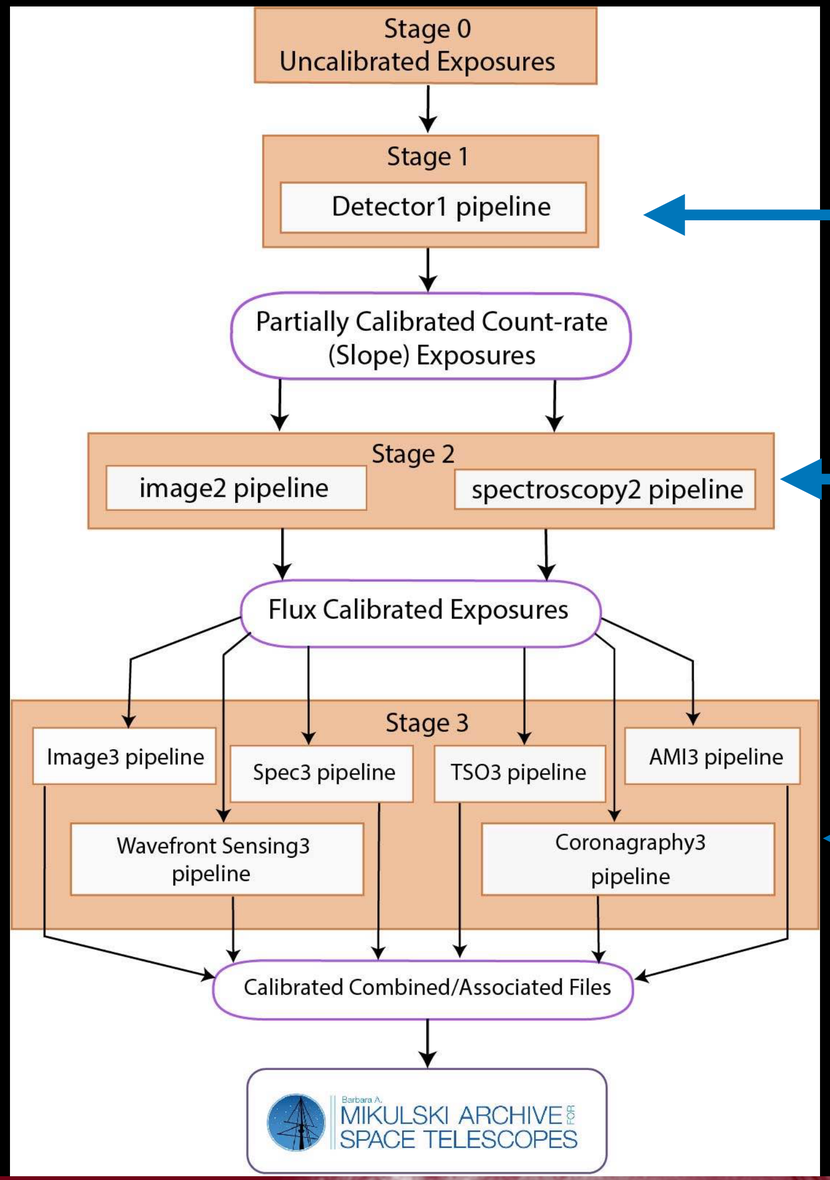
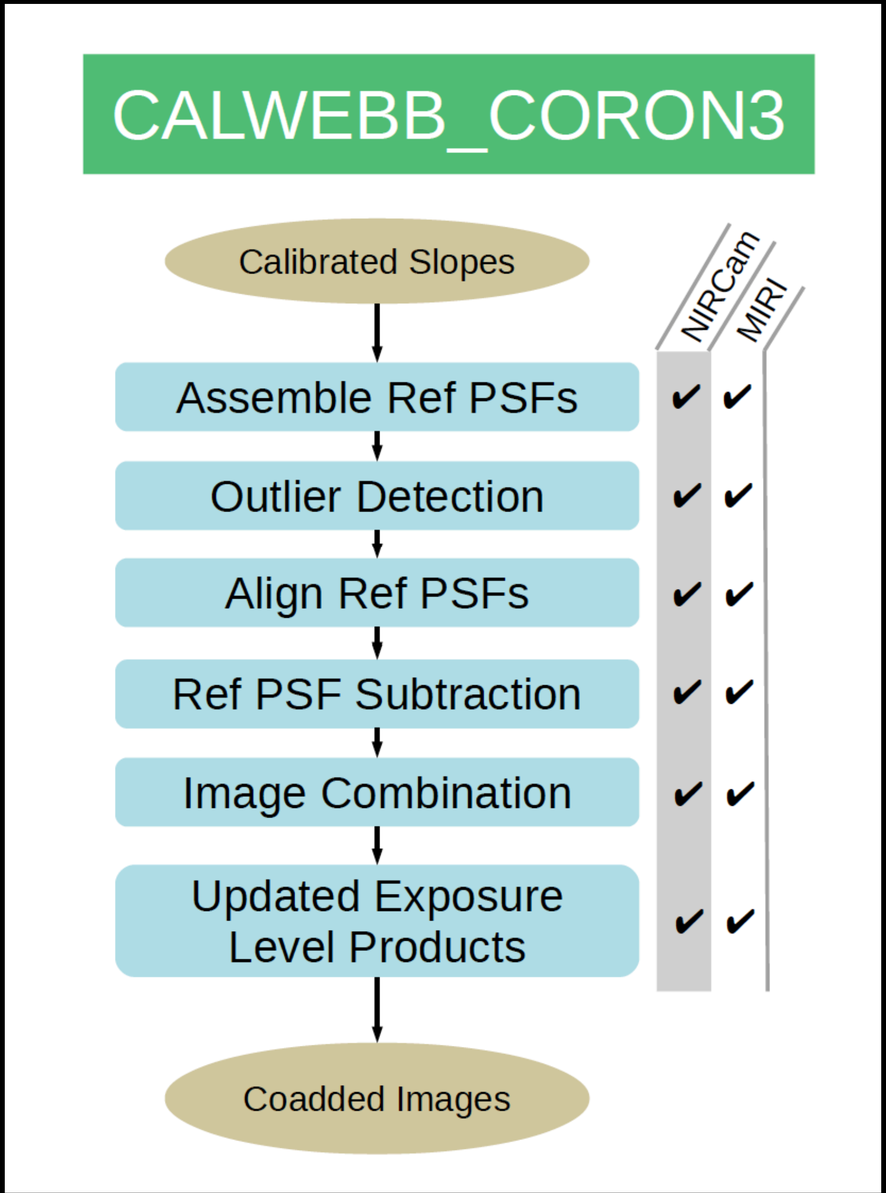


Count rate images, bad pixel correction, other detector level corrections

Calibration of physical units, flat fielding correction, etc

Combination of exposures, final science images

How the data reduction works



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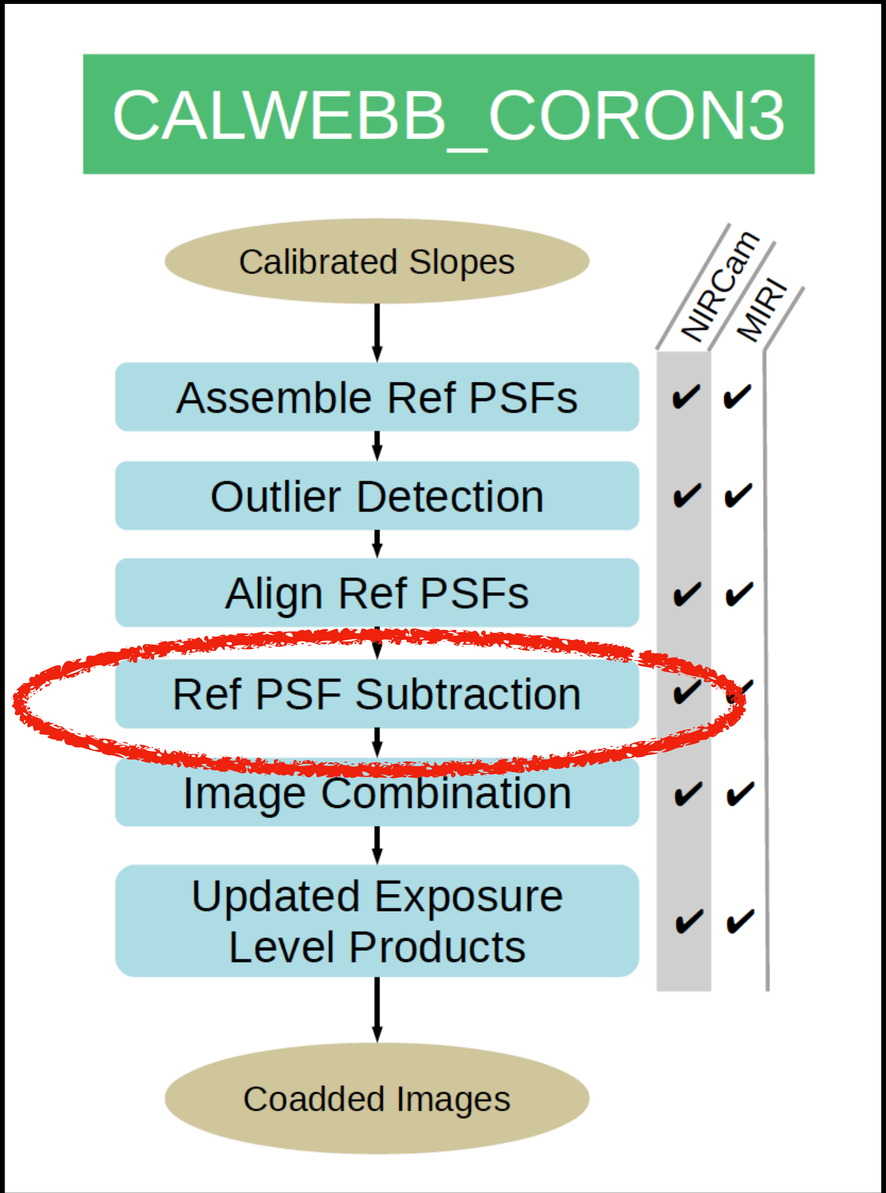
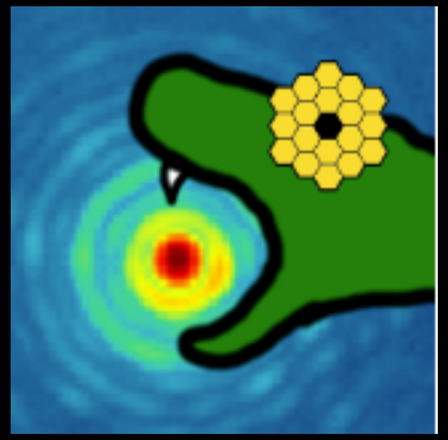


