STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

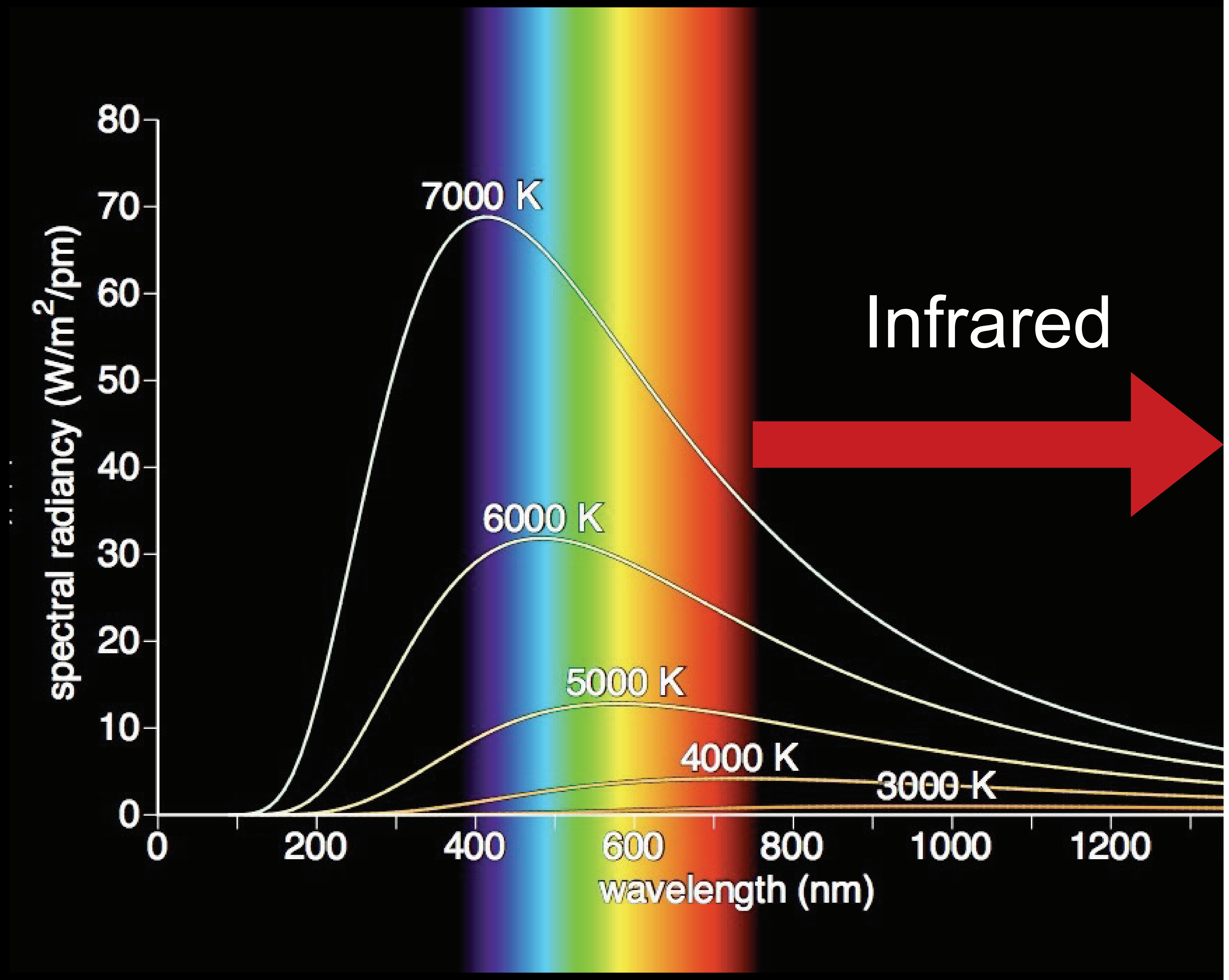
Direct Imaging of Exoplanets *Webb*

Laurent Pueyo

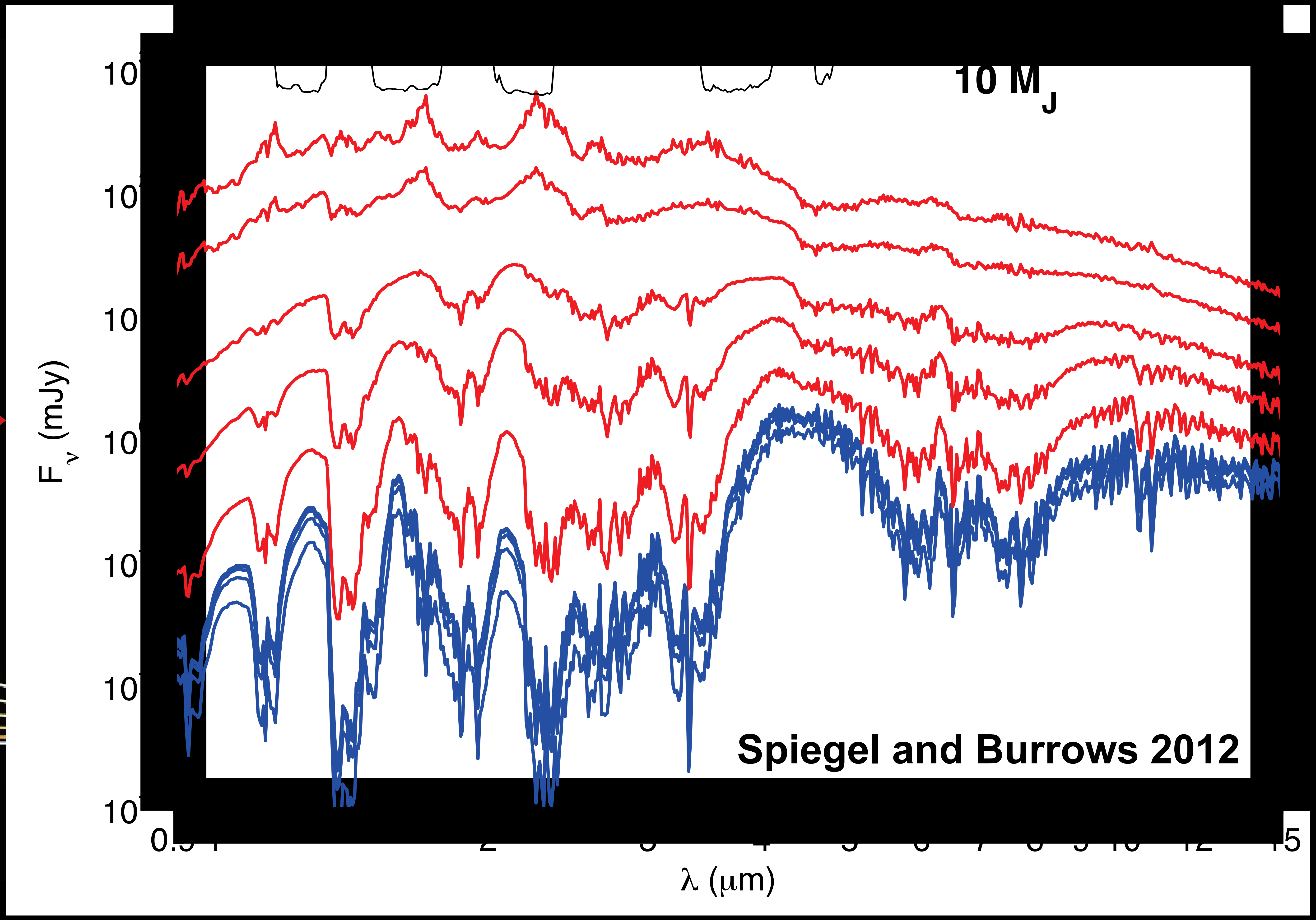
STScI JWST Coronagraphs WG Lead

03/06/2018

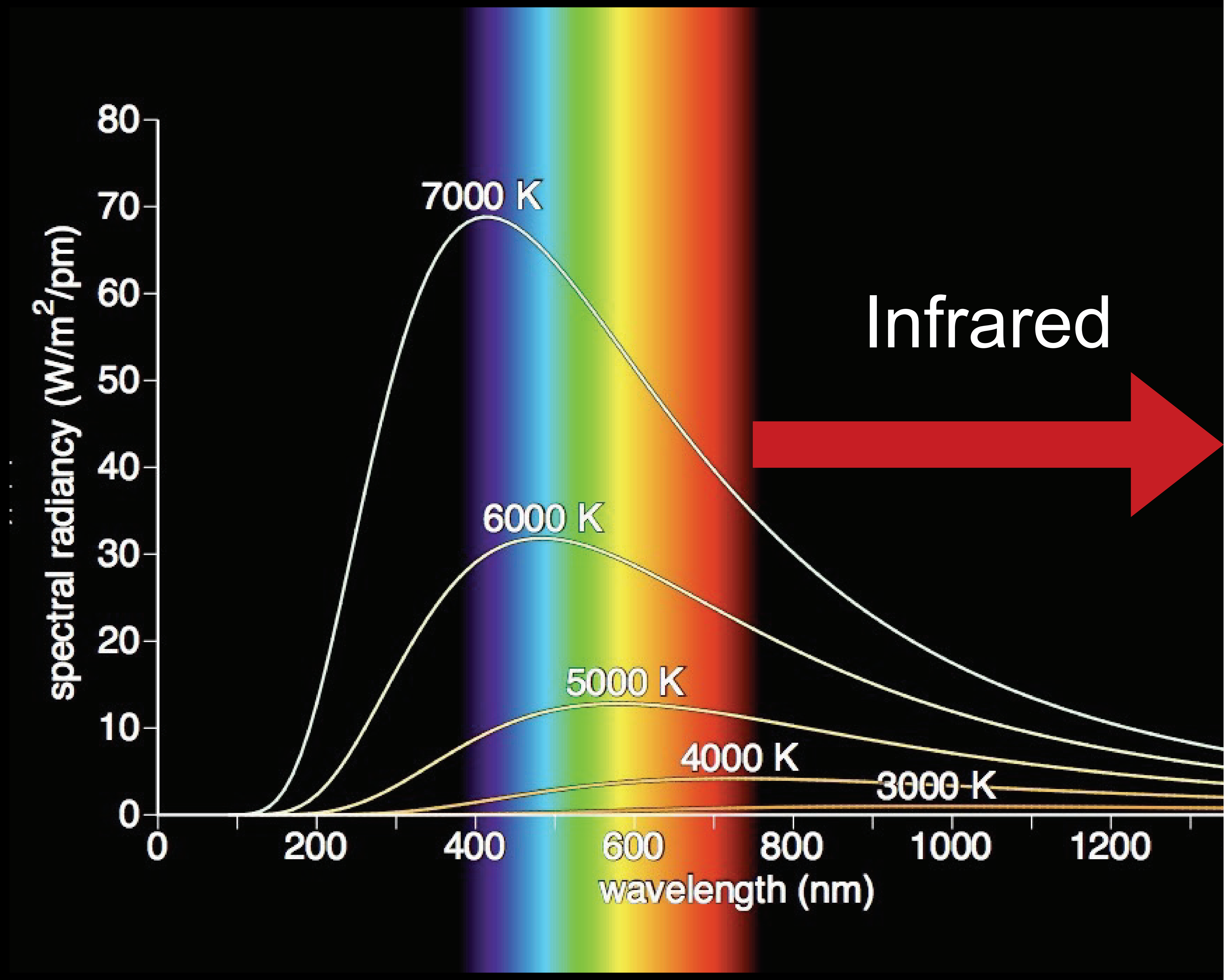
Webb will observe at infrared wavelengths where exoplanets emit most of their light

