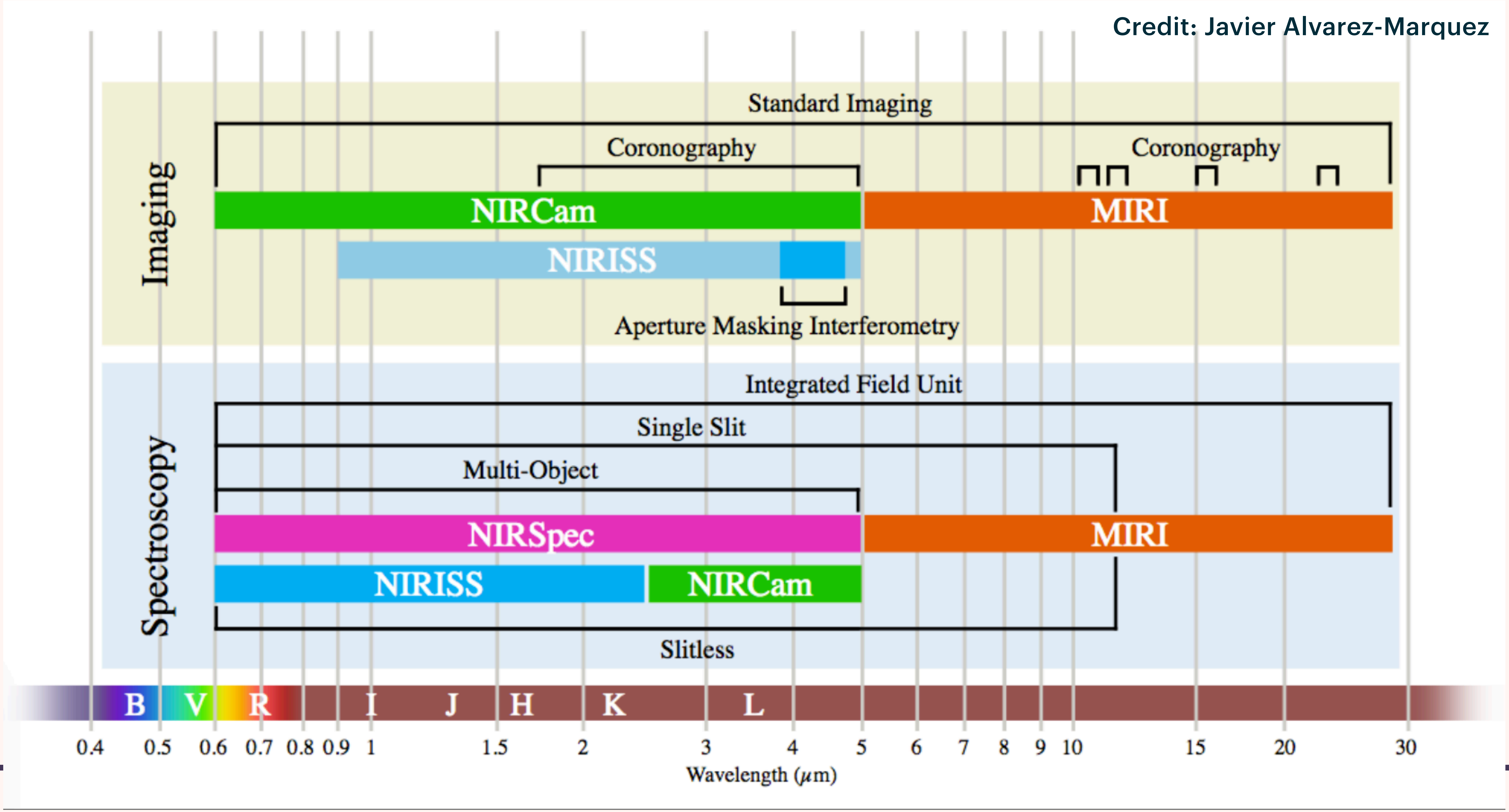
presented by Stacey Alberts (STScI)

INTRODUCTION TO IMAGING WITH JWST

A Hands-on Workshop with JWST-UVIT @ the Center for Excellence in Astronomy and Astrophysics at CHRIST (Deemed to be University), Bangalore, India

