STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

High Contrast Imaging (HCI) with JWST

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JWST Coronagraphs Working Group Lead

Master Class - Level 2 - Nov 19th & 20th 2019 - STScI

JWST High Contrast Imaging (HCI) Level 2 Master Class: Outline

Introduction

- **High Contrast**, **Direct Imaging**, a powerful technique!
- JWST's incredible combination of inner-working angle & sensitivity in the IR, synergy with the ground
- JWST **Coronagraphy**: **NIRCam** & **MIRI**
- JWST **Aperture Masking Interferometry** (AMI): **NIRISS**

HCI Roadmap Walk-Through

- **Parameter & detectability space** of JWST HCI modes
- **Example Science Programs**
- The **HR 8799** exoplanetary system, an **ideal use case** for the Master Class

Proposal Planning Tools & HCI Resources

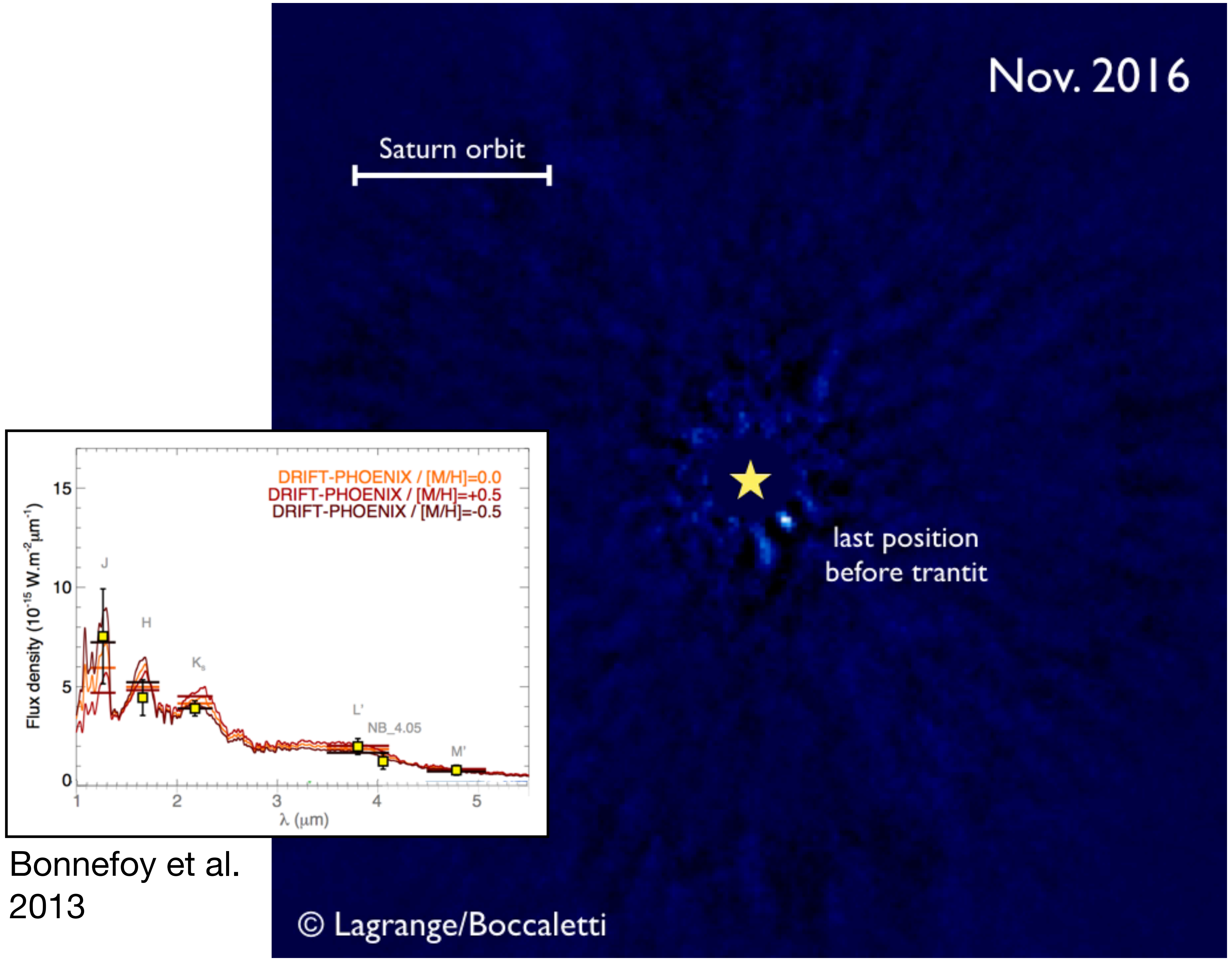
- STScI supported: JDox, ETC, APT, CVT…
- ETC Limitations & high(er) fidelity calculations

Hands-on session & NIRISS/AMI

Introduction

High Contrast, Direct Imaging: a powerful technique!

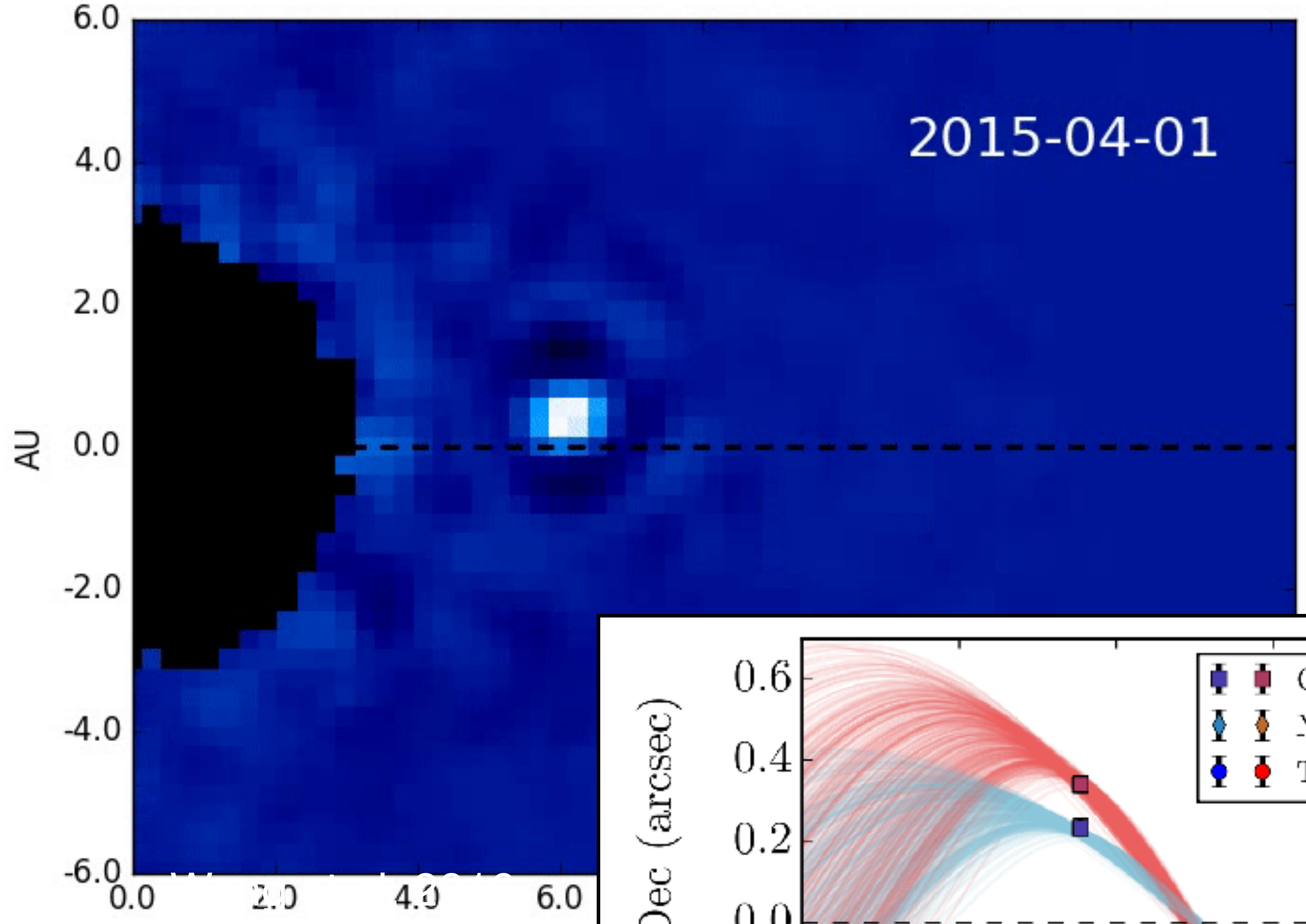
Direct measurement, orbital motion, colors: the **β Pictoris** debris disk & **~10-12 M_{Jup} planet**



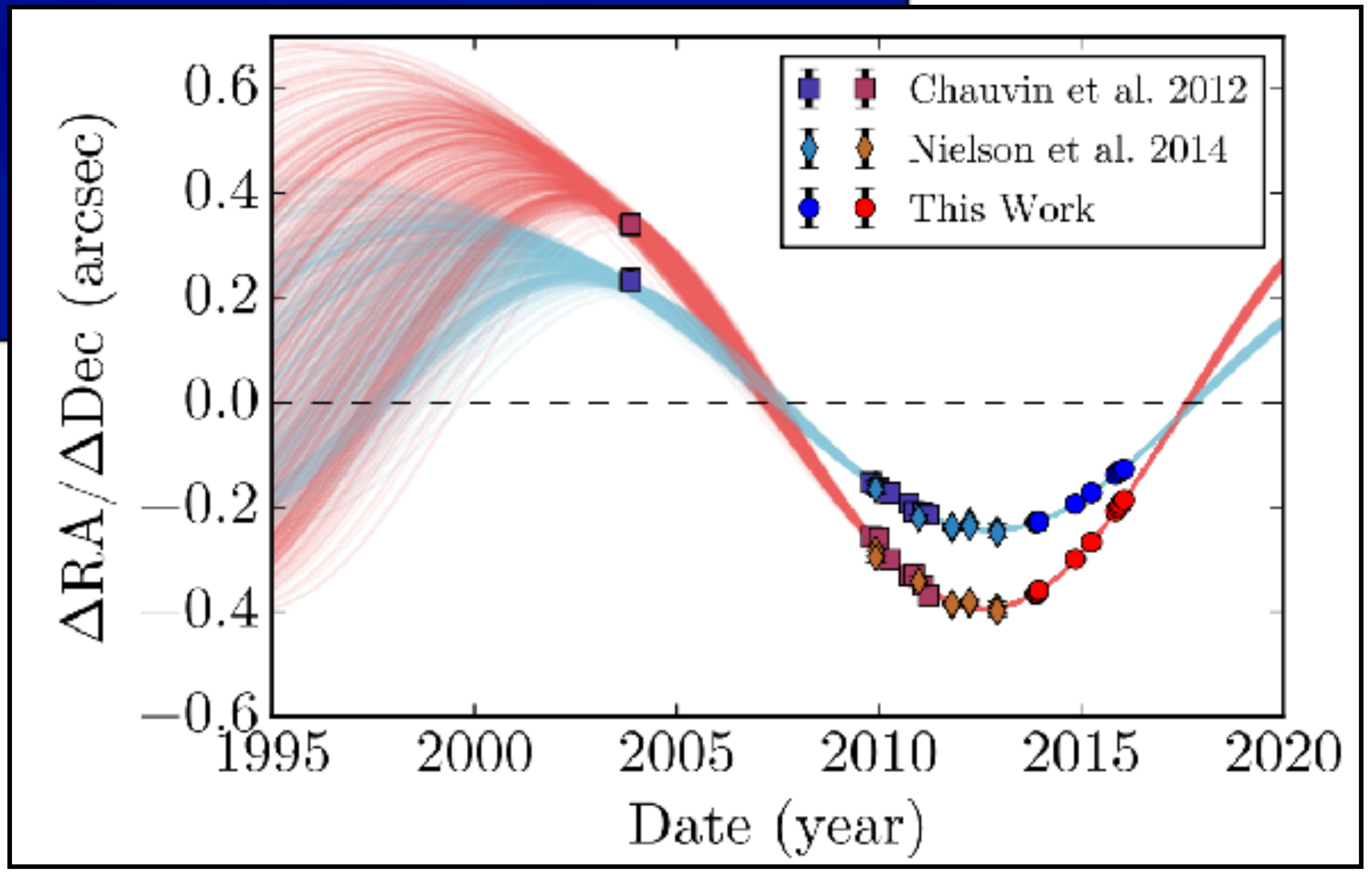
Bonnefoy et al. 2013

Lagrange et al. 2019

VLT/NACO & SPHERE



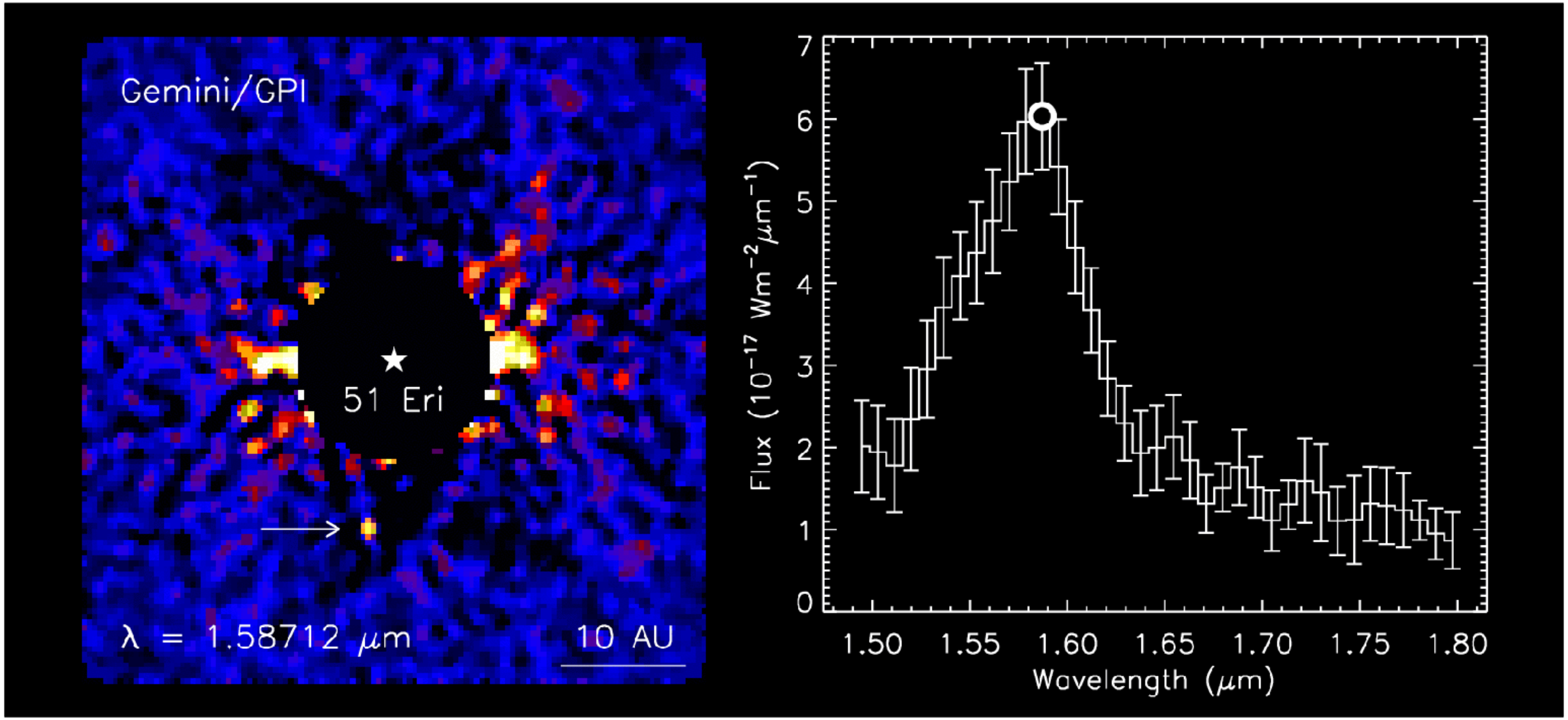
Gemini/GPI



Wang et al. 2016

High Contrast, Direct Imaging: a powerful technique!

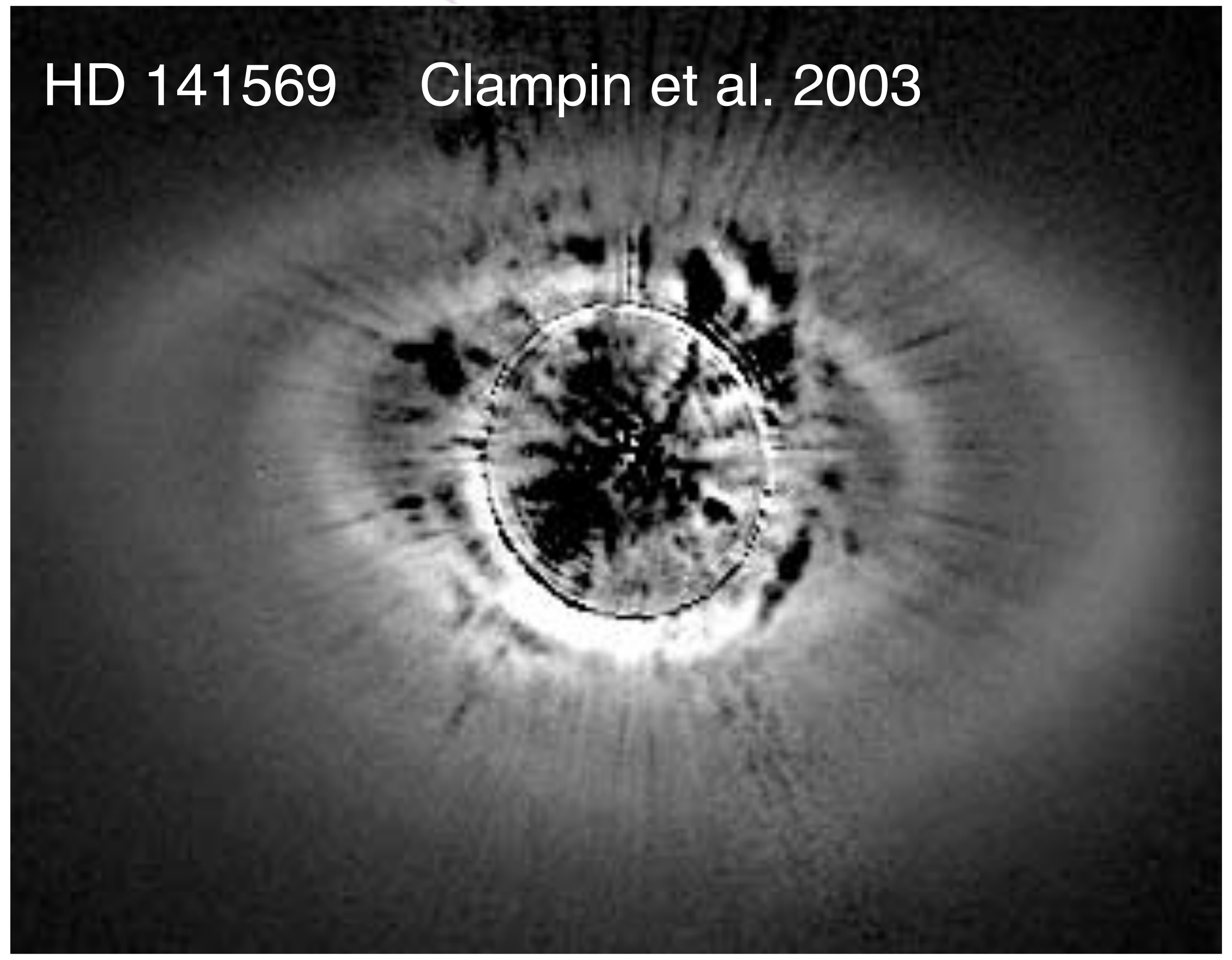
Low-resolution spectra: **51 Eridani b** planet **~2 M_{Jup}, ~700K**

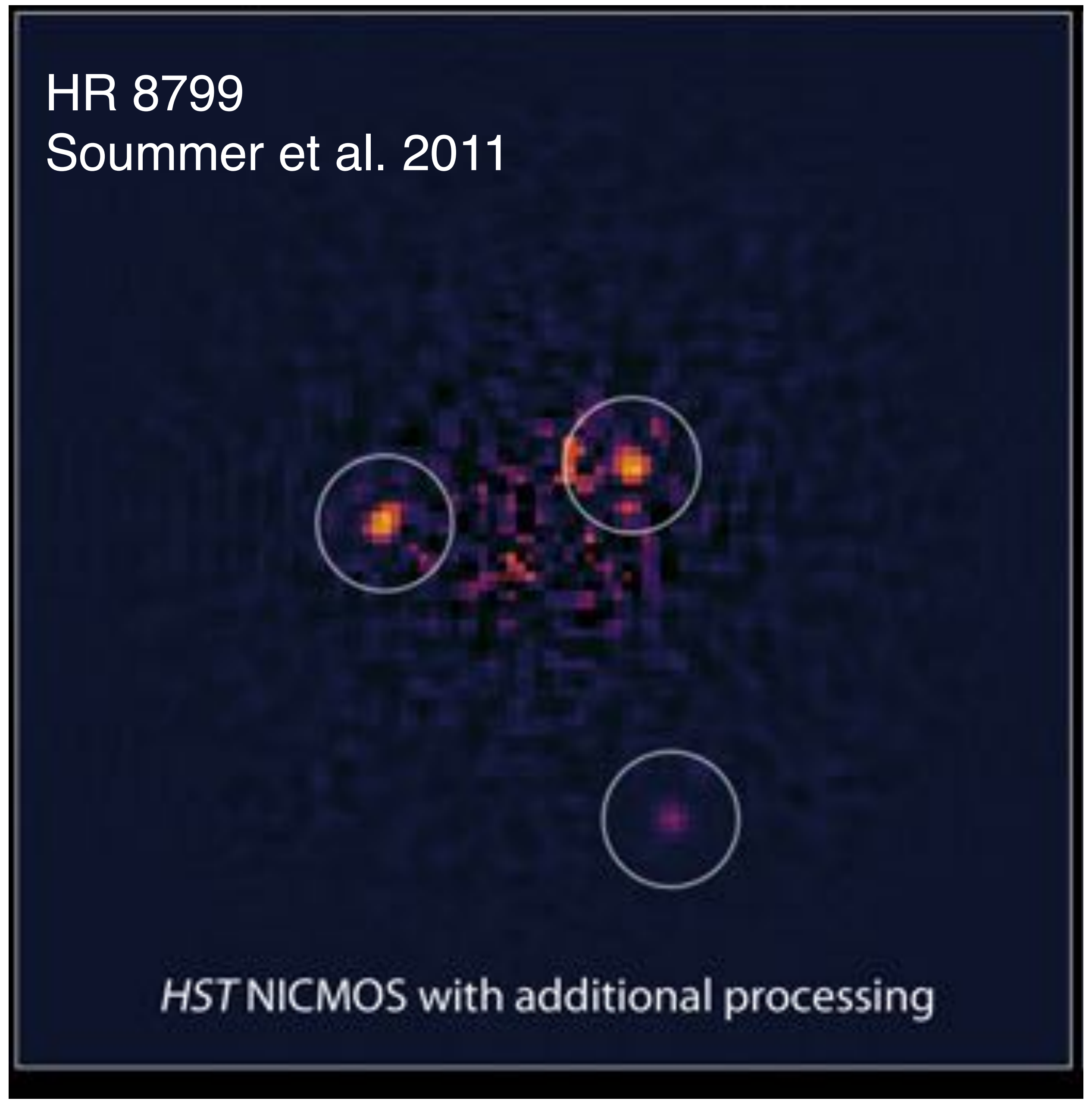


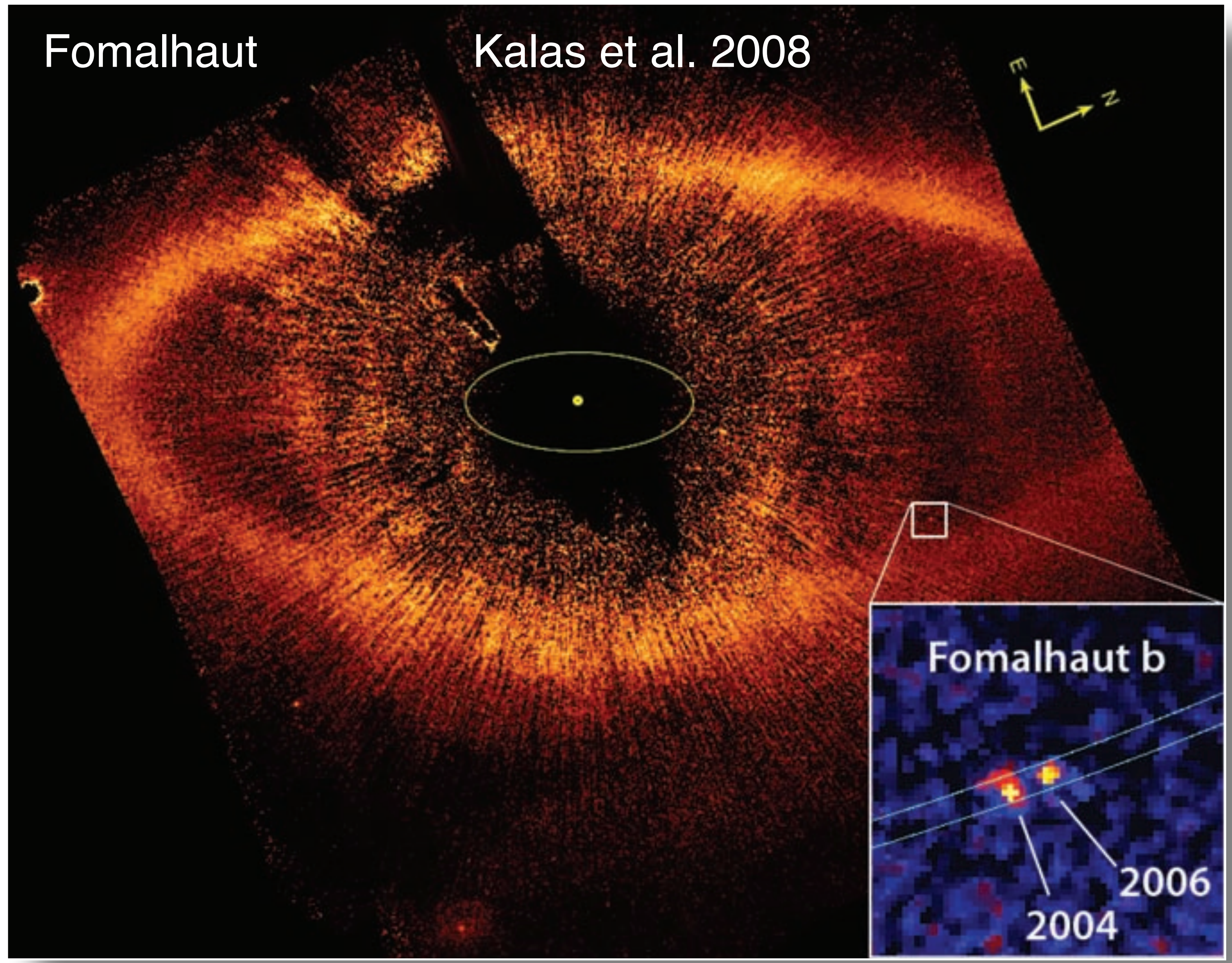
Gemini/GPI

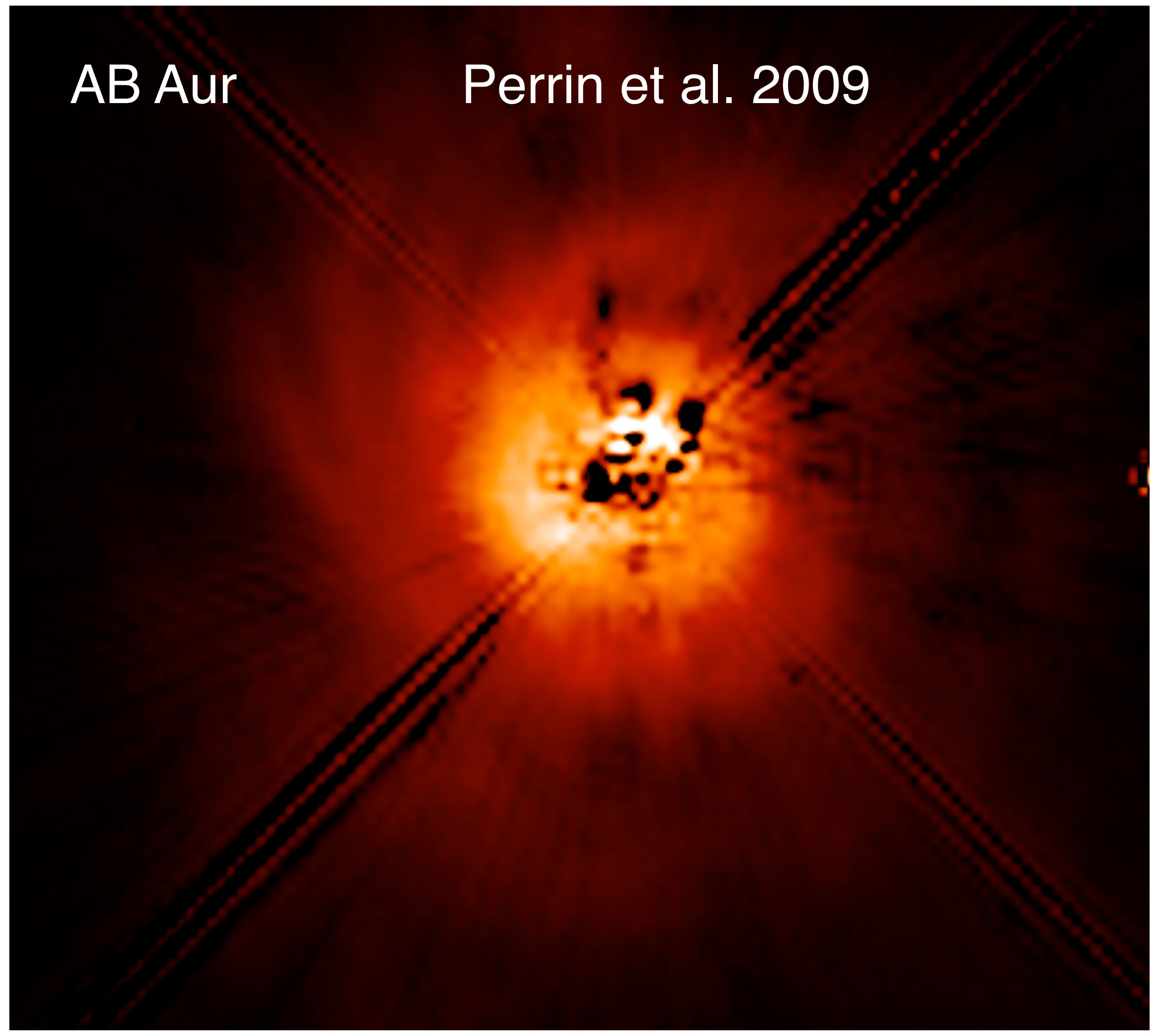
Macintosh et al. 2015, Rosa, R et al. 2015, Rajan et al. 2017

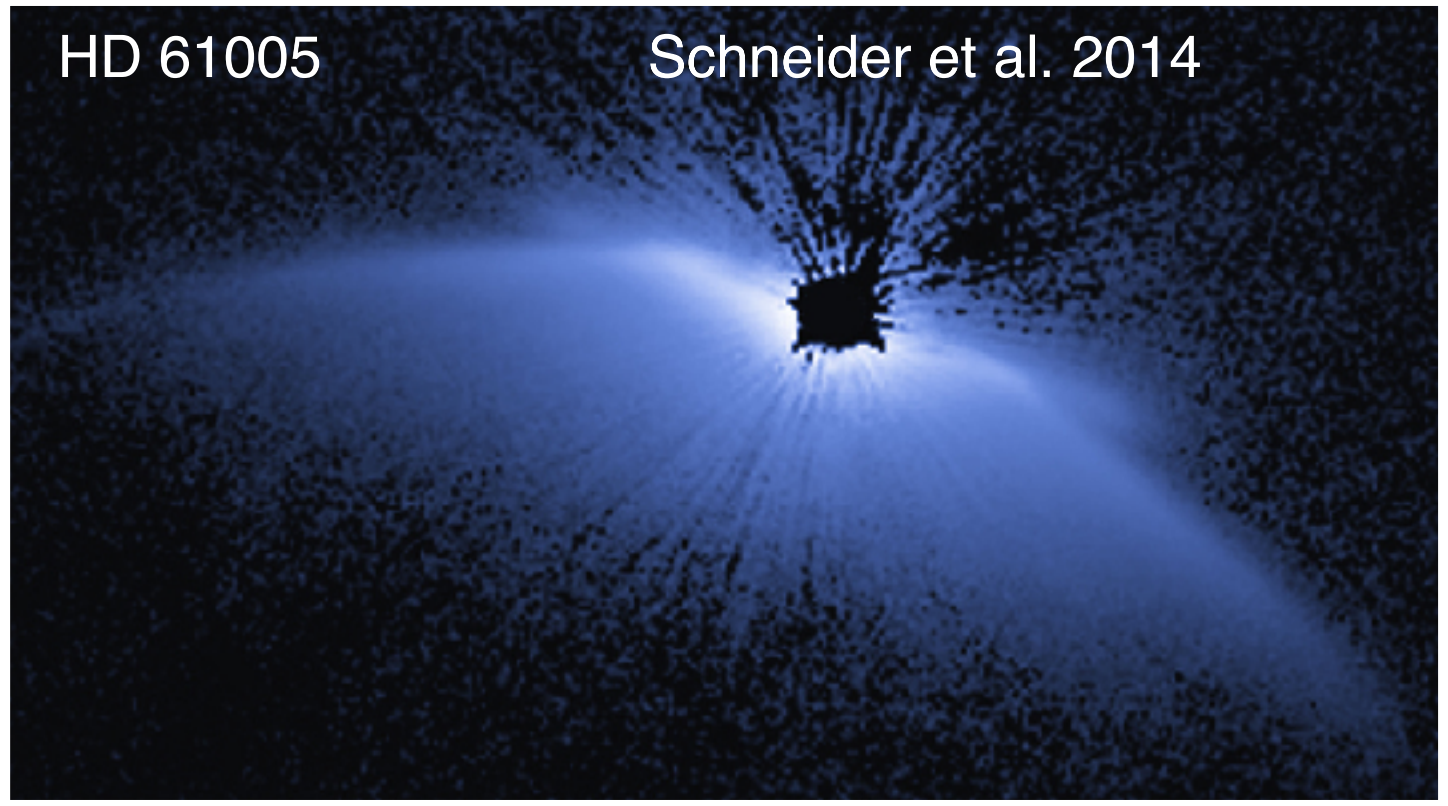
Coronagraphic studies with Hubble of exoplanets, brown dwarfs, and disks

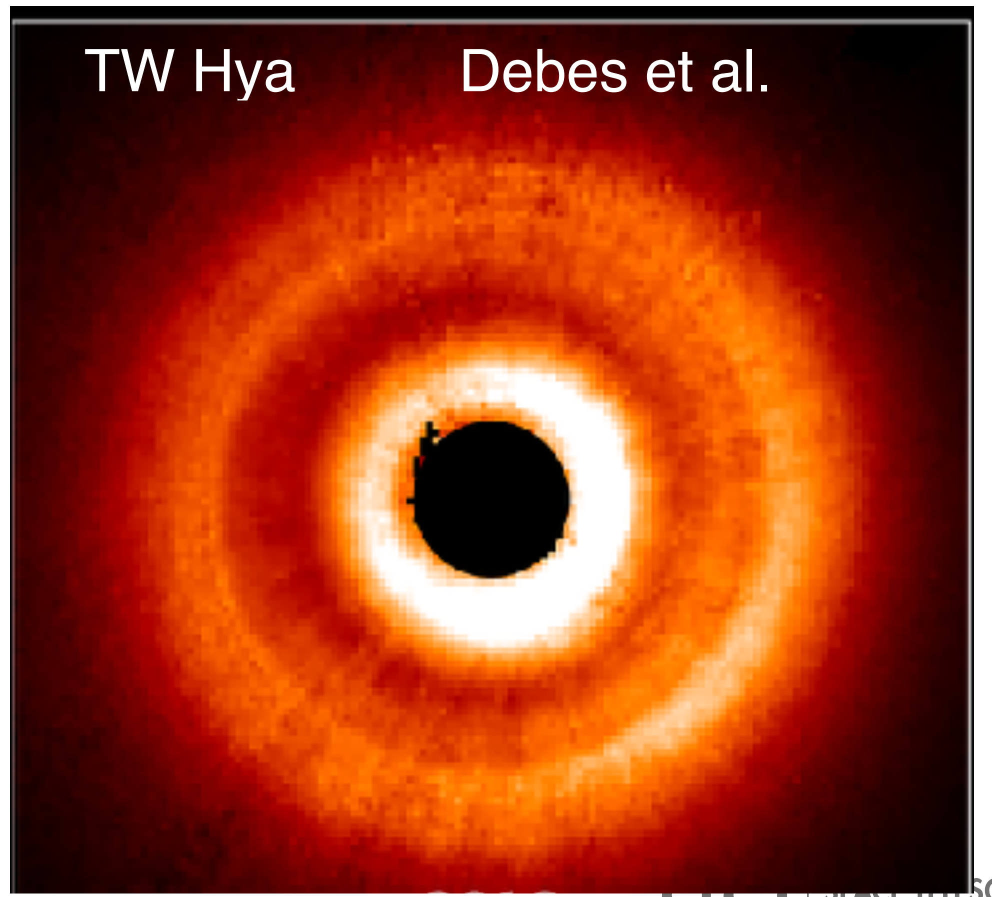




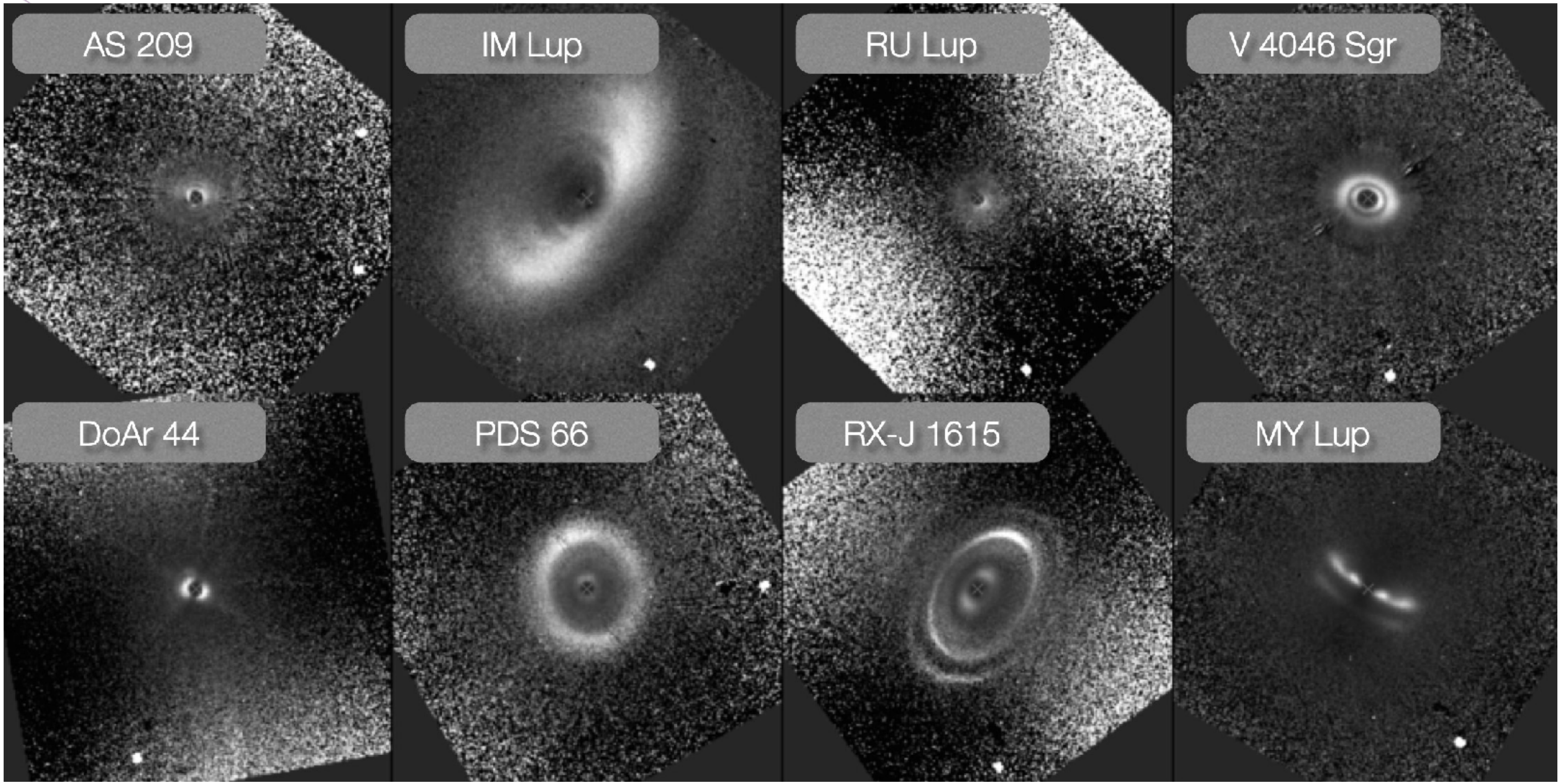






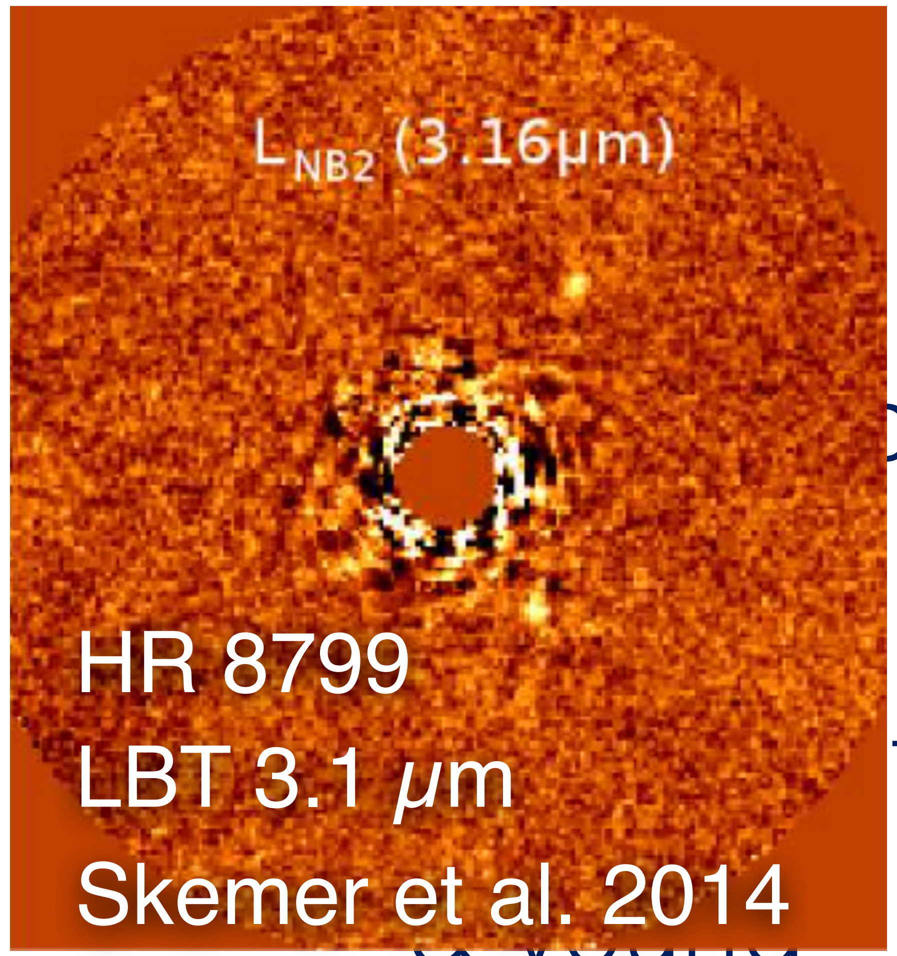


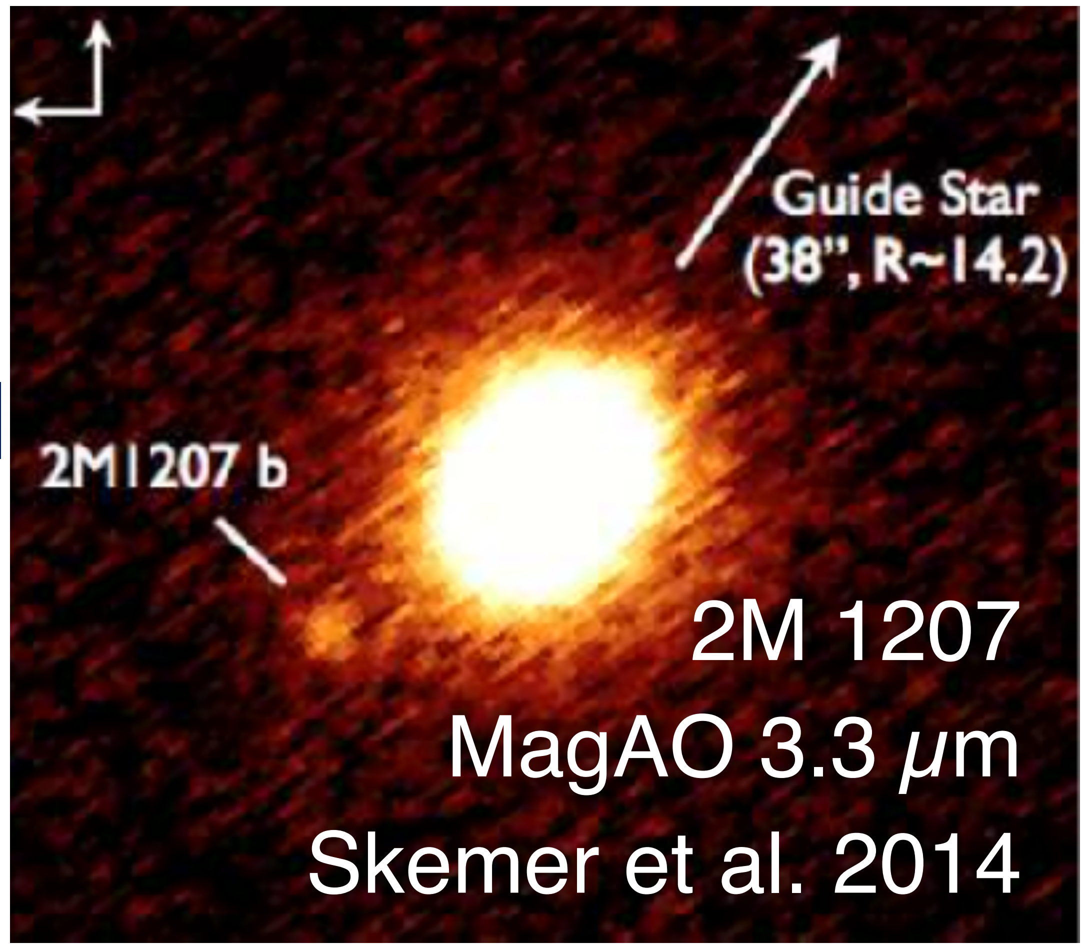
Coronagraphic images of disks in scattered light from the ground

