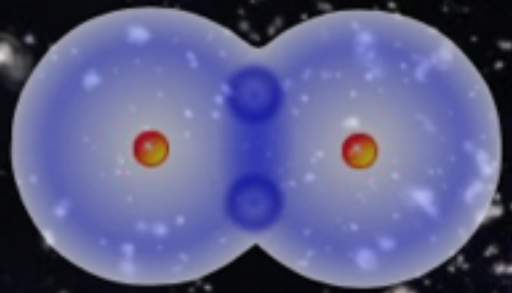
Welcome

The Physics of H_2 in space with the James Webb Space telescope

Institut d'Astrophysique de Paris, 9 Novembre 2016



Goals of the meeting

- Catch up with JWST news and developments: ERS and GO call for proposals are coming !!
- What is JWST capable of (focus on H_2 spectroscopy)?
- What do we need to do (models, lab) to prepare the CfP and science exploitation?
- Organize sub-working groups? Future meetings?

The Physics of H_2 in space with the James Webb Space telescope

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JWST spectroscopic capabilities

- Mission Status
- Instruments (focus on spectroscopy)
- Scientific potential for H_2 observations
- Timeline

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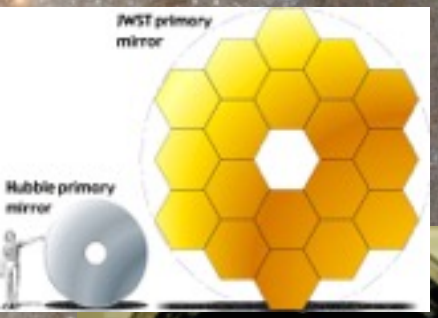
The Physics of H_2 in space with JWST
IAP, November 9th 2016

The JWST: numbers



6.5m, 25m^2 segmented mirror

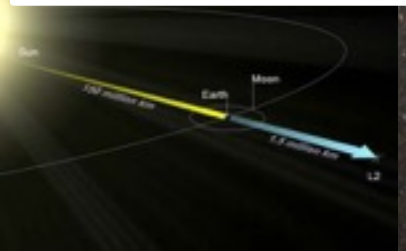
4 instruments IR

6 tons

Multi-layer sunshield (a tennis court!)

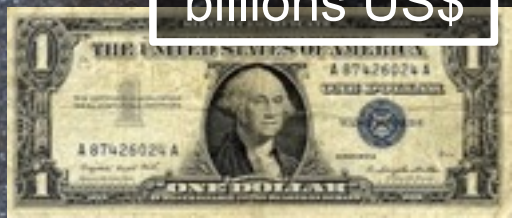
Electronics

Lifetime: 5-10yrs at L2 point



Launch: Oct 2018 by Ariane 5

Cost ~ 4.5 billions US$

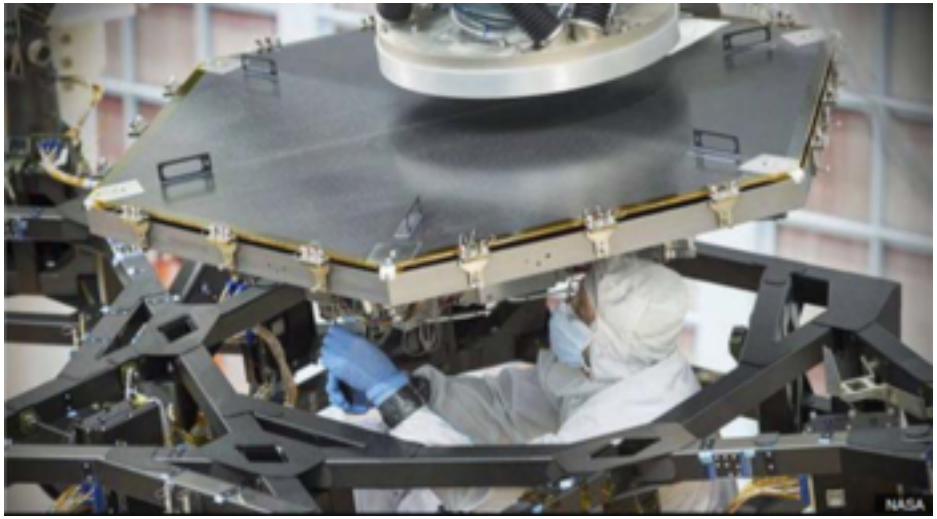


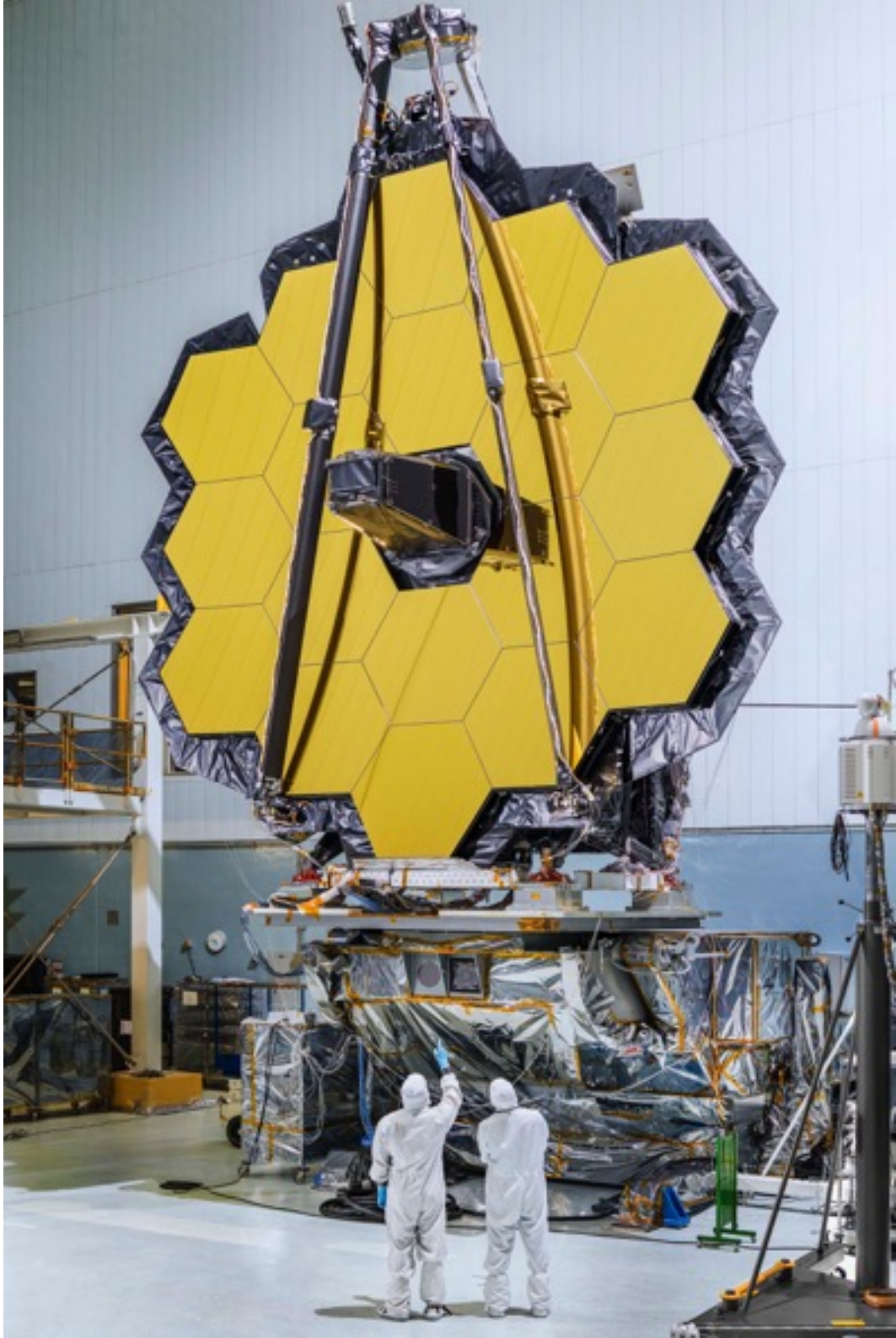
JWST Mission Status

JWST Mission Status

- May - July 2016: optical telescope element (OTE) completed and fully assembled at GSFC.

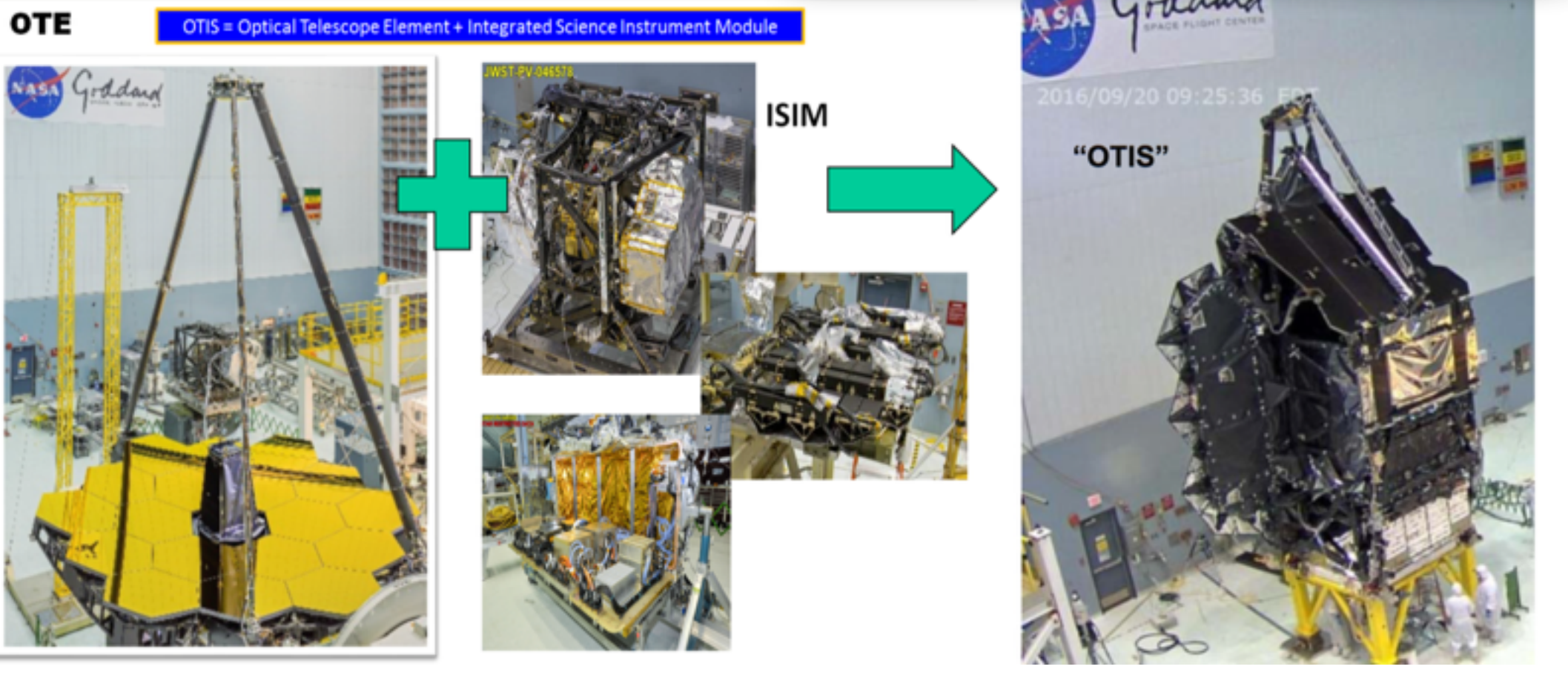
- Mirror surfaces now remain permanently uncovered !





