
# The JWST NIRCam extragalactic GTO program

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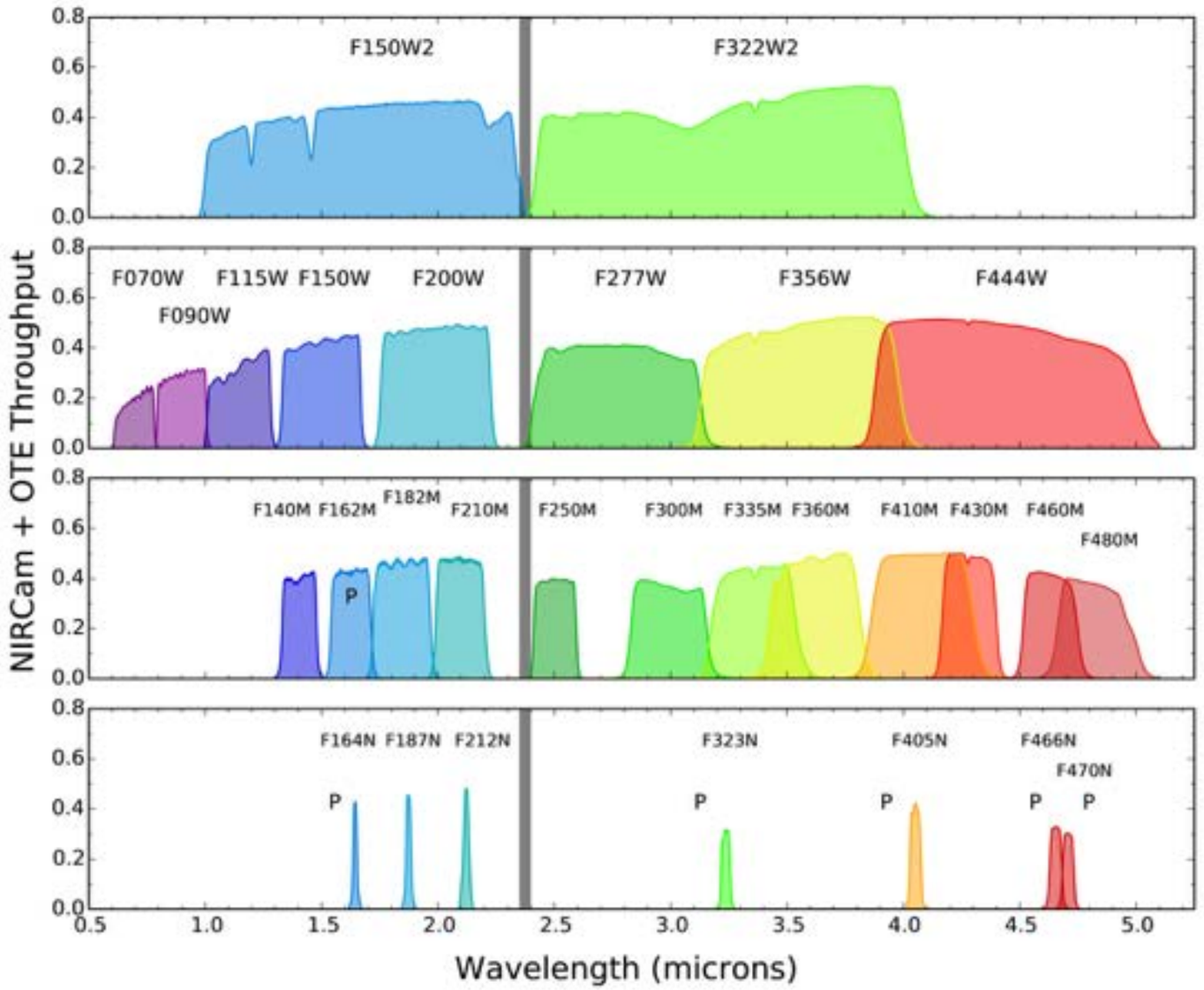
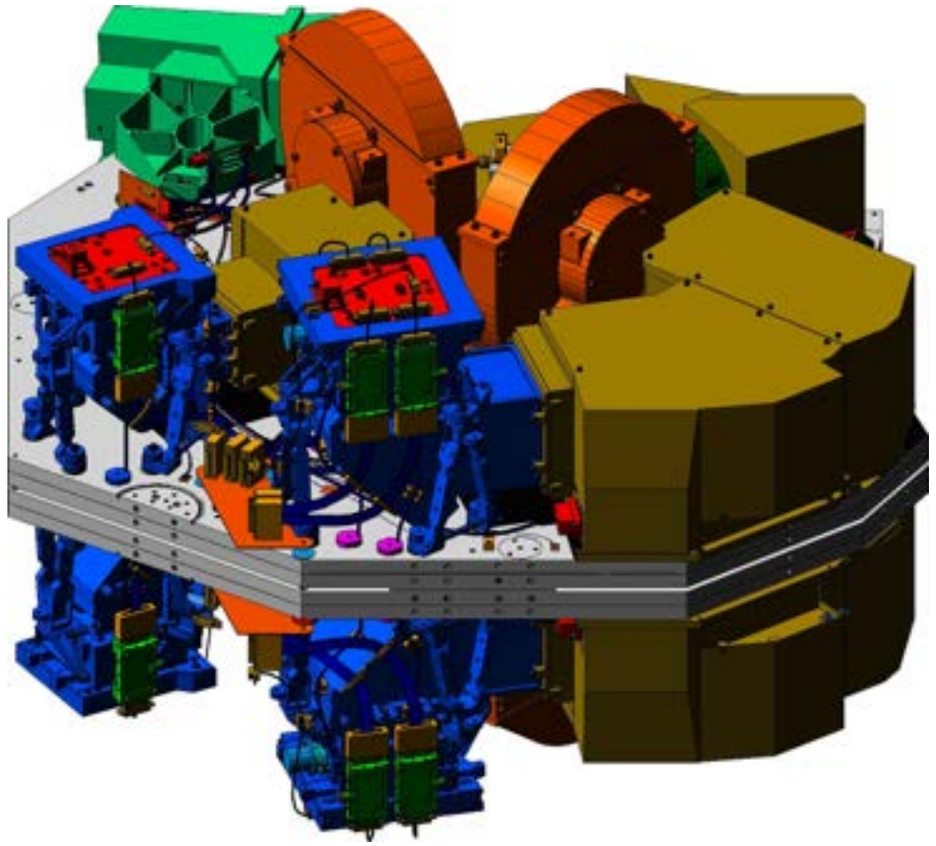
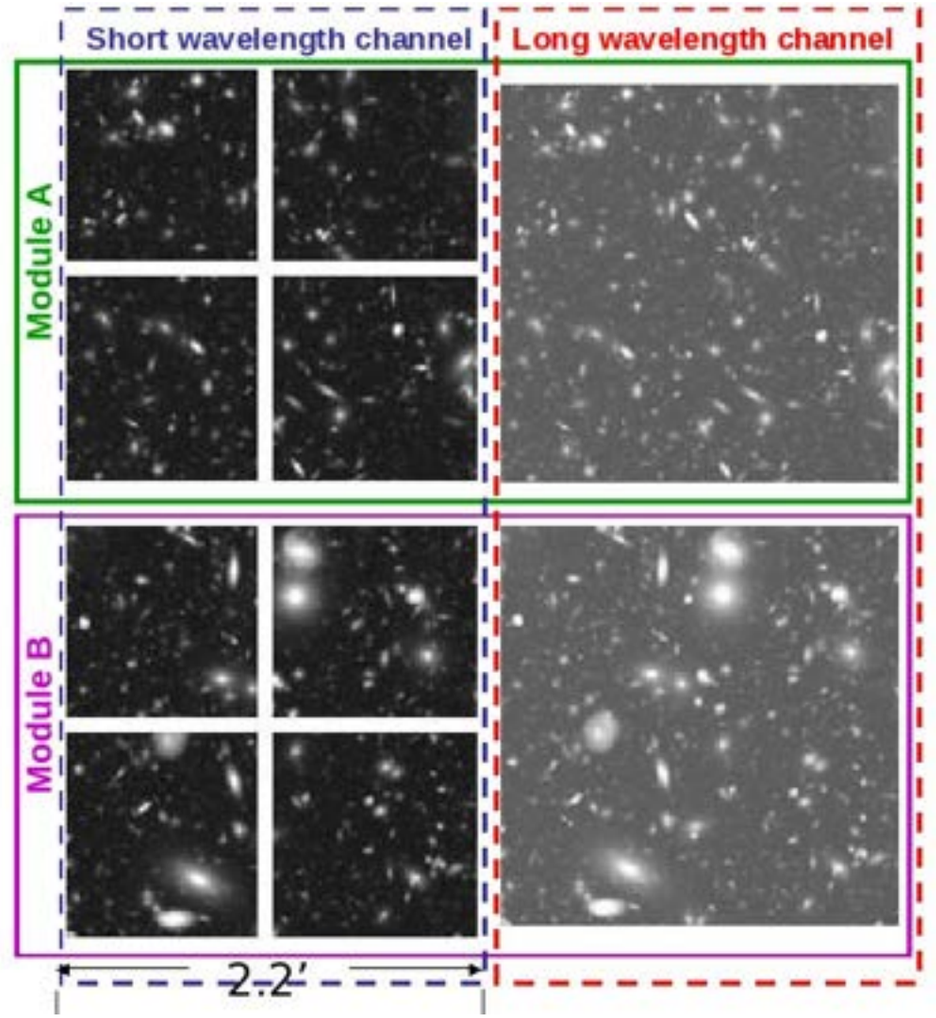
# NIRCam

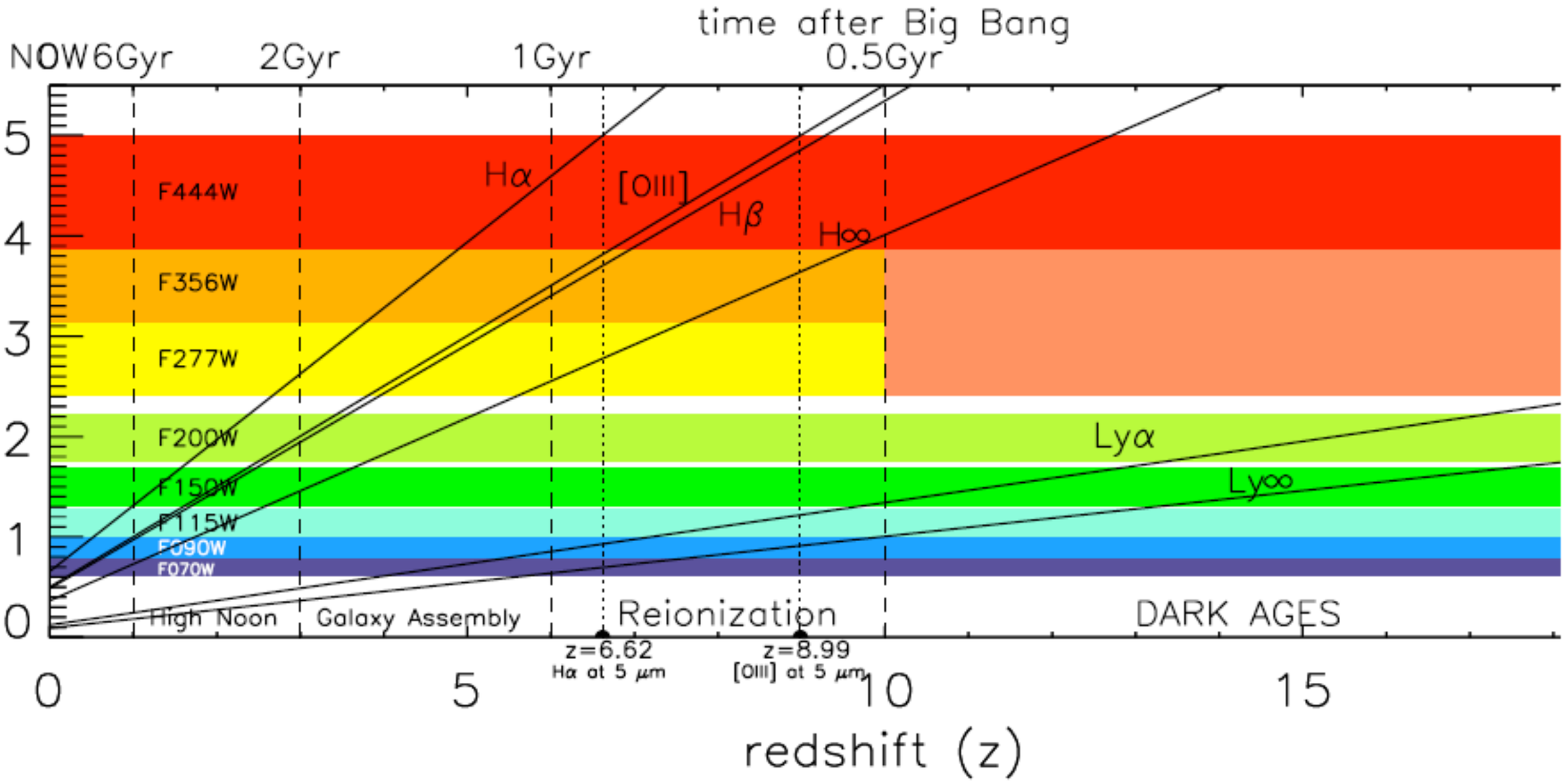
- Imaging from 0.6 to 5 microns, with a dichroic to split between a short wavelength channel (0.6 - 2.3 microns) and long wavelength channel (2.4 - 5.0 microns)
- The entire assembly is mirrored for a full FOV of 2.2’ x 4.4’
- Spatial resolution of ~0.06” below 2 microns, and diffraction-limited at longer wavelengths



