NIRCam: The JWST Near-IR Camera and slitless spectrograph
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NIRCam is the primary near-infrared camera for JWST. It is well-suited for a wide variety of star formation and other scientific studies and will also be used for aligning the JWST primary mirror segments and telescope. NIRCam will provide high sensitivity, high spatial resolution images in a variety of filters over the 0.6 - 5 µm wavelength region including coronagraphic modes and slitless spectroscopic capabilities. NIRCam consists of two identical optical modules that have adjacent 2.2' x 2.2' fields of view on the sky. Each module is composed of two channels that observe the same field at short (< 2.4 µm) or long (> 2.4 µm) wavelengths simultaneously, with optimized spatial sampling in each channel. NIRCam optical elements include narrow (R = 100), medium (R = 10), and wide (R <= 4) filters, coronagraphic imaging spot and bar masks, and grisms that provide wide-field or time-series slitless spectroscopy. These major NIRCam features will be introduced, and some applications to galactic star formation will be briefly presented.

NIRCam: The JWST Near-IR Camera and Slitless Spectrograph

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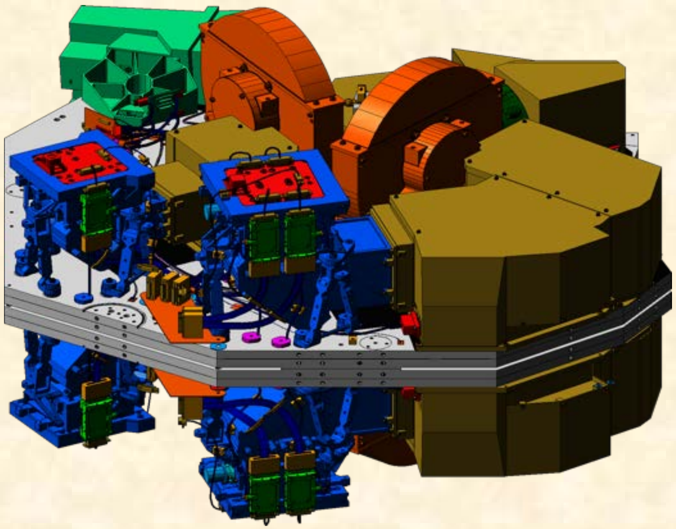
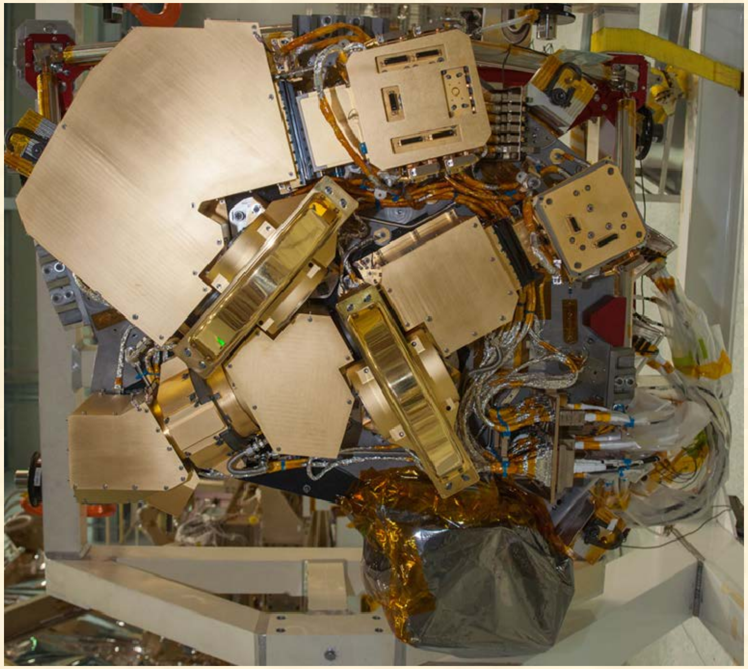
NIRCam: 0.6-5 μm imaging + 2,4-5 μm spectroscopy





- **NIRCam is the JWST near-infrared camera for JWST**
  - **Two nearly identical modules (A & B) with refractive designs to minimize mass and volume**
  - **Dichroic used to split range into short (0.6–2.3μm) and long (2.4–5μm) channels**
  - **Nyquist sampling at 2 and 4μm**
  - **2.2 arc min x 4.4 arc min total field of view seen in two colors (40 MPixels)**
  - **Coronagraphic capability for both short and long wavelengths (Chas Beichman talk)**
  - **Dispersive components in short and long channels allow *slitless spectroscopy***

- **NIRCam is also the telescope wavefront sensor**

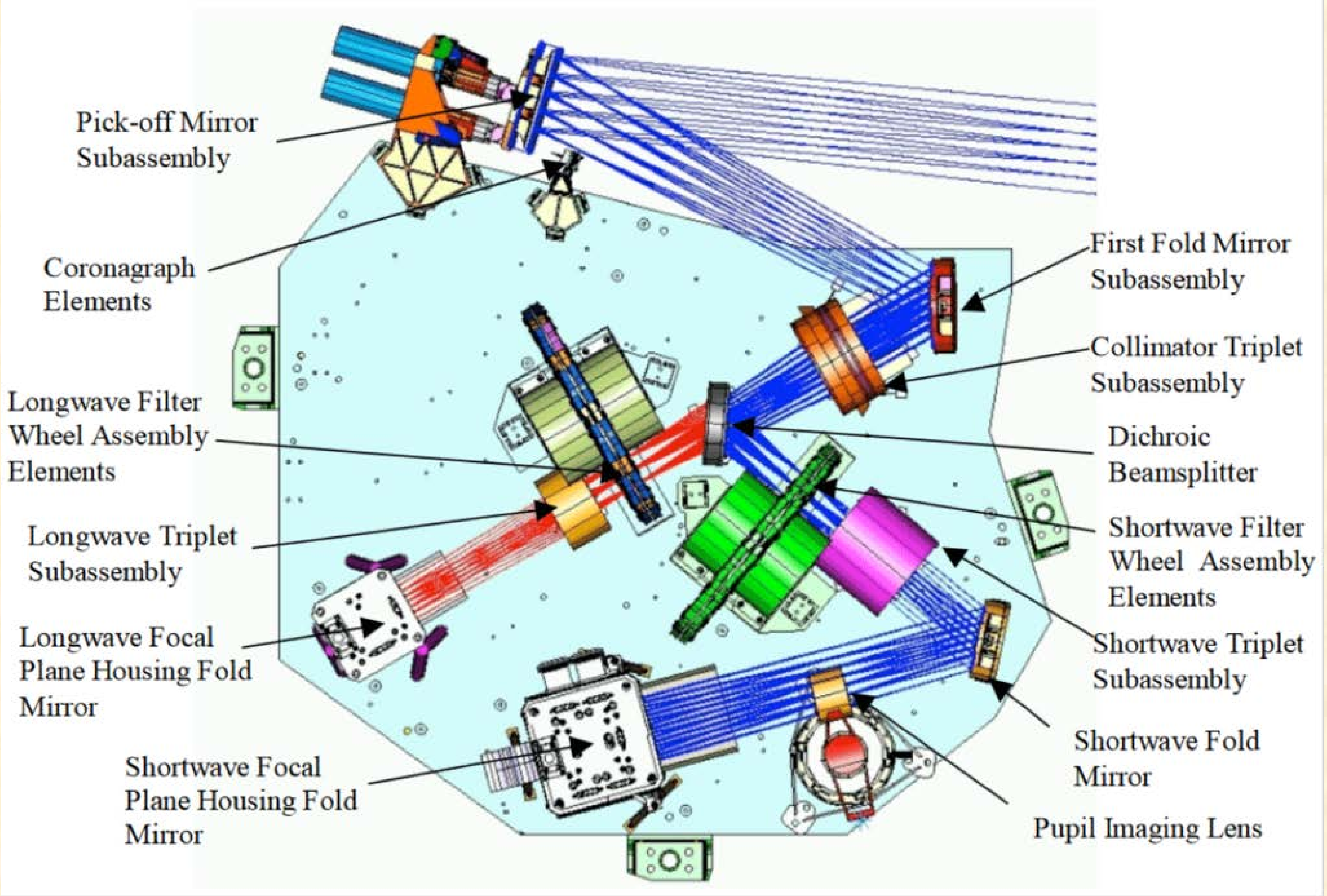
NIRCam Observing Modes (from Jdox)

NIRCam's 5 observing modes for science, from 0.6 to 5.0 μm, have corresponding templates in the Astronomer's Proposal Tool (APT):

- Imaging of two 2.2' × 2.2' fields separated by 44" covering 9.7 arcmin² in total
- Coronagraphic imaging using focal plane occulting masks and pupil plane Lyot stops
- Wide field slitless spectroscopy (2.4–5.0 μm) using $R = \lambda/\Delta\lambda \sim 1{,}600$ grisms
- Time-series imaging (photometric monitoring)
- Grism time series (spectroscopic monitoring)