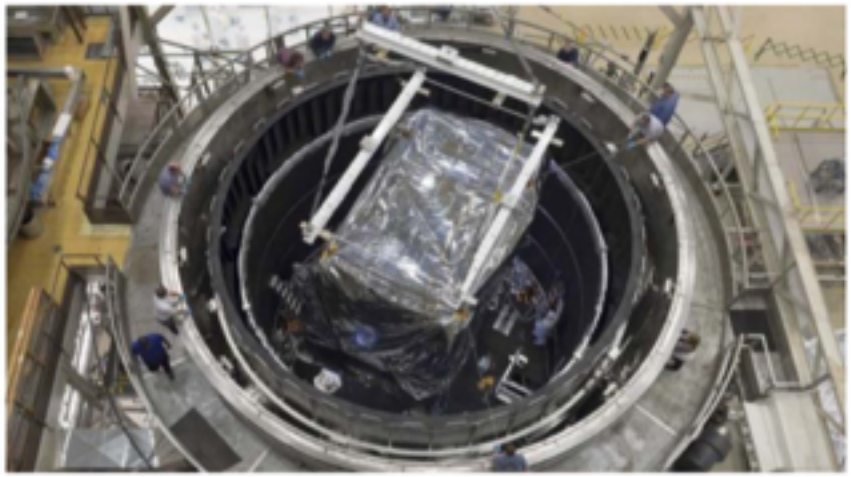
JWST Mission Status

- OTE + ISIM = “OTIS” Aug/Sept 2016 @ GSFC
- OTIS Final Assy (Harness Rad) Sept 2016



JWST Mission Status

- OTIS 2017 : cryo tests @ JSC

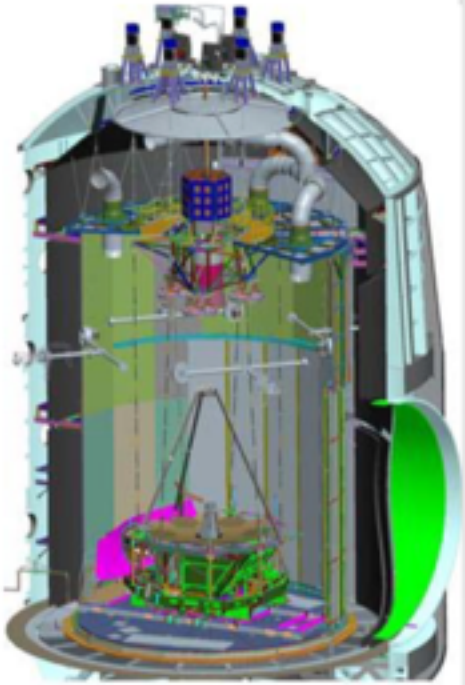


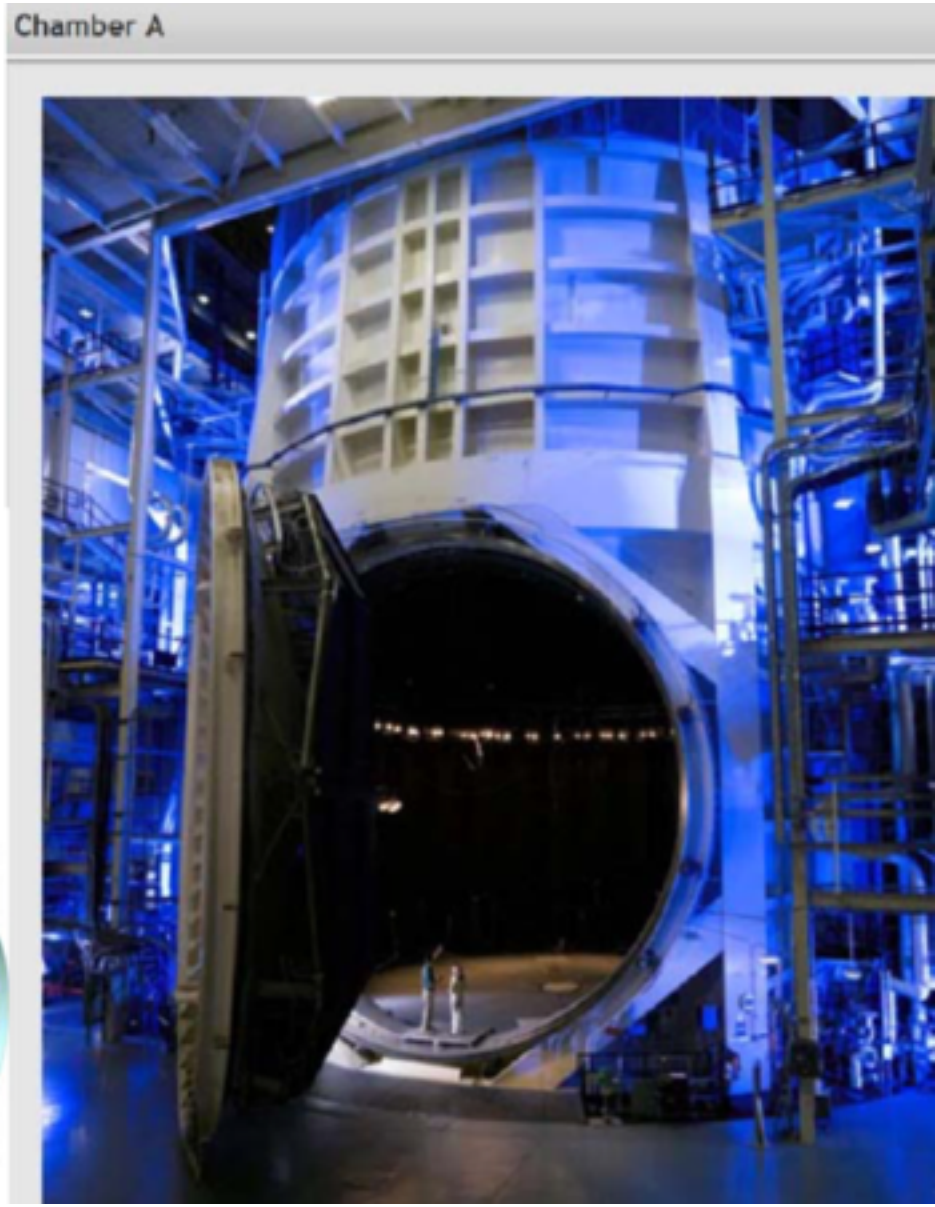
From NASA GSFC ISIM CV3 (above)

to

"SUPER SIZED" NASA JSC OTIS CV test (right)