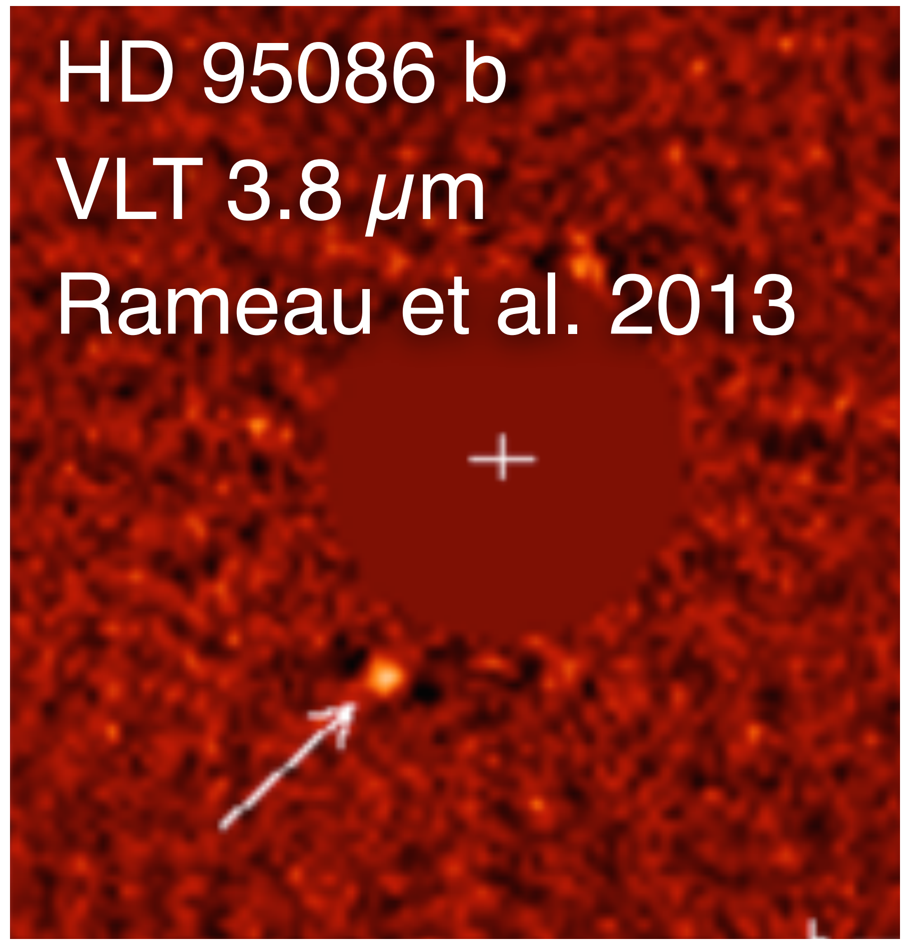


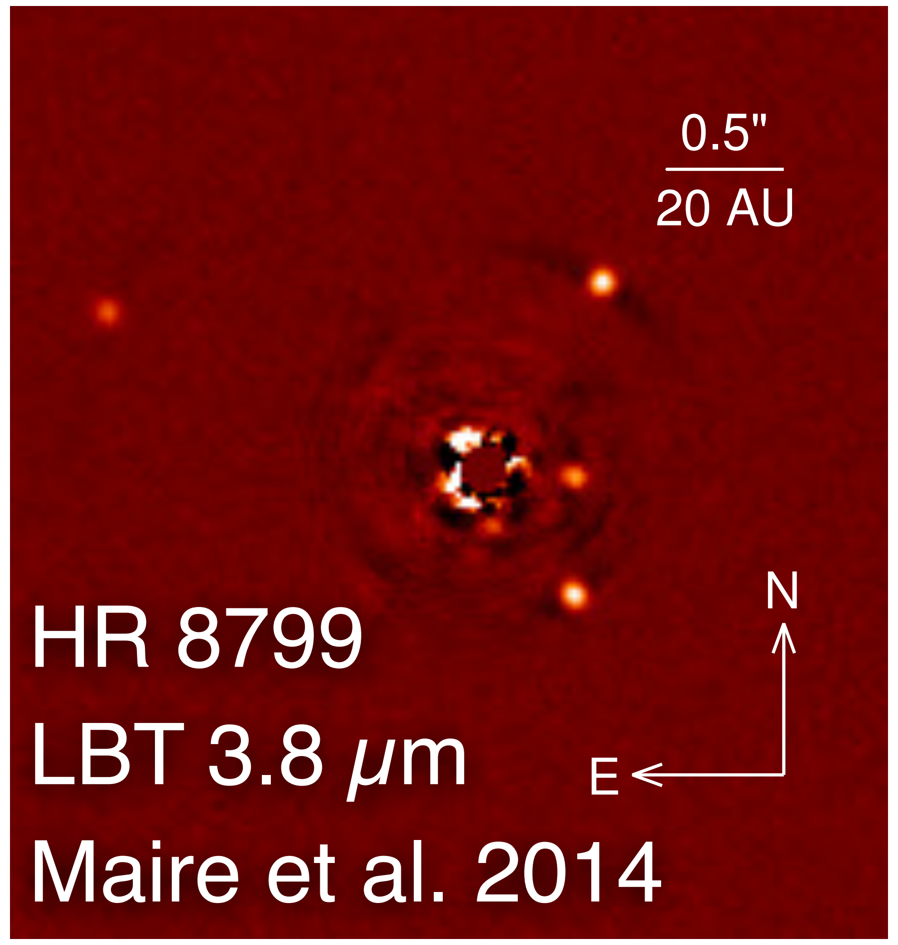
Gallery, courtesy of H. Avenhaus (SPHERE J-band, Polarized scattered light, FWHM ~ 35-50 mas)

examples of 3 to 5 μm exoplanet imaging from the ground

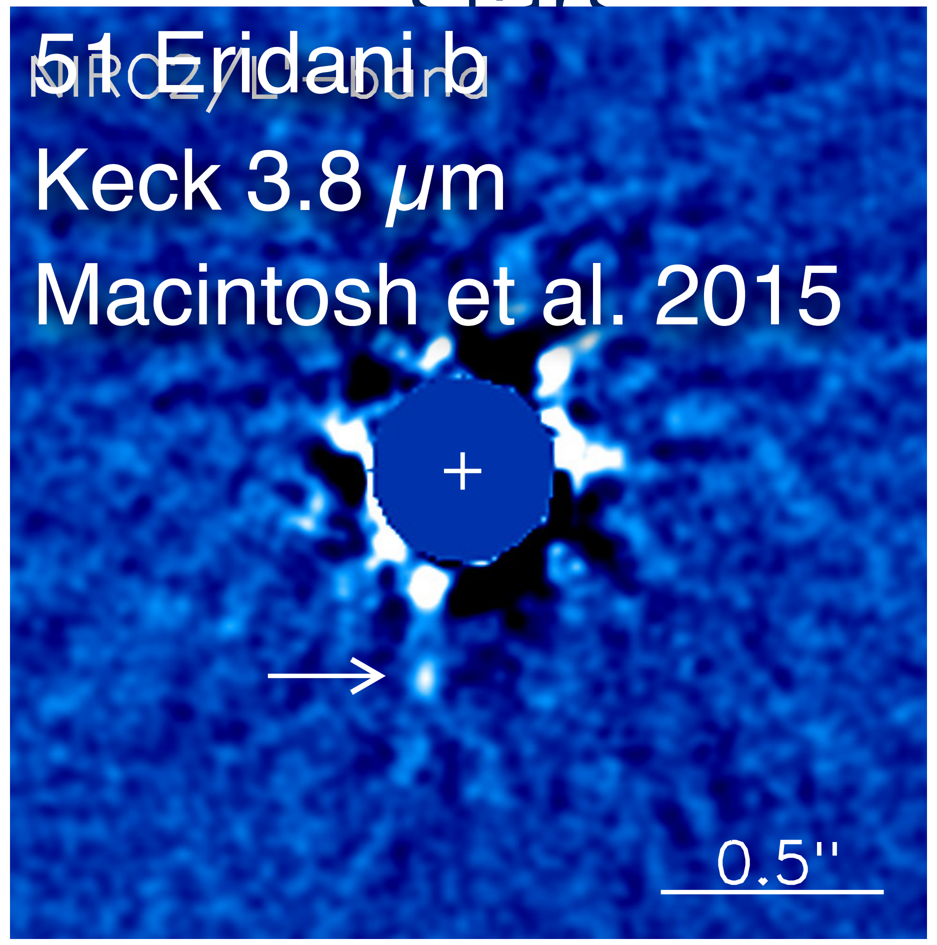


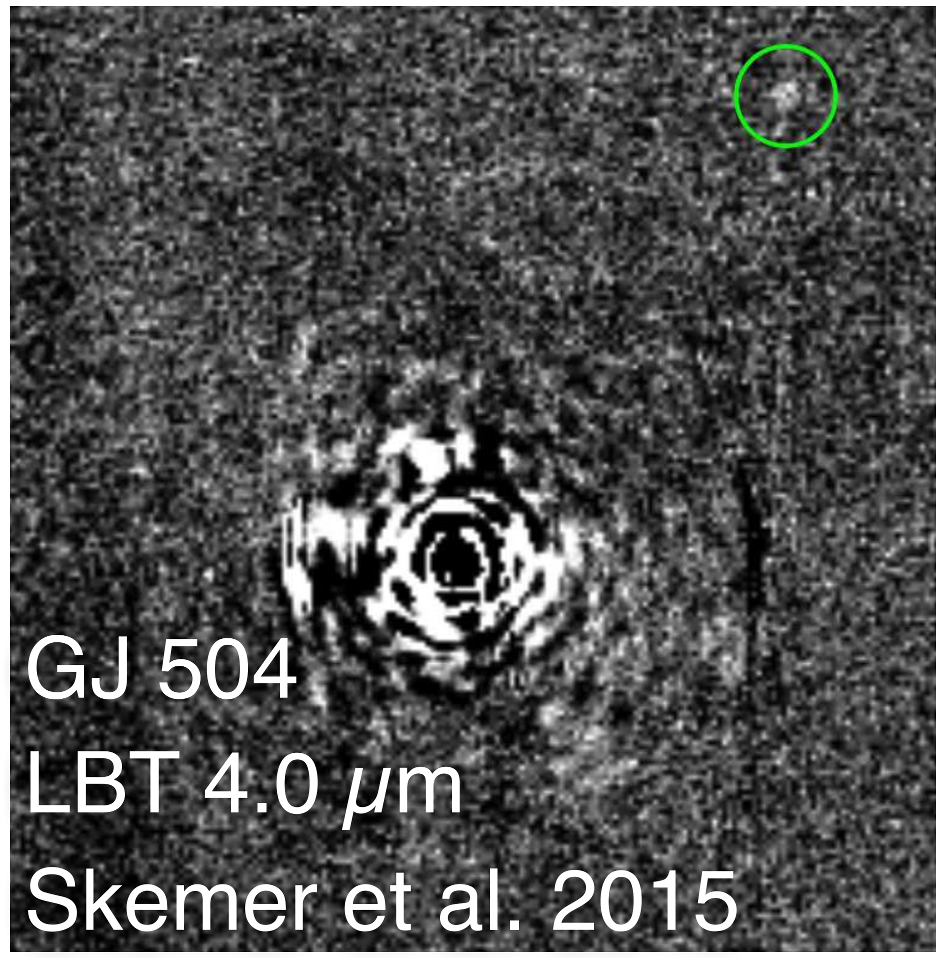


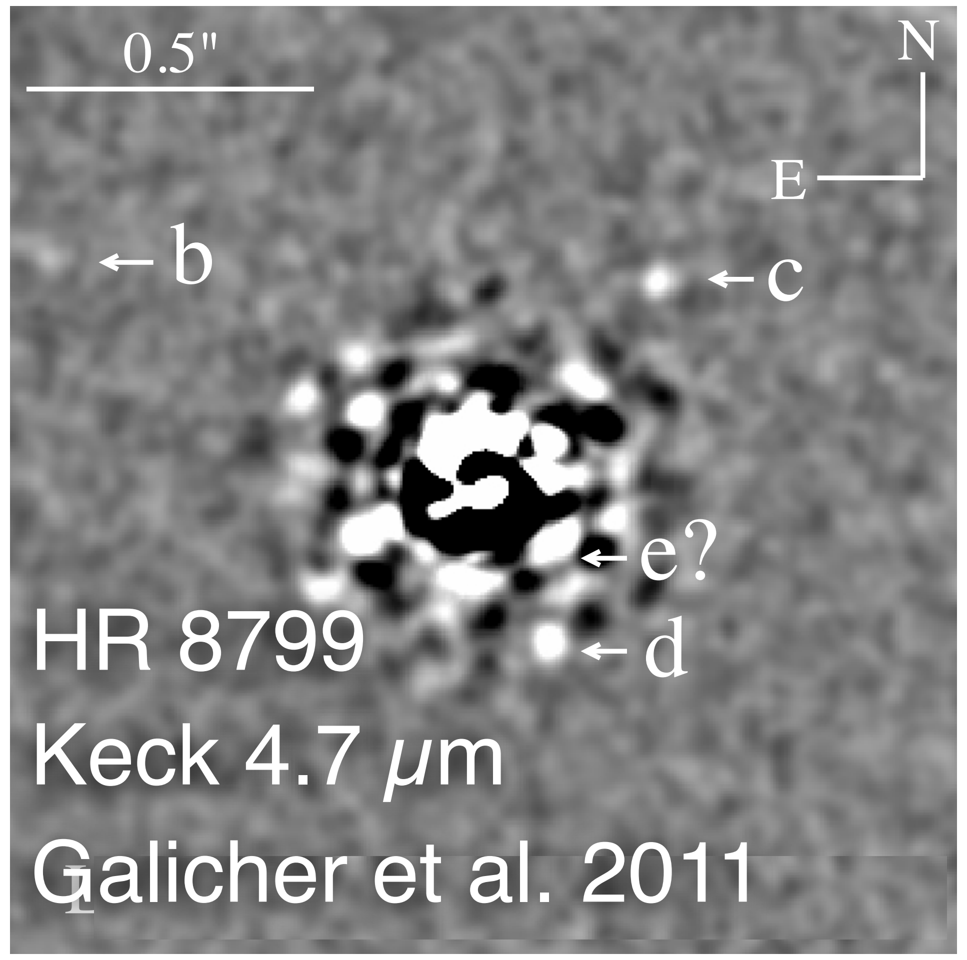


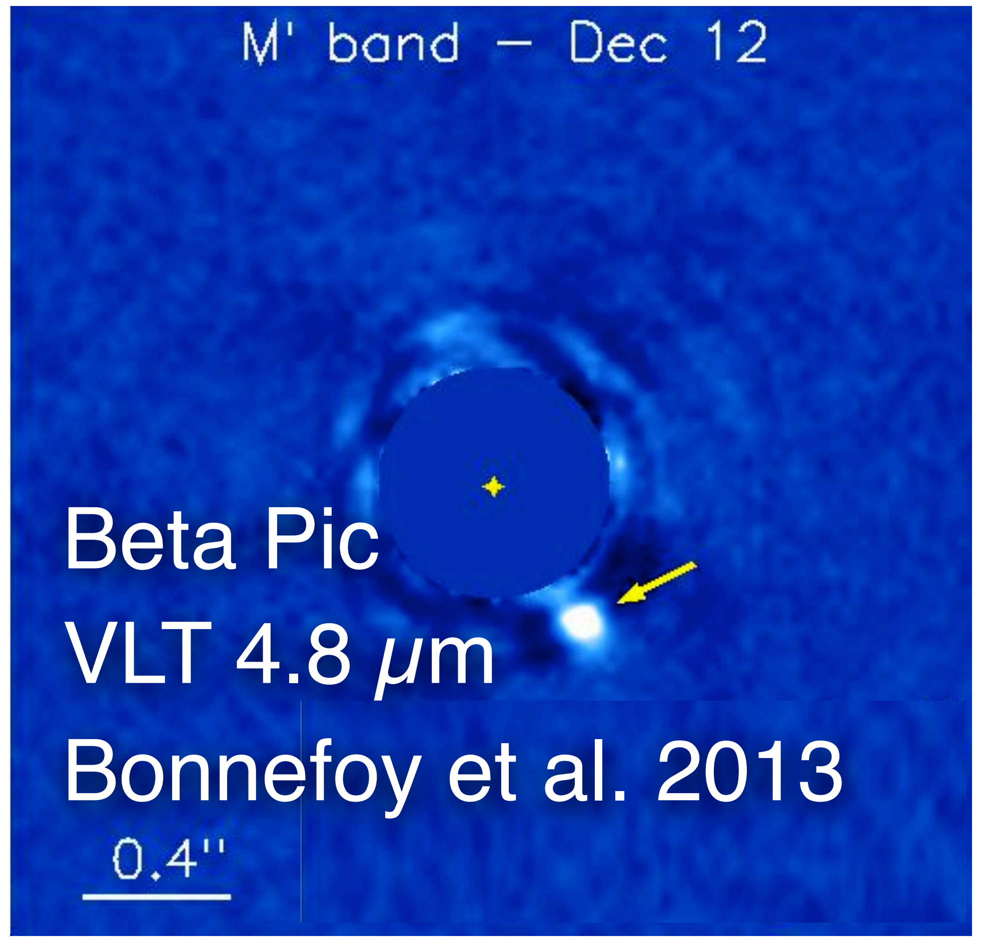


Possible but with great difficulty and around very bright & young stars









i.e Coronagraphy & High Contrast Imaging of QSOs

PG 1700+518

QSO, z ~ 0.3

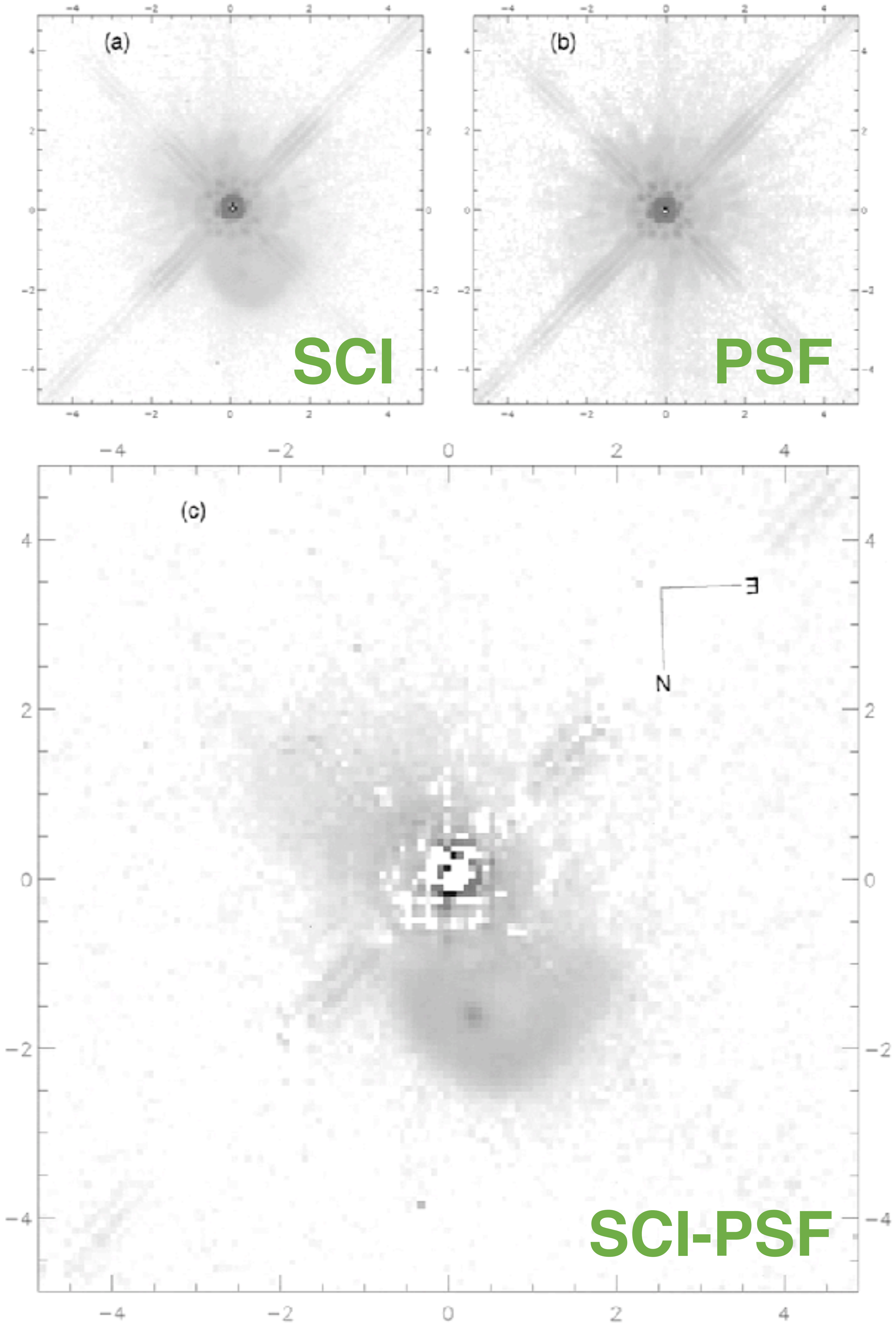
Host Galaxies & Molecular Gas

HST/NICMOS F160W (~ H-band)

Imaging

1997

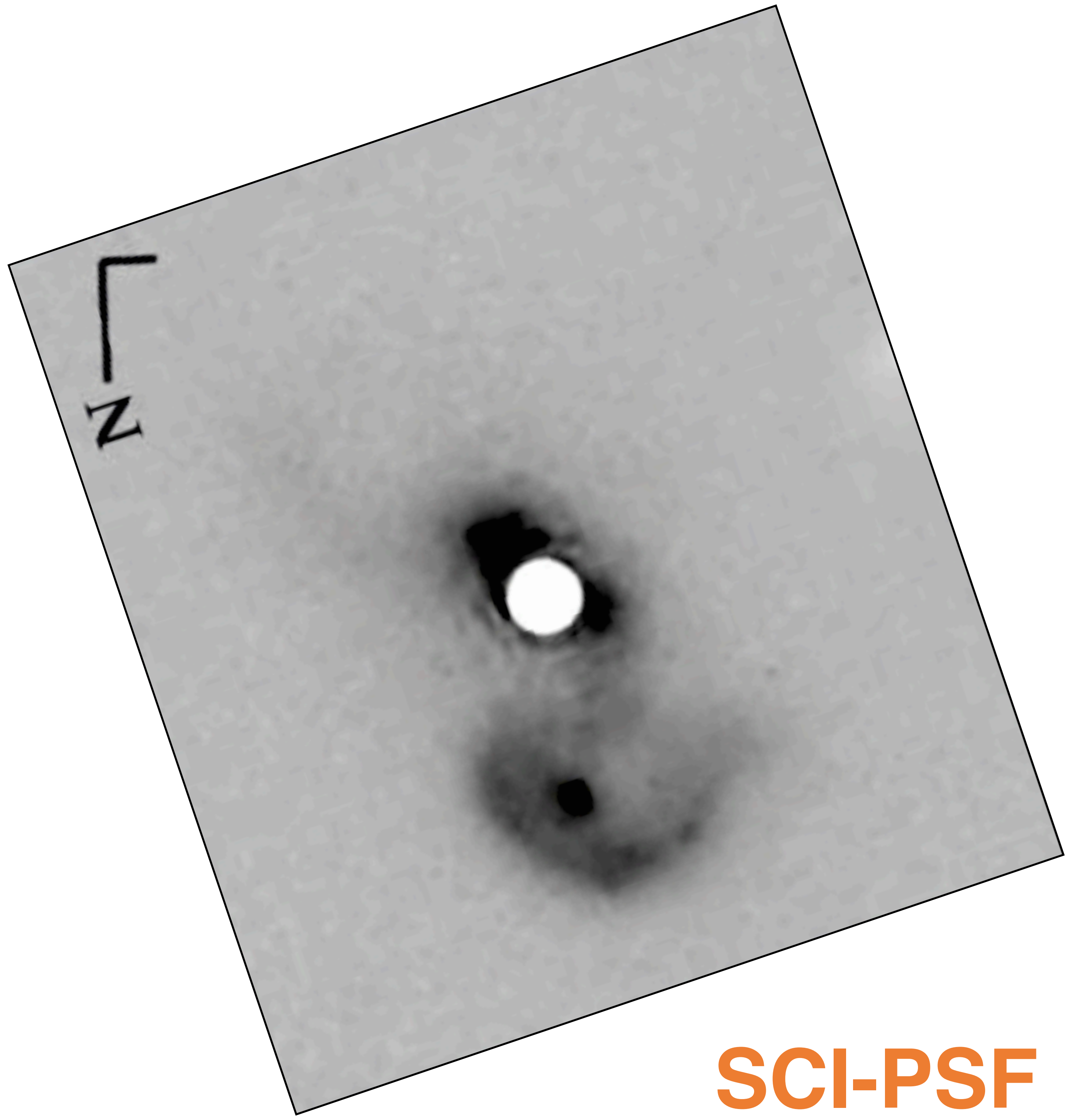
Hines et al. 1999



Coronagraphy

1998

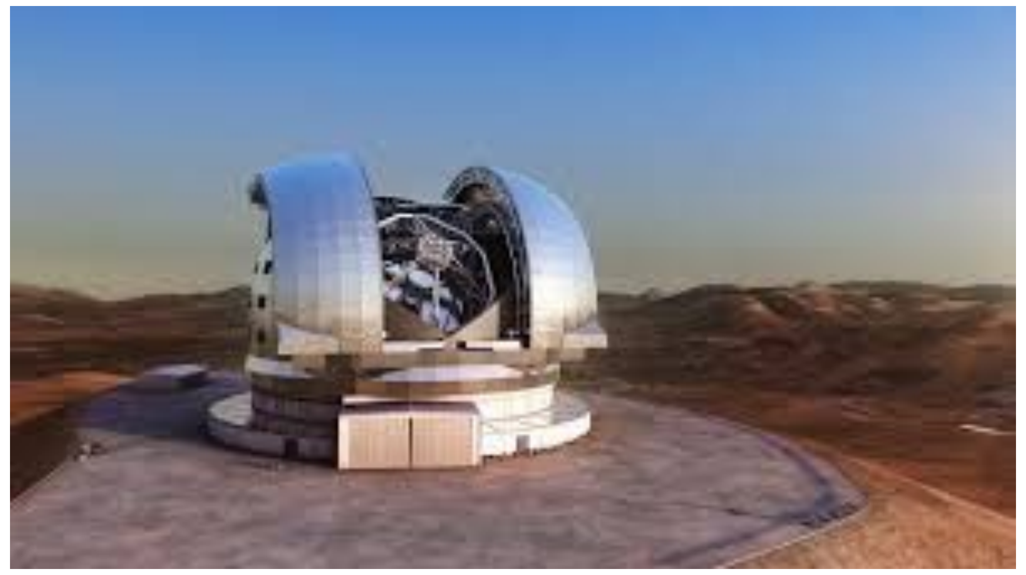
Evans et al. 2009

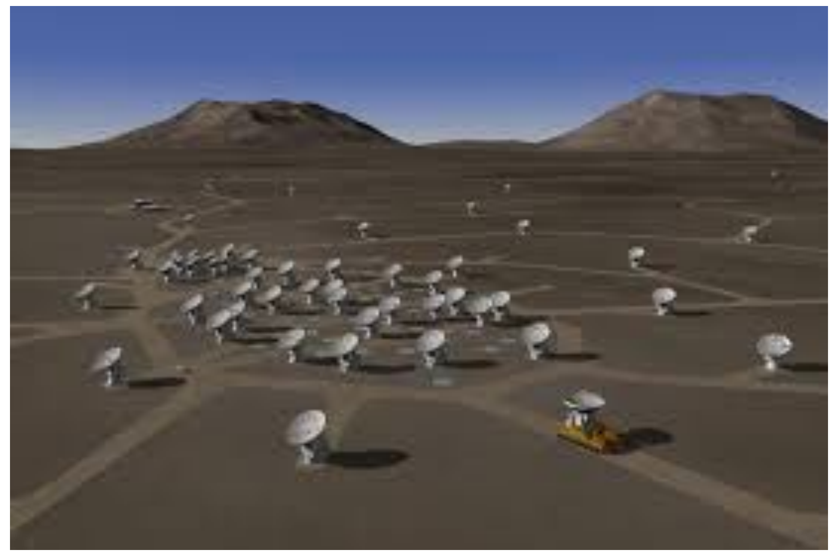


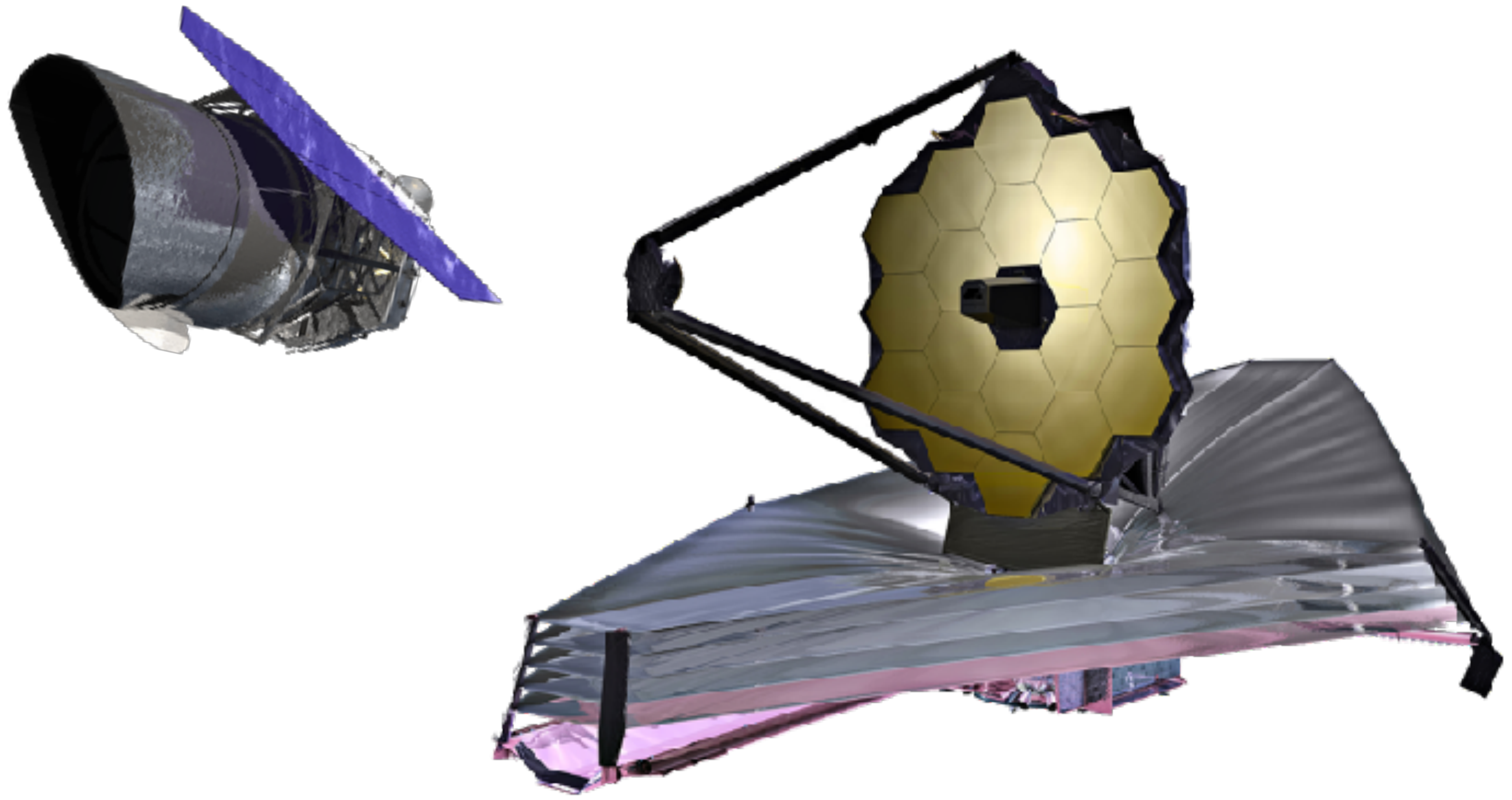
SCI-PSF

Complementarity Ground Space, great era for Direct Imaging

Ground with e**X**treme **A**daptive **O**ptics:
spatial resolution (best IWA)
& spectral resolutions (huge instruments)
multiplexing, upgrades, Imaging, Interferometry
ELTs, ALMA (sub-mm), VLTI & CHARA (0.7 - 5µm)

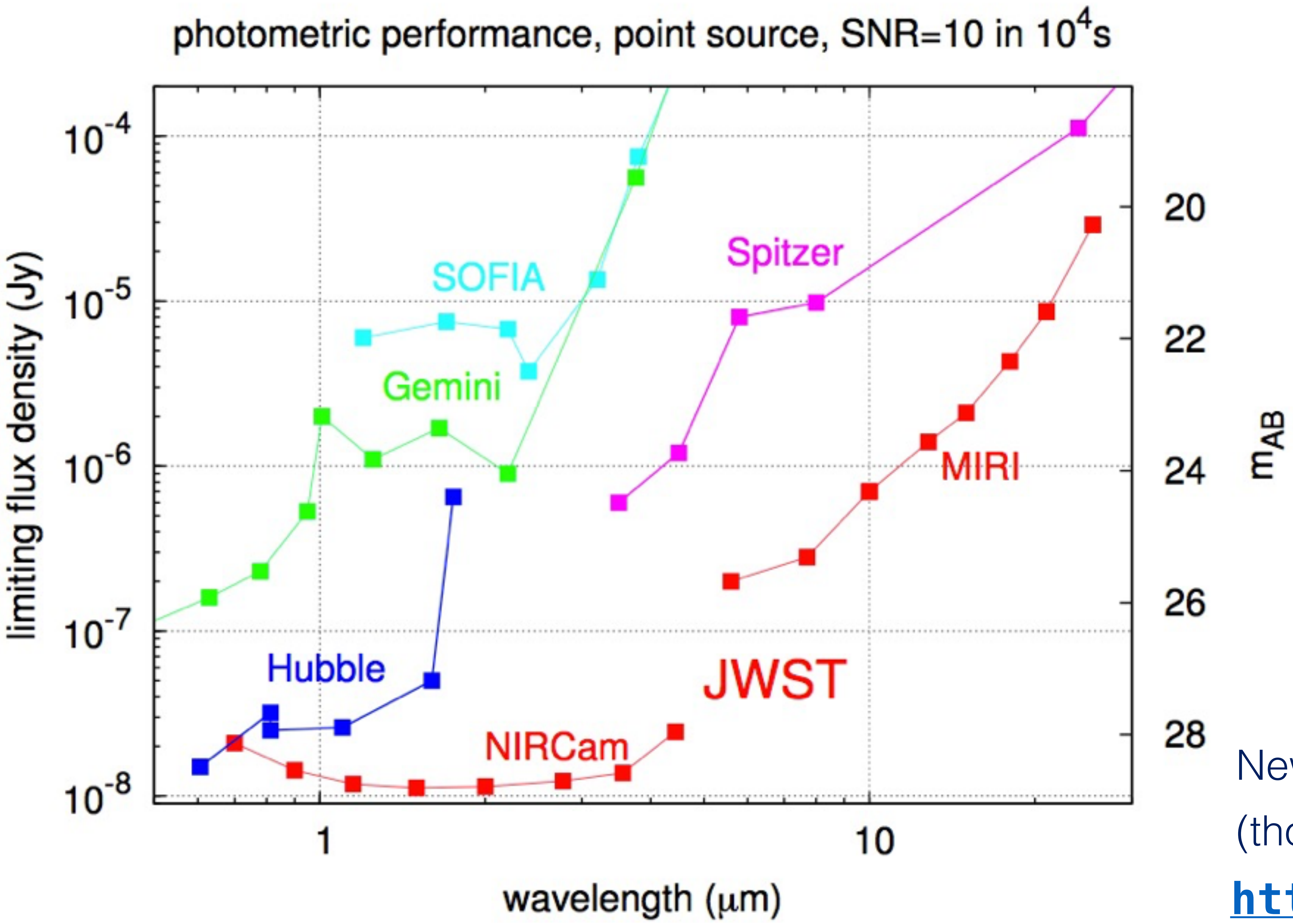






Space with HST, **JWST**, WFIRST
Incomparable **sensitivity** & **stability,**
field of view (@diffraction limit)
PSF homogeneity
No atmospheric bands

JWST: dramatically better sensitivity > 1.5 μm



In background limited regime (i.e beyond ~1")

~ 100 x more sensitive at 2 μm

~1000 x more sensitive at 4 μm

~ 30 x more sensitive than Spitzer at 10 μm and with better angular resolution

New Tool to explore sensitivity (though no HCI)

http://jist.stsci.edu

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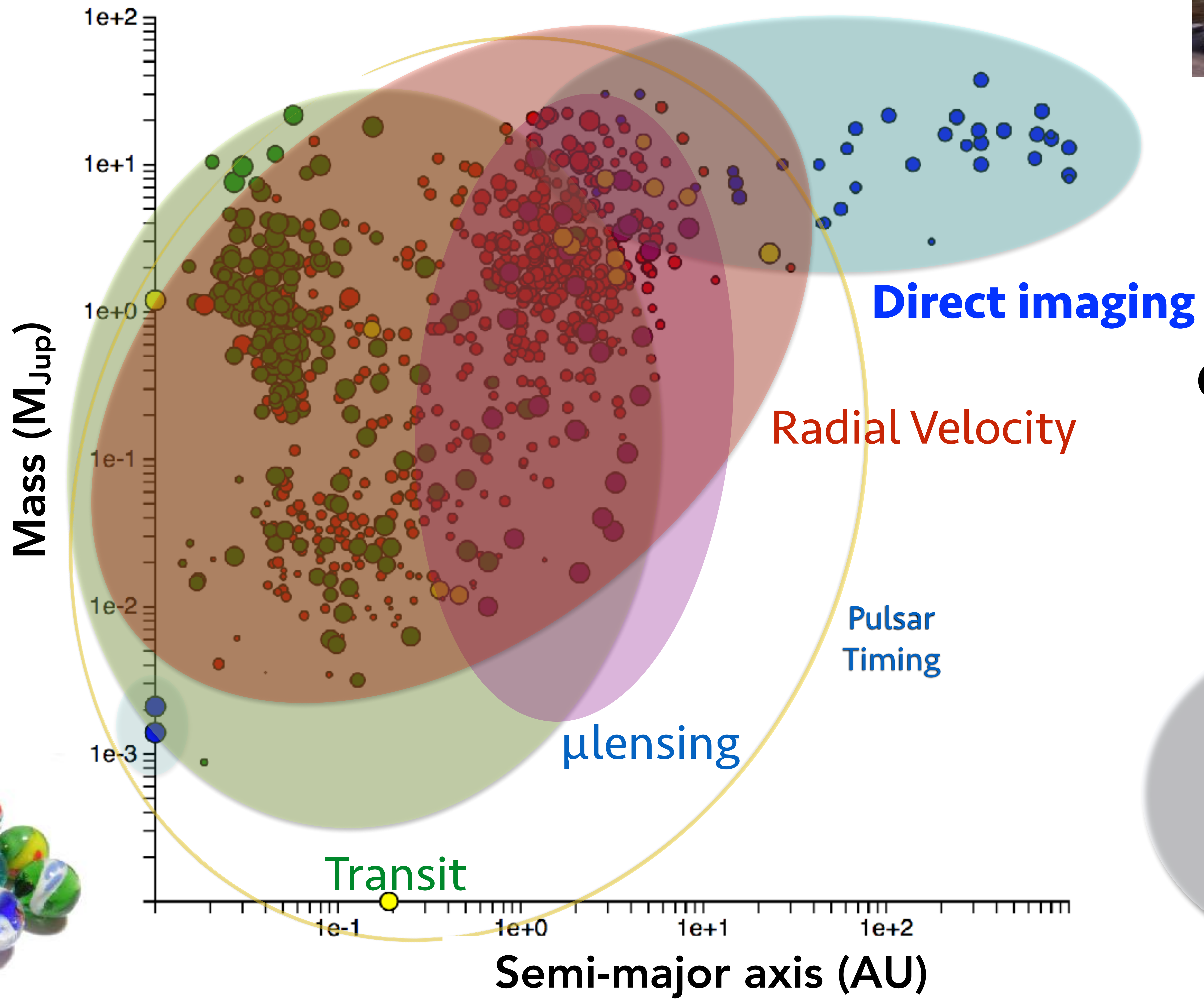
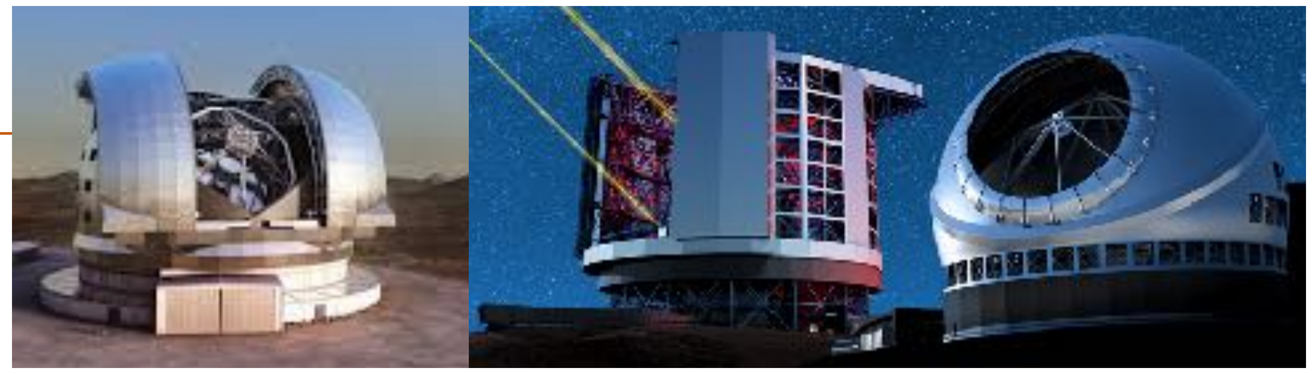
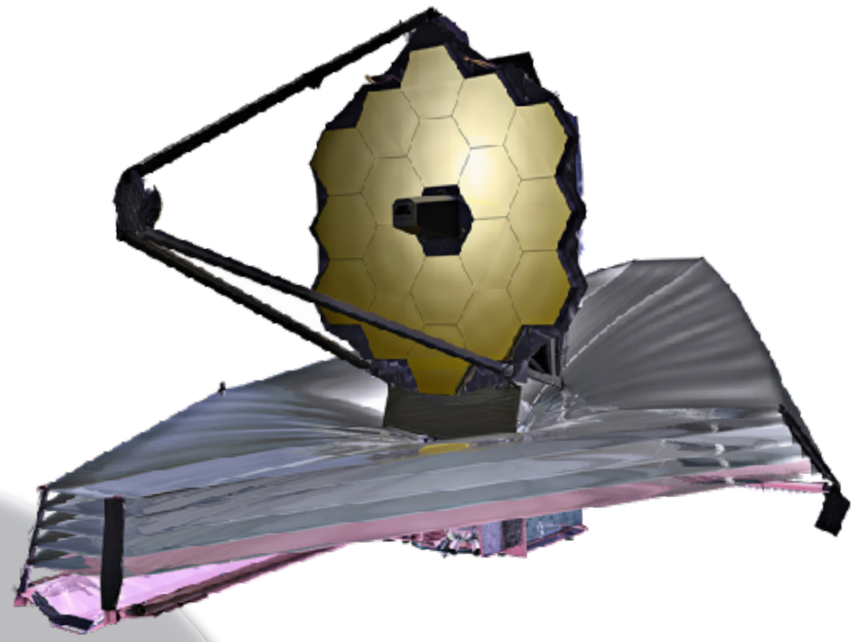
Exoplanet census & detection techniques



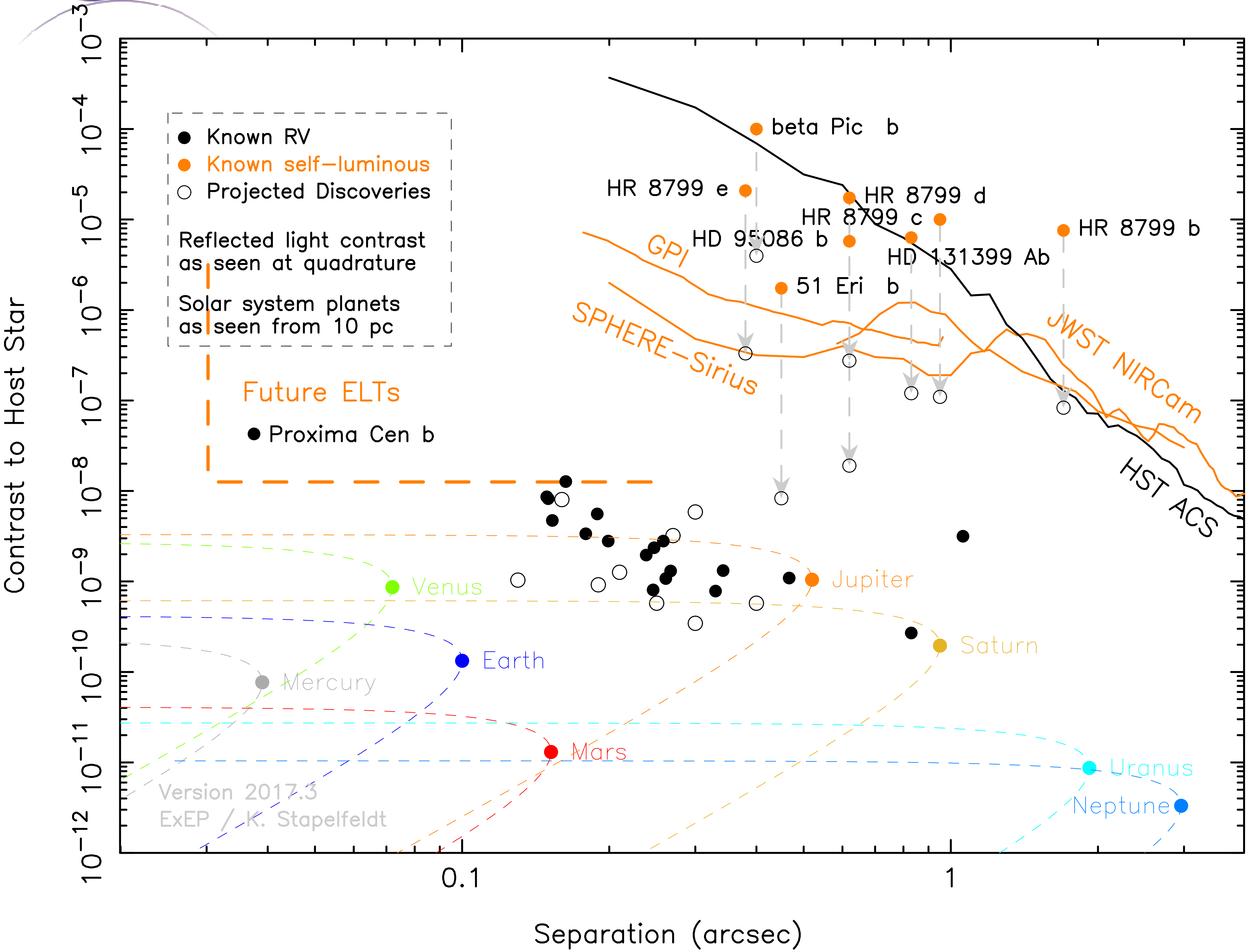


IWA ← → CONTRAST, SENSITIVITY



+ free floating super-jupiters

Great complementarity ground/space, great era for direct imaging



Ground with

eXtreme Adaptive Optics:

spatial (best IWA)