IMAGING MODES

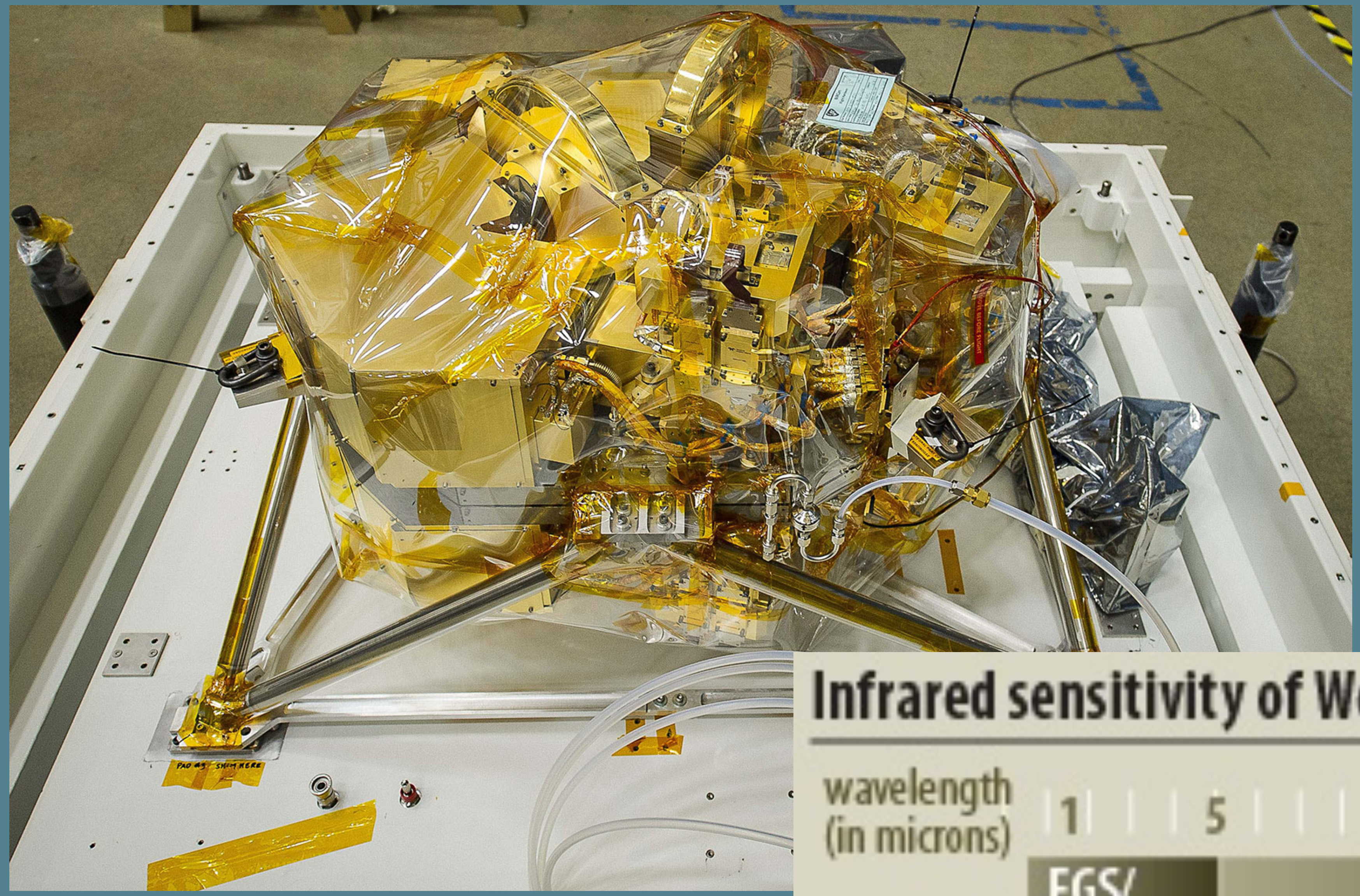


Imaging Modes: Overview

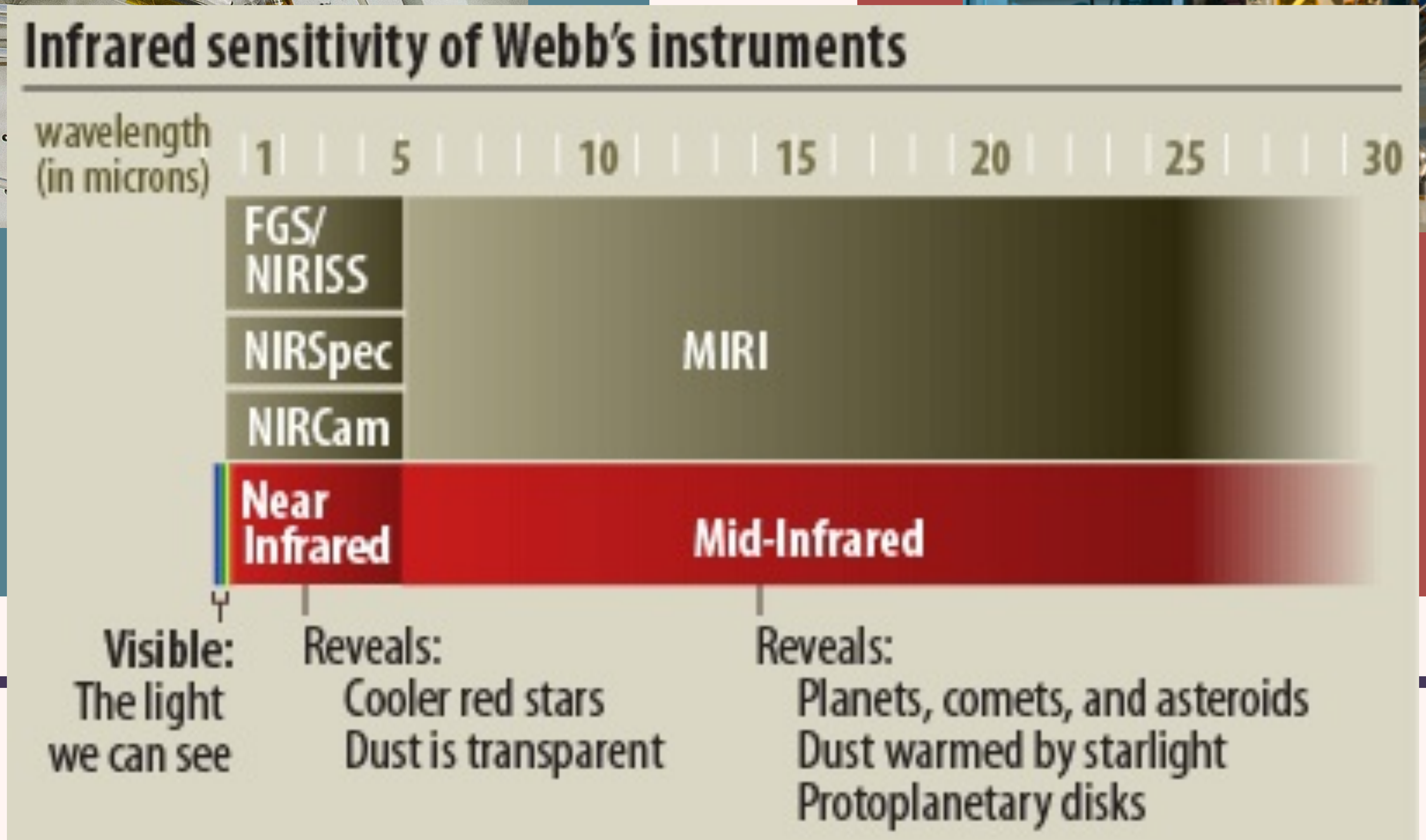
**NIRISS also has an imaging mode

IMAGING MODES

The Near-Infrared Camera (NIRCam)



Mid-Infrared Instrument (MIRI)