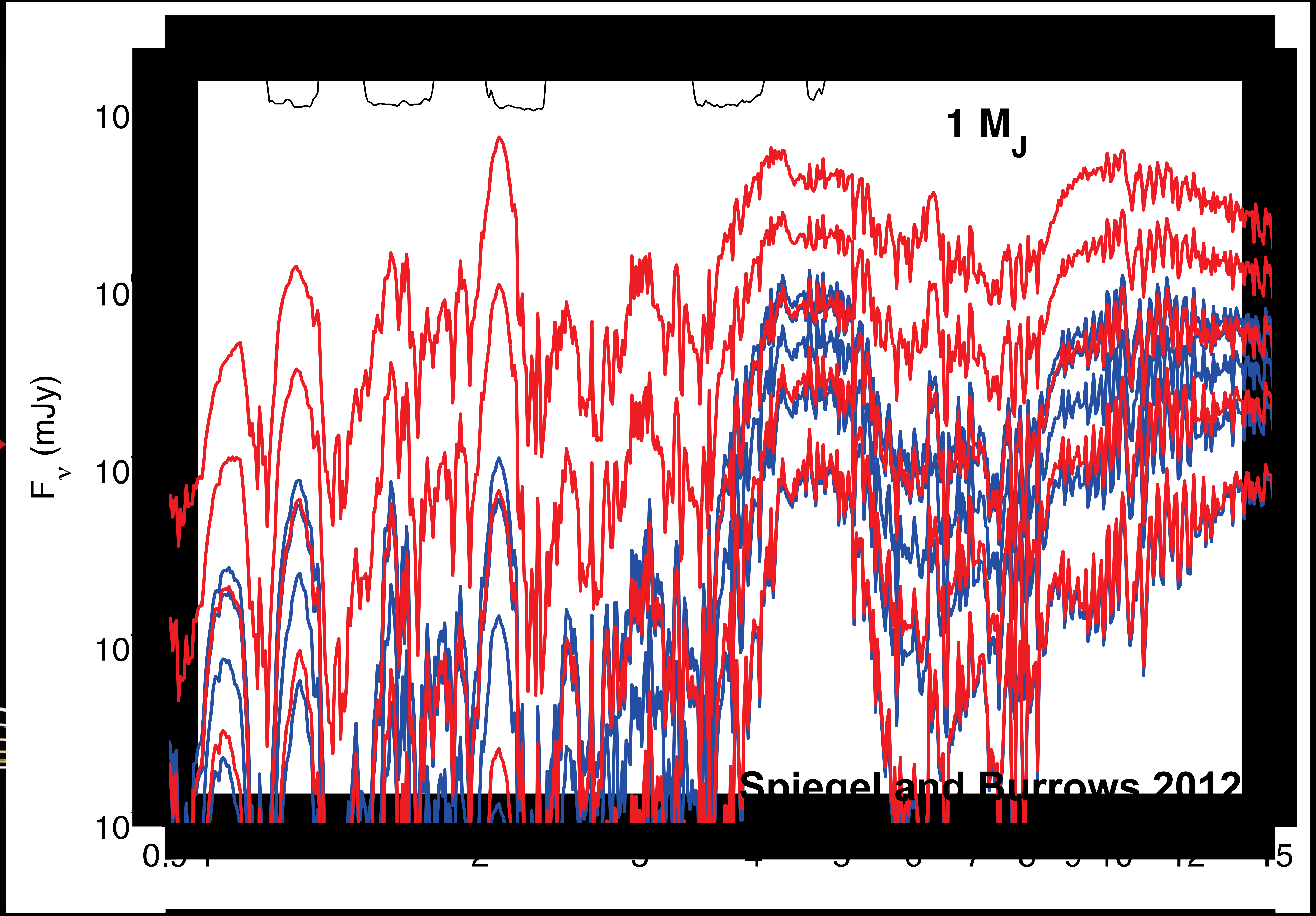


Infrared

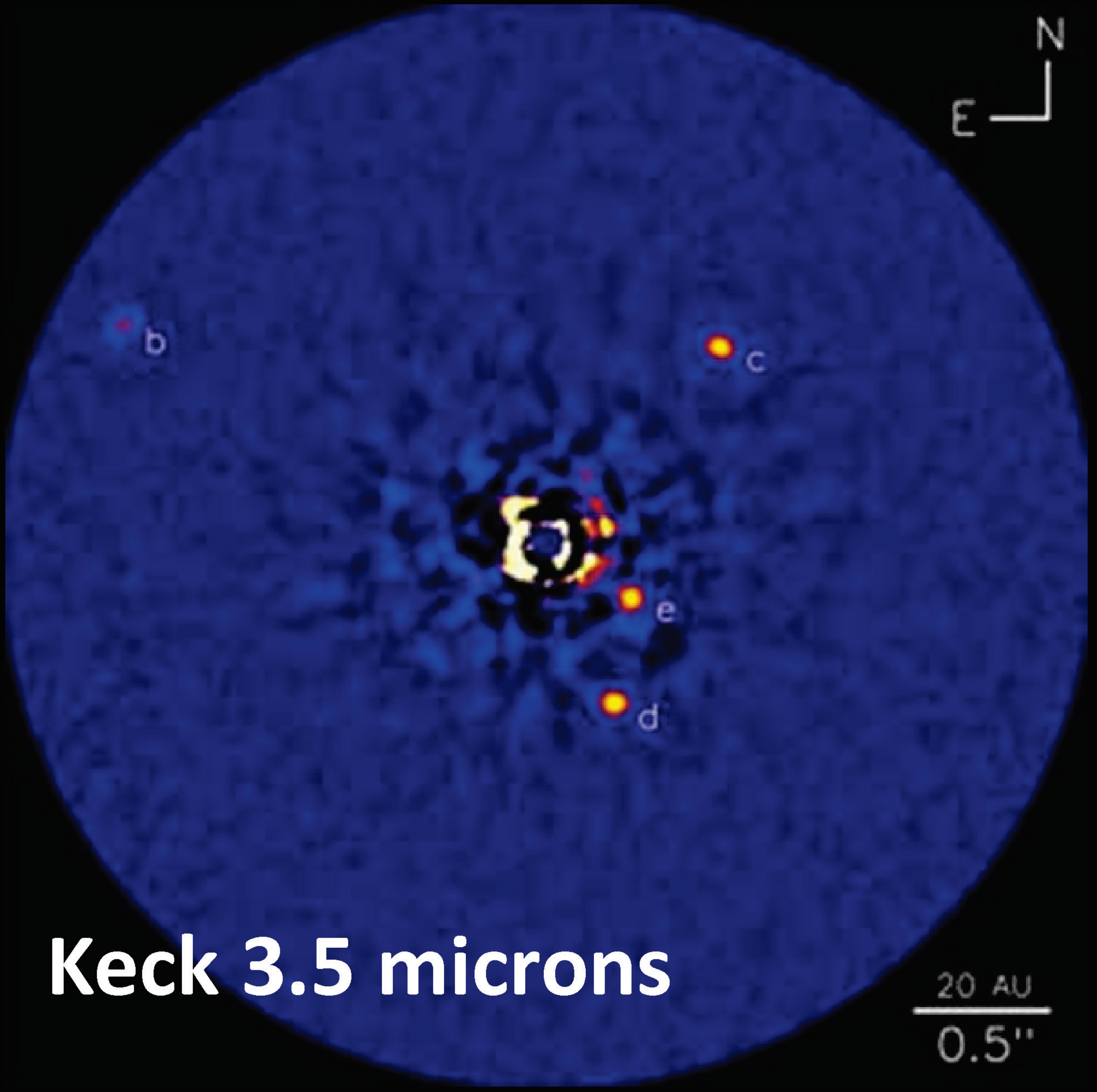


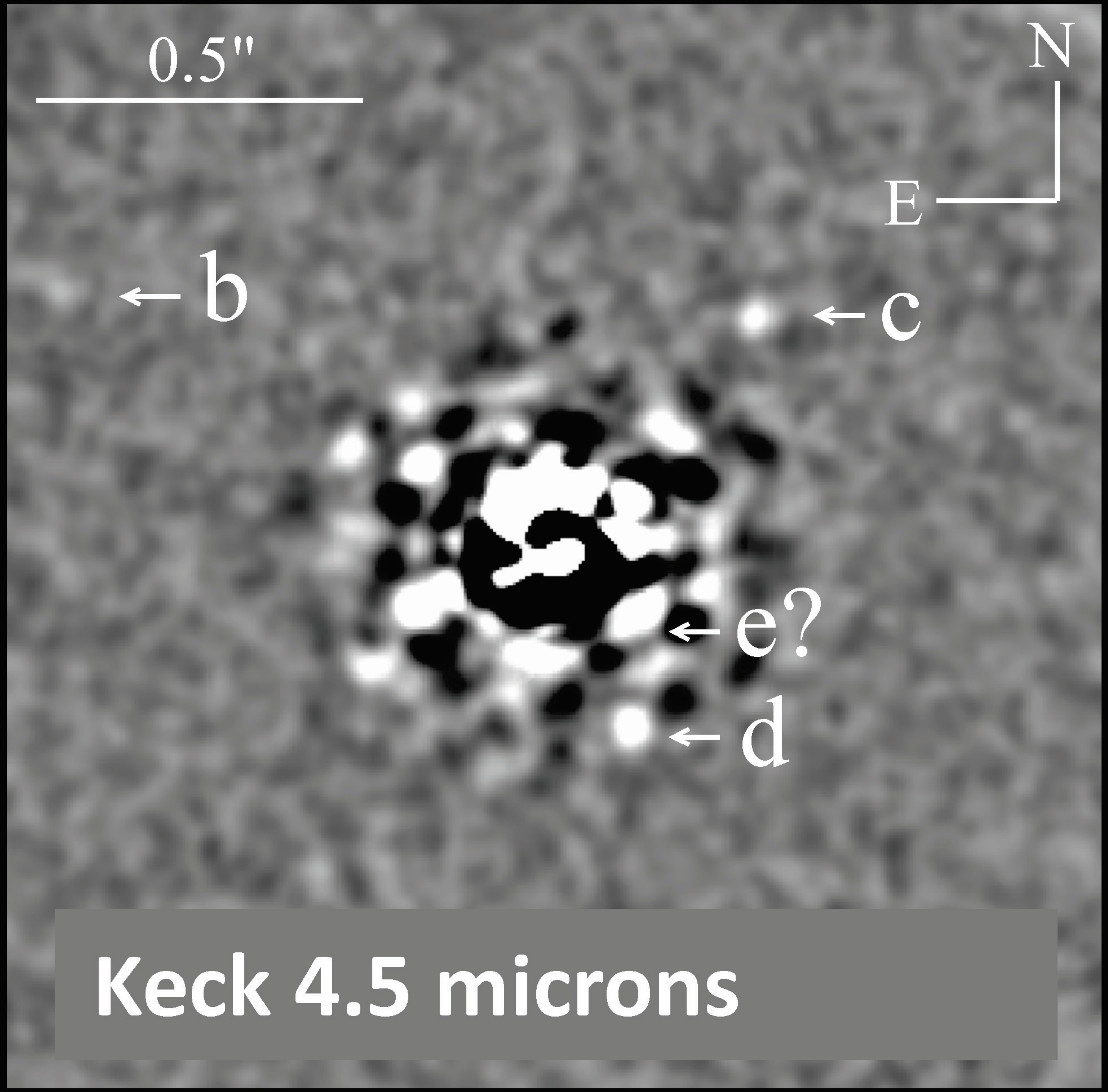
Webb will observe at infrared wavelengths where exoplanets emit most of their light

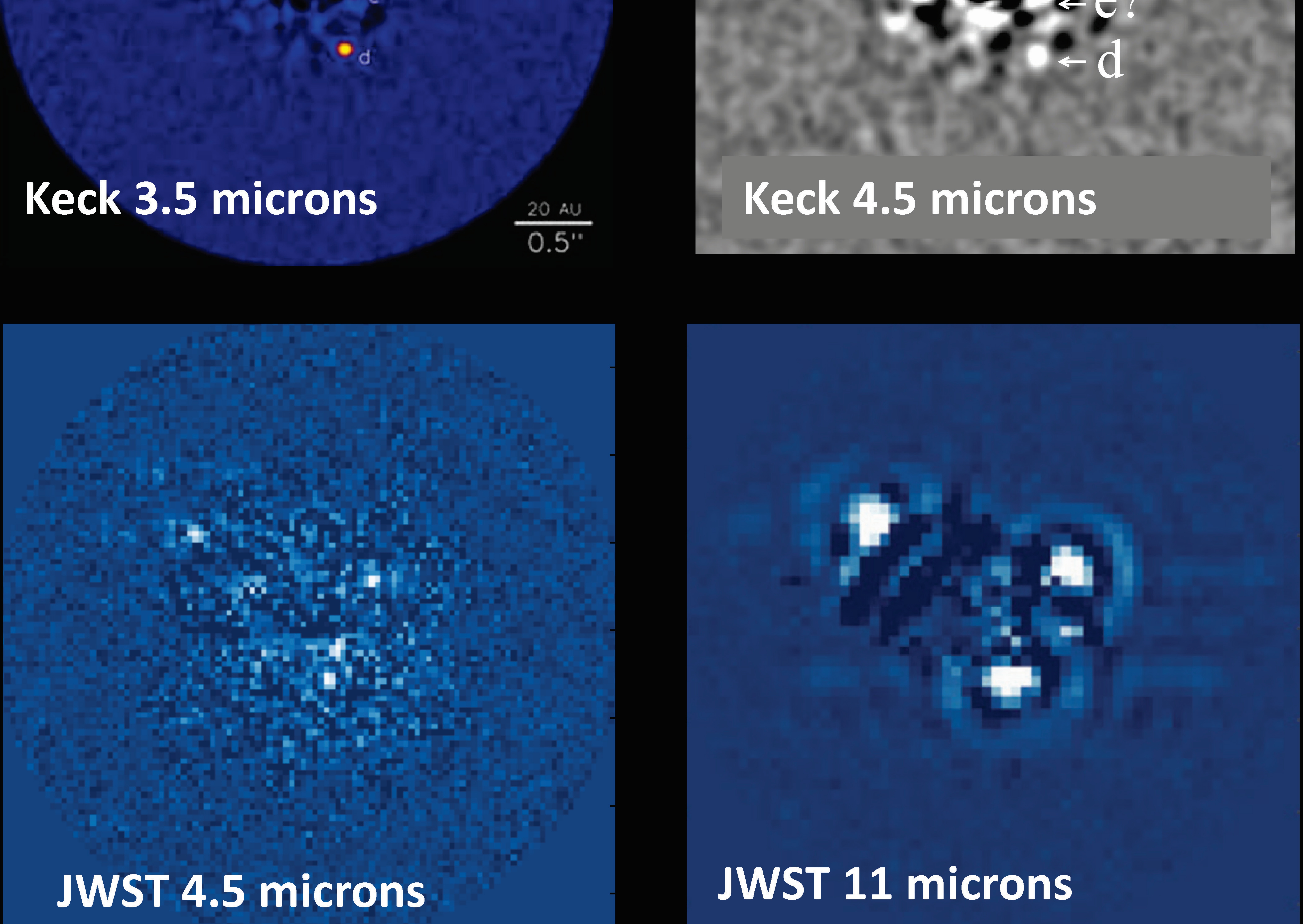




Longer wavelength images of directly imaged exoplanetary systems



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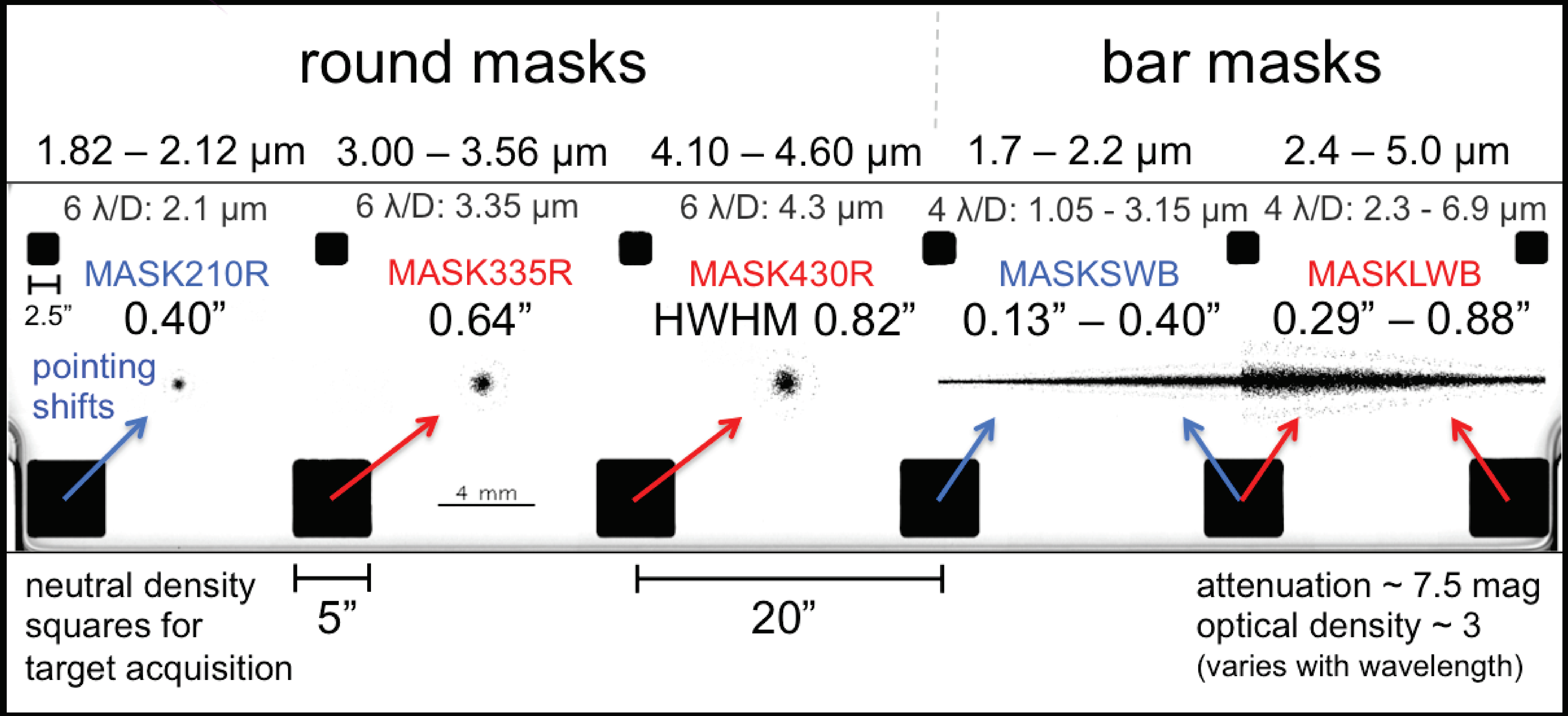
JWST 11 microns

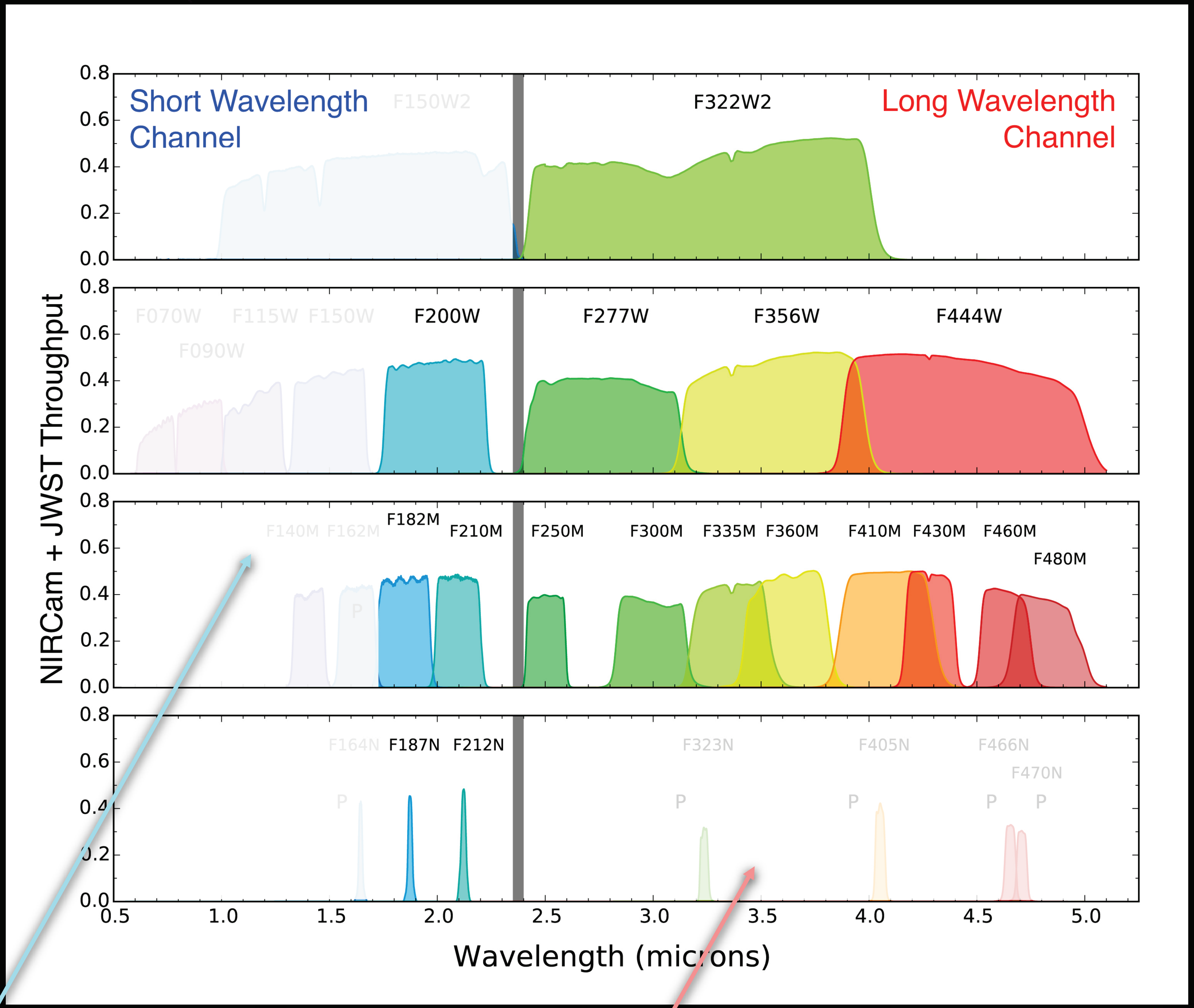
NIRCam Coronagraphs



	Name	Shape	Inner Working Angle	Wavelength Range
SW channel	MASK210R	round	0.40”	1.8 - 2.2 µm
	MASKSWB	bar	0.13 - 0.40”	1.8 - 2.2 µm
LW channel	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 360º 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.