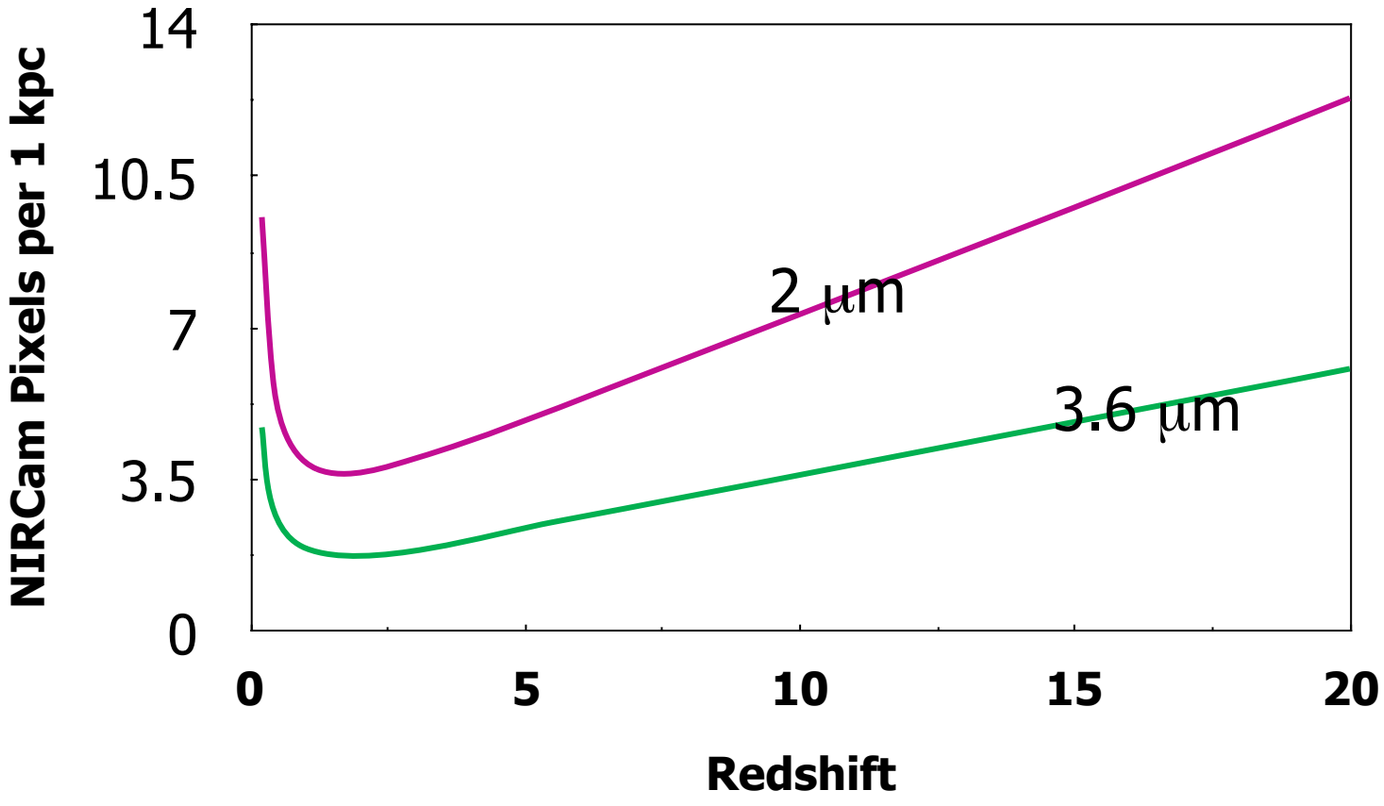


# NIRCam probes new parameter space

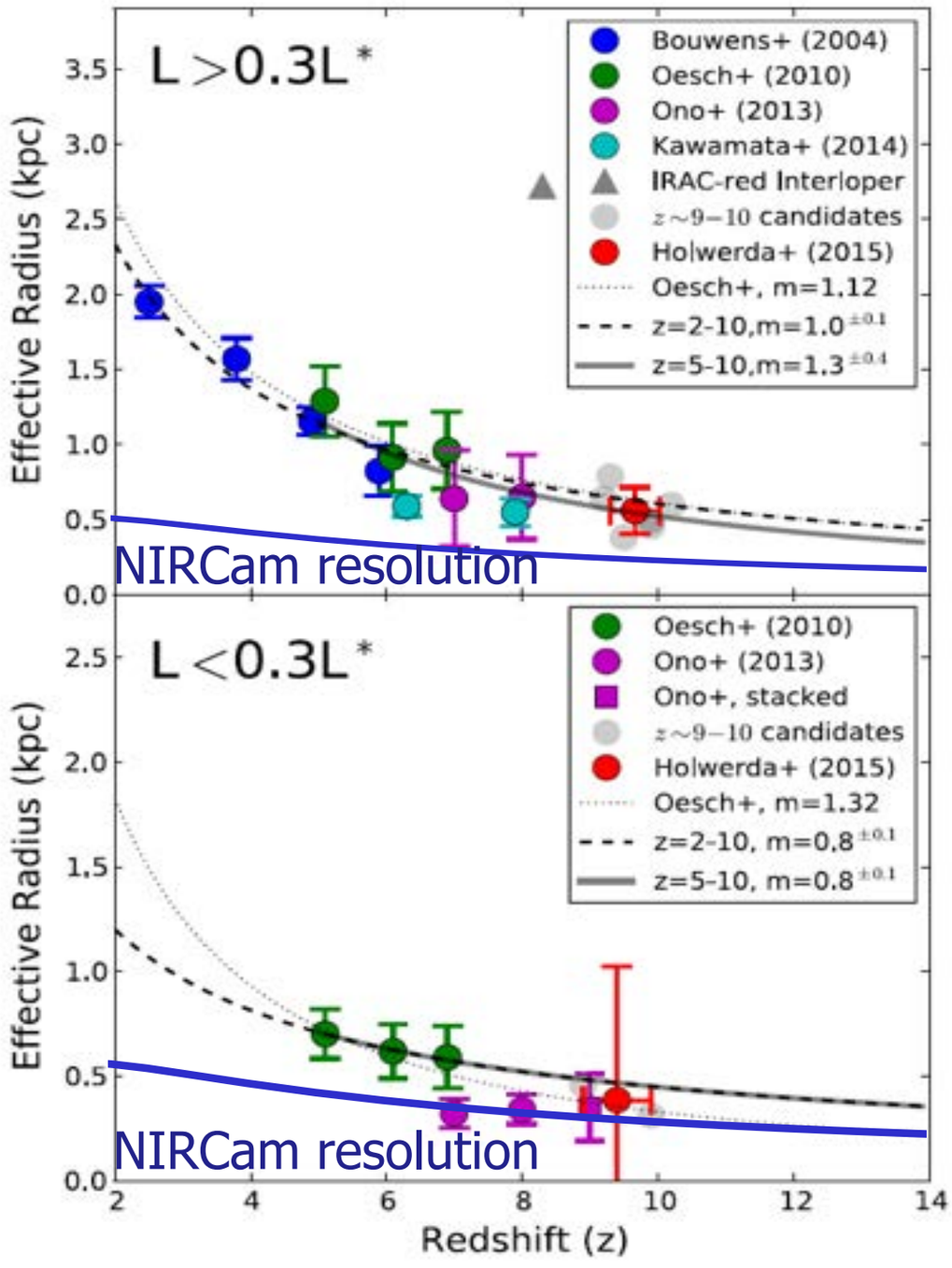



- Deep rest-optical constraints at z >3 - stellar masses to z~10.
- Sensitive enough to detect galaxies at z >11.
- Rest-UV coverage even beyond z >15.

# Importance of NIRCam resolution




JWST + NIRCam have enough resolution to study the structure of distant galaxies. The plots at right show the two-pixel resolution at 2 microns.




Holwerda et al. 2015 ApJ, 808,6

# NIRCam GTO Science Goals

Redshift Frontier:  z>9 galaxies

- Early galaxy emergence

End of Dark Ages (7 < z < 9)

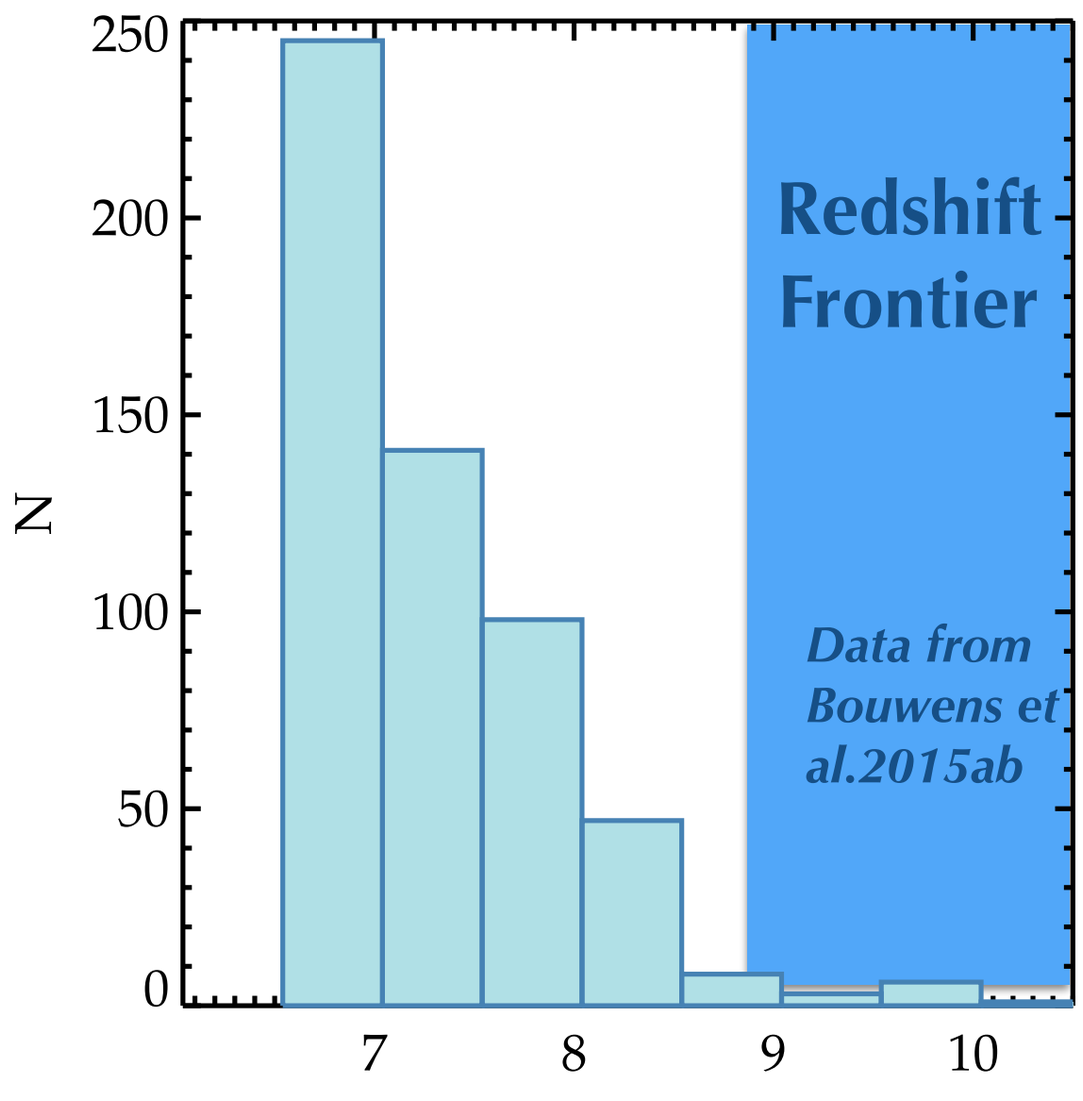
- Contribution to Reionization and early galaxy growth.