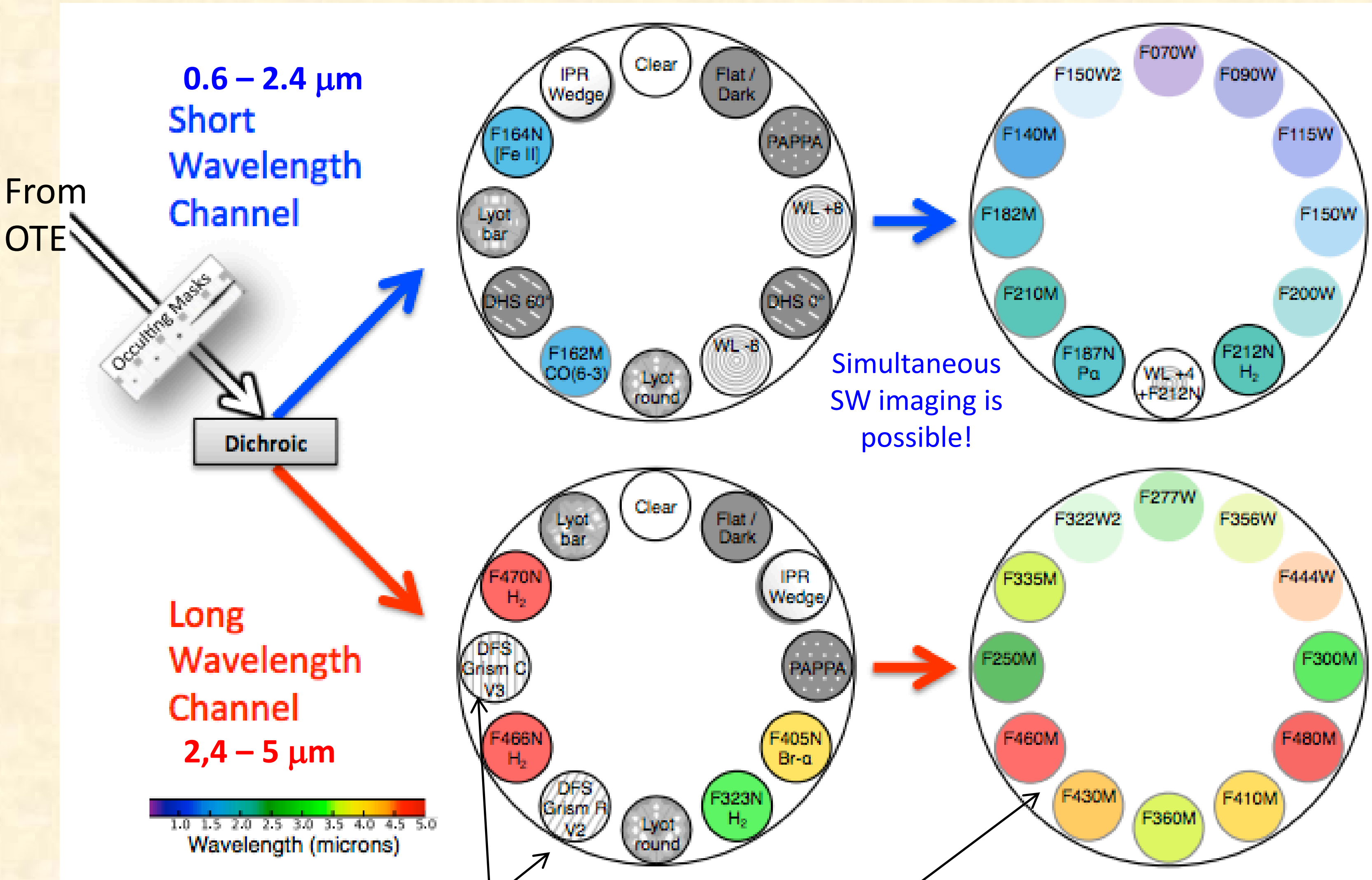
Simultaneous observations of the same field of view are available in the short wavelength channel (0.6–2.3 μm) and long wavelength channel (2.4–5.0 μm).

NIRCam: Two identical optical modules

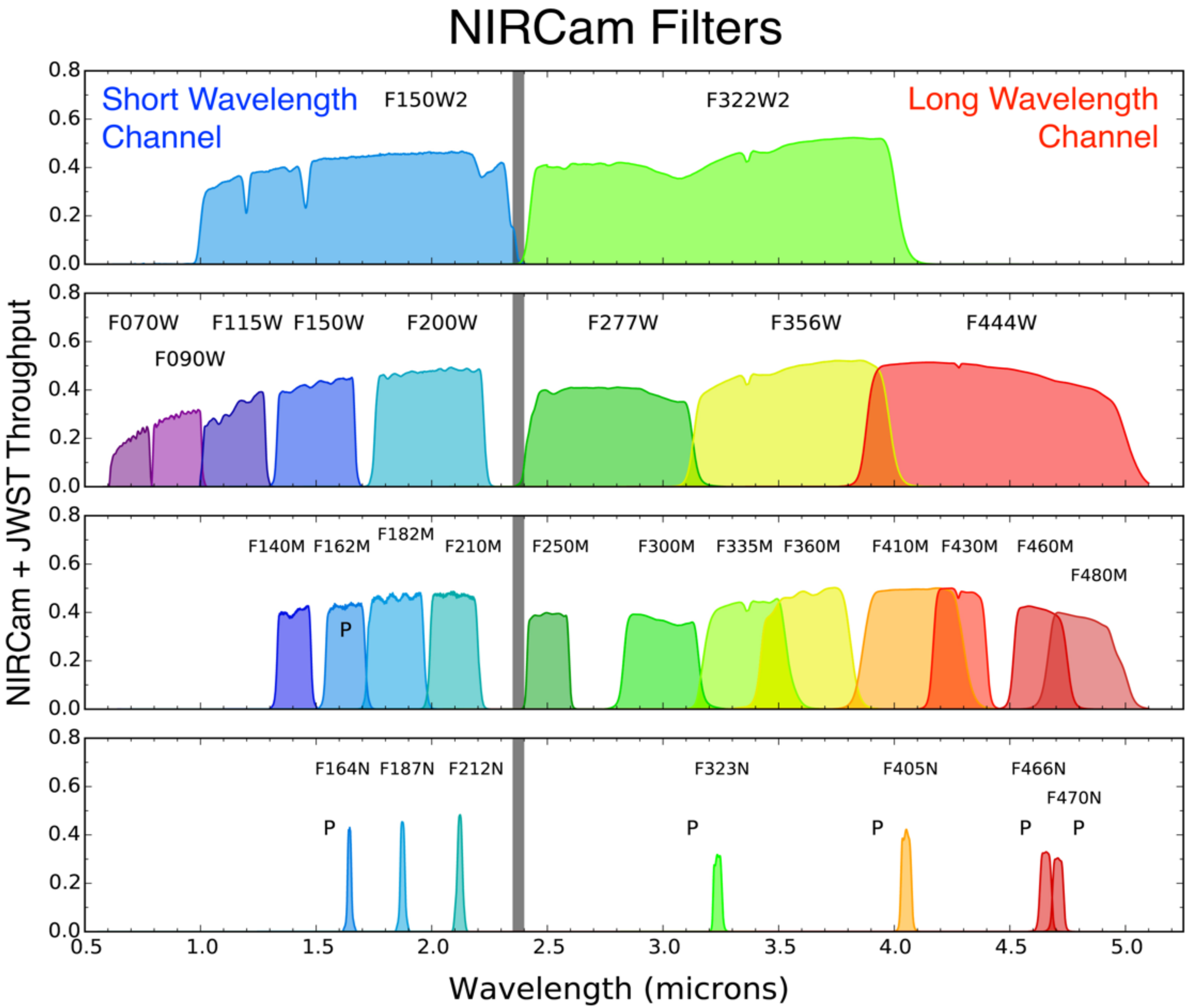


NIRCam modes: selectable with wheels

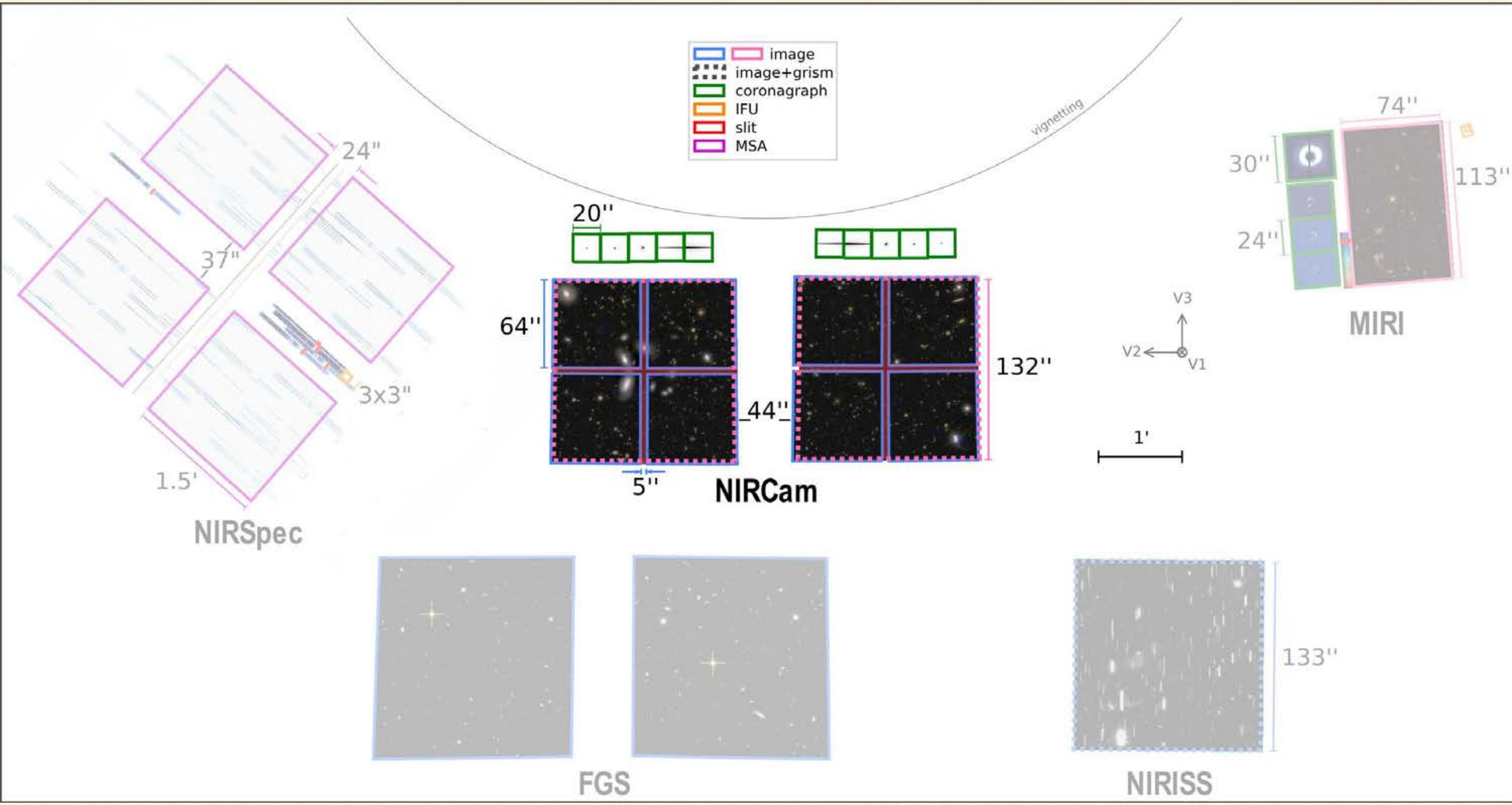
No Short Wavelength Spectroscopic Capabilities in Cycle 1