& spectral resolutions,

multiplexing, upgrades

Space

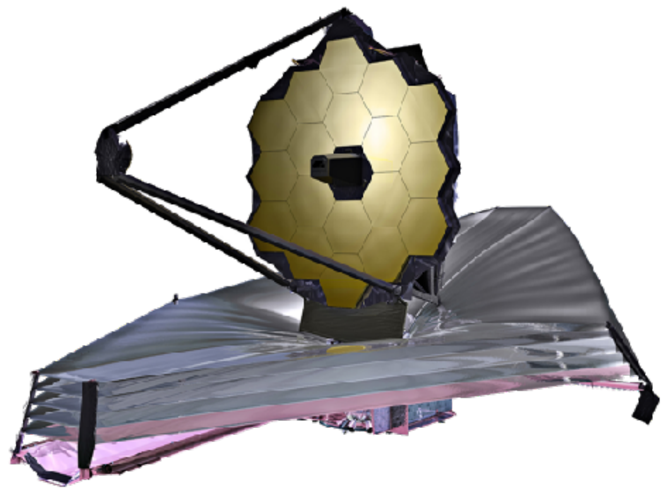
Incomparable **sensitivity,**

& **stability,**

field of view

PSF homogeneity

No atmospheric bands



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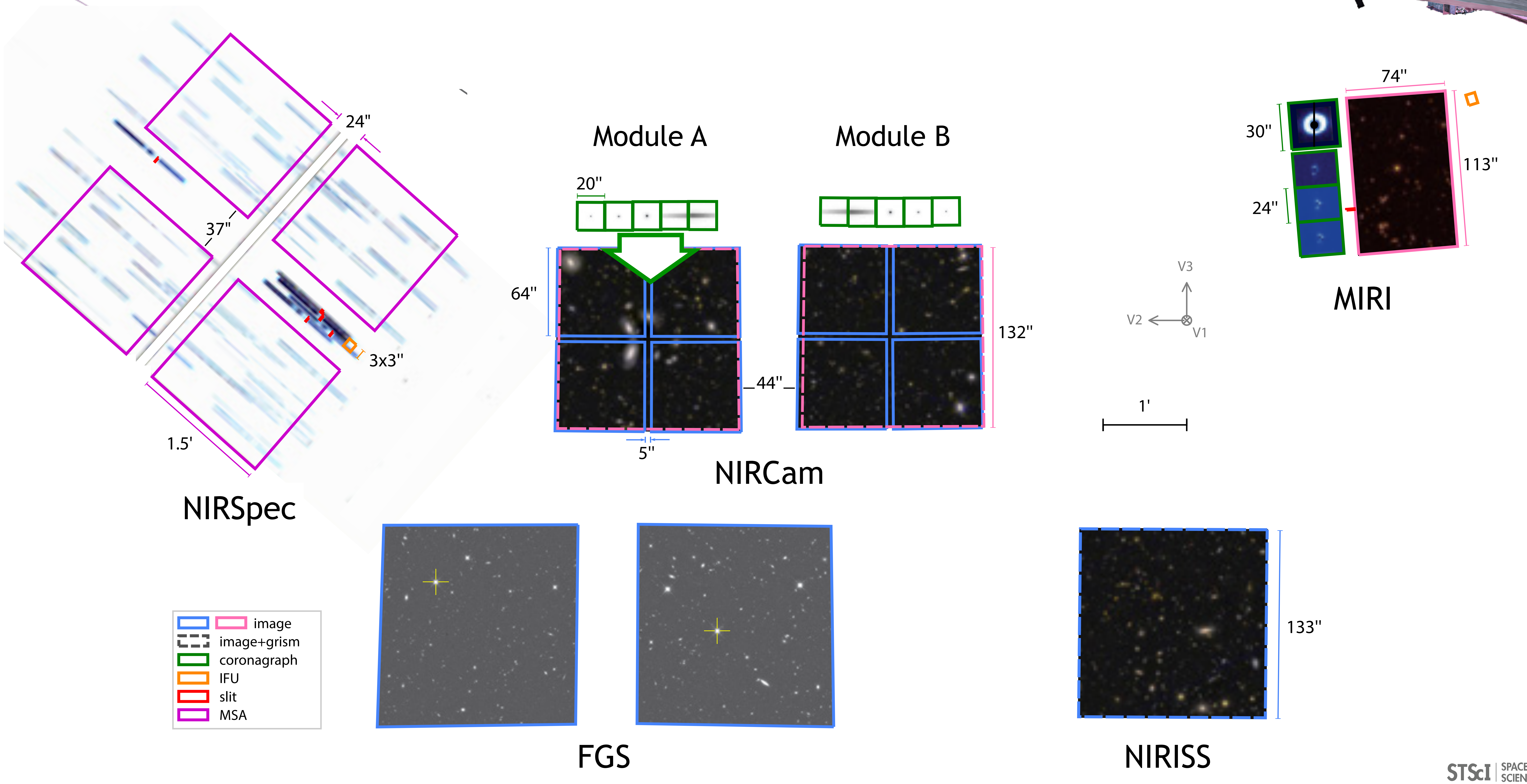
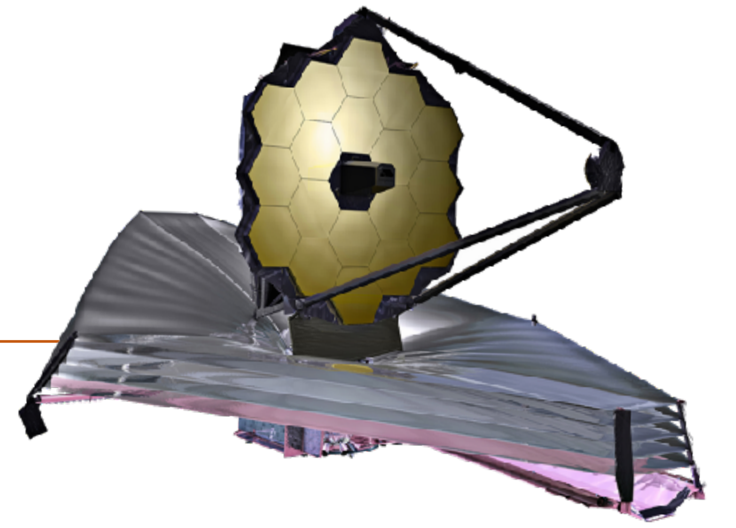
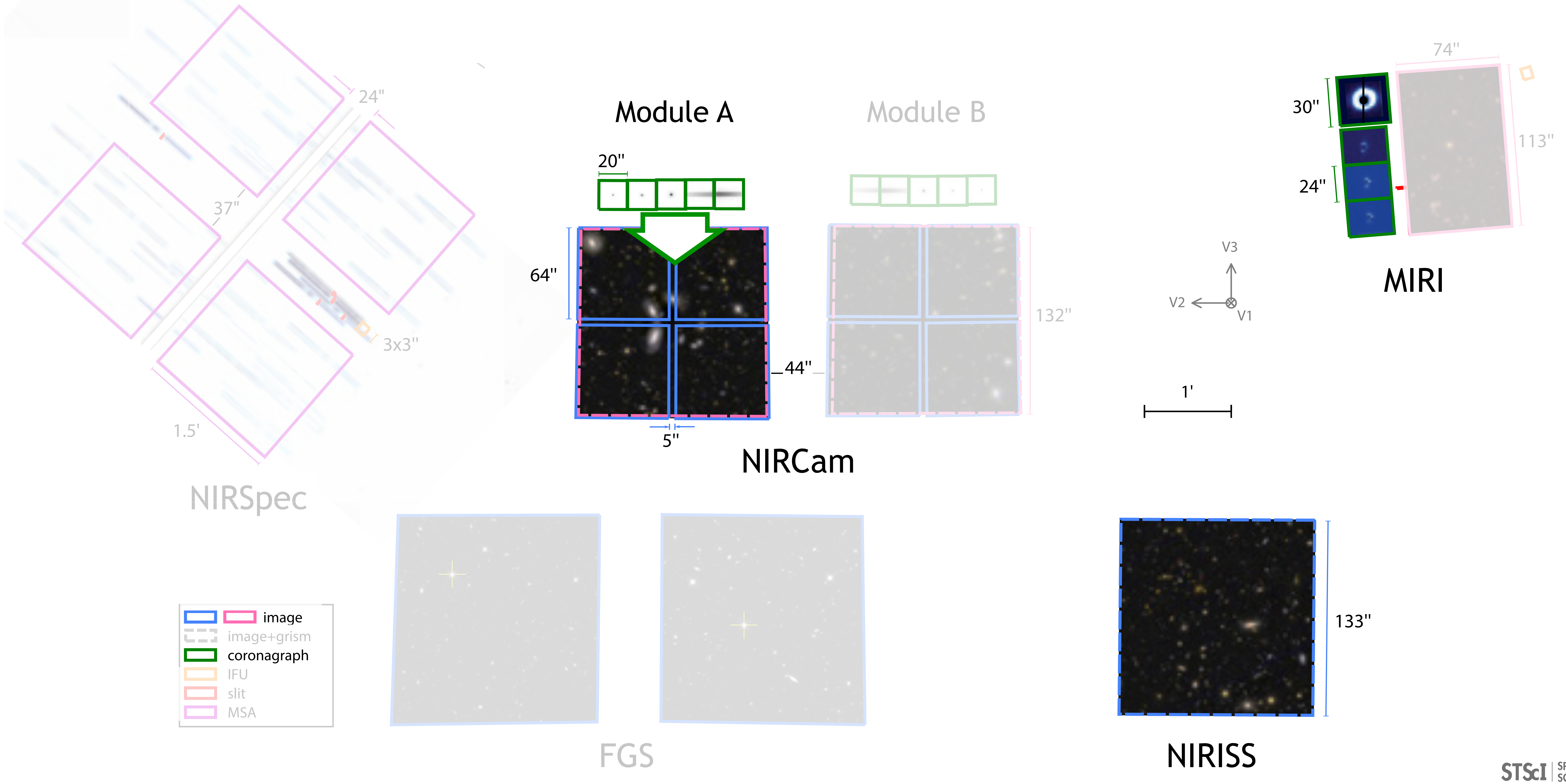
The JWST Focal Plane



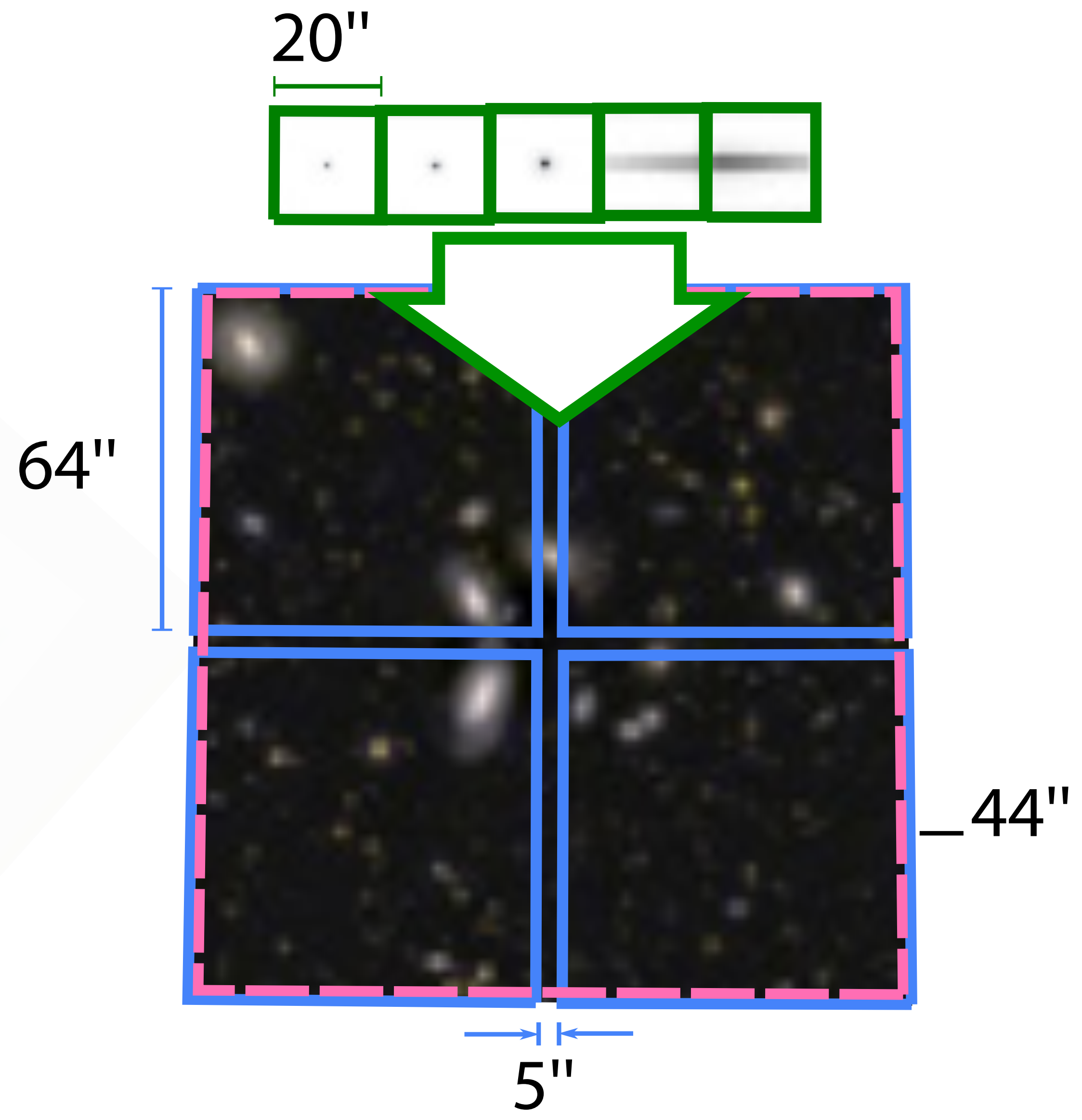
The JWST Focal Plane and main HCI instruments





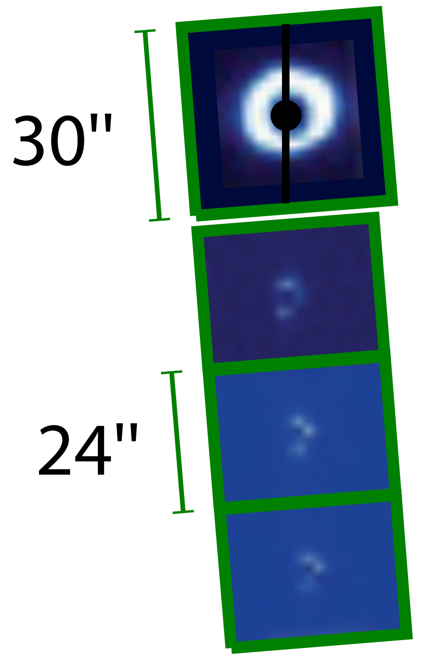
NIRCam & MIRI Coronagraphy in the JWST Focal Plane

NIRCam

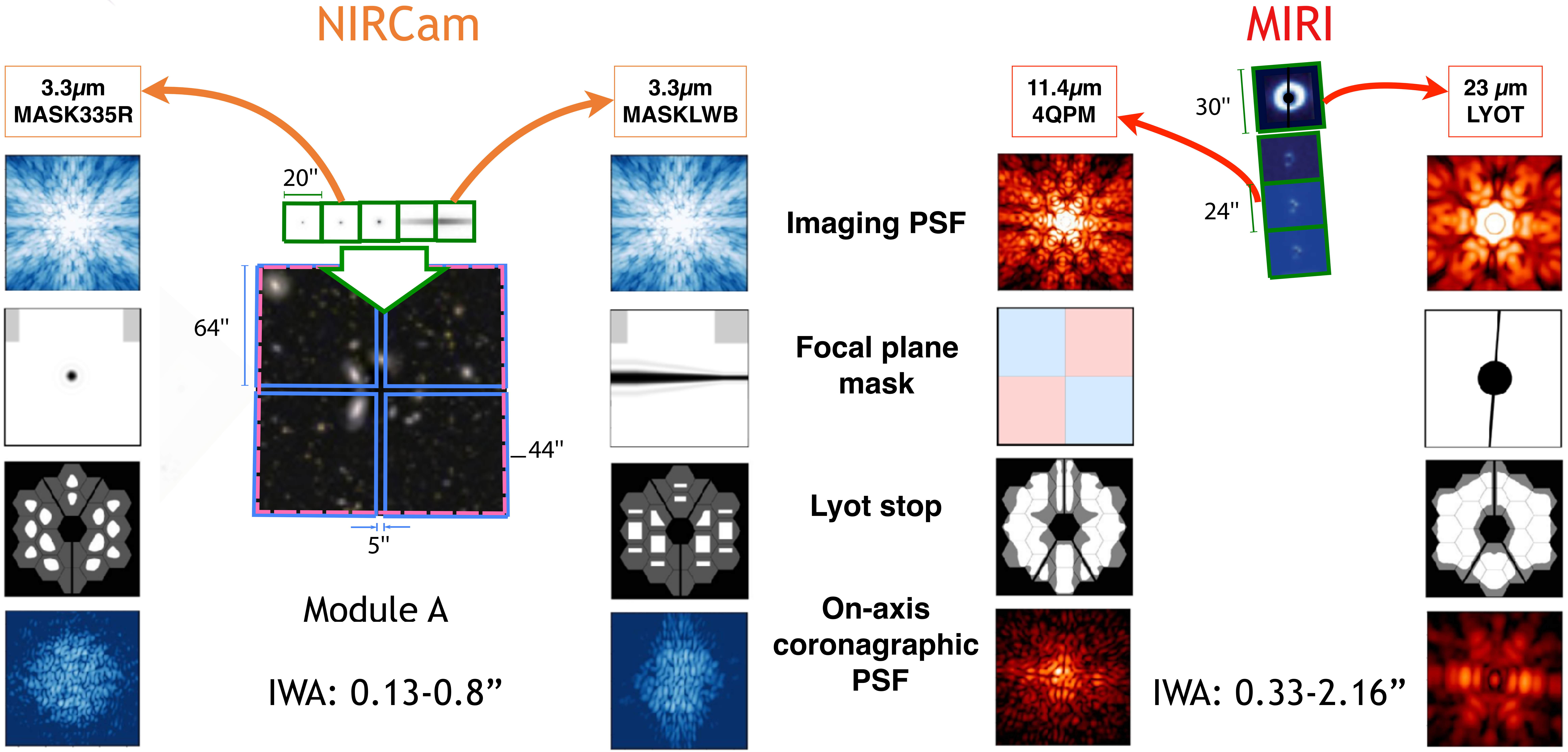


Module A

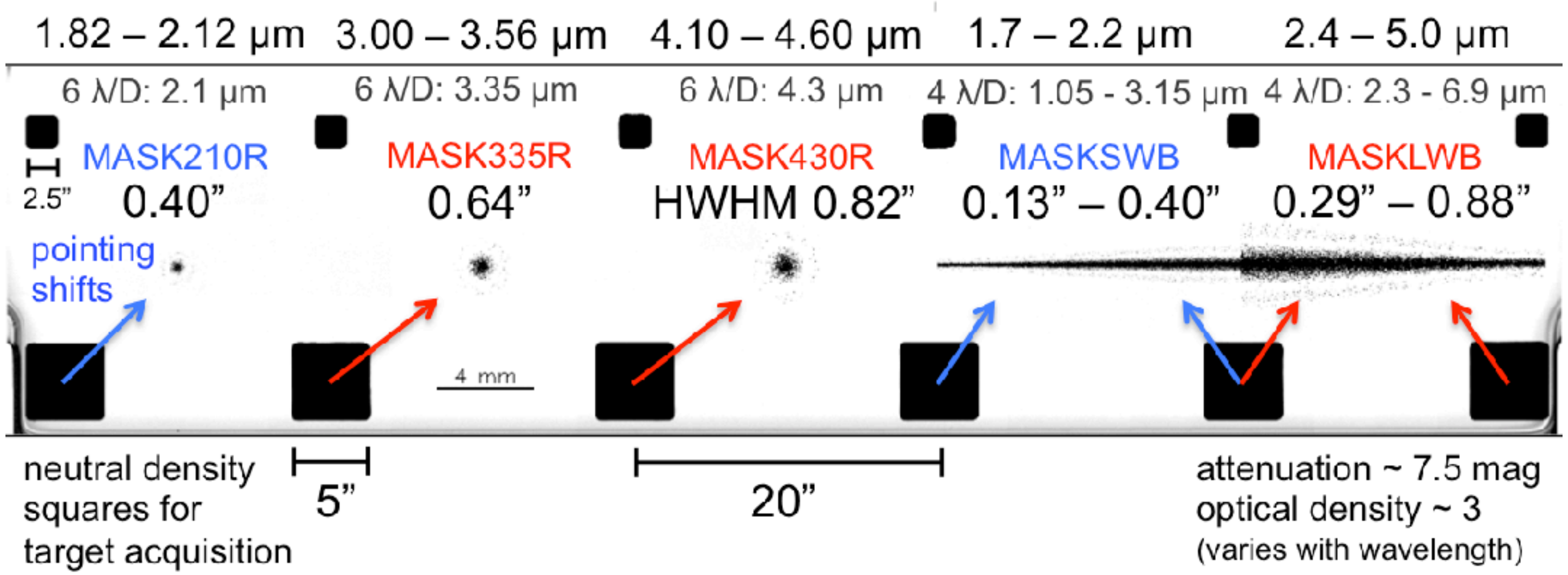
MIRI



NIRCam & MIRI Coronagraphy in the JWST Focal Plane



JWST NIRCam Coronagraphs



Name	Shape	Inner Working Angle	Wavelength Range
MASK210R	round	0.40"	1.8 - 2.2 µm
MASKSWB	bar	0.13 - 0.40"	1.8 - 2.2 µm
MASK335R	round	0.63"	2.5 - 4.1 µm
MASK430R	round	0.81"	2.5 - 4.6 µm
MASKLWB	bar	0.29 - 0.88"	2.5 - 4.8 µm

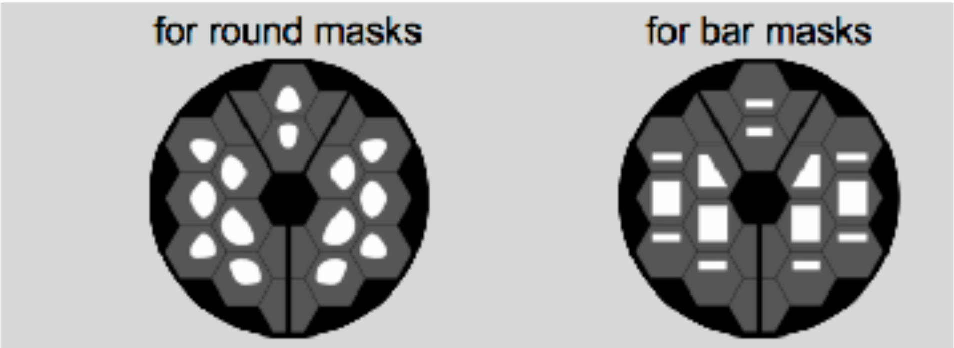
5 Lyot coronagraphs, pseudo band-limited with soft-edged grayscale occulters

Round occulters provide 360° azimuthal coverage for disk observations and planet searches

Relatively large (HWHM = 0.4-0.8"): optimized for 6 λ/D at λ= 2.1, 3.3, 4.3

Bar occulters provide allow selection of inner working angle to match wavelength. Optimized for 4 λ/D. Each filter has its own location along the wedge

Lyot stops suppress PSF wing diffraction. Throughput = 19%

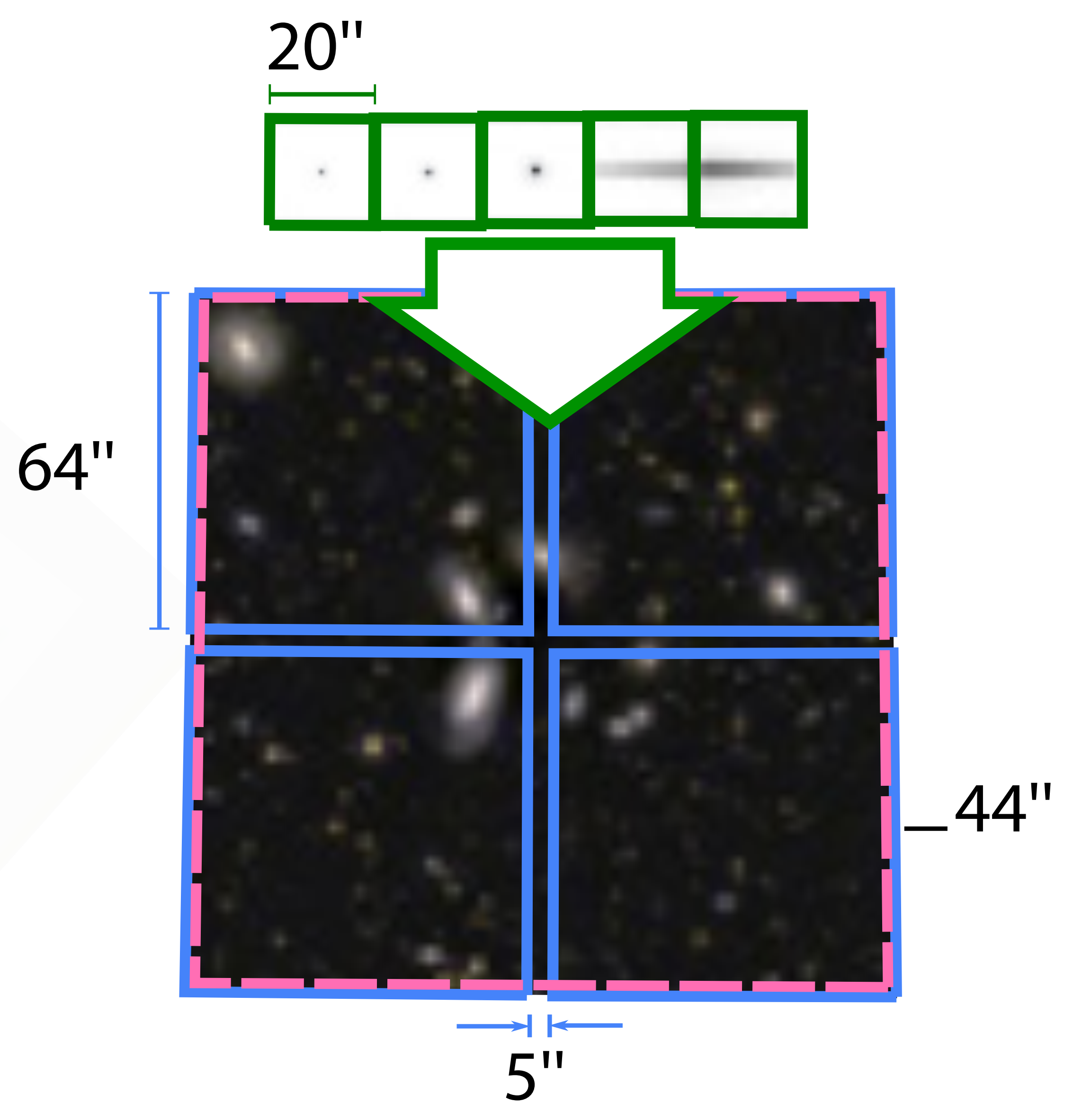


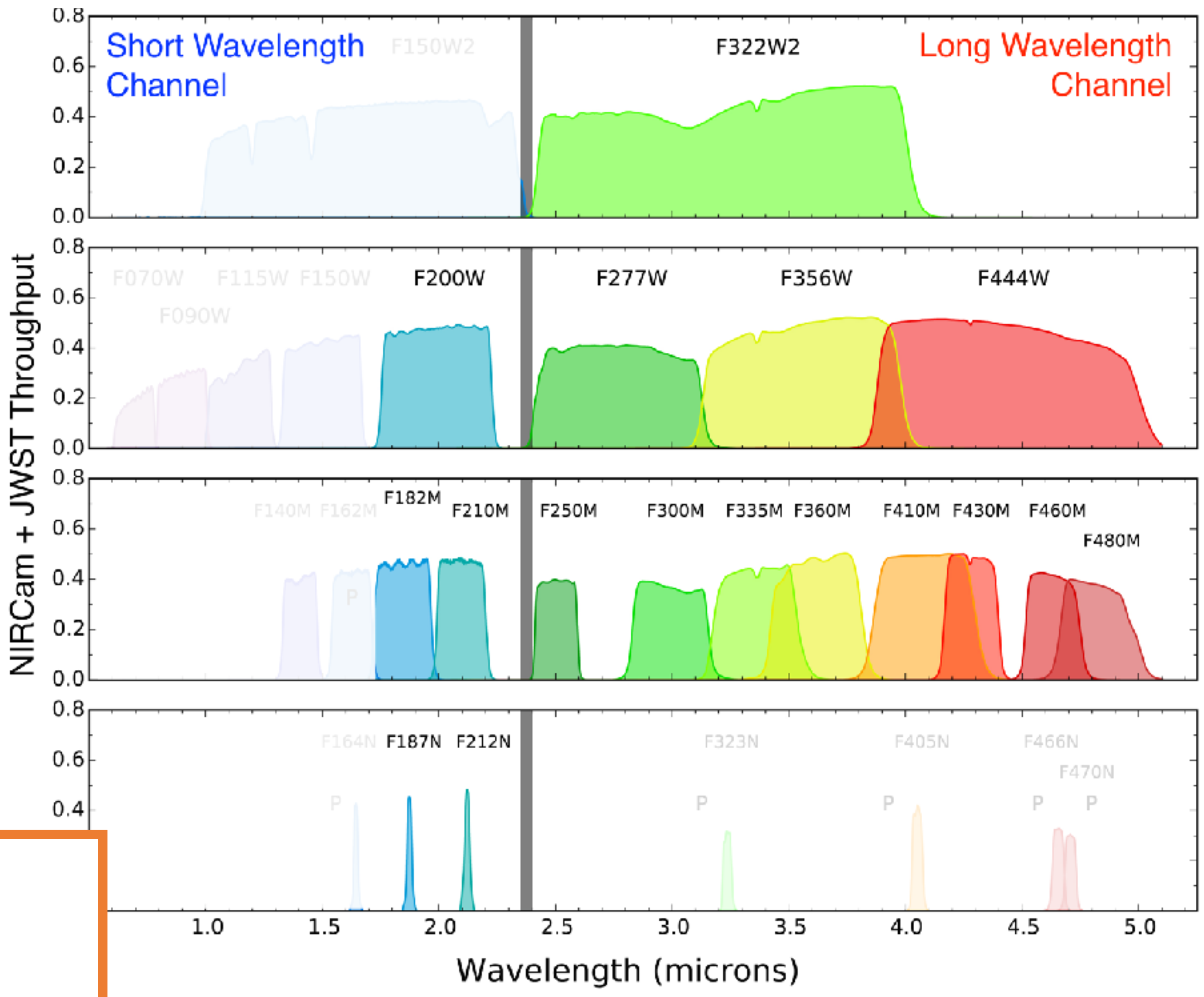
Coronagraph optics are outside the FOV during normal imaging observations

NIRCam & MIRI Coronagraphy in the JWST Focal Plane

NIRCam

Module A

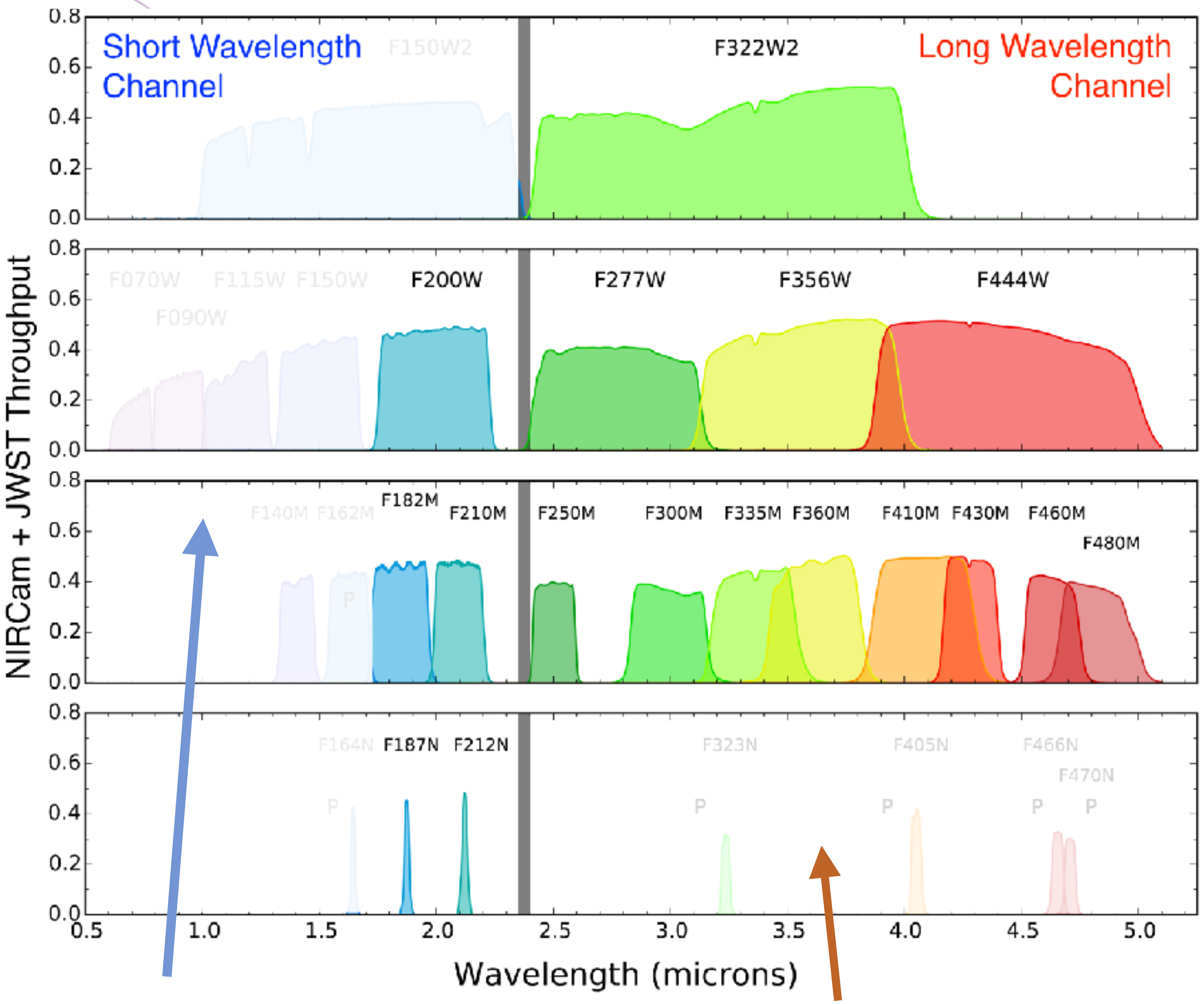




Currently SW and LW data cannot be saved simultaneously

It may change in later cycles

Most NIRCam filters are available for coronagraphy



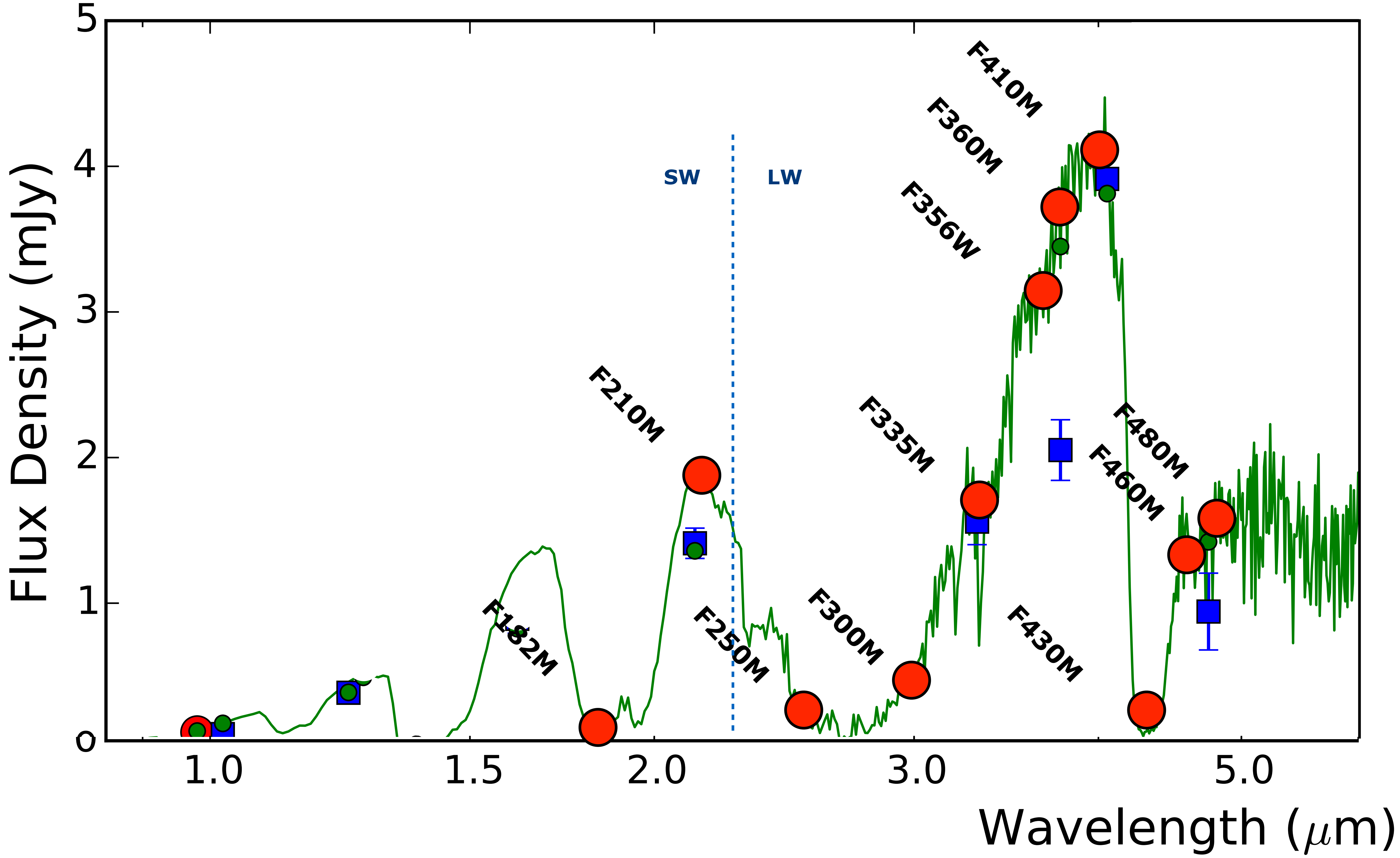
SW filters below 1.8 μm **unavailable**
Coronagraph mask anti-reflection coating has low throughput for λ < 1.8 μm

LW narrow band filters **unavailable** as installed in same pupil wheel as the coronagraph Lyot stops

Filter	
F182M	H_2O, CH_4
F187N	Paschen Alpha
F200W	continuum
F210M	H_2O, CH_4
F212N	H_2
F250M	continuum, CH_4
F277W	continuum
F300M	H_2O ice
F322W2	double-wide, max sensitivity
F335M	PAH, CH_4
F360M	continuum
F410M	continuum
F430M	CO_2, N_2
F444W	continuum
F460M	CO
F480M	CO

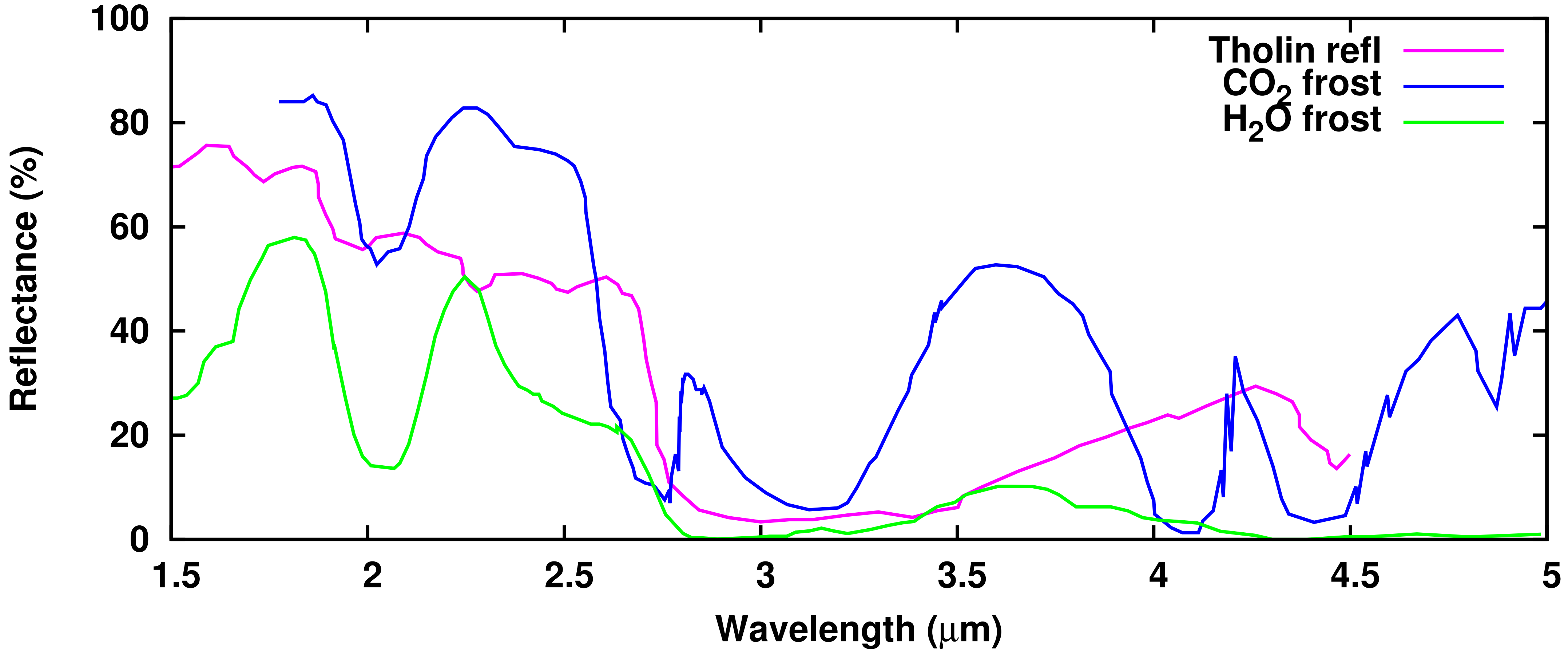
NIRCam is well suited for characterizing substellar companions & disks

Exoplanet and brown dwarf atmospheres



Teff = 1000 K, log(g) = 3.5 model from Barman et al.