Galaxy Buildup (3 < z < 6)

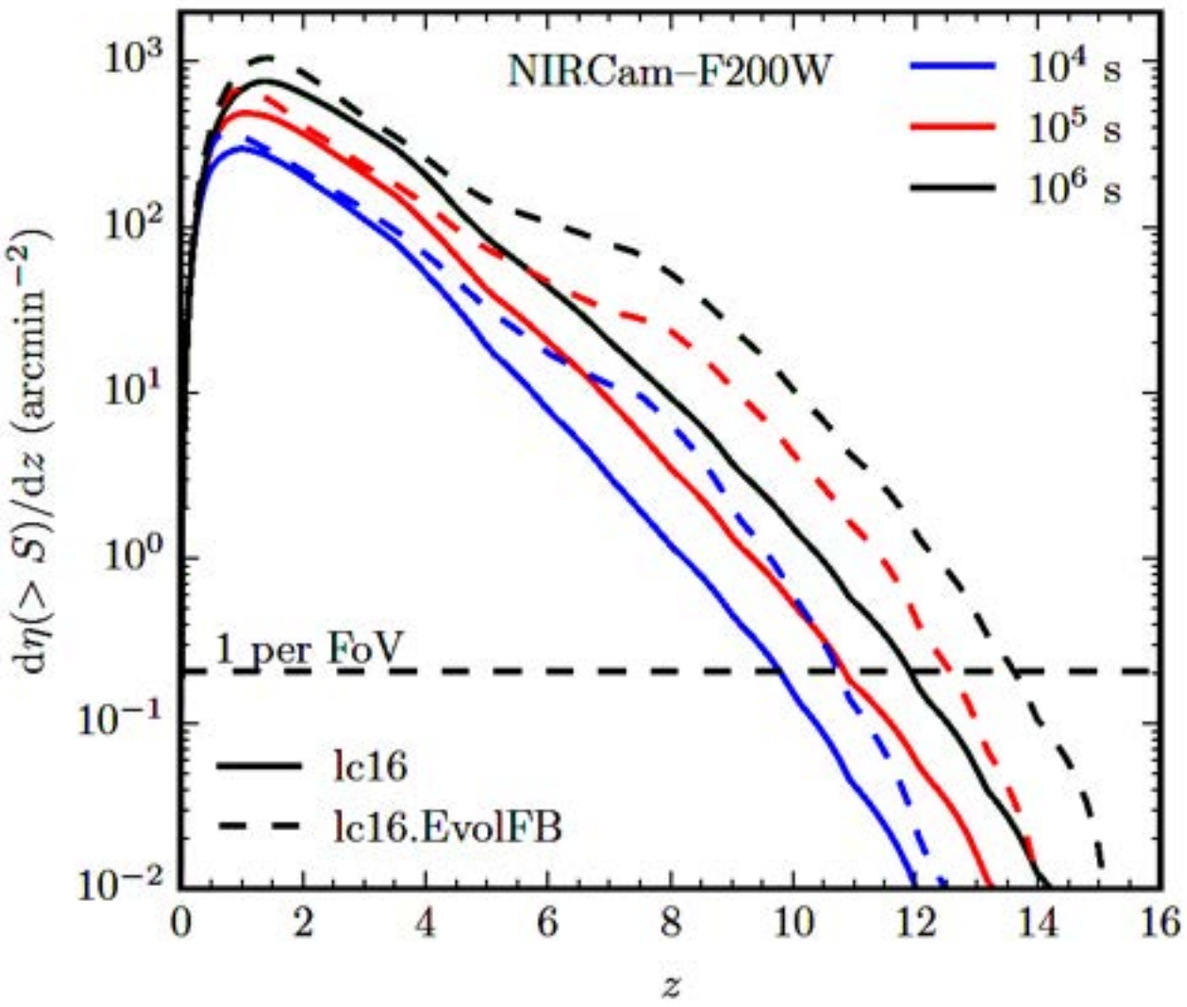
- Modes of star formation, stellar mass buildup, first quenched galaxies?

Cosmic High Noon (1< z < 3)

- High-z dwarf galaxies, substructure.




# How Much Area Is Needed?




From Cowley et al. arXiv:1702.02146v1,
FoV here equals 2.2'x2.2'

- If a sample of 10 galaxies at z~12 is desired, then ~167 arcmin$^2$ using almost 100,000 secs of exposure time per location is needed
  - Alternate SF history: only 17 arcmin$^2$ are needed.
- If a sample of 100 galaxies at z~7 is desired , then ~ 33 arcmin$^2$ using 10,000 secs of exposure time per location is needed.

***Variety of survey depths/areas required to achieve science goals***

# GTO Extragalactic Program Overview

## *Time Allocations*

NIRCam - 425 hours
- 244 hours Deep Imaging Survey
- 181 hours Medium Imaging Survey

NIRSpec - 724 hours
- 148 hours Deep MOS Survey
- 200 hours Medium MOS Survey
- 106 hours Wide MOS Survey
- 270 hours IFU observations

NIRCam Exoplanet & Solar System Program (350 hrs):
- Coronography of young planets/debris disks
- Spectroscopy of young widely separated planets
- Transit spectroscopy of mature planets
- Y-dwarfs
- Kuiper belt science
- Imaging/Spectroscopy of Asteroids, NEOs, Comets

More program details (and other instrument GTO plans):