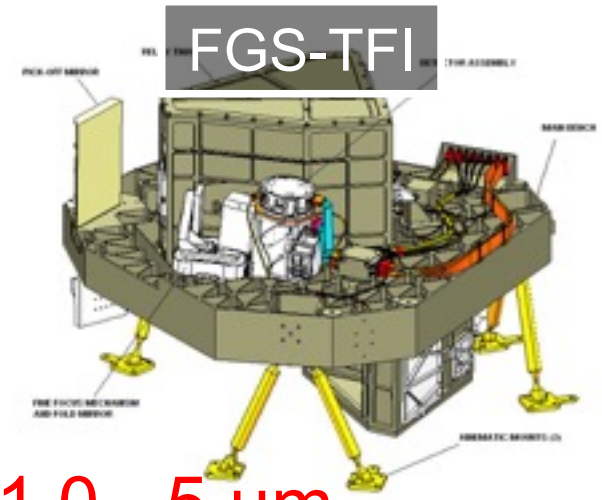
See people for size comparison



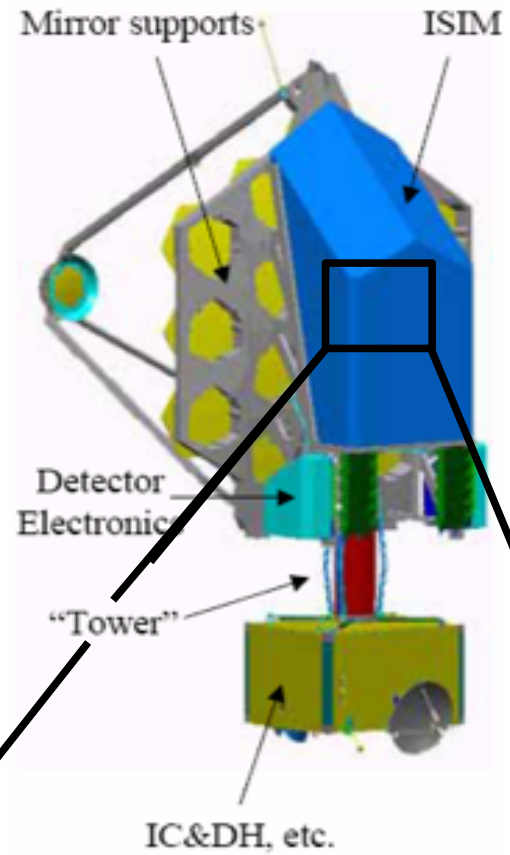


JWST Science Capabilities

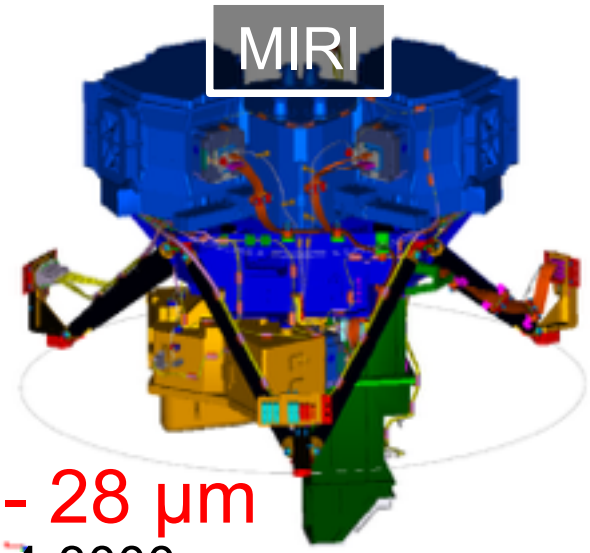
JWST Instruments



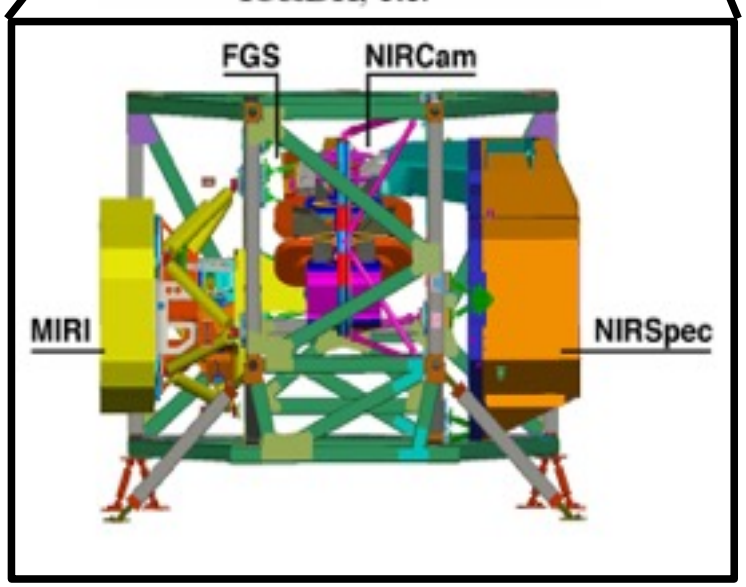
1.0 - 5 μm
R=70-150
2.2'x2.2'

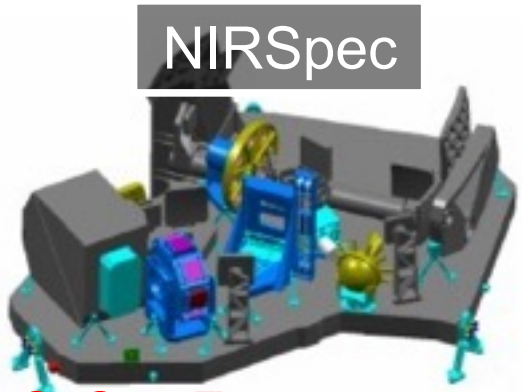


0.6 - 5 μm
R=4, 10, 100
2 × 2.2′×2.2′



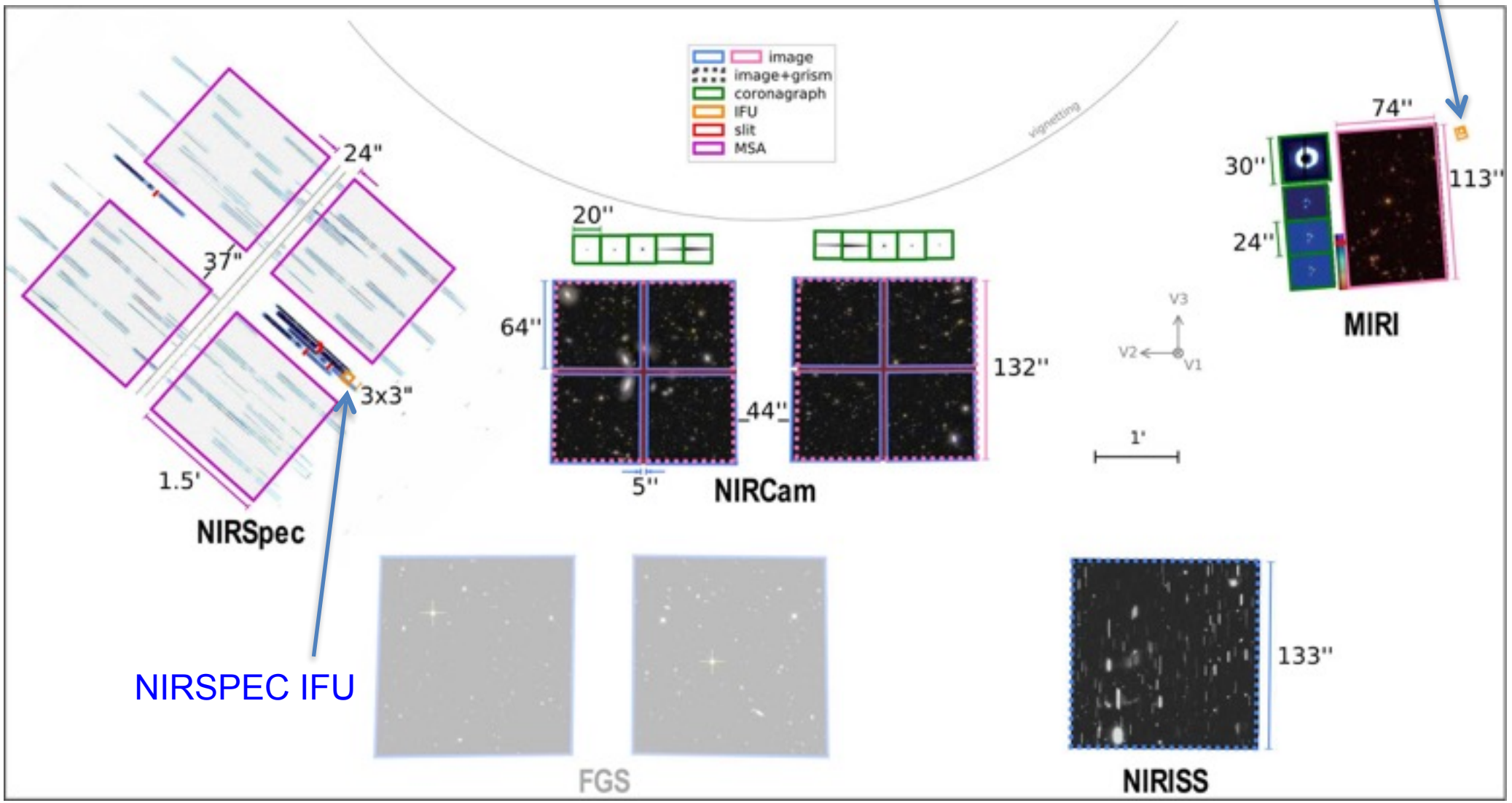
5 - 28 μm
R=4-3000
MSU 1.9'x1.4' + IFU 8''x8''





0.6 - 5 μm
R=100-3000
MSU 3'x3' + IFU 3''x3''

Mapping of the Focal Plane



- MIRI & NIRSPEC IFUs separated by about 13.5 arcmin in the JWST plane
- Guide star will not be the same for MIRI and NIRSpec
- Relative orientation of NIRSpec and MIRI on sky is different

JWST Spectroscopic capabilities

Instrument	Type	Wavelength (microns)	Spectral resolution	Field of view
NIRISS	slitless	1.0-2.5	~150	2.2′ x 2.2′
NIRCam	slitless	2.4-5.0	~2000	2.2′ x 2.2′
NIRSpec	MOS	0.6-5.3	100/1000/[2700]	9 square arcmin.
NIRSpec	IFU	0.6-5.3	100/1000/2700	3″ x 3″
MIRI	IFU	5.0-28.8	2000-3500	>3″ x >3.9″
NIRSpec	SLIT	0.6-5.0	100/1000/2700	Single object
MIRI	SLIT	5.0-10.0	60-140	Single object
NIRSpec	Aperture	0.6-5.3	100/1000/2700	Single object
NIRISS	Aperture	0.6-2.5	700	Single object

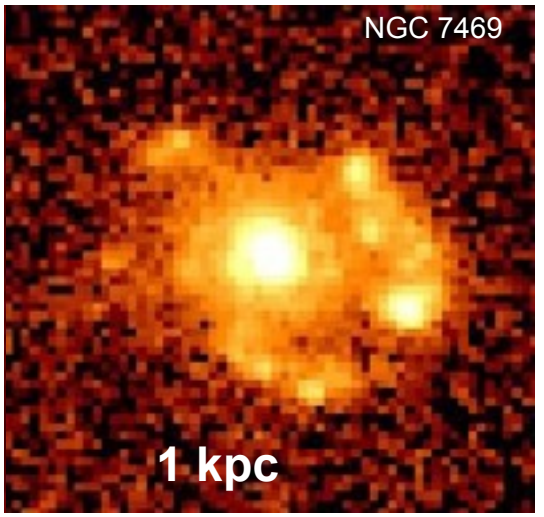
JWST IFUs: PHYSICAL COVERAGE AND RESOLUTION

	NIRSpec	MIRI
FoV	3” x 3”	4” x 4” - 8” x 8”
Sampling	0.1”	0.2” - 0.6”

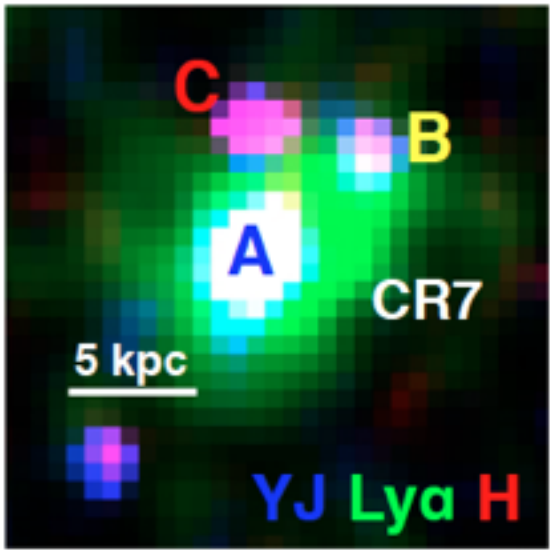
- Nearby galaxies (e.g. NGC7469 @ z= 0.016)
  - The FoV covers regions of 1-2 kpc
  - mapped on < 100pc scales
  - not ideal for large scale mosaics

- High-z galaxies (e.g. CR7 @ z=6.6)
  - The IFU FoV covers regions of 5-15 kpc
  - mapped on ~kpc scales
  - entire galaxy in one IFU pointing