Debris disk dust composition and ices



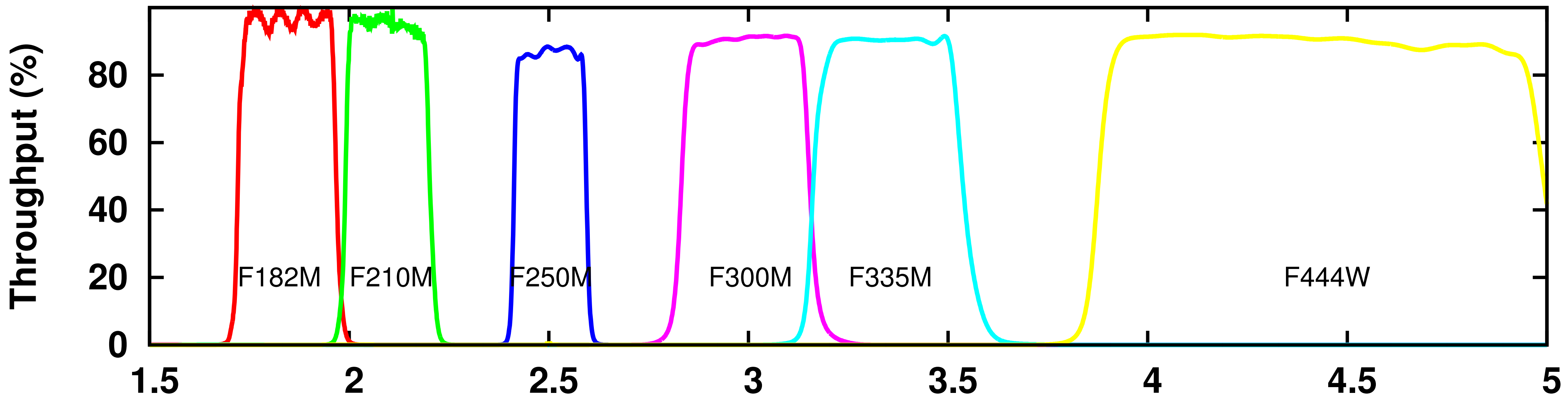
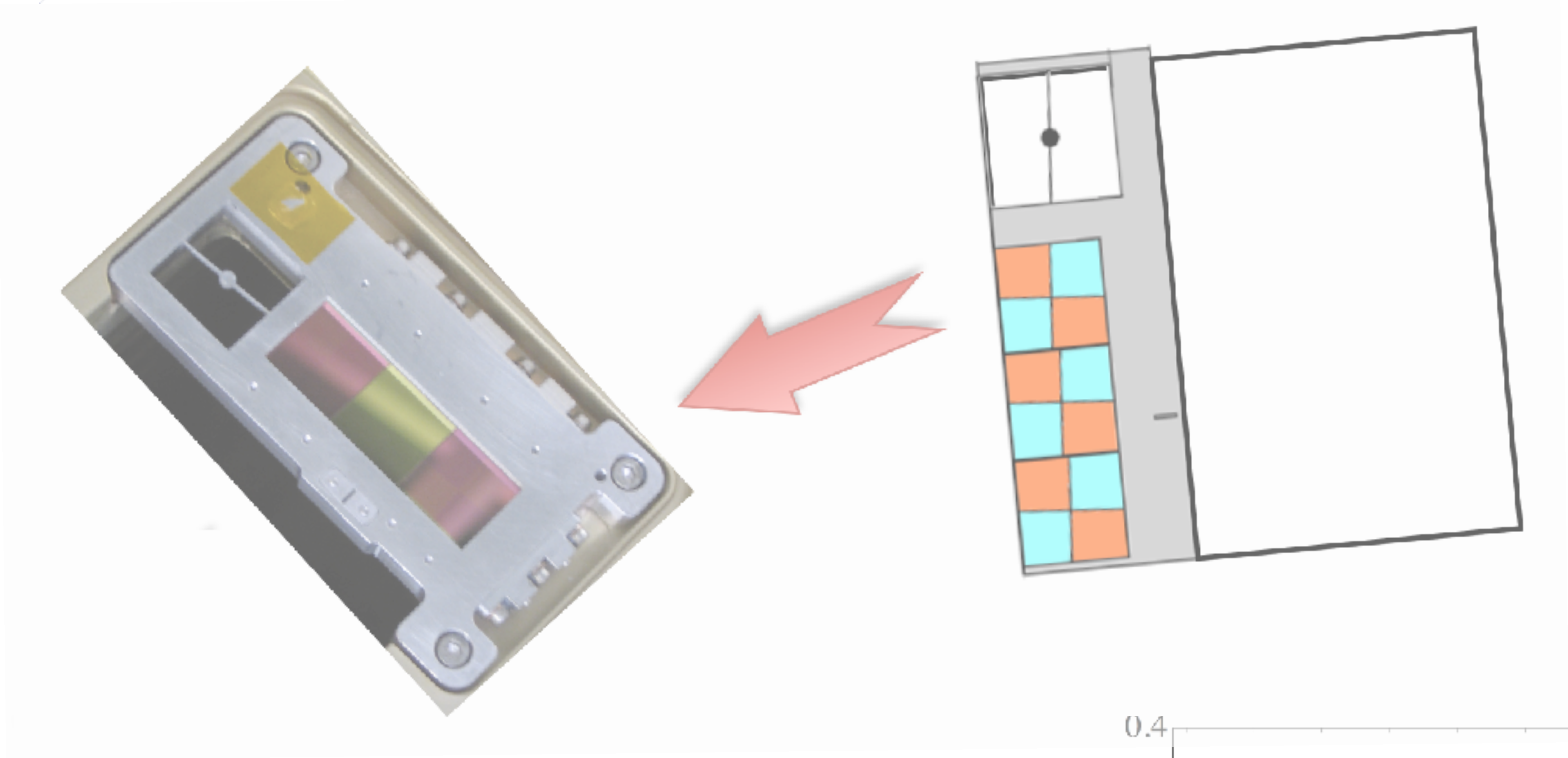
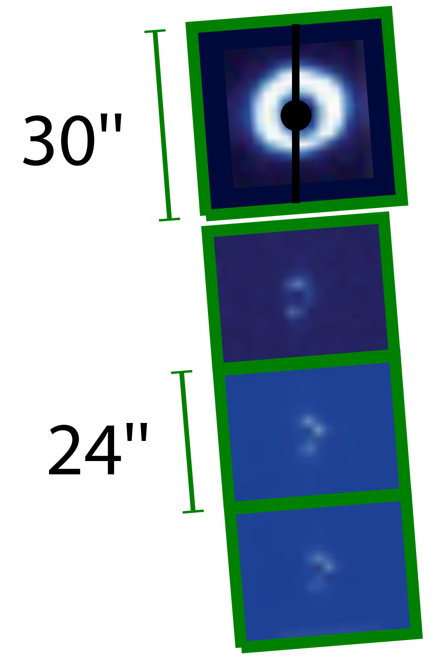


Figure courtesy Andras Gaspar et al. (NIRCam GTO)

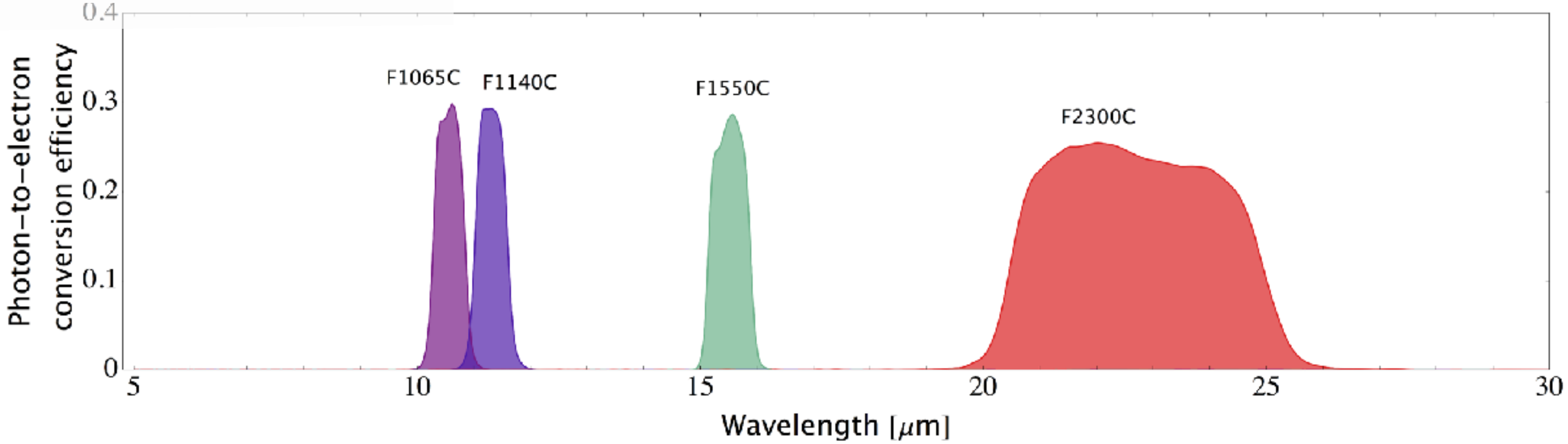
NIRCam & MIRI Coronagraphy in the JWST Focal Plane



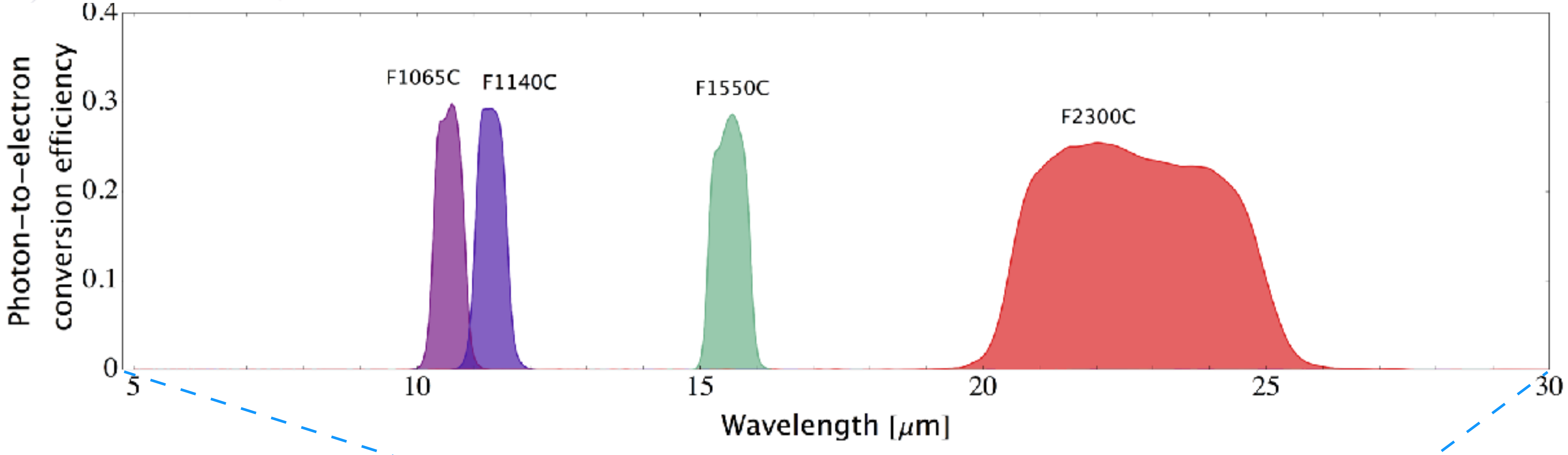
MIRI



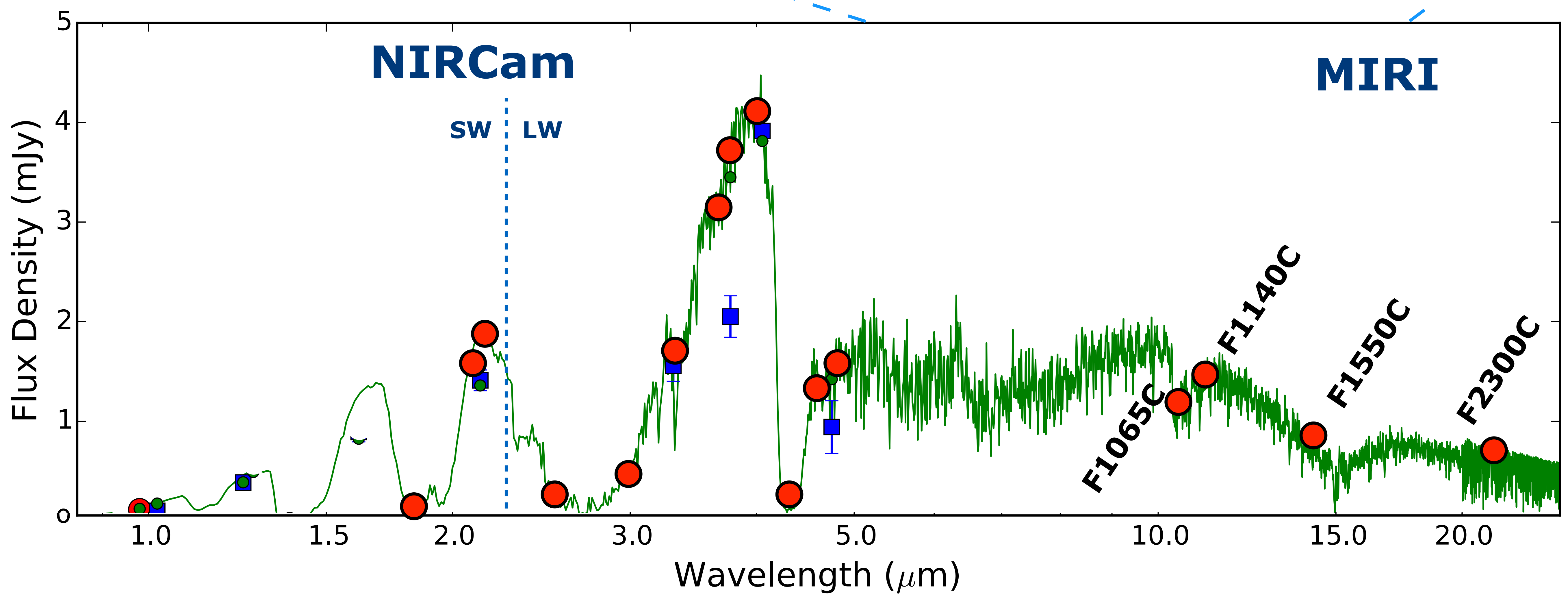
One mask, one filter



MIRI filters for coronagraphy



Filter	
F1065C	Ammonia
F1140C	Continuum (planets); Si, PAHs (disks)
F1550C	Continuum
C2300C	Continuum, especially for disks



Teff = 1000 K, log(g) = 3.5 model from Barman et al.

Ammonia feature at 10.65 μm is main spectral feature at 5-20 μm for cool exoplanet atmospheres (T~ 200-500 K).

Continuum slope from 11.4 - 15.5 measures planet temperature.

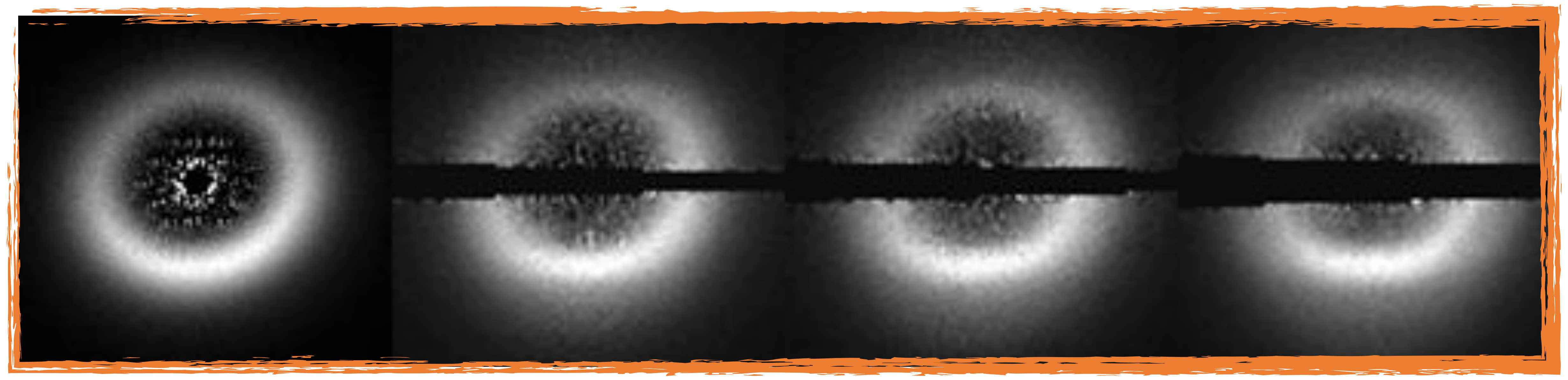
These filters also suitable for studies of circumstellar disks and AGN.

Studying Disk Compositions: Panchromatic Imaging

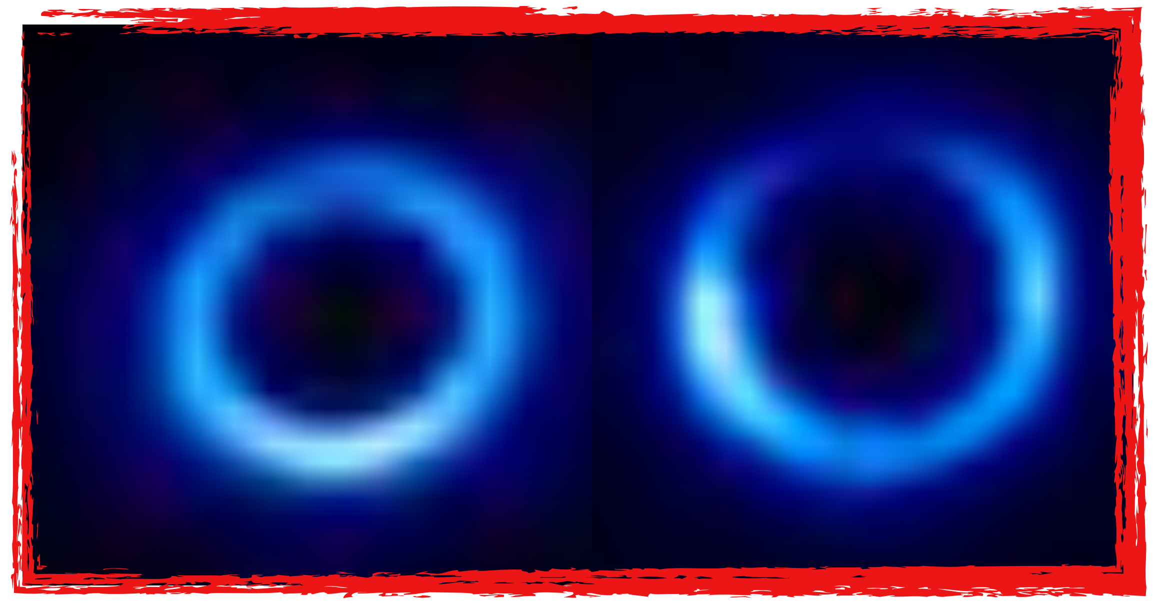
High contrast at longer wavelengths: **3-5 μm**, **10+ μm**

Much **deeper sensitivity & wider field of view** than AO, superb **optical stability**

Options: **NIRCam** & **MIRI coronagraphs**, **NIRISS AMI**, **NON-coronagraphic PSF subtraction!**



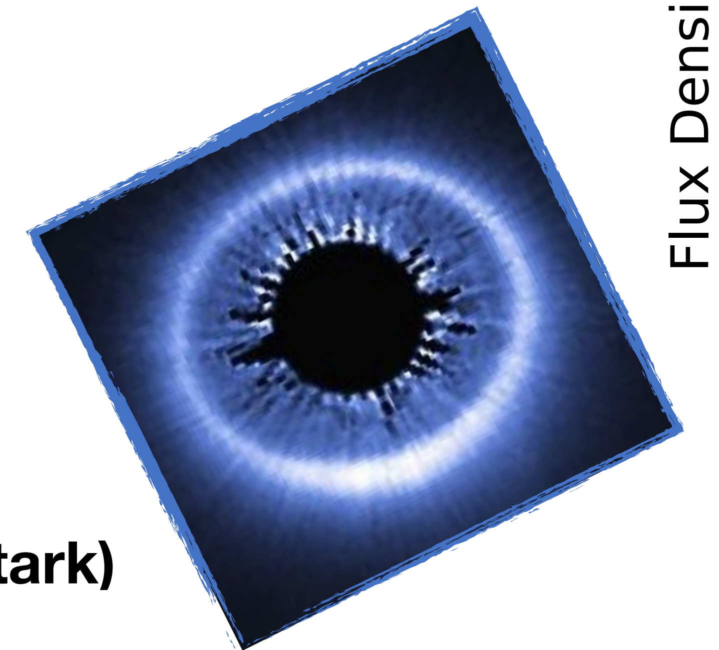
(Simulations by J. Lebreton)



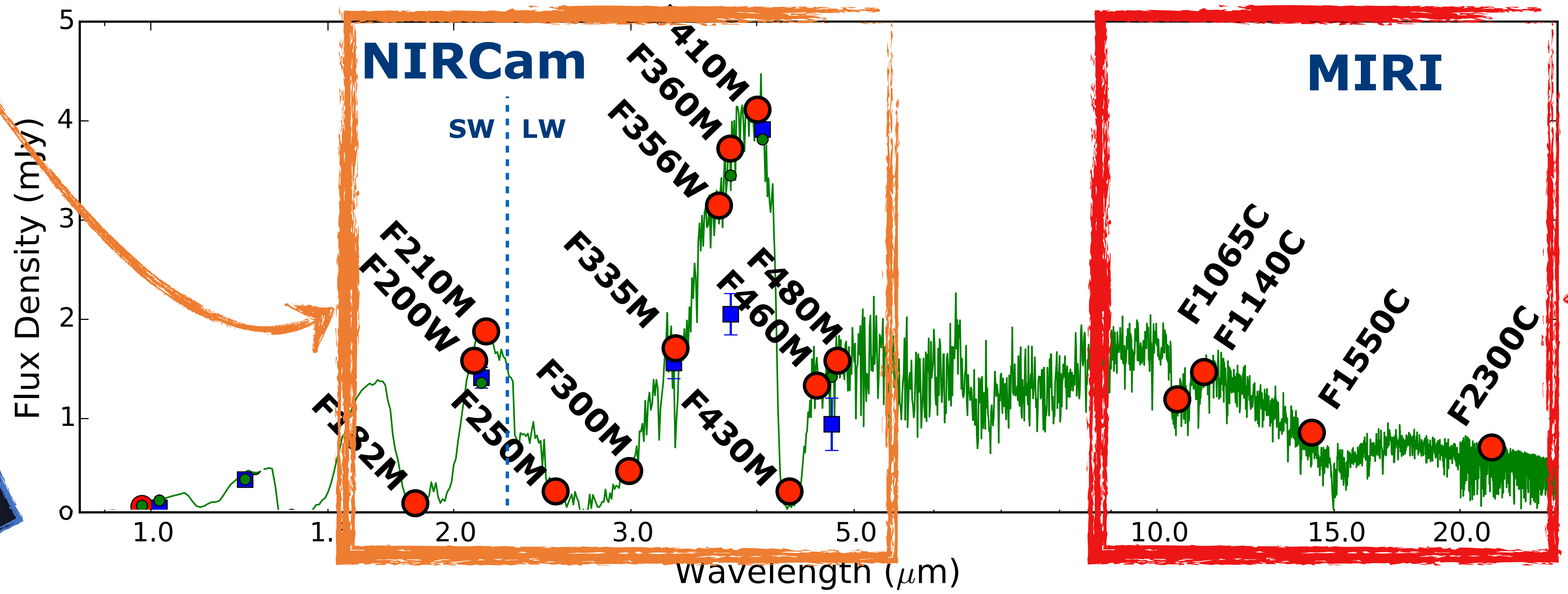
(Simulations by A. Boccaletti)

Colors, albedos, phase functions of scattering particles, Ices at 3.3 μm

E.G.: HD 181327



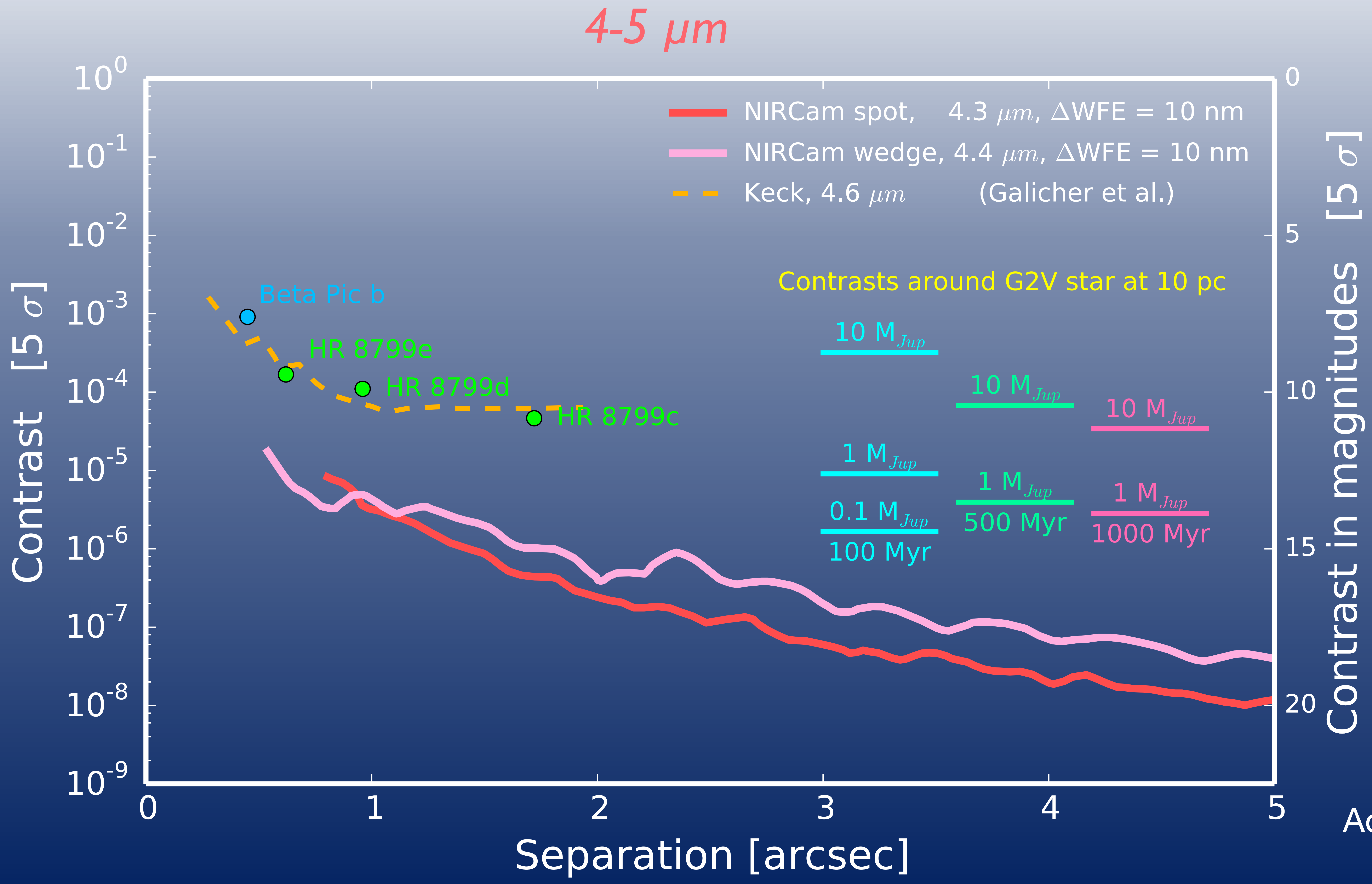
(HST C. Stark)



Teff = 1000 K, log(g) = 3.5 model from Barman et al.

Silicates at 10-11 μm

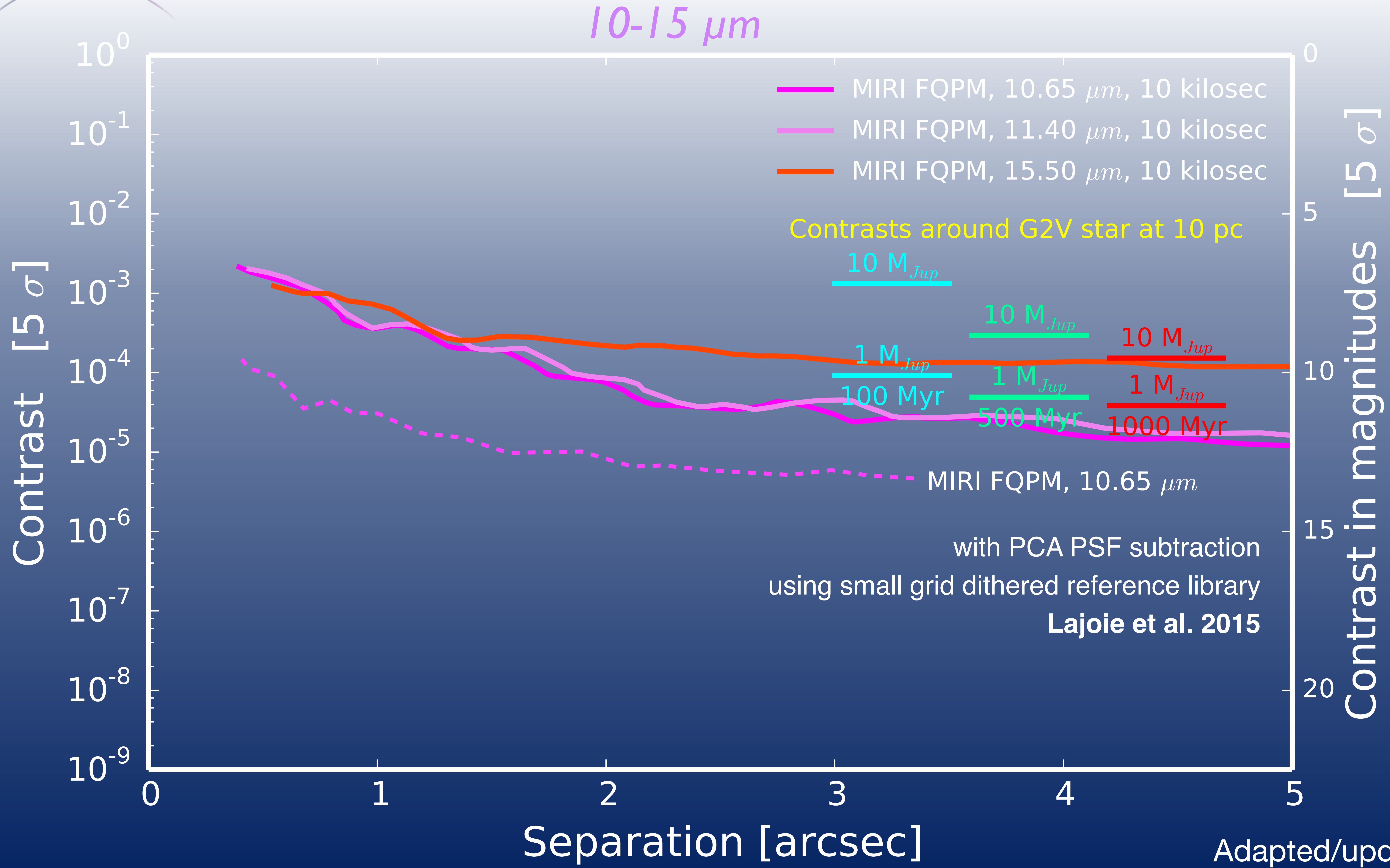
NIRCam Coronagraphy: sensitivity!!!



NIRCam expected contrasts: below 10^{-5} at 1”, 10^{-7} at 4”

Adapted/updated from Beichman et al. 2010

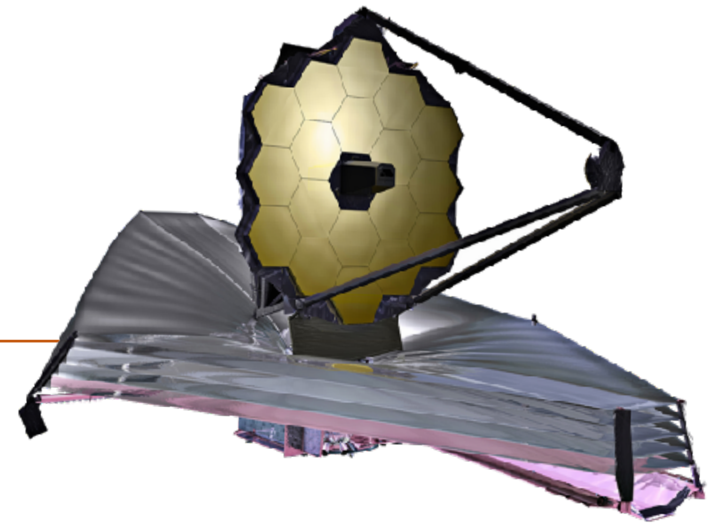
MIRI Coronagraphy: expected contrasts

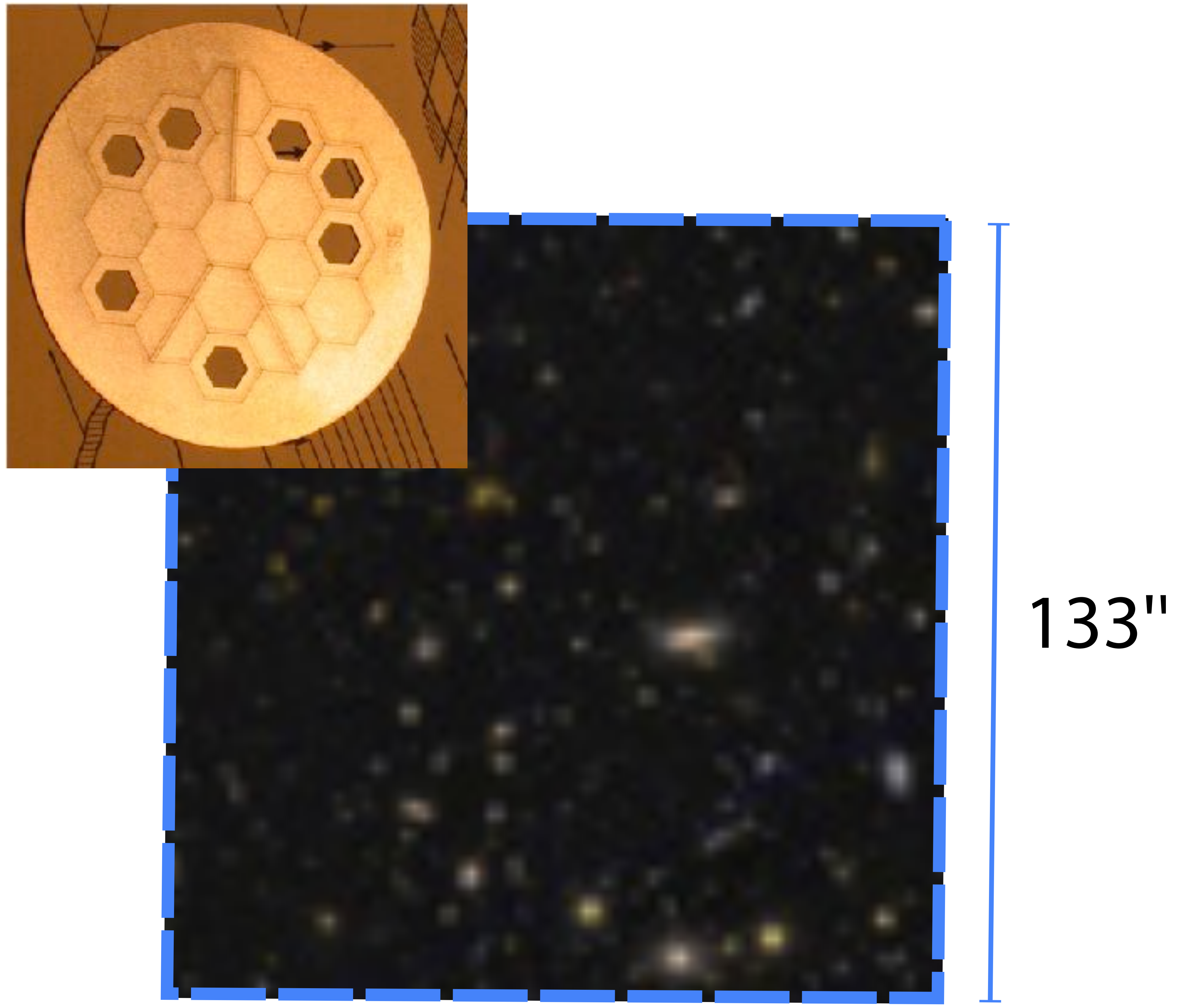


MIRI contrasts:
10^{-4} to 10^{-5}
for r > 1”

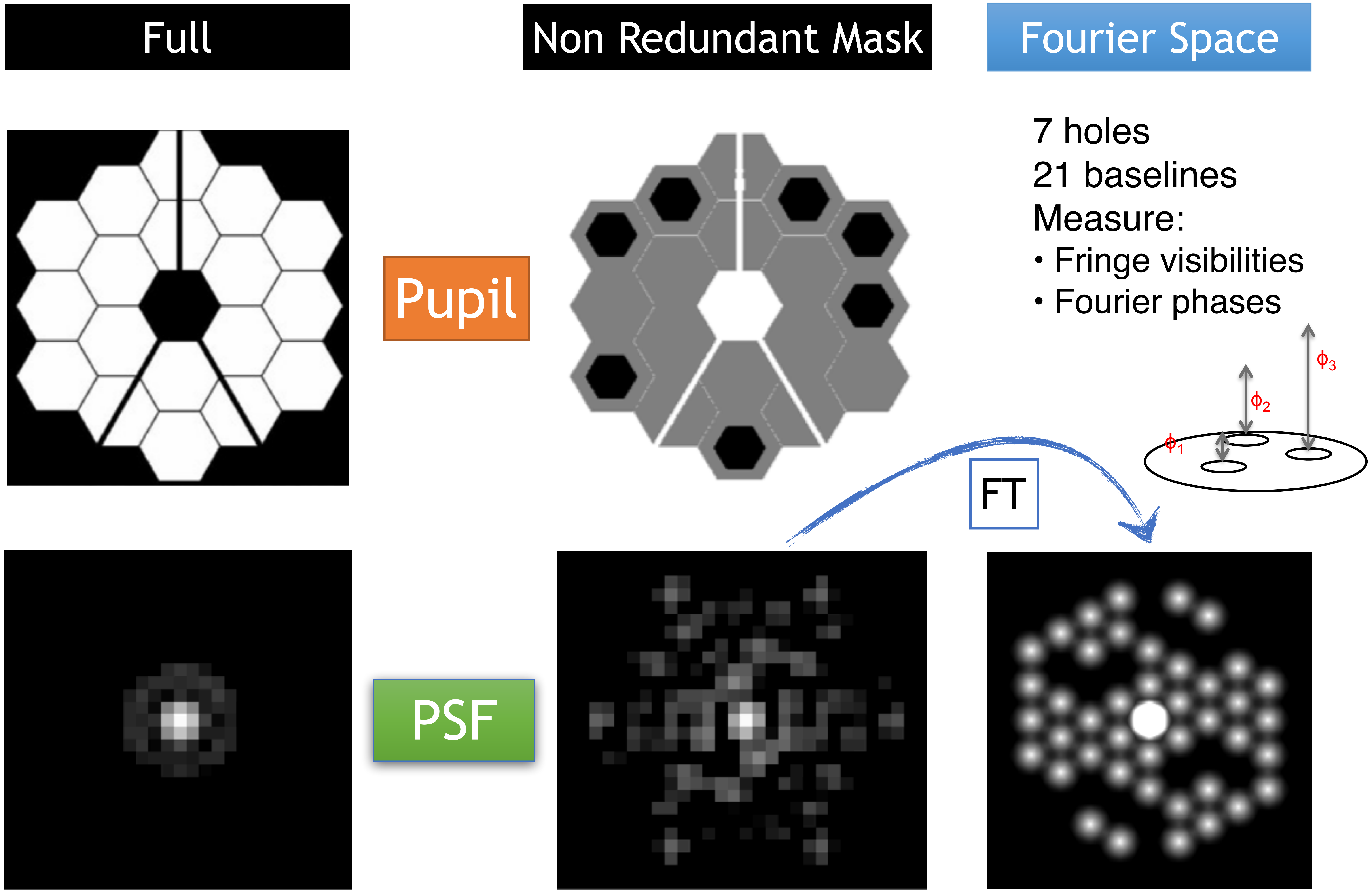
Adapted/updated from Beichman et al. 2010

JWST/NIRISS Aperture Masking Interferometry (AMI)



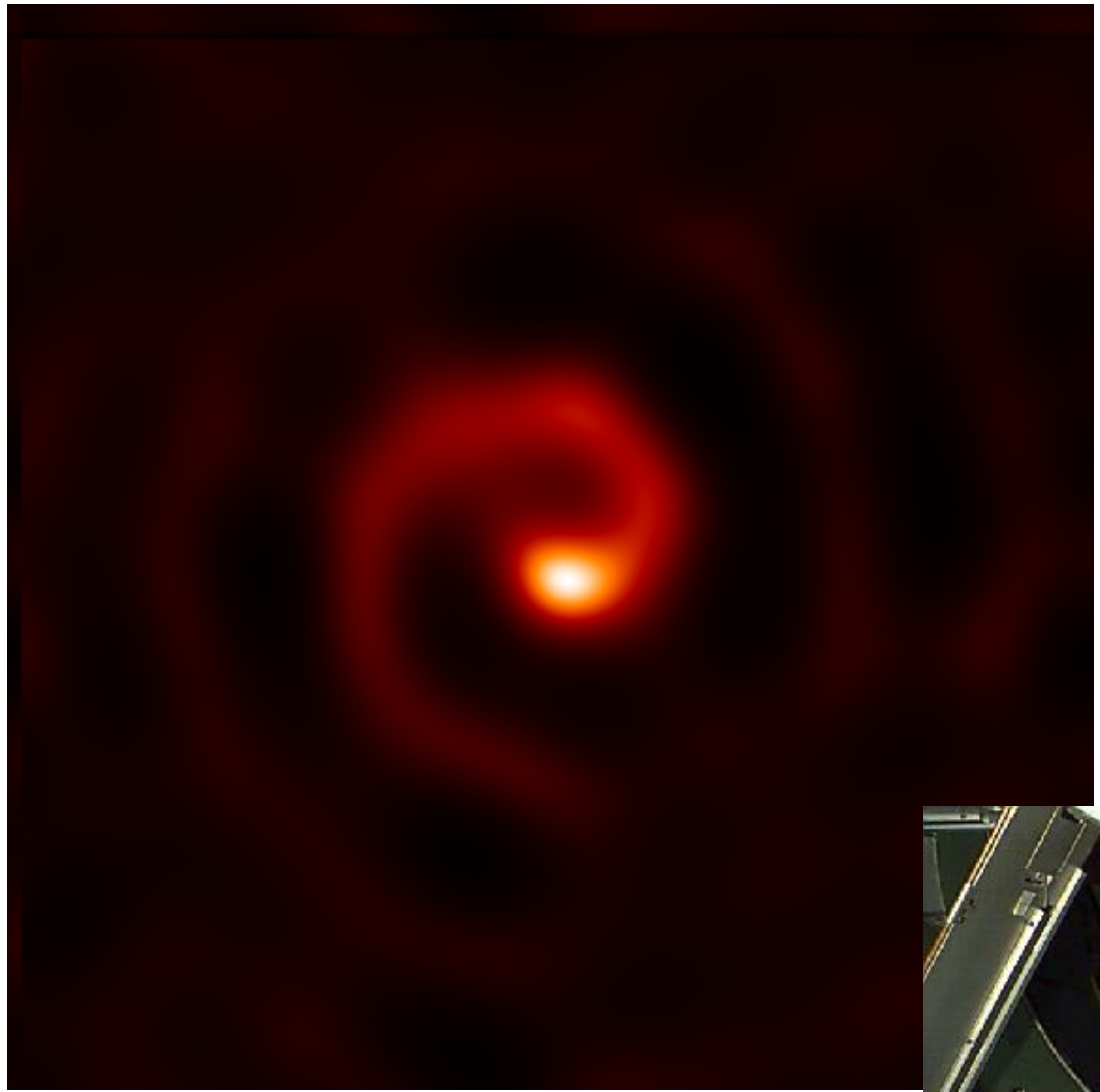


NIRISS



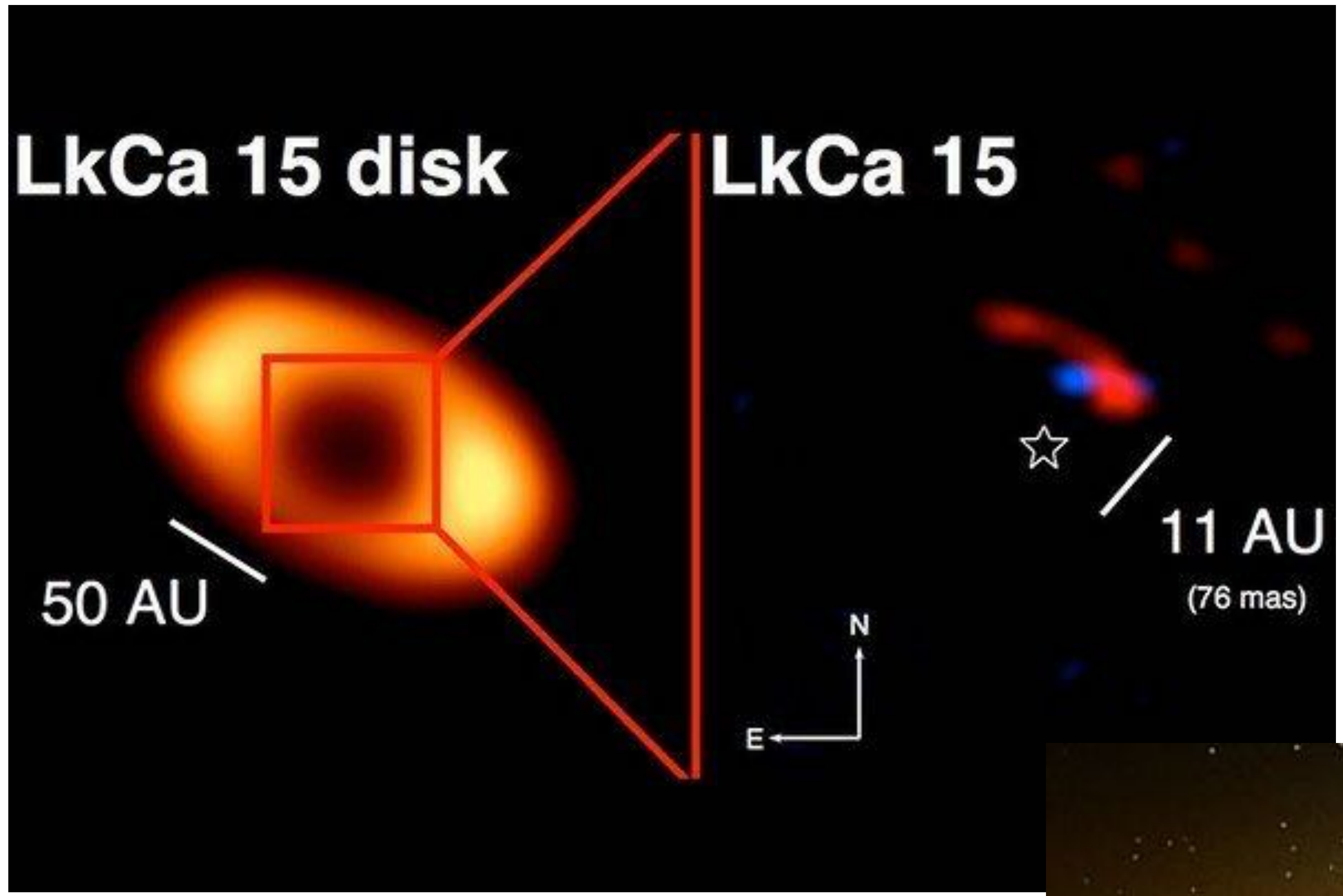
NIRISS Aperture Masking Results (Keck)