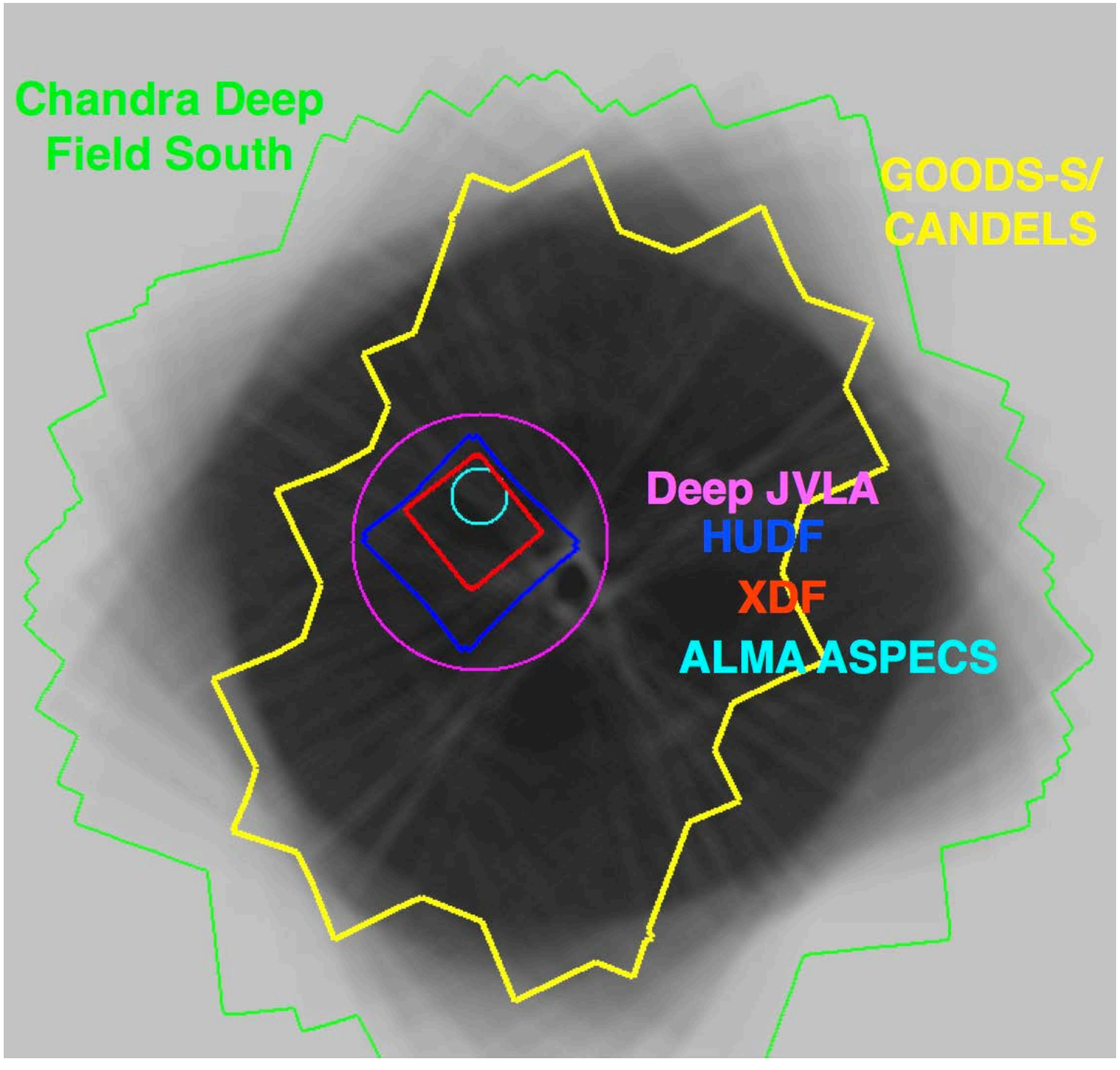
www.tinyurl.com/jwst-gto-programs

# Where on the Sky?

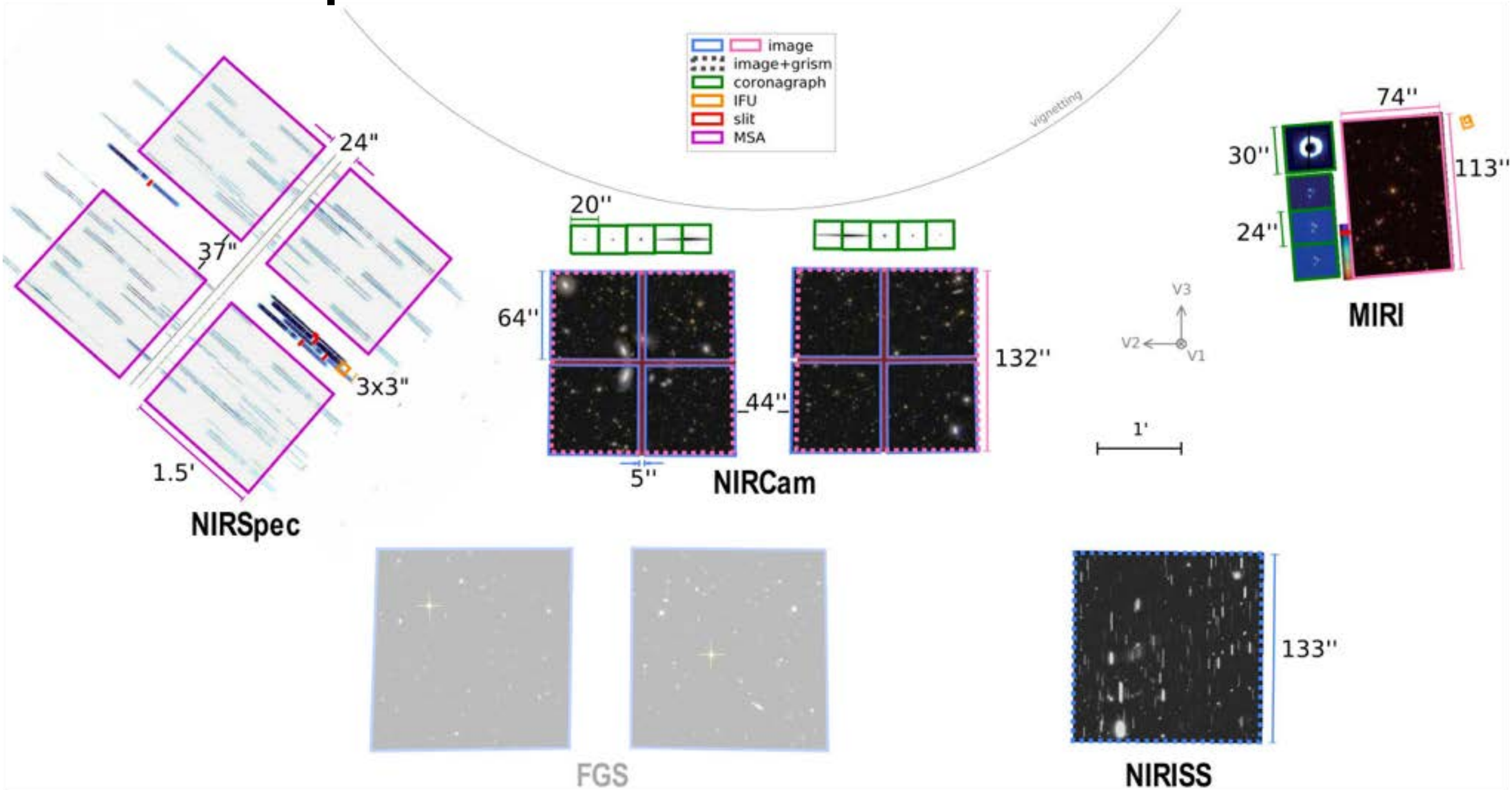
**Deep survey in GOODS-S (46 arcmin²)**

- **Ancillary data**
  - **Deep JVLA**
  - **HUDF / XDF**
  - **ALMA ASPECS**

**Medium depth survey in GOODS-S and GOODS-N (190 arcmin²)**

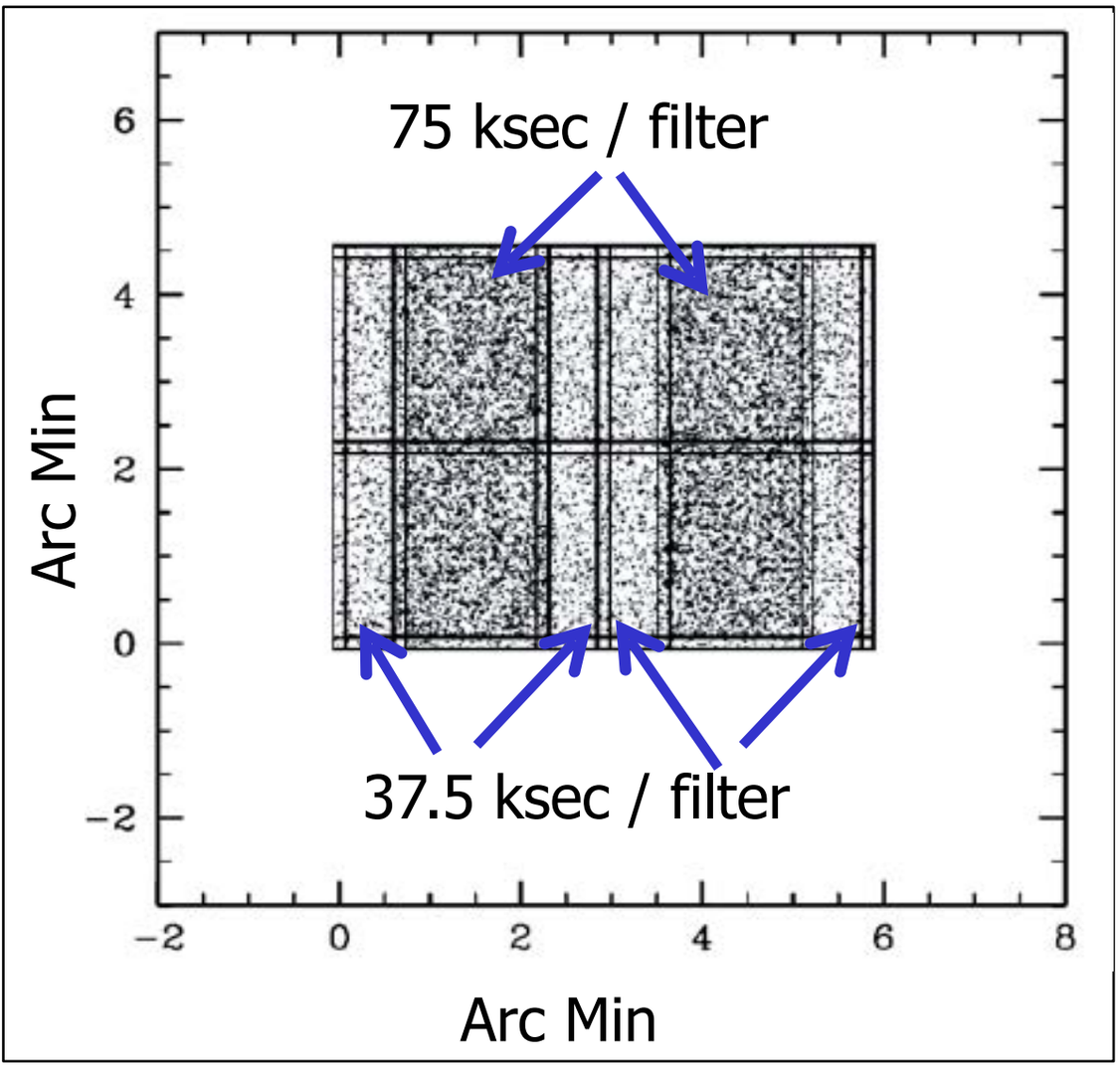


# Parallel Exposures — The JWST Focal Plane




The positions of the instruments on the JWST focal plane opens up the possibility of coordinated parallel observations with other instruments.

# Sample NIRCam Mosaic Program

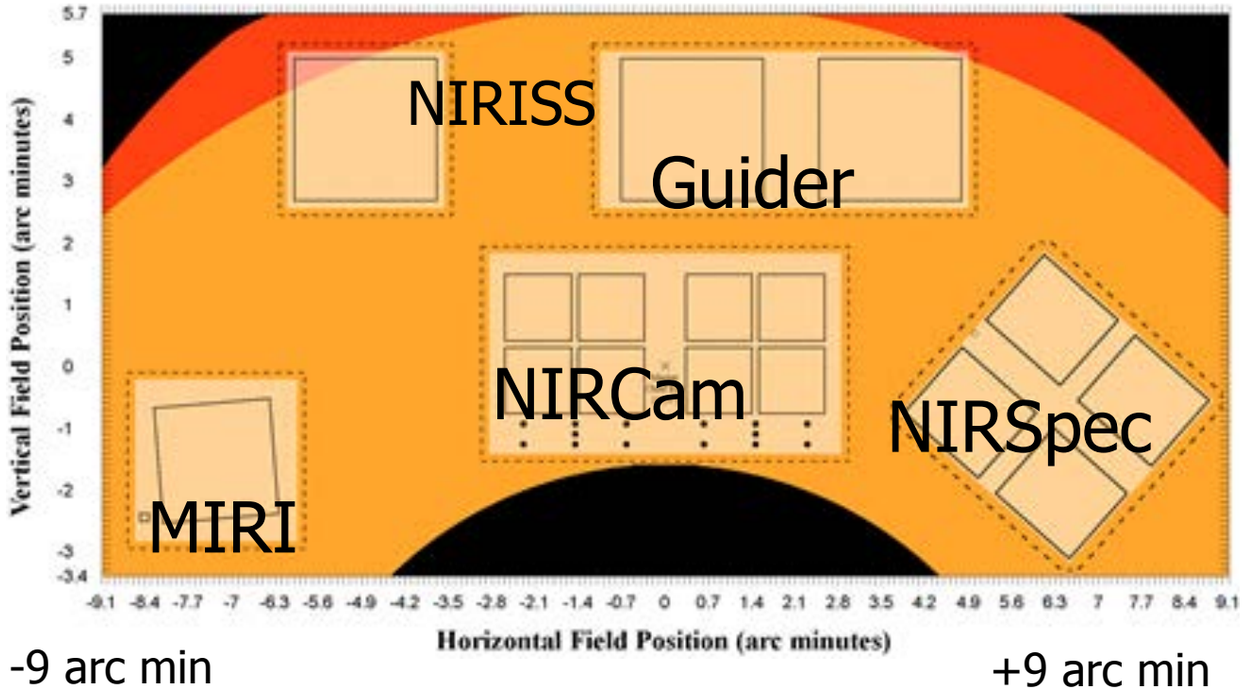



• Dithers required to cover gaps between SW detectors (~5″) and gaps between two modules (~43″).

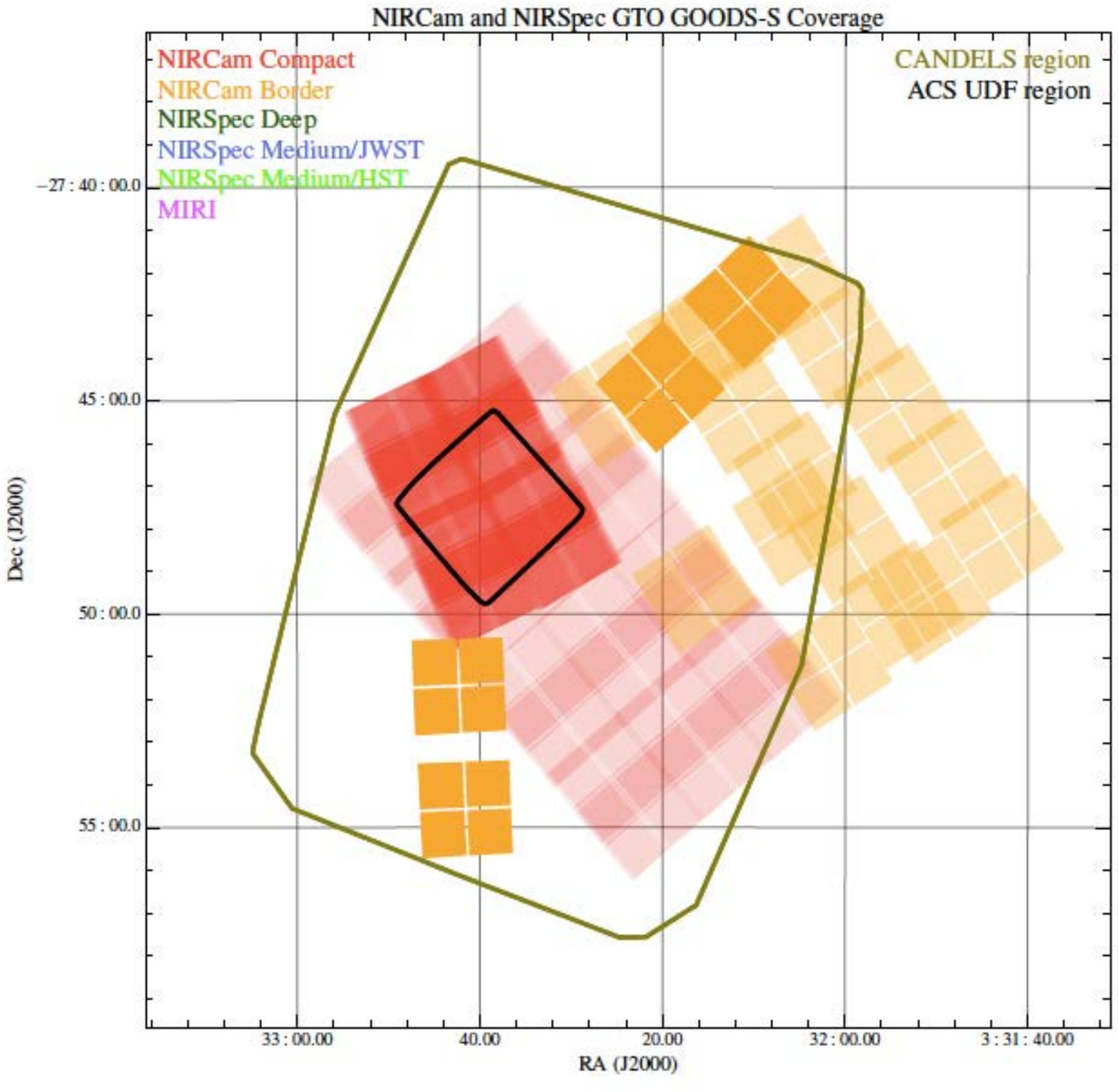
• Use two base positions + dithers to cover an area that can then be efficiently studied with the 4 NIRSpec MSA quadrants

• Use the mosaic mode in APT to replicate in “tiles”

• Dither size must also satisfy need for sampling/efficiency for coordinated parallel.