Most NIRCam filters are available for coronagraphy

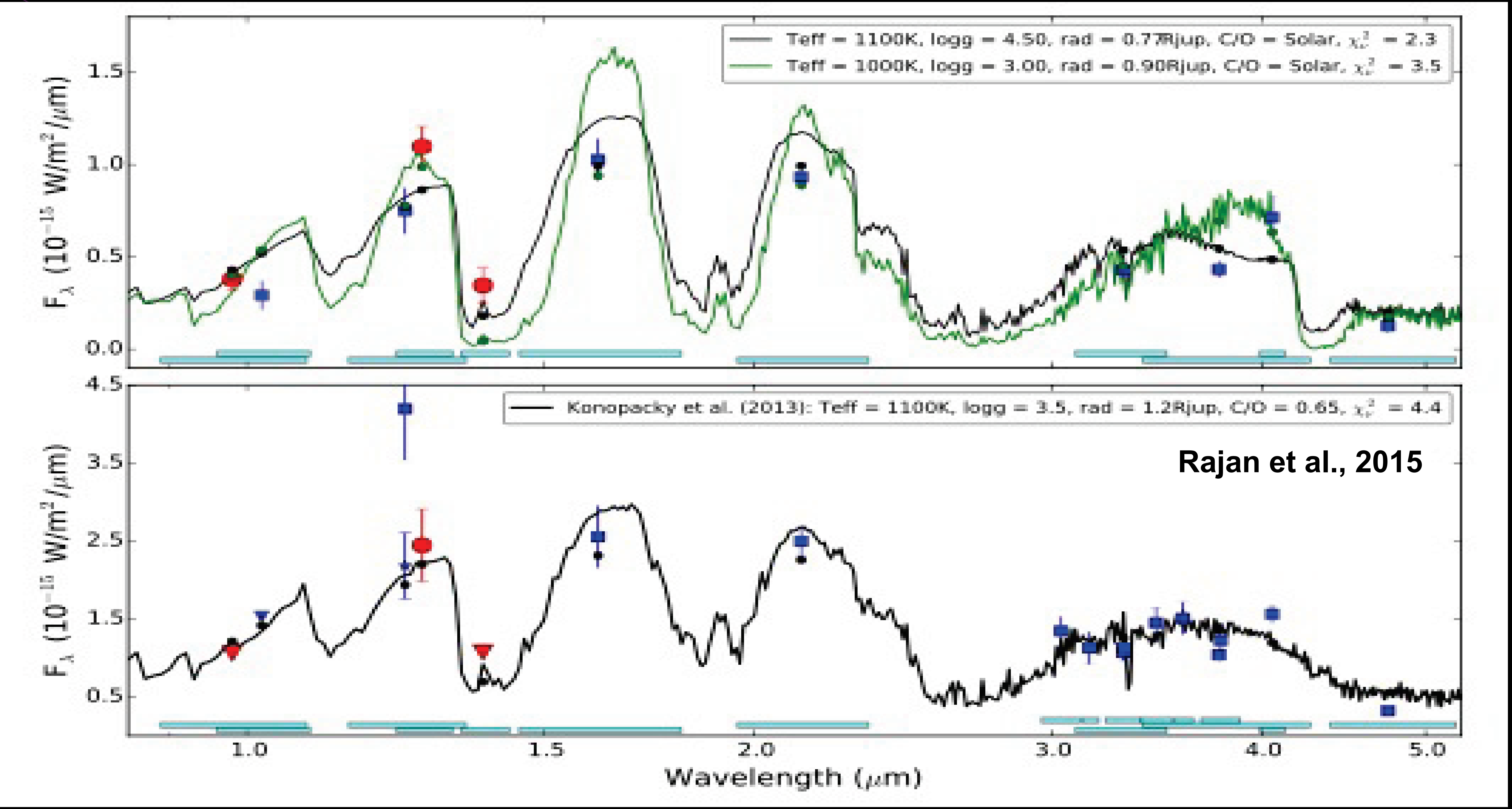


SW filters below 1.8 μm unavailable.
Coronagraph mask anti-reflection coating has low throughput for λ < 1.8 μm

LW narrow band filters unavailable.
These are 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

Webb will characterize giant planets



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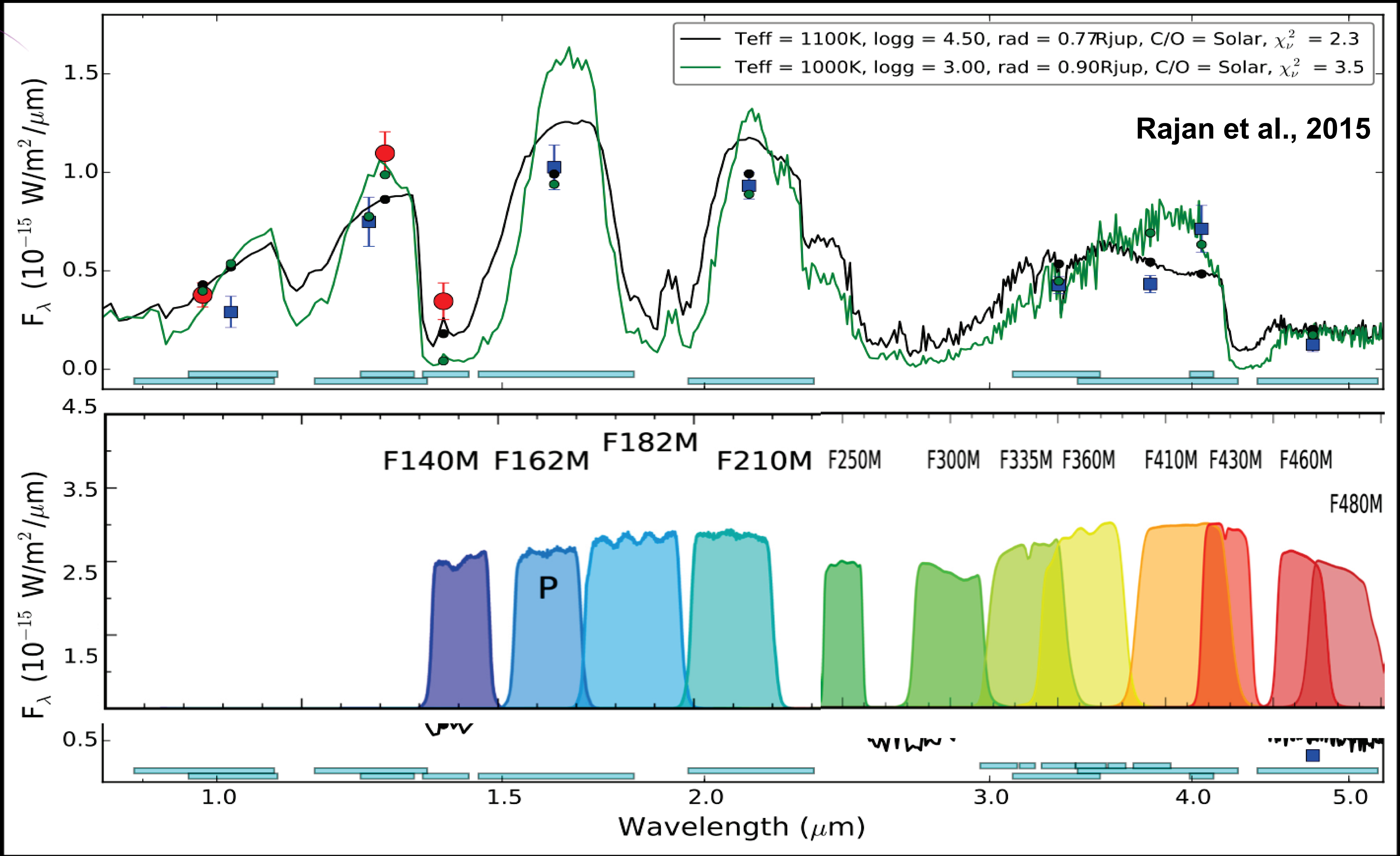
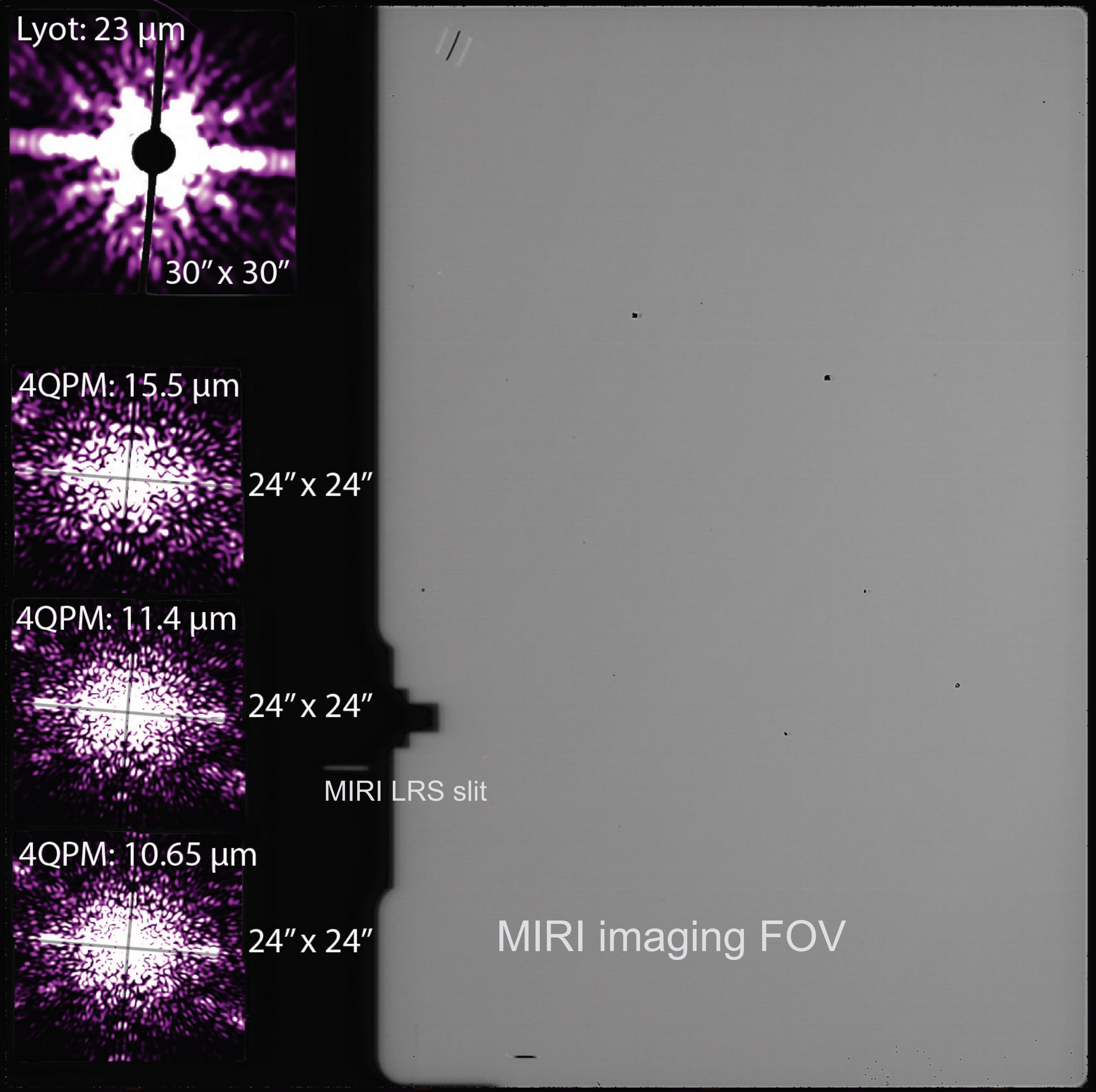


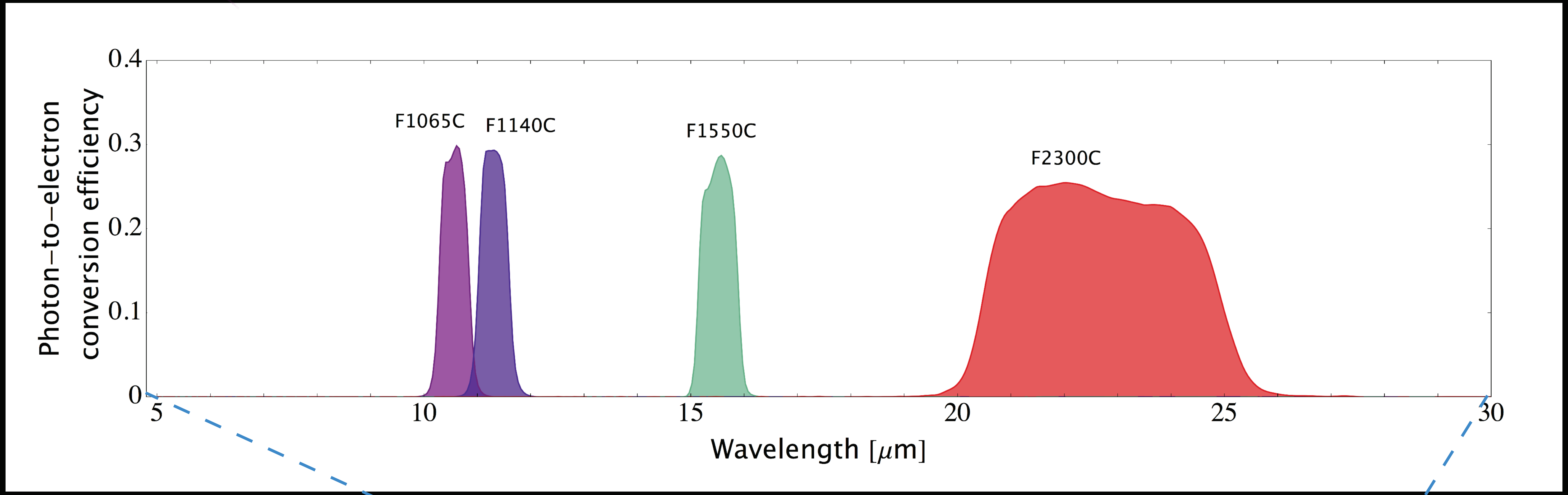
MIRI Coronagraphs



- 3 four-quadrant phase mask coronagraphs, at fixed filters: 10.65, 11.4, 15.5 μm. These provide good contrast down to 1 λ/D, but are relatively narrow band. (R~20)
- One Lyot coronagraph. The occulter is relatively large (optimized for 3 λ/D at 23 μm; r=2.16”) but broader bandwidth (R~5) optimized for sensitivity to disks.
- Coronagraph masks are always in the FOV, along left side of MIRI imager detector.

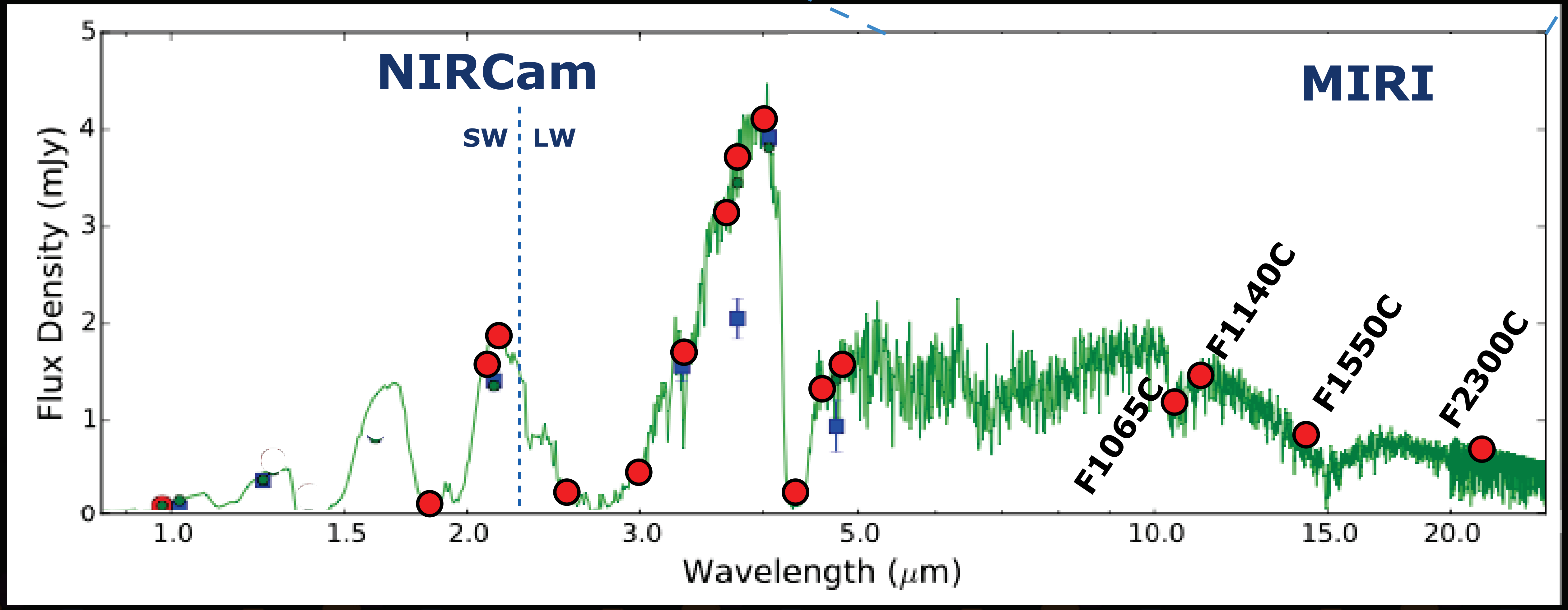
Name	Type	Inner Working Angle	Bandwidth
F1065C	FQPM	0.33”	0.75 μm
F1140C	FQPM	0.36”	0.8 μm
F1550C	FQPM	0.49”	0.9 μm
F2300C	Lyot	2.16”	5.5 μm

MIRI Filters for Coronagraphy



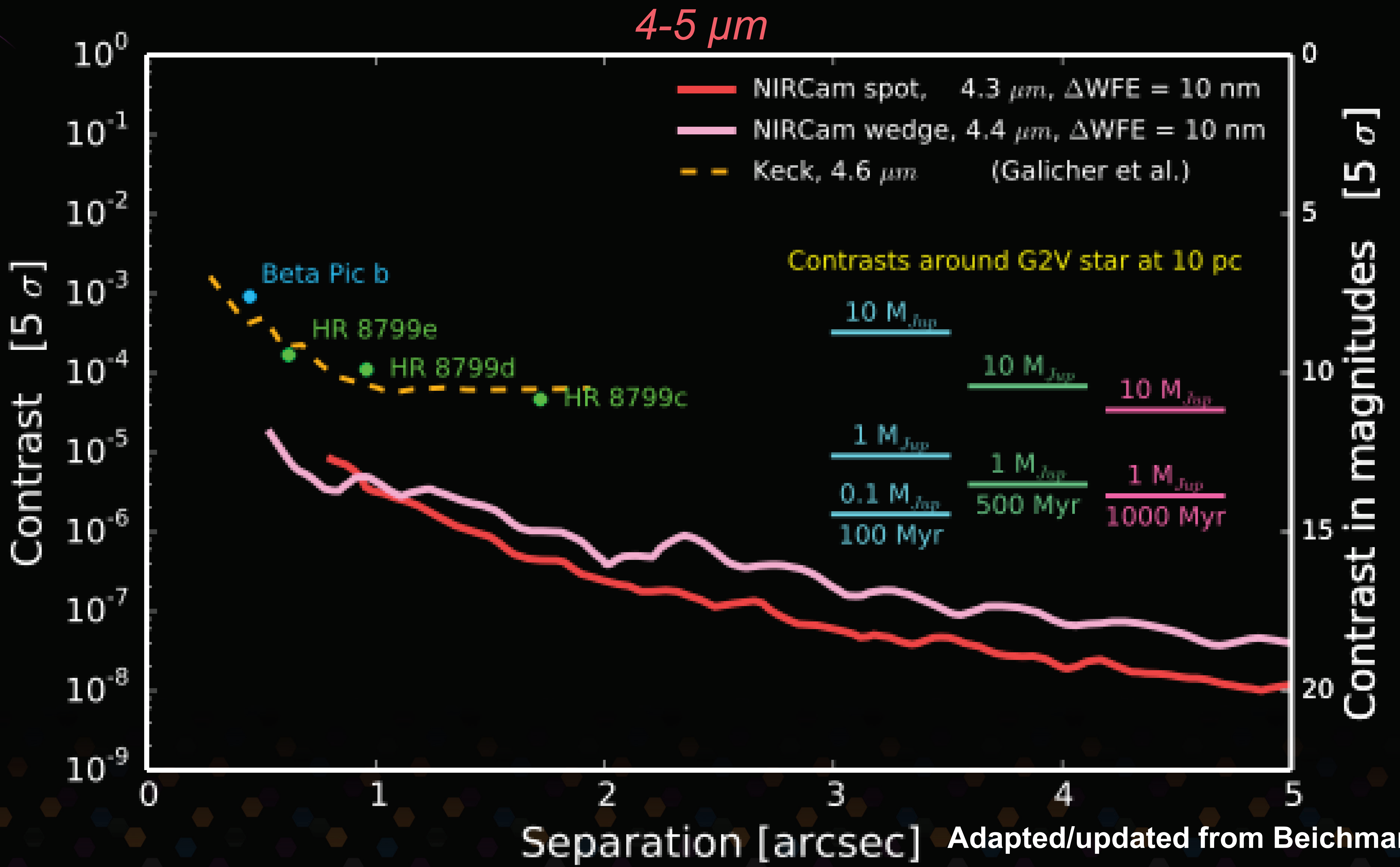
Filter	
F1065C	Ammonia
F1140C	Continuum (planets); Si, PAHs (disks)
F1550C	Continuum
C2300C	Continuum, especially for disks

- 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.