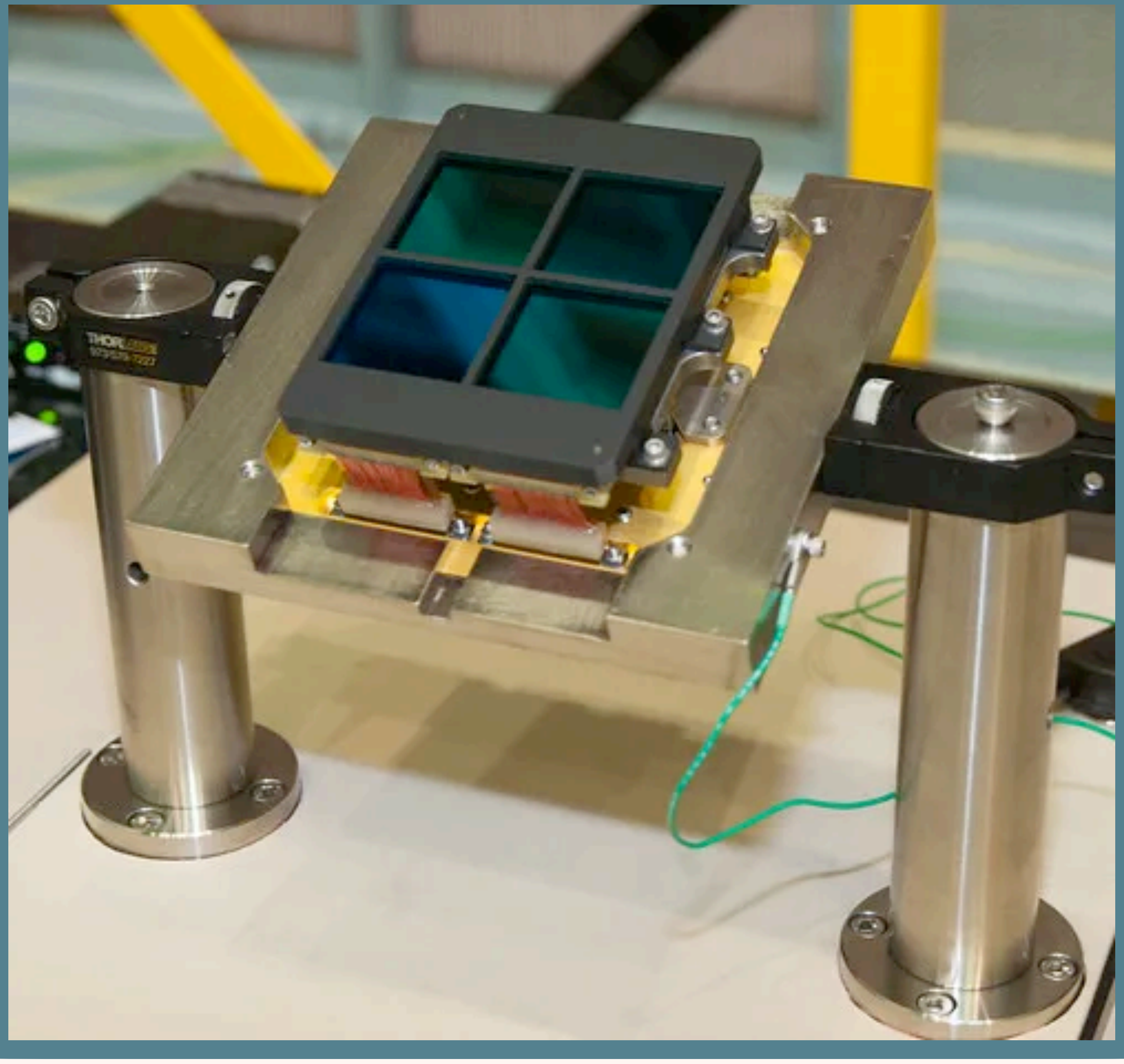


**NIRISS also has an imaging mode

IMAGING MODES

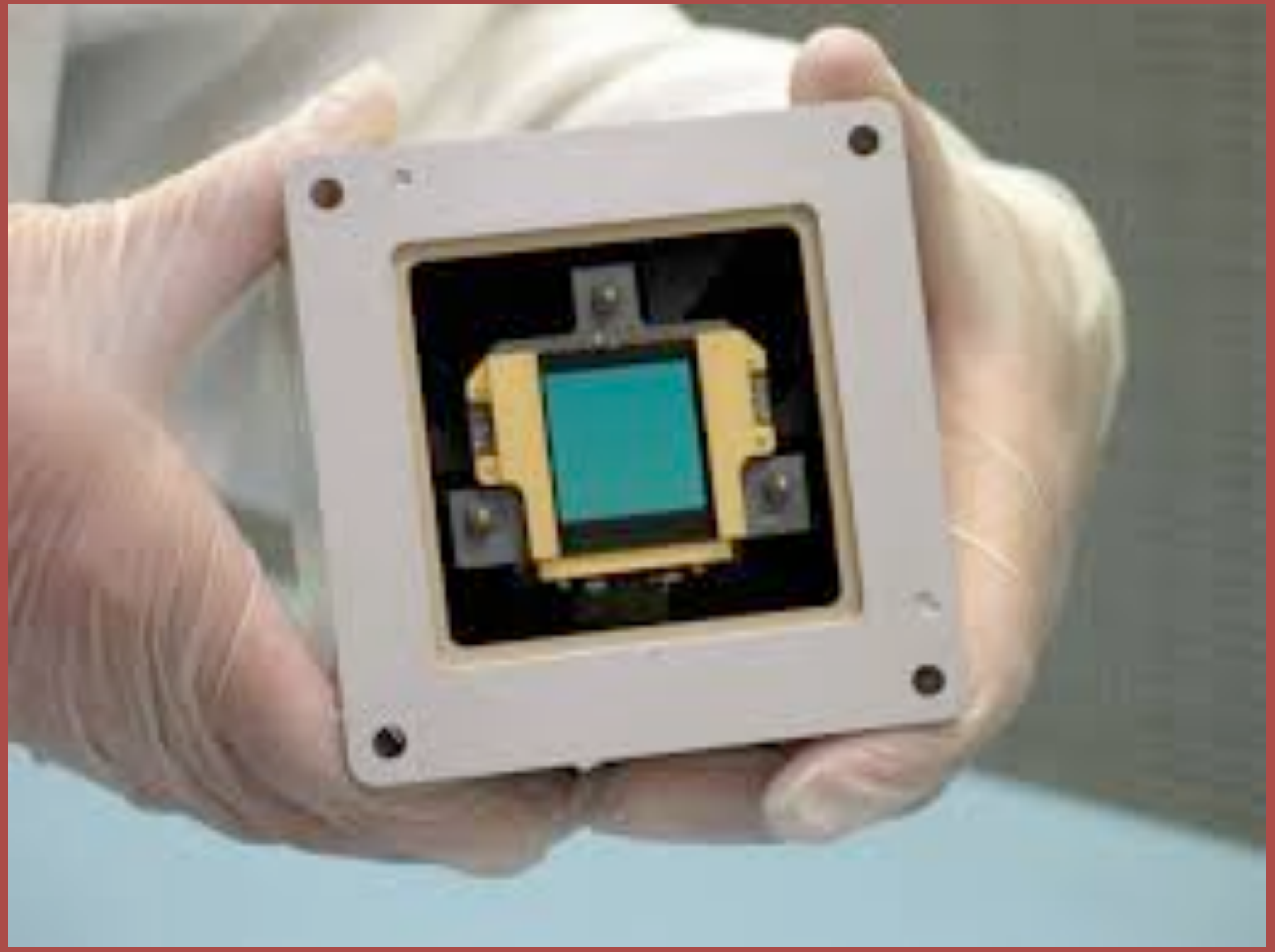
The Near-Infrared Camera (NIRCam)

Mercury-cadmium-telluride (HgCdTe) detectors



Mid-Infrared Instrument (MIRI)