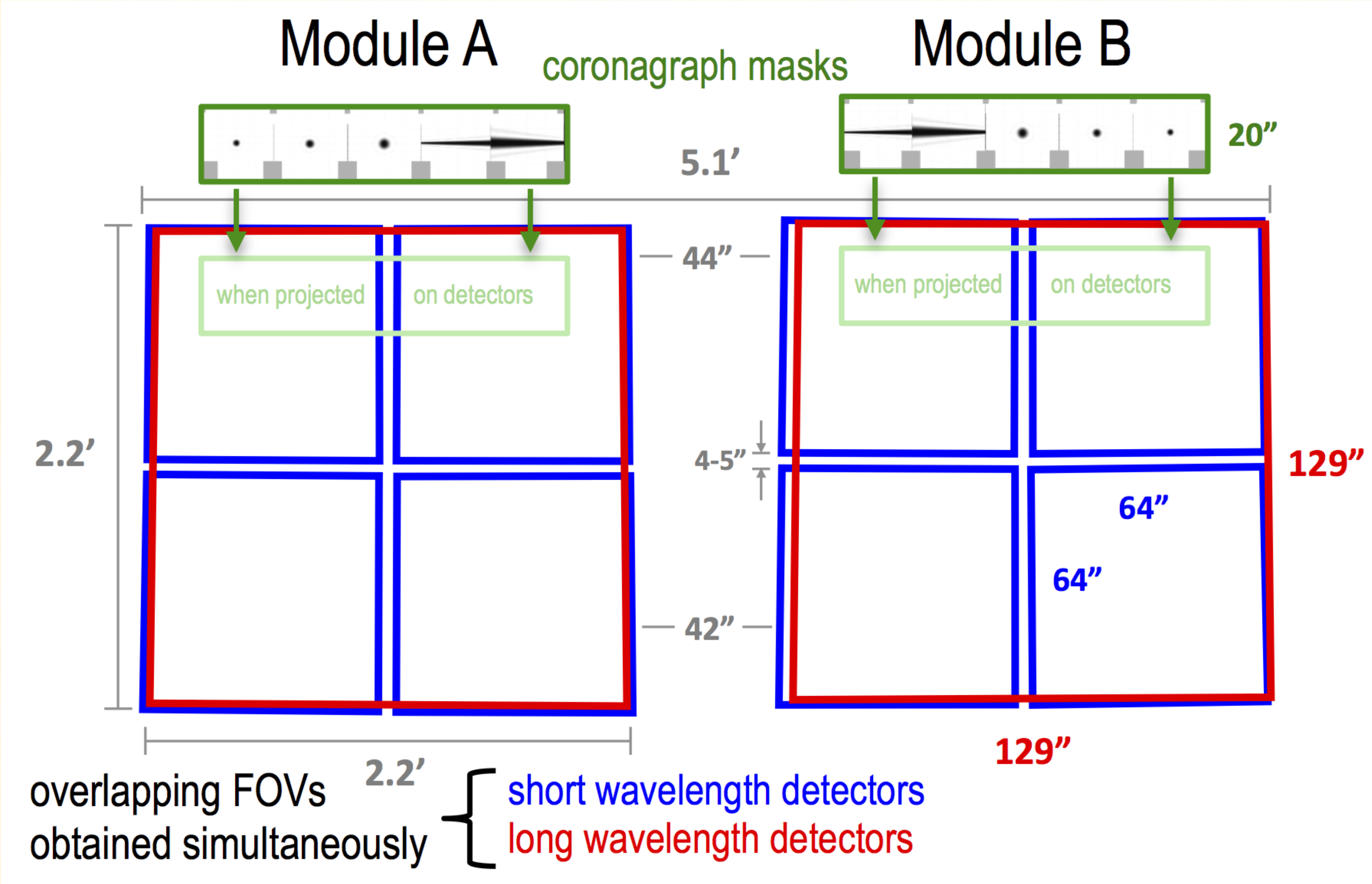
2 LW grisms in each module provide R~1500 slitless spectroscopy:
Chose dispersion orientation and filters to suit your science


NIRCam Filters
Short Wavelength Channel
Long Wavelength Channel
F150W2
F322W2
F070W
F090W
F115W
F150W
F200W
F277W
F356W
F444W
F140M
F162M
F182M
F210M
F250M
F300M
F335M
F360M
F410M
F430M
F460M
F480M
F164N
F187N
F212N
F323N
F405N
F466N
F470N
P
NIRCam + JWST Throughput
Wavelength (microns)
0.0
0.2
0.4
0.6
0.8
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