spaceKLIP

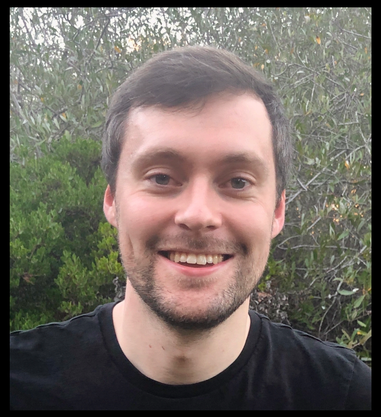


SpaceKLIP is a data reduction pipeline for JWST high-contrast imaging.

https://github.com/kammerje/spaceKLIP

Marshall Perrin

Jens Kammerer
ESO



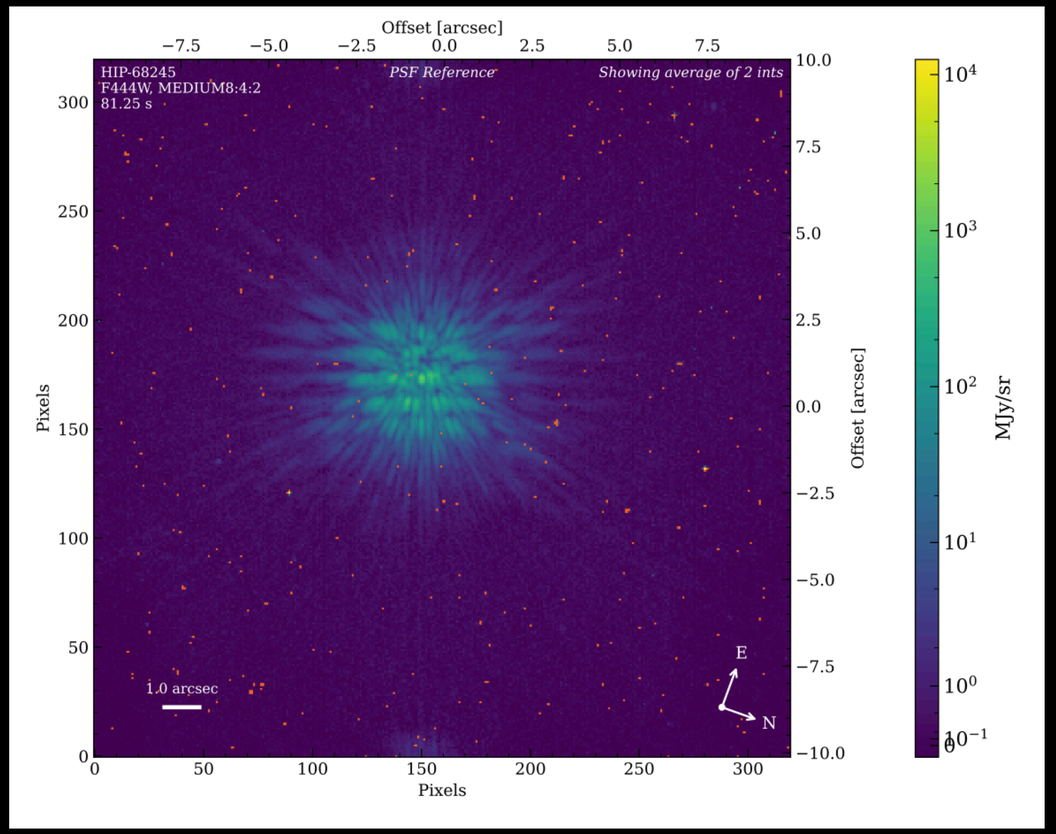
Aarynn Carter
STScI

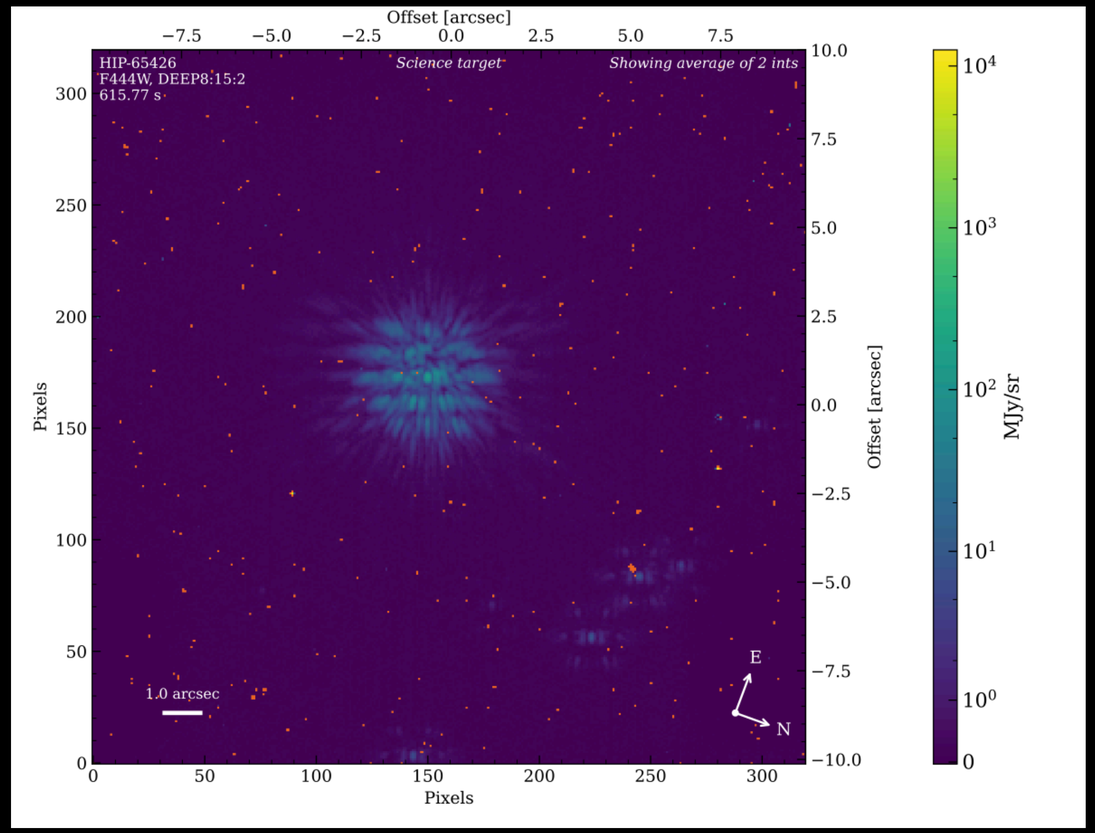
Jarron Leisenring

+ many more!