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

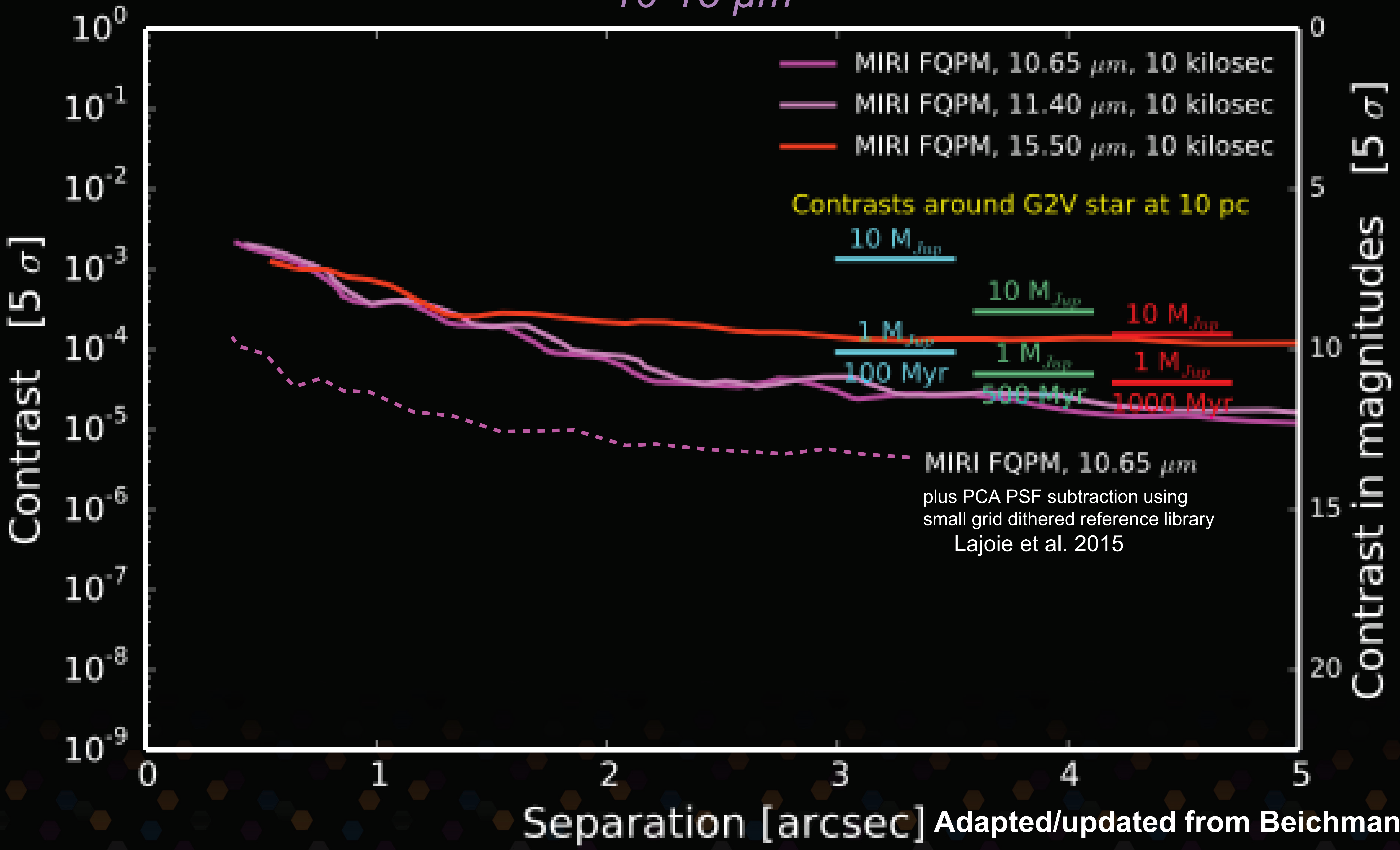
NIRCam contrasts: below 10^{-5} at 1”, 10^{-7} at 4”



Adapted/updated from Beichman et al. 2010

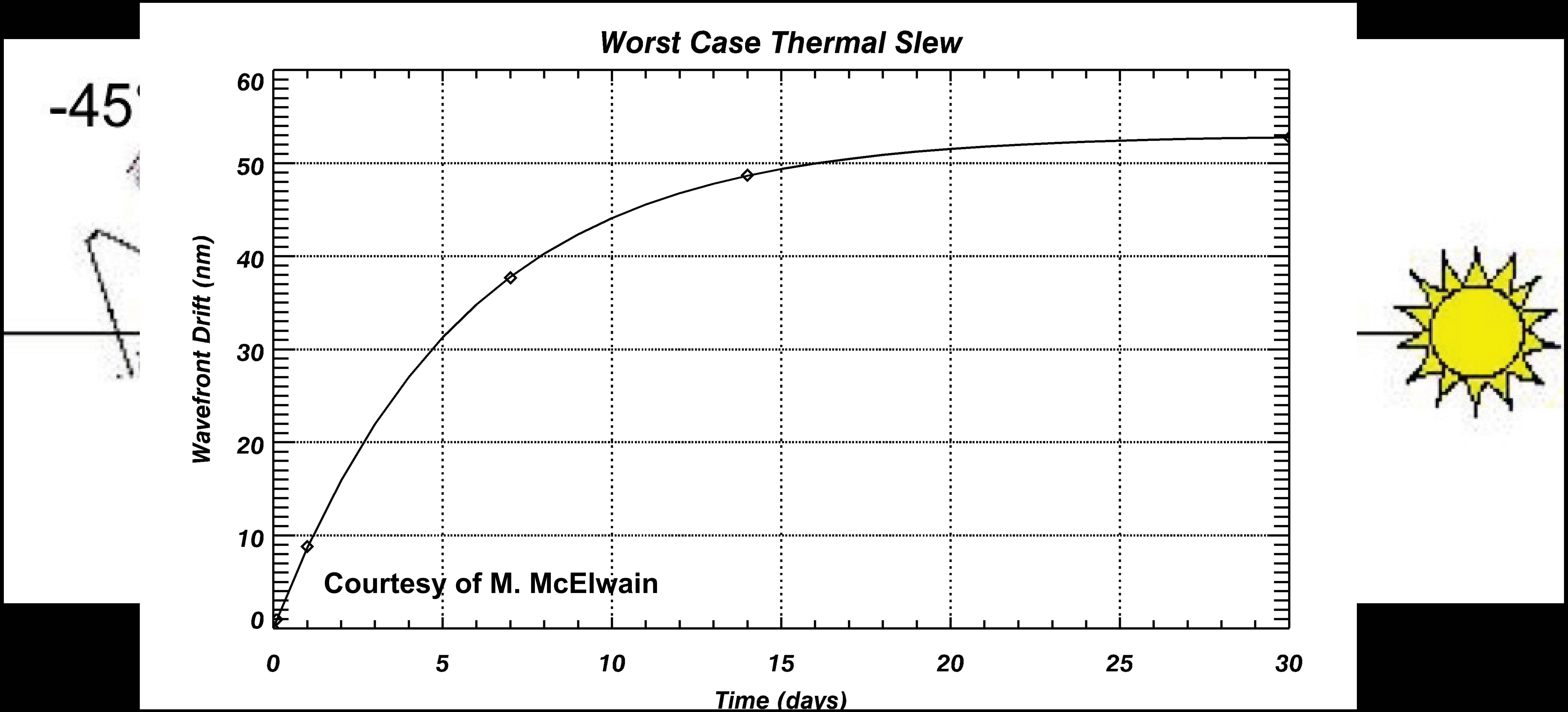
MIRI contrasts: 10^{-4} to 10^{-5} for r > 1”

10-15 μm

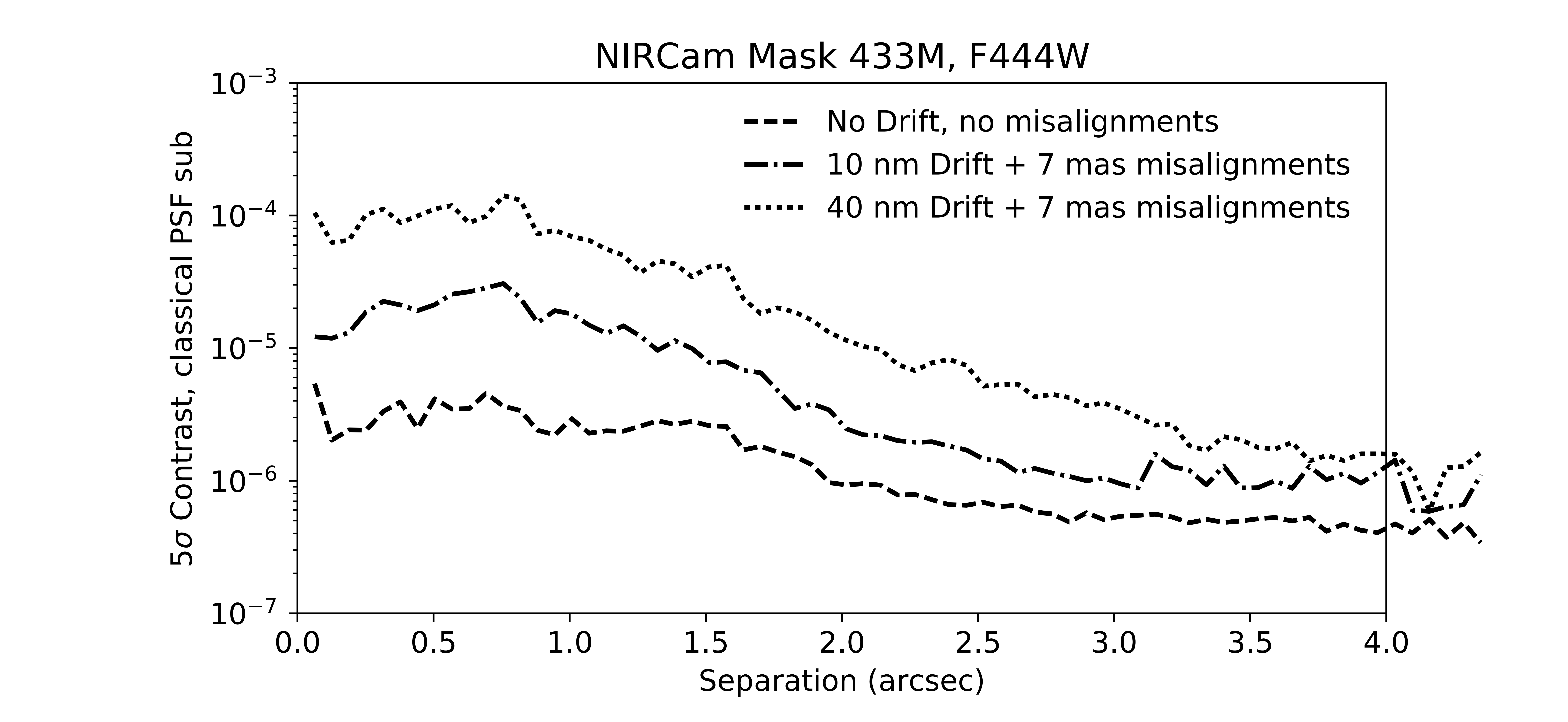


Adapted/updated from Beichman et al. 2010

Webb predicted wavefront stability



Webb predicted wavefront stability



Webb Pipeline & Data Products

Written in python, based on astropy

Users can replace specific modules

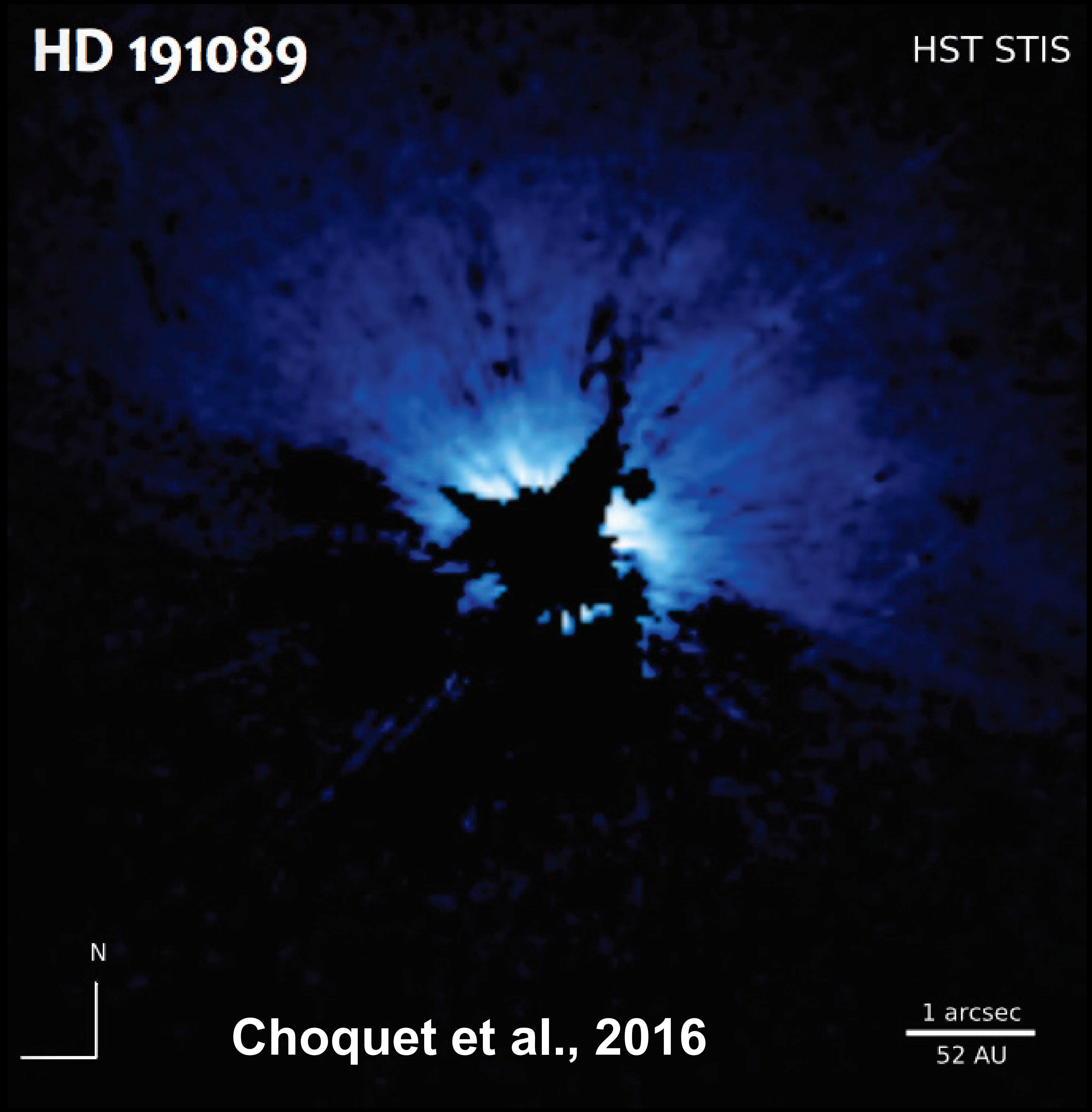
Will be freely available (github)

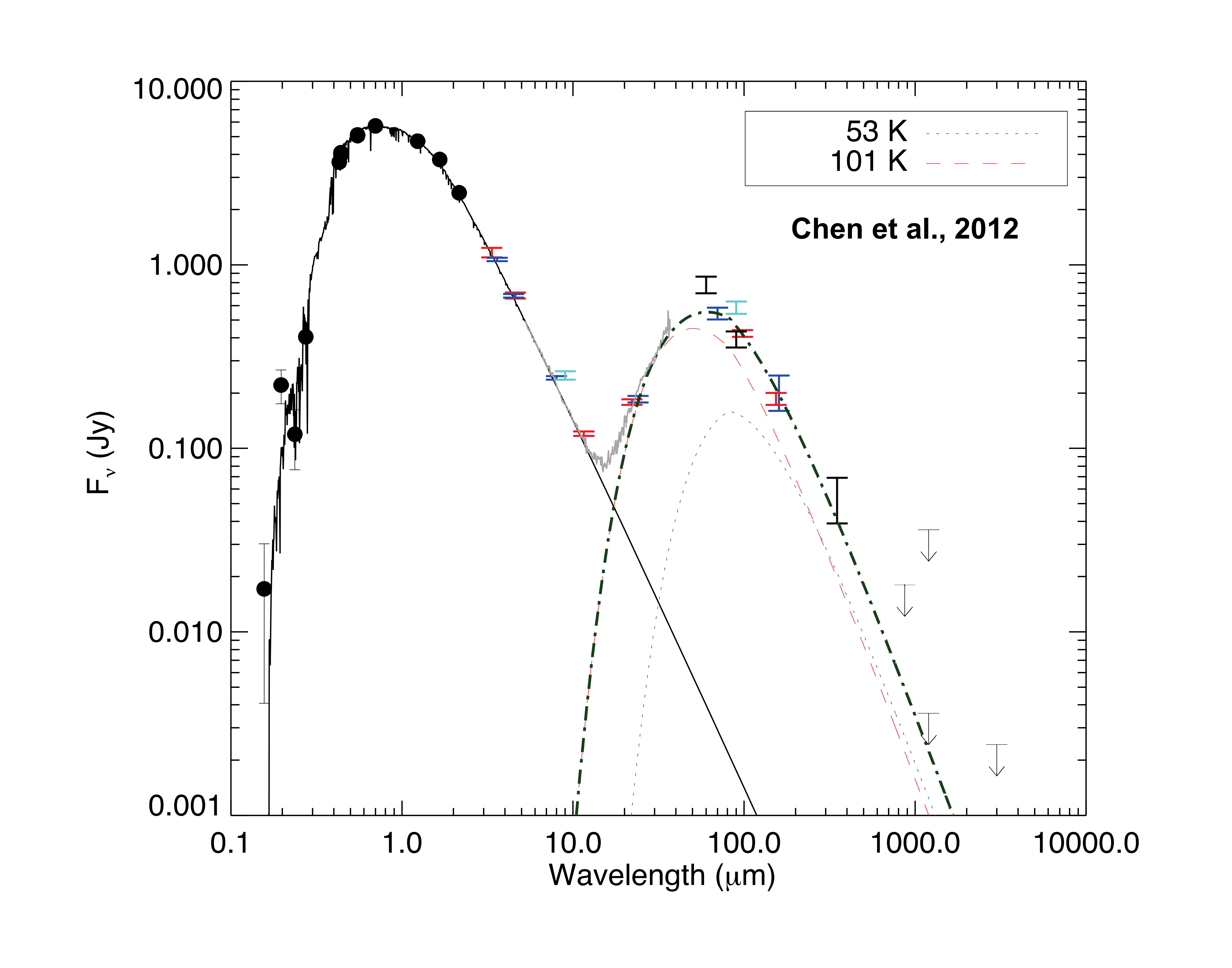
Users can rerun all or part of pipeline

Now that you've met JWST's direct imaging modes…

Let's talk science!!!!