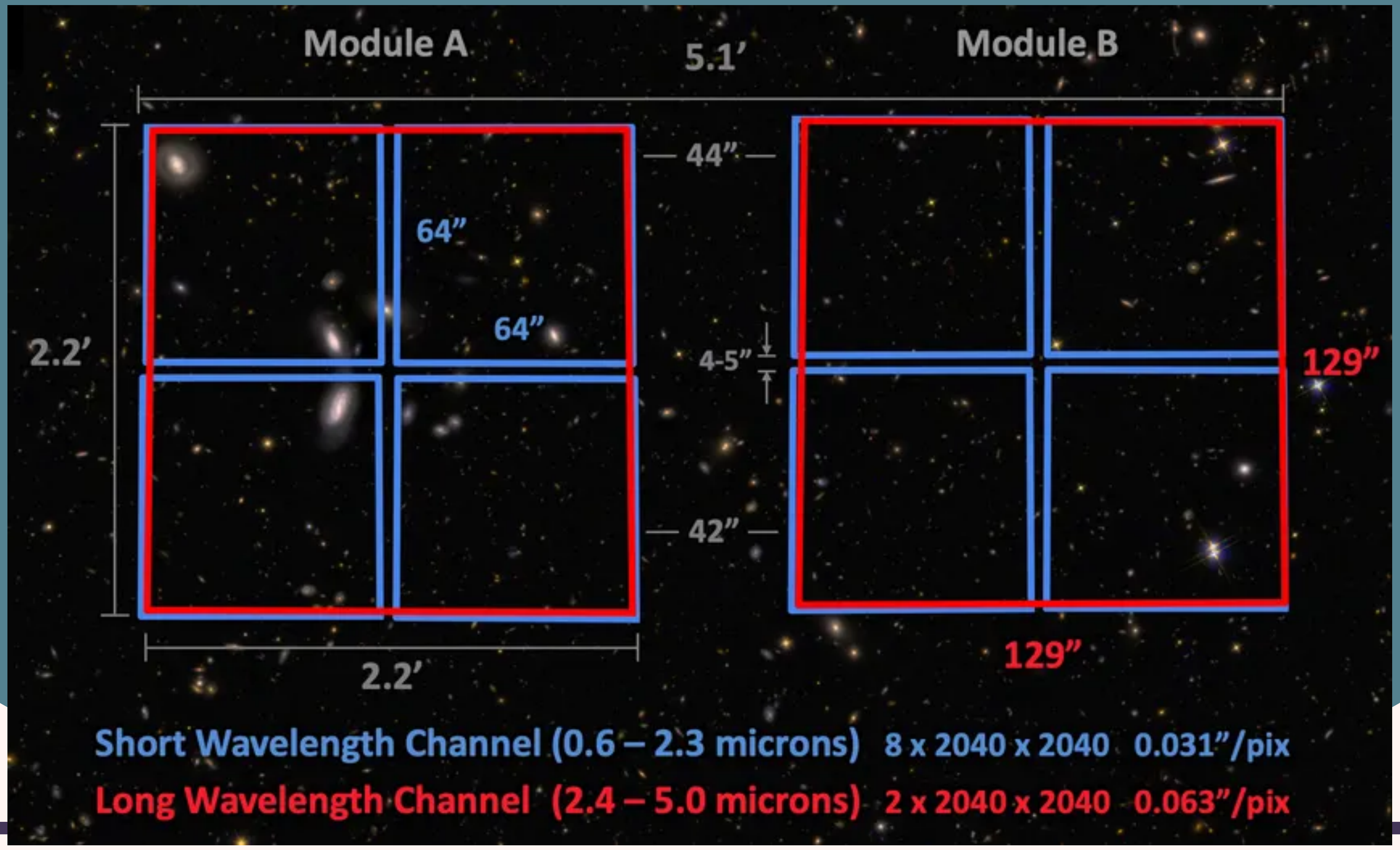
Arsonic-doped Silicon (Si:As) detectors (Like Spitzer/IRAC)



IMAGING MODES

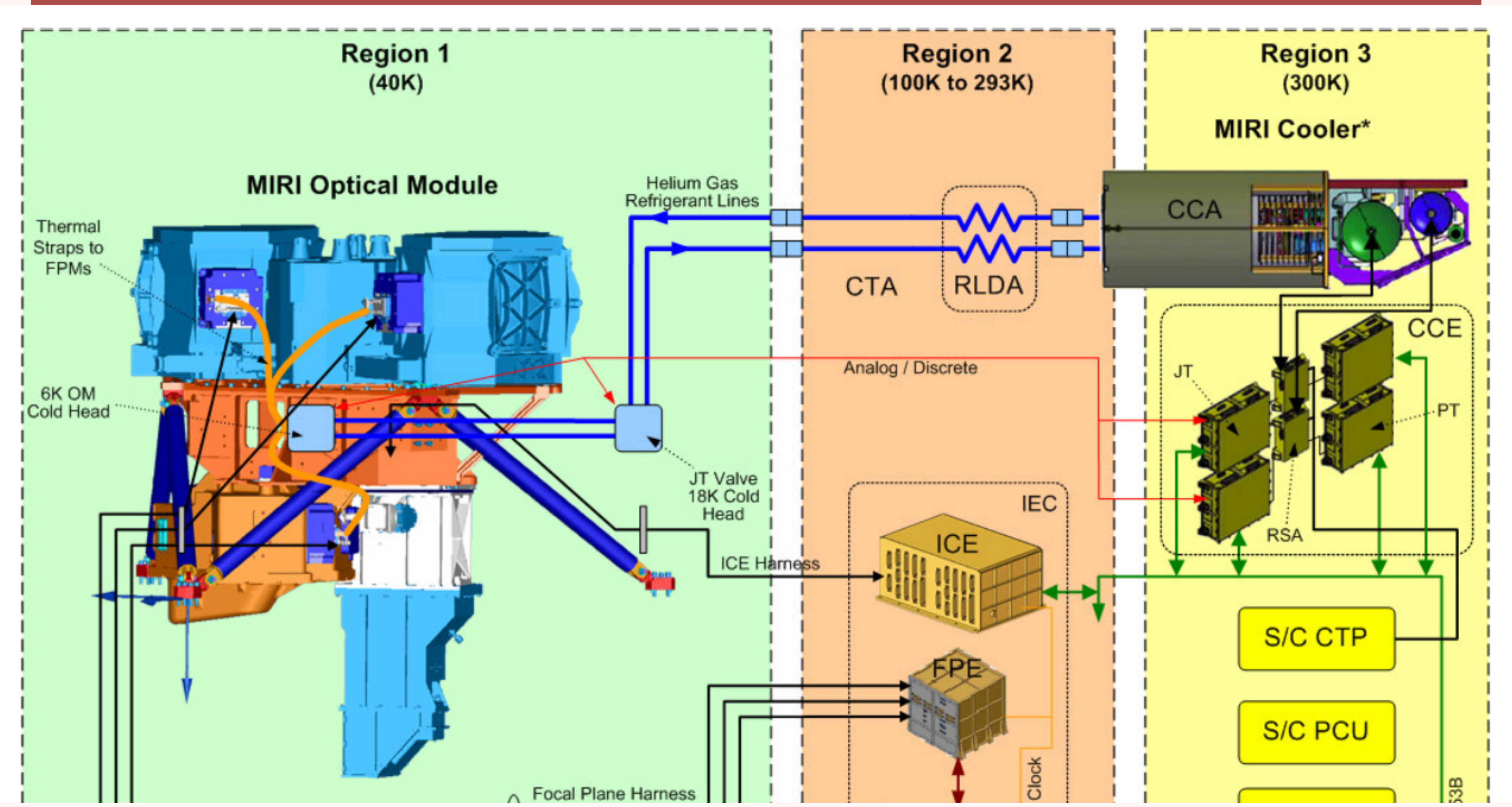
The Near-Infrared Camera (NIRCam)

10 detectors (8 SW, 2 LW)
4 million pixels each
Two redundant modules
Wavefront sensing
Operating Temperature: ~35 K