How the data reduction works

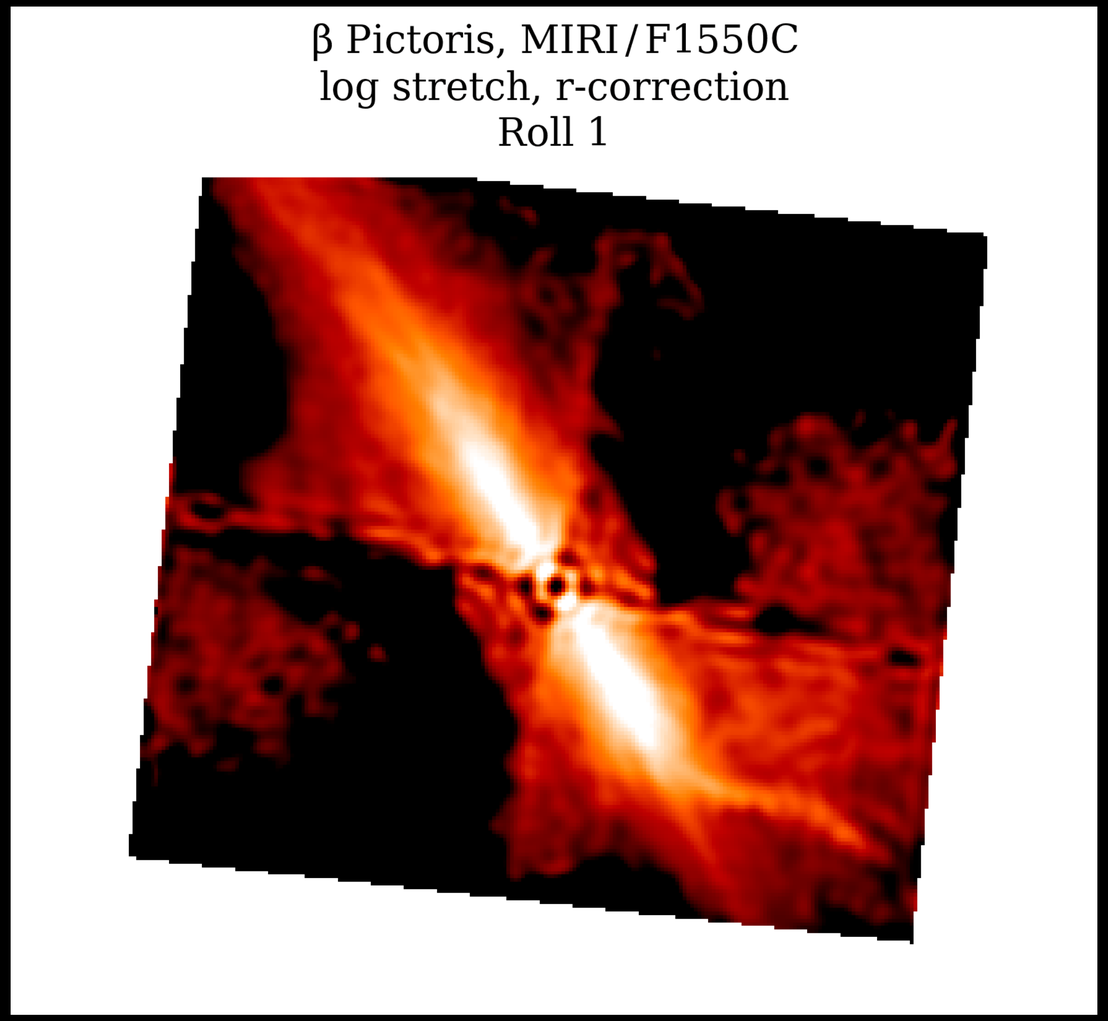
RDI: Reference differential imaging





How the data reduction works

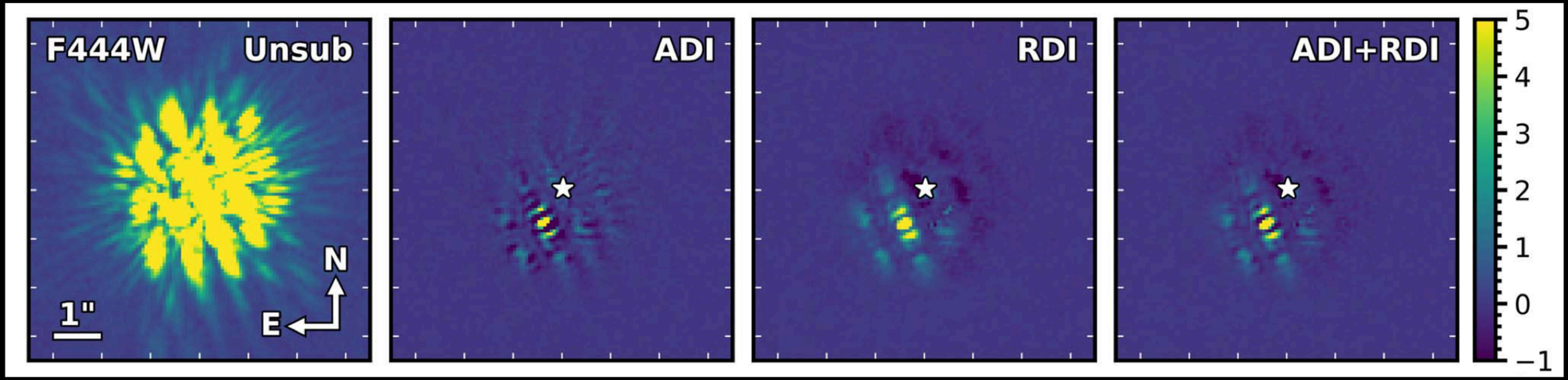
ADI: Angular differential imaging



How the data reduction works

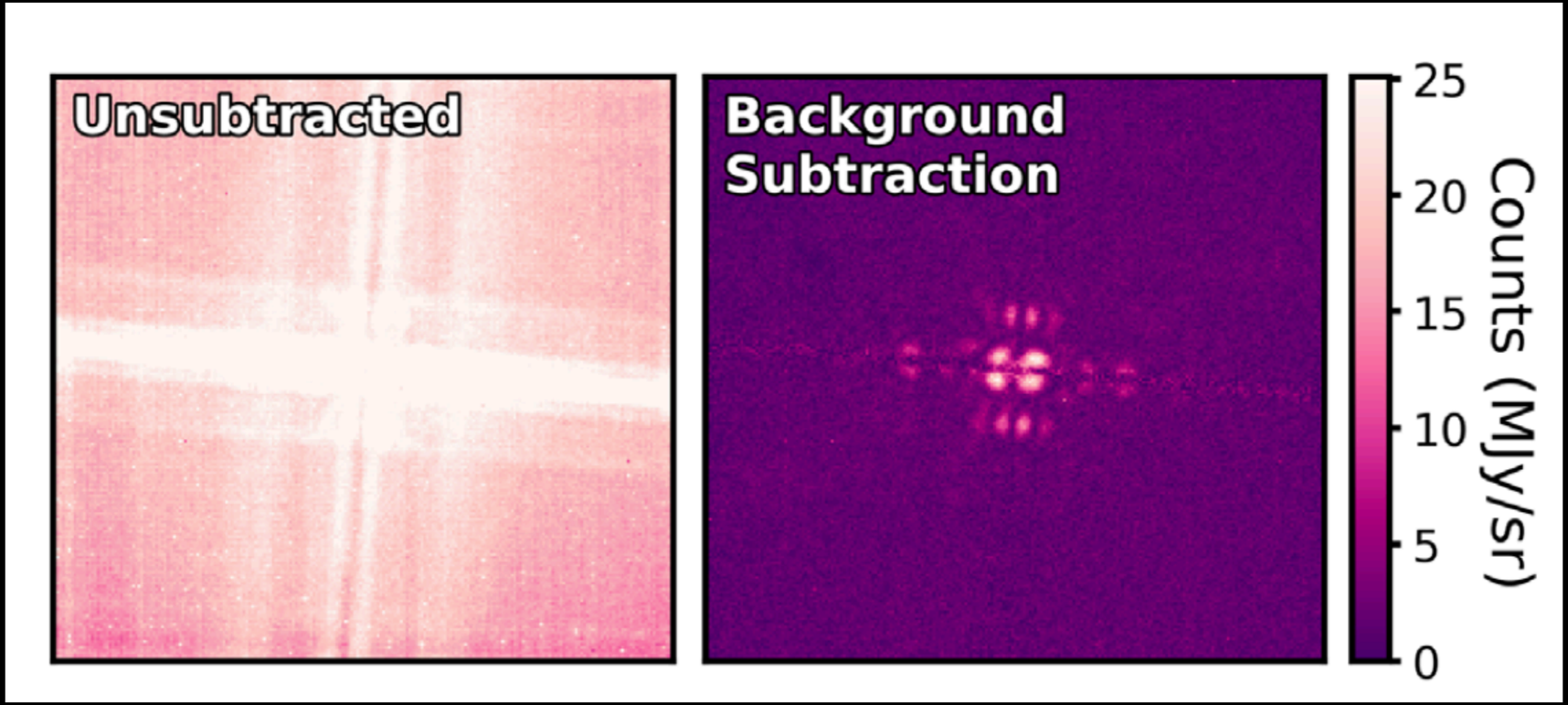
RDI: Reference differential imaging

ADI: Angular differential imaging



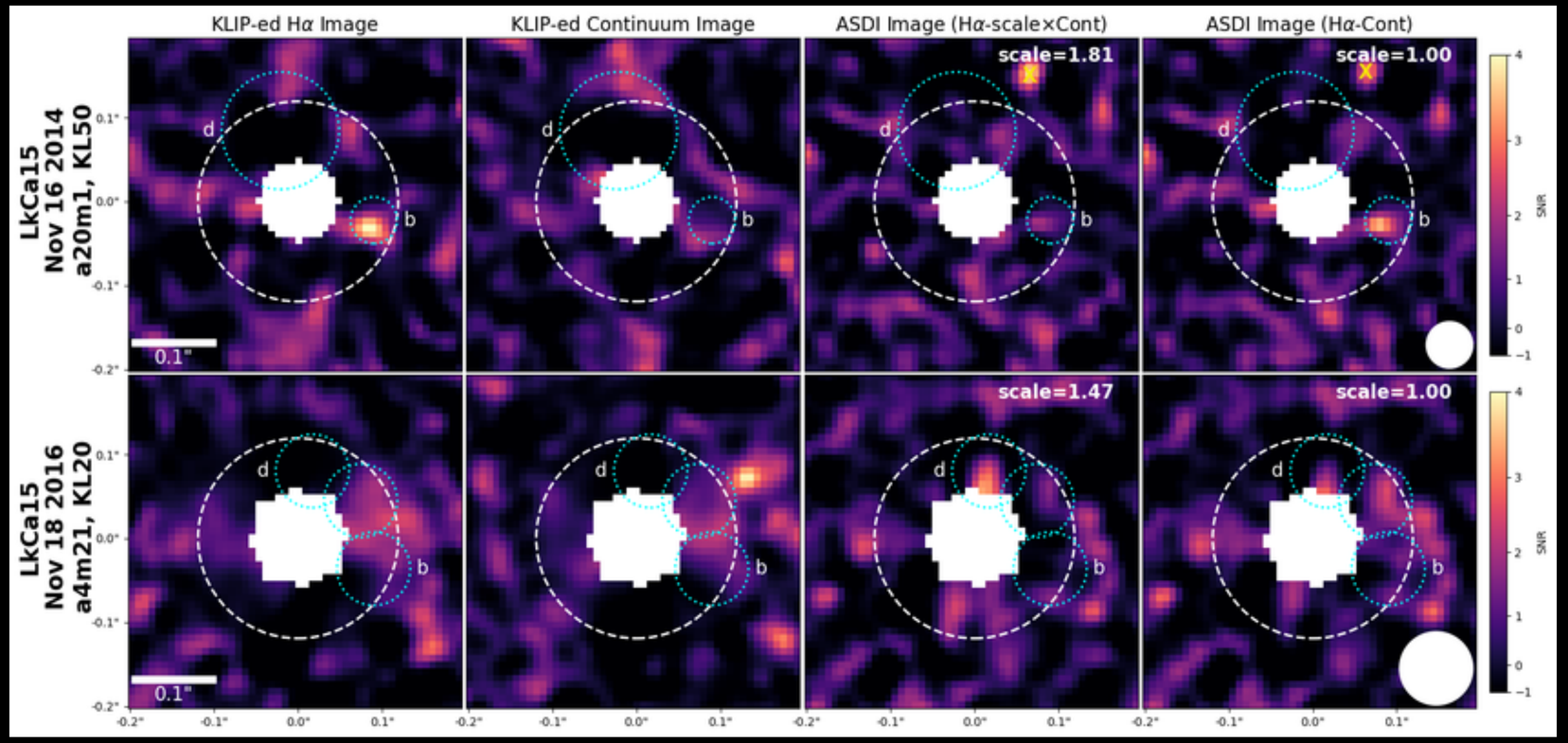
How the data reduction works