Wolf Rayet 104 or "Pinwheel Nebula"
Reconstructed images over > 6 years

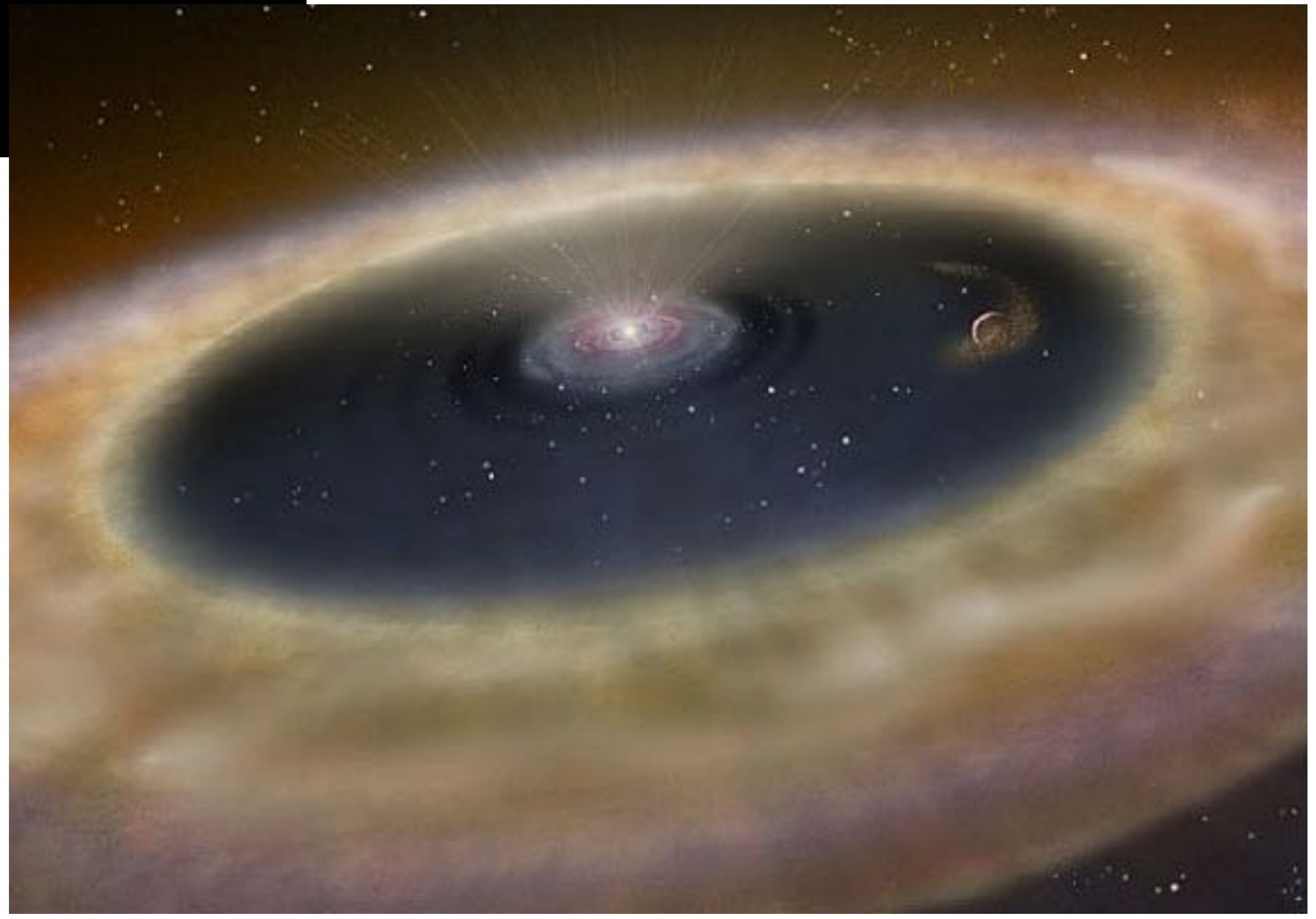


Tuthill (photo), Monnier, Danchi 1999

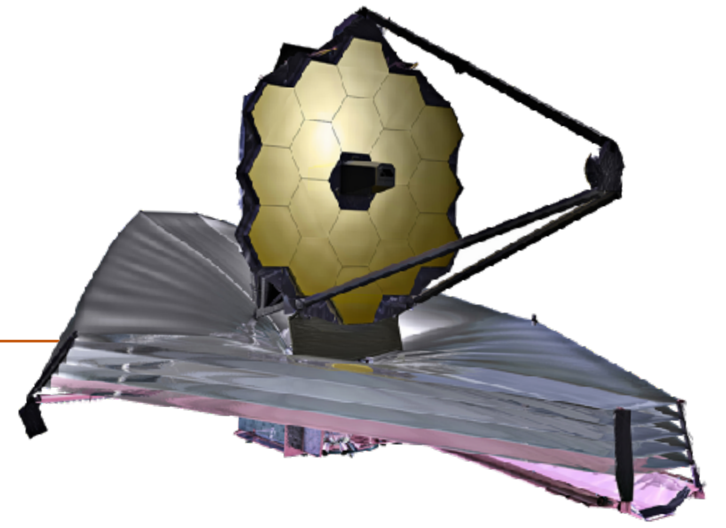
Potential protoplanet LkCa 15 b



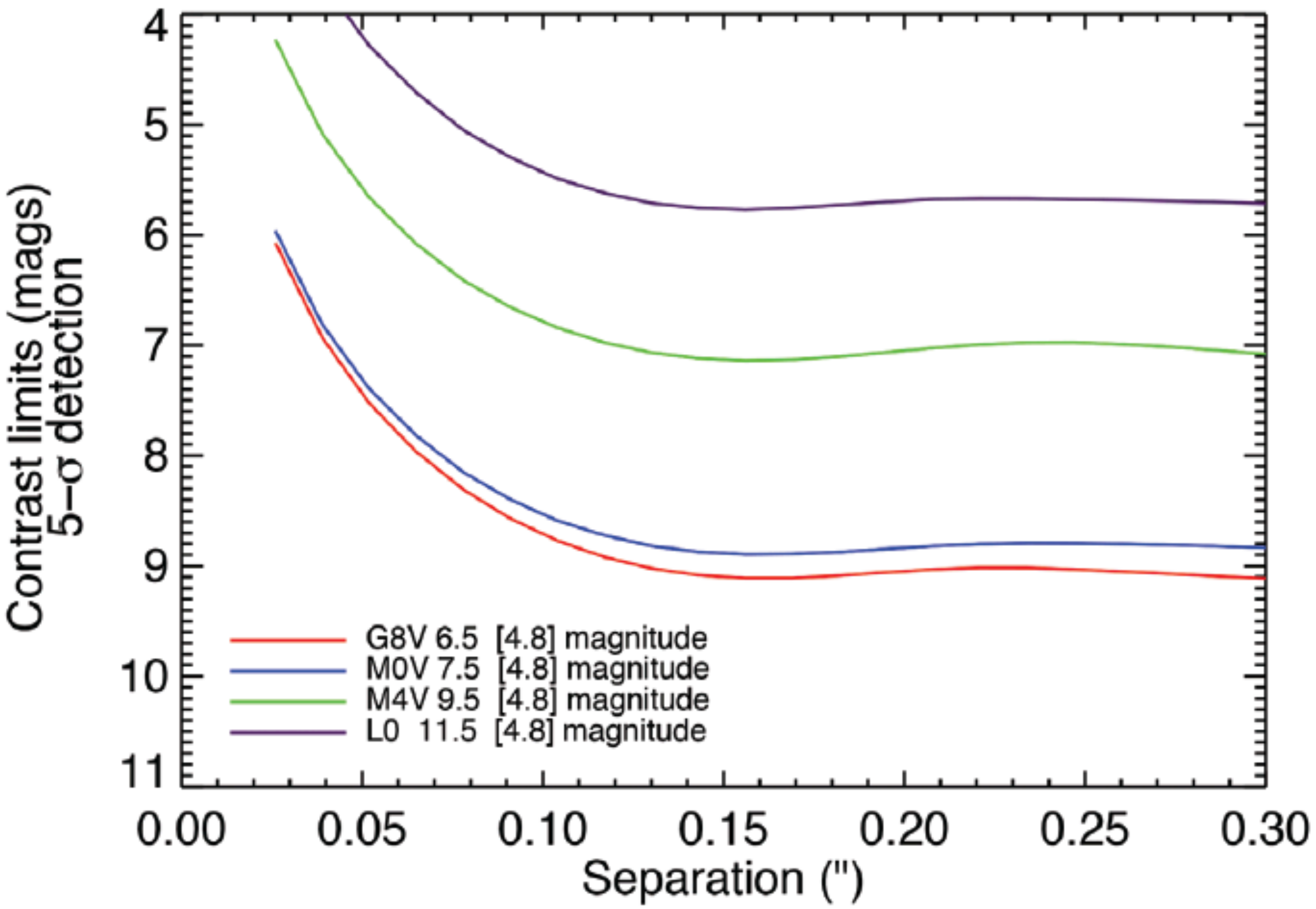
Kraus & Ireland 2012

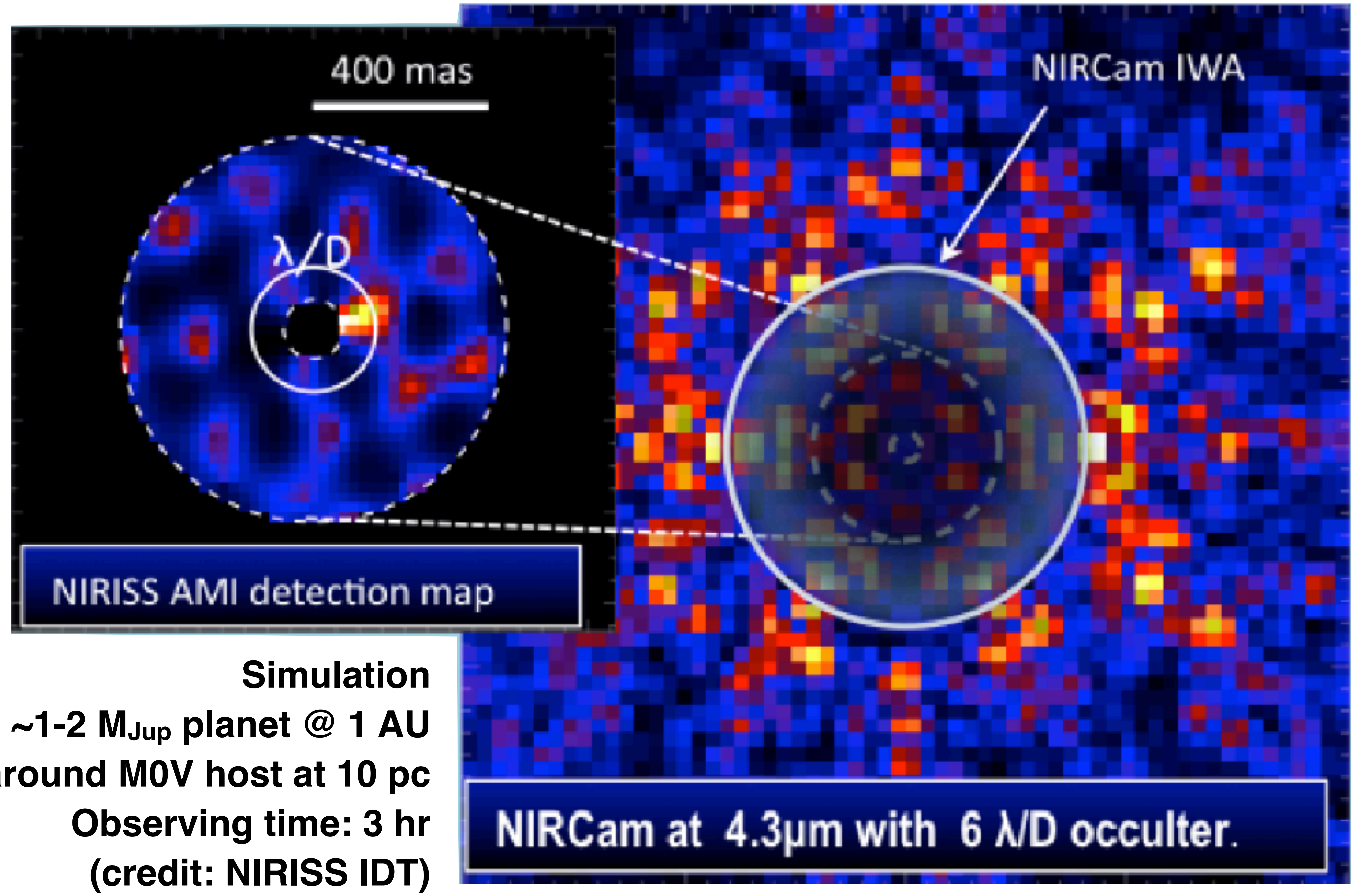


NIRISS AMI Predicted Performances



Probe separations of ~40 to 400 mas
At contrast of up to 9 mag
Filters: F380M, F430M, F480M, (and F277W)





Simulation
~1-2 M_{Jup} planet @ 1 AU
around M0V host at 10 pc
Observing time: 3 hr
(credit: NIRISS IDT)

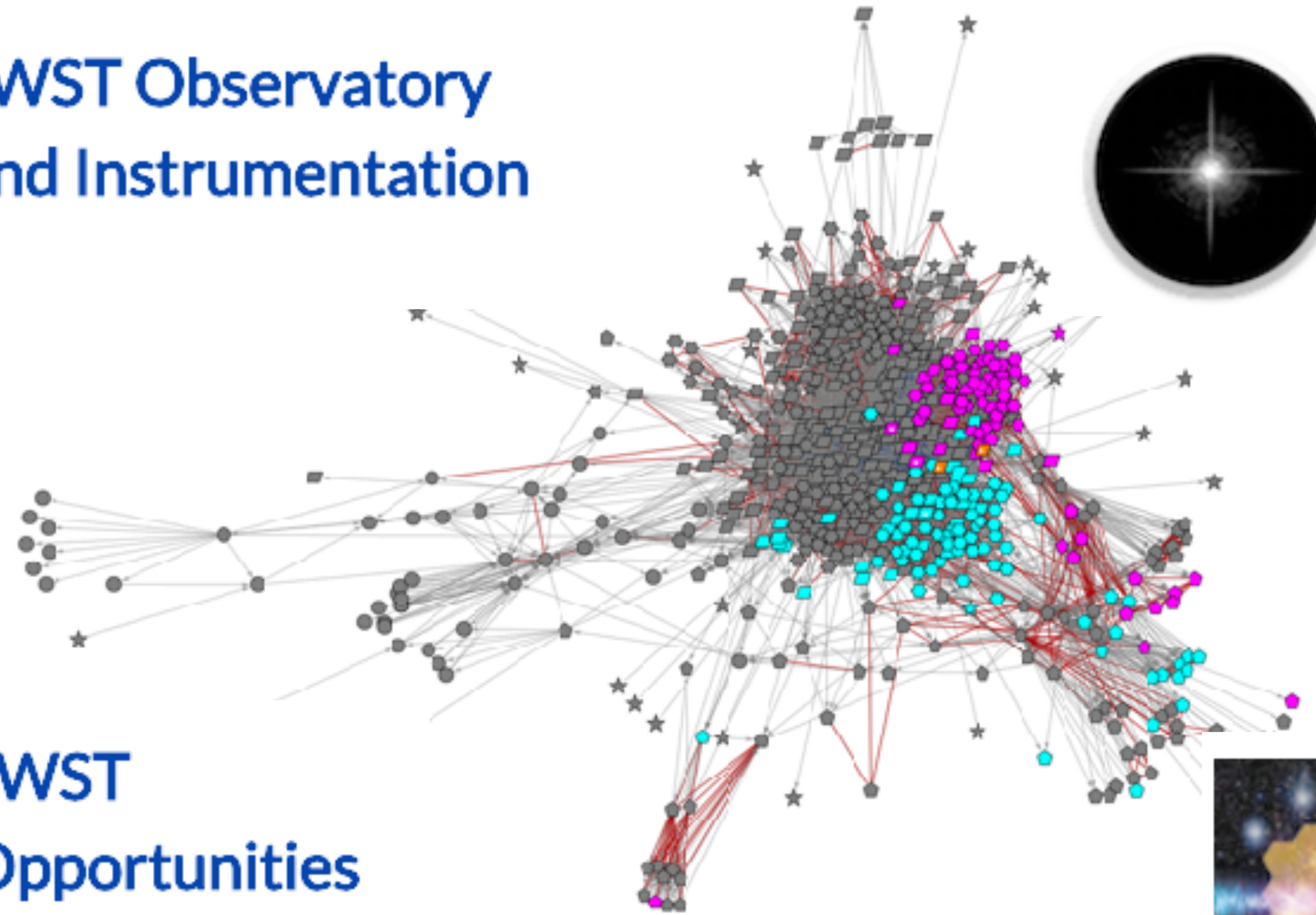
AMI Talk and exercises led by Deepashri Thatte later in this session

HCI Roadmap Walkthrough

JDox: the documentation platform: web-based, agile, integrated

JWST Observatory and Instrumentation

JWST Observation Planning



JWST Opportunities and Policies

JWST Data Calibration and Analysis

jwst-docs.stsci.edu

James Webb Space Telescope User Documentation

HOME | INSTRUMENTS | PLANNING | CALL FOR PROPOSALS | DATA | Search

JWST Observation Planning Documentation / JWST Proposing Tools

The HCI Roadmap article

jwst-docs.stsci.edu/methods-and-roadmaps/jwst-high-contrast-imaging/jwst-high-contrast-imaging-roadmap

OPEN

Proposing Opportunities

- JWST Cycle 1 Proposal Opportunities
- JWST General Science Policies

Proposal Preparation

- General Proposal Planning Workflow
- Understanding Exposure Times
- Methods and Roadmaps
  - Imaging
  - Wide Field Slitless Spectroscopy
  - High-Contrast Imaging
    - High Contrast Imaging Roadmap

Home / Methods and Roadmaps / JWST High-Contrast Imaging / JWST High Contrast Imaging Roadmap

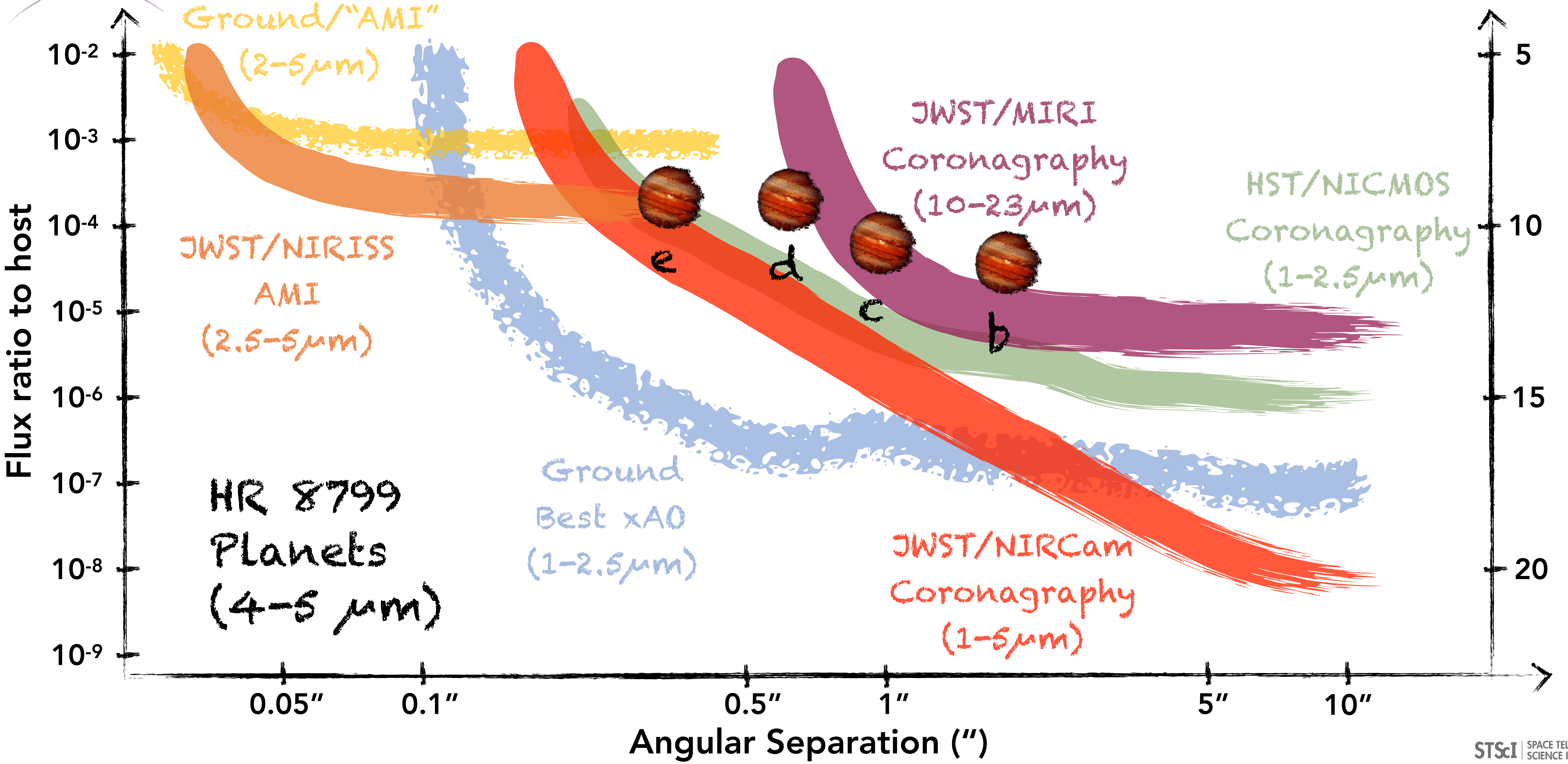
JWST High Contrast Imaging Roadmap

This roadmap outlines the suggested flow of planning considerations required for a High-contrast Imaging (HCI) observation with JWST and should be used in consultation with the General Proposal Planning Workflow.

On this page

NIR to MIR Coronagraphy & Aperture Masking: Ground & Space

NIR to MIR Coronagraphy & Aperture Masking: Ground & Space



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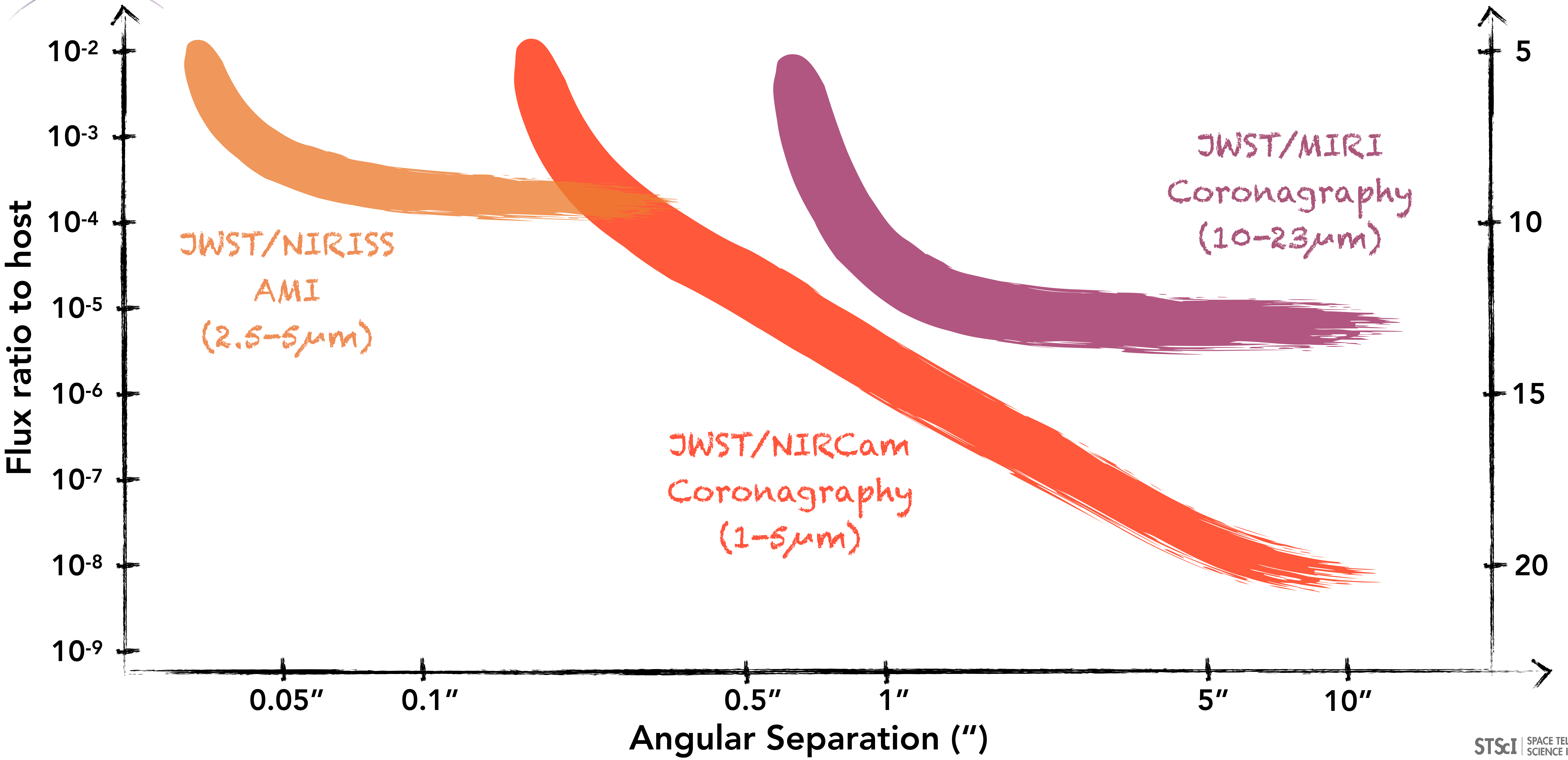
NIR to MIR Coronagraphy & Aperture Masking: Ground & Space



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NIR to MIR Coronagraphy & Aperture Masking: Ground & Space

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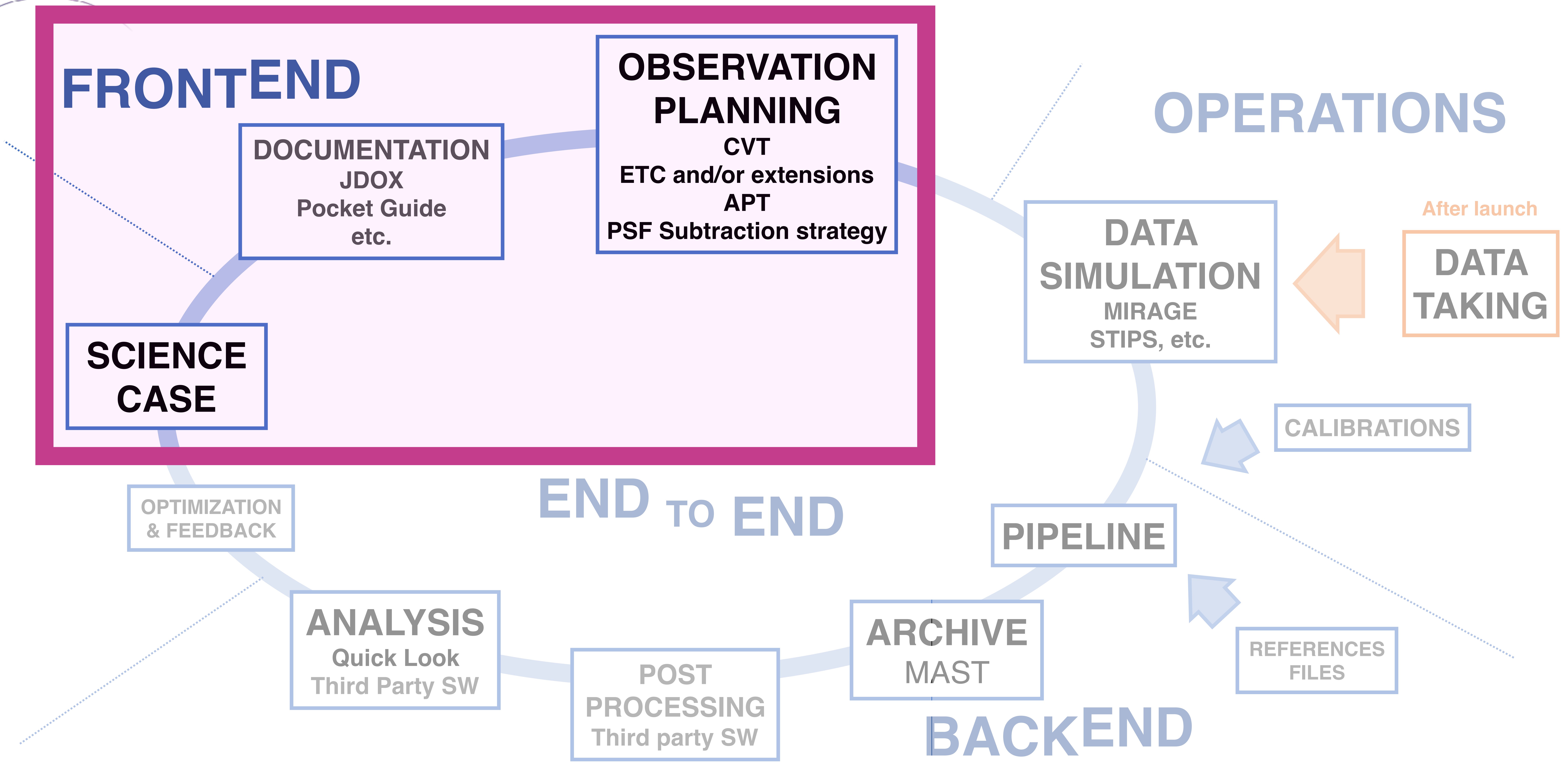
Proposal Planning Tools & HCI Resources

From an astrophysical idea to a result



Why do we recommend two rolls plus a PSF calibrator?

Factors degrading PSF calibration and subtraction

Wavefront drifts of the observatory

PSF star color differences

Self-subtraction biases (esp. for disks)

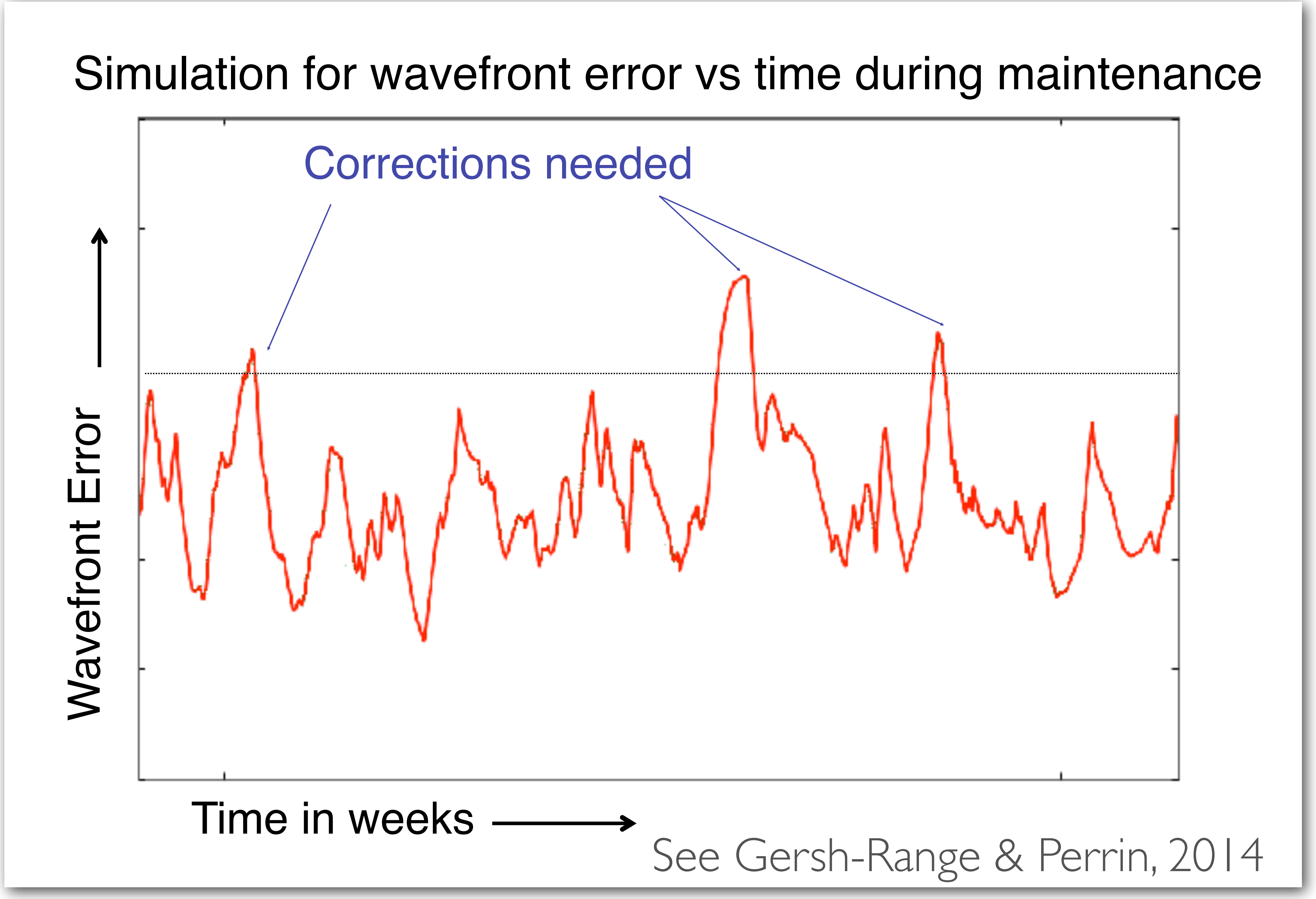
Imperfect target acquisitions

Line-of-sight jitter and dynamic wavefront error

By scheduling science and PSF calibration observations back-to-back, wavefront drifts should be minimized. (predicted to be negligible; sub-nm).

Performance and stability will not truly be known until measurements in flight.

Expect Hubble-like stability:
small wavefront changes driven by temperature drifts



Changes in sun pitch angle will cause small changes in OTE temperature (< 1 K), but very slowly (predicted time constant ~ 5 to 9 days).

Why do we recommend two rolls plus a PSF calibrator?

Factors degrading PSF calibration and subtraction

- Wavefront drifts of the observatory
- PSF star color differences
- Self-subtraction biases (esp. for disks)
- Imperfect target acquisitions
- Line-of-sight jitter and dynamic wavefront error

Observing science target at 2 rolls has proven highly effective with HST.
Allows PSF subtraction at nearly same spacecraft attitude (for wavefront stability), eliminates stellar color mismatch terms, increases efficiency (PSF calibrator is also more science data), and helps mitigate detector artifacts.

However, this comes at the cost of introducing self-subtraction biases, especially given the limited available roll (~10° max) of JWST.

For robustness, we conservatively advocate PSF calibration via both ADI+RDI.

Why do we recommend two rolls plus a PSF calibrator?

Factors degrading PSF calibration and subtraction

Wavefront drifts of the observatory

PSF star color differences

Self-subtraction biases (esp. for disks)

Imperfect target acquisitions

Line-of-sight jitter and dynamic wavefront error

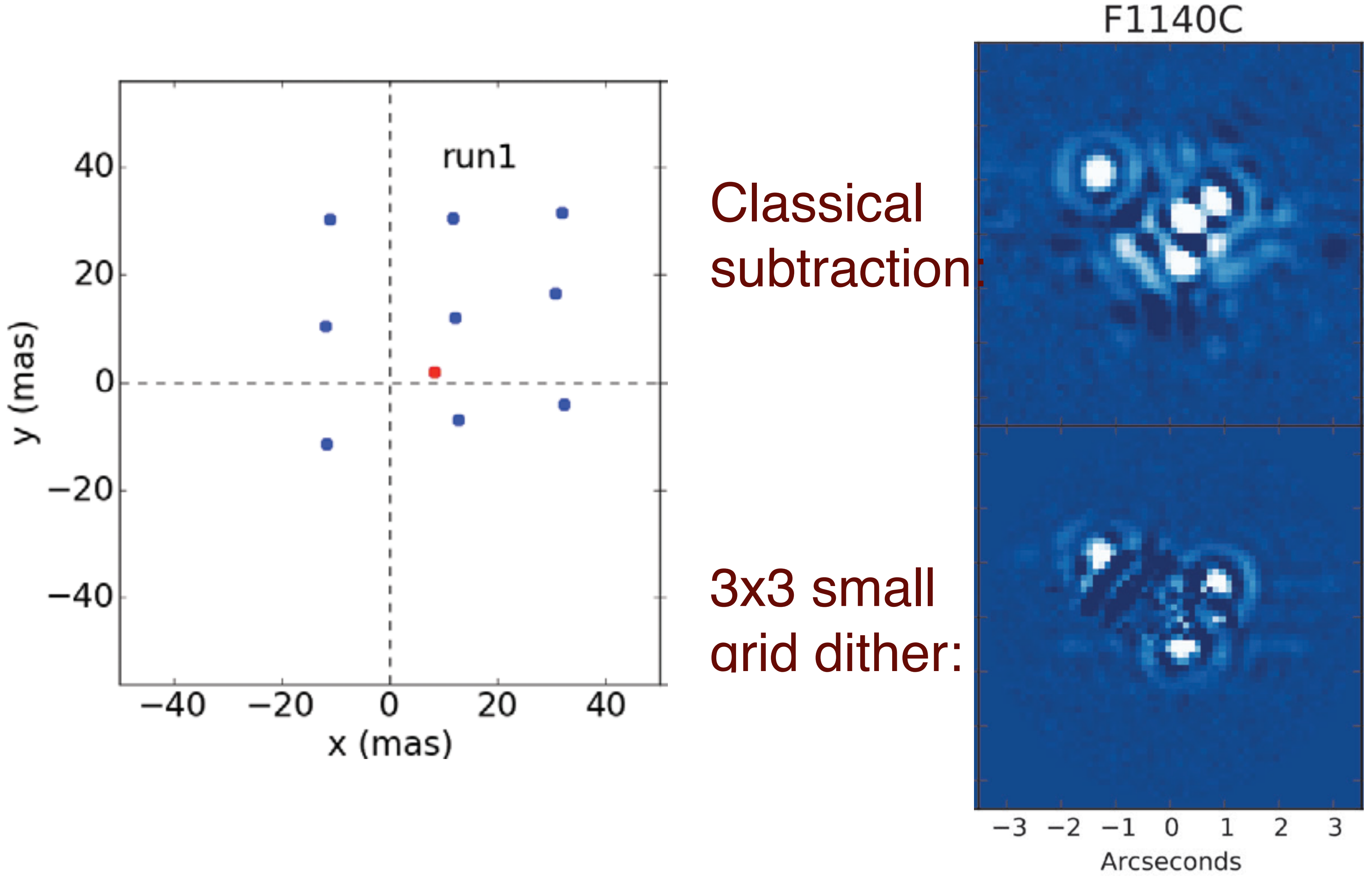
Optional:
Perform sub pixel dithers of the PSF star to build mini PSF reference library, then synthesize an optimal PSF that matches the target
position precisely. “Small Grid Dithers”.

>10x contrast improvement for MIRI,
3-5x improvement for NIRCam.

Cost: 5-9x longer PSF star exposure times.

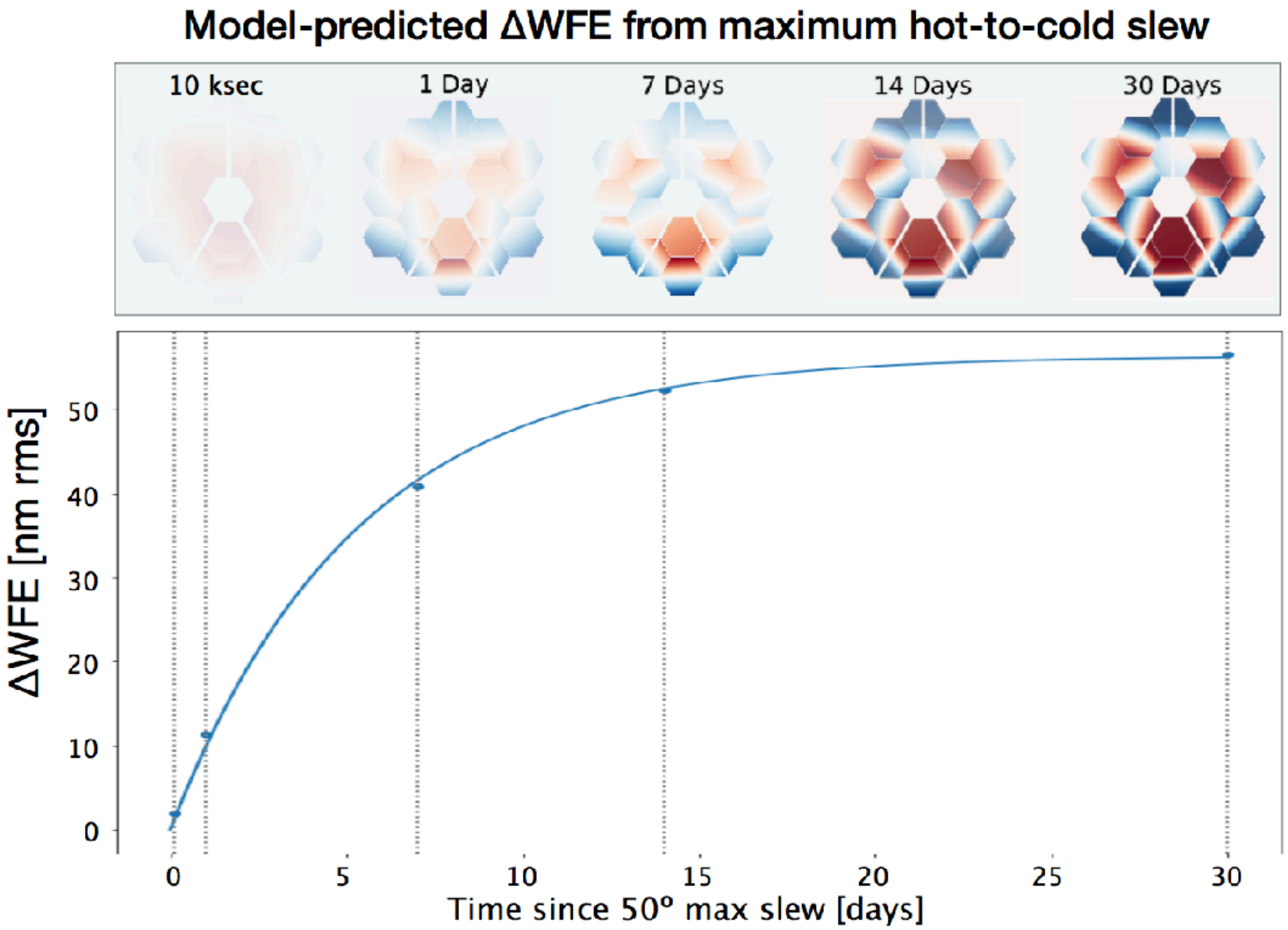
Target acq is required for all coronagraphy. Expected precision is very good (~ few mas) but residuals still matter.

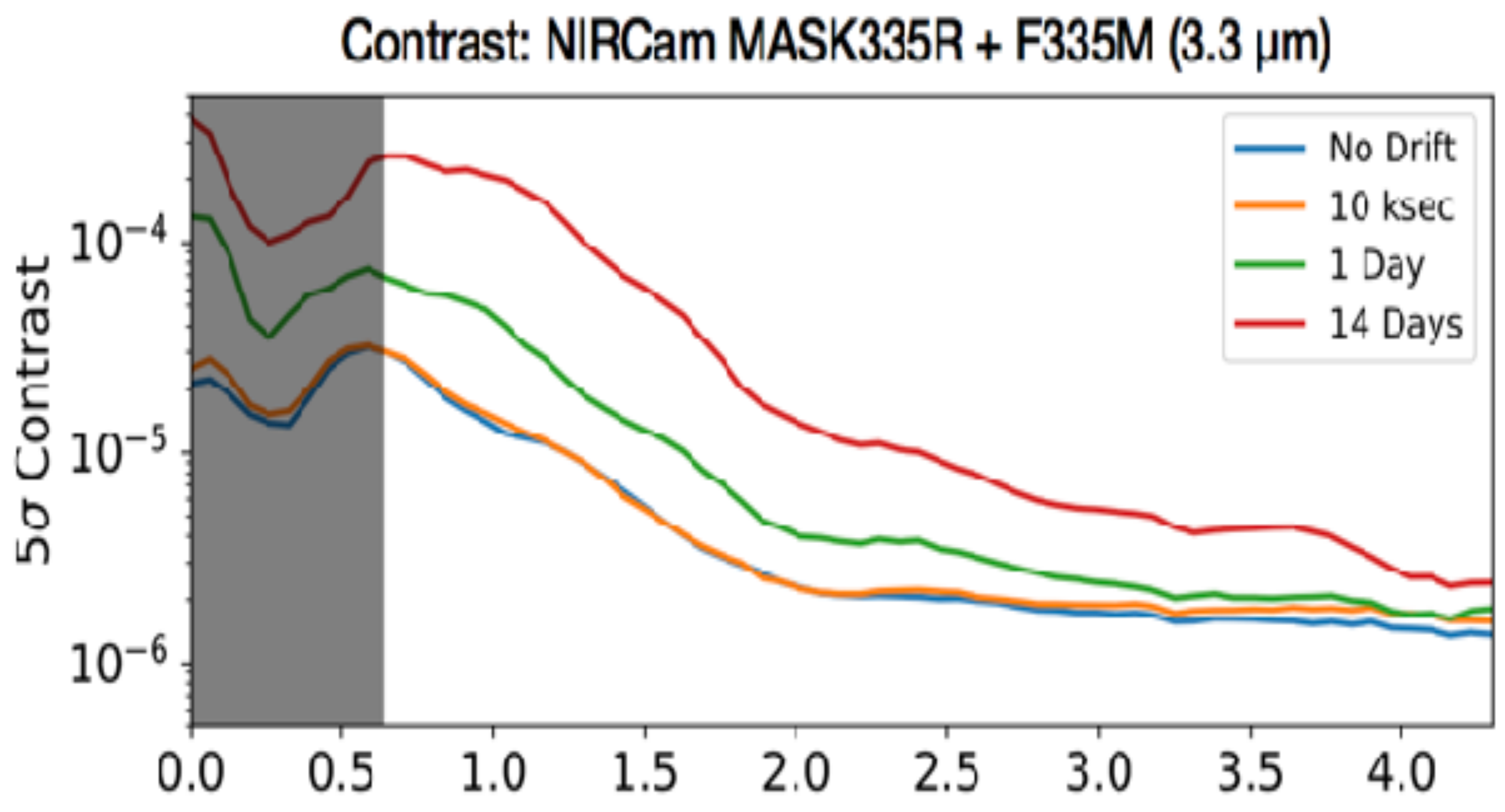
All coronagraphs are sensitive to misalignments; MIRI FQPMs more sensitive than NIRCam Lyot corons.