SEYFERT 1 + STARBURST

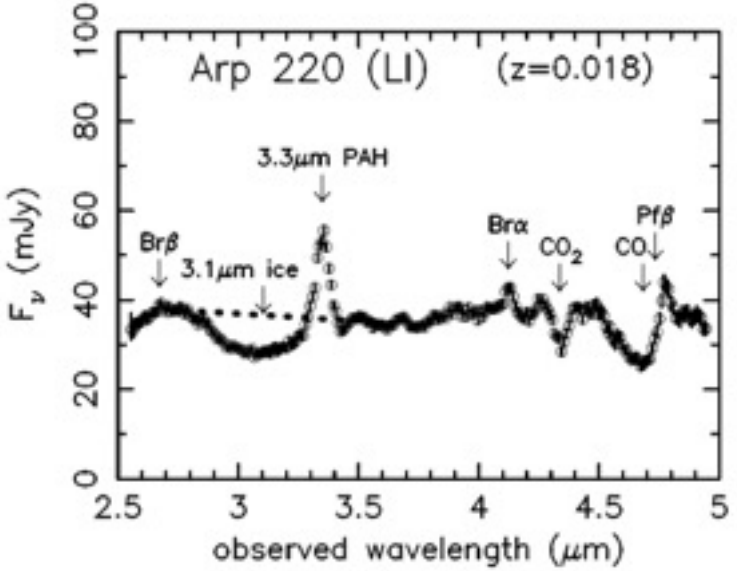


CR7

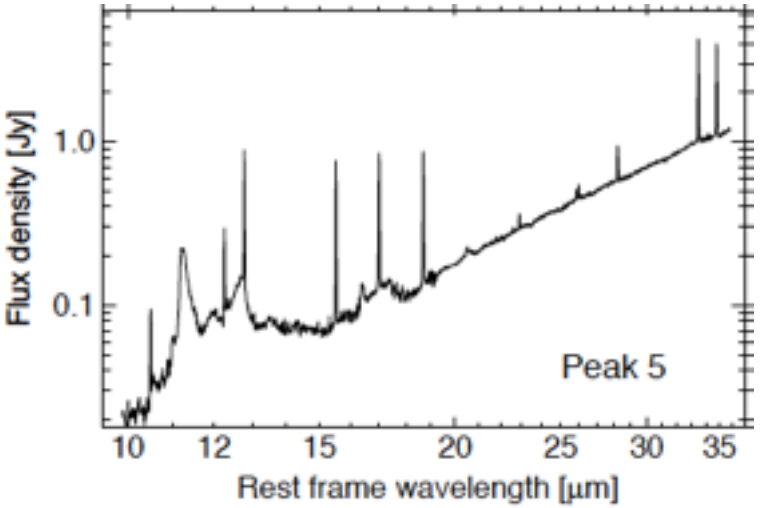


Science Capabilities: Exposure times

- **NIRSpec** (e.g. Arp 220)
  - Emission lines fluxes in the nuclear region
    - Brγ, H_2, Paγ, ~ 10^{-15} erg/s/cm/arcsec^2
    - Brα (4.3 10^{-14}) , Brβ (2.5 10^{-14})
  - Continuum ~ 2-5 mJy/arcsec^2 at 2μm
  - In 15 minutes of integration time (R2700):
    - Lines: S/N ~ 10-60 (per spaxel)
    - Cont: S/N ~ 4-10 (per spaxel, per sp. pixel)

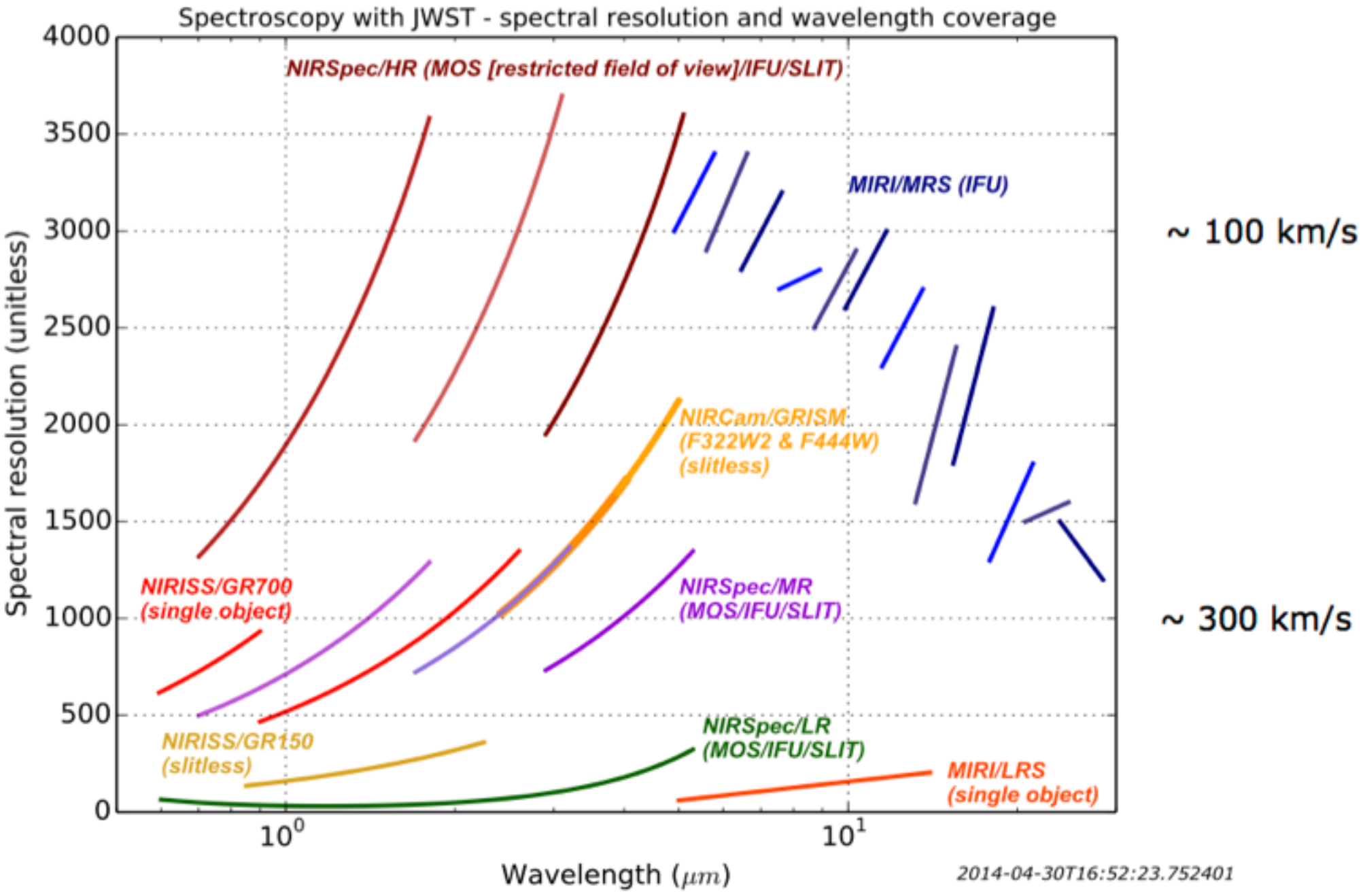


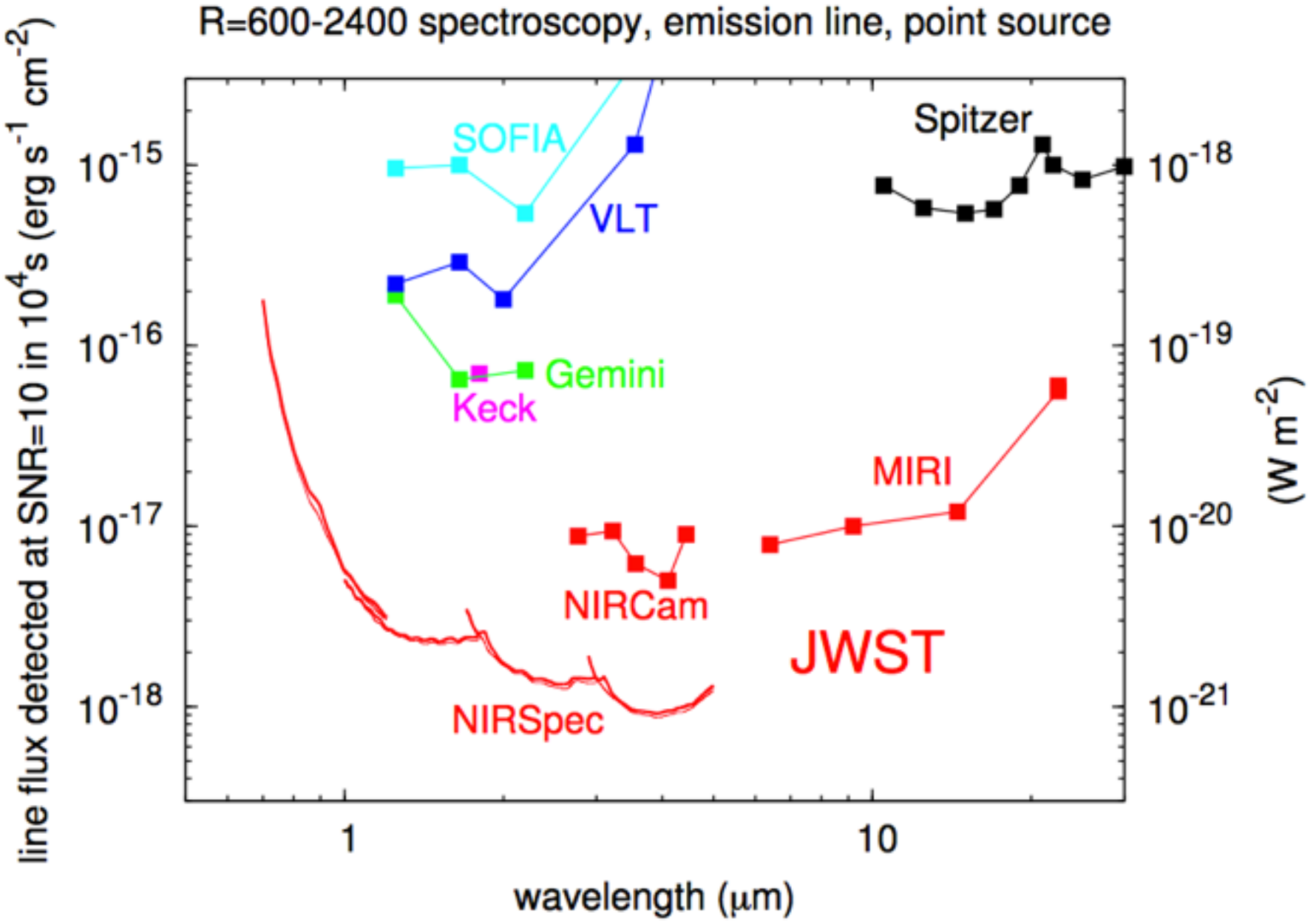
- **MIRI** (e.g. The Antennae)
  - Emission lines fluxes ~10^{-13} to ~10^{-14} erg/s/cm^2
  - Σ_{line} ~10^{-13} to ~10^{-15} erg/s/cm^2/arcsec^2
  - Continuum ~ 1 mJy – 100 mJy/arcsec^2
  - In 15 minutes of integration:
    - Lines & cont: S/N > 10 per sp. pixel (0.2”-0.3”)