Background subtraction for MIRI



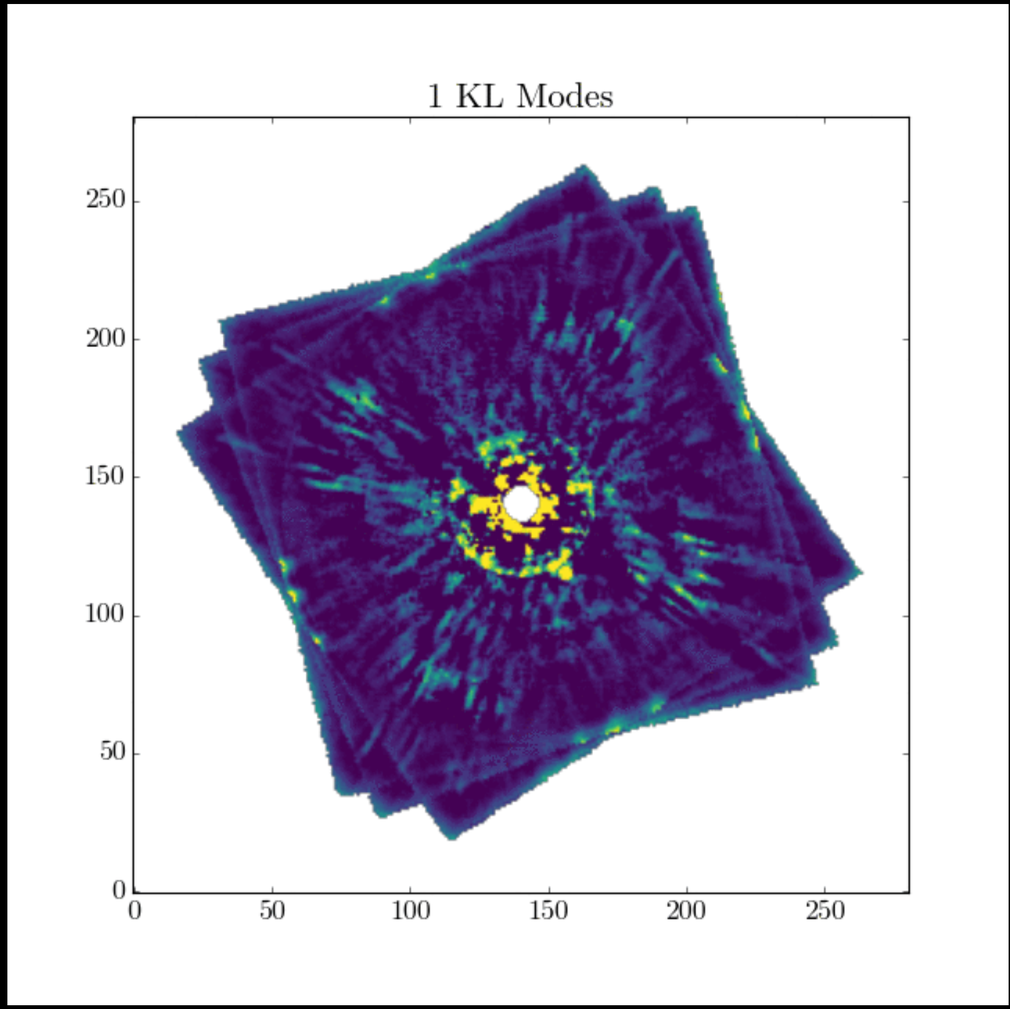
How the data reduction works

KLIP modes: how to improve the PSF characterization



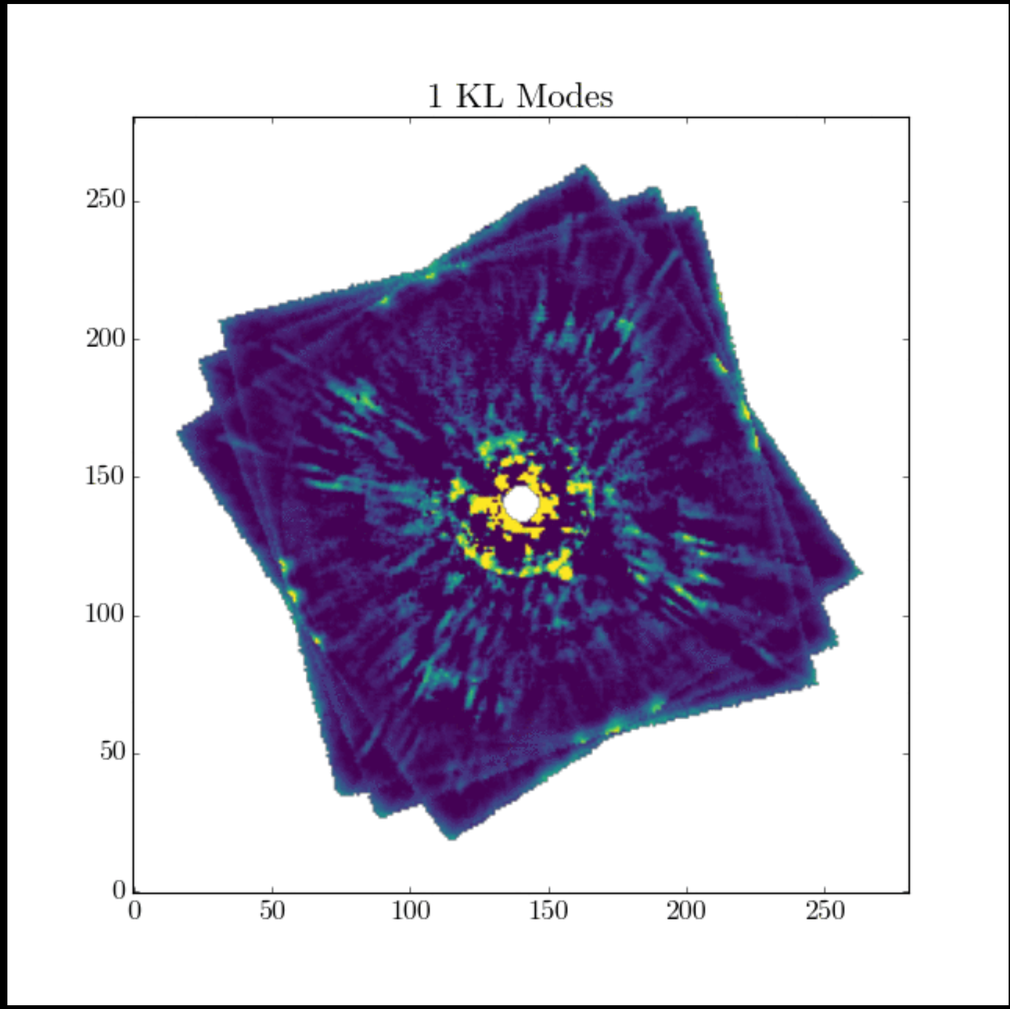
How the data reduction works

KLIP modes: how to improve the PSF characterization



How the data reduction works

KLIP modes: how to improve the PSF characterization



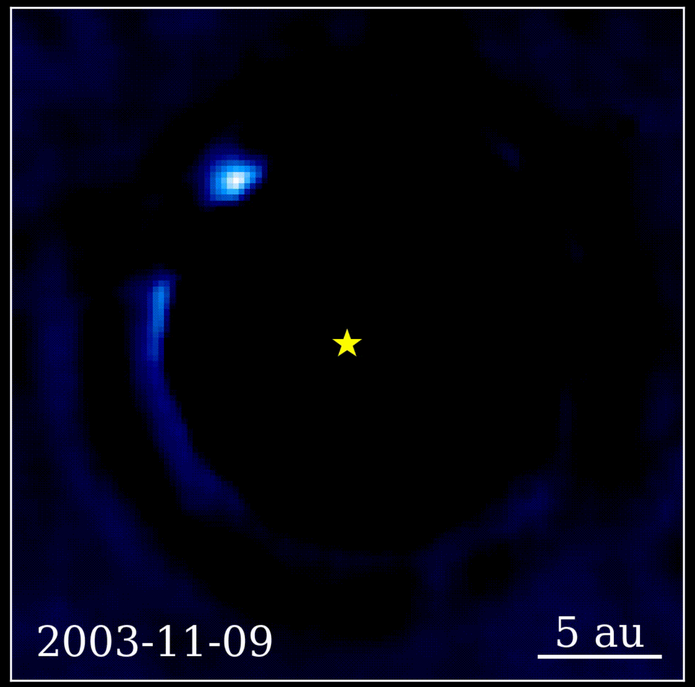
We want to optimize the number of clip modes