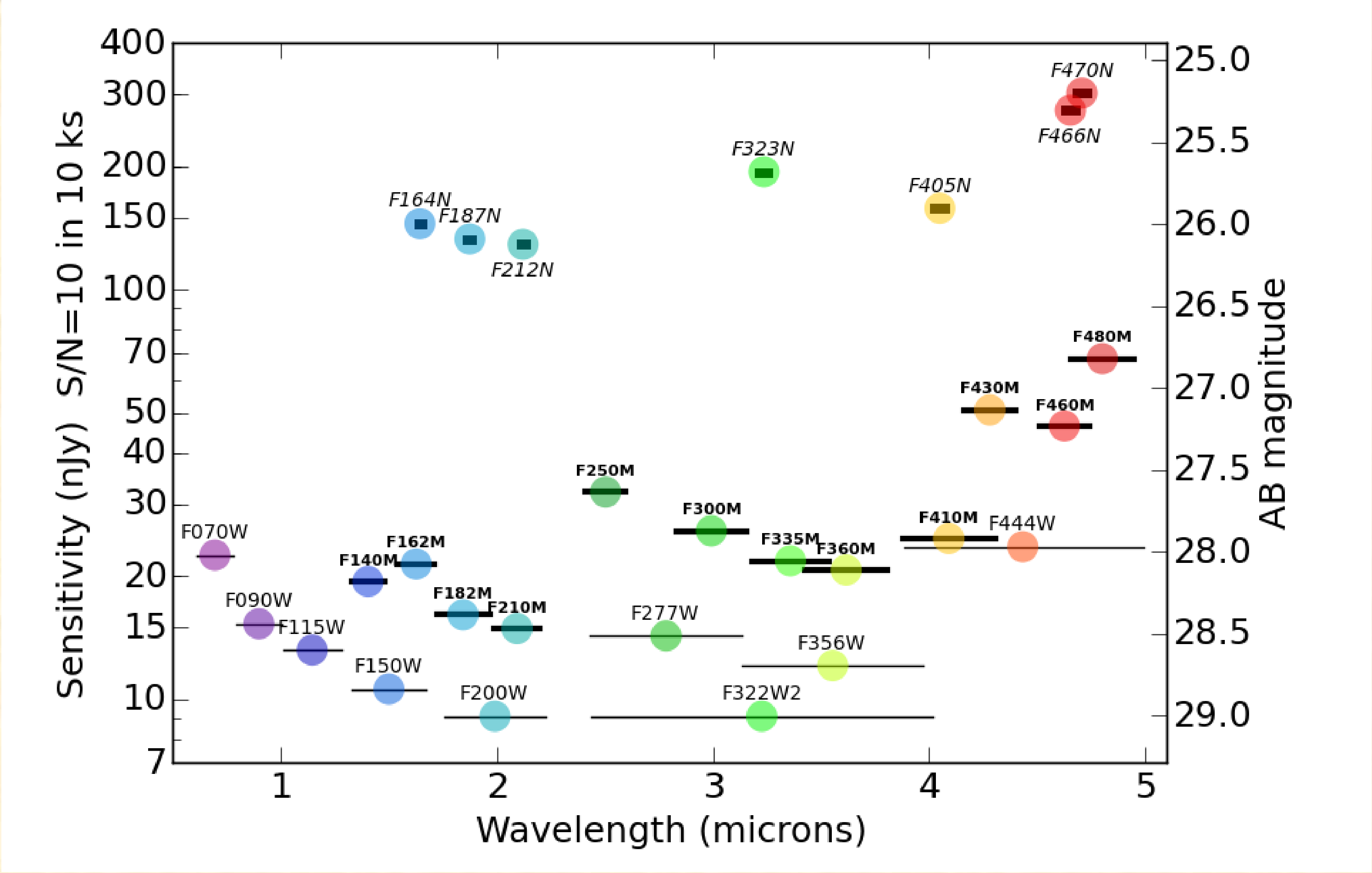
NIRCam and the JWST Focal Plane



NIRCam Field of View

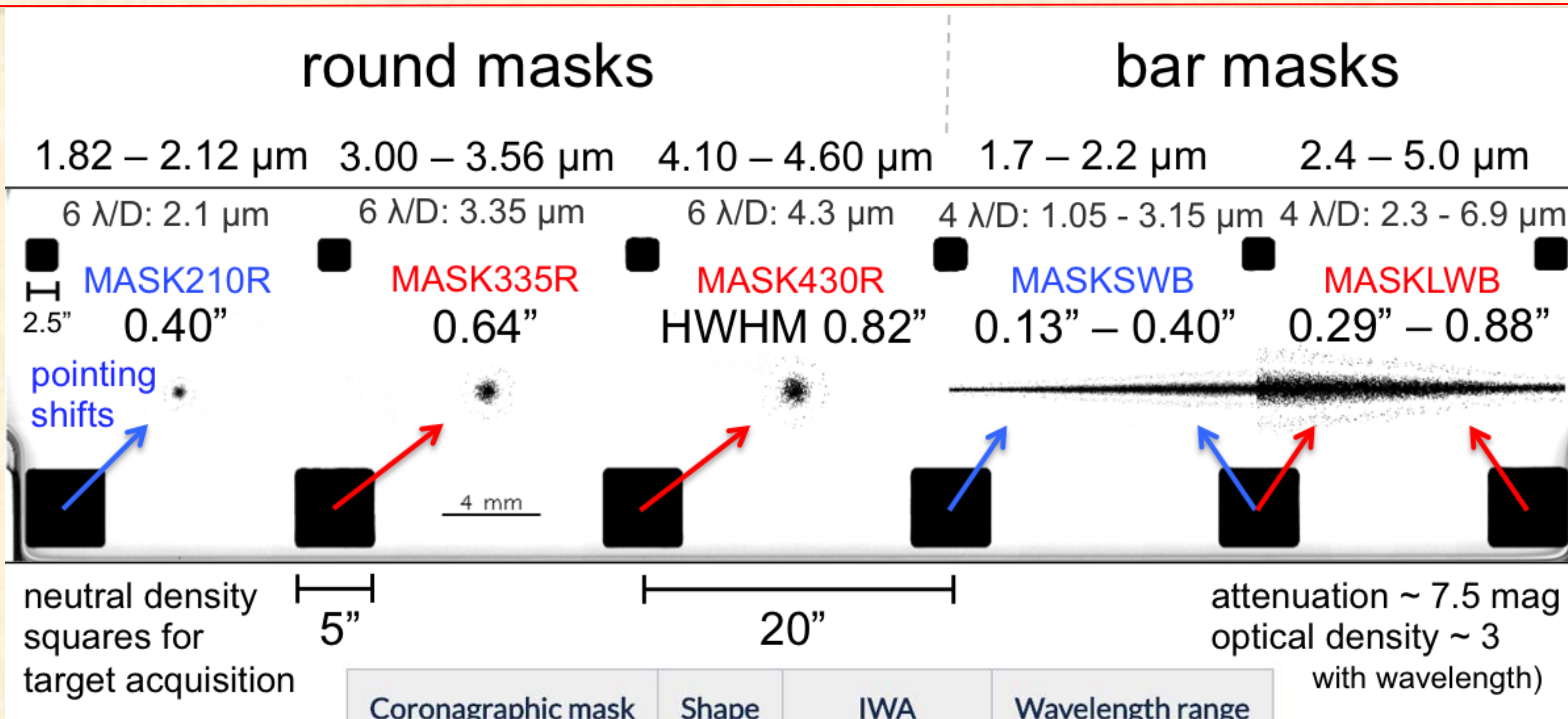


NIRCam Point-Source Imaging Sensitivity

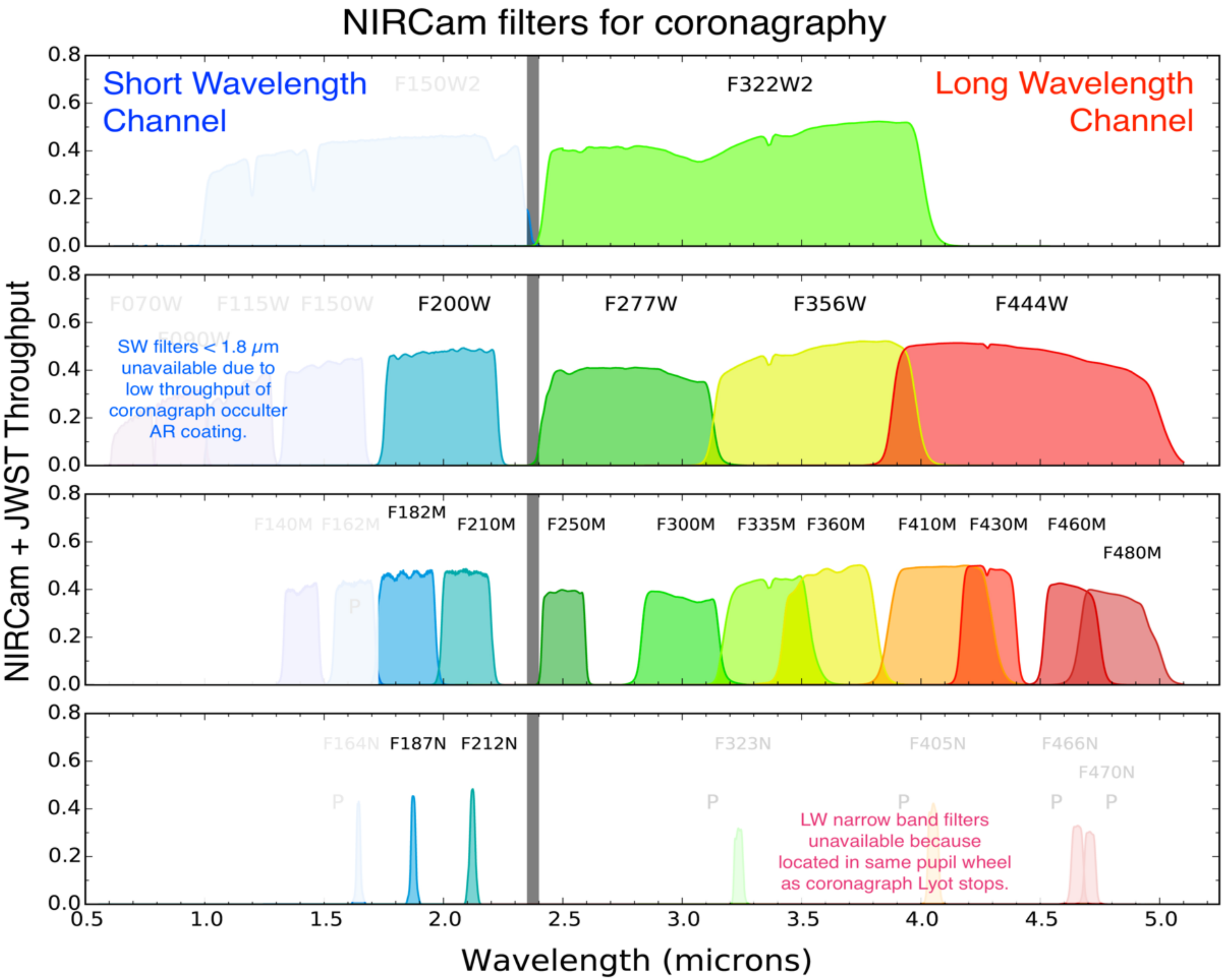


S/N = 10 detection limits for point sources in a 10 ks image (comprised of 10 exposures, 1 ks each). The sources are assumed to have flat spectra in nJy (and AB magnitudes). Zodiacal light is assumed to be 1.2 times the minimum. Filter widths are shown as horizontal bars.