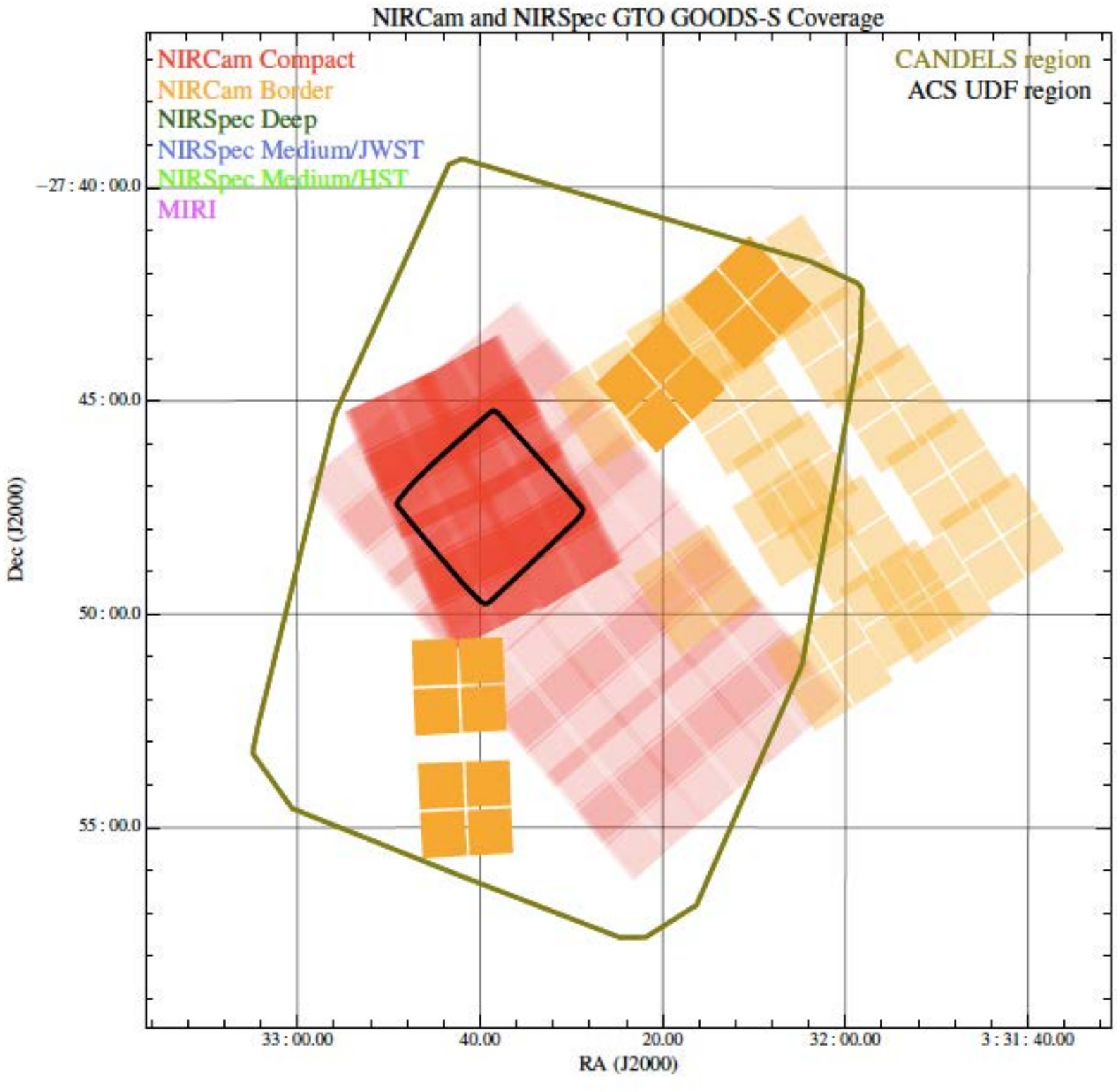
# NIRCam GTO Pattern in GOODS-S




## NIRCam compact:

- Geometrically clean mosaics, with chip gaps and inter-arm gaps removed by dithers.
- Facilitates NIRSpec follow-up.
- Includes Deep (dark red) and medium (light red) depths.

# NIRCam GTO Pattern in GOODS-S

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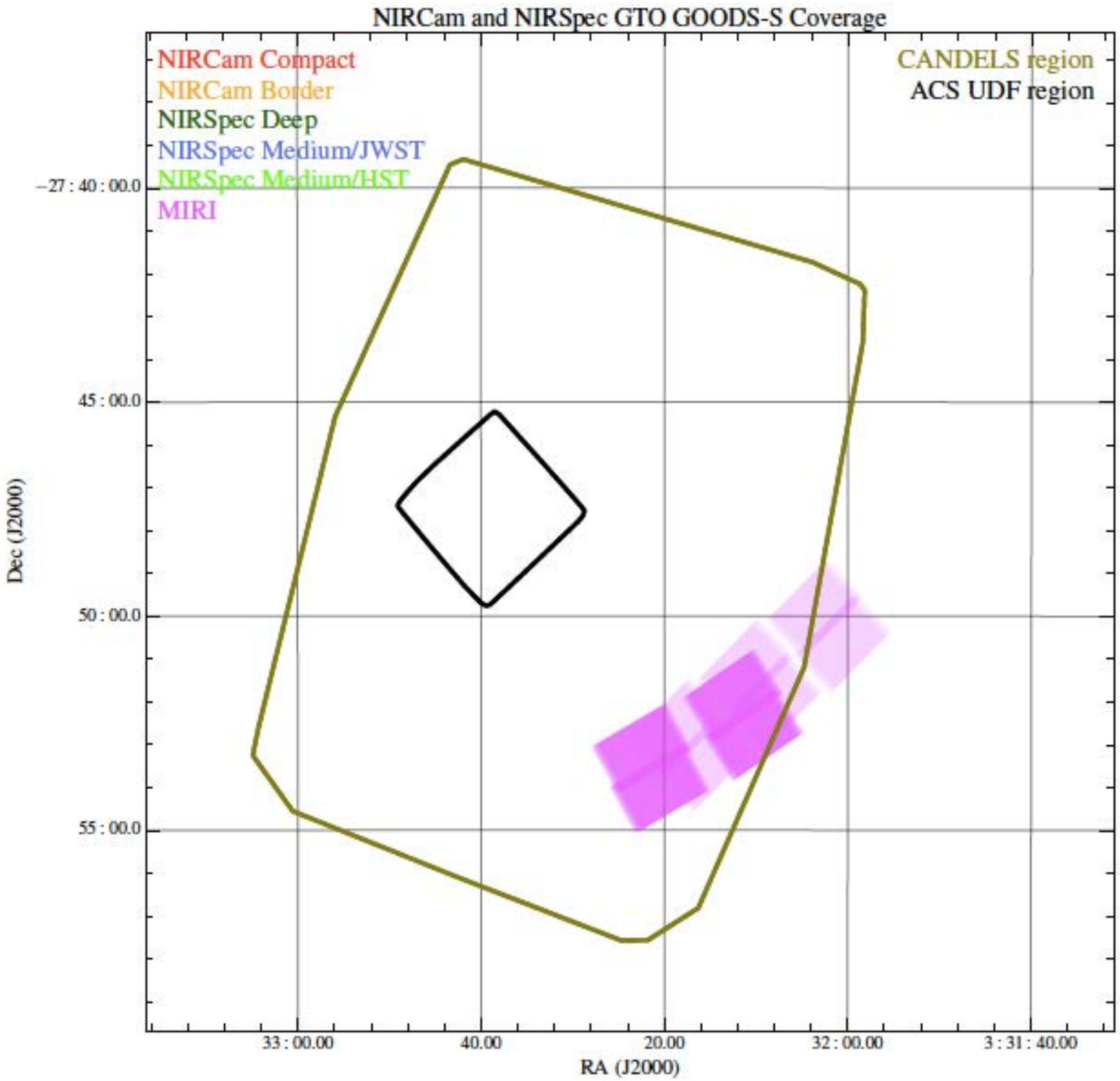
## NIRCam Border

- Obtained in parallel to NIRSpec observations.
- Maximize NIRSpec operational efficiency.
- Disjoint geometry, allow inter-arm and chip gaps to open.

# MIRI Parallel Imaging in GOODS-S



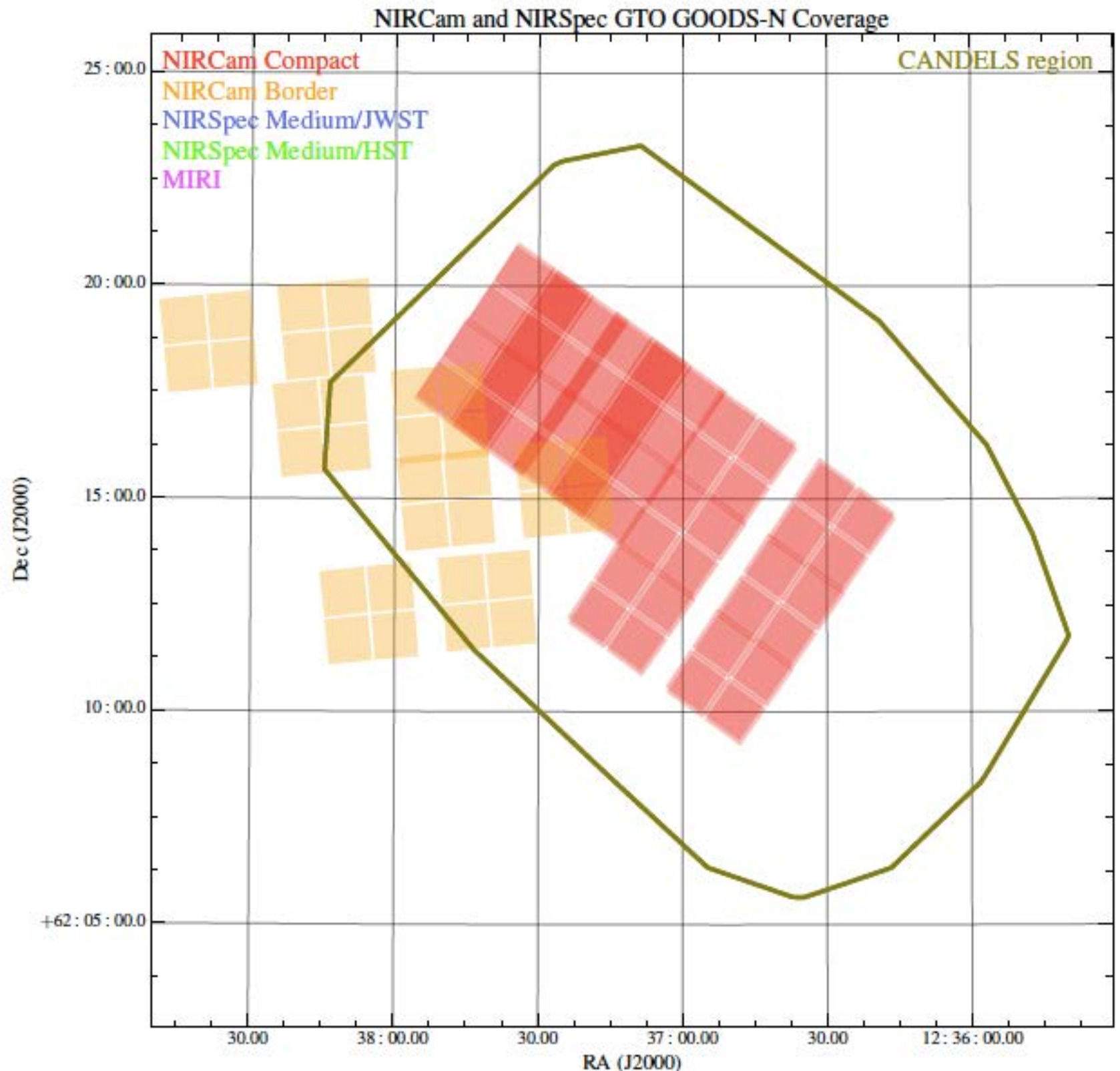

**MIRI deep**

- **4 pointings, 8 arcmin²**
- **167 ksec in F770W (26.7 AB)**
- **better constraints on z~6 stellar masses (absent emission lines).**

**MIRI medium**

- **4 pointings, 8 arcmin²**
- **5.6 ksec in F770W (24.9 AB)**
- **19.4 ksec in F1280W (24.3 AB)**
- **obscured star formation / luminous AGN.**