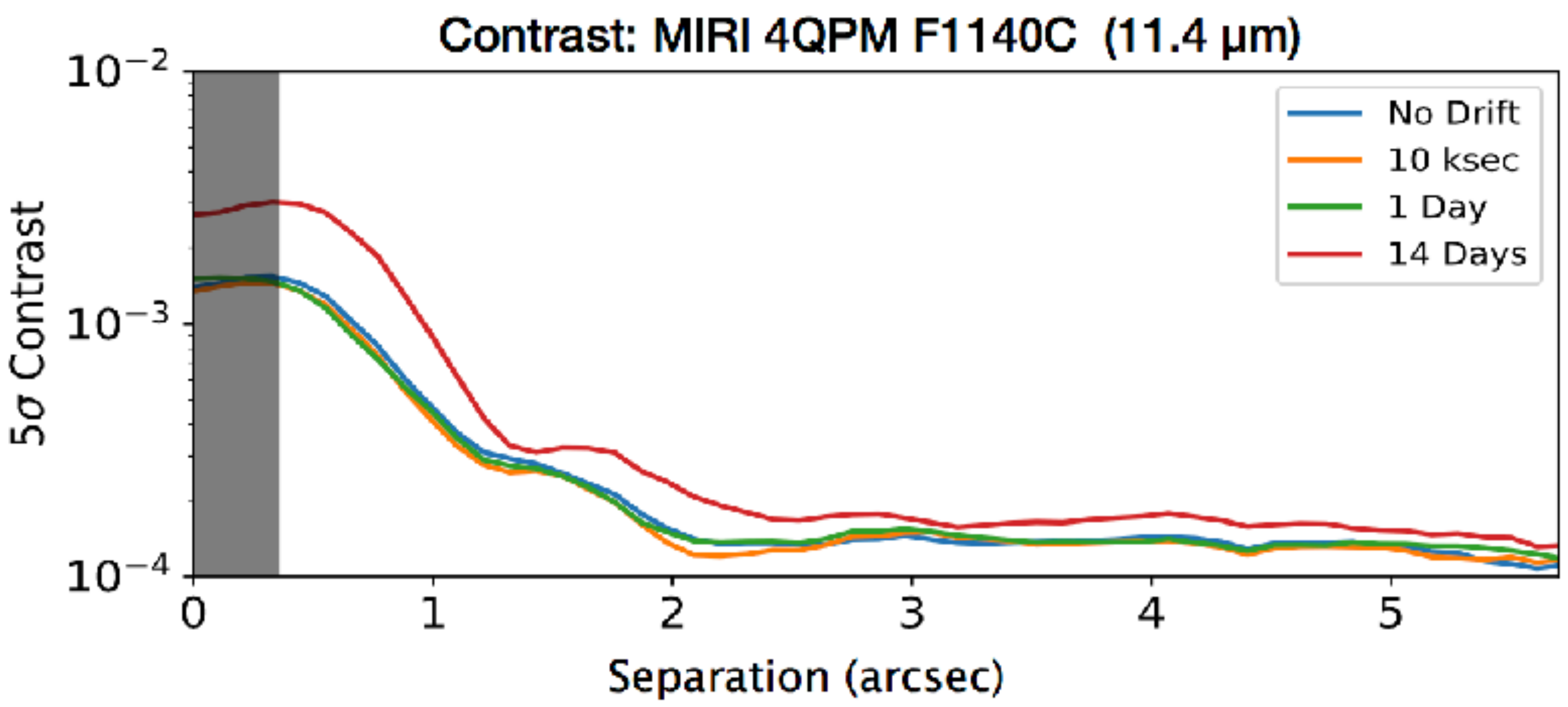


Simulated small grid dither PS subtraction
Lajoie et al. 2106

Towards the generation of realistic datasets : impact of slew



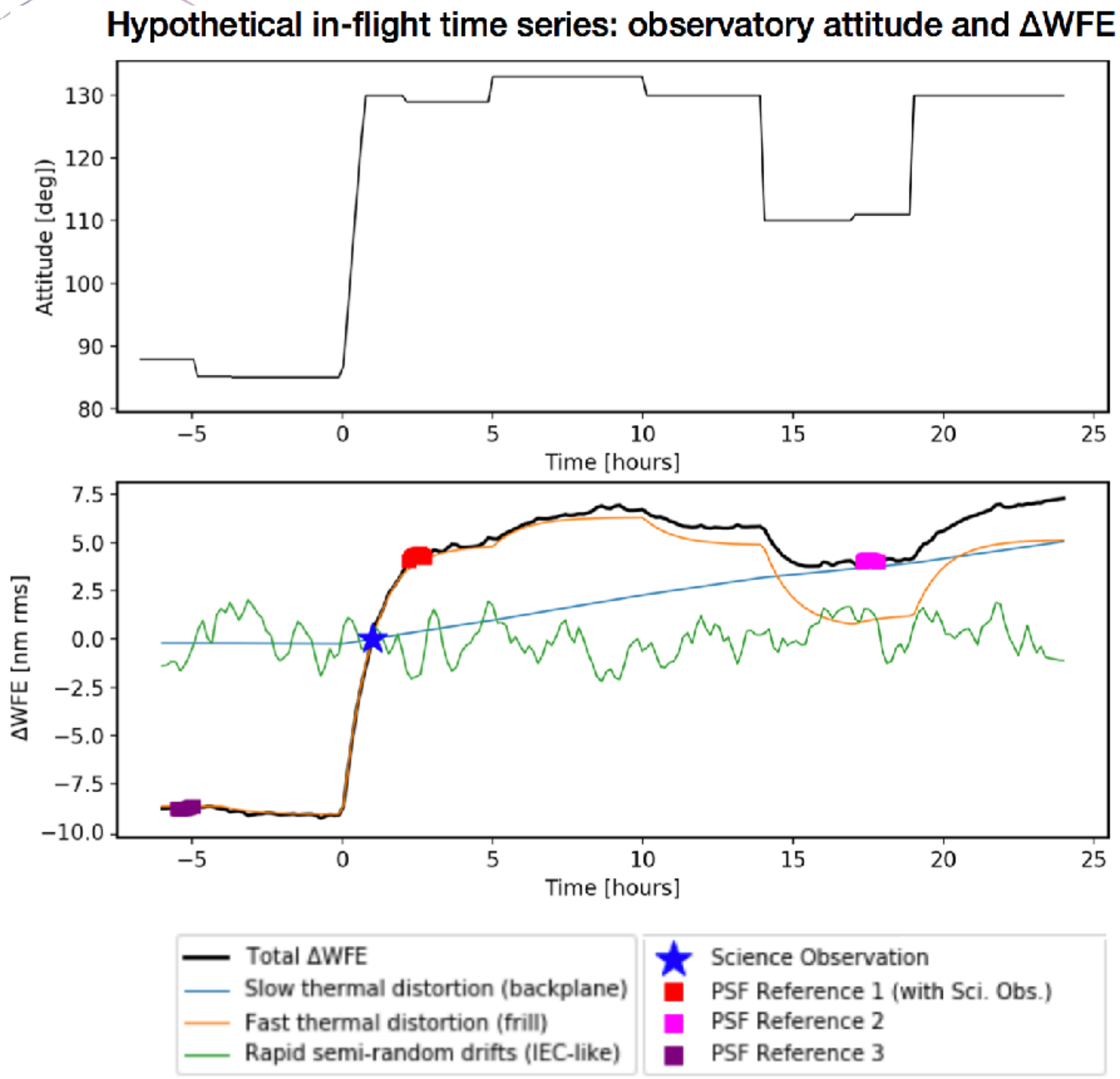


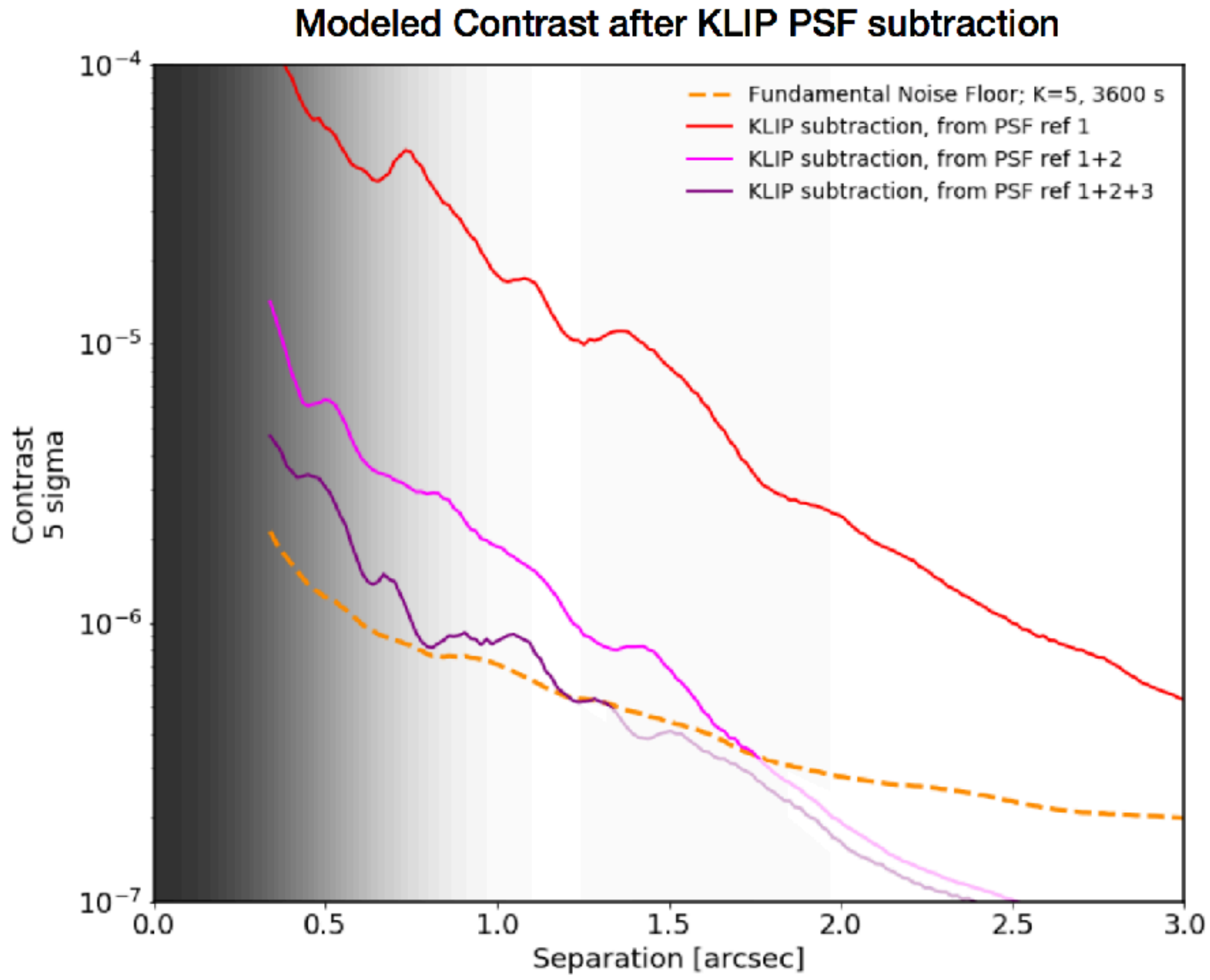


Perrin et al. SPIE 2018

Brooks et al. #AAS233

Towards the generation of realistic datasets : impact of slew



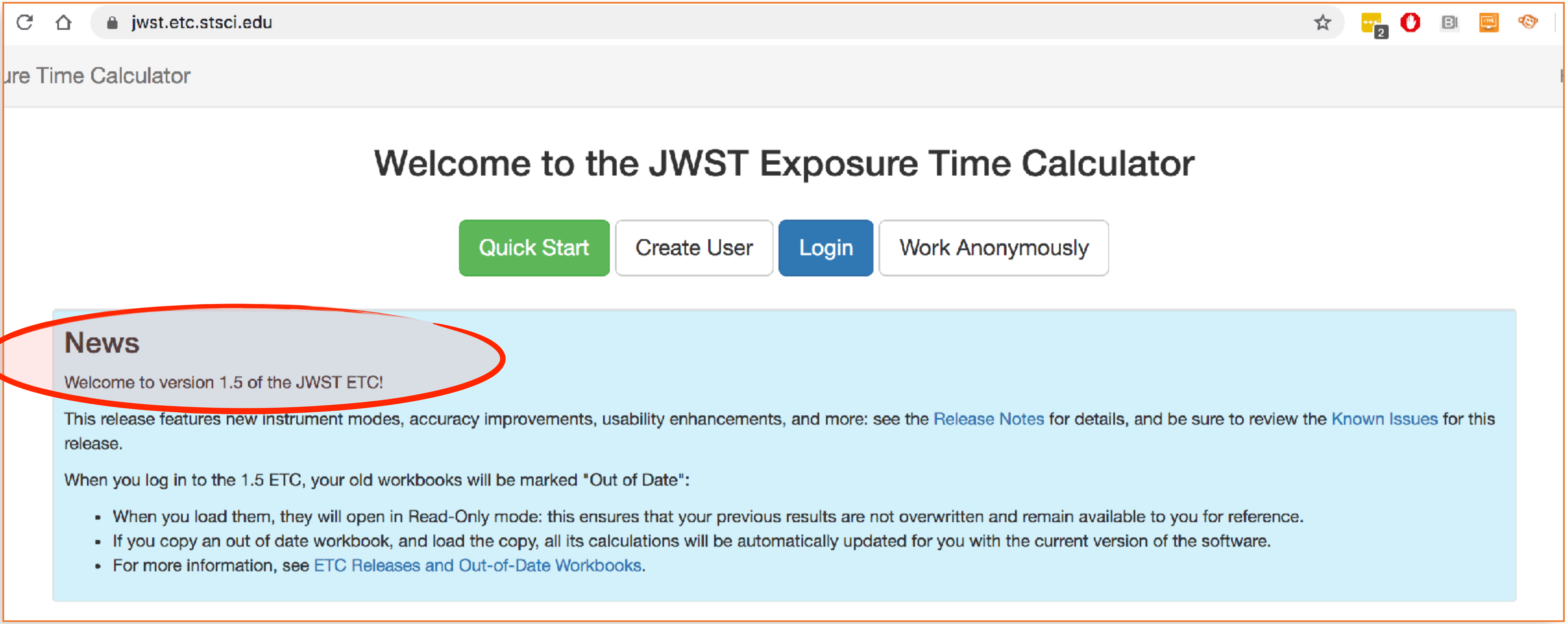


Perrin et al. SPIE 2018

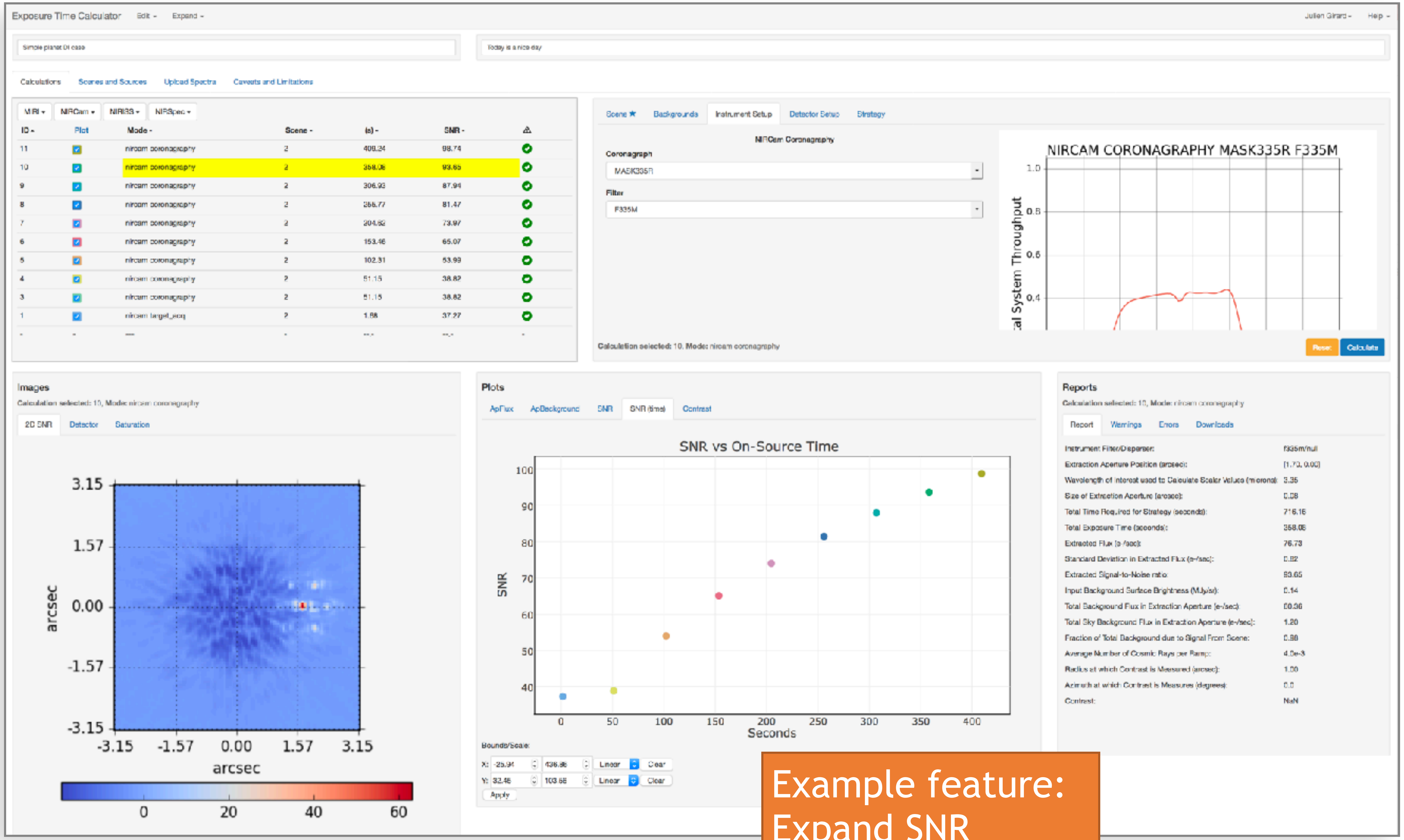
Brooks et al. #AAS233

ETC: Exposure Time Calculator: now at v1.5 (soon 1.6)

https://jwst.etc.stsci.edu/



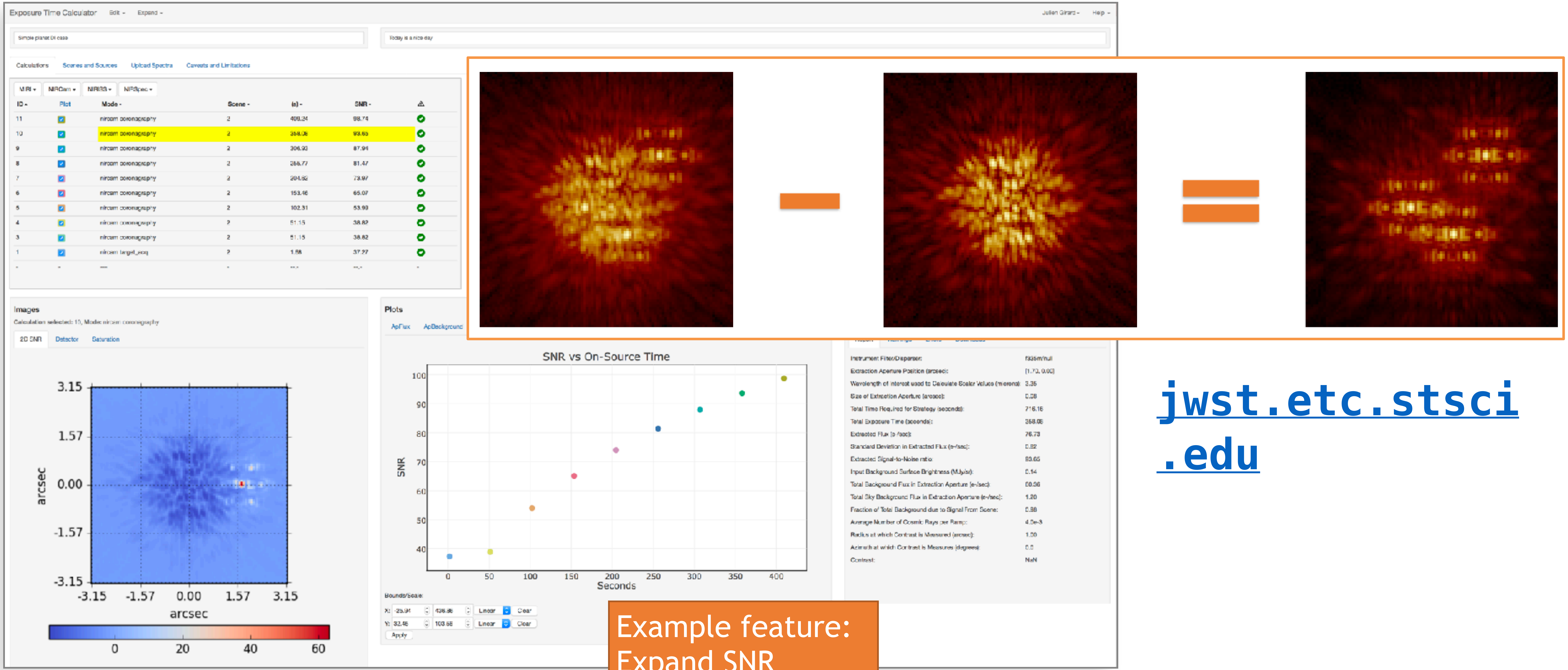
ETC for Coronagraphy: PSF subtraction from a reference star



jwst.etc.stsci.edu

Example feature: Expand SNR through filters

ETC for Coronagraphy: PSF subtraction from a reference star



jwst.etc.stsci.edu

Example feature: Expand SNR through filters

ETC for Coronagraphy: Limitations for High Contrast Imaging

Pre-computed PSF library from WebbPSF with a discrete number of angular separations (sparse spatial sampling)

➜ Calculations can be inaccurate in the speckle limited regime (close to the coronagraphs, typically at separations < 1”)

ETC does not account for spectral mismatch (only photometrically) of the PSF reference star

ETC supposes a perfect centering (target acquisition) of all stars

➜ Calculations can be optimistic

PSF calculations “on the fly” are time consuming: can be done in command line with Pandeia engine or with PanCAKE (not yet fully supported)

- ✦ Custom small grid dithers and positioning
- ✦ Custom spectral sampling
- ✦ Custom field of view

https://github.com/spacetelescope/pandeia-coronagraphy

The ETC PSF subtraction strategies assume the same detector readout parameters for all stars in a workbook

➜ If one wants to use a brighter reference star, several ETC workbooks are needed

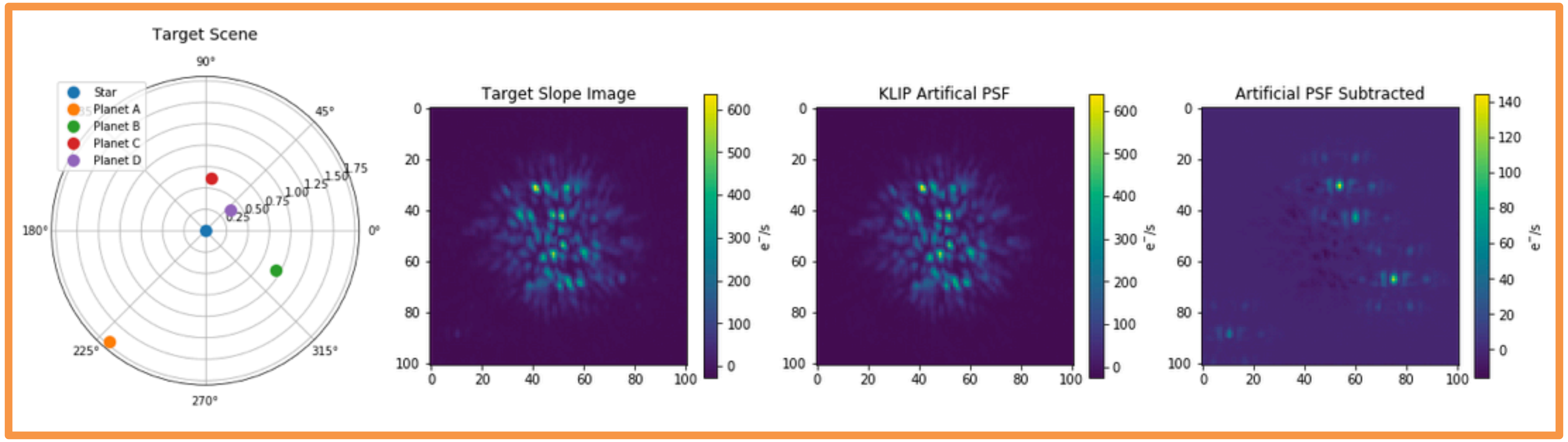
The ETC cannot inject ring like features or disks

Can be done with pyNRC (not supported by STScI) https://pynrc.readthedocs.io

ETC extensions: PanCAKE (STScI) & pyNRC (NIRCam IDT)

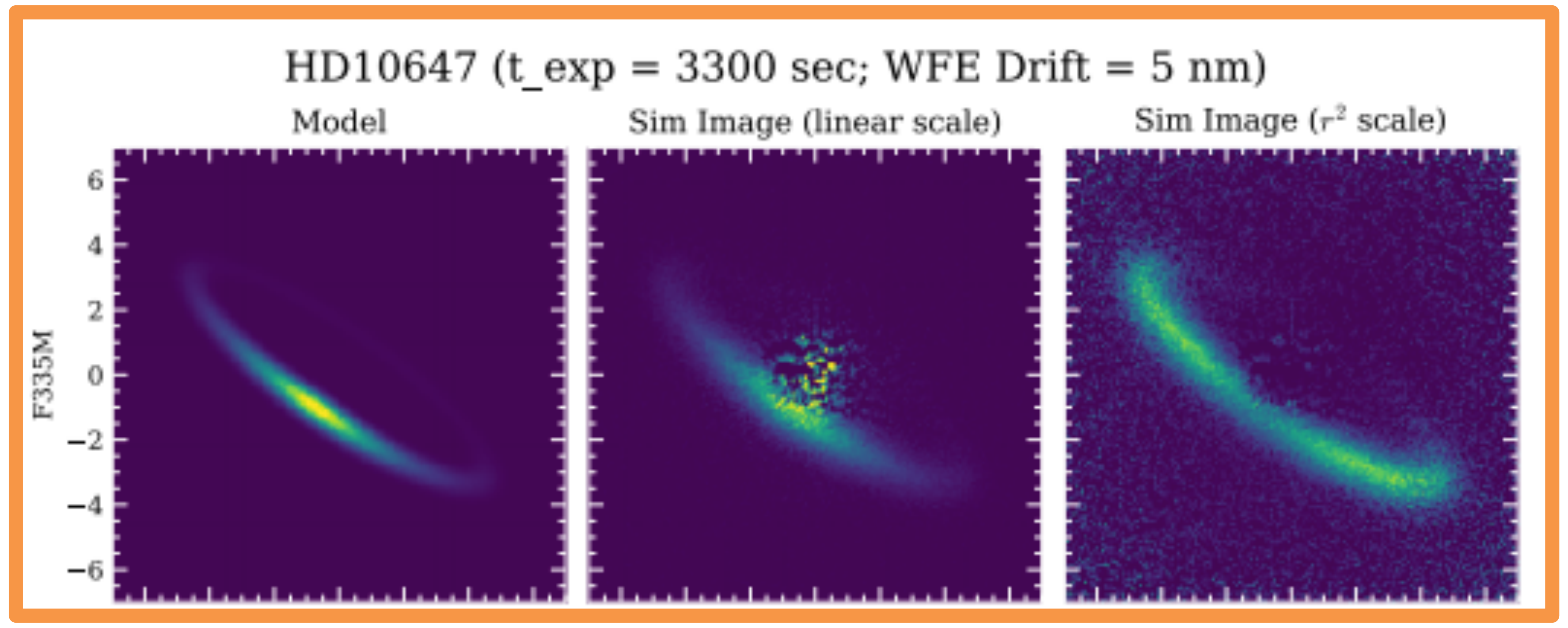
github.com/spacetelescope/pandeia-coronagraphy

- Can call WebbPSF "on the fly"
  - custom PSF grids/dithers, FoV, spectral sampling, more precise extractions
- Several coronagraphic specific functions
  - Contrast curves
- Currently improving the scene compatibility with ETC UI and outputs



Van Gorkom, York, Perrin, Girard

Check also (disks)! pyNRC



Leisenring

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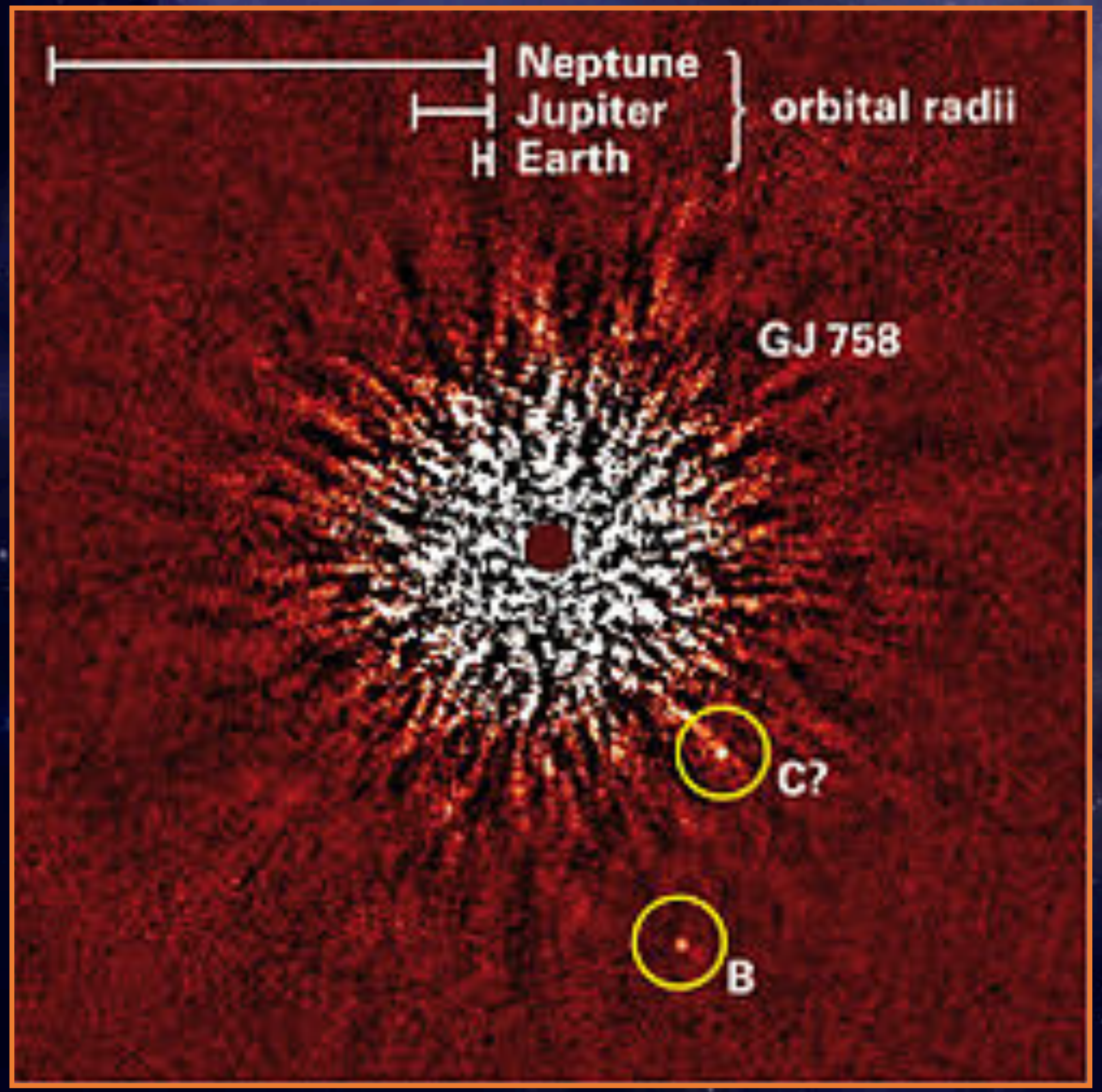
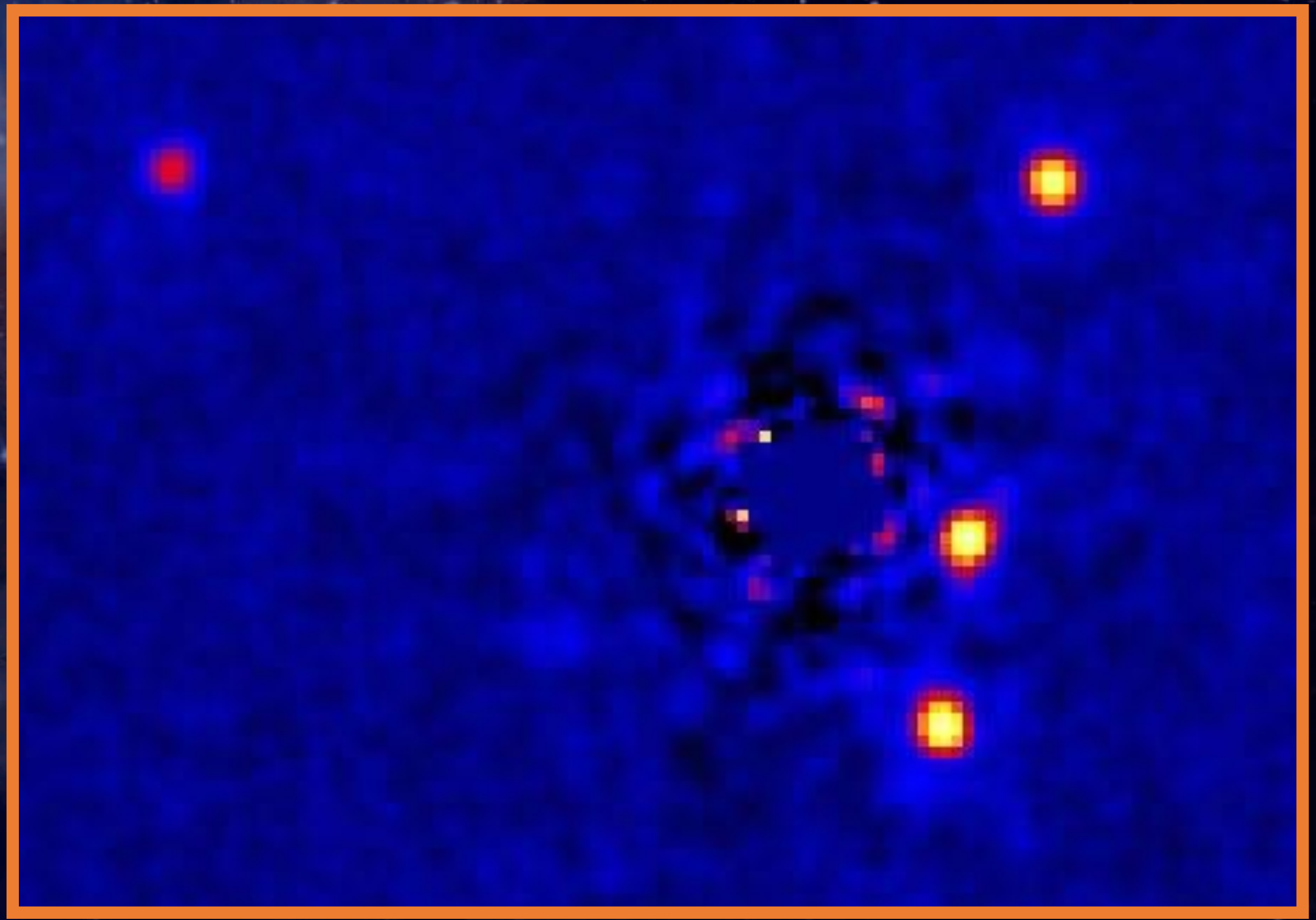
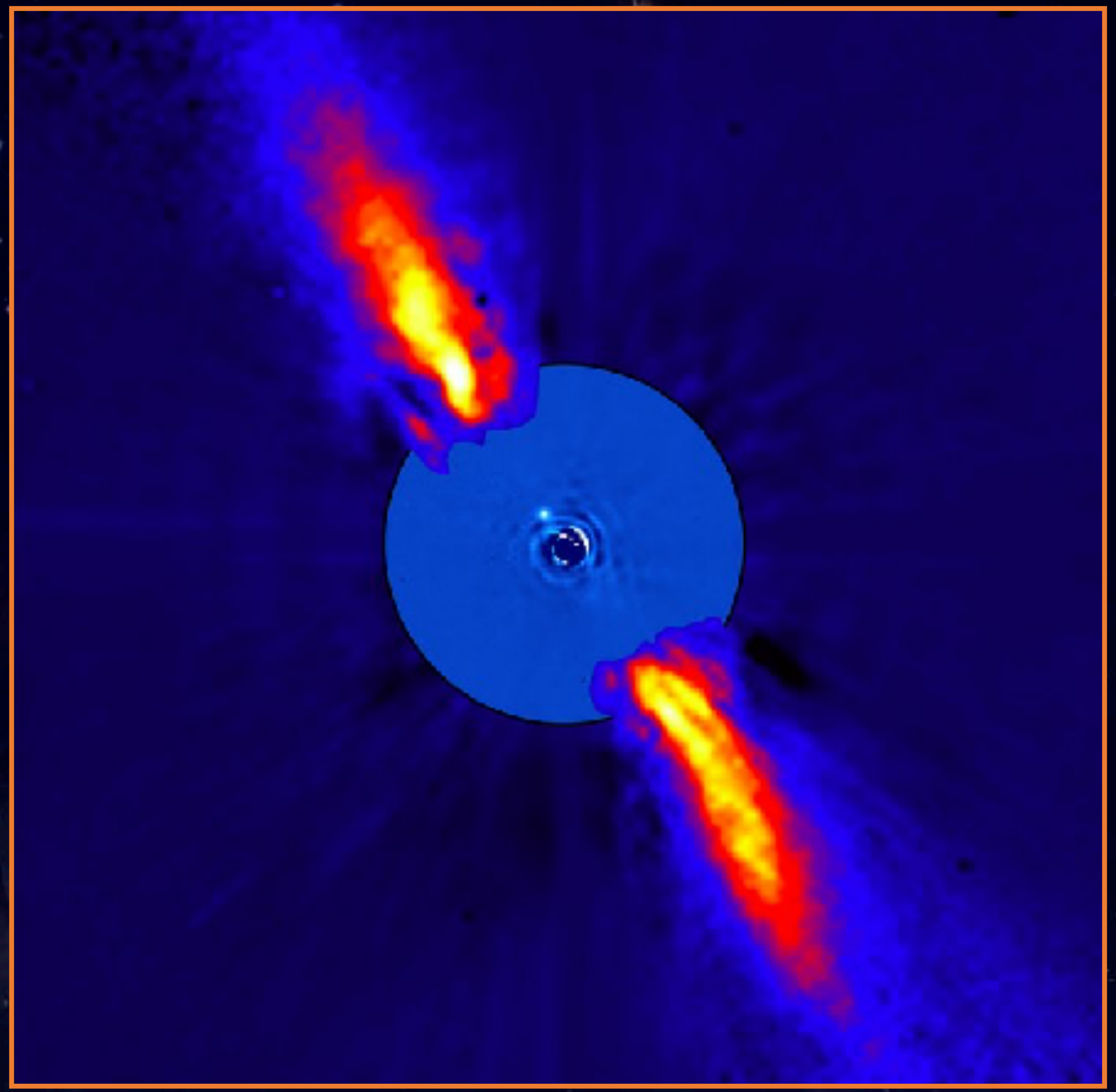
Coronagraphy

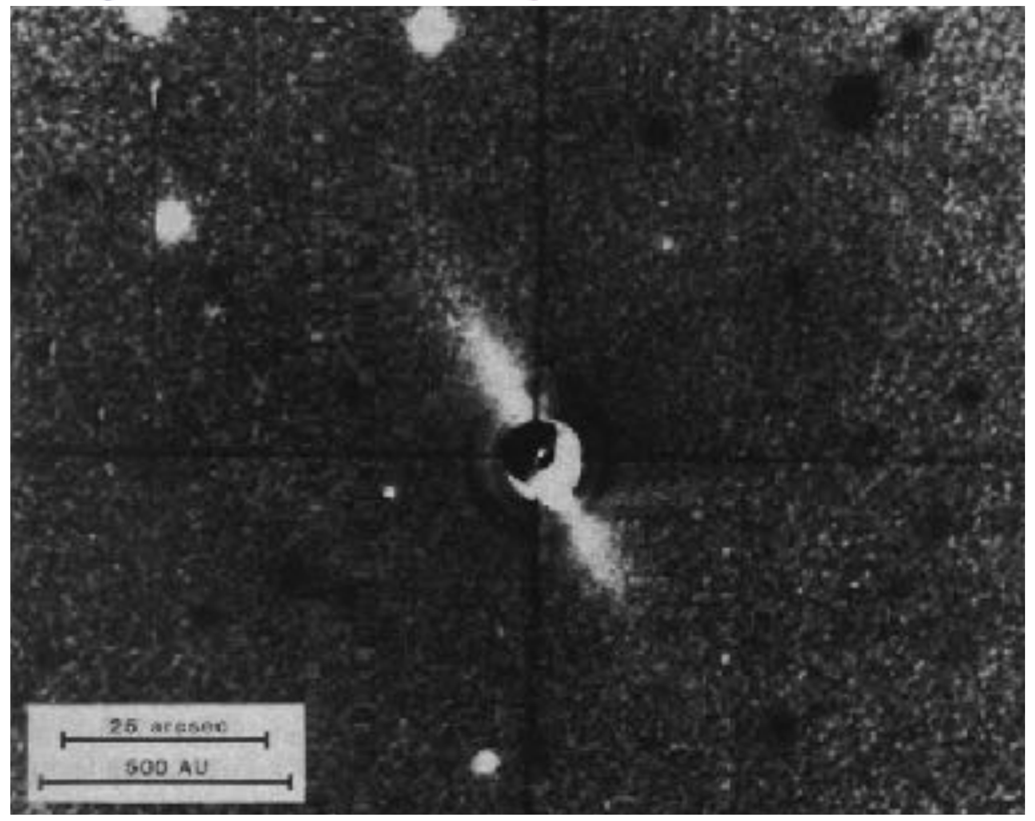
Example Science Programs



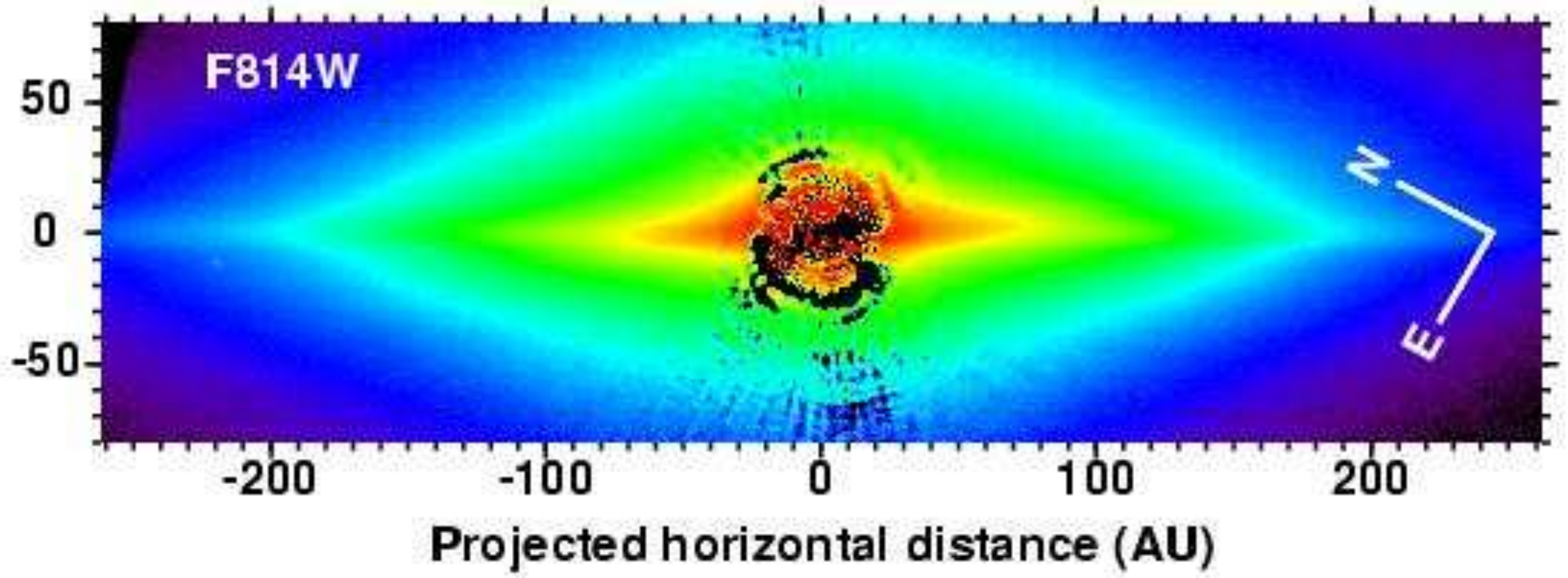




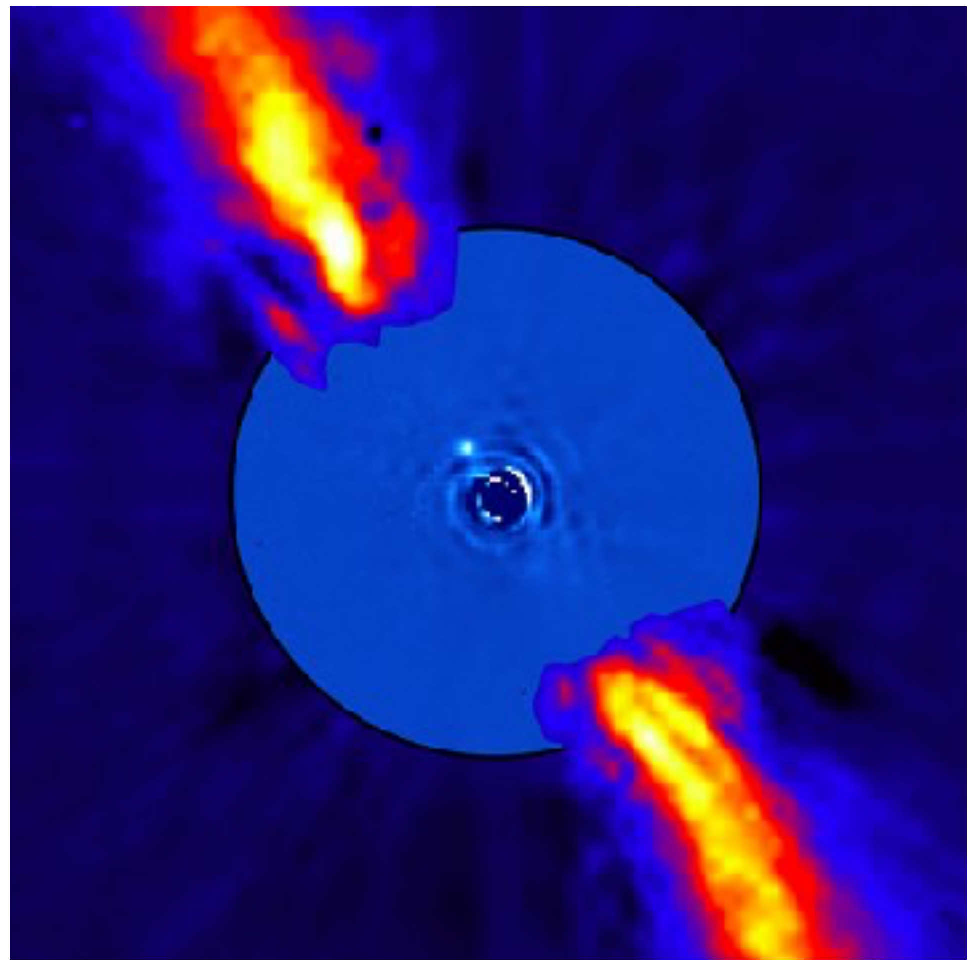
Example Science Program: deep imaging of the β Pic debris disk



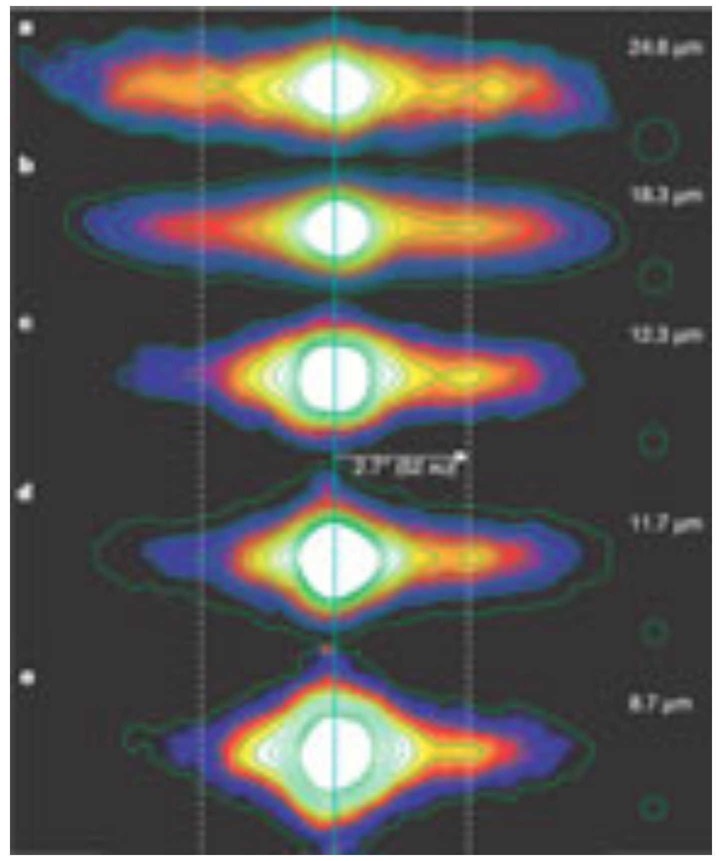
Smith & Terrile 1984



Golimowski et al. 2006



Lagrange et al. 2009, 2010



Telesco et al. 2005

Goals: Characterize the archetypal debris disk around Beta Pic with deep imaging in multiple filters across JWST's entire wavelength range.

Measure disk structure, composition, and interactions with planets. Test for presence of water and CO2 ices, and of organic tholins (like on Titan). Measure color variations and asymmetries across the disk. Probe thermal emission from both the warm inner belt and outer cooler main disk.

Obtain a comprehensive legacy dataset on this target, for analysis alongside similar data on several other debris disks from the NIRCam and MIRI GTO programs.

(note, observing the known planet Beta Pic b is not a goal of this program given its projected separation in 2019.)

Example Science Program: Beta Pictoris debris disk

Which coronagraphs and filters?

- NIRCam, 6 medium band filters for disk composition: 1.82, 2.10 in SW; 2.5, 3.0, 3.3, 4.1 in LW. Use round coronagraphs for full azimuthal coverage (MASK210R and MASK335R).
- MIRI, F1550C (for warm inner disk) and F2300C (for cooler outer disk).

Observing strategy and PSF subtraction?

- Standard sequence, ADI+RDI.
- One of the brightest disks in the sky; a relatively easy target. Does not need small grid dithers.

Exposure times?

- Obtain consistent dataset with NIRCam & MIRI GTO observations of several other disks; therefore adopted fixed deep exposures per filter list rather than optimizing to source specifics.
- 20 minutes per filter per roll for NIRCam; 30 minutes for MIRI.
- Note, for NIRCam can take multiple filters on same coronagraph after one target acq; MIRI needs to switch coronagraph and do target acq for every filter change.

Choosing a PSF star for Beta Pic

- This time we can take a shortcut for picking a PSF calibrator star:

Science target: Beta Pic.	Spectral Type A6, K mag = 3.48.	05 47 -51 03
PSF reference: Alpha Pic.	Spectral Type A8, K mag = 2.57.	06 48 -61 56

Why did we pick Alpha Pic?

- Successfully used as PSF reference in many HST observations.
- Close match in spectral type, nearby, 1 mag brighter, known single star.