(computation vs results)

Some results from JWST

The Beta Pic system

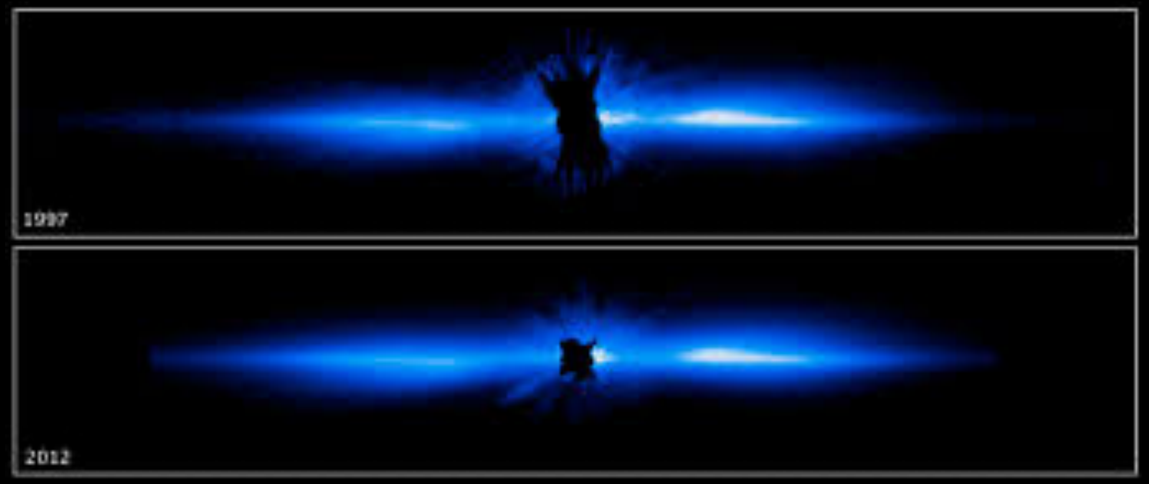
- Young (~20 Myr)
- Close (~19 pc)
- 2 planets
- Bright disk
- Exocomets



Jason Wang

Beta Pic b

Beta Pic seen with HST



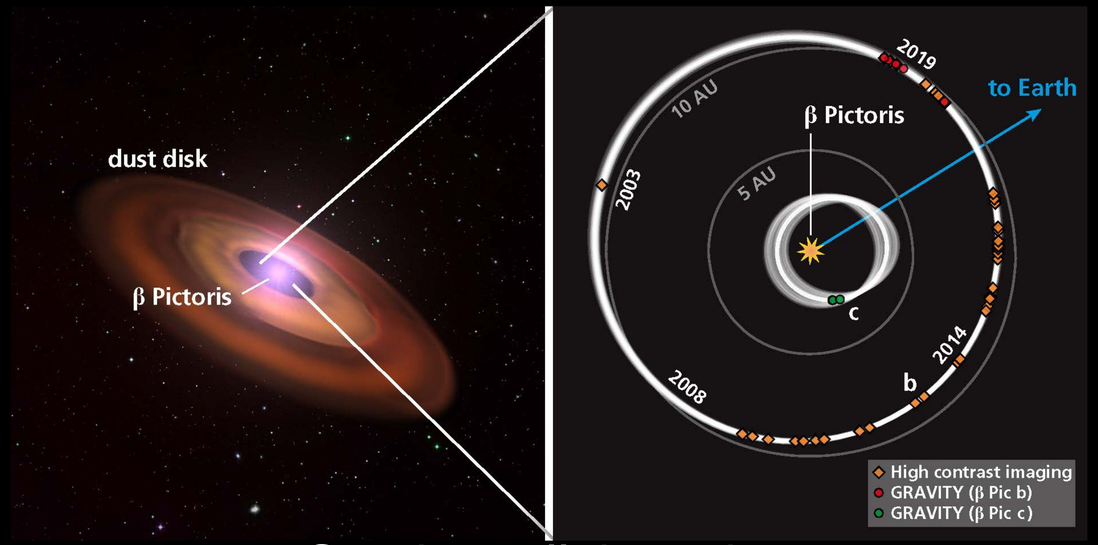
Apai+15

Some results from JWST

The Beta Pic system

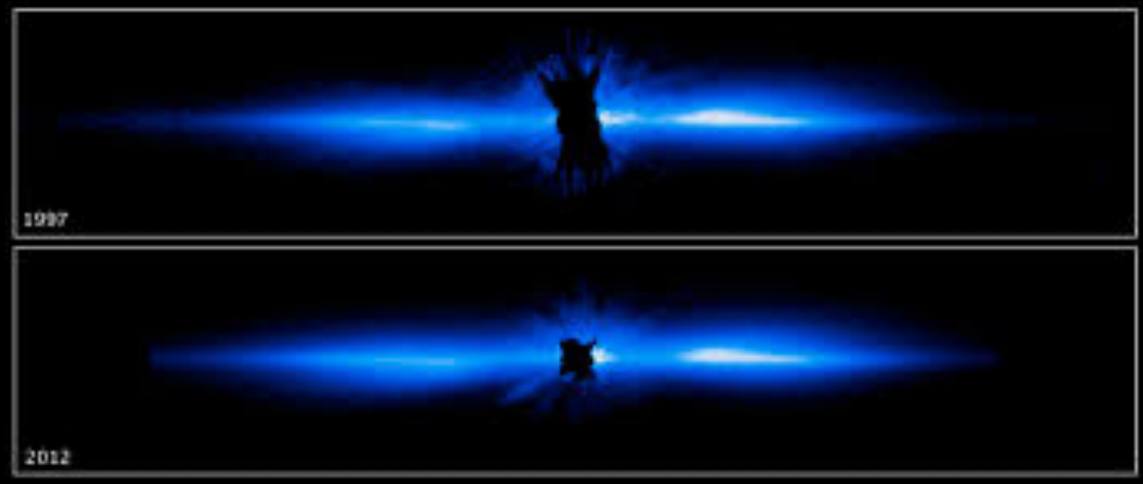
- Young (~20 Myr)
- Close (~19 pc)
- 2 planets
- Bright disk
- Exocomets