Disclaimer:
Refer to STScI ETC for
Updated sensitivities

JWST Spectroscopic capabilities: spectral resolution

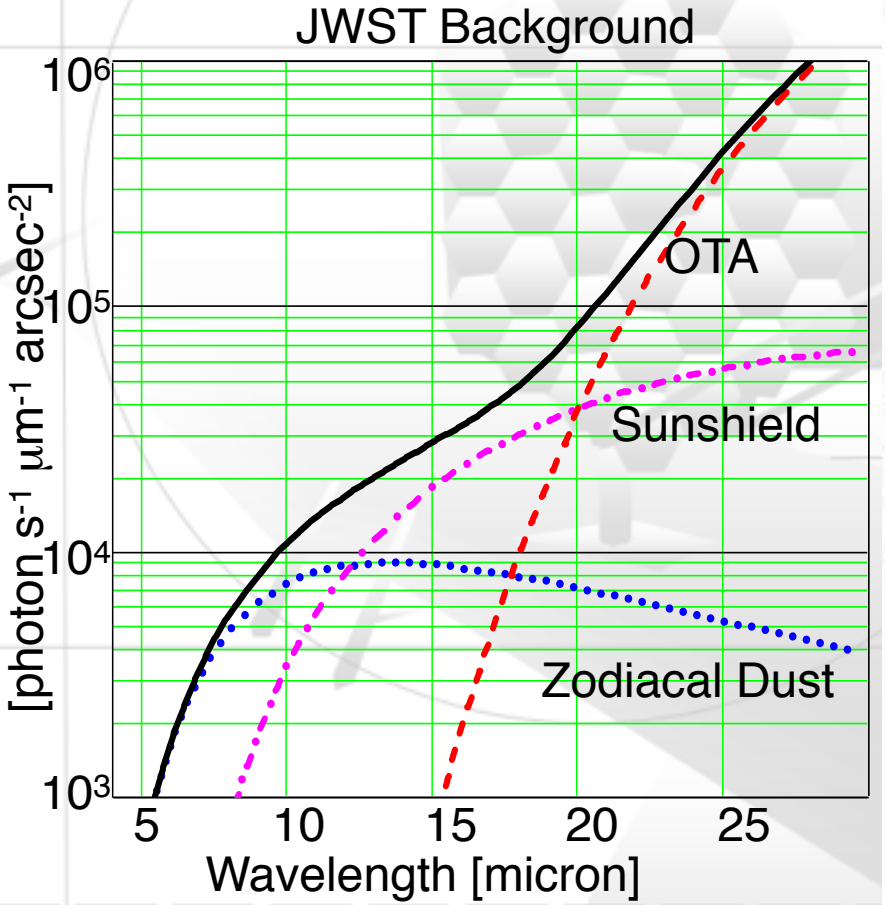


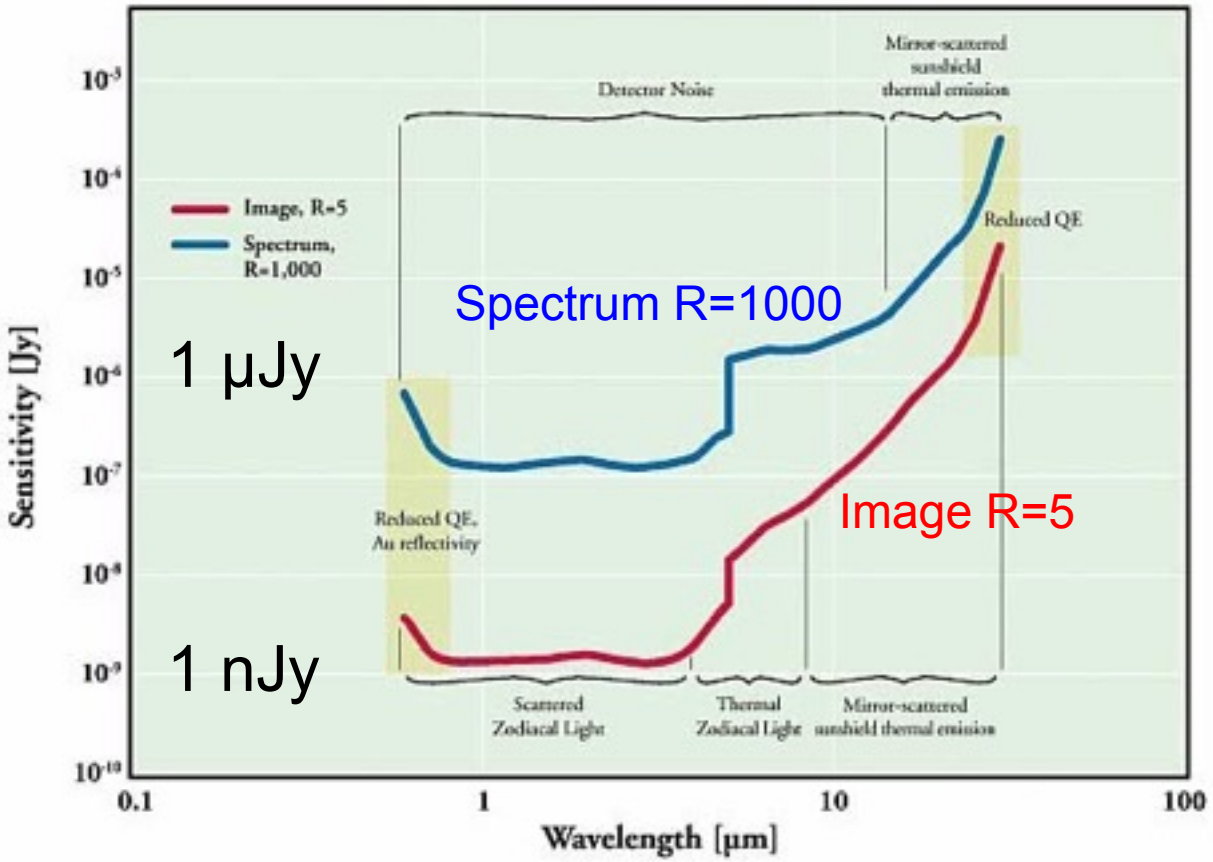


- High sensitivity (point source, 10sigma, 10 ksec):
  - x100 more sensitive than previous instruments @ similar wavelengths
  - **NIRSpec** (>1μm): Lines ~ 8.E-19 to 5.E-18 erg/s/cm^{-2} / cont.(R=100): 0.1-0.4 μJy
  - **MIRI**: Lines: ~8.E-18 to 6.E-17 erg/s/cm^{-2} continuum: 0.04 - 10 mJy

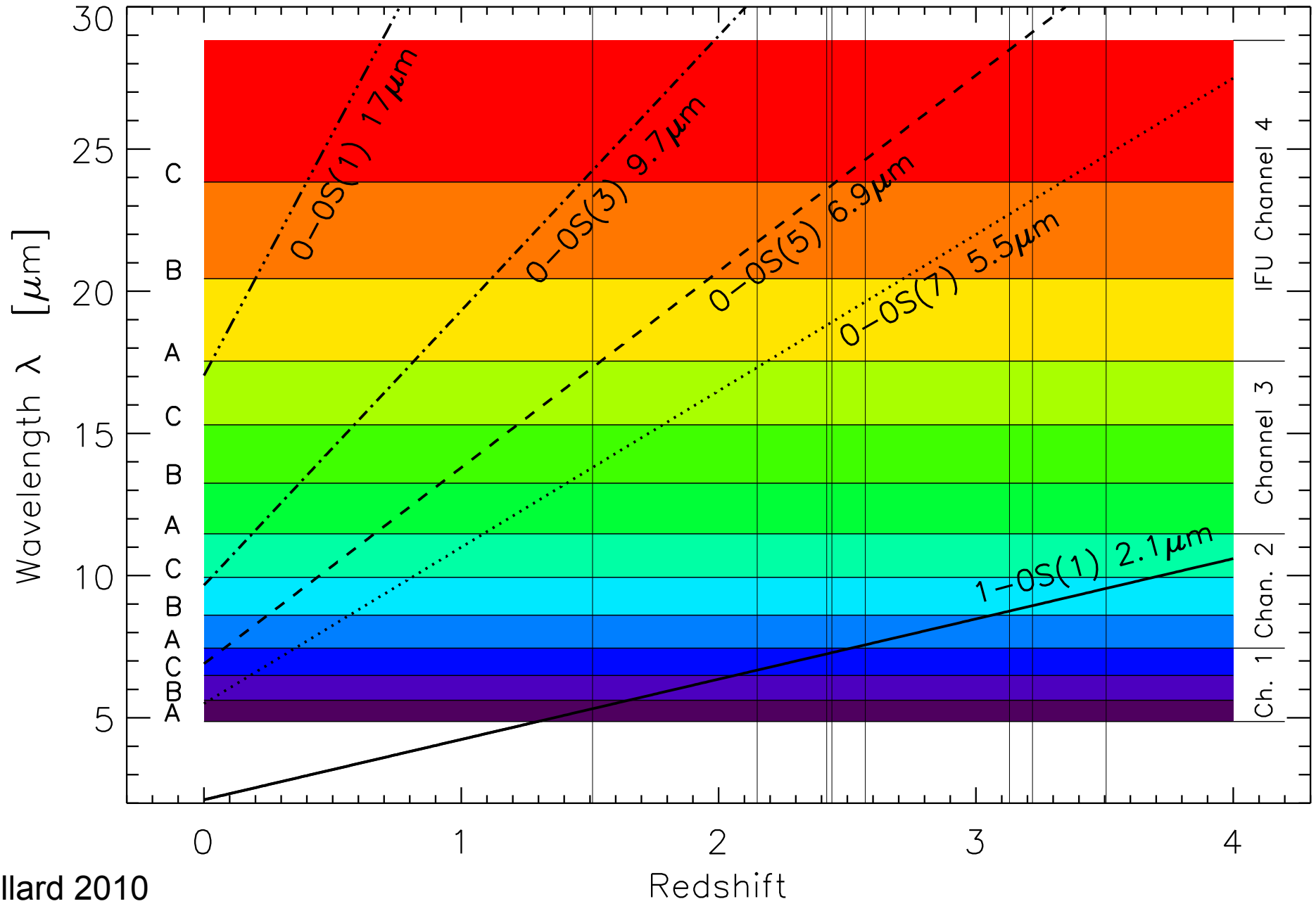
JWST Limiting Sensitivities

- Sensitivity is limited by background radiation from the sky and telescope.
- The limiting flux (10 σ) shown is for a point source at the North Ecliptic Pole (minimum background) in a 10,000 second exposure.