Beta Pic observing program overall

- Slew to target (1800 s)
- Observe Science Target NIRCam SW (4800 s)
- Observe Science Target NIRCam LW (7700 s)
- Roll Observatory ~10°
- Observe Science Target NIRCam SW (4800 s)
- Observe Science Target NIRCam LW (7700 s)
- Slew to PSF star
- Observe PSF star NIRCam SW (4800 s)
- Observe Science Target NIRCam LW (7700 s)

- Slew back to Target
- Observe Science Target F1550C (3600 s)
- Observe Science Target F2300C (3600 s)
- Roll Observatory ~10°
- Observe Science Target F1550C (3600 s)
- Observe Science Target F2300C (3600 s)
- Slew to PSF star
- Observe PSF star F1550C (3600 s)
- Observe PSF star F2300C (3600 s)

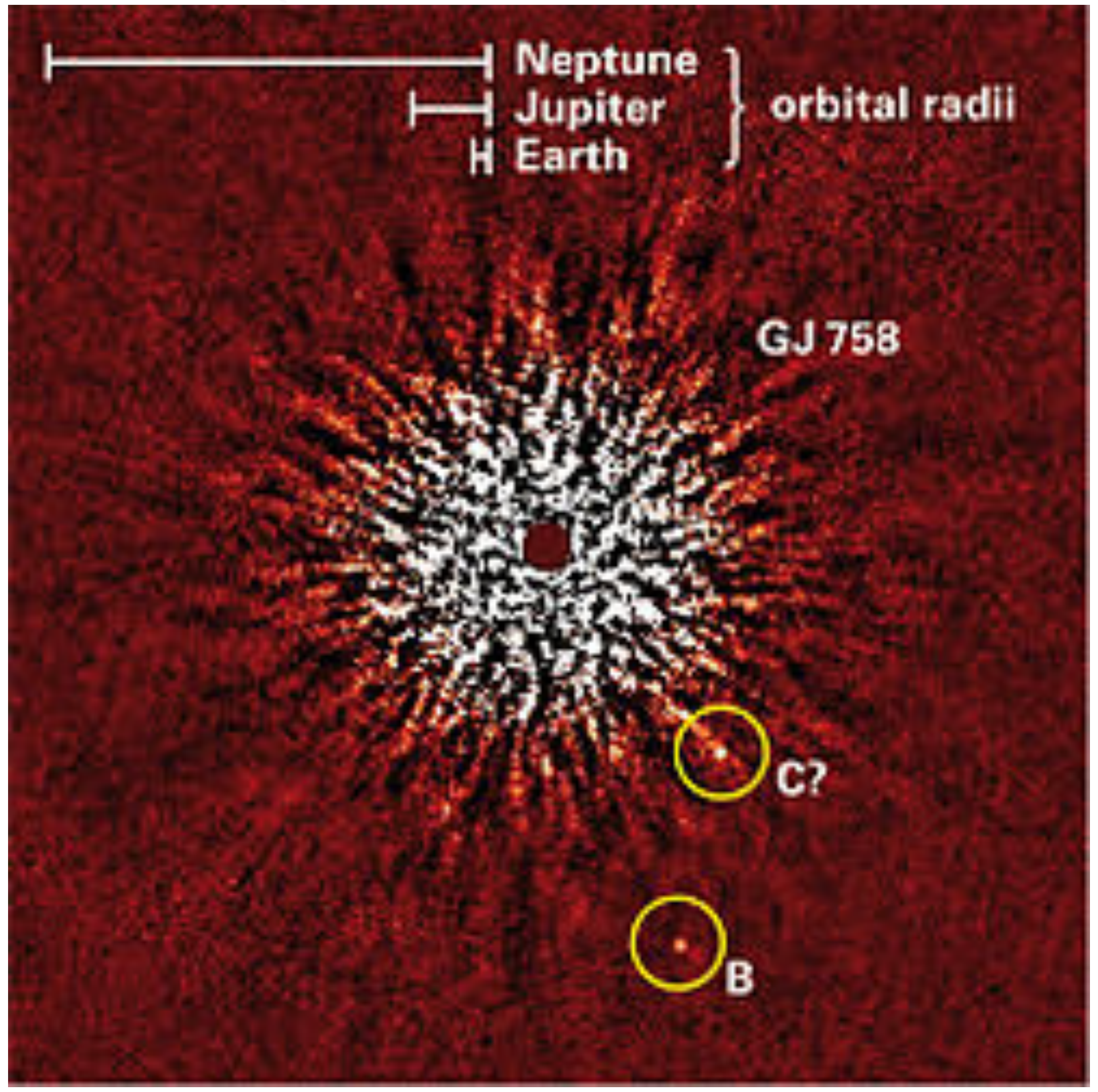
Program total time is dominated by overheads. (8.7 hr science time, 18.5 hr total charged).

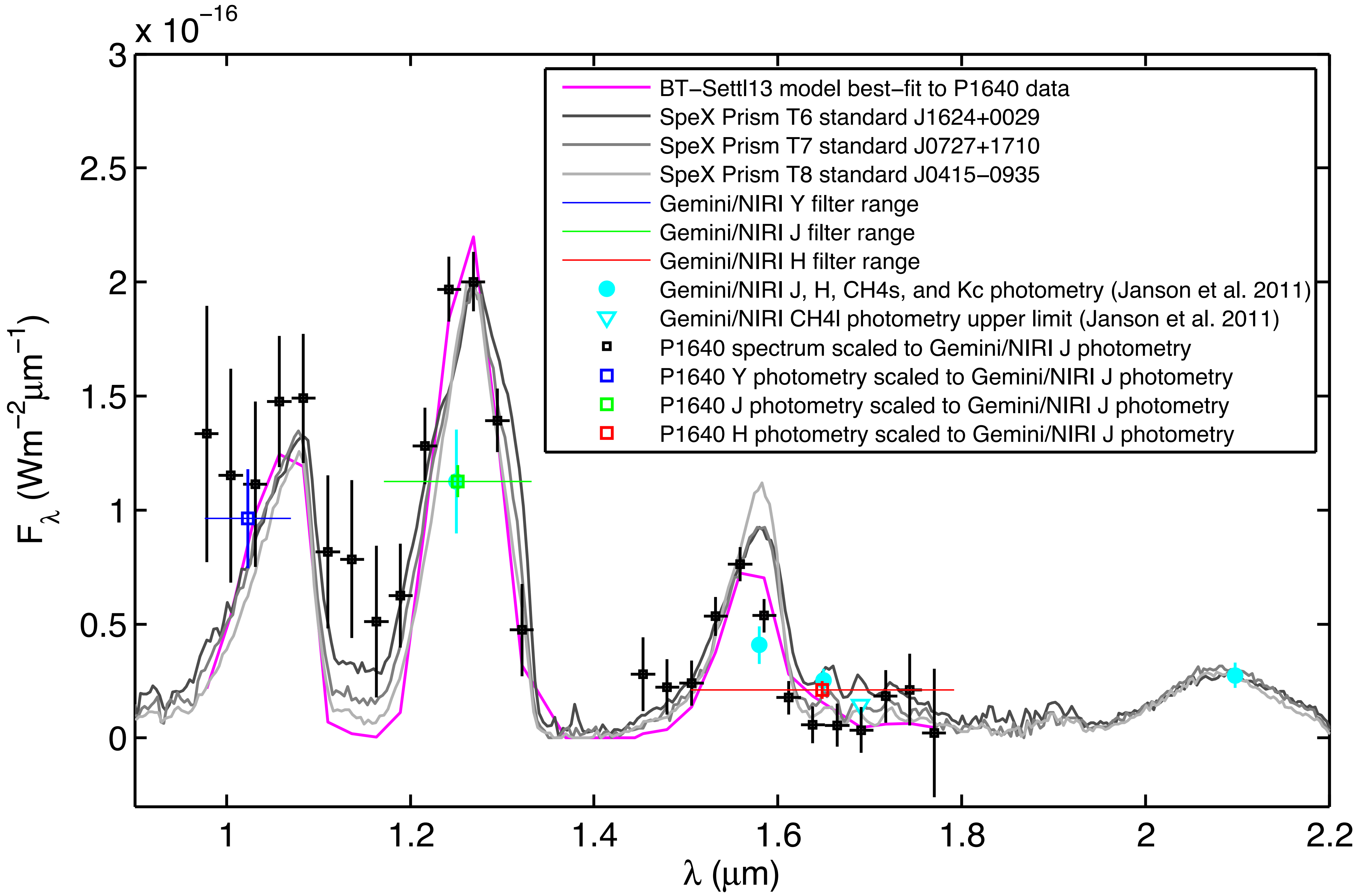
Could save a little time if we minimized slews (reorder to group all PSF star obs at end), but that would increase time delay between some science visits + their PSF reference by over 5 hrs; we opted against this trade.

Notes, need to set orientation constraints to avoid the disk major axis landing along any FQPM quadrant boundaries.
Preferred is ~ 45° relative to the MIRI FQPM axes (loose tolerance).

#21, not on JDox (PDF of provided)

Example Science Program: Characterizing the Brown Dwarf GJ758





~700 K, methane-rich brown dwarf.

Nearly edge-on orbit.
Radial velocity trends will yield dynamical mass.
Host star is G9, 19 pc distant.

See:
Thalmann et al. 2009
Currie et al. 2010
Jansson et al. 2011
Nilsson et al. 2017

Program goals:

Characterize the atmosphere of this cool benchmark brown dwarf at long wavelengths.

Measure effective temperature and atmospheric ammonia absorption.
Compare to atmospheres of field brown dwarfs. Combine with existing shorter wavelength data to retrieve atmospheric properties in detail.

Example Science Program: Characterizing the Brown Dwarf GJ

Which coronagraphs?

- MIRI, all 3 FQPMs. To get continuum fluxes, temperature, and ammonia absorption.

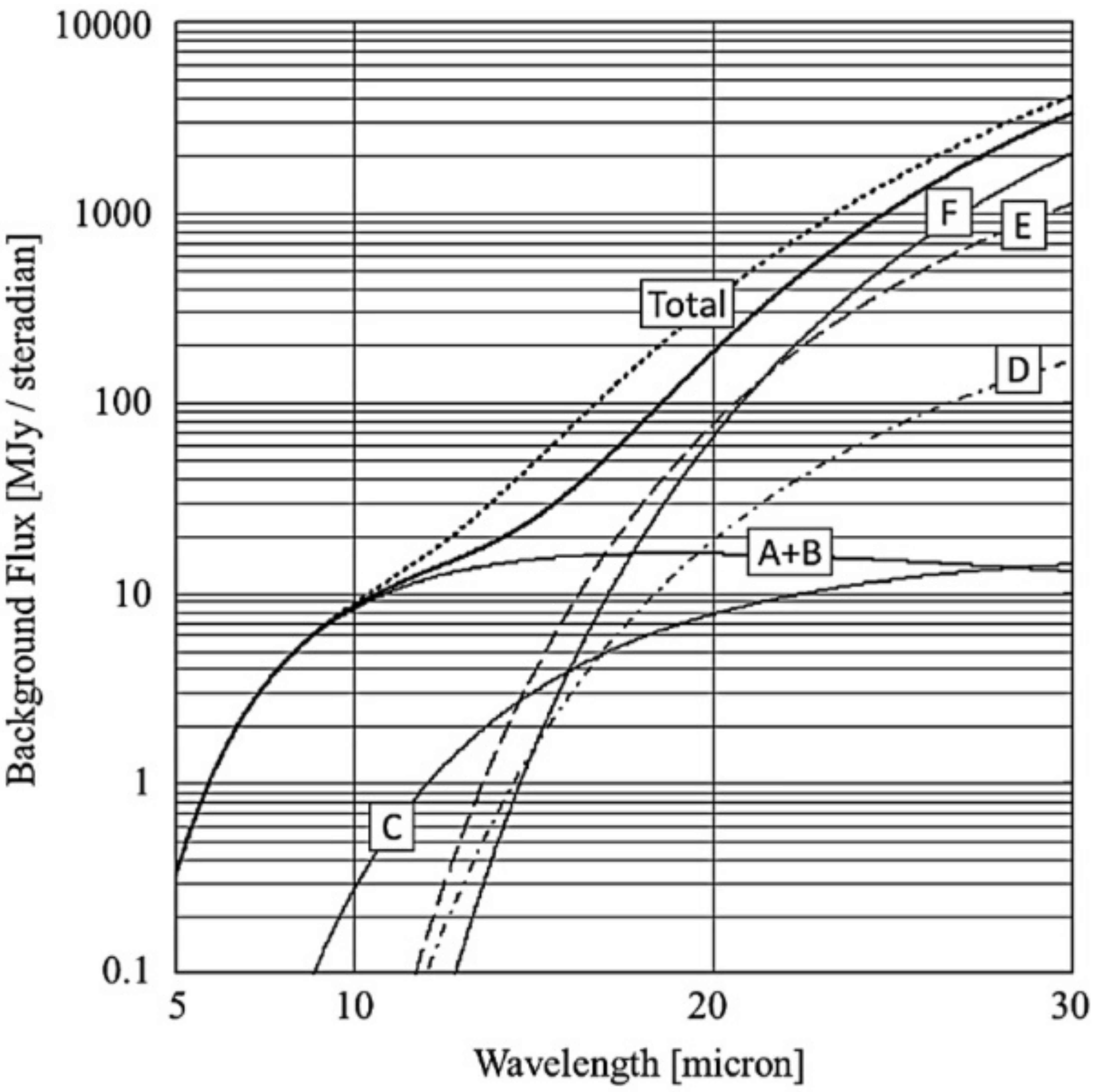
Observing strategy and PSF subtraction?

- Standard sequence, 2 rolls science + PSF star, repeat for each FQPM filter.
- Extrapolating from NIR data, companion contrast is moderate ~ 10-4 at 10 μm. But edge-on orbit will move it inward to projected separation of 1” by 2019.
- Therefore use small grid dither on PSF star to optimize contrast close to the star.

Exposure times?

- Upload to ETC a model spectrum fit to NIR data; normalize to available K band photometry.
- Setup ETC scene with target star, companion, reference star. Calculate exposure times. See splinter session for details!
- Calculated that just a few hundred s yields very high SNR at 10.6 & 11.4 μm. 15 μm is much harder due to increased thermal background, needs longer integration.

Thermal background matters at the longest wavelengths



Thermal background rises significantly beyond 15 μm

from primary mirror & sunshield thermal emission.

Limiting factor for MIRI F1550C and F2300C coronagraphy; less significant for all other filters.

This is included in the background model used by the JWST ETC.

Choosing a PSF REFEERENCE star for GJ 758

- **Science target is quite bright; needs similarly bright PSF reference for comparable exposure times.**
- **Relatively few 4th mag stars, hence small set to choose from. Here's what we picked:**

Science target: GJ 758.	**Spectral Type G9, K mag = 4.49.**	**19 23 + 33 13**
PSF reference: HD 190360.	**Spectral Type G7, K mag = 4.08.**	**20 03 + 29 53**

Why did we pick HD 190360?

- Relatively near by (~9 deg separation.)
- Close match in spectral type (not as critical at MIRI wavelengths but still good to have)
- 0.4 mag brighter (allows shorter exposure time on PSF star, which helps reduce cost of taking PSF observation 9x in small grid dither pattern.)
- We're 100% certain it's not a binary. (known RV planet host star with extensive observations that rule out binarity).

GJ 758 b observing program overall

Slew to target (1800 s) → Observe Science Target F1065C (1800 s) → Observe Science Target F1140C (1800 s) → Observe Science Target F1550C (2400 s)

F1065C:
270 s per exposure

Roll Observatory ~10° → Observe Science Target F1065C (1800 s) → Observe Science Target F1140C (1800 s) → Observe Science Target F1550C (2400 s)

F1140C:
270 s exposure

Slew to PSF star → Observe PSF star, small grid. F1140C (3400 s) → Observe PSF star, small grid. F1065C (3400 s) → Observe PSF star, small grid. F1550C (5000 s)

F1140C:
720 s exposure

Program total time is dominated by overheads: slews, target acqs, etc. (2 hr science time, 7.25 hr total charged).

Reordering visits can (slightly) trade efficiency against closeness in time of PSF calibrators; how this is handled by APT's "Smart Accounting" is still in flux.

Notes, need to set orientation constraints to avoid the companion landing along any FQPM quadrant boundaries.

#36, not on JDox (PDF of draft provided)

The HR 8799 Science Use Case

Face on system (faint debris disk)

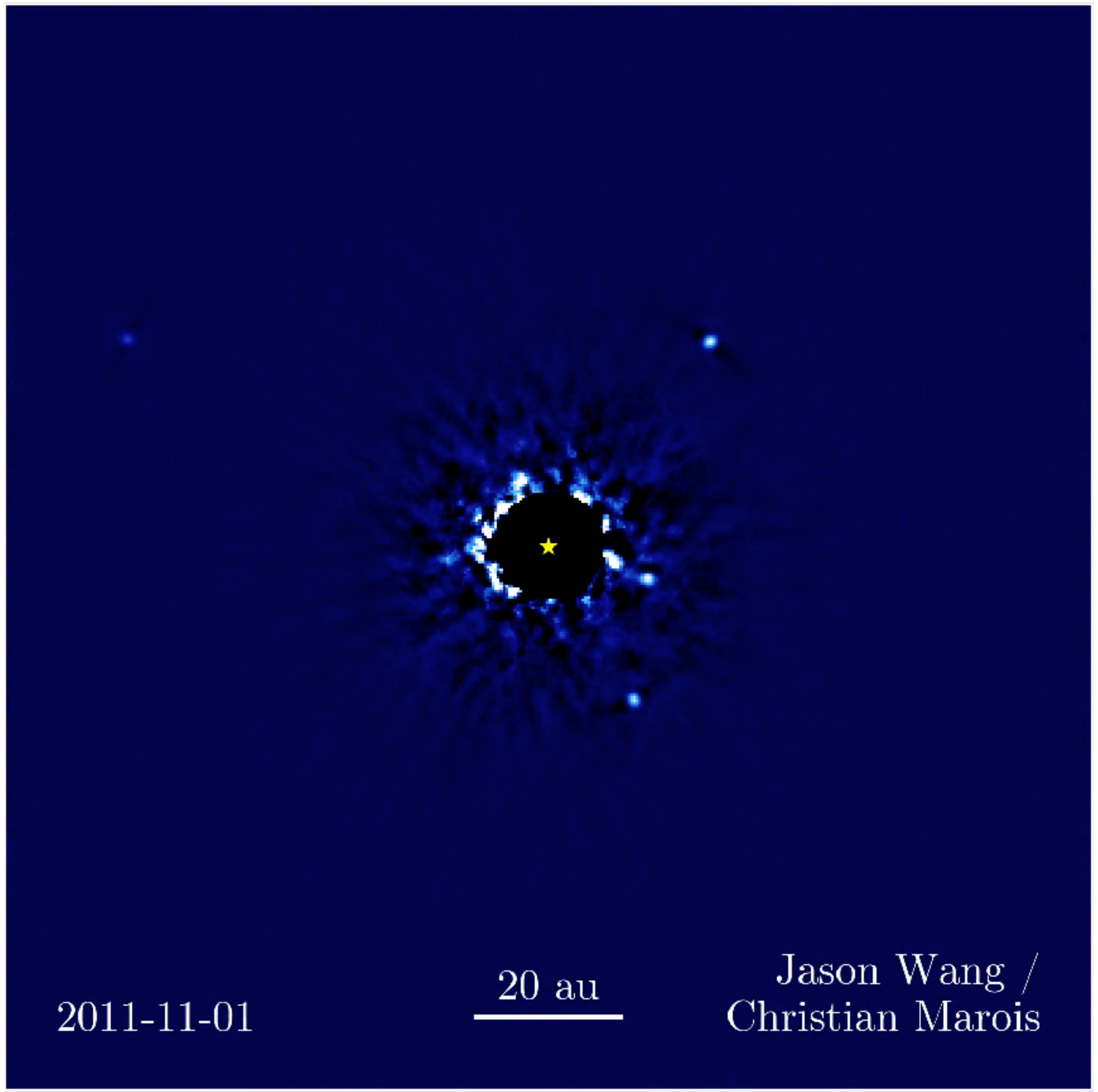
4 planets with mass < 8 M_{Jup}

b at 1.7” is the faintest

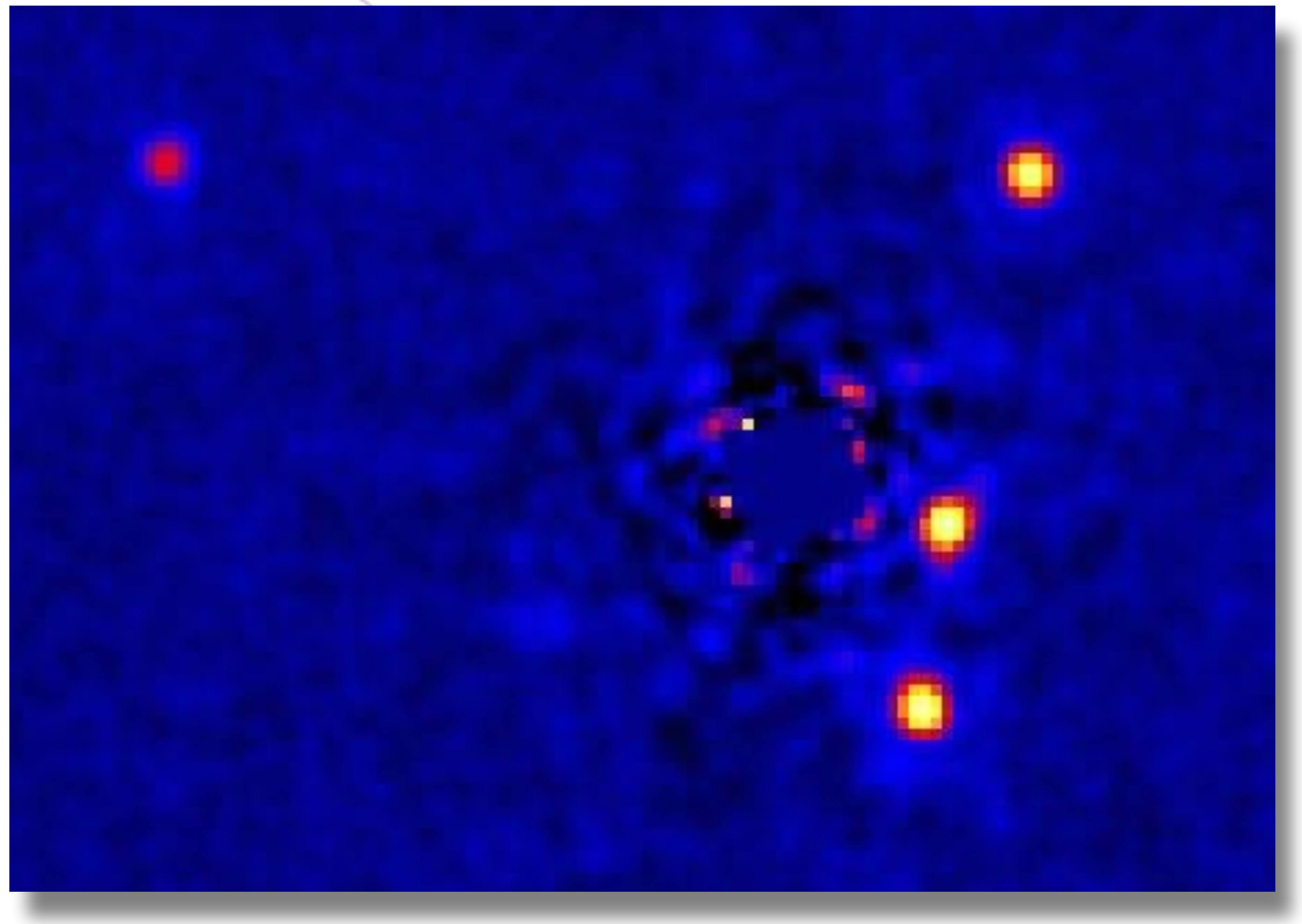
b c d e are all doable with NIRCam Coronagraphy

b & c can be done with MIRI 4QFM coronagraph

e can be attempted with NIRISS/AMI

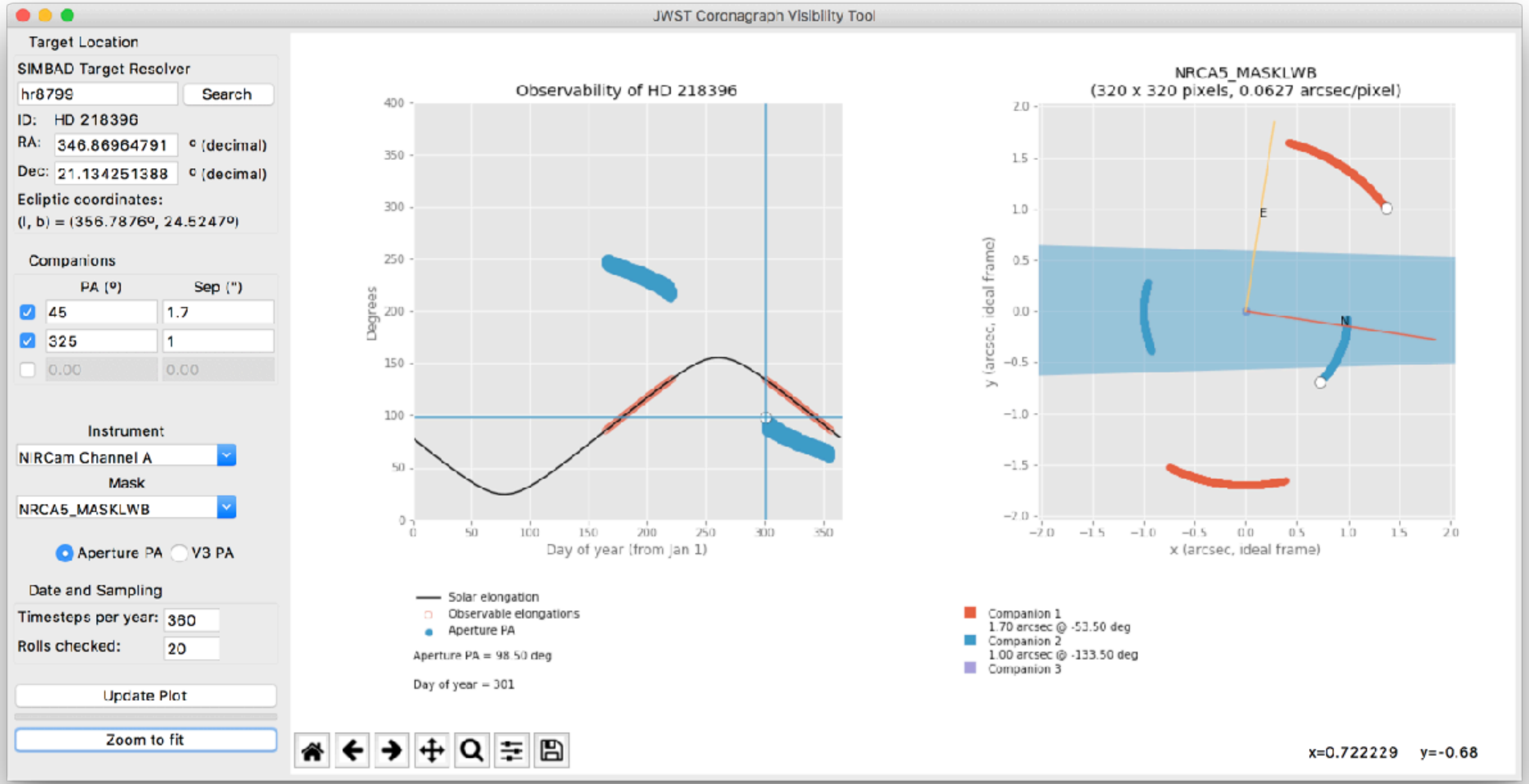


Example Science Program: the HR8799 4-planet system



discovered by Marois, here Currie et al. 2014

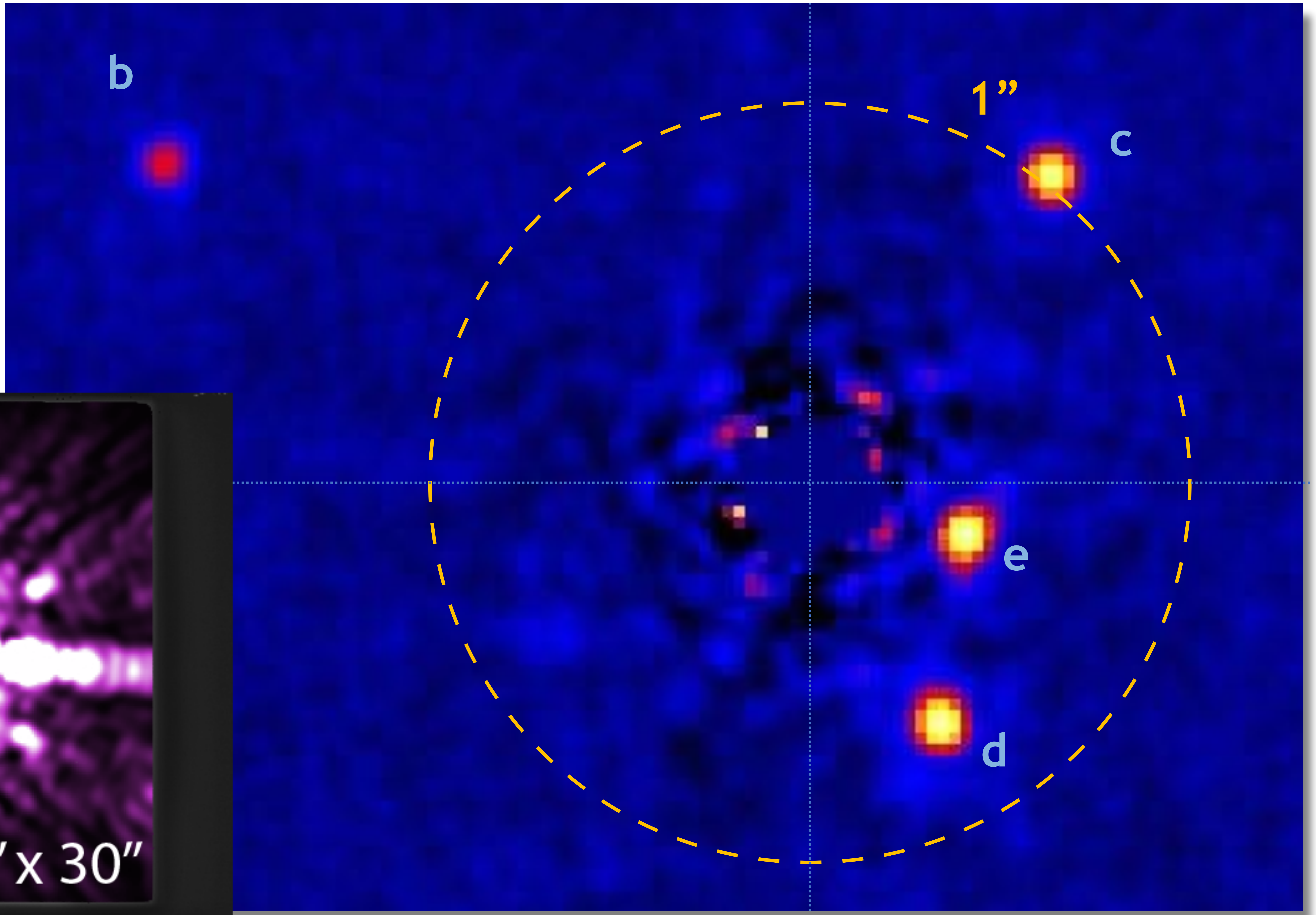
Coronagraph Visibility Tool (CVT)



Setting special requirements

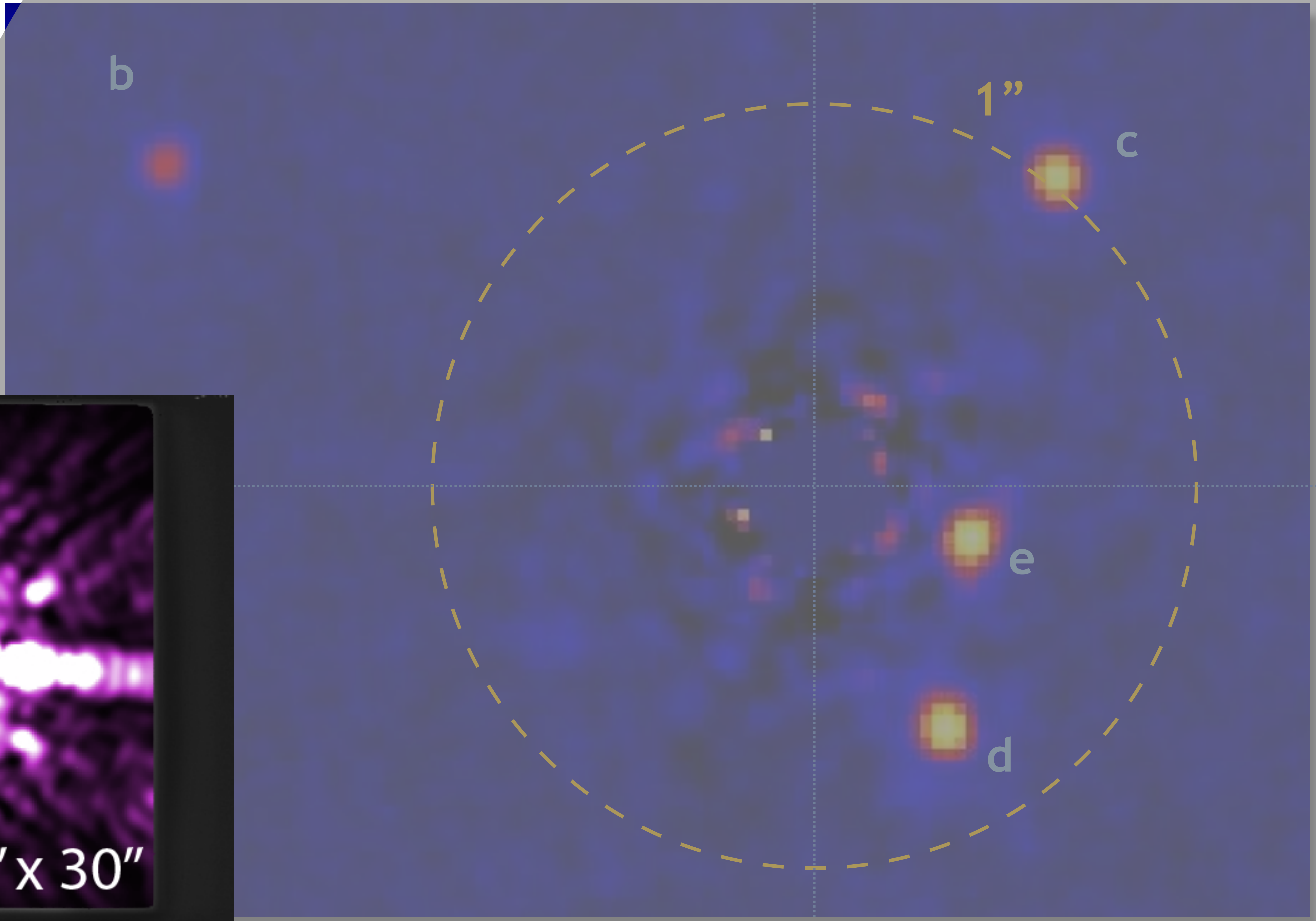
for position angles

Example Science Program 1: the HR8799 4-planet system

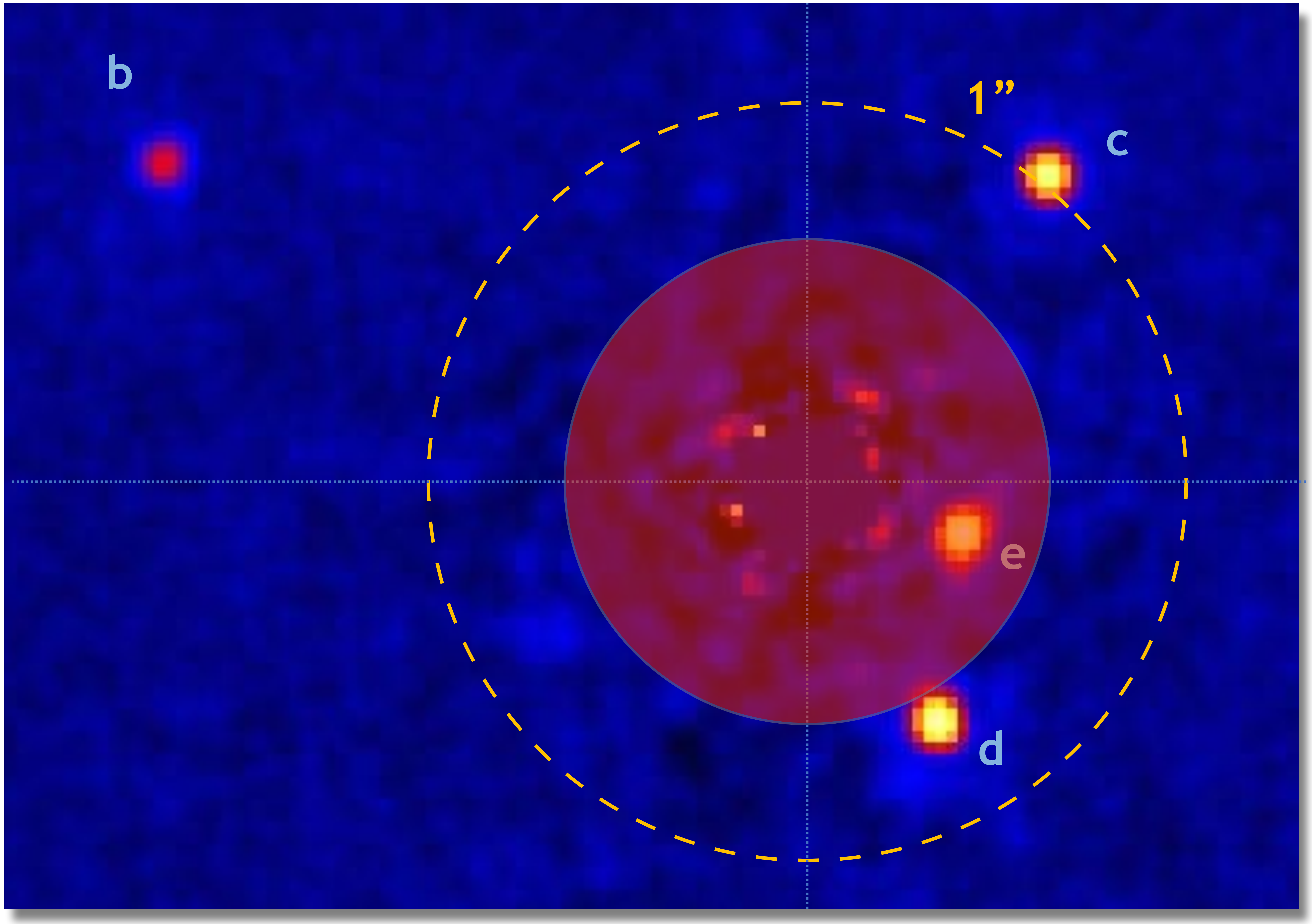


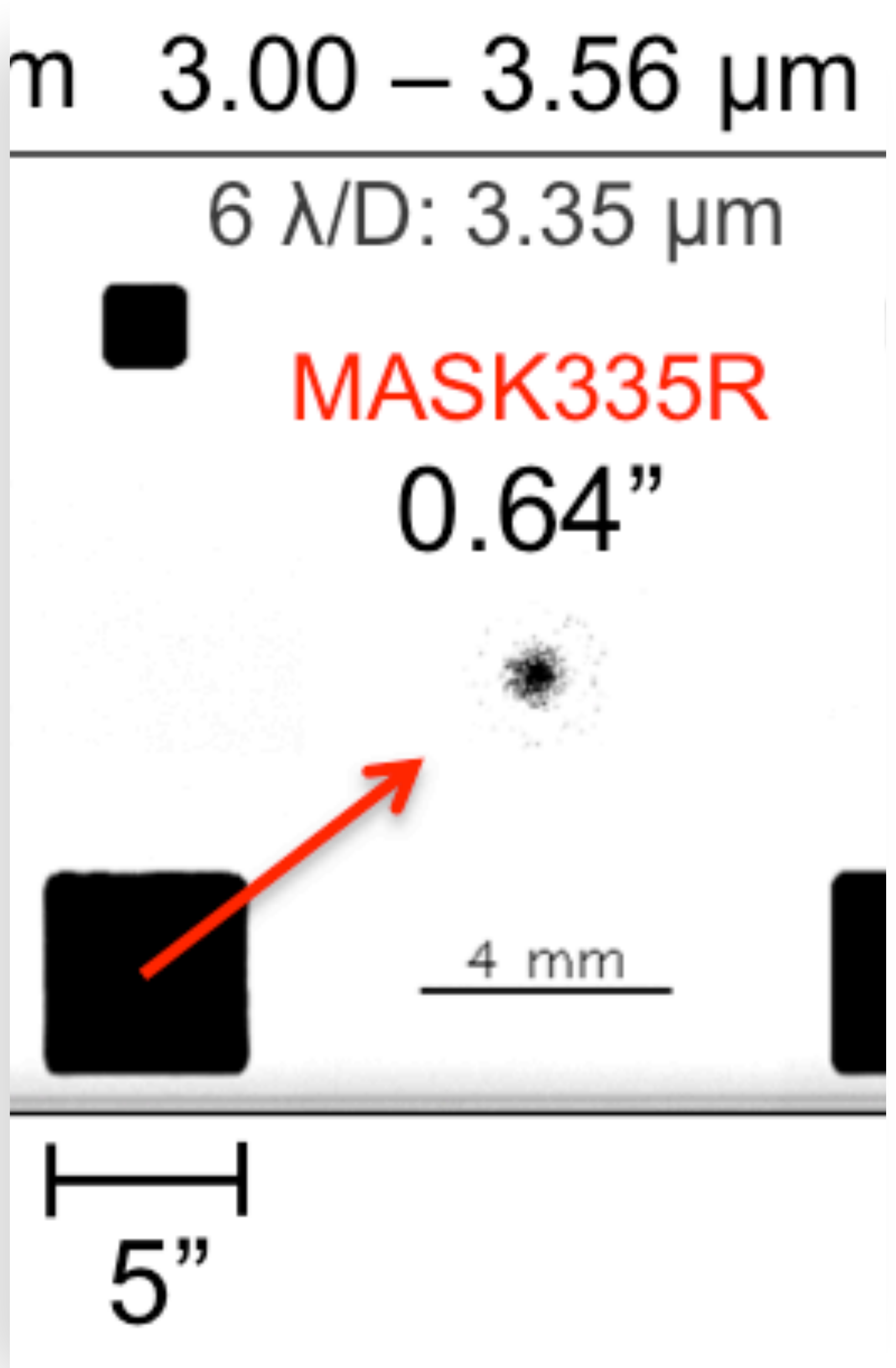
Example Science Program 1: the HR8799 4-planet system

size
2.16”!!!