Planet orbits



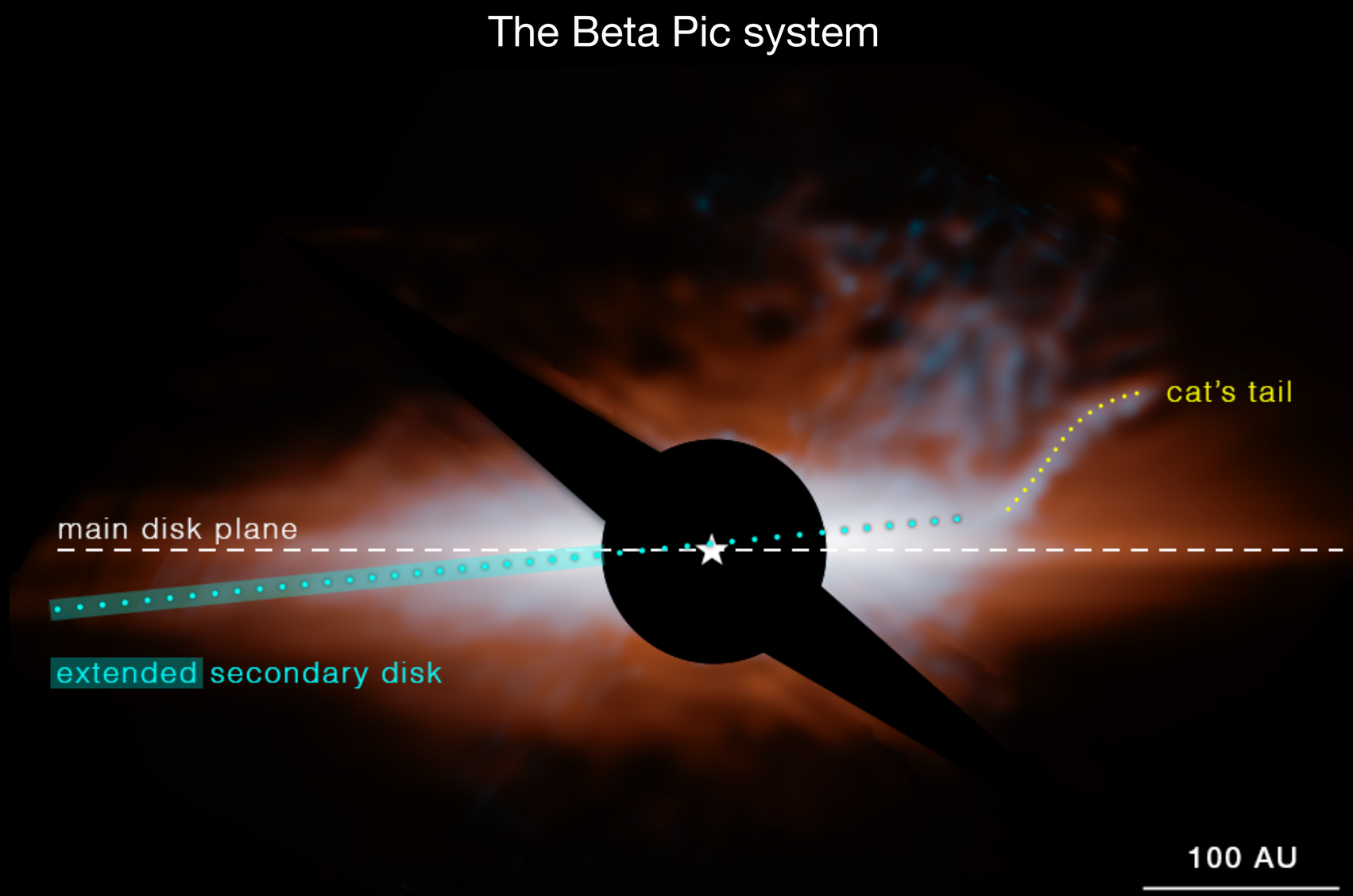
Gravity collaboration

Beta Pic seen with HST



Apai+15

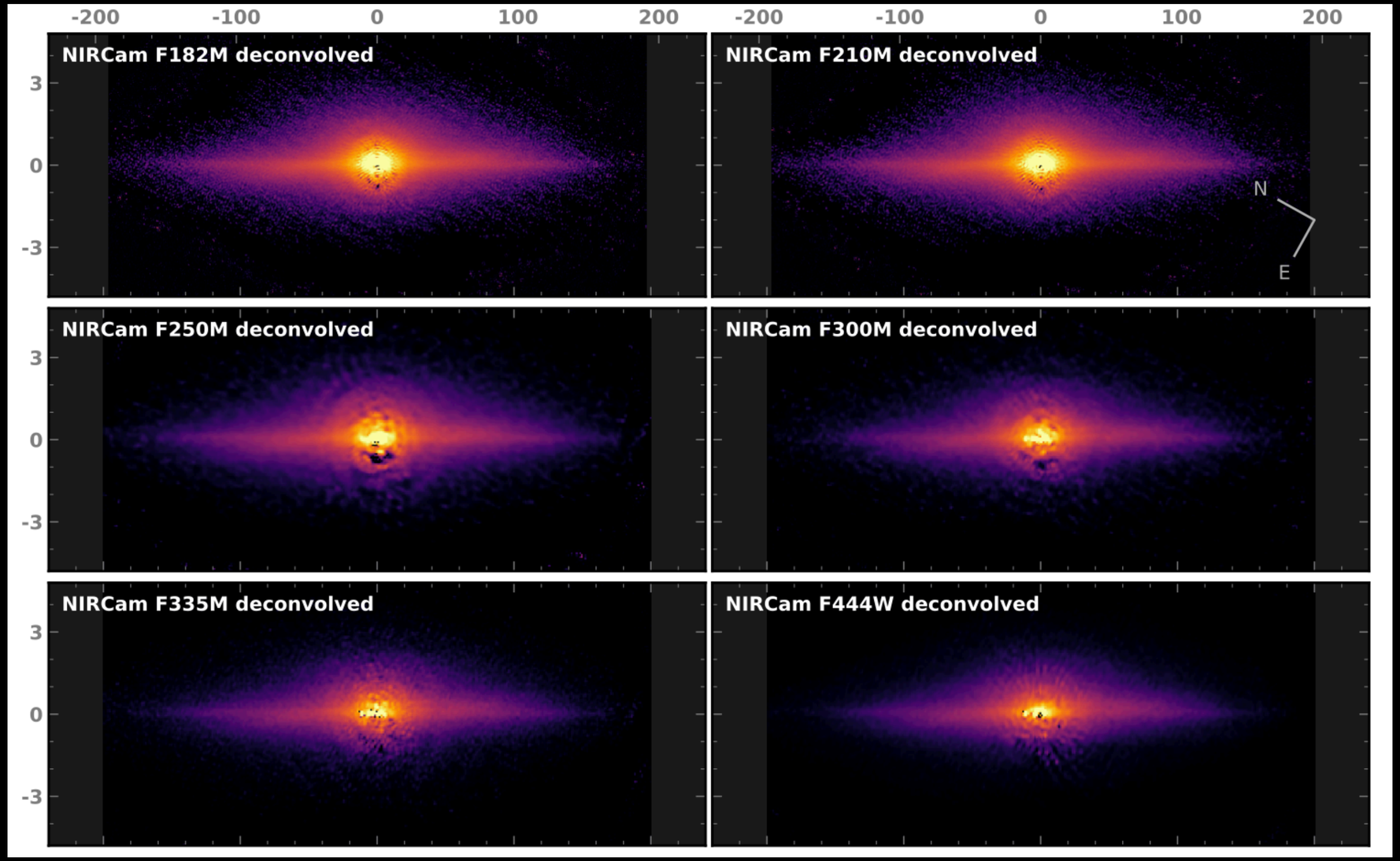
Some results from JWST



Rebollido+24

Some results from JWST

The Beta Pic system

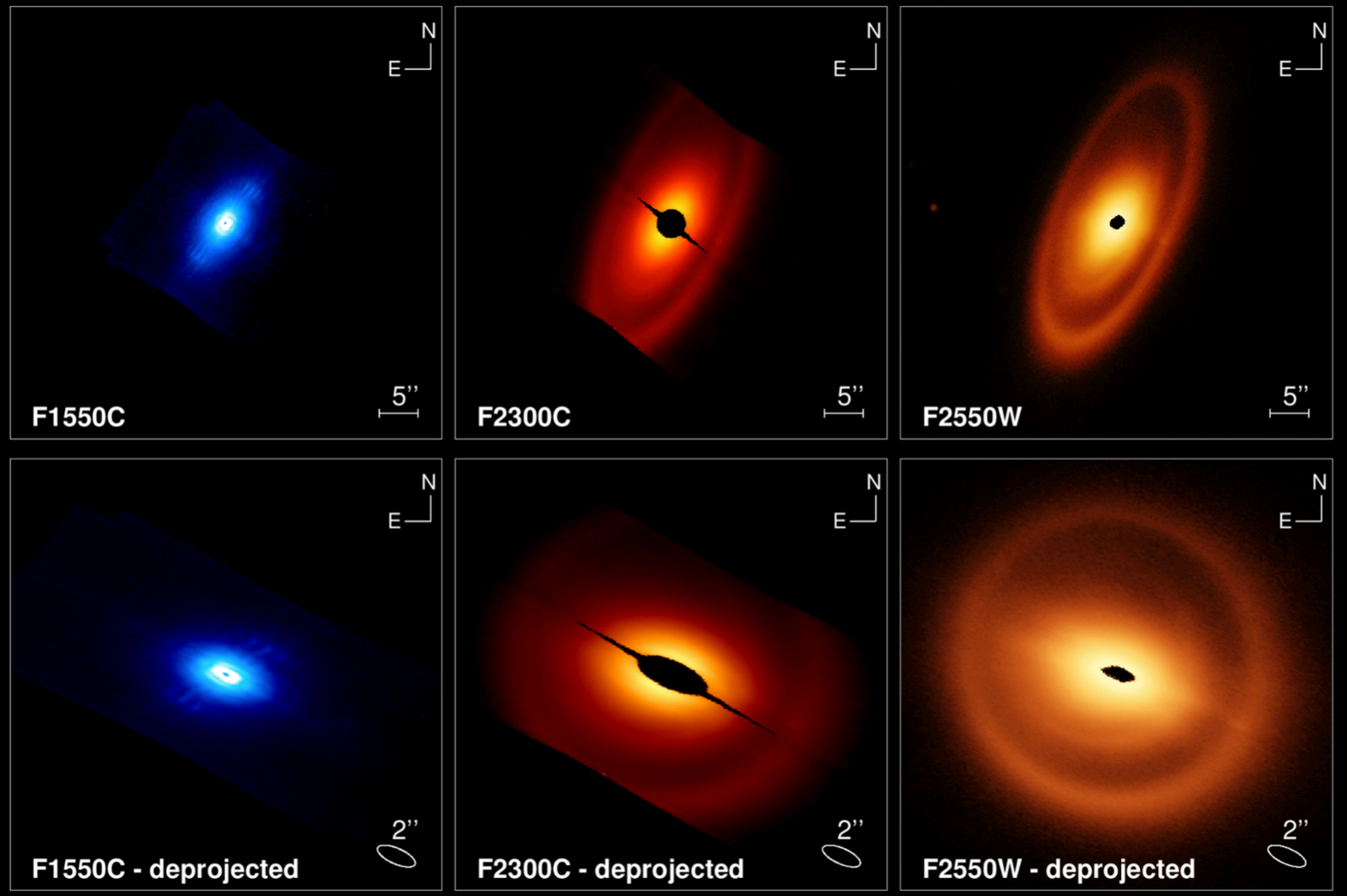