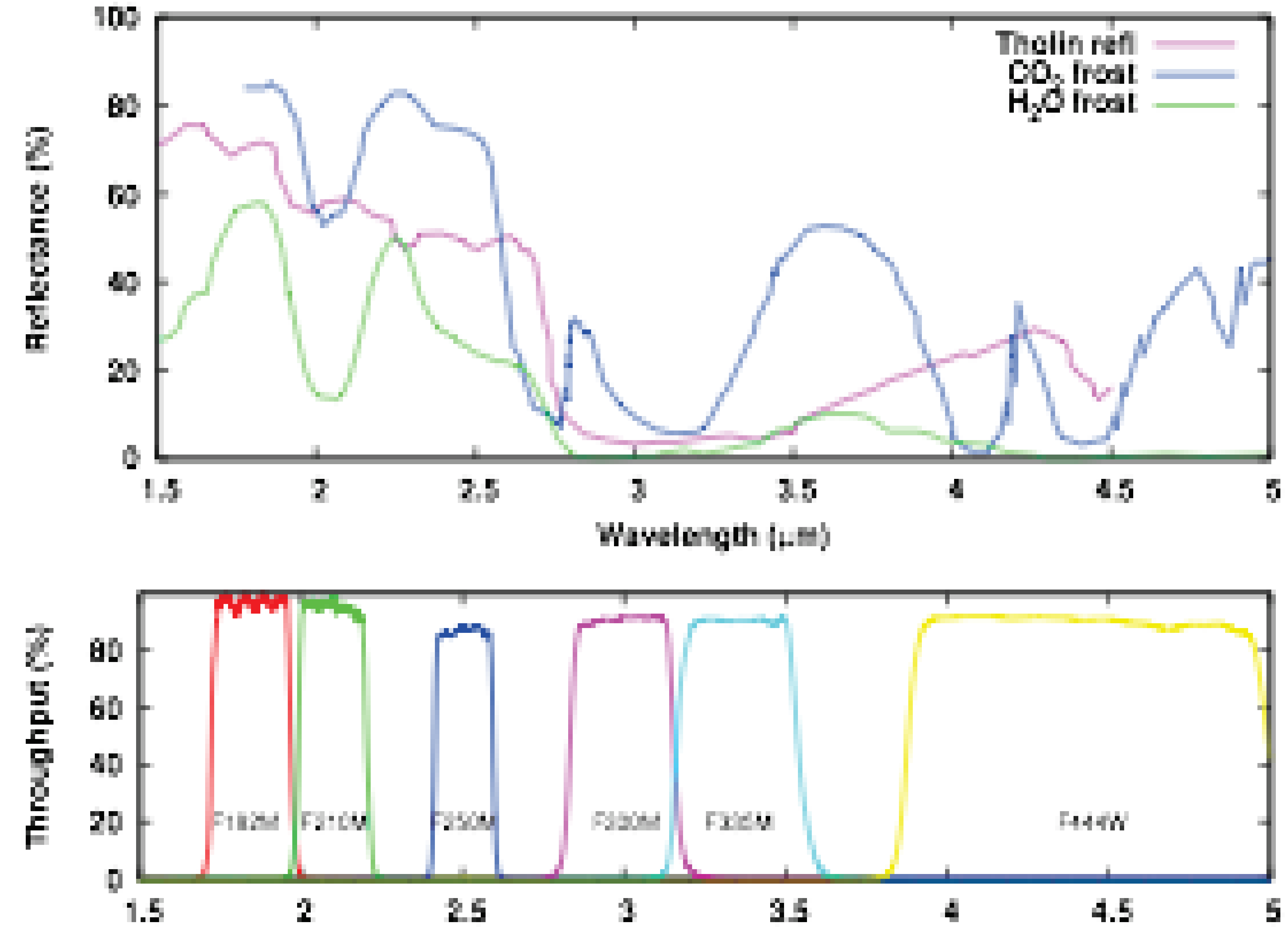
Webb will yield key insights regarding the nature of dust in debris disks





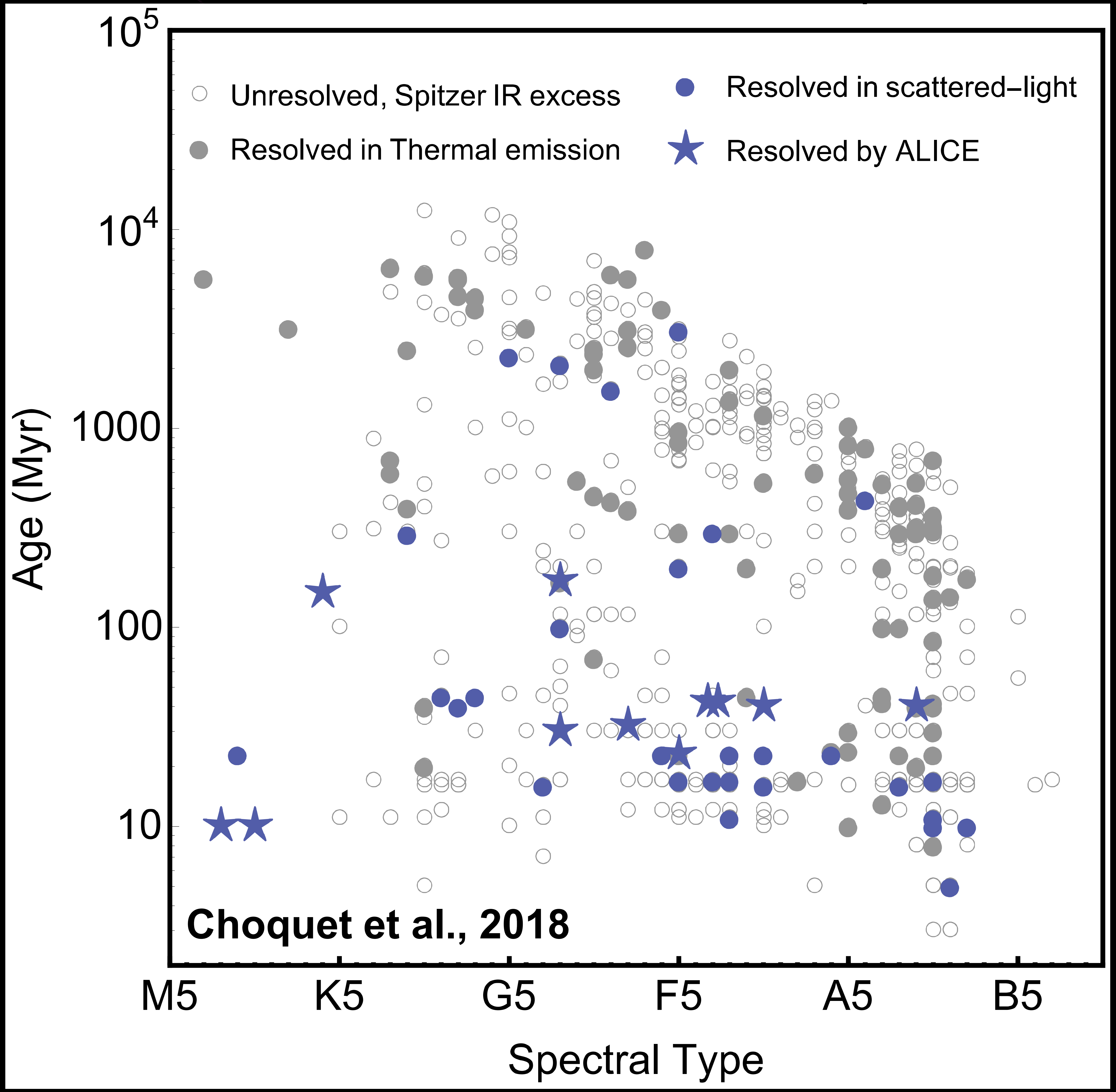
Webb will yield key insights regarding the nature of dust in debris disks

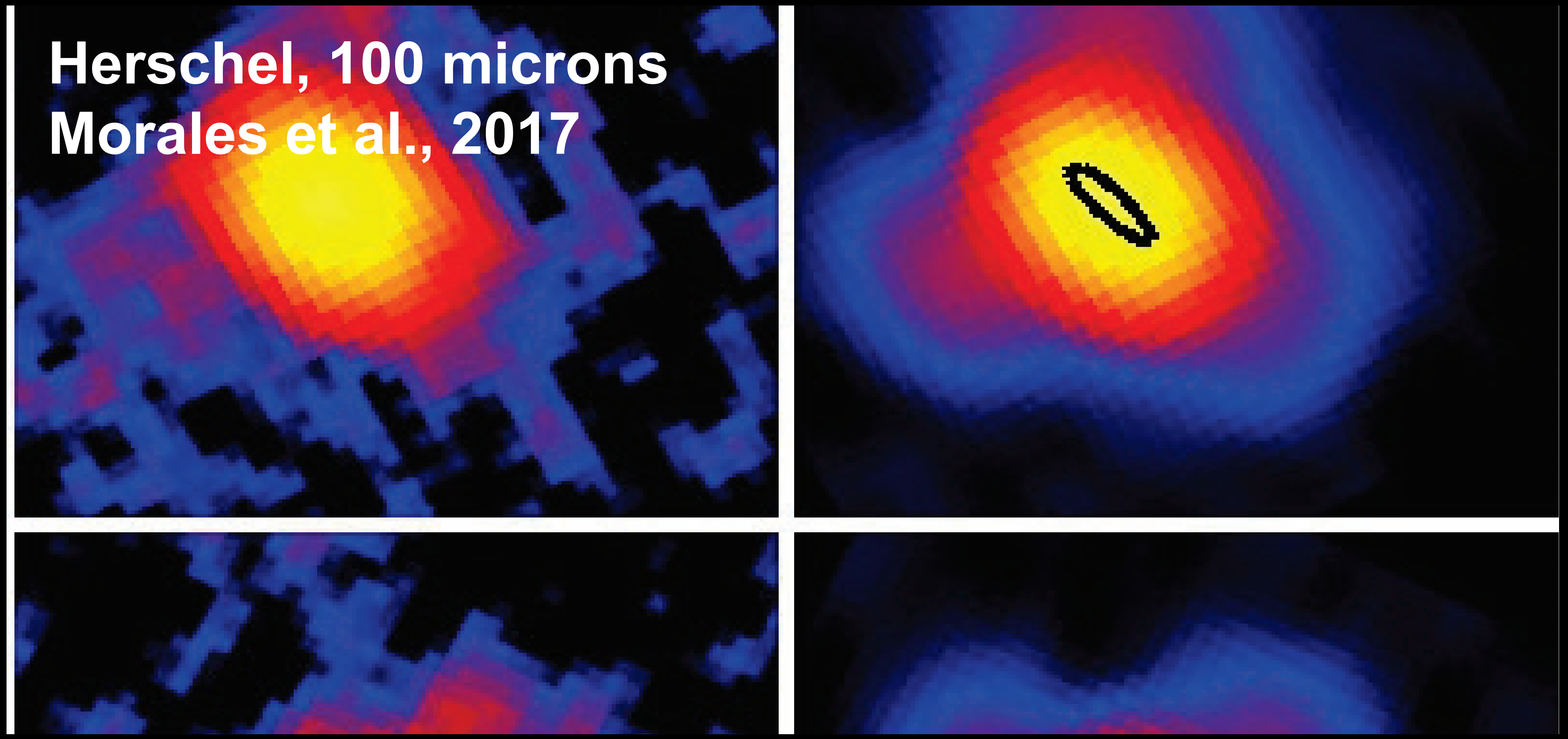
Choquet et al., 2016

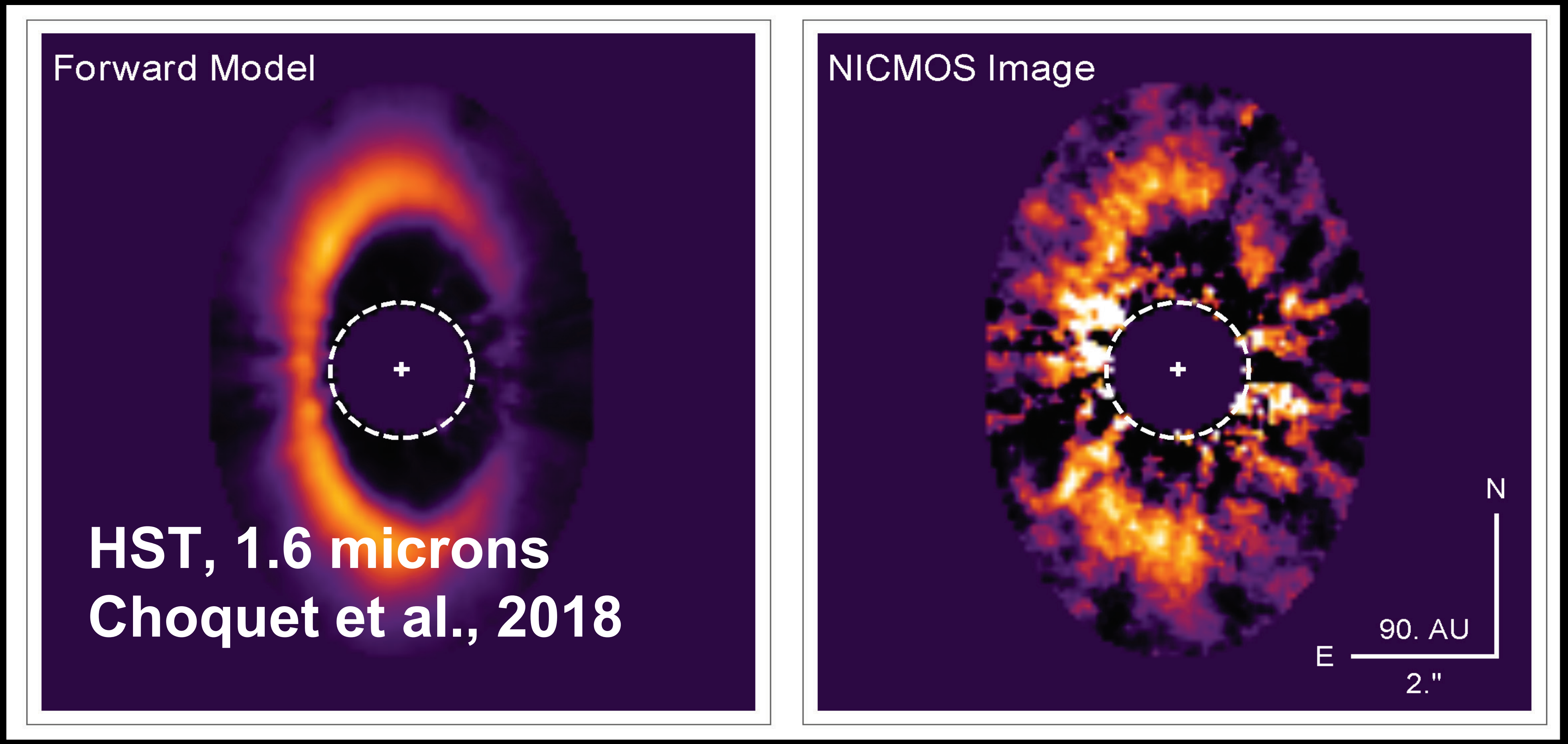


Courtesy Andras Gaspar et al. (NIRCam GTO)

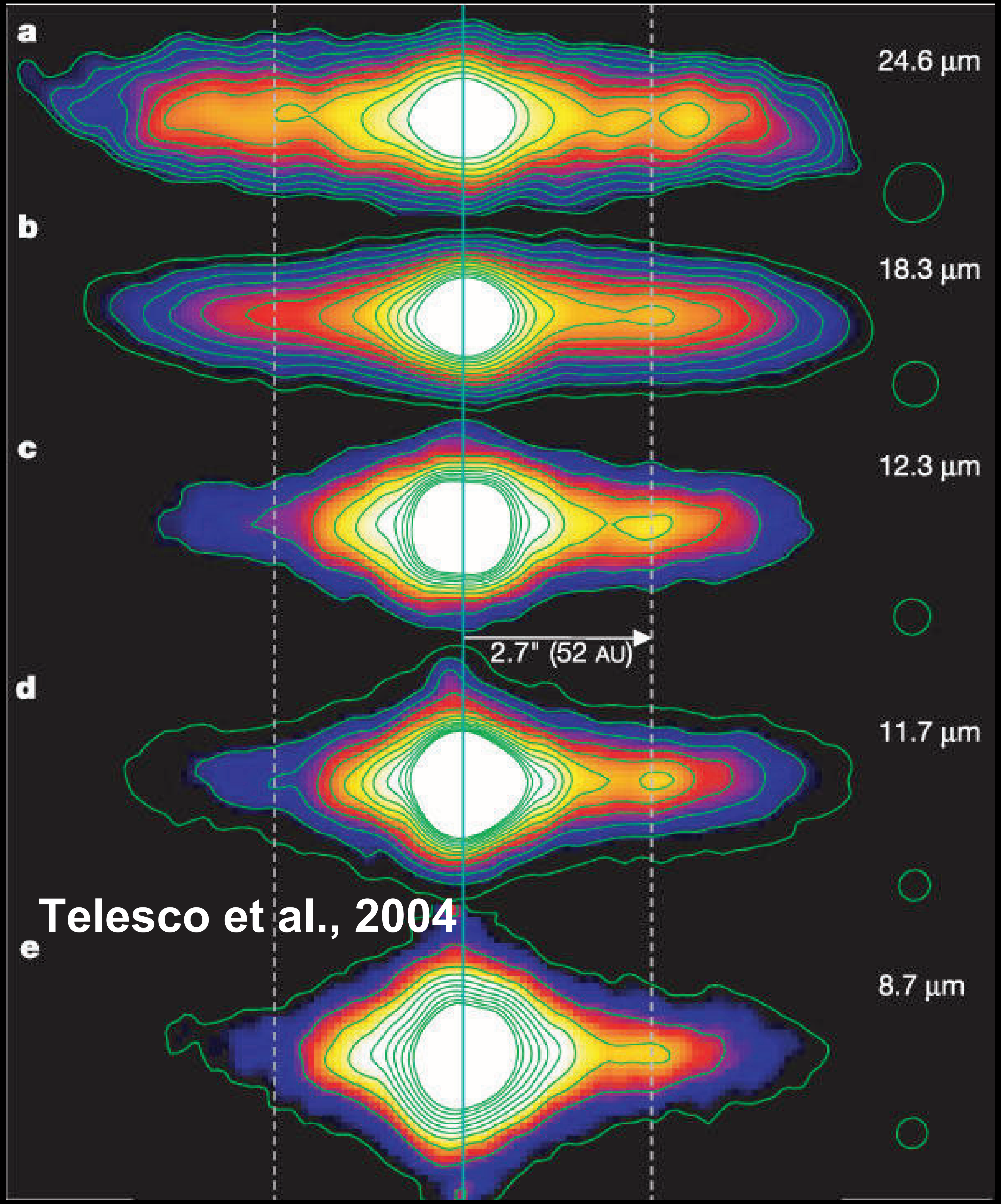
Webb will yield key insights on the dust location in debris disks.