NIRCam Coronagraphs



Coronagraphic mask	Shape	IWA	Wavelength range
MASK210R	round	0.40″	1.82–2.12 µm
MASK335R	round	0.63″	3.0–3.56 µm
MASK430R	round	0.81″	4.10–4.60 µm
MASKSWB	bar	0.13″–0.40″	1.7–2.2 µm
MASKLWB	bar	0.29″–0.88″	2.4–5.0 µm


NIRCam filters for coronagraphy
Short Wavelength Channel
Long Wavelength Channel
F150W2
F322W2
F070W
F115W
F150W
F090W
F200W
F277W
F356W
F444W
SW filters < 1.8 μm unavailable due to low throughput of coronagraph occulter AR coating.
F140M
F162M
F182M
F210M
F250M
F300M
F335M
F360M
F410M
F430M
F460M
F480M
F164N
F187N
F212N
F323N
F405N
F466N
F470N
P
LW narrow band filters unavailable because located in same pupil wheel as coronagraph Lyot stops.
NIRCam + JWST Throughput
Wavelength (microns)
0.0
0.2
0.4
0.6
0.8
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

NIRCam Coronagraphic Pupil Masks

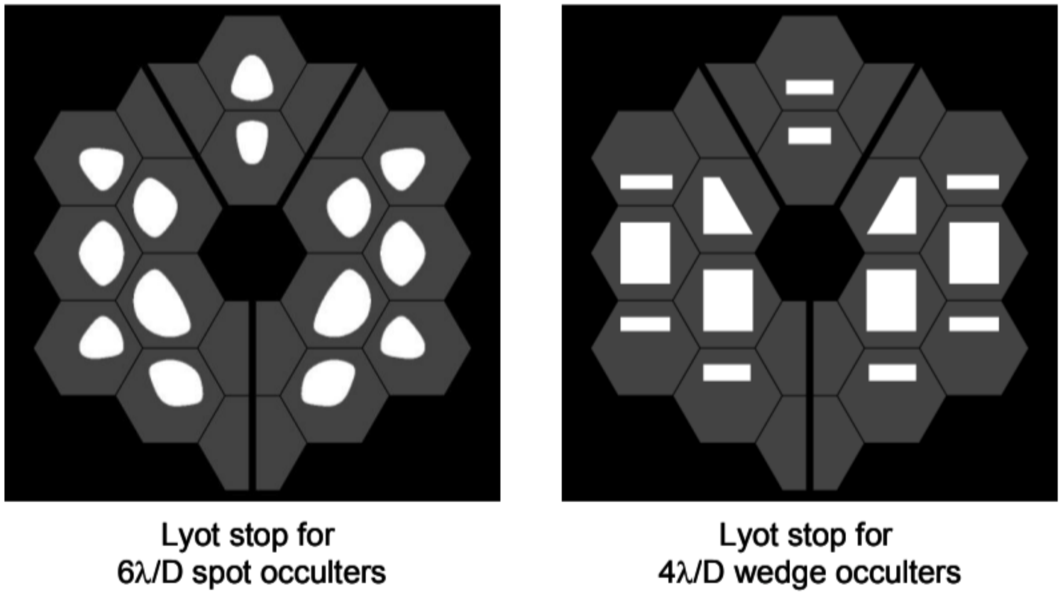
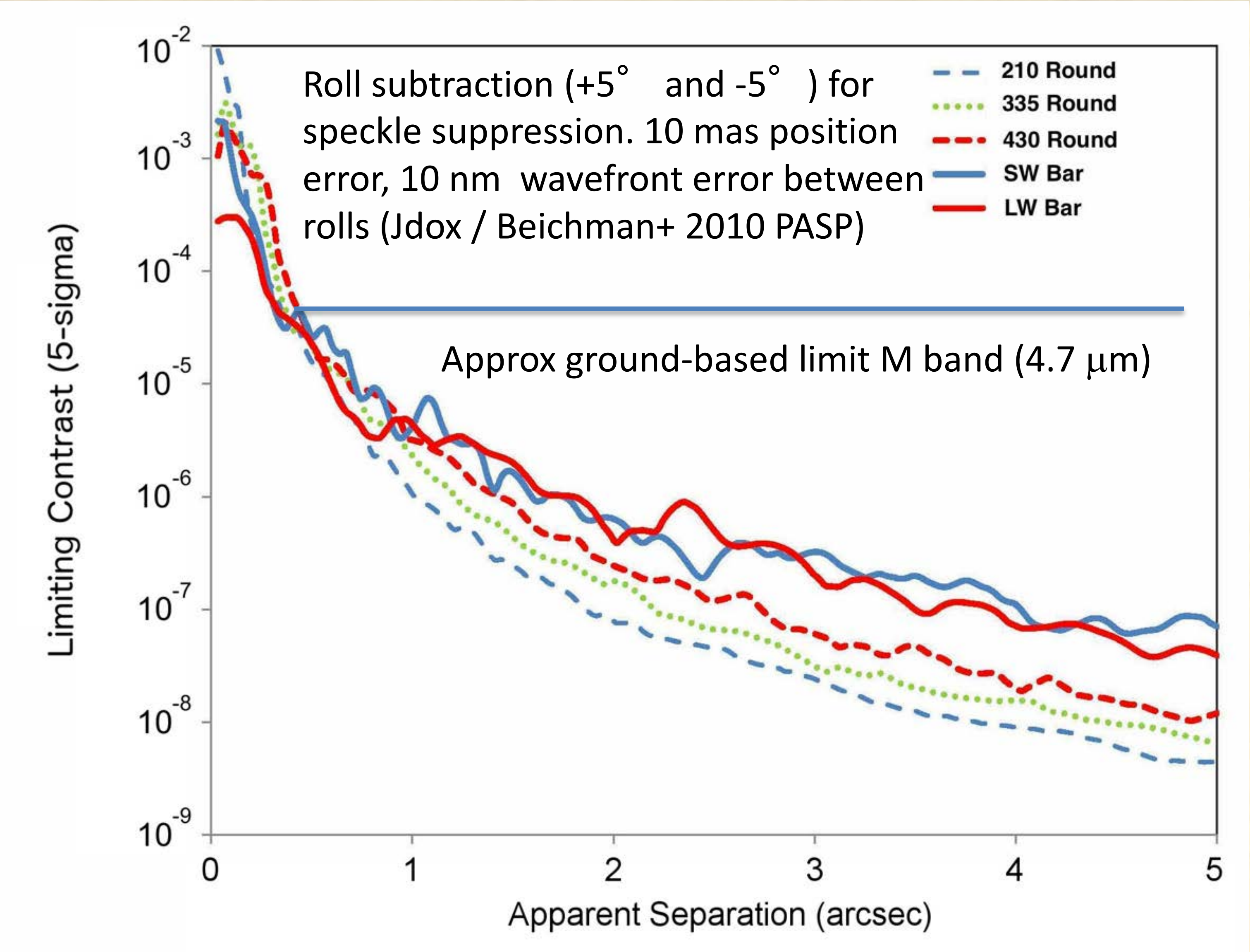


Figure 6. Openings in the Lyot stops (white) superposed on the JWST pupil pattern. The throughput for each is ~19%.

Krist+ 2007 SPIE

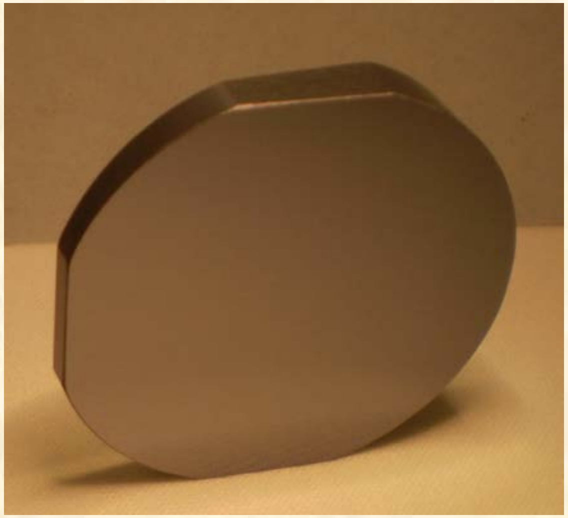
- Coronagraphic throughput is not great

NIRCam Coronagraphic Performance



NIRCam Si grisms

- Provide LW (2.4– 5 μm) single object and multi-object, wide-field spectroscopy at R > 1000
- Fabricated by D. Jaffe group at U. Texas using Si lithographic techniques (Jaffe+ 2008 SPIE)



NIRCam Si grism

Table 1 Basic grism parameters.

Material	Optical grade monocrystalline Si
Operating temperature	~30 to 35 K
Groove frequency	65 mm^{-1}
Prism angle	6.16 deg
Blaze angle	5.75 deg
Maximum thickness	8.0 mm
Diameter	48.0 mm, circular with side flats
Clear aperture	42.0 mm, circular
AR coating	2.4 to 5.0 μm

NIRCam LW Grism Spectra

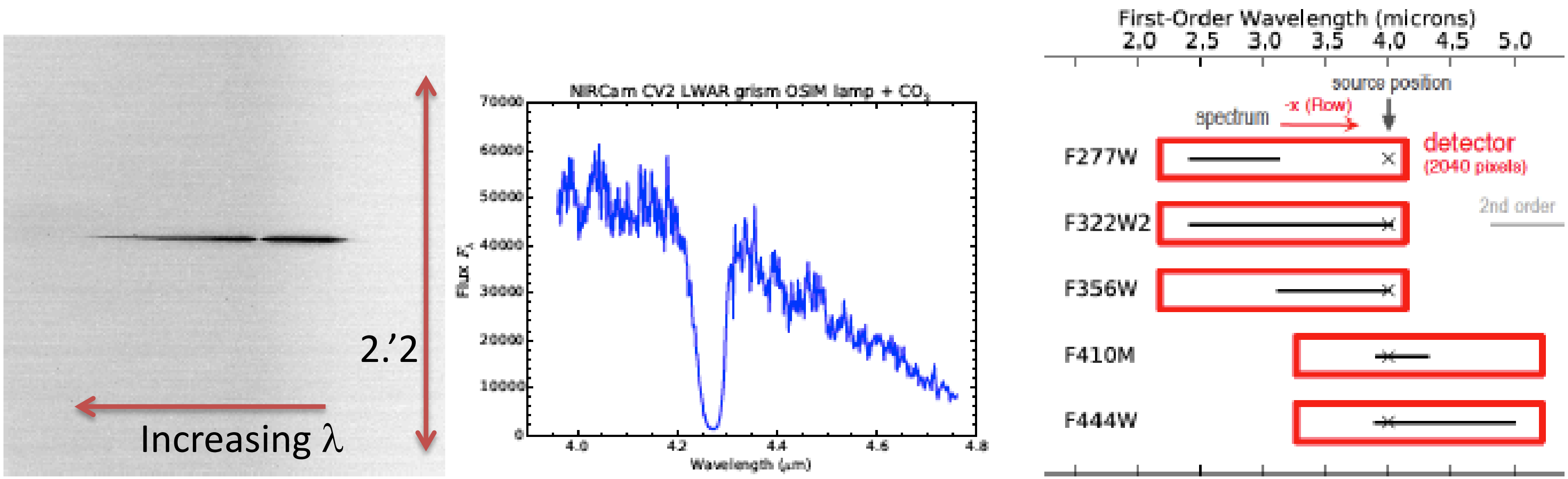


Figure 1. Left: NIRCam spectral image of the OSIM super-continuum lamp taken with the LWA R grism and F444W filter during JWST instrument instrument testing at NASA GSFC in August 2014. Wavelength increases to the left (-X direction). Center: Extracted spectrum from the image with an approximate wavelength calibration applied. The continuum decreases toward longer wavelengths due to low fiber transmittance, and the broad feature near 4.27 μm is due to CO_2 absorption. Both of these features are artifacts of the test equipment and not NIRCam itself. Right: Layout of an object's LW R grism spectra spectrum relative to its direct image position for different filters (image courtesy of D. Coe).