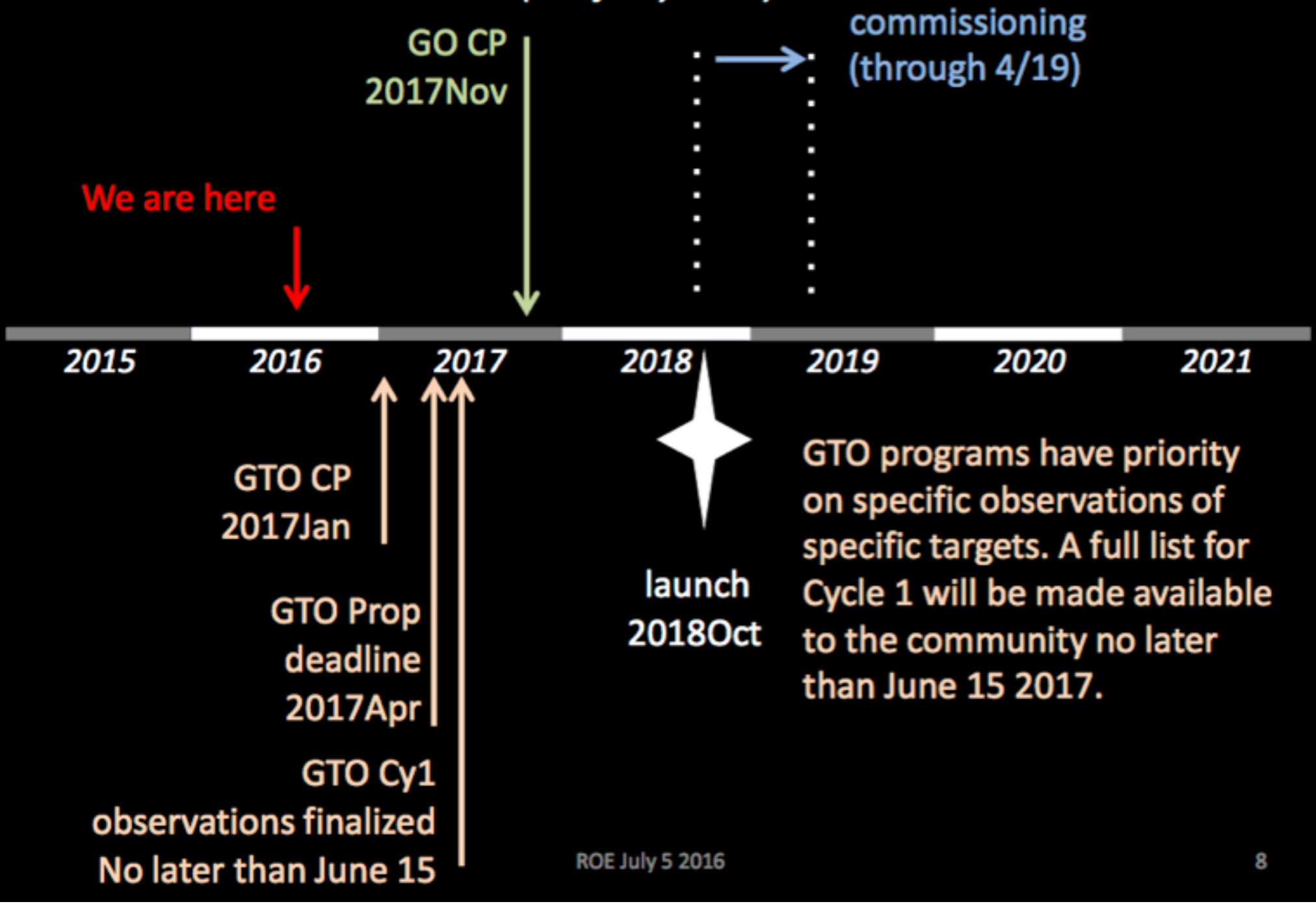
Redshifted H_2 lines with MIRI



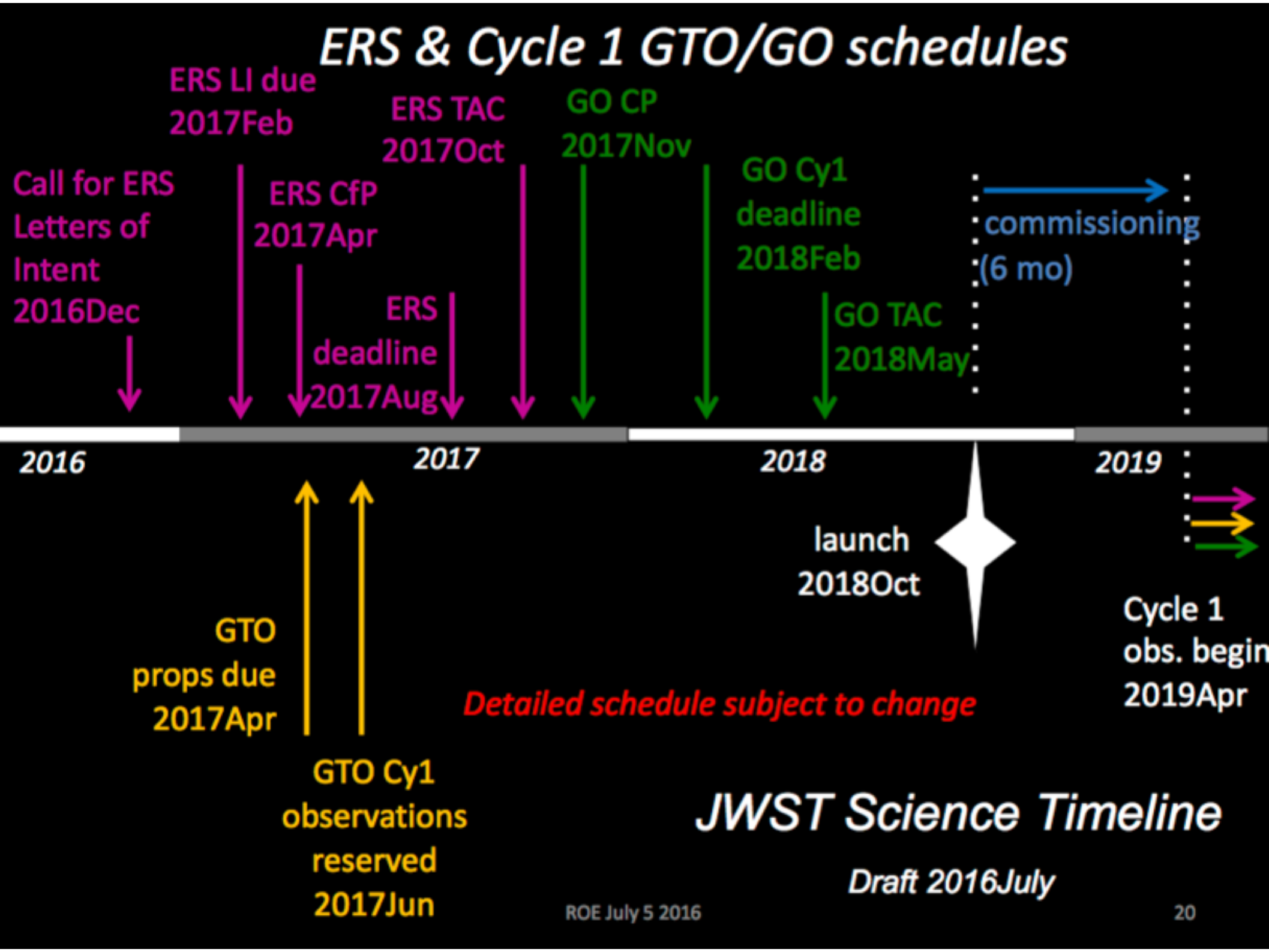
Guillard 2010

JWST Science Planning Timeline

(as of July 2016)



ERS & Cycle 1 GTO/GO schedules



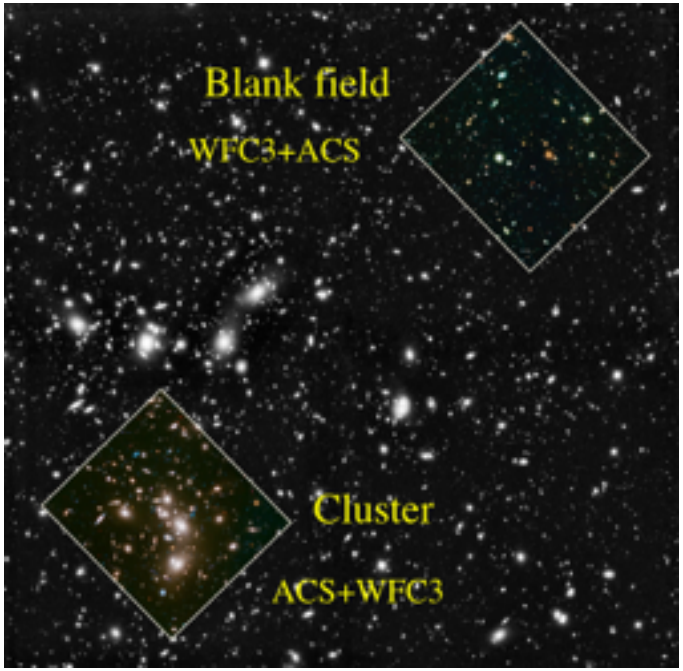
JWST Science Timeline

Draft 2016July

Parallel mode observations with JWST: definitions

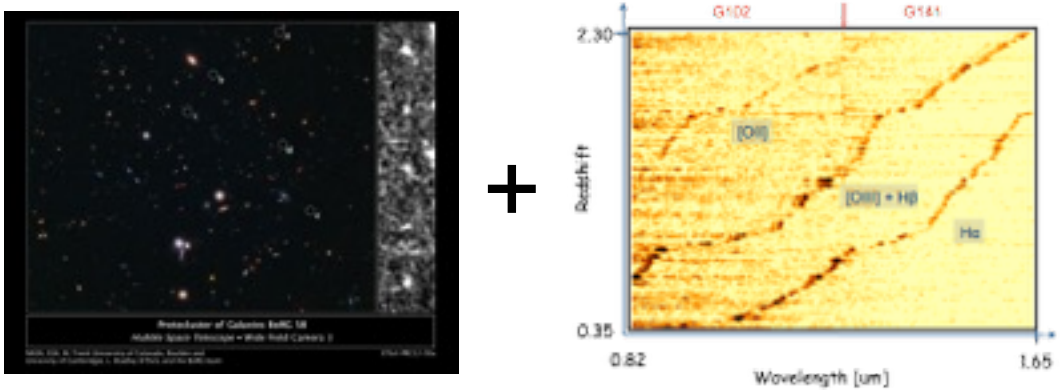
Coordinated Parallels

- All observations contribute to a single, coherent science program
  Fully achieving the science goals outlined in the proposal requires observations with all instruments specified in the proposal
- Observations are submitted as a single proposal
  APT templates will be developed for JWST
- Coordinated parallels are common with HST
  e.g. ACS+WFC3 for multi-wavelength imaging