Kammerer+24

Rebollido+24

Some results from JWST

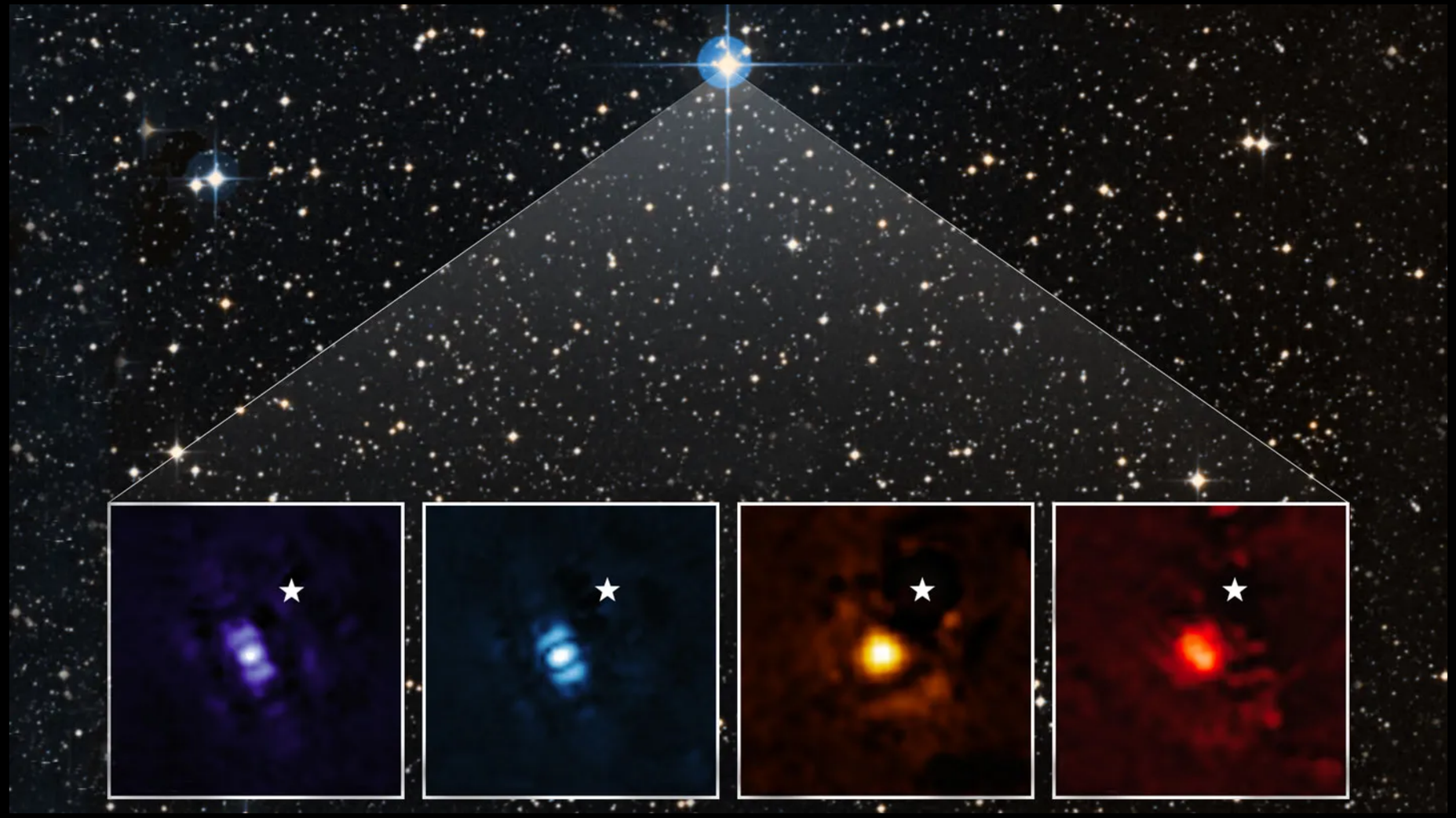
The Fomalhaut system



Gaspar+23

Some results from JWST

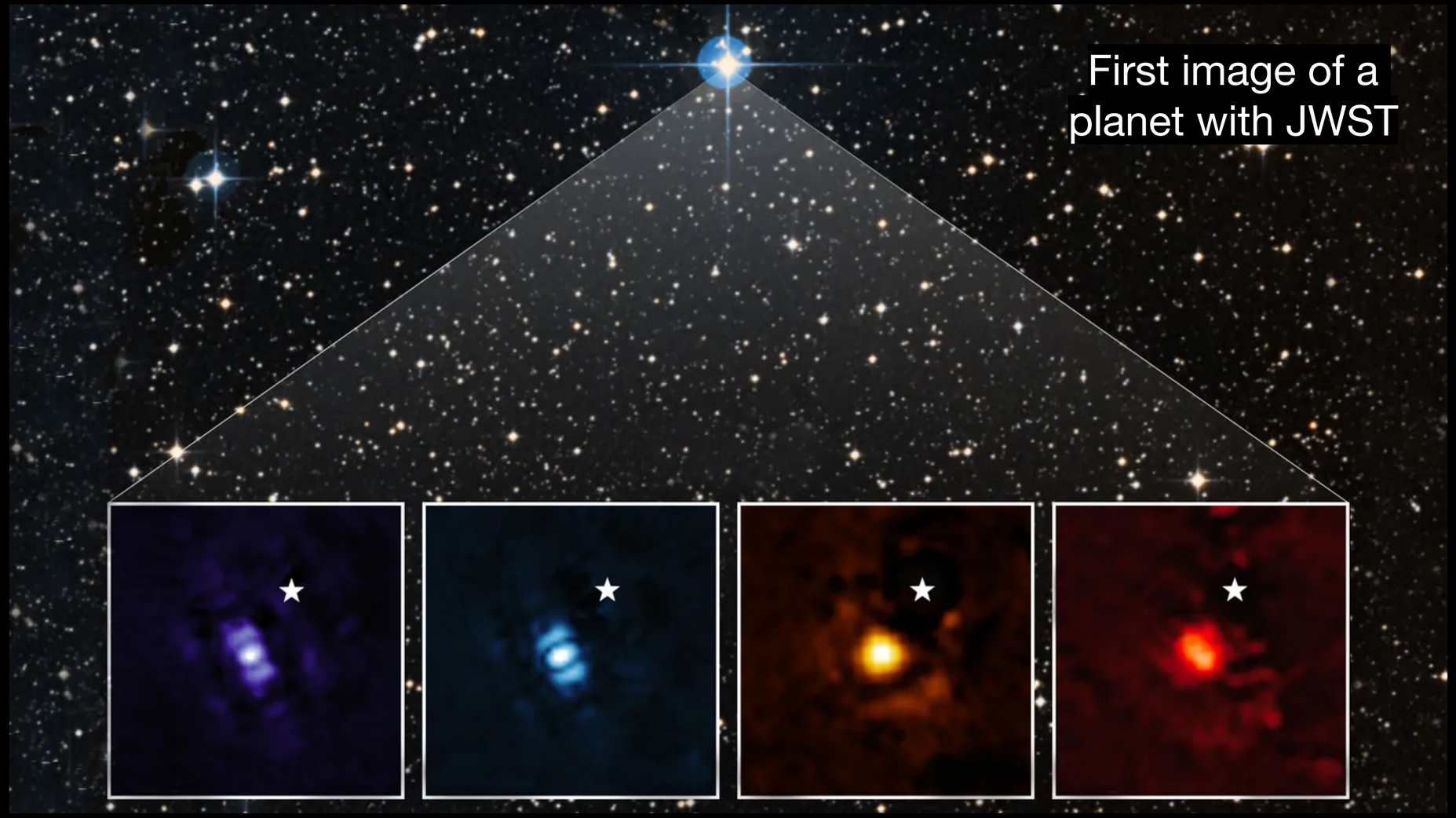
HIP 65426 b



Carter+23

Some results from JWST

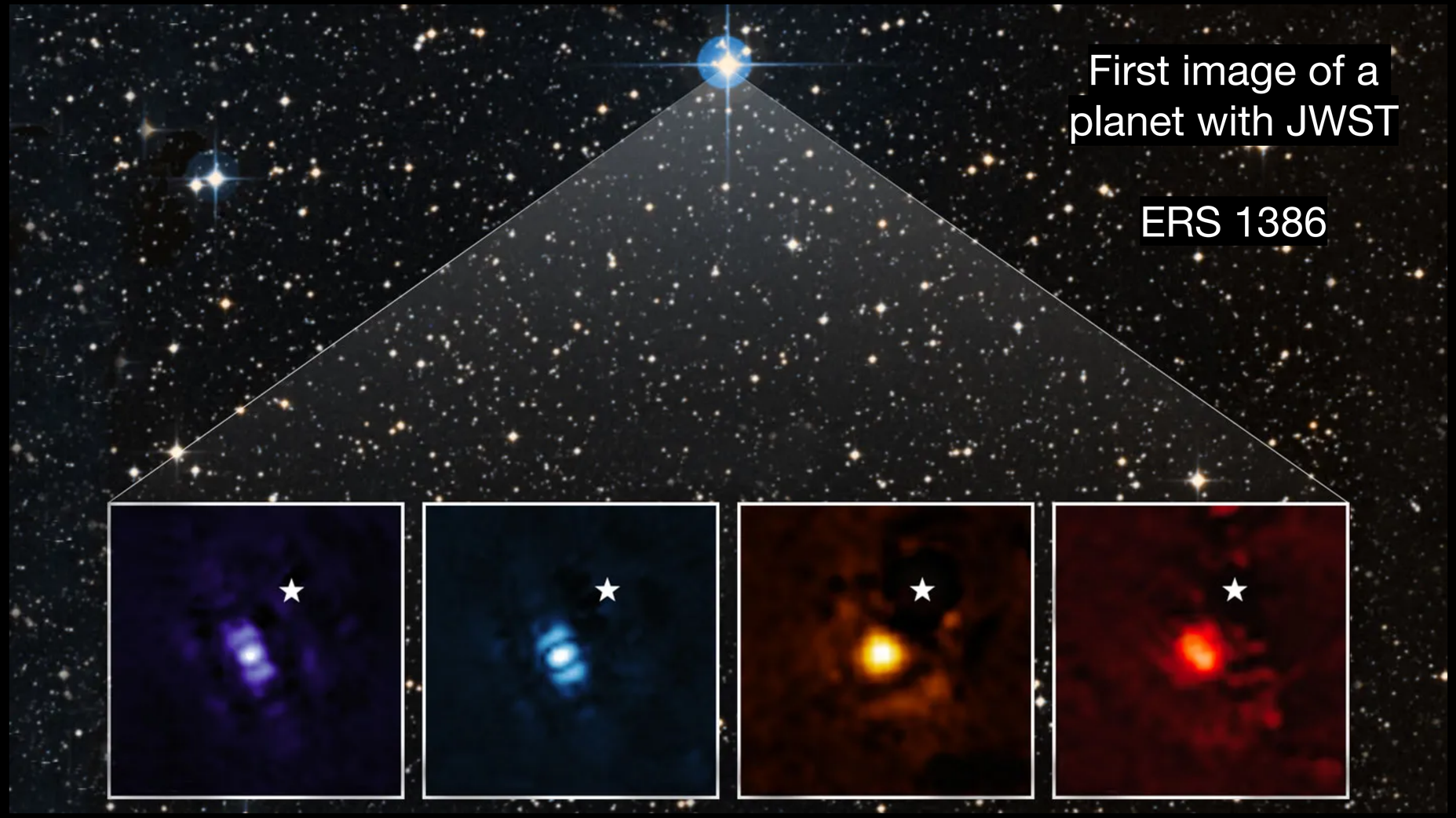
HIP 65426 b