Grism undeviated wavelength is 4.0 μm

*** NIRCam FOV is 2.′2 x 2.′2 with dispersion of 10 Å per 0.″065 x 0.″065 pixel ***

NIRCam Spectral Coverage & Resolution

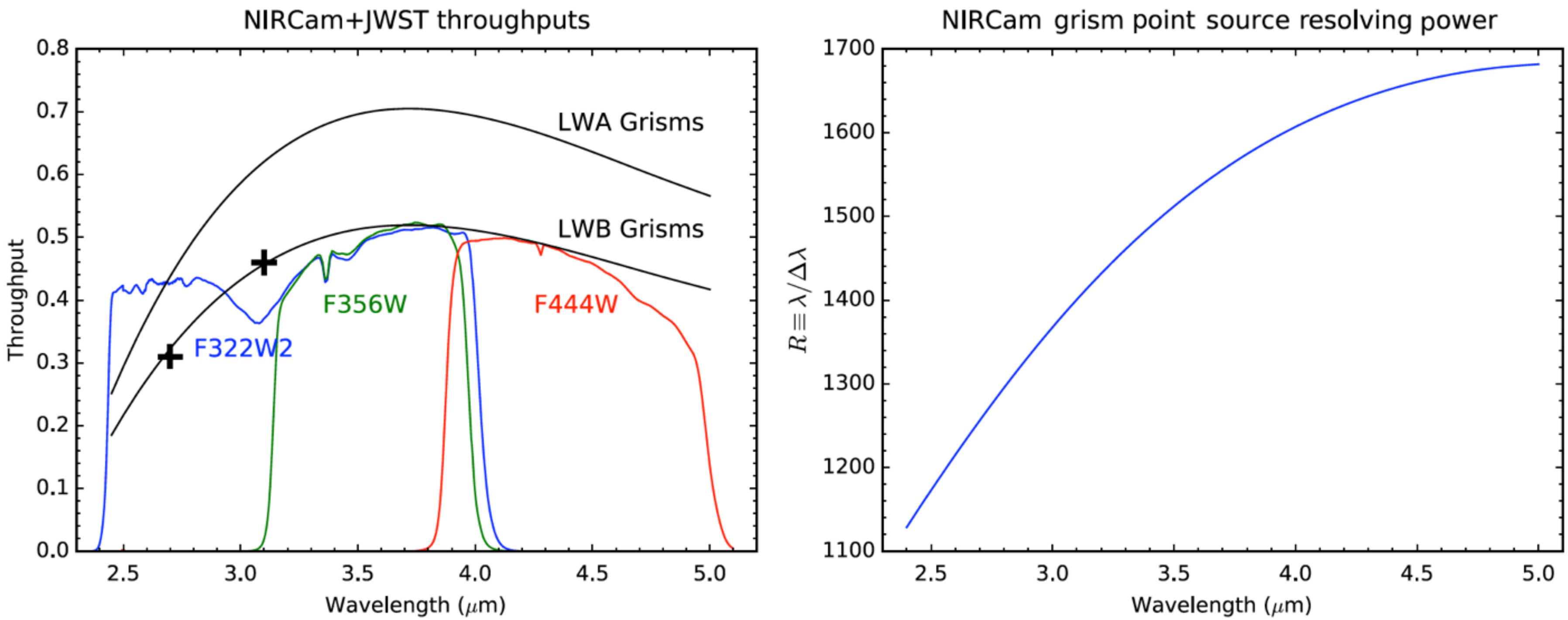
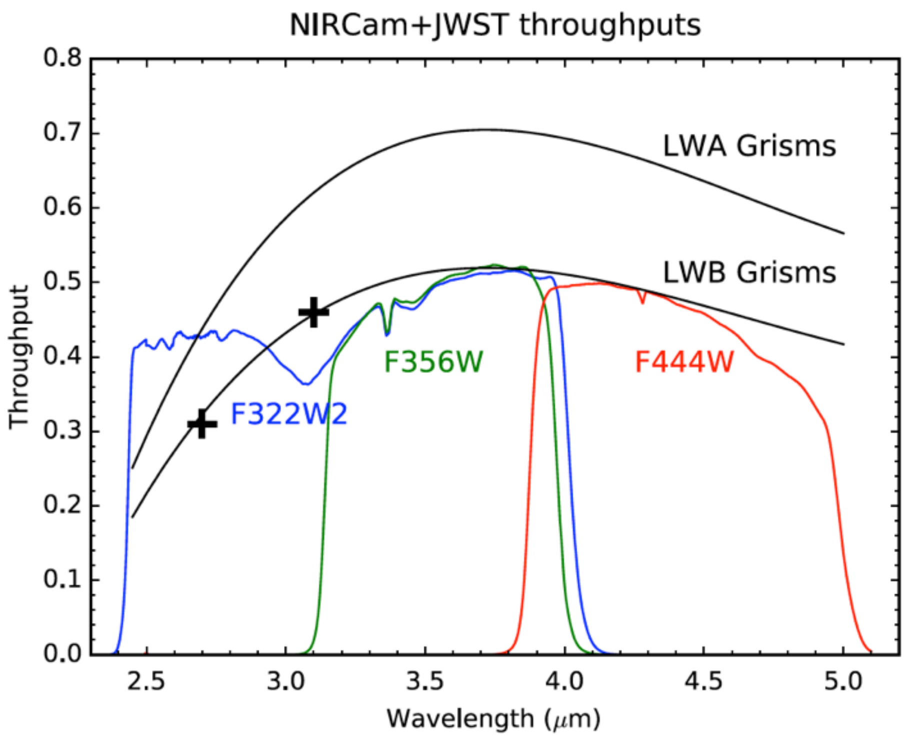
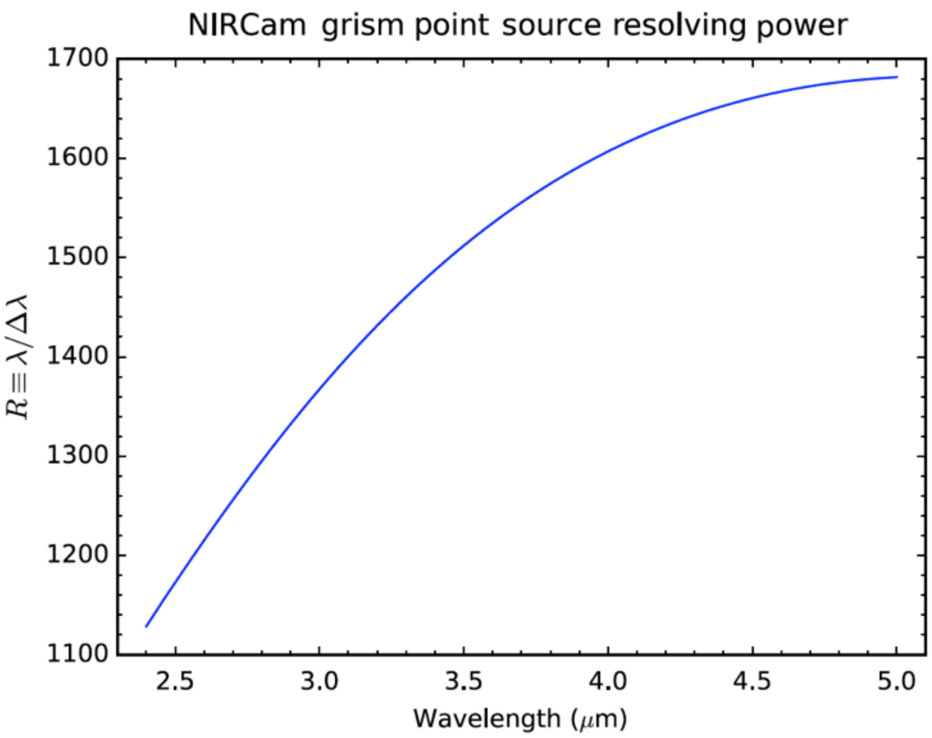


Fig. 2 (a) Total system throughput including all OTE and NIRCam optics and the detector quantum efficiency for several NIRCam filters (module A optics and QE shown; module B is similar). The theoretical LW grism efficiency curves must be multiplied by the optics curves for a chosen filter to produce the system throughput at each wavelength. The module B LW grisms are AR coated on only one side and therefore have throughputs ~25% lower than the LWA grisms. Module B grism throughputs were measured at two wavelengths and are shown as crosses. (b) Spline curve fit to the grism FWHM spectral resolving power R versus wavelength for point sources. This is limited by pixel sampling of the PSF at shorter wavelengths ($\lambda \lesssim 4$ μm) and by diffraction and the quasi-hexagonal pupil shape[19] at longer wavelengths ($\lambda \lesssim 4$ μm).