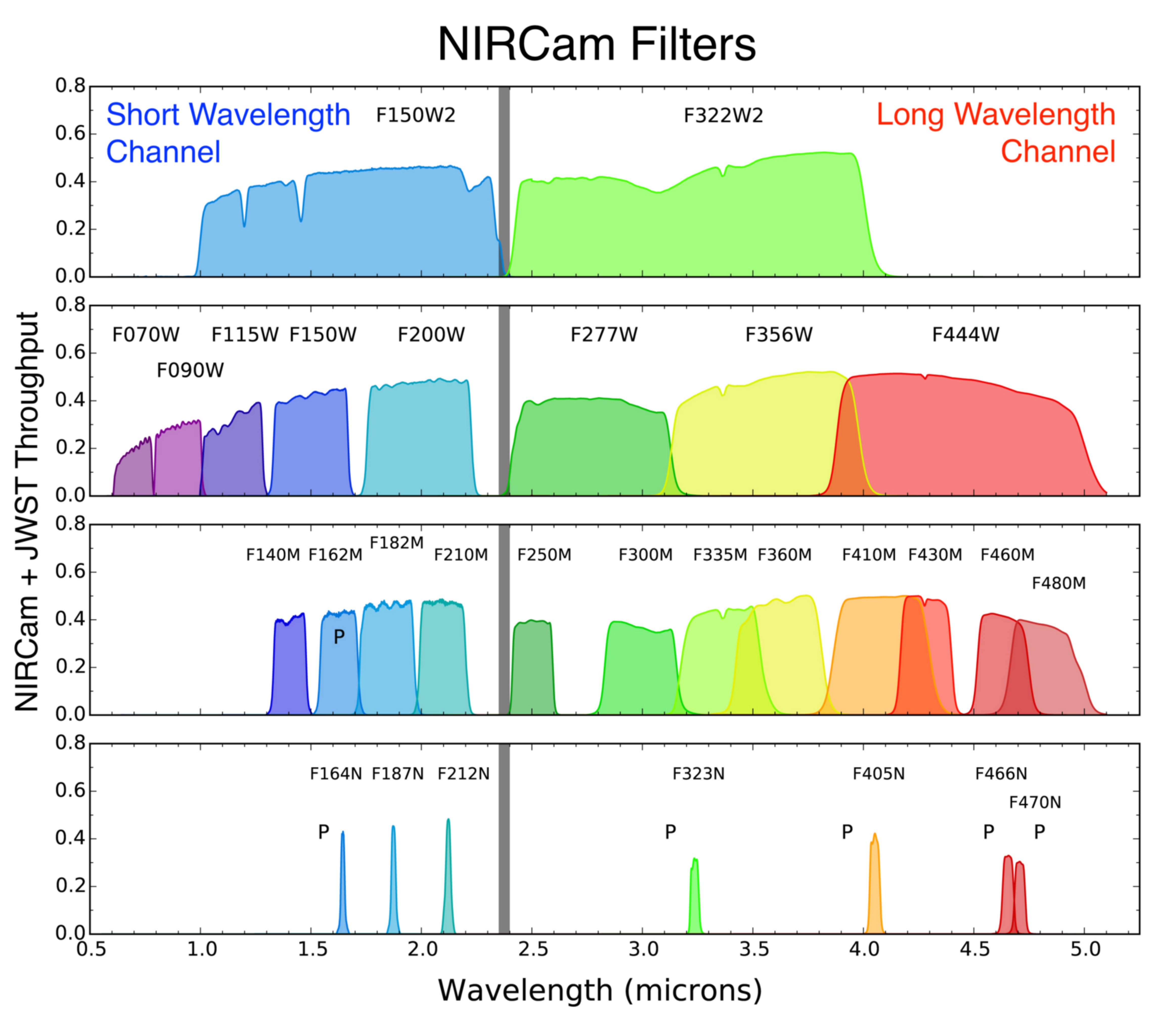


Mid-Infrared Instrument (MIRI)

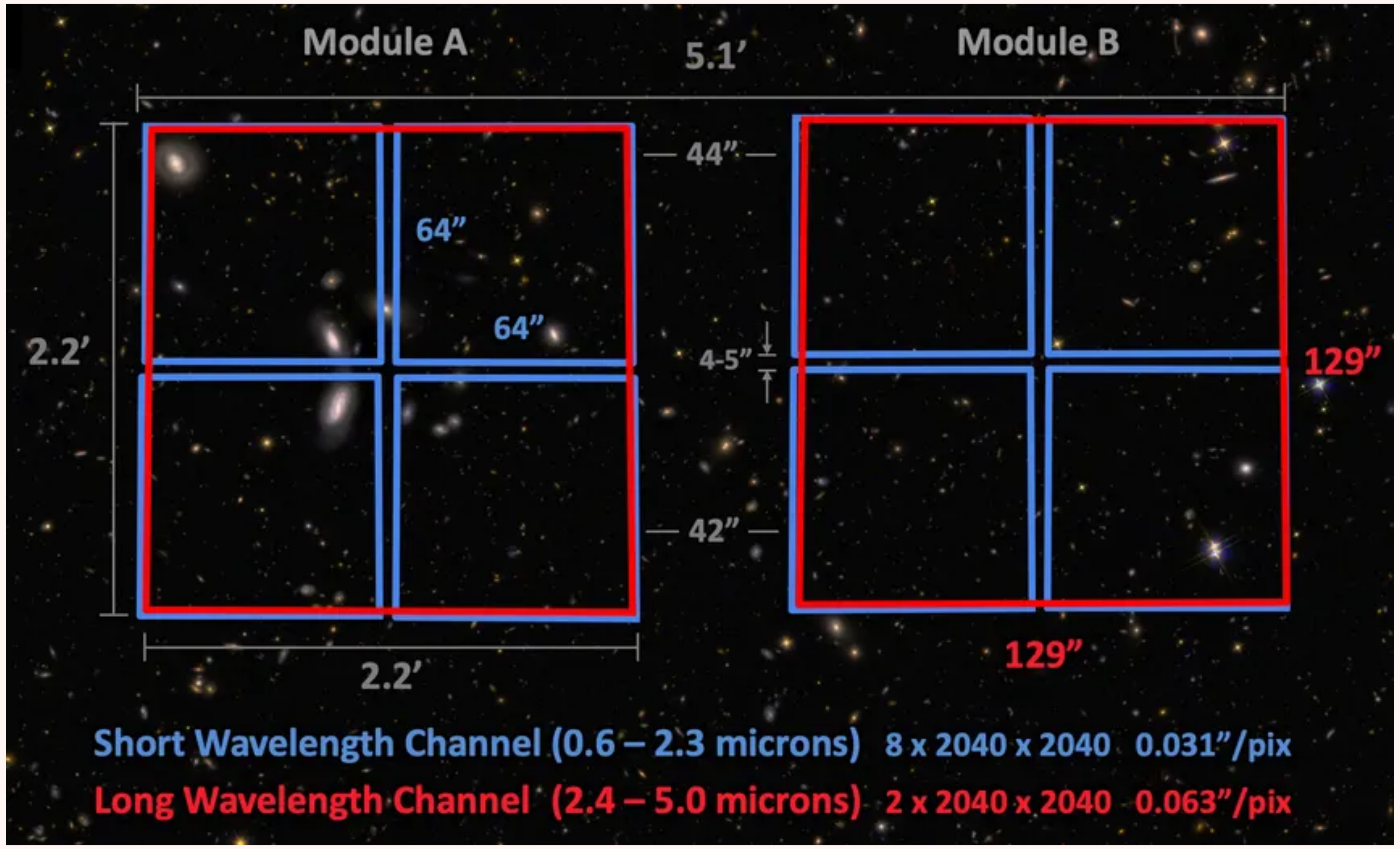
Three detectors (two for the IFU)
1 million pixels each
Closed-loop Cryocooler
Operating Temperature: ~6 K