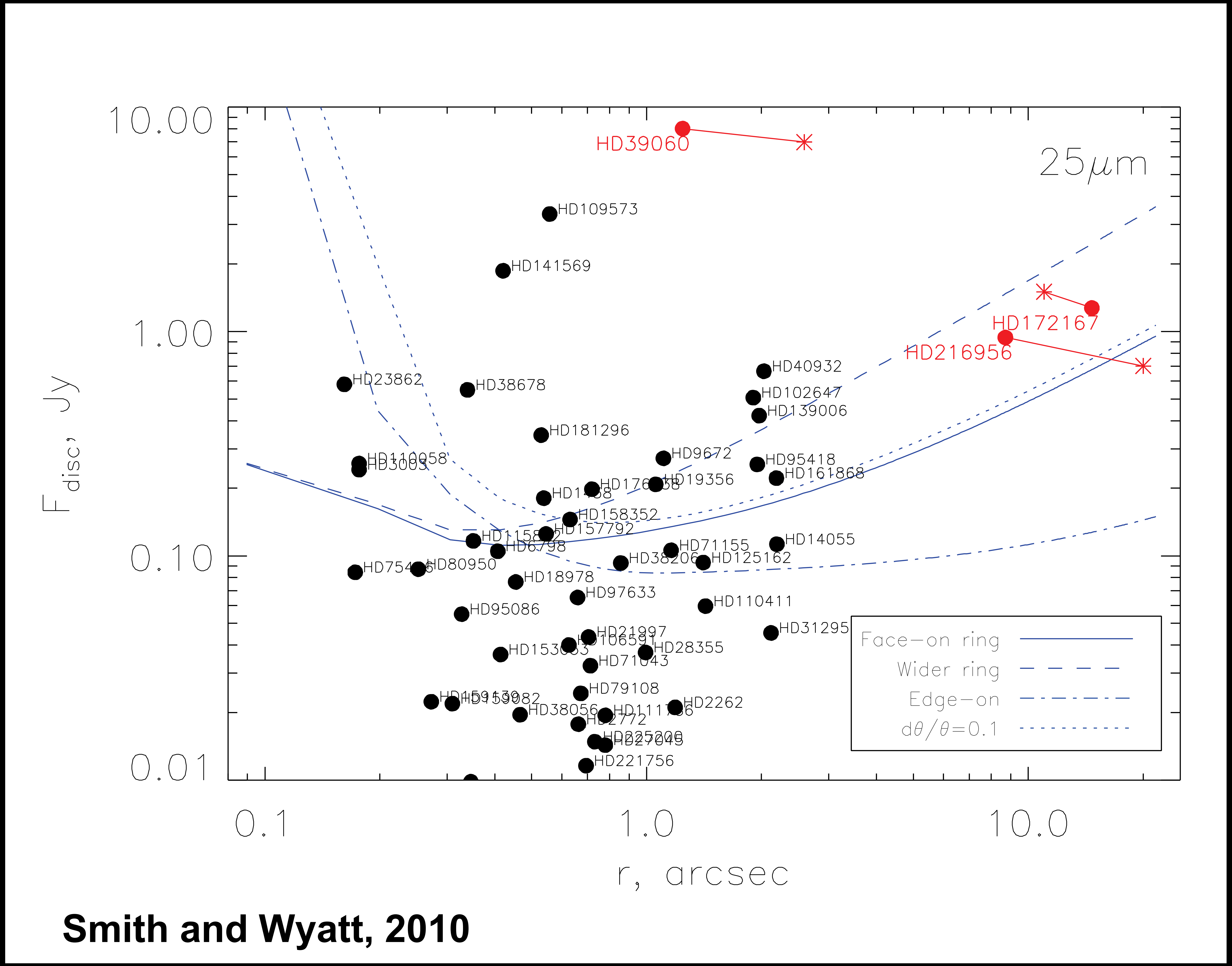




Webb will yield key insights on the morpholgy of debris disks.

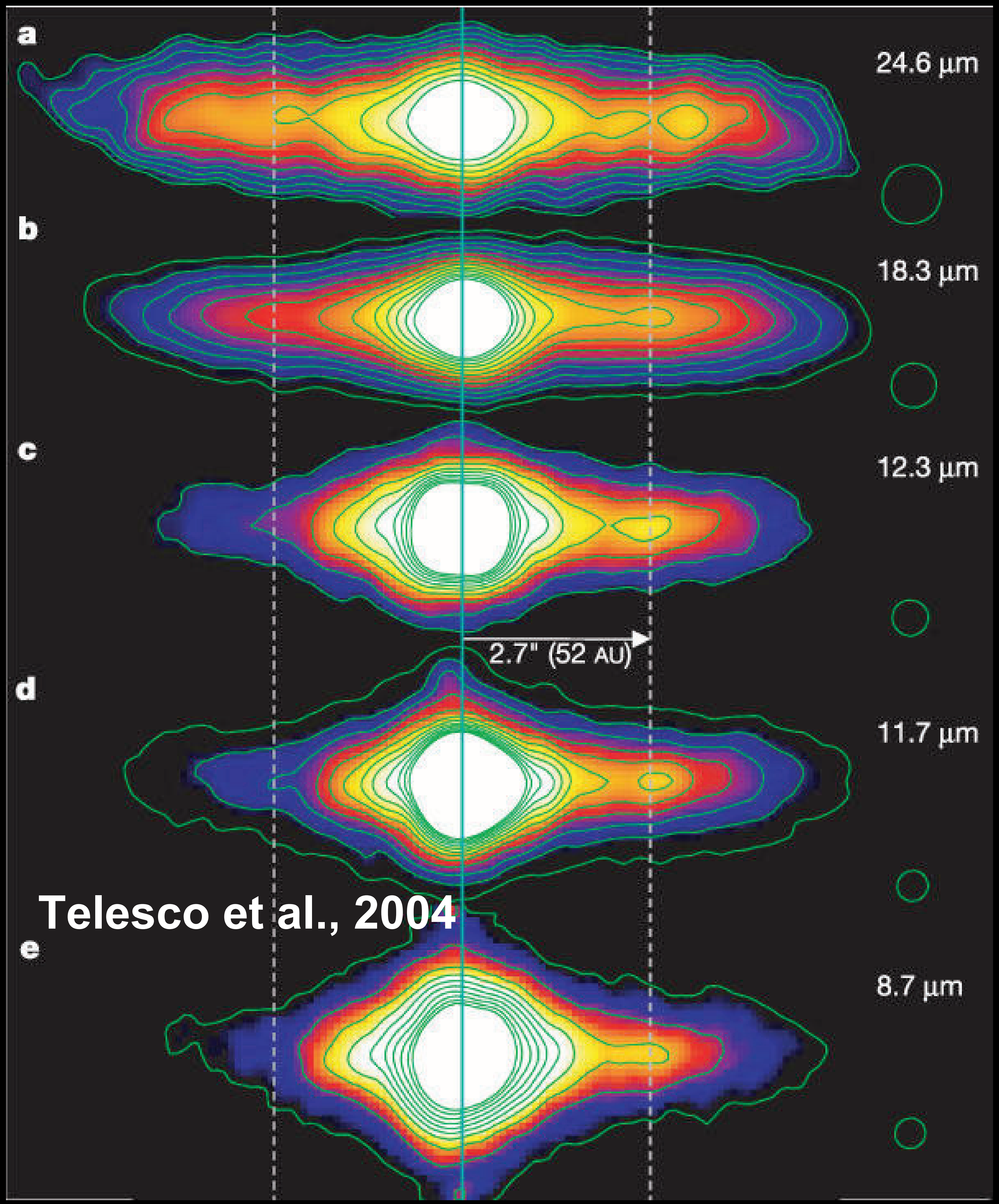


Telesco et al., 2004

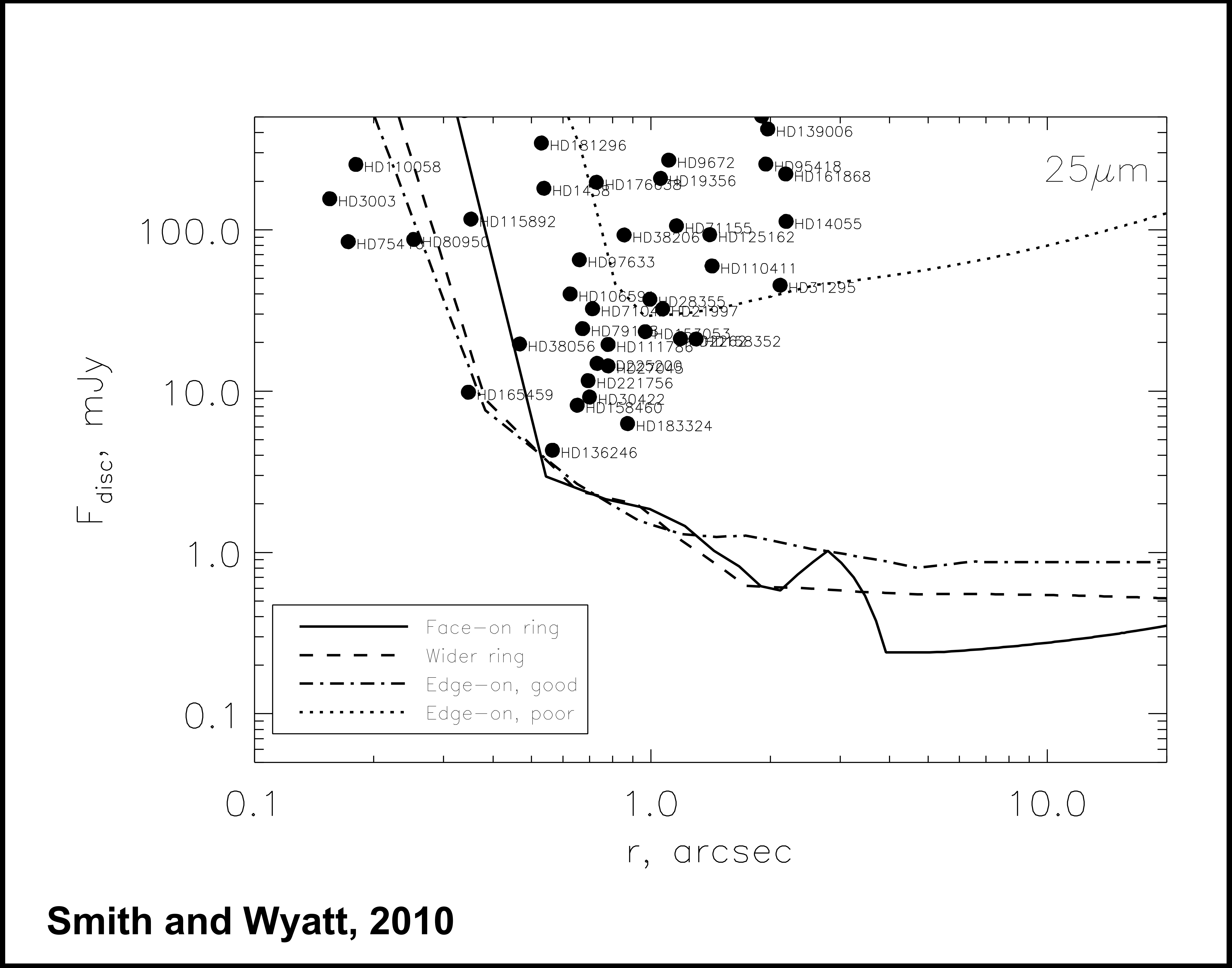


Smith and Wyatt, 2010

Webb will yield key insights on the morpholgy of debris disks.