# NIRCam GTO Pattern in GOODS-N

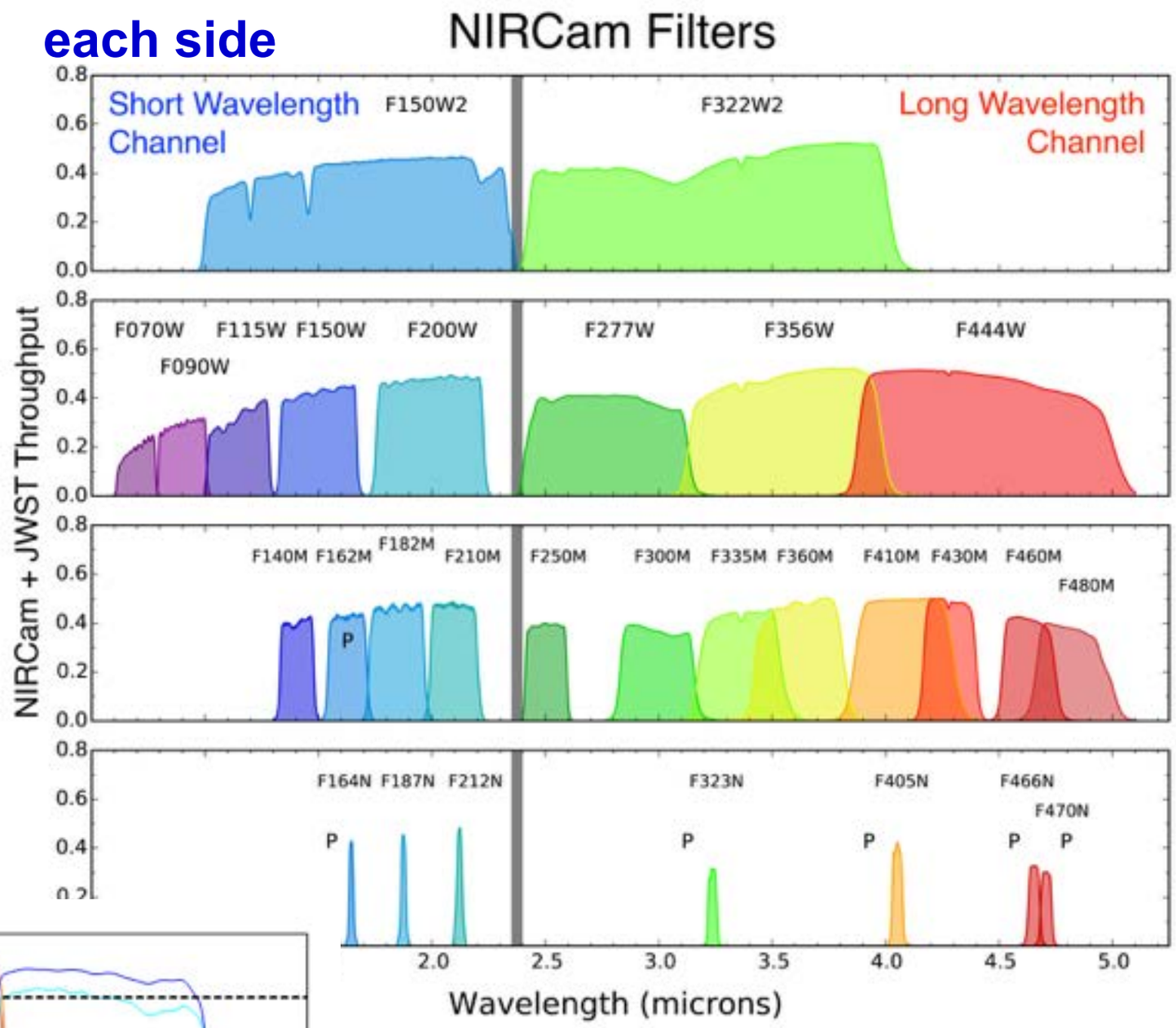


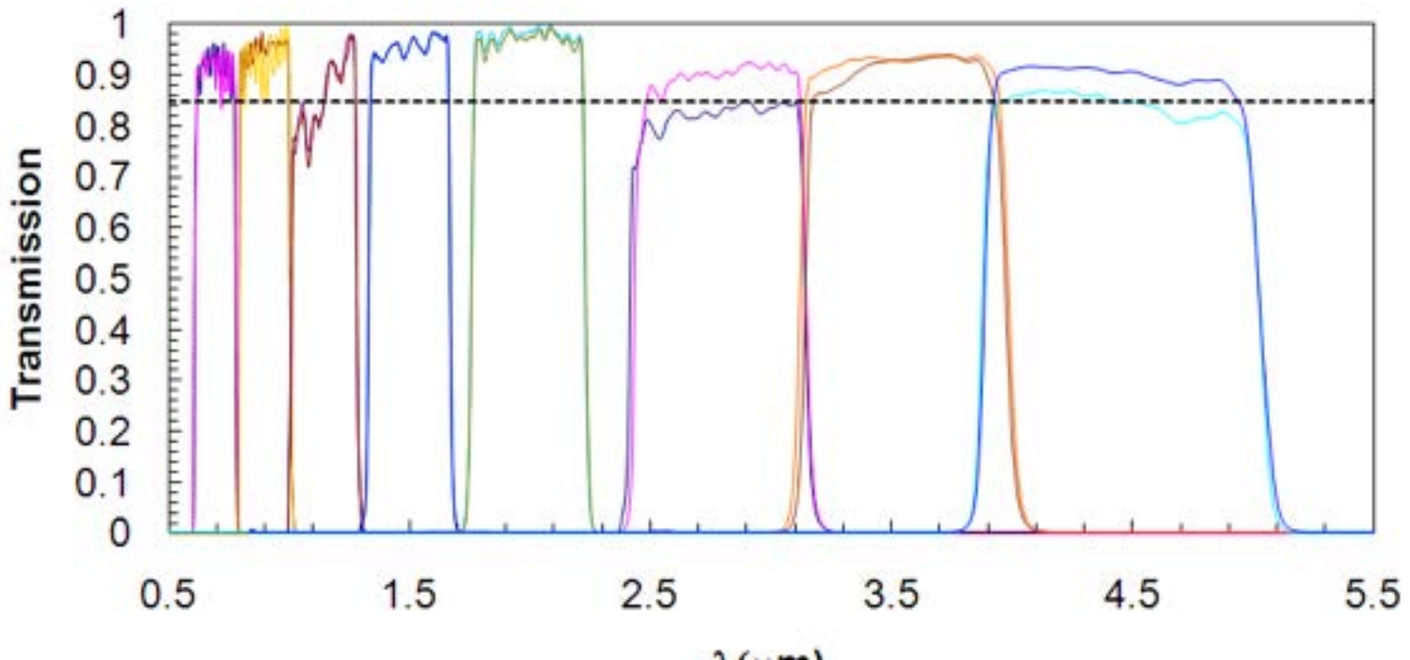

**NIRCam medium survey including compact and border components.**

# Filters

**Filters have names indicating wavelength (100x microns) and width (Wide, Medium, or Narrow)**

**Pick one from each side**

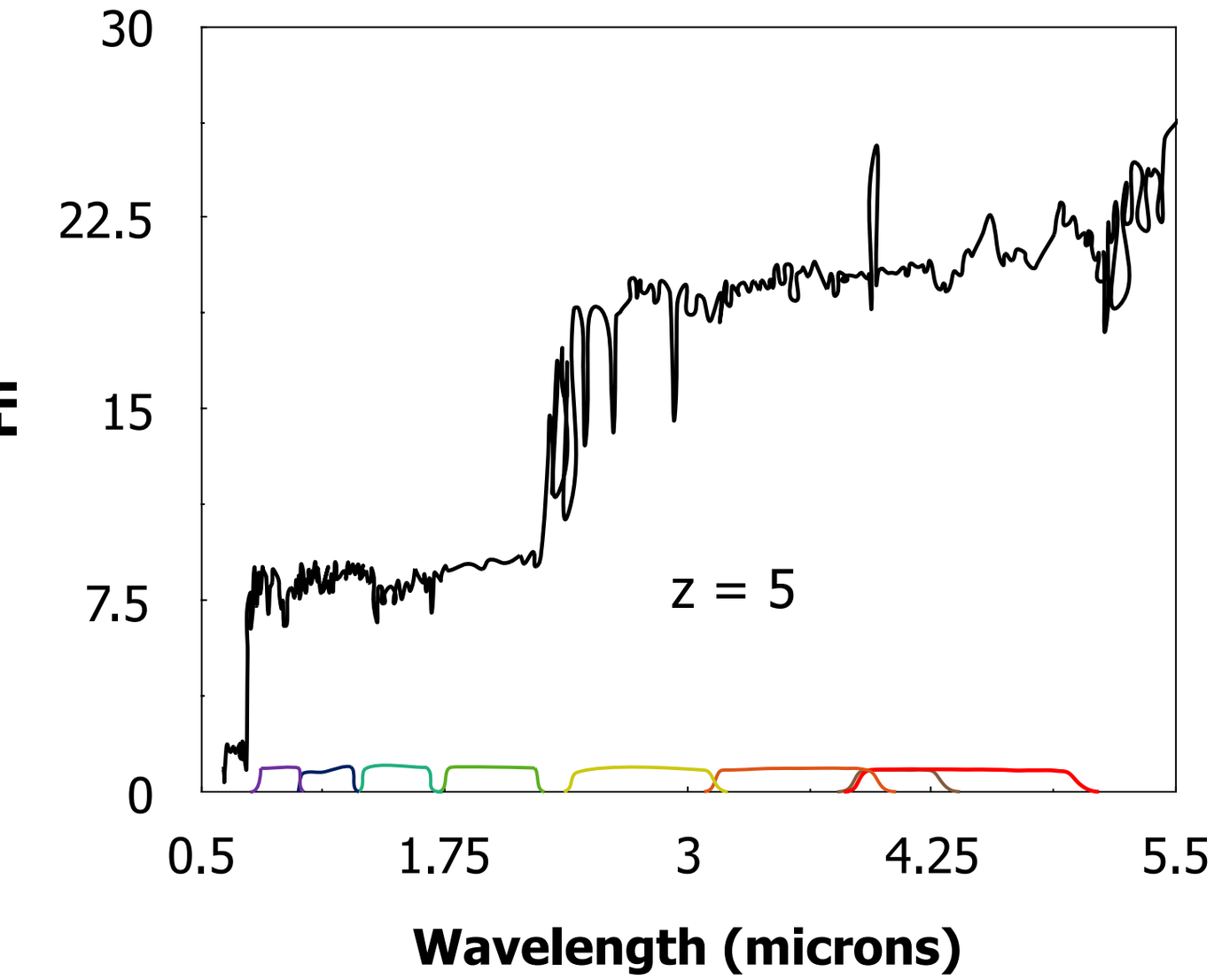



**Transmission of flight W filters.**

# NIRCam GTO Filter Selection

*Short wavelengths for UV-dropout selection at z>7. Long wavelengths for rest-optical constraints (7<z<10) and highest redshift dropouts.*

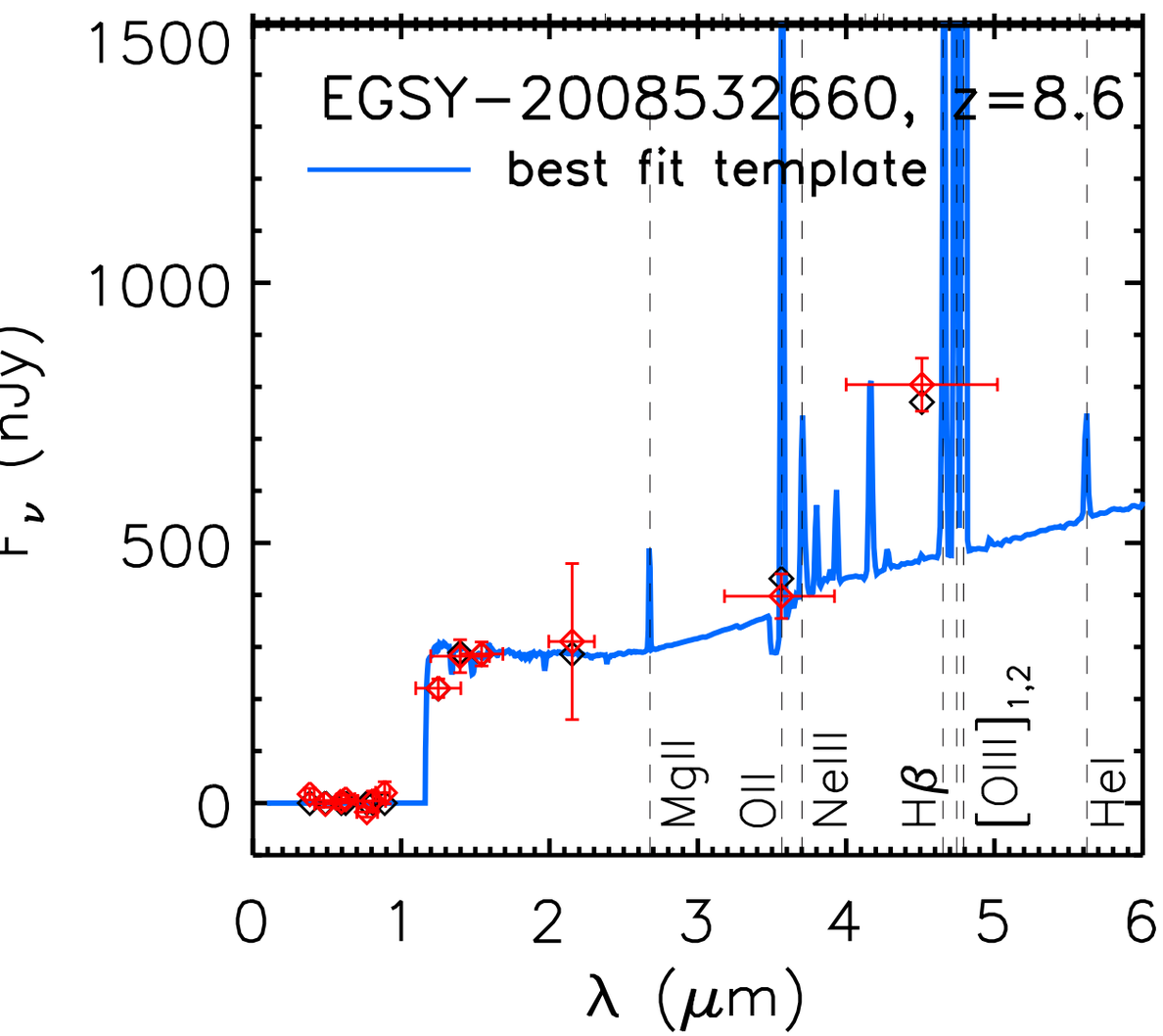



- **10 filter combinations:**
- Short wavelength channel:
  F070W, F090W, F115W, F150W, F200W
- Long wavelength channel:
  F277W, F335M, F356W, F410M, F444W

- Existing optical imaging in CANDELS region, add F070W to areas of Medium/Border pointings that are outside HST footprint.