Imaging Modes: NIRCam Overview

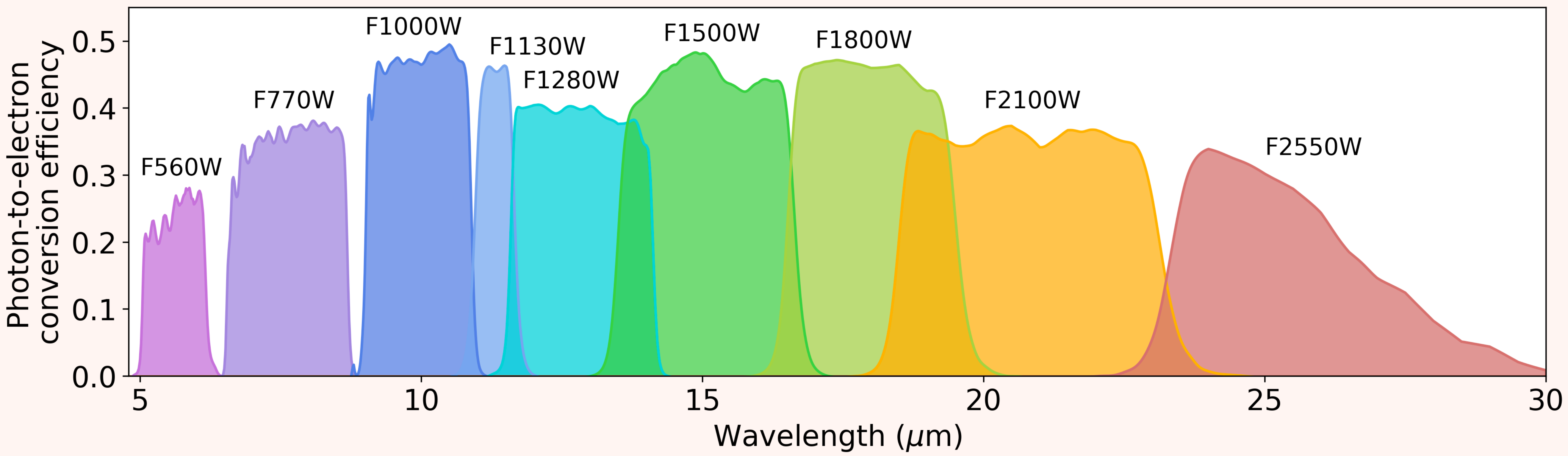


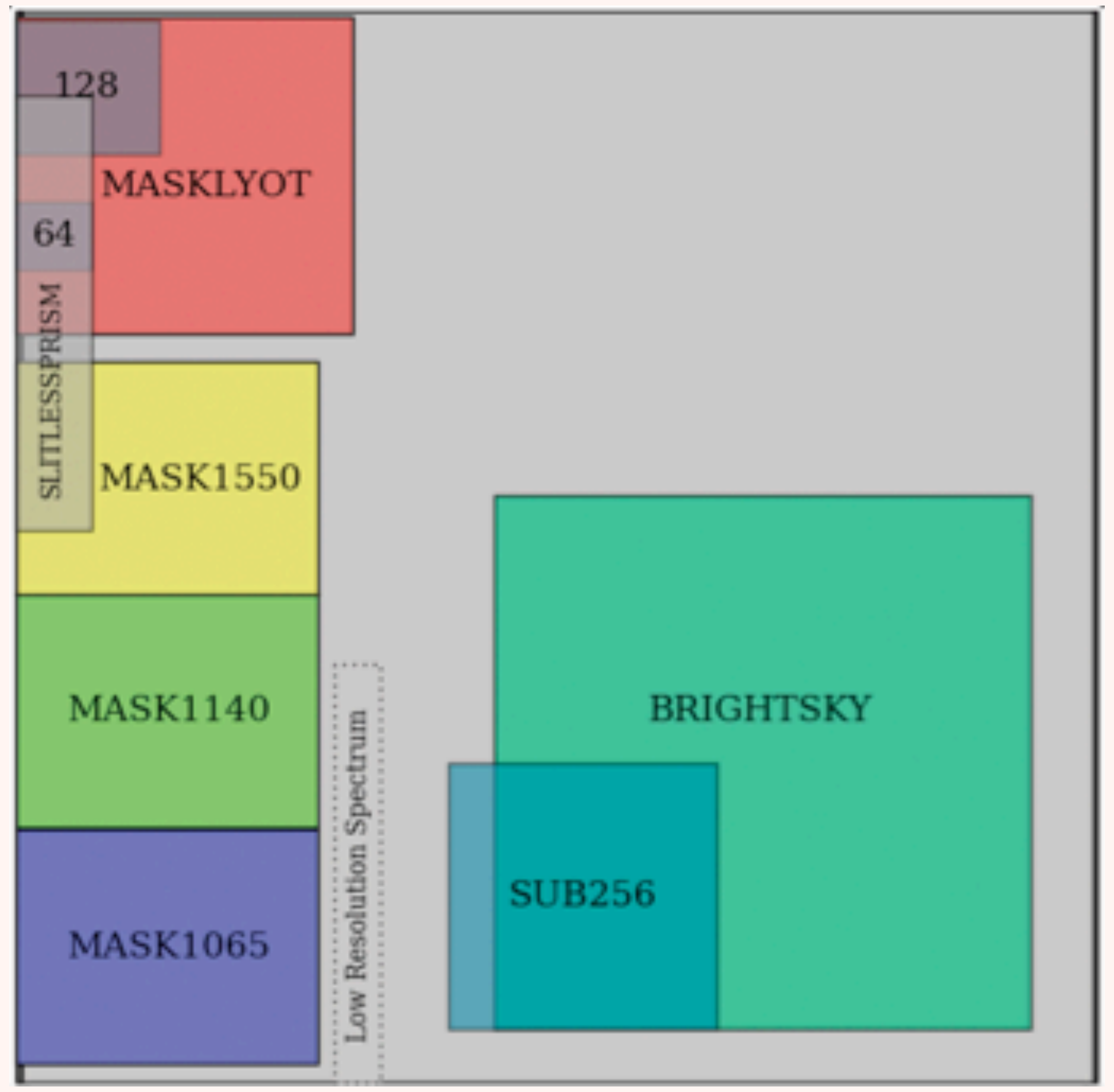
9.7 sq arcmin FOV



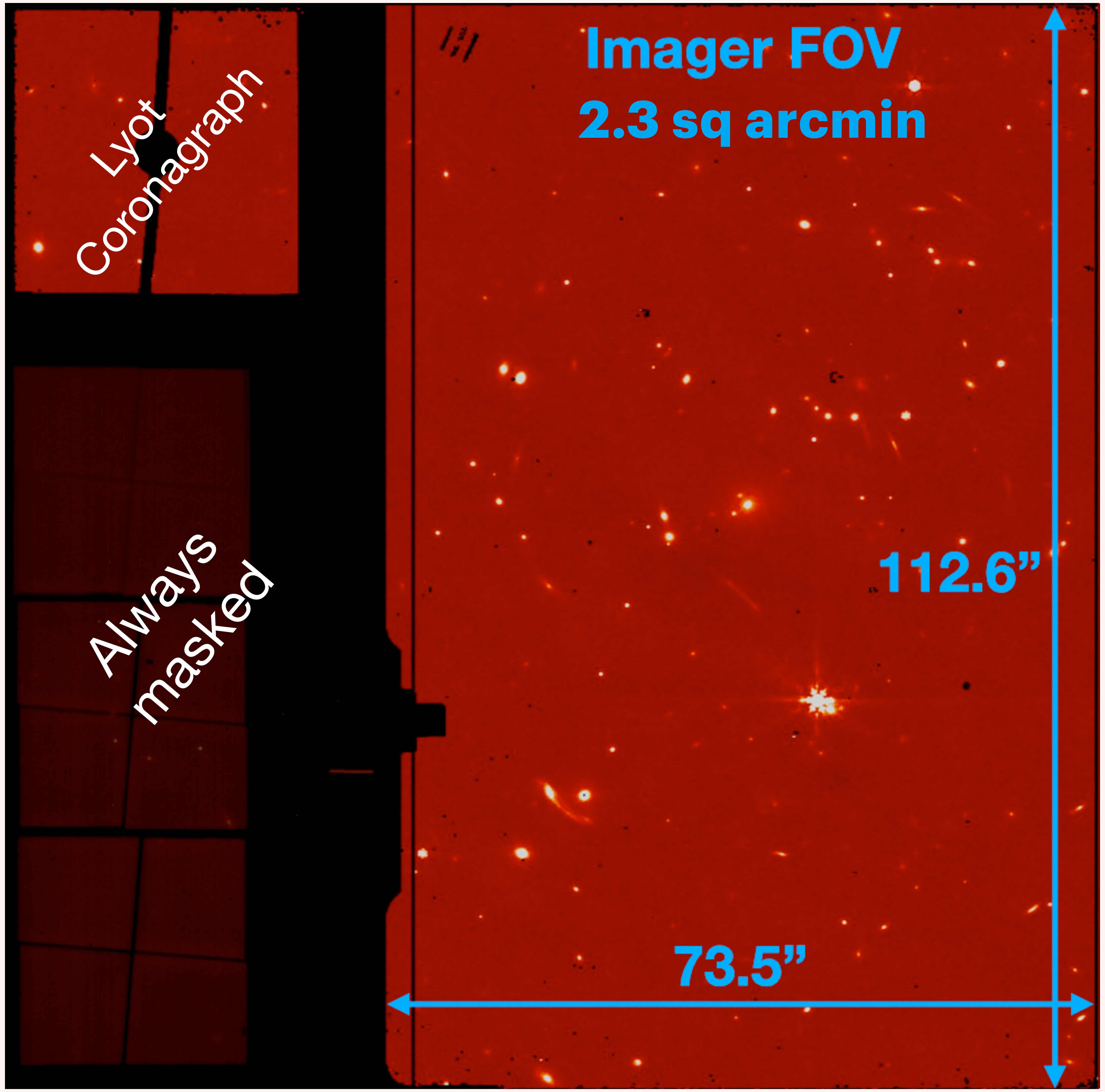
- Simultaneous short and long wave filters