Carter+23

Some results from JWST

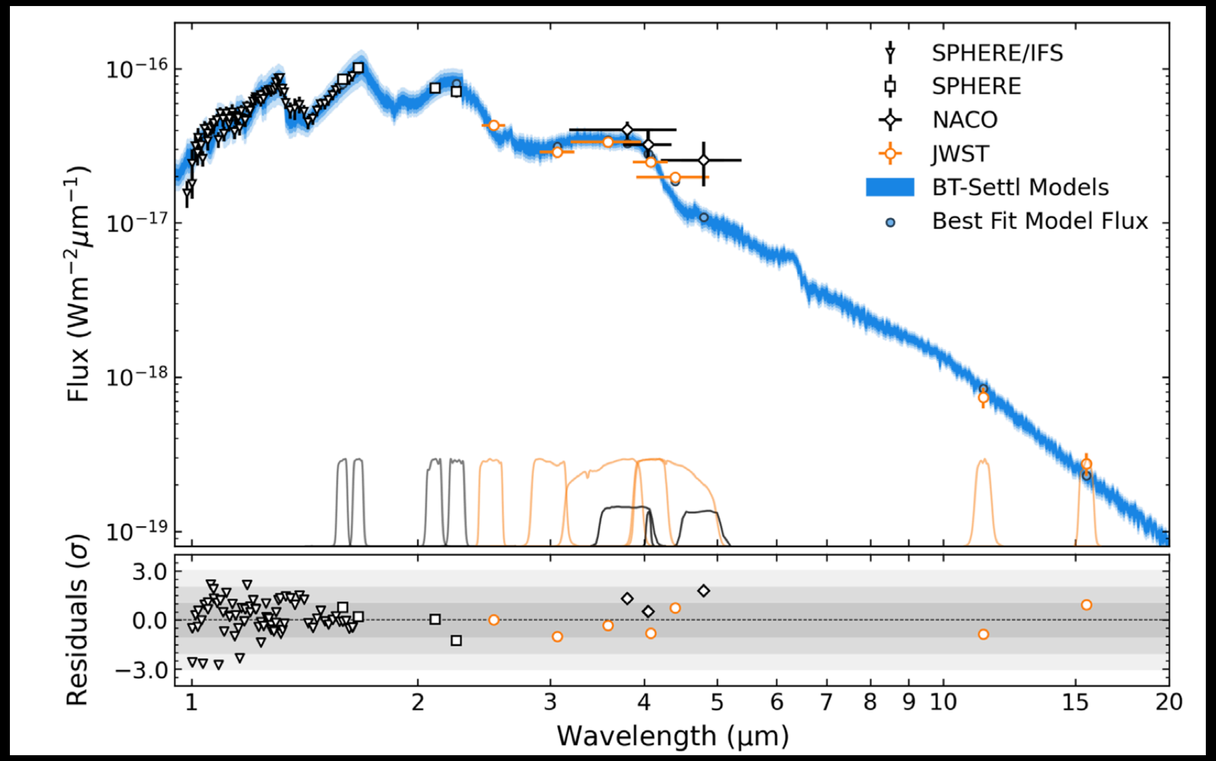
HIP 65426 b

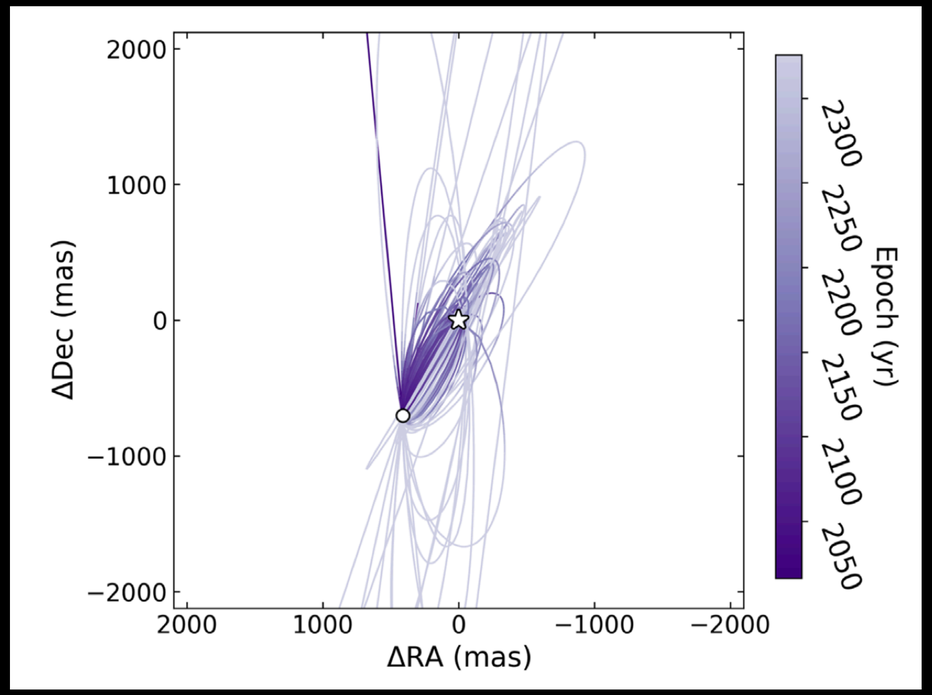


Carter+23

Some results from JWST

HIP 65426 b

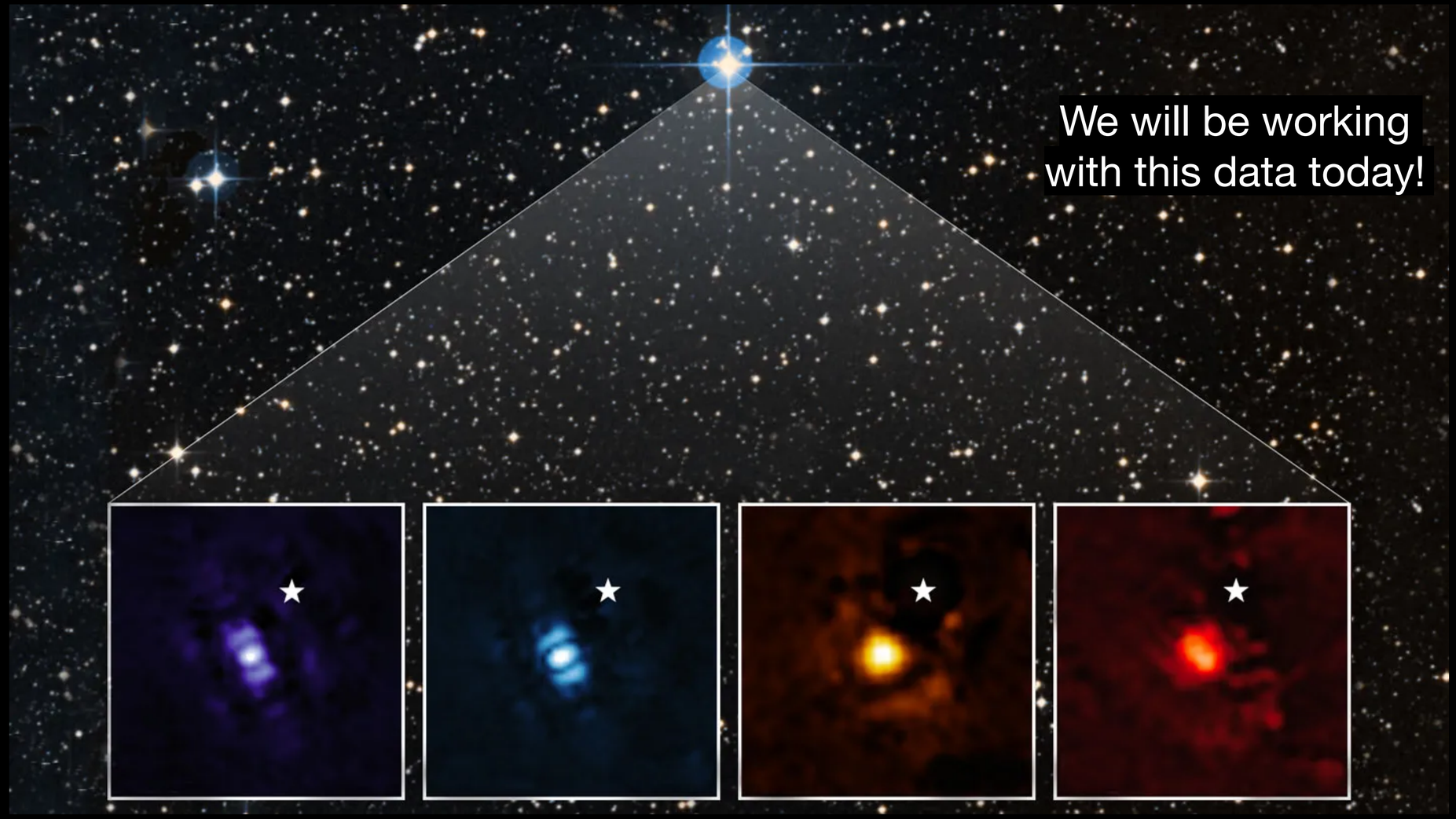




Carter+23

Some results from JWST

HIP 65426 b



Carter+23