# Medium Band Filters in GTO Survey

**Roberts-Borsani et al. 2016, ApJ, 823, 143**




- Rest-optical lines can be very strong at z>6, significant impact on medium-band flux.
- Inclusion of F410M and F335M provides additional spectral resolution in the red.
  - Improves photometric redshifts.
  - Improves stellar masses (allows discrimination between emission lines and stellar continuum).
- F410M has essentially the same sensitivity as F444W because of rapidly rising zodi background.

# Predicted Sensitivities for GTO Program

| Subsurvey | Area □′ | 10σ Point Source Magnitude (AB) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | F070W | F090W | F115W | F150W | F200W | F277W | F335M | F356W | F410M | F444W |
| Deep | 46 | — | 29.5 | 29.8 | 29.9 | 29.9 | 29.5 | 28.8 | 29.4 | 29.0 | 29.1 |
| Medium | 190 | 28.0[a] | 28.6 | 28.8 | 28.9 | 29.0 | 28.6 | 28.0[a] | 28.6 | 28.1 | 28.3 |

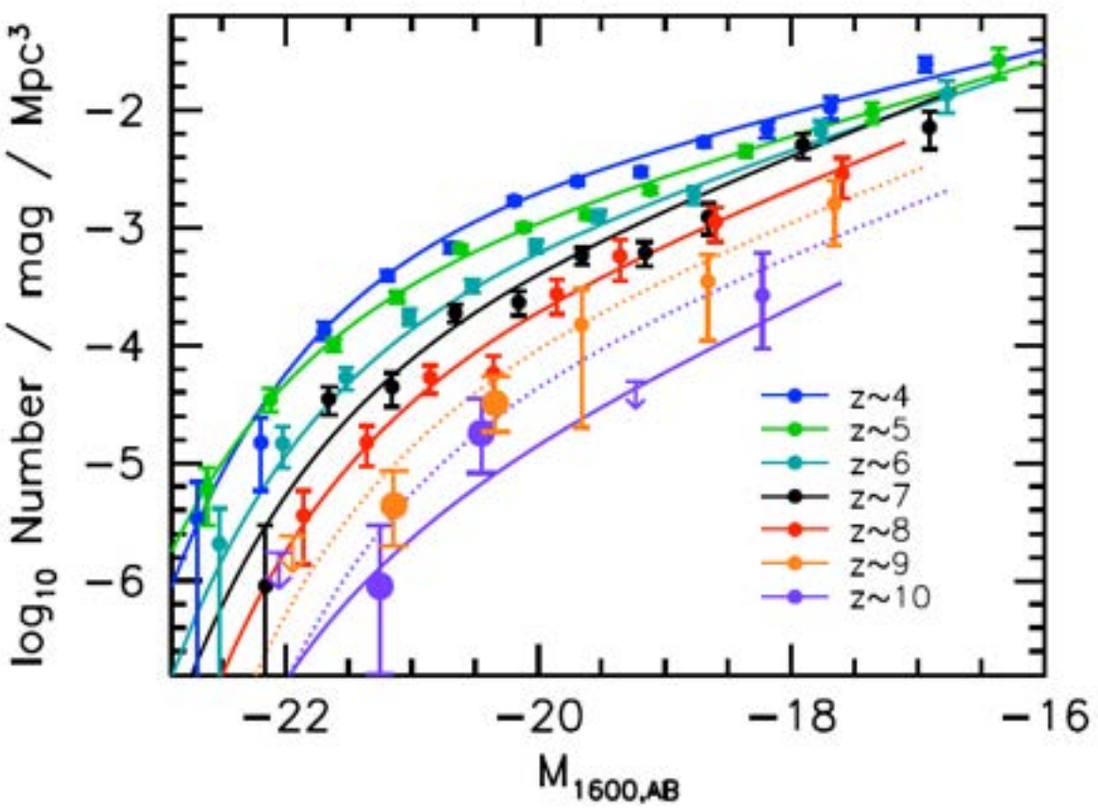
| Subsurvey | Number Pointings | Area □′ | Exposure Times (Ksec) F770W | F1280W | 10σ AB Mag Limit F770W | F1280W |
|---|---|---|---|---|---|---|
| Deep/MIRI | 4 | 8 | 167 | — | 26.7 | — |
| Medium/MIRI | 7 | 14 | 5.6 | 19.4 | 24.9 | 24.3 |

- NIRCam/Deep (46 arcmin$^2$): 10-sigma limits of m~29.7
- NIRCam/Medium (190 arcmin$^2$): 10-sigma limits of m~28.7
  - Deeper than HST and will have the superior spatial resolution at wavelengths > 1 micron.
- MIRI limits are 10x those achieved on Spitzer and will have much greater spatial resolution.

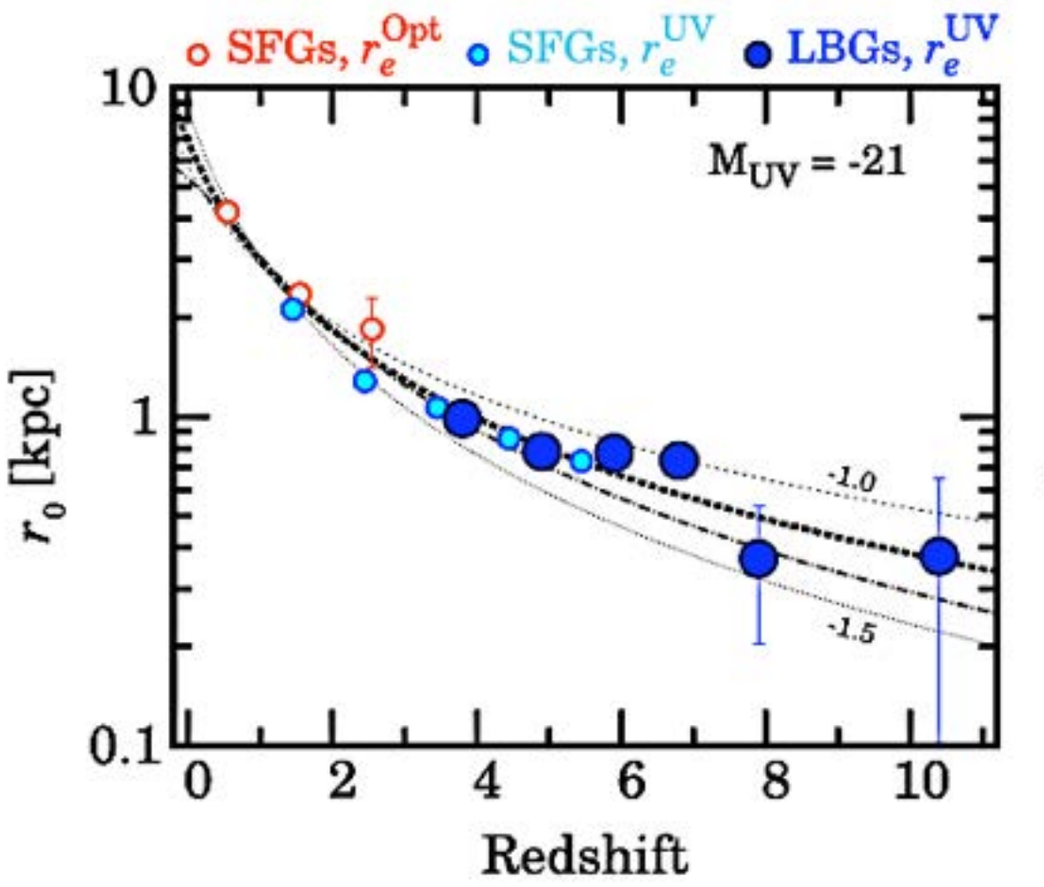
# JWST Mock catalog tool :
# informed survey planning to achieve science goals

(C. Williams, E. Curtis-Lake, K. Hainline, J. Chevallard, B. Robertson, S. Charlot et al.)