- Short wave: 0.6-2.5um (0.03” resolution)
- Long wave: 2.5-5um (0.06” resolution)

Imaging Modes: MIRI Overview

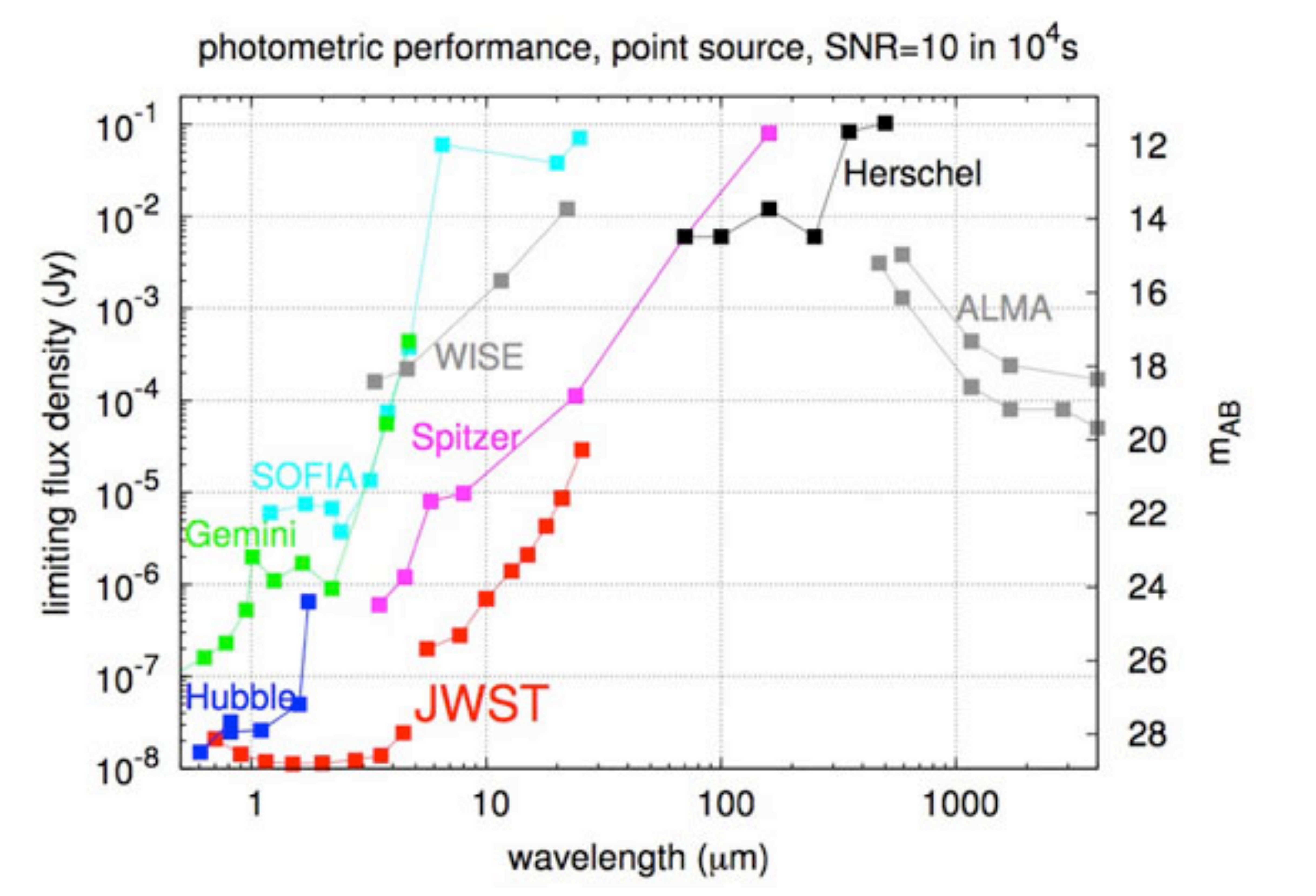




- 5.6 - 25.5um
- 0.2-0.8" resolution
- Nyquist sampled at 7.7um, oversampled at >10um