Pure Parallels

- Pure parallel observations constitute stand-alone science programs that are crafted to take advantage of scheduling opportunities offered by unrelated, independent prime science programs
  - Pure parallels increases the science return by adding new science
  - Observing parameters are set based on the scheduling requirements of the prime program; pure parallels do not influence those requirements
- Observations are submitted as a separate, stand-alone program
  Standard APT templates for JWST.
  Parallel programs are matched against suitable prime programs once those programs are fully defined



The Brightest of Reionising Galaxies (WFC3-IR direct + WFC3 Infrared Spectroscopic Parallel Survey – WFC3-IR grism)

Parallel mode observations with JWST: implementation status

As of Oct 2016:

- All two-instrument pure-parallel combinations will be available for Cycle 1

- Instrument combinations for coordinated parallels have been prioritised by STScI, working in conjunction with the SWG. Top 5 priorities are:
    1. NIRCam Imaging + MIRI Imaging (*)
    2. NIRCam Imaging + NIRISS WFSS (*)
    3. MIRI Imaging + NIRISS WFSS (*)
    4. NIRSpec MOS + NIRCam Imaging (TBD)
    5. NIRCam Imaging + NIRISS Imaging (*)

- Coordinated parallel templates for at least 4 combinations (*) and GO Pure Parallels will be available by the start of the APT GTO proposal preparations for Cycle 1. **All parallel observations are limited to two instrument combinations in Cycle 1**

- The remaining coordinated parallel templates (incl. 3-instrument coordinated parallels) will be implemented prior to launch and will be available in Cycle 2.

Summary

- JWST NIRSpec and MIRI IFS (coordinated) programs extremely powerful. Open a qualitative new window into studies of extended sources because its unique combination of features:
  - Increased sensitivity by factors 100 wrt previous instruments
  - Wide spectral coverage from the optical (0.6μm) to the mid-IR (28μm)
  - Stable sub-arcsec angular resolution over the entire spectral range
  - Similar intermediate (R~2000-3000) spectral resolution over spectral range

… typical on-target times will be short, minutes to a few hours (for faint cosmological sources), and consequently overhead time can be not negligible.

… Therefore we should think our science and observational strategy carefully, keeping in mind the efficiency of our individual programs, and the overall productivity and science return of JWST.

Extras

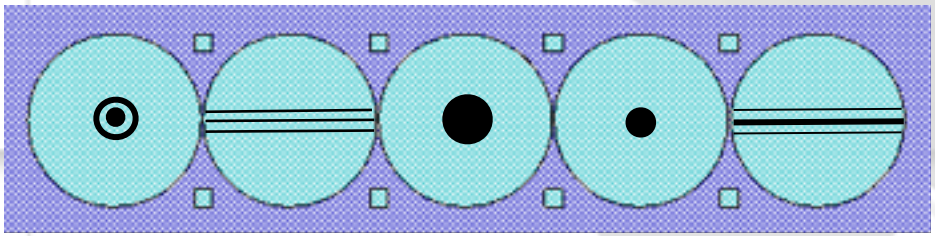
The Near Infrared Camera

2 functionally identical (mirror image) modules

- 2 channels in each module:

Short Wavelength (0.6-2.3 μm)	Long Wavelength (2.4-5.0 μm)
HgCdTe FPA Format (2×2) × (2040 × 2040)	HgCdTe FPA Format 1 × (2040 × 2040)
0.032 arcsec/pixel	0.065 arcsec/pixel
FOV= 2.21×2.21 arcmin^2	FOV= 2.21×2.21 arcmin^2

- Sensitivity (10σ, R=4, 10^4 s):
  - 1.1 μm: 10.4 nJy
  - 2.0 μm: 12.1 nJy
  - 4.4 μm: 24.5 nJy
- Coronagraphic masks:



Filters (W ⇒ R=4, M ⇒ R=10, N ⇒ R=100)

Short Wavelength	Long Wavelength
F070W (Filter Wheel)	F270W (Filter Wheel)
F090W	F356W
F110W	F444W
F150W	F250M
F200W	F300M
F140M	F335M
F212N (1% H_2 2.12 μm)	F360M
F150W2 (WFS Filter)	F390M
F225M(A), F164N (1% Fe)(B)	F430M
F108N (1% He 1.080 μm)	F460M
F187N (1% Pα 1.875 μm)	F480M
	F405N (1% Brα 4.05 μm)
F210M (Pupil Wheel)	F325N (1% H_2 3.25 μm)
F162M	F418N (1% H_2 4.18 μm)
F182M	F460N (1% CO 4.6 μm)
	F470N (1% H_2 4.70 μm)

The Near Infrared Spectrograph

R=1000 mode

1.0 - 5.0 μm
Micro-shutter array (MSA) or fixed slits
Covered by three 1st-order gratings:
- 1.0 - 1.8 μm
- 1.7 - 3.0 μm
- 2.9 - 5.0 μm

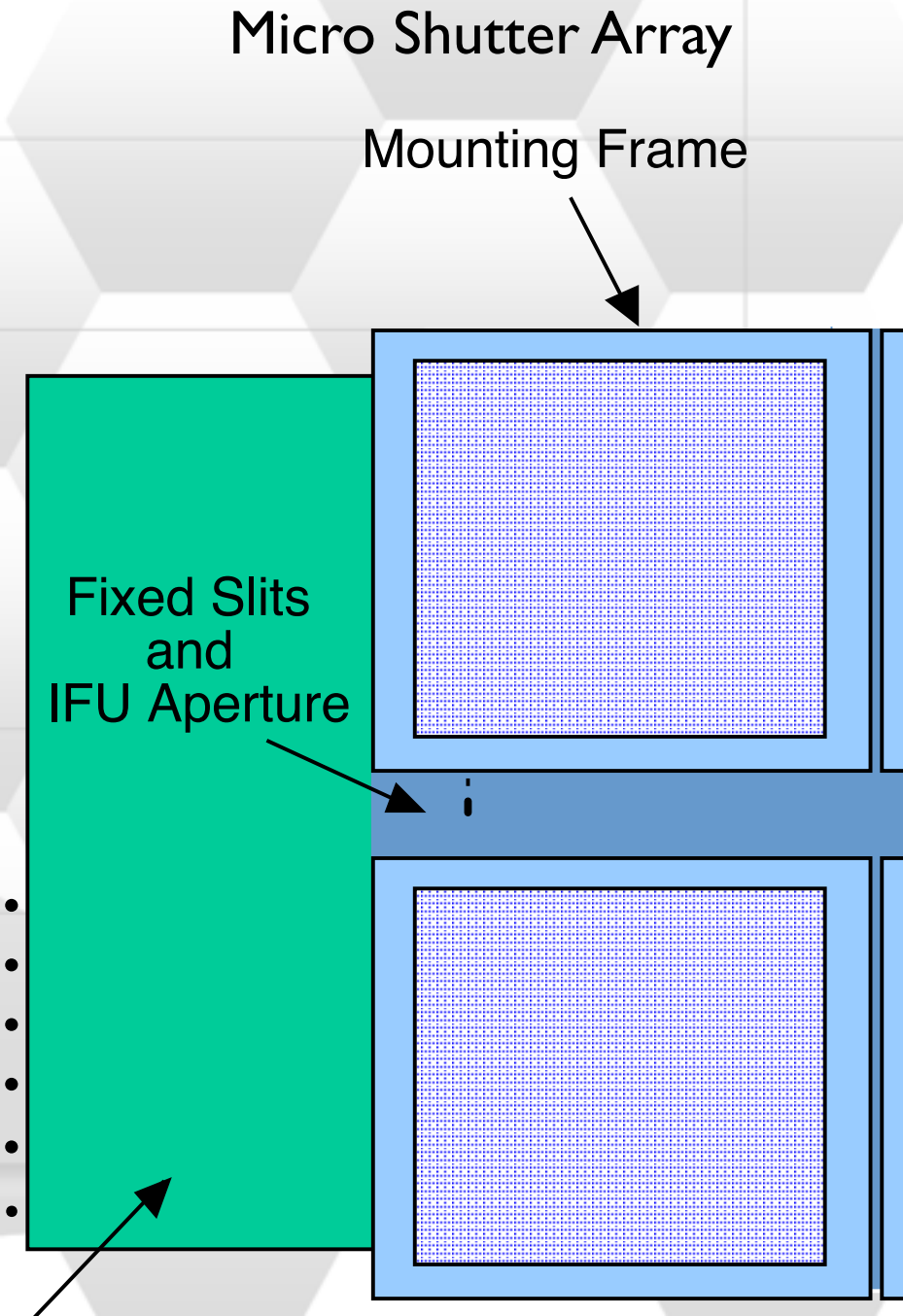
Sensitivity (10σ in 10^4 s):
5.2×10^{-19} erg cm^{-2} s^{-1}
(emission line)

R=3000 mode

1.0 - 5.0 μm
Fixed slit or integral field unit
Also uses three 1st-order gratings