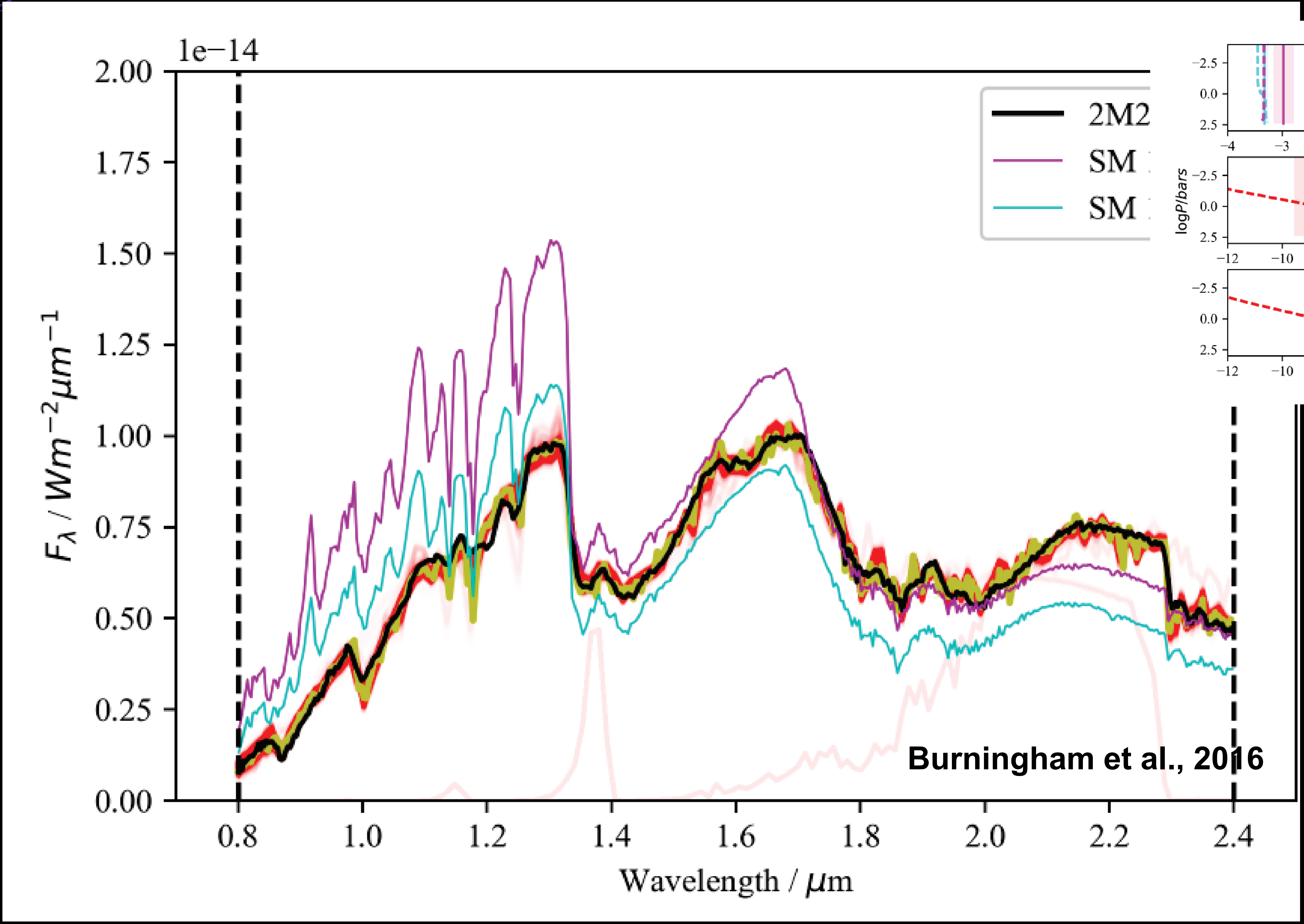


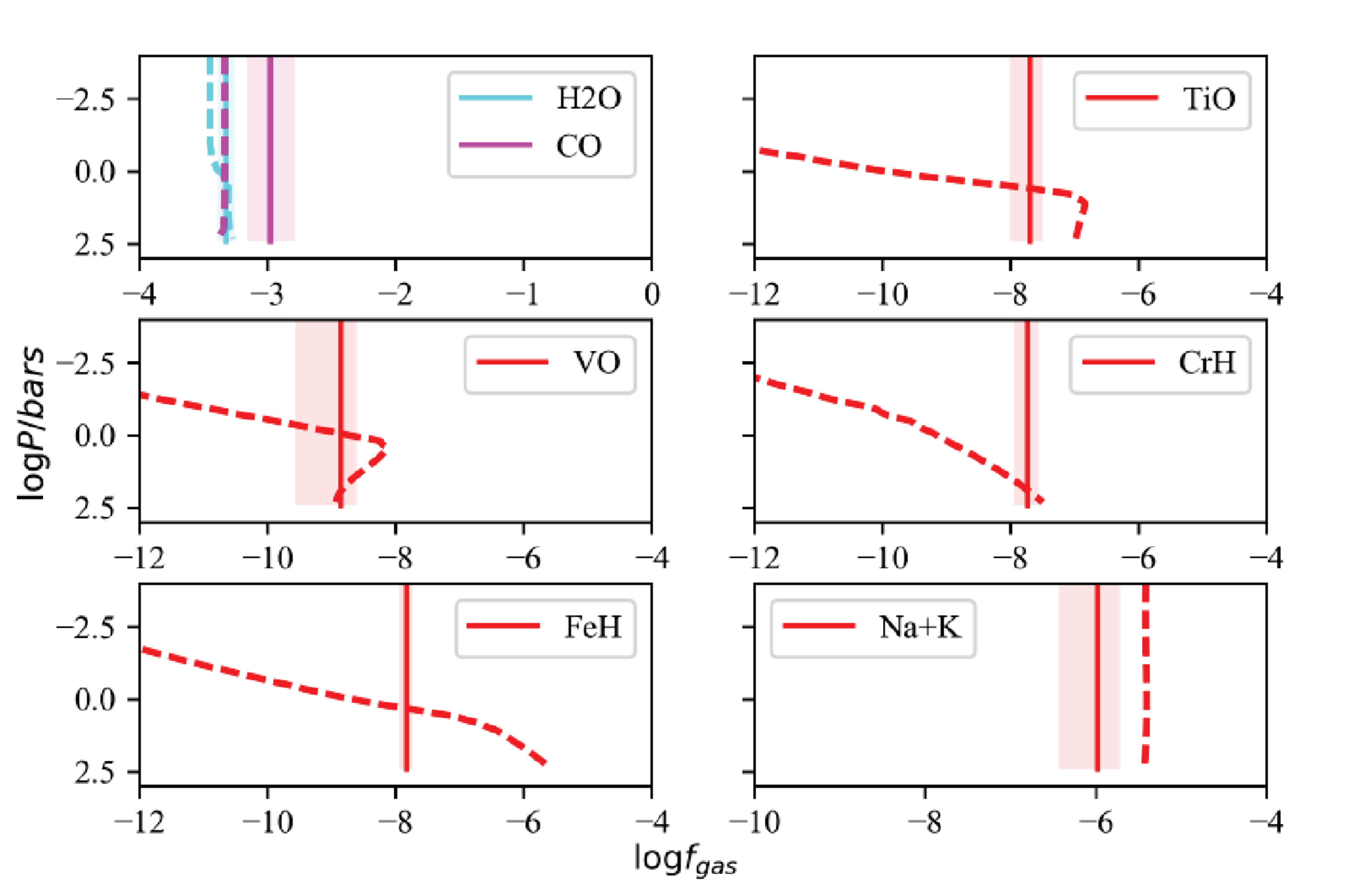
Telesco et al., 2004

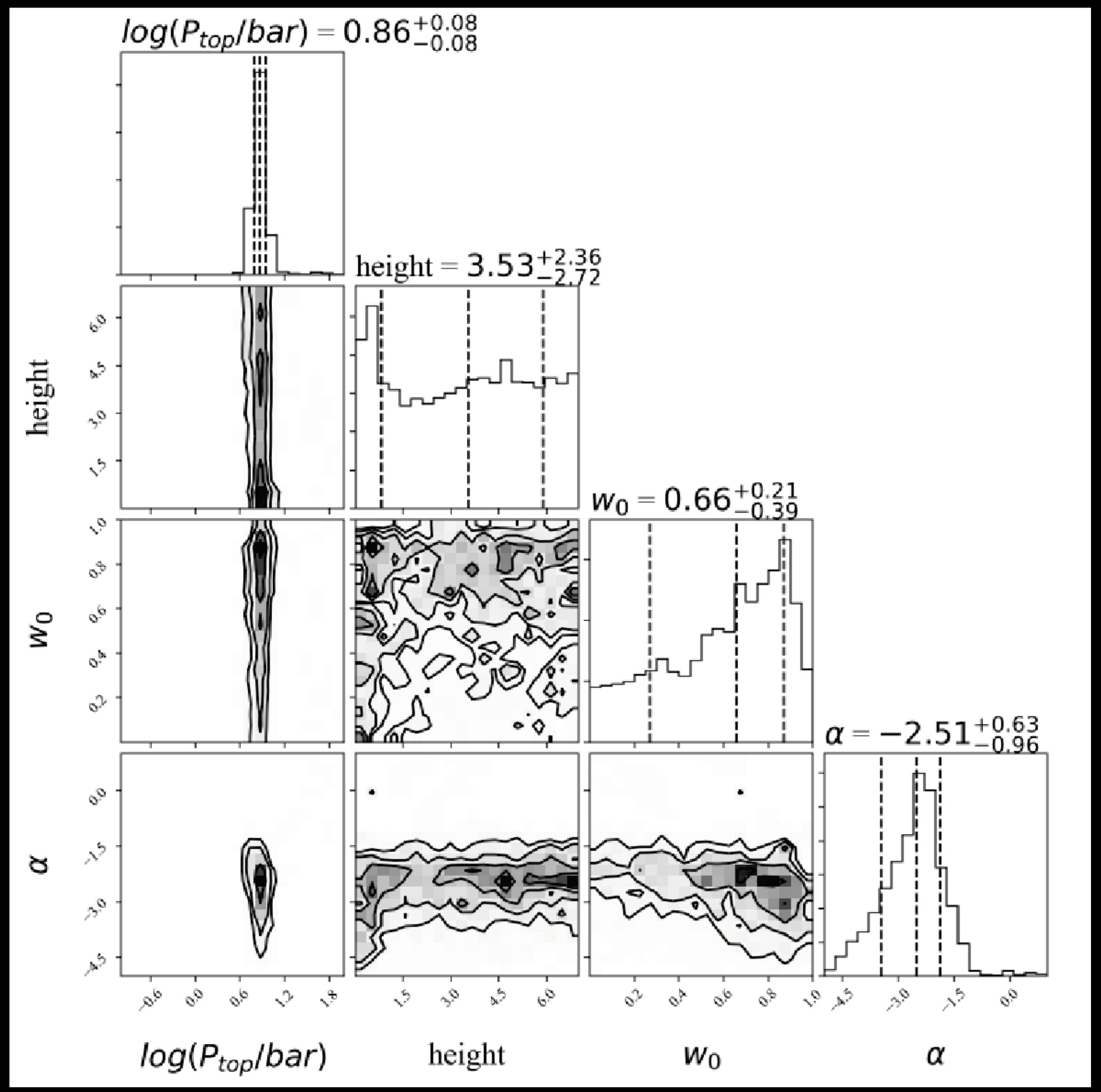


Smith and Wyatt, 2010

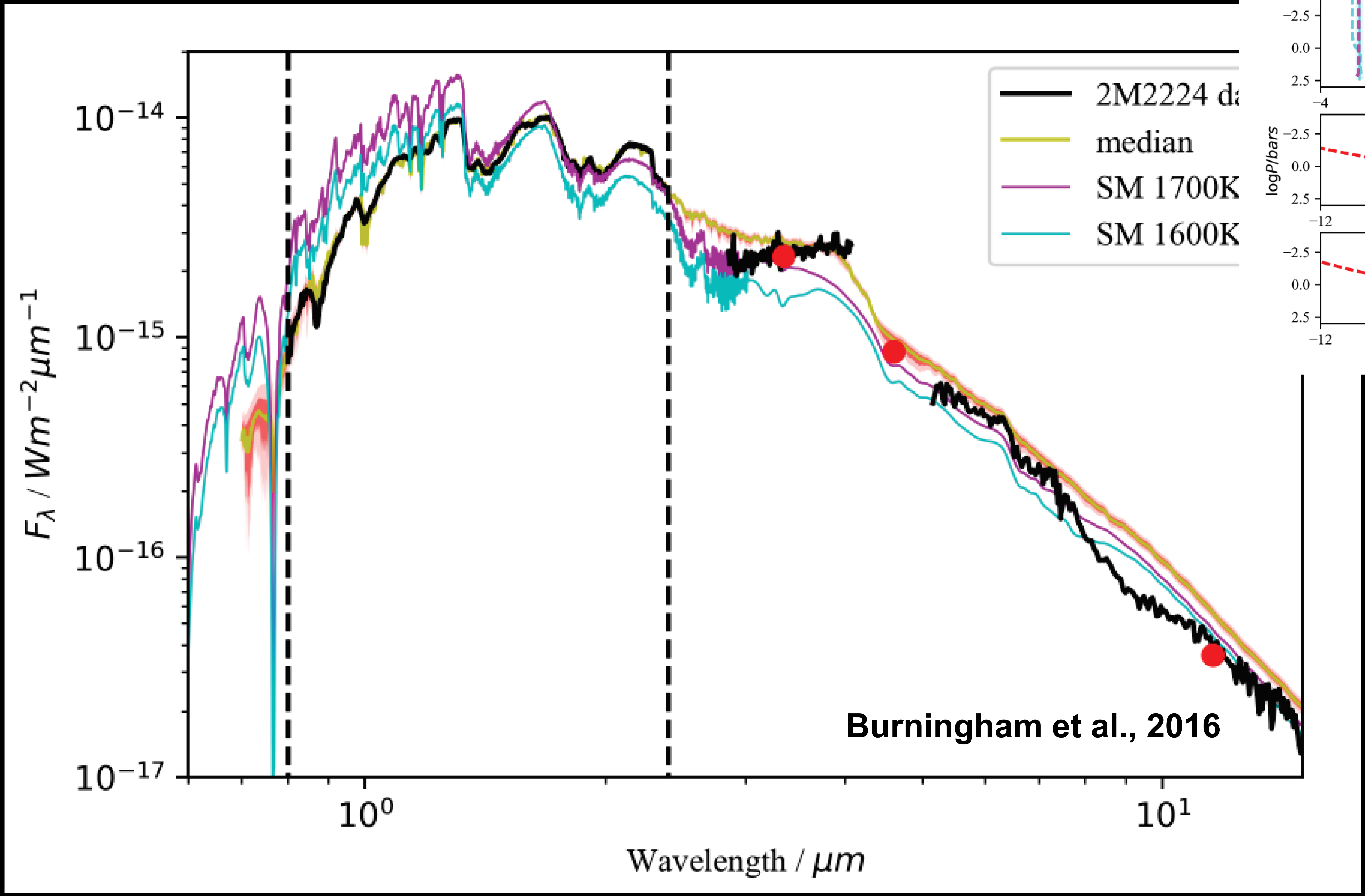
Webb will characterize brown dwarfs, giant planets

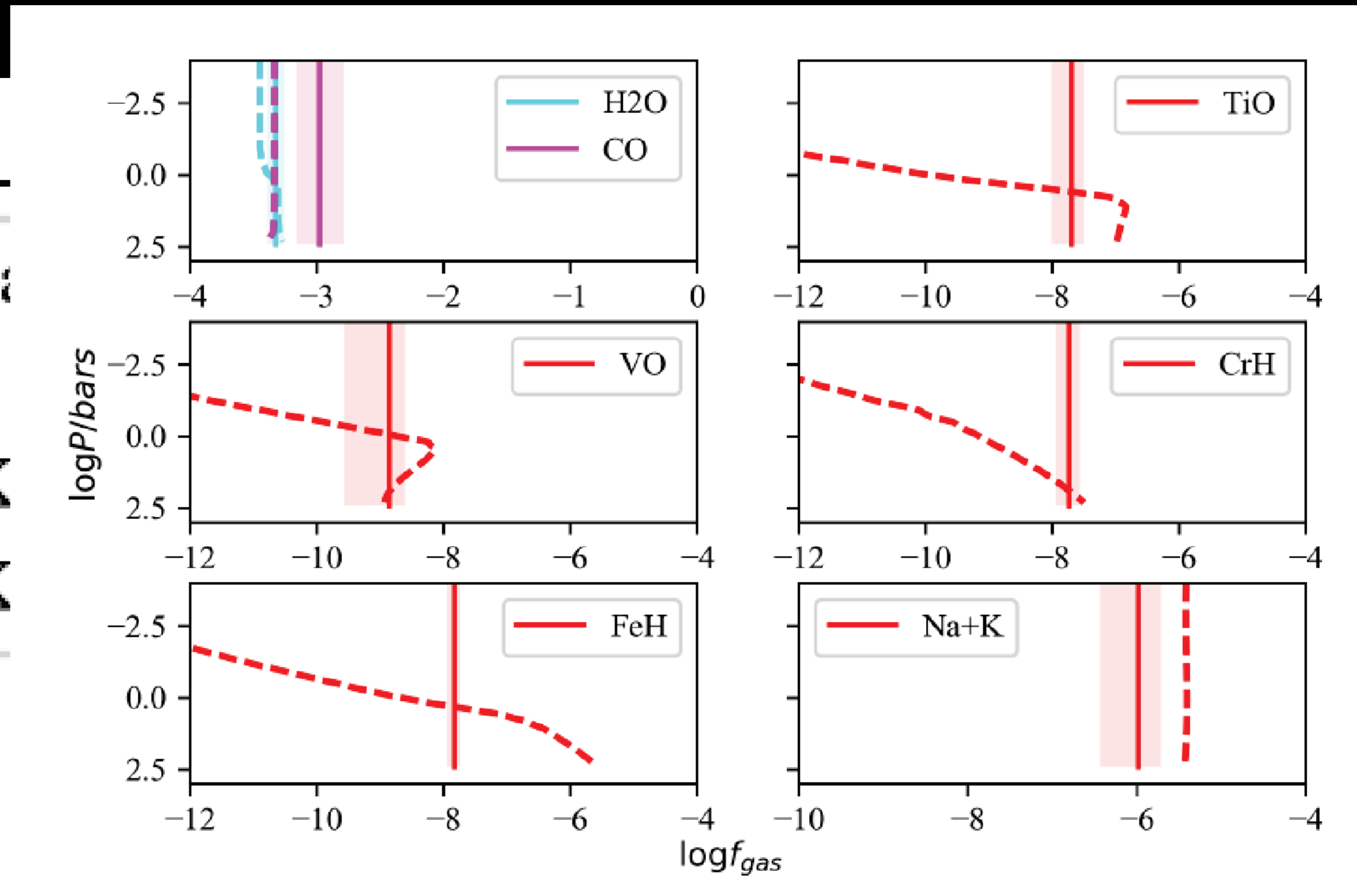


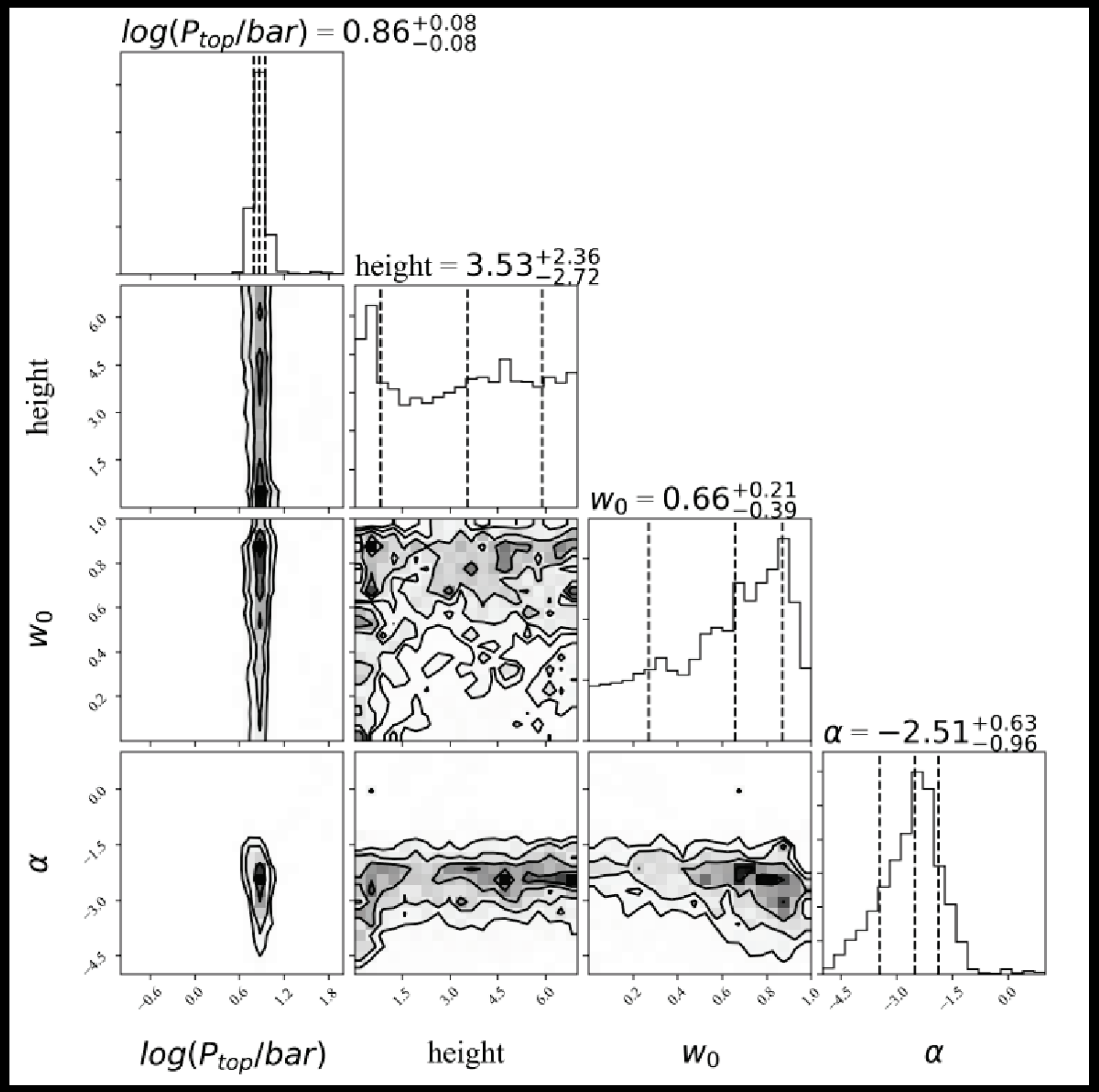




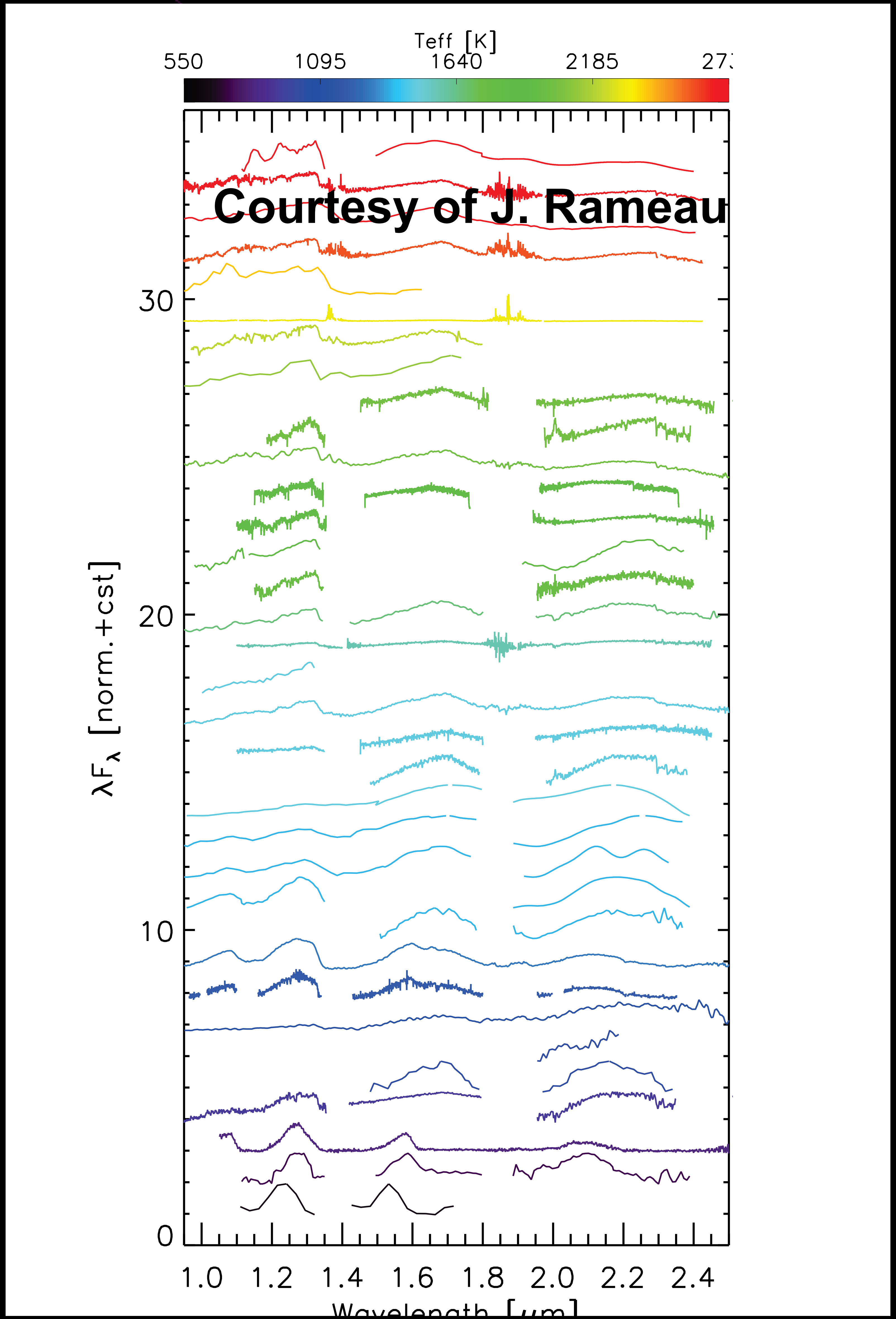
Webb will characterize brown dwarfs, giant planets