Greene+ (2018 JATIS 035001-3)

Spectroscopic throughput & Resolving Power





Module A Grism Saturation & Sensitivity

λ (μm)	F_{cont} (μ Jy)[b]	F_{line} (W m^{-2})[c]	K_{sat} (A0V)[d]	K_{sat} (M2V)[d]	Filter[e]
2.5	11.1	1.09E-20	4.3	4.3	F322W2
2.7	8.7	7.35E-21	4.5	4.6	F322W2
2.9	8.0	5.98E-21	4.3	4.5	F322W2
3.1	7.9	5.22E-21	4.2	4.4	F322W2
3.3	6.7	3.97E-21	4.2	4.5	F322W2
3.5	6.5	3.45E-21	4.0	4.3	F322W2
3.7	6.3	3.05E-21	3.9	4.2	F322W2
3.9	7.0	3.11E-21	3.6	3.9	F322W2
4.1	12.1	4.99E-21	3.5	3.8	F444W
4.3	13.5	5.18E-21	3.2	3.5	F444W
4.5	15.1	5.38E-21	2.9	3.0	F444W
4.7	19.1	6.38E-21	2.5	2.7	F444W
4.9	25.1	7.88E-21	2.2	2.3	F444W

a. Module B grisms will have sensitivities approximately 1.16 times higher (worse) and saturation limits 0.33 mag brighter.

b, c 10 σ point-source and unresolved emission line sensitivities for 10,000 s integrations

d K-band Vega magnitudes for saturation (80% full well or 65,000 electrons) for 0.68 s integrations (2 reads) of 2048 x 64 pixel regions in stripe mode (4 outputs).

e Narrower filters will have similar saturation values and somewhat better sensitivities

Sensitivities are ~2-5x worse than NIRSpec depending on filter bandpass and zodiacal background

Spectroscopic Sensitivity

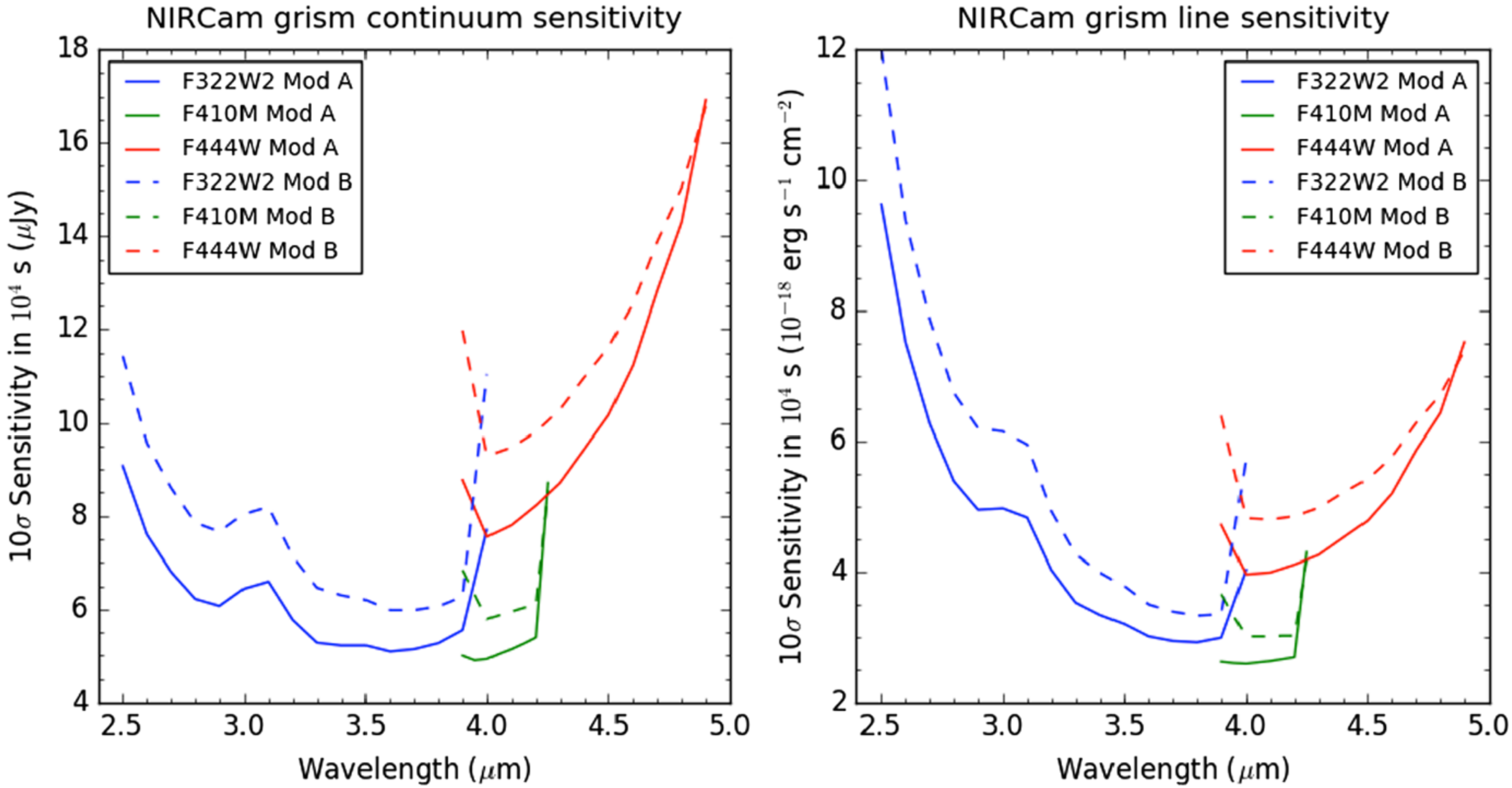


Fig. 3 (a) Point-source continuum and (b) emission line sensitivities are shown for grisms with F322W2, F410M, and F444W filters for both modules A and B. Note that the narrower bandwidth of the F410 filters results in significantly better sensitivity than the wider F444W at common wavelengths.

Star formation example (K Hodapp & L Chu)

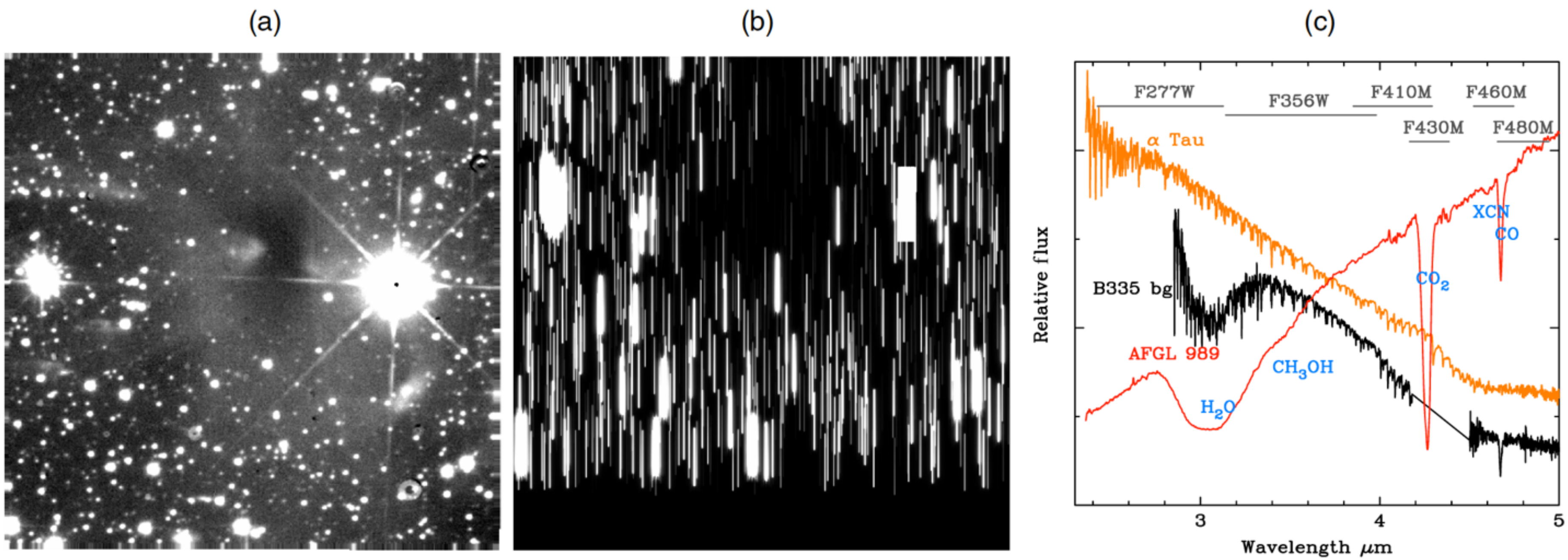


Fig. 6 (a) B335 dark cloud *K*-band ($\lambda = 2.2$ μm) UKIRT image acquired in 3.2 h integration time. (b) Simulated 0.45 h JWST NIRCam spectral image using the module A C grism and F430M filter, using simulated PSFs for $K = 20$ mag (vega) and brighter stars in the UKIRT data, and fainter stars added using the TRILEGAL background model[35] with measured extinctions applied. Spectra are vertically offset from the UKIRT image because the $\lambda = 4.0$ μm undeviated wavelength is outside the bandpass of the F430M filter. (c) Interstellar ice spectra are shown with NIRCam filter bandpasses. A star behind the B335 cloud (black) is the same spectral type as α Tau[36] (orange), but it shows $\lambda = 3$ μm H_2O and CO ice absorption due to the intervening B335 cloud. The infrared space observatory spectrum of AFGL 989[37] shows numerous strong and weak ice features that NIRCam will detect and measure, including $\lambda = 4.3$ μm CO_2 absorptions from ice mantles forming on dust grains in the cloud.