**Uses:** Filter depths/combinations
Survey areas
Image simulation
NIRSpec MSA assignment testing



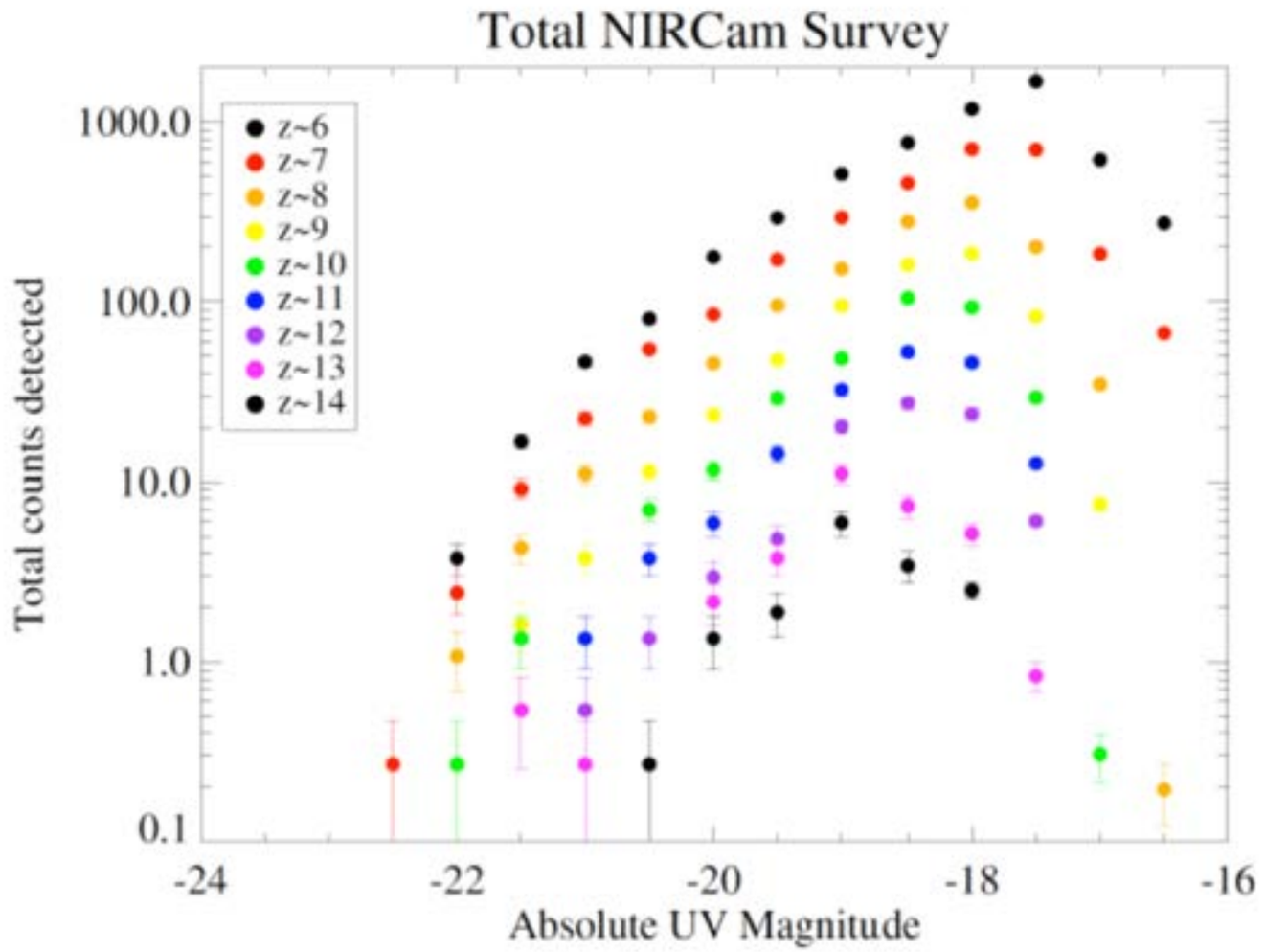

Bouwens et al. 2016

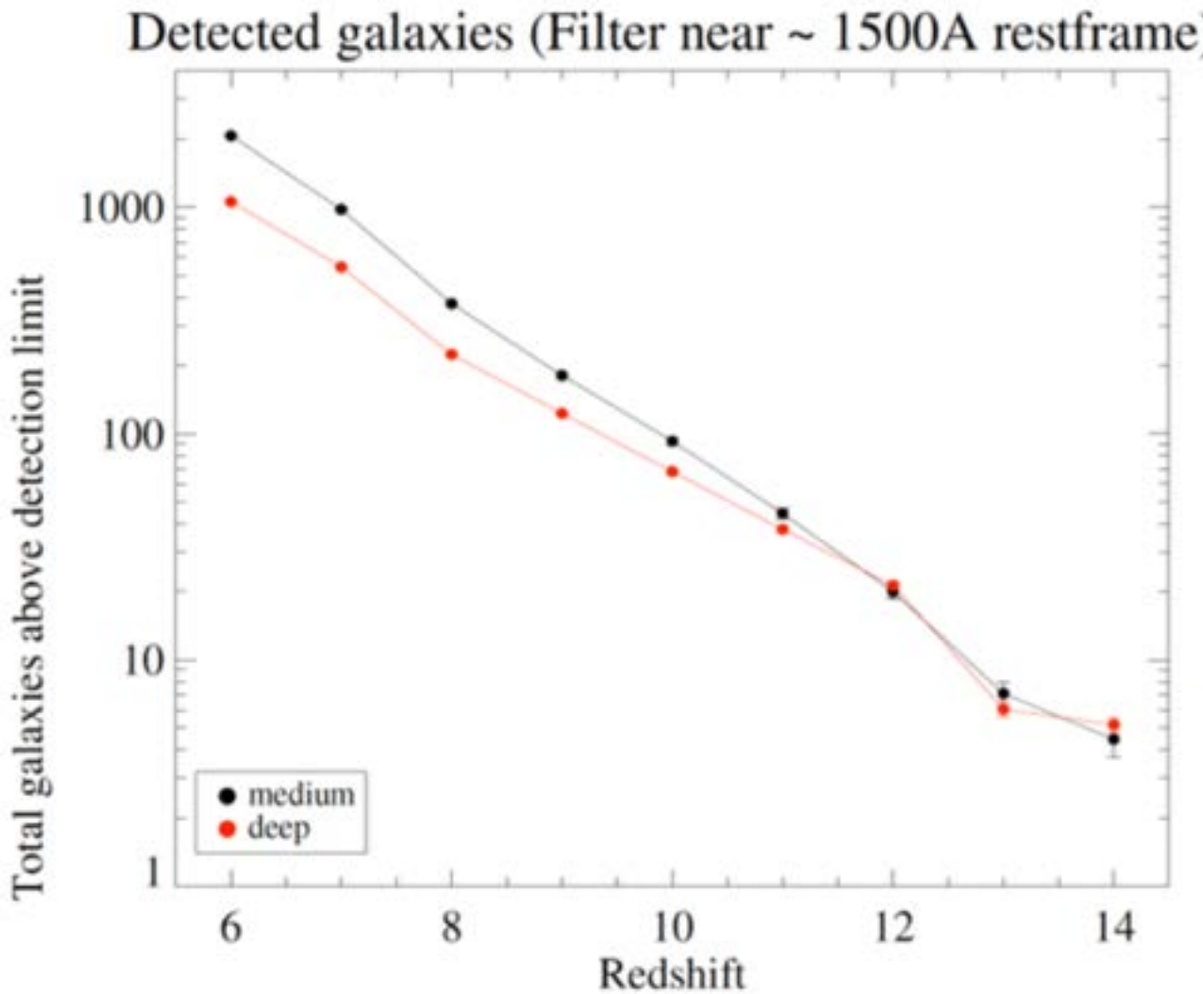



Shibuya et al. 2015

# JWST Mock catalog predictions: NIRCam Number Counts

(C. Williams, E. Curtis-Lake, K. Hainline, J. Chevallard, B. Robertson, S. Charlot et al.)

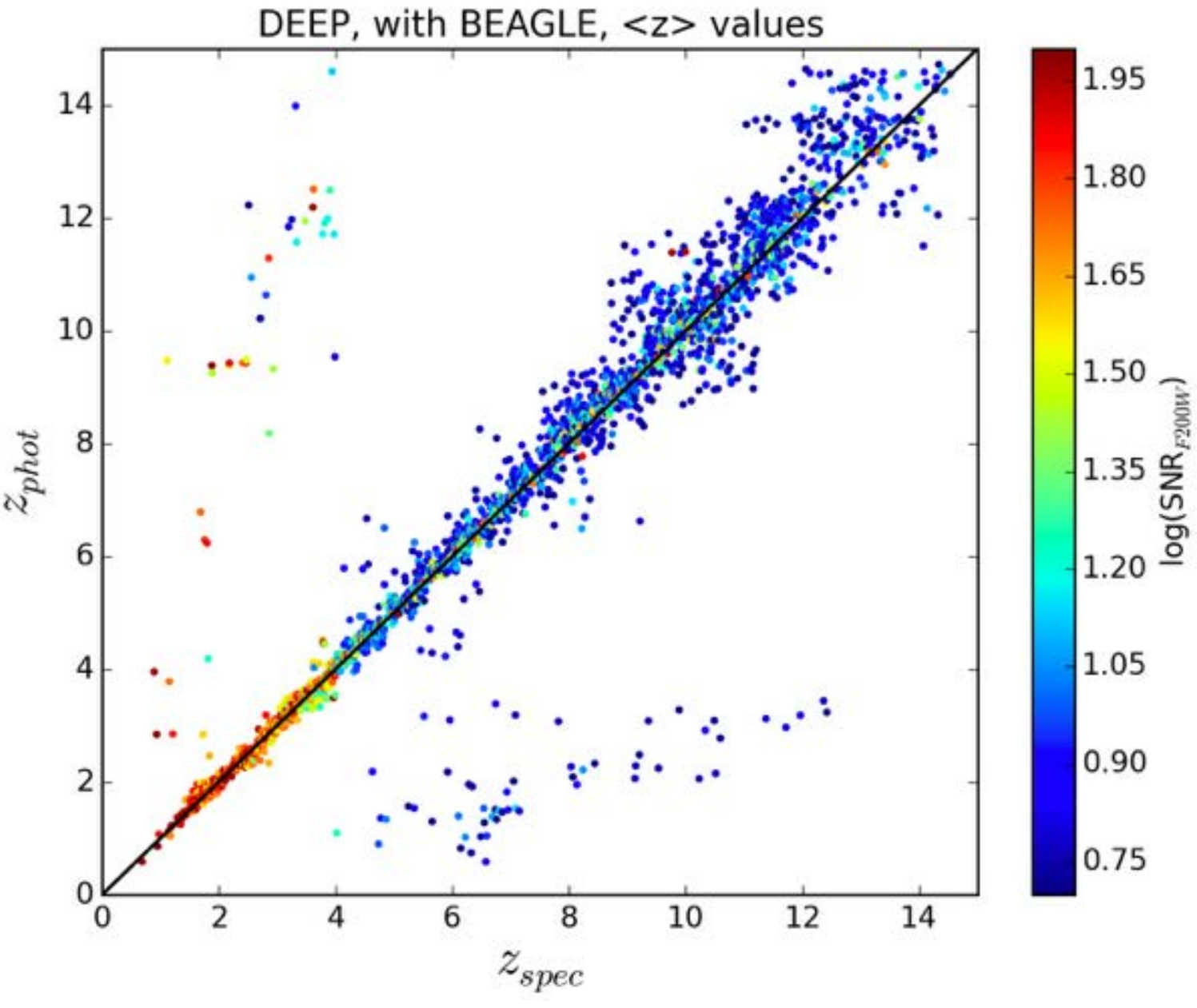


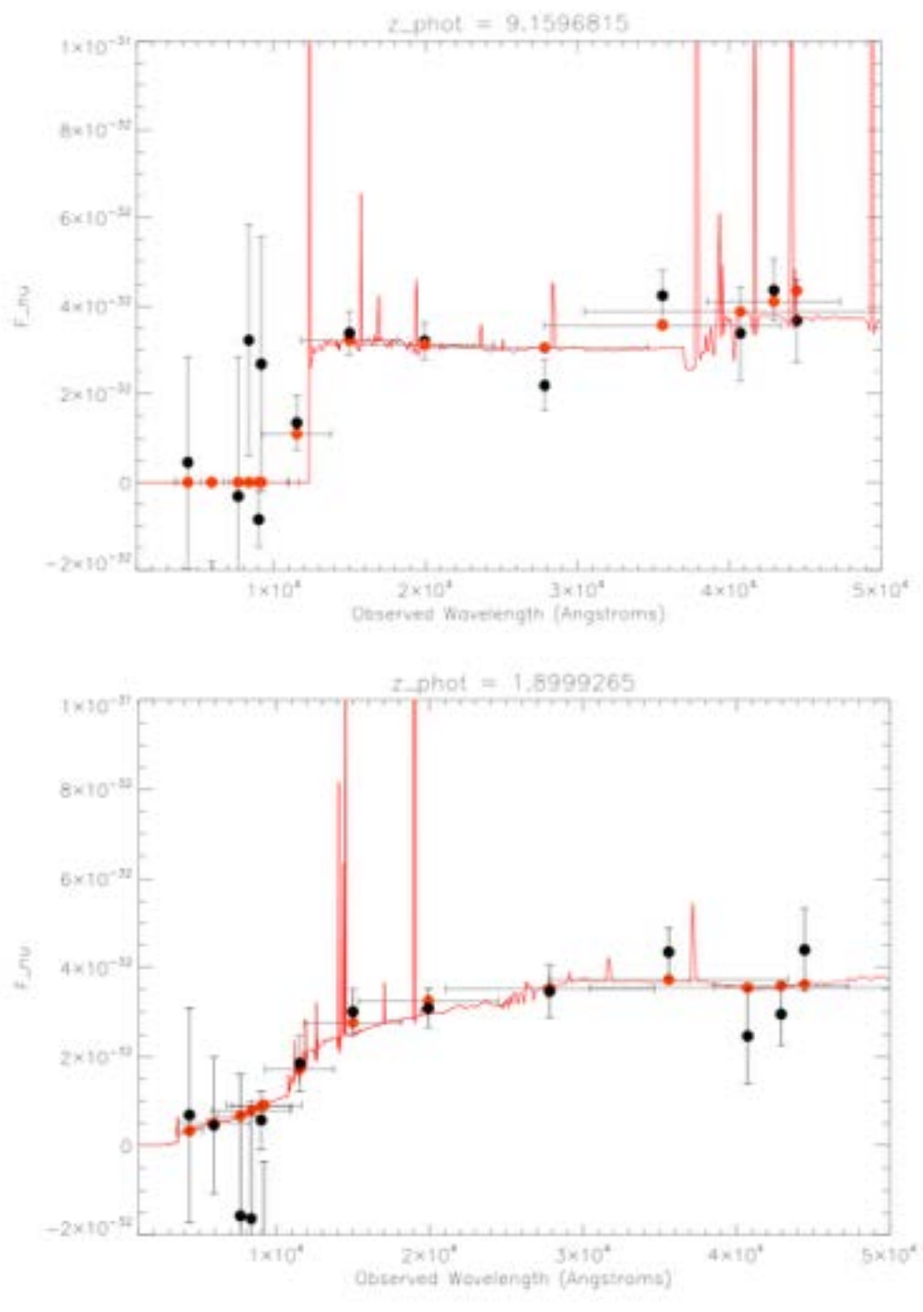

We should detect 1000s of galaxies at z ~6, and 10s of galaxies even to z~10-15 (depending on luminosity function evolution)

# JWST Mock catalog predictions: Photometric Redshift Analysis

K. Hainline, J. Chevallard, C. Williams, E. Curtis-Lake, B. Robertson, S. Charlot et al.




Because of the wavelength range of NIRCam and our survey filter choices, we can recover photo-z's out to $z$ ~ 14-15.



# Summary: NIRCam GTO Extragalactic Survey (~425 hr)

- NIRCam Deep:
  - 46 arcmin$^2$ survey in GOODS-S reaching 29.5-30 AB
- NIRCam Medium:
  - 190 arcmin$^2$ survey in GOODS-S / GOODS-N reaching 28.5-29 AB
- NIRCam filters span 0.9-5 microns
  - two medium band filters (F335M, F410M) improve photo-z, stellar mass recovery.
- MIRI parallel 7.7 micron imaging over ~8 arcmin$^2$