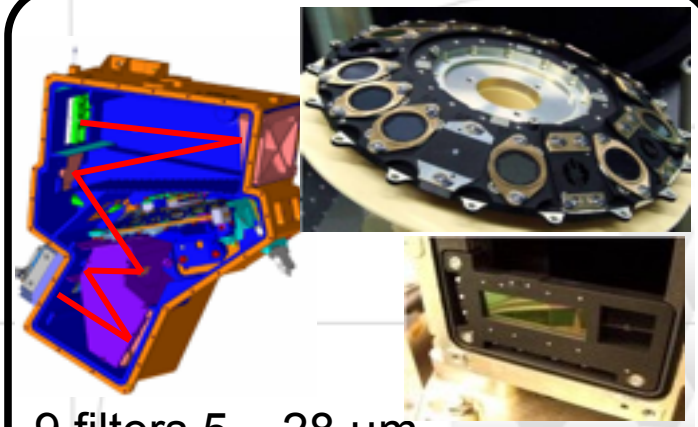
R=100 mode

0.6 - 5.0 μm
Micro-shutter array or fixed slits
Covered by single dual-pass prism
Sensitivity (10σ in 10^4 s): 120 nJy at 2 μm

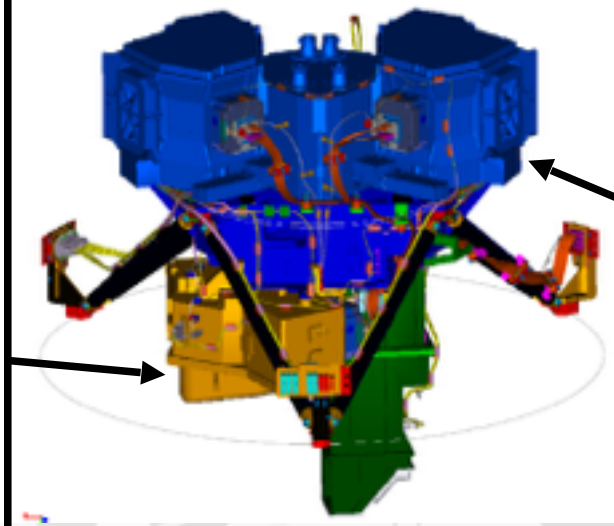


MIRI (Mid-Infrared Instrument)

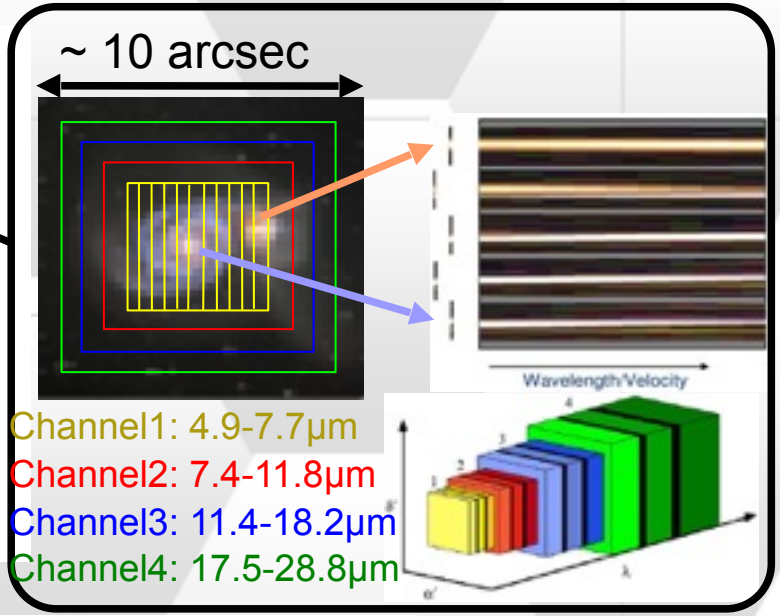
Imager



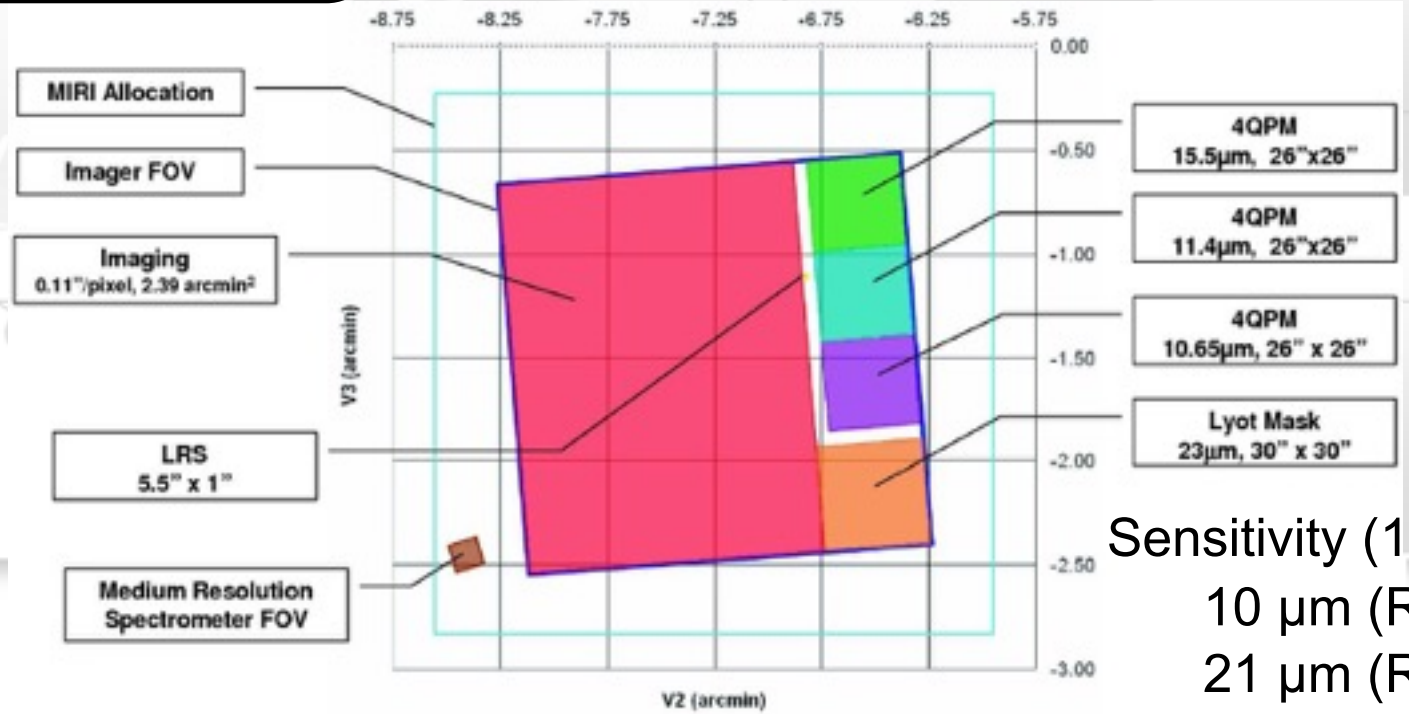
-9 filters 5 – 28 µm
- 4 coronographs
- 1 spectro R~100 (5-11µm)
- FWHM = 0.19” @ 5.6µm



IFU Spectrograph



Channel1: 4.9-7.7µm
Channel2: 7.4-11.8µm
Channel3: 11.4-18.2µm
Channel4: 17.5-28.8µm



Sensitivity (10σ in 10^4 s):
10 µm (R=5): 0.7 µJy
21 µm (R=4.2): 8.7 µJy

POINTING & TARGET ACQUISITION. OVERHEADS

- Point and Shoot strategy : possible but pointing accuracy ~ 0.3 – 0.4”
- A better accuracy generally needed, then Target Acquisition (TA) required

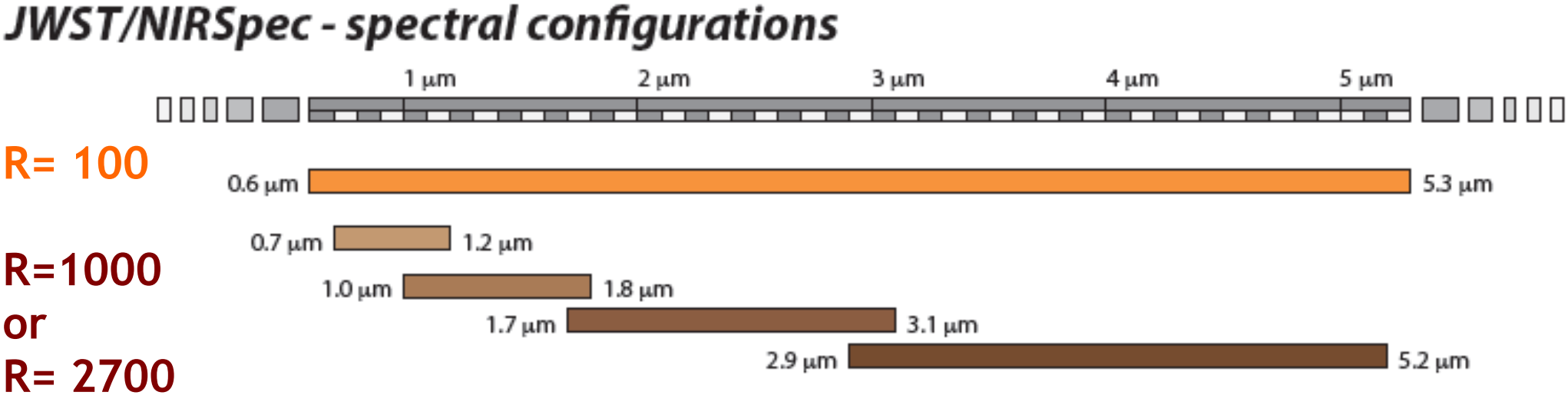
- In a coordinated proposal (one visit): 1 slew + 2 GS+TAs are required
- Overheads:
  - One large telescope slew: 1800 sec
  - 2 GS acquisition: 2 x 240 sec
  - 2 x TA: 2 x 600 sec
  - One slew between instruments (13’): ~150 sec

➢ all this: ~ 1.2h

- In a non-coordinated mode (2 visits, dif. epoch to keep orientation): 2 slews
- Overheads: coordinated proposal + 32 minutes in addition

SPECTRAL COVERAGE & RESOLUTION

NIRSpec 0.7 to 5 μm in four contiguous spectral settings (R~1000-3000)



MIRI 5 to 28.8 μm in three settings with four non-contiguous spectral range

JWST/MIRI – spectral configurations

R (x10³)=	***3.1-3.7***	***2.9-3.3***	***1.8-2.9***	***1.3-1.9***
λ (μm)=	***4.9-7.8***	***7.5-11.9***	***11.5-18.2***	***17.5-28.8***