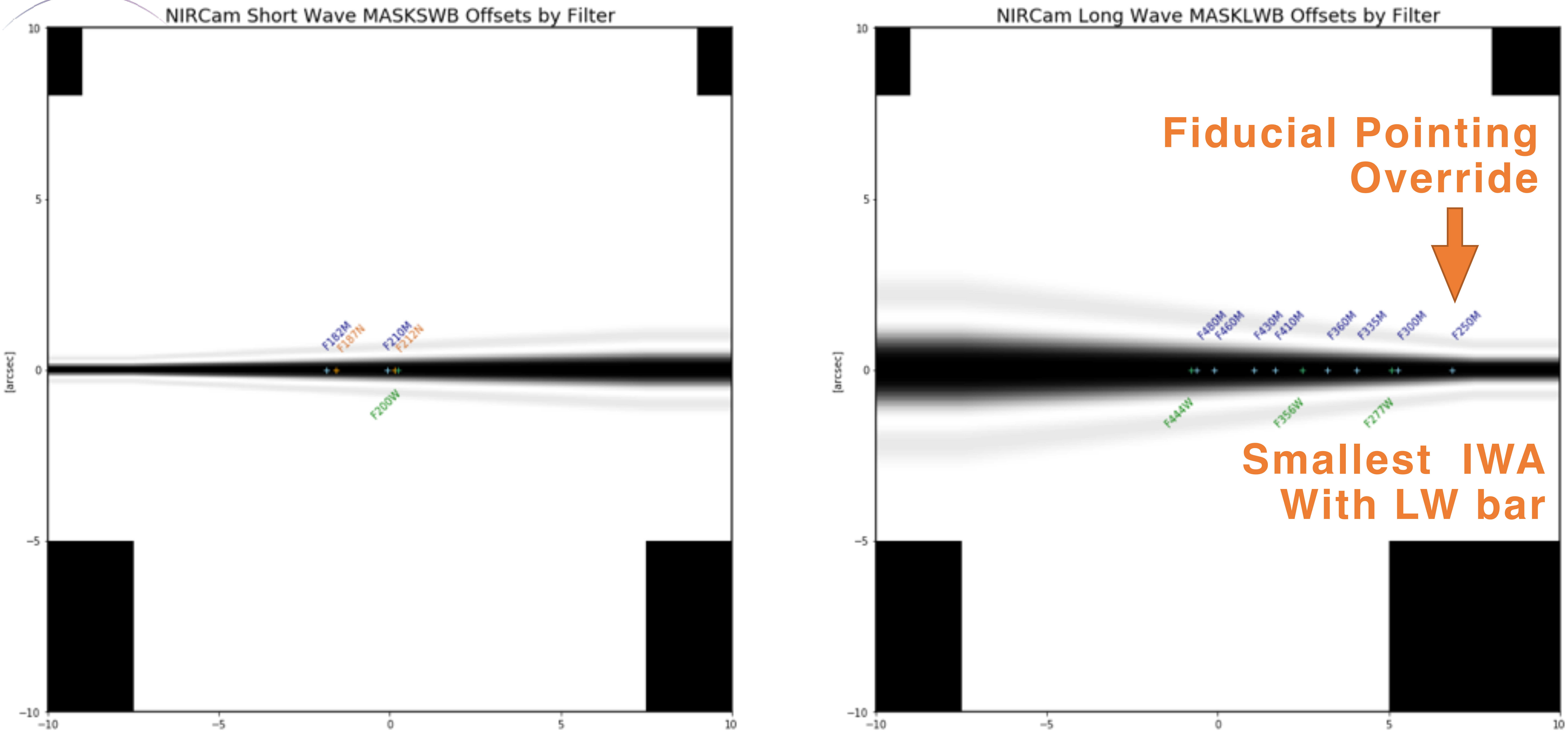
Example Science Program 1: the HR8799 4-planet system





IWA~0.64”

NIRCam Coronagraphy: bar coronagraphs (wedge occulters)

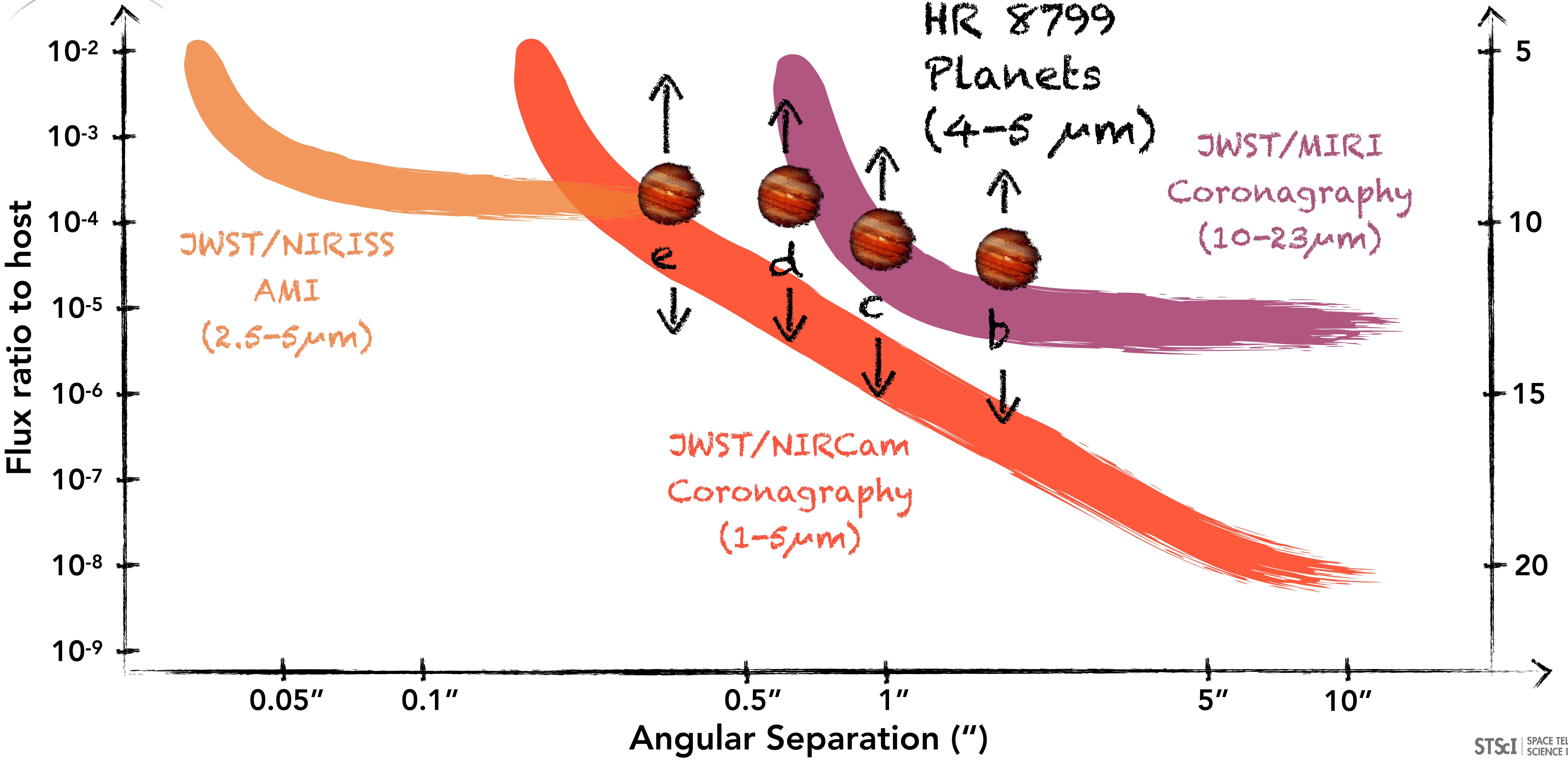


Example Science Program #36 & NIRCam Coronagraphs

Credit: J. Leisenring (pyNRC, U. Of Arizona)

Note: All compass axes should be (N, E) not (V3, V2)

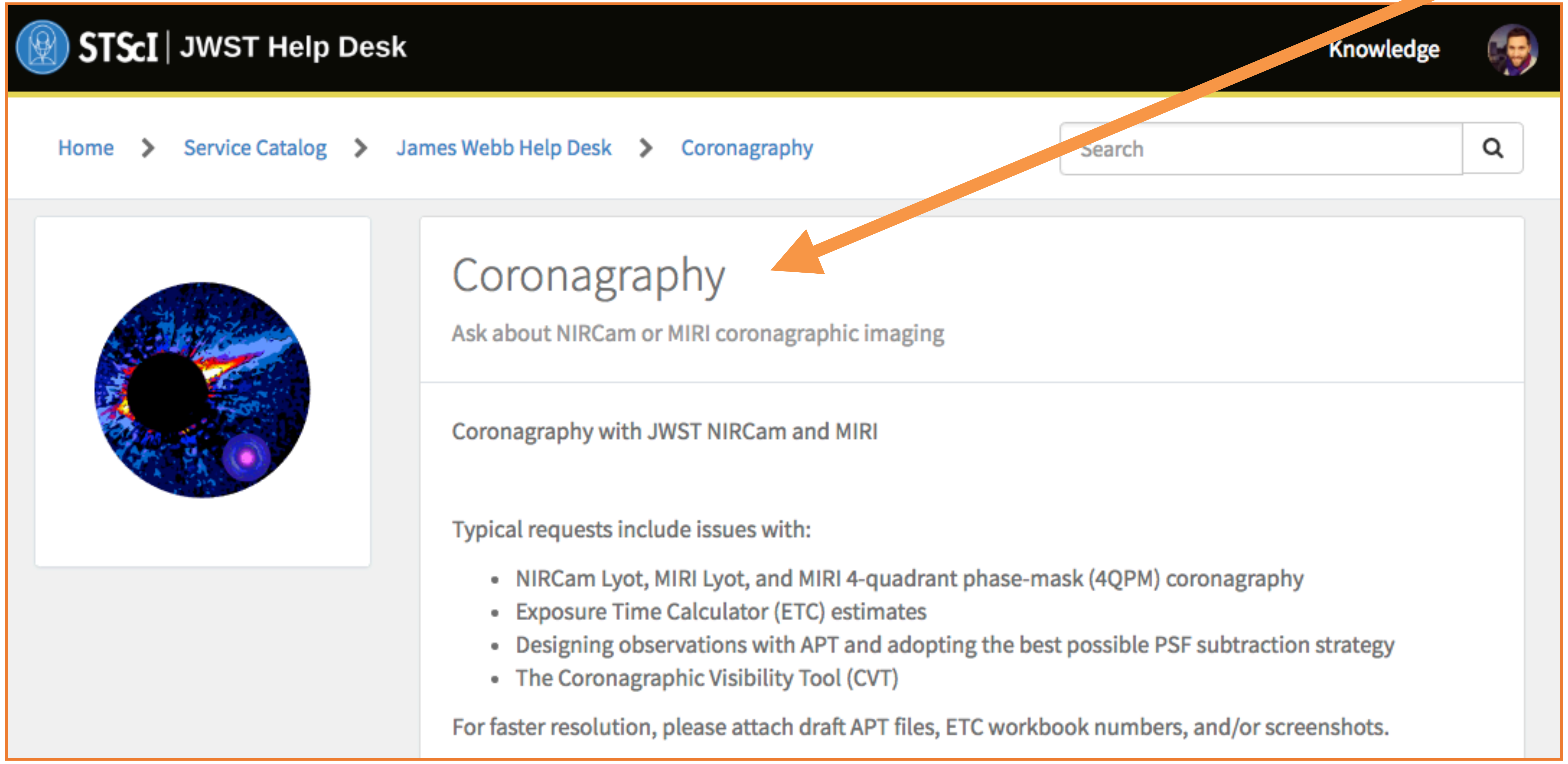
NIR to MIR Coronagraphy & Aperture Masking: Ground & Space

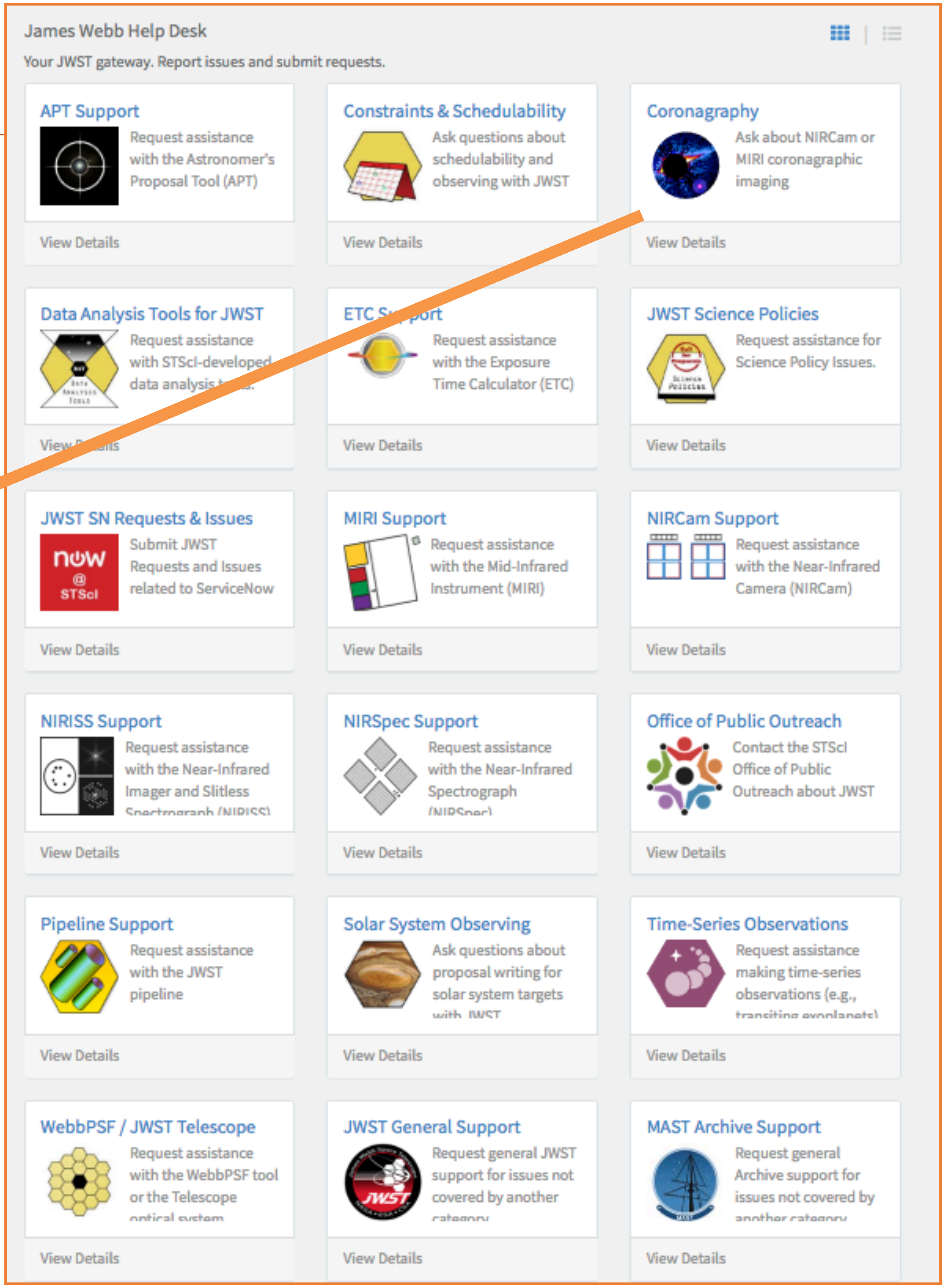


Extra Slides, Extra Resources

Help Desk

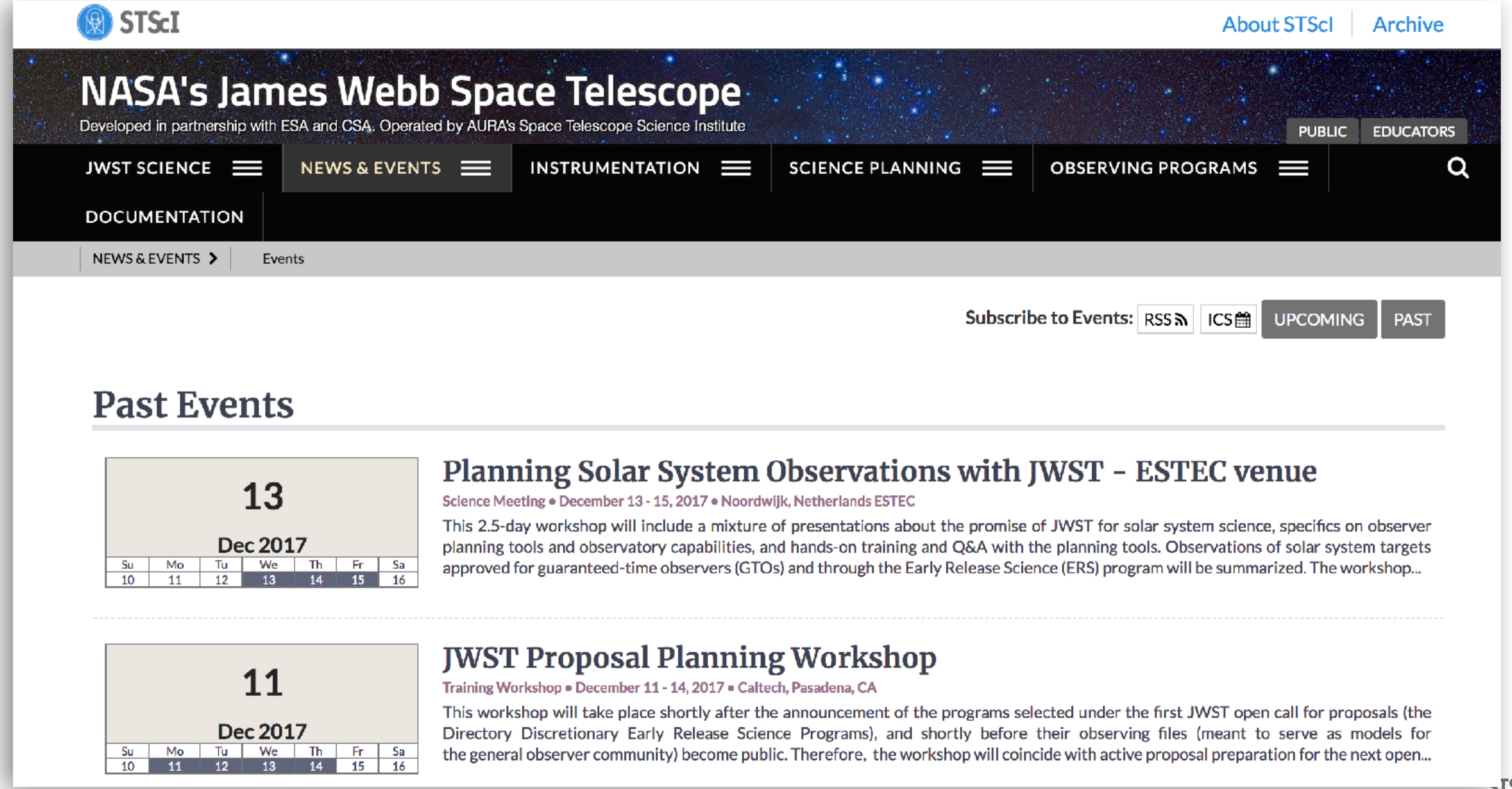
jwsthelp.stsci.edu



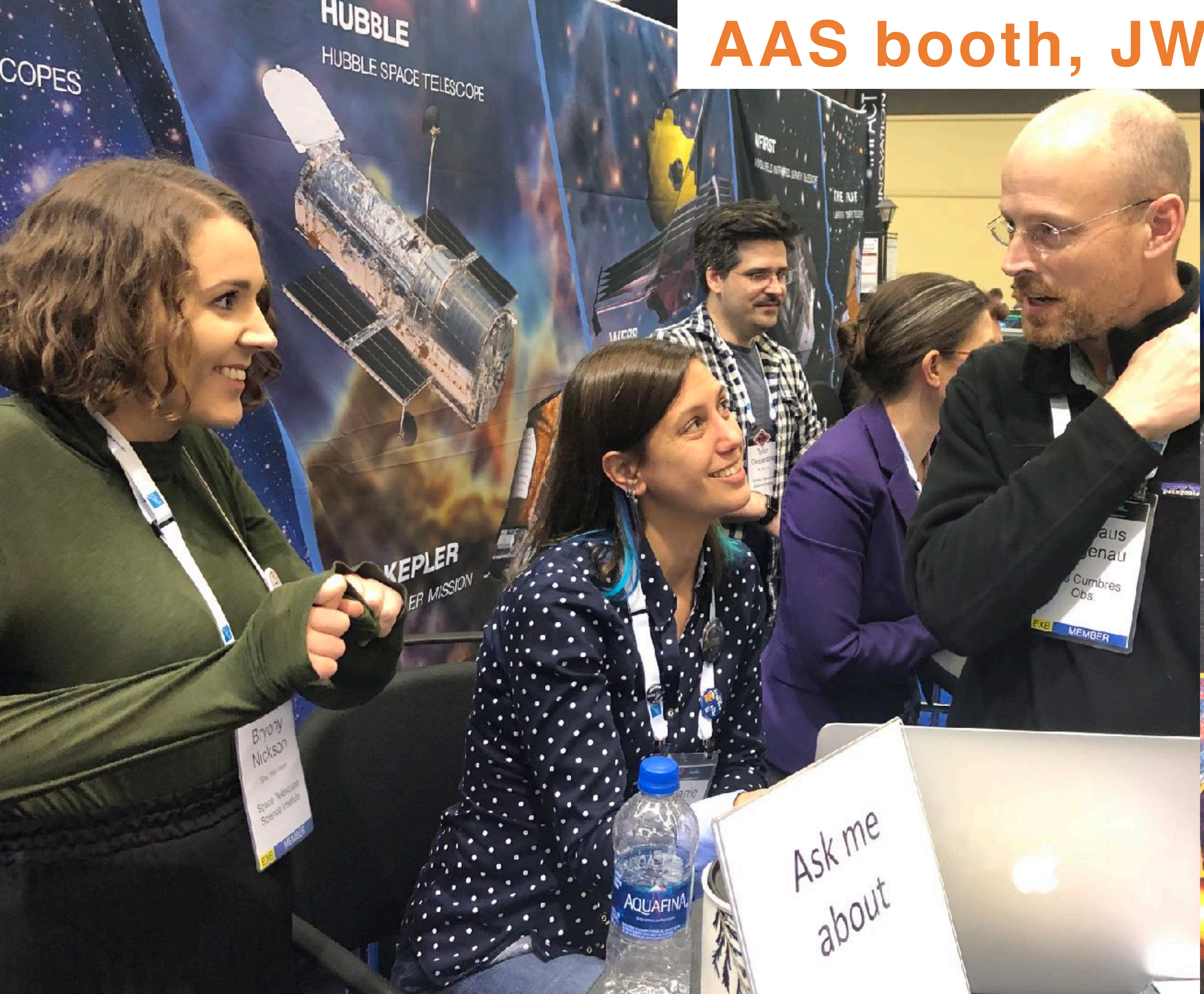


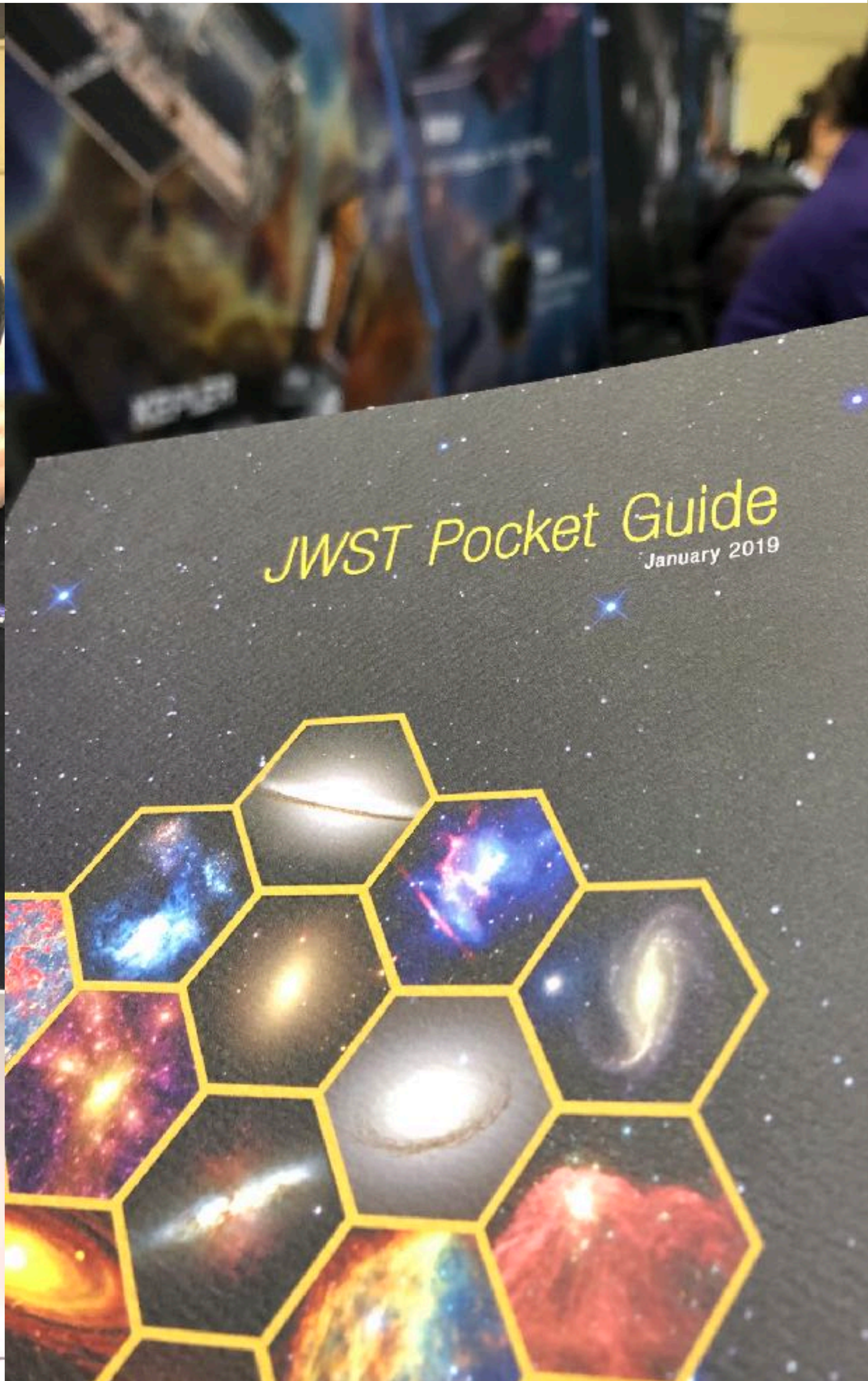
https://jwst.stsci.edu/events

Proposal Planning Workshop: material, presentations

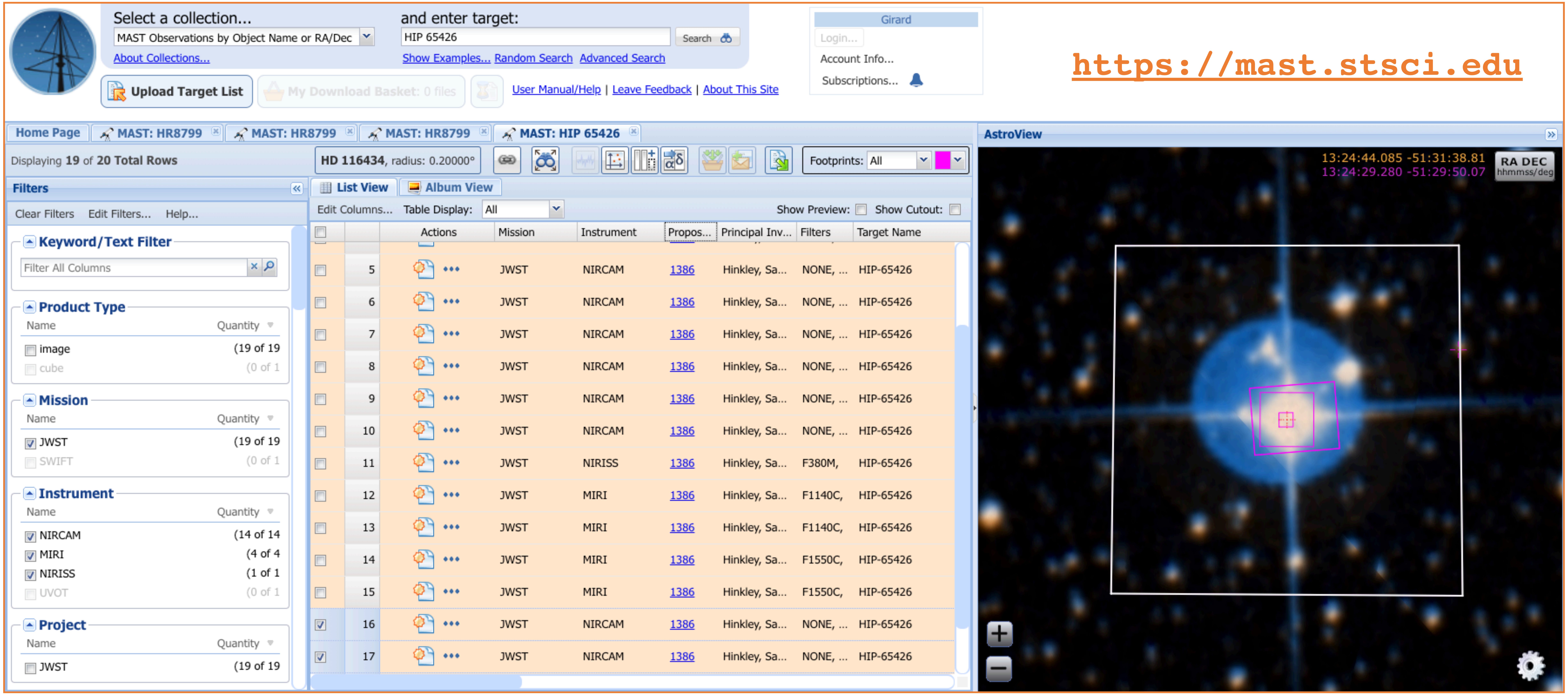


AAS booth, JWST pocket Guide





Approved programs on MAST: example of ERS #1386 (Hinkley)



4 Ideas which aren’t always true

Coronagraphy is the **only way** to **perform & achieve high contrast imaging**

Coronagraphy & high contrast imaging **do not** concern **extragalactic science**

Images from **space** are **sharper**

Coronagraphic observing strategies & data (post-)processing are **for experts**

4 "Take Home" from this talk!

Coronagraphy is **NOT** the **only way** to **perform & achieve high contrast imaging**

Moderate to high contrasts can be achieved with other techniques (Imaging, IFU, AMI)

Coronagraphy & high contrast imaging **do** ~~**not**~~ concern **extragalactic science**

Images from **space** are **sharper**, **in general (HST "trademark")**

6.5 to 40-meter class ground based facilities with (x)AO can provide better FWHM in some cases (rather bright objects) but with a limited FoV, stability & sensitivity, unlike NIRCam

Coronagraphic observing strategies & data (post-)processing are **not just for experts**

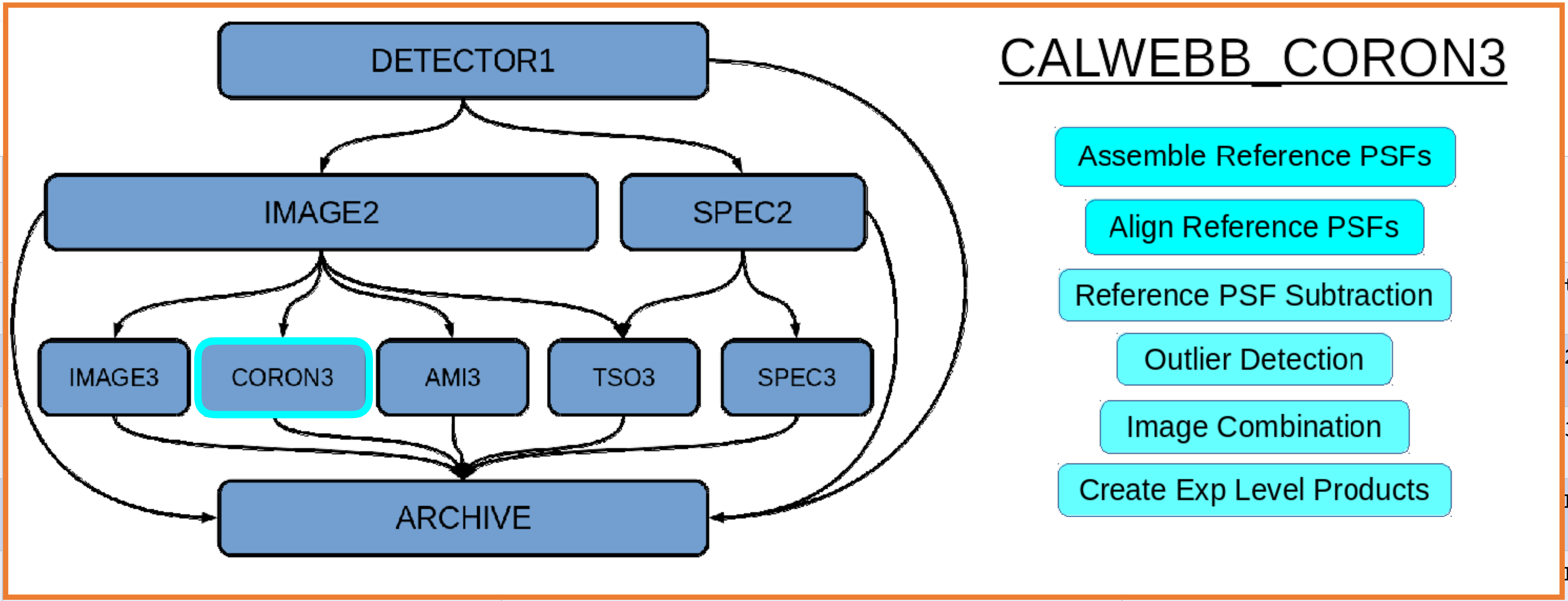
At STScI , the CWG works in synergy with other working groups & divisions, the IDTs and the general community to provide the best possible support

Pipeline for coronagraphy

Pipeline/Step	Command line	iPython + modules (run method)	iPython + classes (call method)
Detector1	strun calwebb_detector1.cfg <file>	from jwst.pipeline import calwebb_detector1	from jwst.pipeline import Detector1Pipeline
Image2	strun calwebb_image2.cfg <file>	from jwst.pipeline import calwebb_image2	from jwst.pipeline import Image2Pipeline
Image3	strun calwebb_image3.cfg <file>	from jwst.pipeline import calwebb_image3	from jwst.pipeline import Image3Pipeline
Spec2	strun calwebb_spec2.cfg <file>	from jwst.pipeline import calwebb_spec2	from jwst.pipeline import Spec2Pipeline
Spec3	strun calwebb_spec3.cfg <file>	from jwst.pipeline import calwebb_spec3	from jwst.pipeline import Spec3Pipeline
Coron3	**strun calwebb_coron3.cfg <file>**	**from jwst.pipeline import calwebb_coron3**	**from jwst.pipeline import Coron3Pipeline**
DQ Initialization	strun dq_init.cfg <file>	from jwst.dq_init import dq_init_step	from jwst.dq_init import DQInitStep
Assign WCS	strun assign_wcs.cfg <file>	from jwst.assign_wcs import assign_wcs_step	from jwst.assign_wcs import AssignWcsStep

jwst-docs.stsci.edu/display/JDAT/CALWEBB_CORON3

Pipeline for coronagraphy



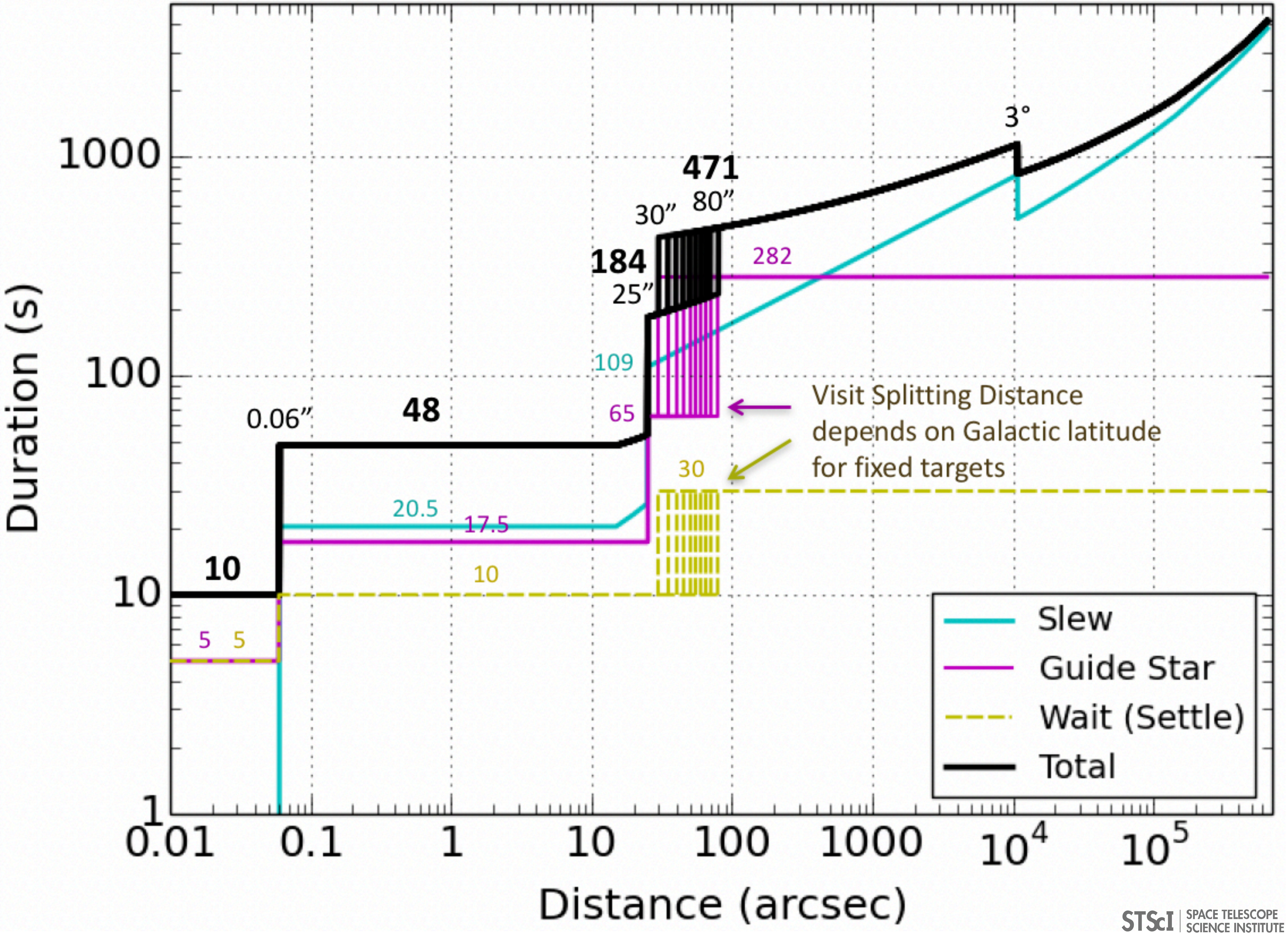
Pipeline/Step			
Detector1			tor1Pipeline
Image2			2Pipeline
Image3			3Pipeline
Spec2			Pipeline
Spec3			Pipeline
Coron3	**strun calwebb_coron3.cfg <file>**	**from jwst.pipeline import calwebb_coron3**	**from jwst.pipeline import Coron3Pipeline**
DQ Initialization	strun dq_init.cfg <file>	from jwst.dq_init import dq_init_step	from jwst.dq_init import DQInitStep
Assign WCS	strun assign_wcs.cfg <file>	from jwst.assign_wcs import assign_wcs_step	from jwst.assign_wcs import AssignWcsStep

jwst-docs.stsci.edu/display/JDAT/CALWEBB_CORON3

Reference star & overheads: slew, settle, reacquire guide star

Changing attitude

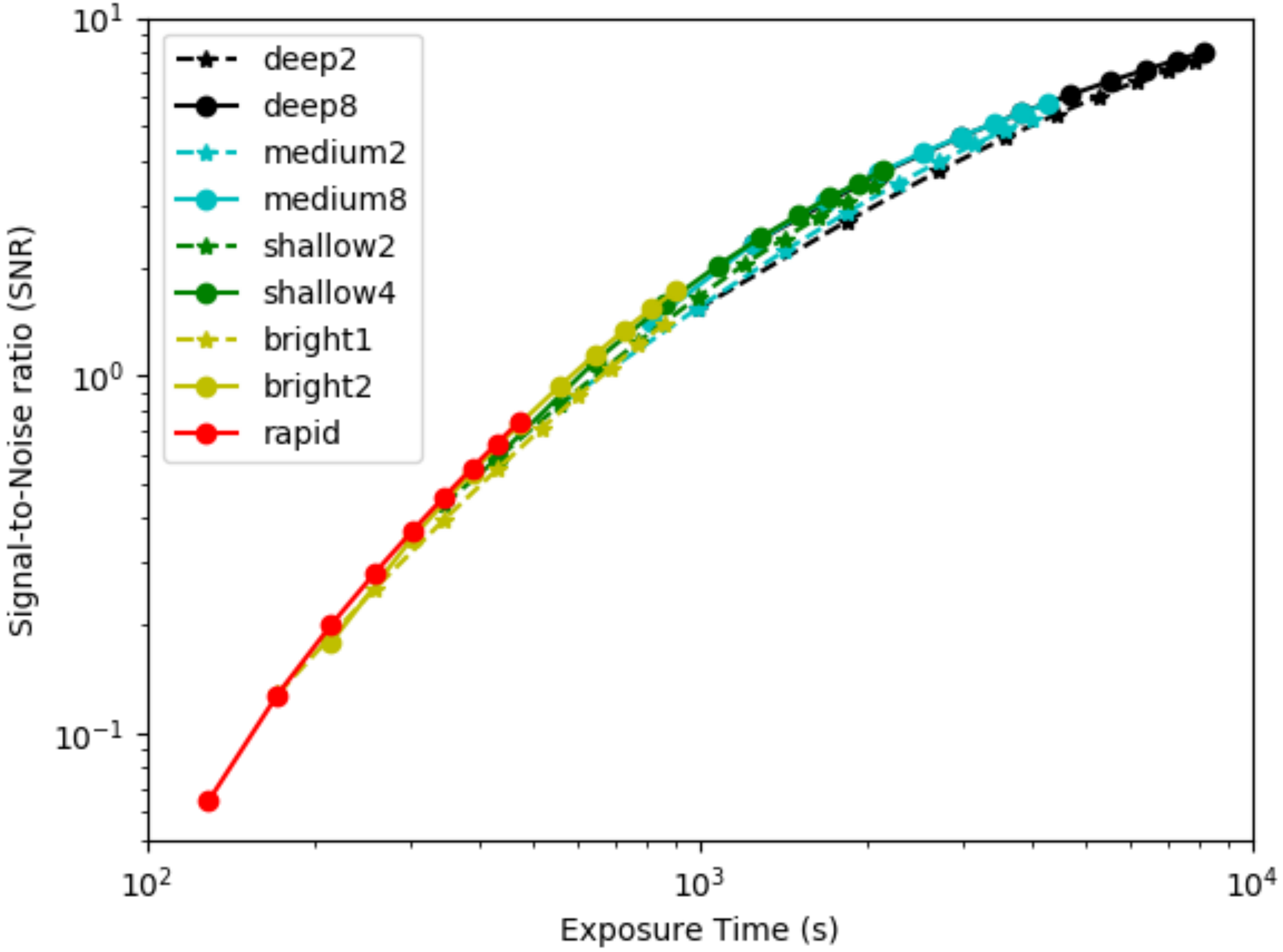
1. Update observatory pointing and roll
2. Let disturbances settle
3. Reacquire guide star
   - ✦Fine guide (always)
   - ✦Track (>0.06")
   - ✦Acquisition (>25")
   - ✦Identification (new visit)



ETC: Finding the best exposure parameters

Selecting the optimal combination of readout pattern, ngroups, nints and nexps is a trade-off

- More frames decreases read noise
- Shorter groups increases data volume
- Longer groups increases the chance of a cosmic ray hit during the group
- Shorter integrations make ramp fits more uncertain in the presence of non-linearity
- More dithered exposures decreases flat field errors (not currently modeled by ETC!)
- Patterns that skip a lot of frames have higher read noise, but have slightly better duty cycle



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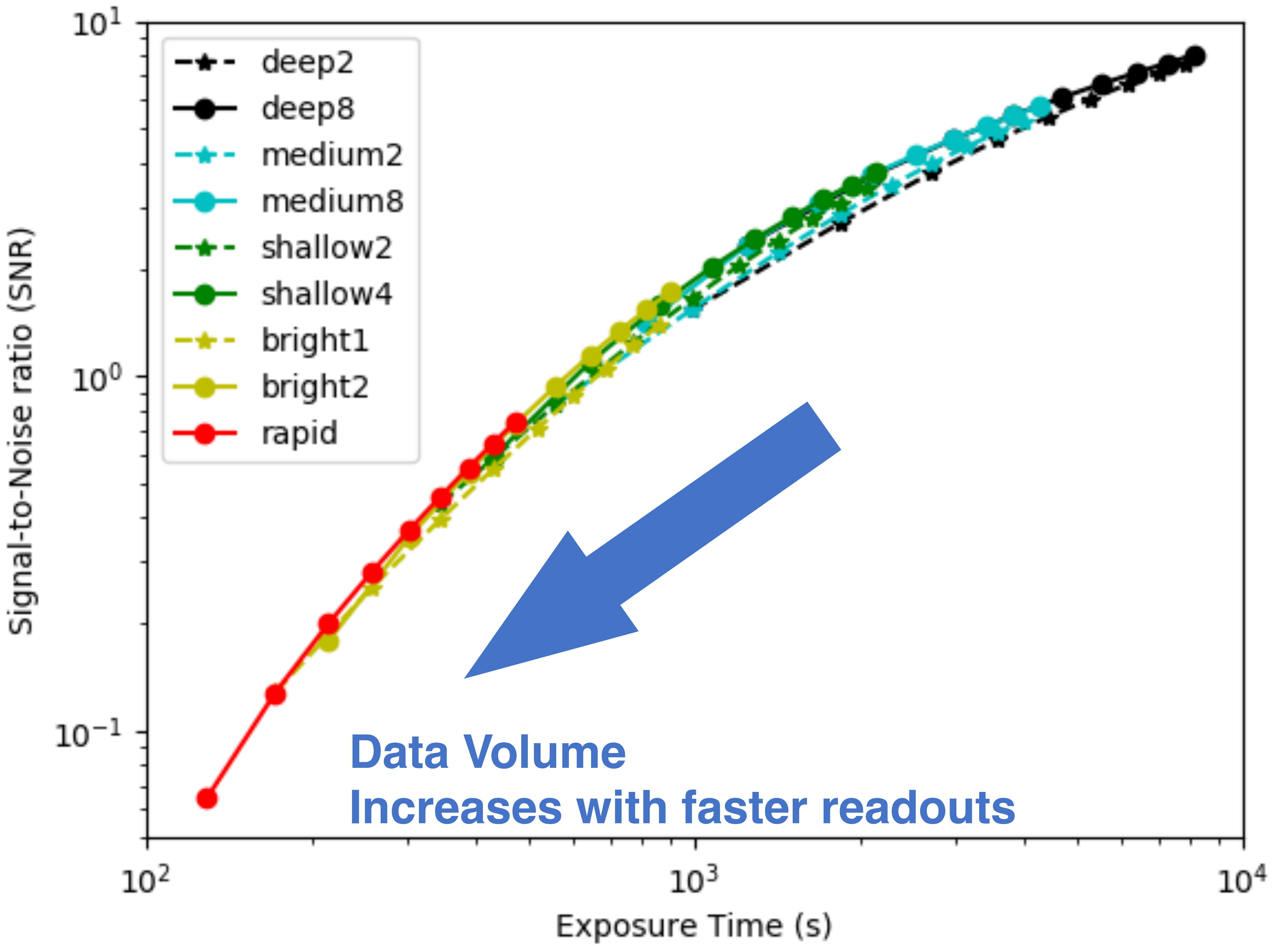
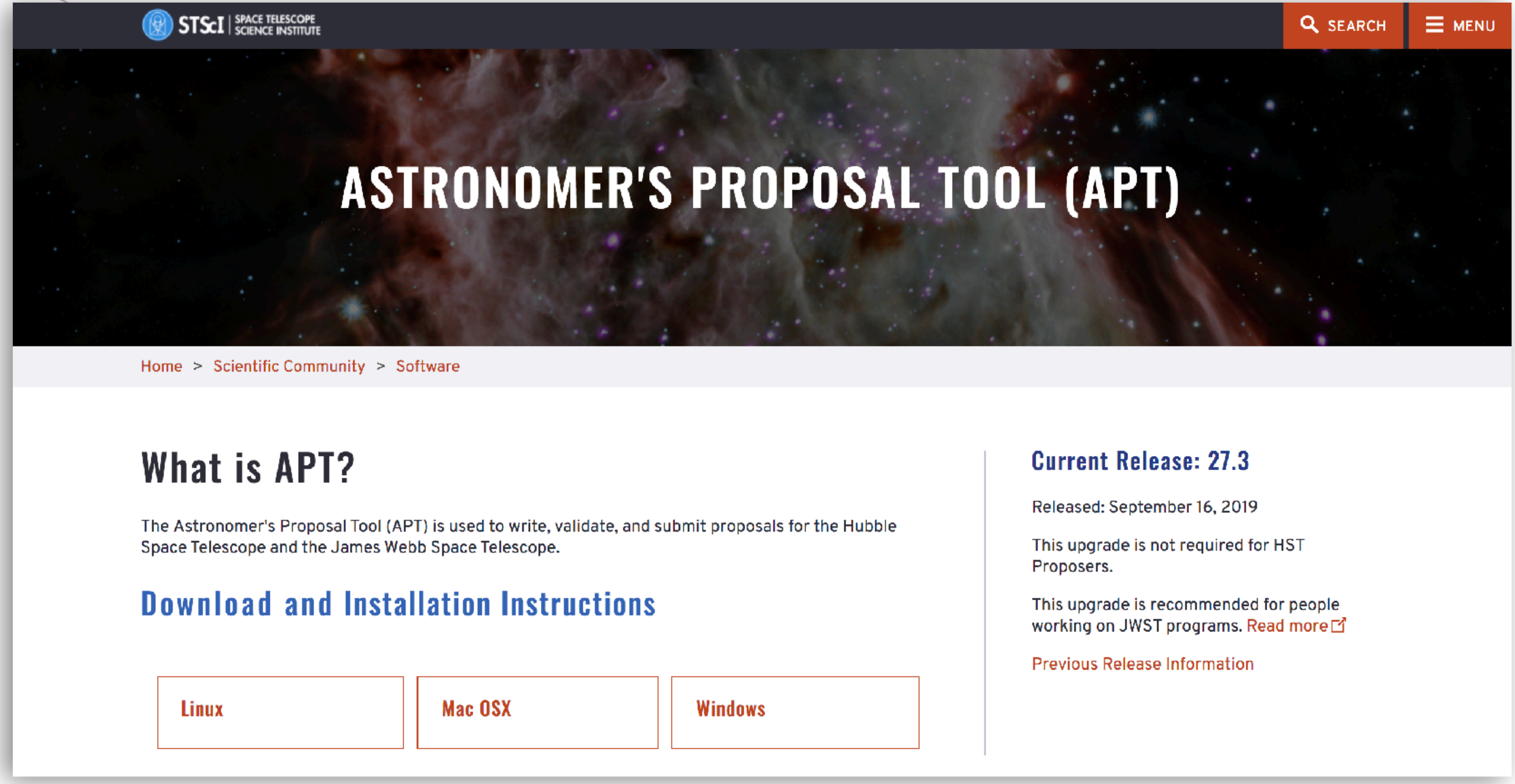


APT 27.3

www.stsci.edu/scientific-community/software/astronomers-proposal-tool-apt



Technical Documents / Coronagraphy, AMI

Coro

Title	Author	Year
A PSF Library for Coronagraphy with JWST	Stark, C., Pueyo, L. & the JWST Coronagraphs Working Group	2017
An APT Implementation of the JWST Coronagraph SODRM Programs	Stark, C. & Van Gorkom, K.	2017
NIRCam Filter, Weak Lens and Coronagraphic Throughputs	Hilbert, B. & Stansberry, J.	2017
Comparative Study of the Efficiency of Various JWST Coronagraph Observation Strategies	Pueyo, L., Soummer, R. & the JWST Coronagraphs Working Group	2016
Exposure Time Calculations for Coronagraphic Observations: Overview of User Needs	Pueyo, L., Soummer, R. & the JWST Coronagraphs Working Group	2016
How to Implement a JWST Coronagraphic Observation Sequence in APT	Stark, C. & Van Gorkom, K.	2016
Science Use-Cases for the Preparation of Coronagraphic Operations Concepts and Policies	Soummer, R., et al.	2015
The Mid-Infrared Instrument for the James Webb Space Telescope, V: Predicted Performance of the MIRI Coronagraphs	Boccaletti, A., et al.	2015
Simulations of JWST MIRI 4QPM Coronagraphs Operations and Performances	Lajoie, C-P., Soummer, R., Hines, D. & Rieke, G.	2014
Simulations of MIRI Four-Quadrant Phase Mask Coronagraph (III): Target Acquisition and CCC Mechanism Usage	Lajoie, C-P., Hines, D., Soummer, R. & the JWST Coronagraphs Working Group	2014
Simulations of Target Acquisition with MIRI Four-Quadrant Phase Mask Coronagraph (IV): Predicted Performances Based on Slew Accuracy Estimates	Lajoie, C-P., Soummer, R., Hines, D. & the JWST Coronagraphs Working Group	2014

https://jwst.stsci.edu/instrumentation/technical-documents