Greene+ 2017 JATIS

NIRCam Star Formation GTO Science

Making of Stars & Planets: Testing the Standard Model

1) What physical variables determine the shape of the IMF?

2) How do cloud cores collapse to form isolated protostars?

3) What are the initial conditions for planet formation?

4) How do disks evolve to shape their planetary systems?

Updated Program: 125 hours

NIRCam Star Formation GTO Programs

Initial Conditions Massive Star Formation: 18 hours (E. Young)

Evolution of Volatiles in Icy Clouds: 38 hours (K. Hodapp)

End of the IMF & Free-floating Planets: 16 hours (M. Meyer)

Origins of Protostars and Planets: 33 hours (T. Greene & J. Leisenring)

Physics and Chemistry of PDRs: 20 hours (K. Misselt)

Strong scientific synergy with the NIRISS (planets in formation and star clusters), MIRI (extinction mapping, protostars, disks, and star formation in local group), NIRSPEC, IDS (star clusters near and far) Teams.

Further Information

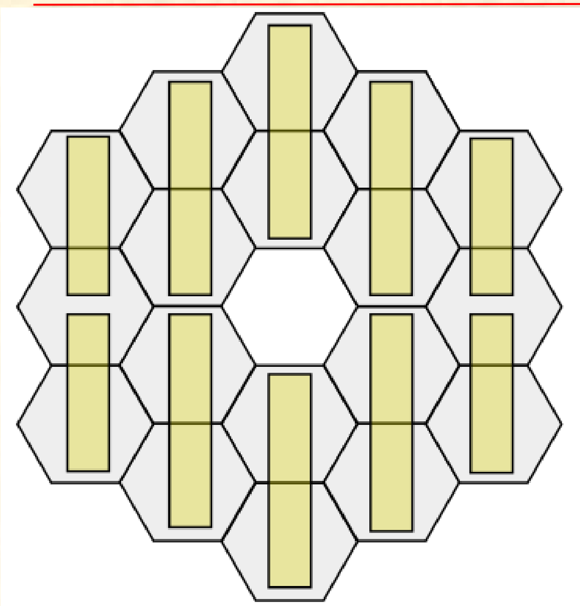
- Jdox NIRCam information: https://jwst-docs.stsci.edu/near-infrared-camera
- Astronomer's Proposal Tool for planning observations: http://www.stsci.edu/hst/proposing/apt
- JWST exposure time calculator:
- Lots of technical papers: just ask!

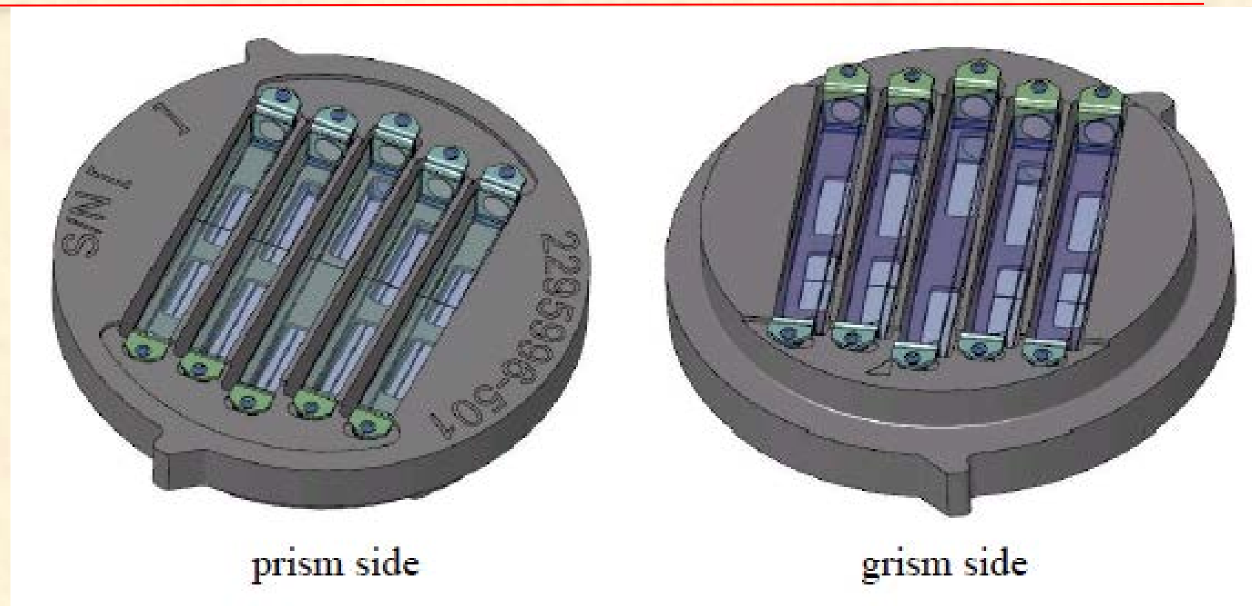
Appendix

NIRCam's Dispersive Optics

- NIRCam has 2 types of dispersive elements that can be employed for *simultaneous* spectroscopic observations
- ***Dispersed Hartman Sensors (DHSs)*** in SW channels provide R~2500 spectra over 1 – 2 μm
  - Each consists of 10 fused silica grisms + prisms that subtend a total of about 40% of the telescope pupil
- ***Si grisms*** in the 2.4 – 5 μm LW channels
  - 2 in the LW pupil wheel of each module with perpendicular dispersions, resolving power R ~ 1500
- Both Si grisms and DHSs were developed for wavefront sensing and are useful for science
  - LW grisms are approved for science, DHSs are being evaluated

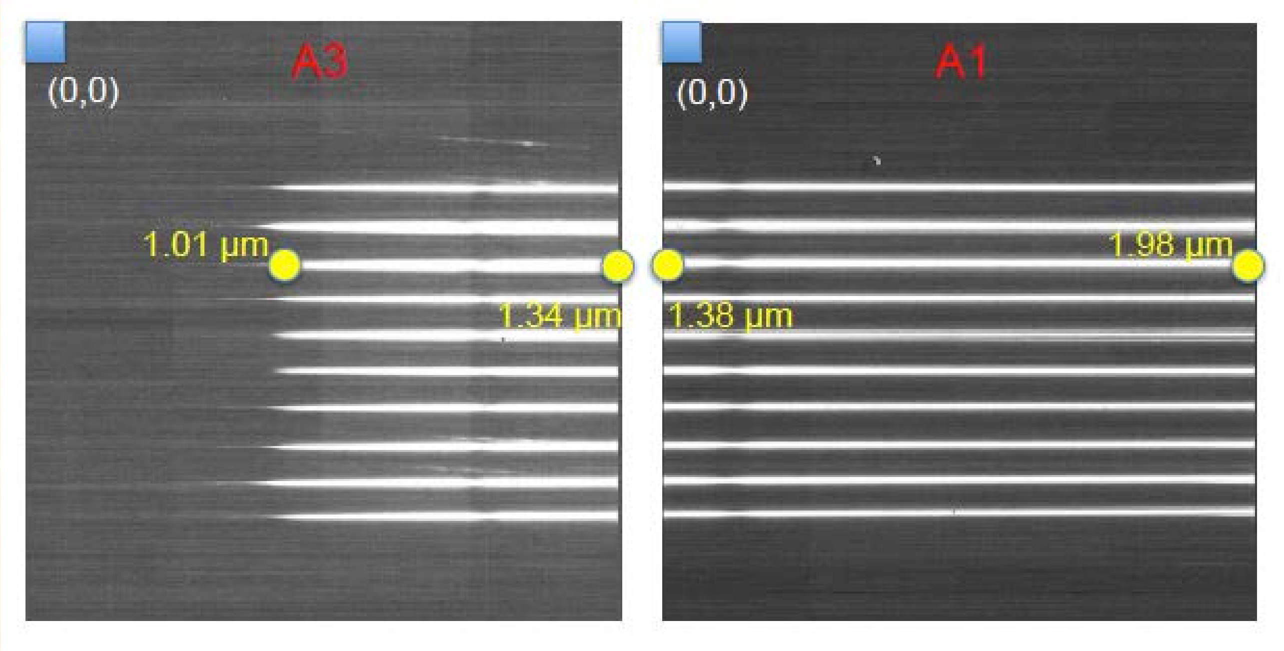
NIRCam Dispersed Hartman Sensors





- Each NIRCam DHS consists of a Fused Silica grism (disperses light) and a prism wedge (separates spectra)
  - 10 grism + prism pairs in each DHS (right) subtend a total of ~40% of JWST pupil (left)
  - DHS elements span telescope segment boundaries (0 deg shown; also 60 deg orientation)

Future Possible Simultaneous 1 – 2 μm Spectra



- DHS elements disperse ~40% JWST's light onto 2 NIRCam SW detectors with a small gap in-between

- Dispersed Hartmann Sensor (DHS) elements in the SW channel of NIRCam provide 1 – 2 μm spectra using 10 sub-apertures of the JWST pupil, potentially allowing simultaneous spectra of bright stars during LW grism observations
- This is not an approved science mode for Cycle 1; it may be approved for later cycles. There may be limitations on spectra.