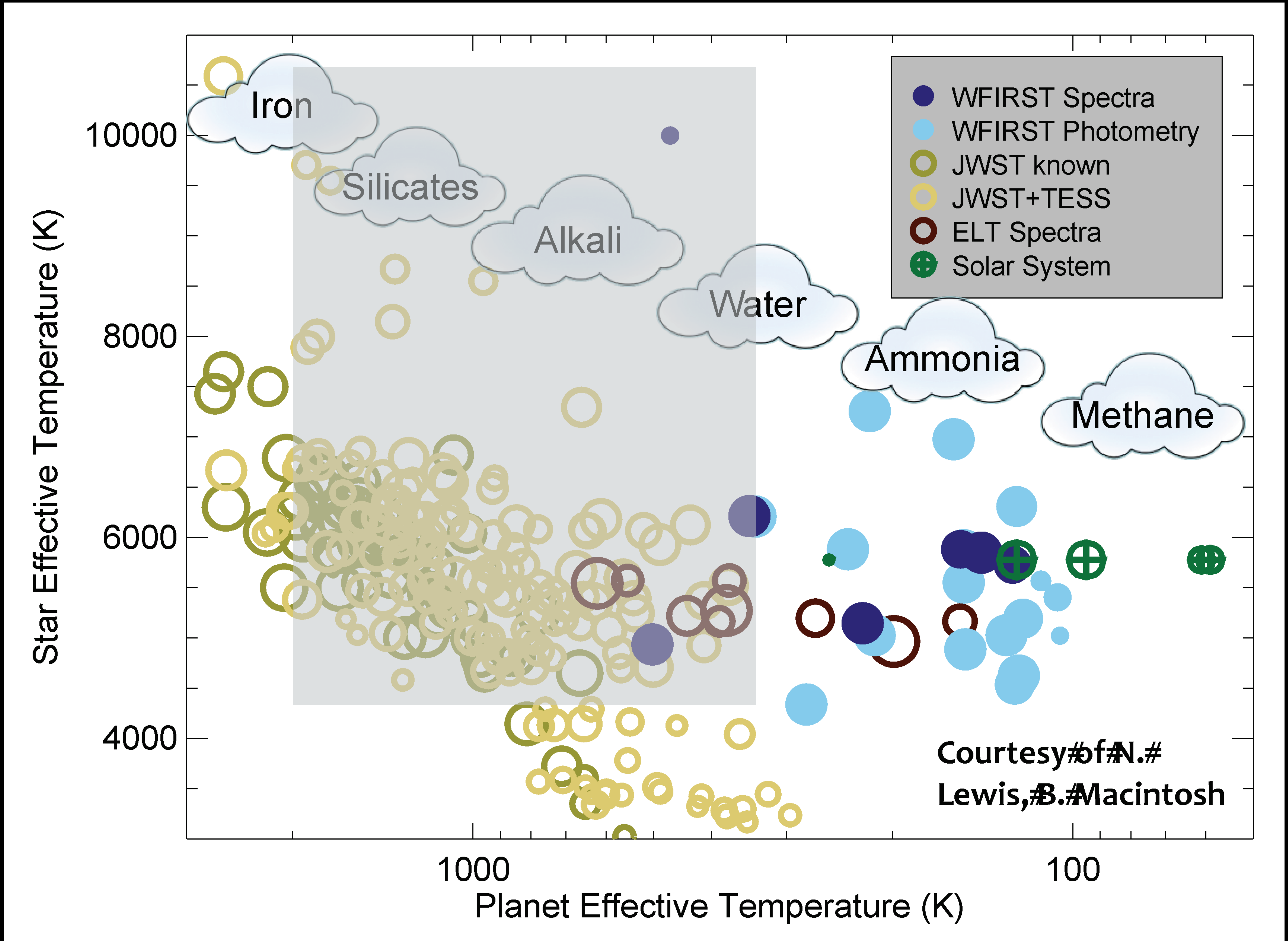




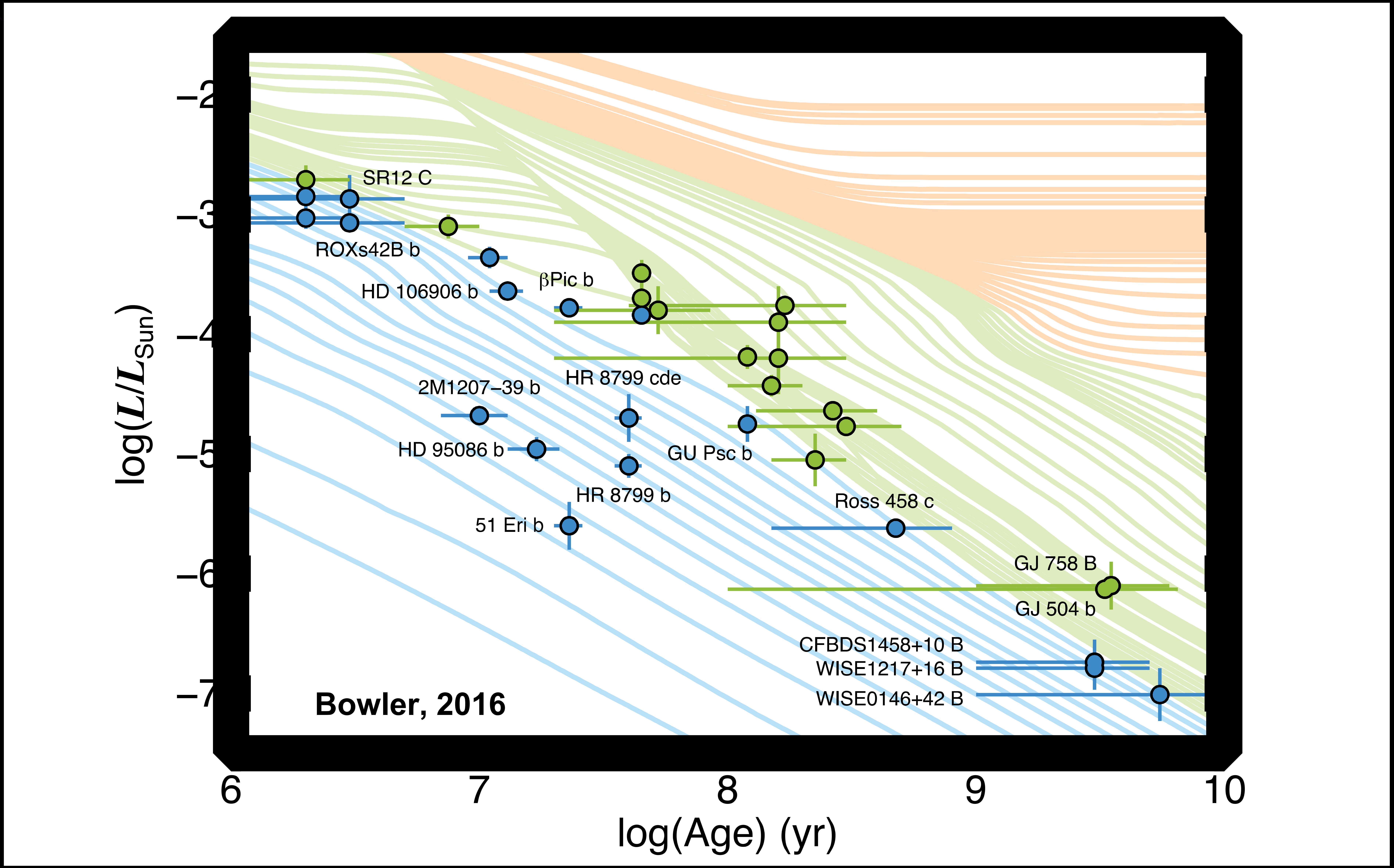
Webb will characterize giant planets, **spectra**



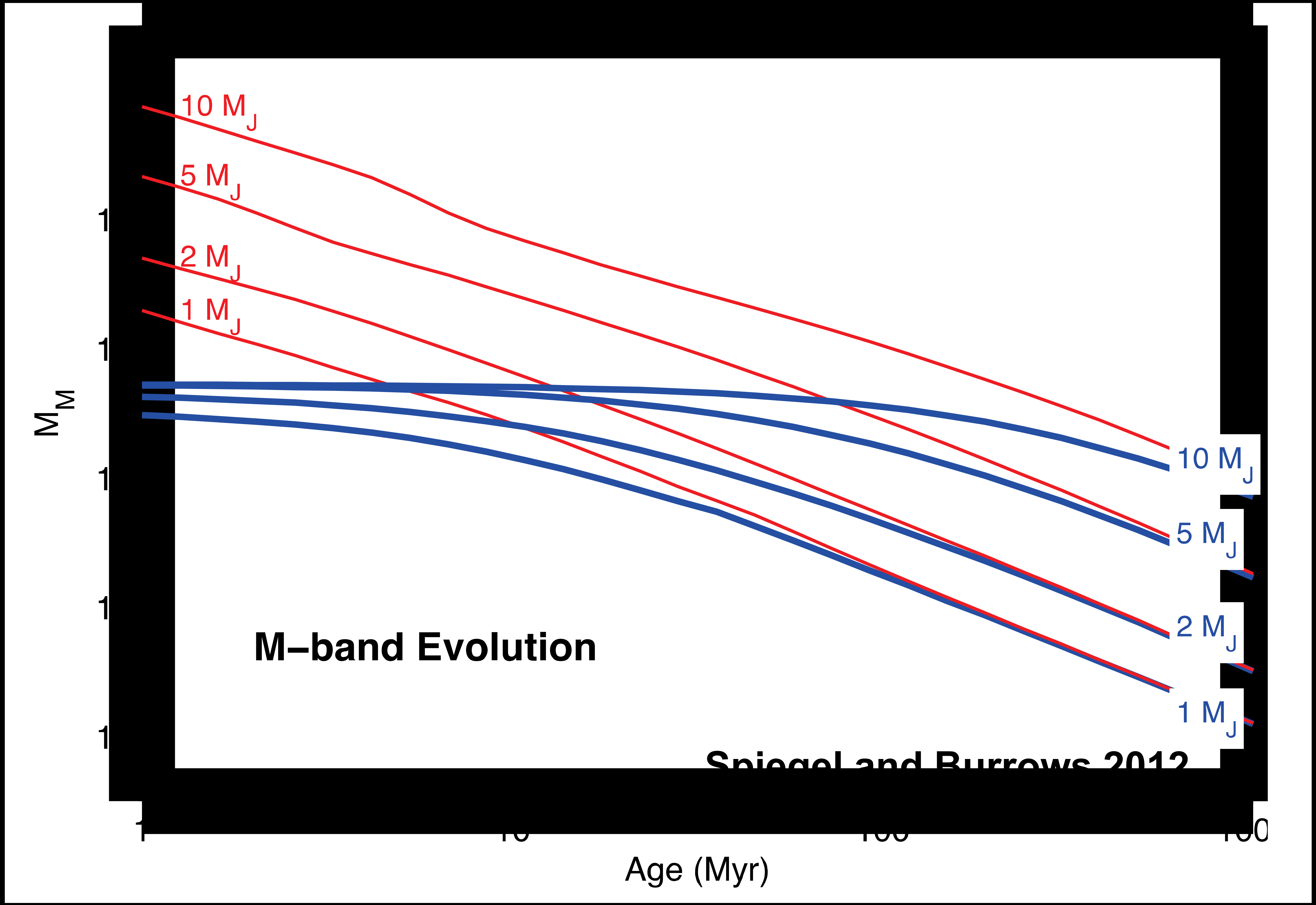
Webb direct imaging spectra in context



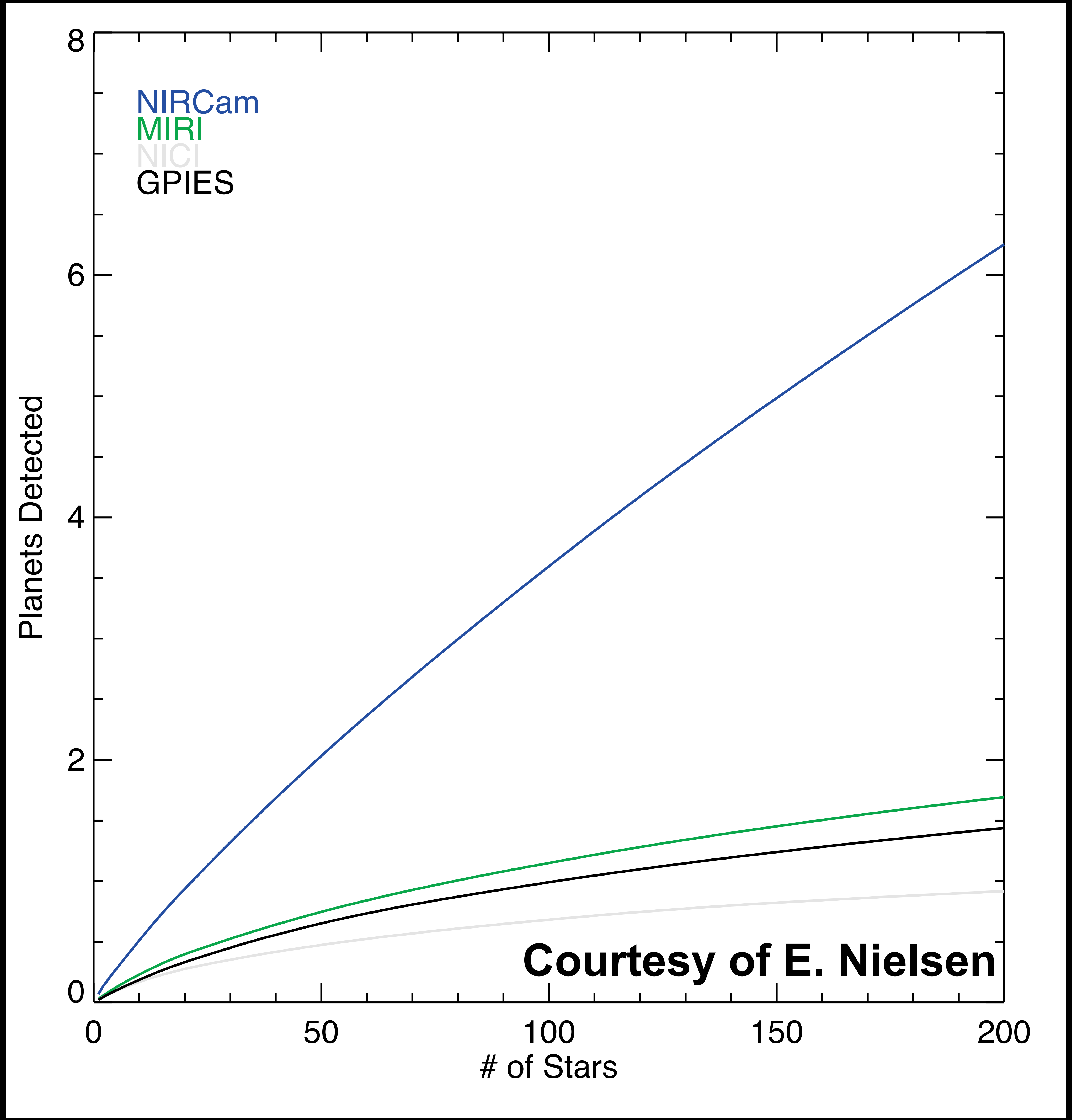
Webb will characterize giant planets



Webb will find giant planets around older stars



Cooling tracks for young Giant planets



Expected yield based with hot-start and published occurrence rates.

Thank you

JWST will enable detection and characterization solid state ices and silicate features in circumstellar disks.

JWST will spatially resolve the low surface brightness mid-infrared thermal emission from hundreds of nearby disks for the first time.

JWST will constrain giant planet formation/evolution by detecting giant planets around older stars than current ground based surveys.

JWST will constrain giant planet formation/evolution by characterizing most of the already known young giant planets.