SENSITIVIES

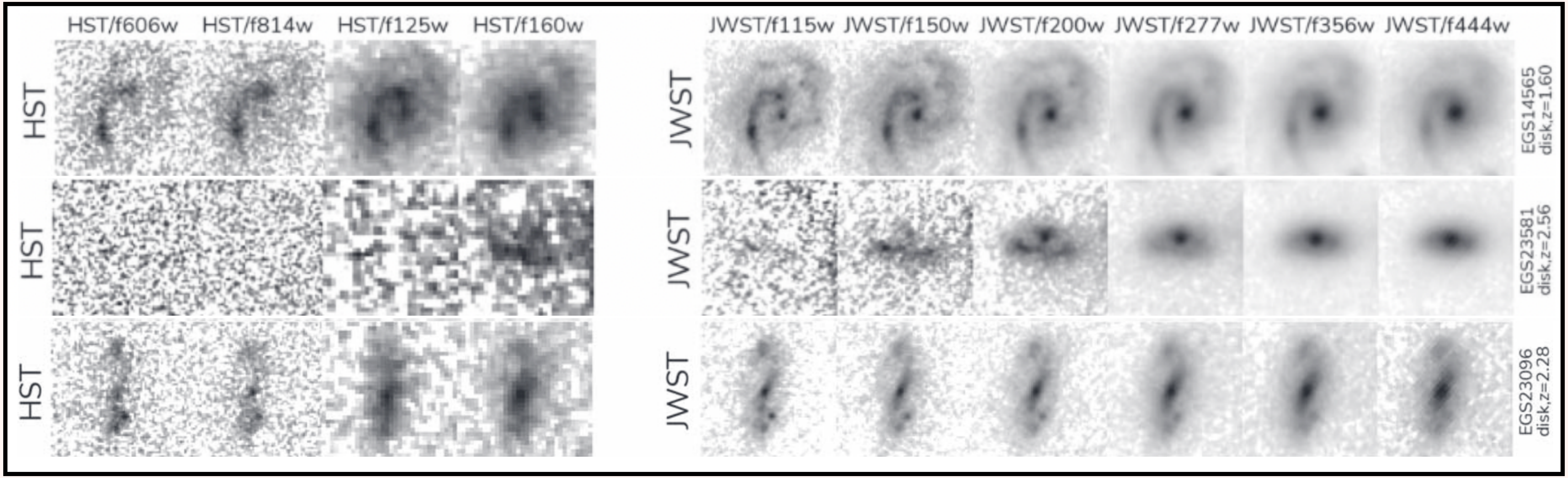


100 - 1,000 x more sensitive than HST, Spitzer, WISE

RESOLUTION

HST vs NIRCam

Ferreira et al. 2023



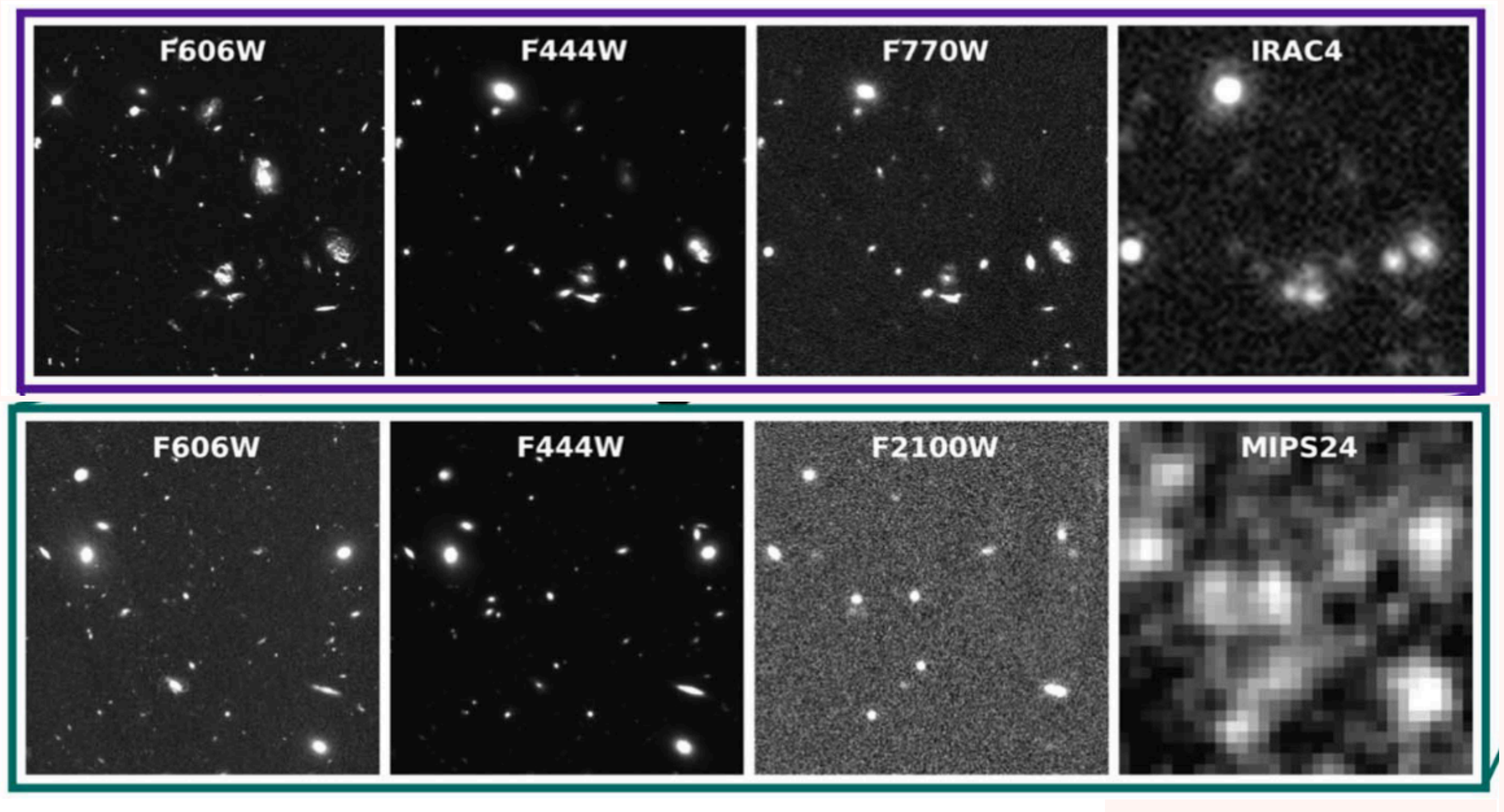
Longest HST filter

NIRCam counterpart to Longest HST filter (Check out the resolution!)

RESOLUTION

HST vsNIRCam vs MIRI vs Spitzer IRAC/MIPS

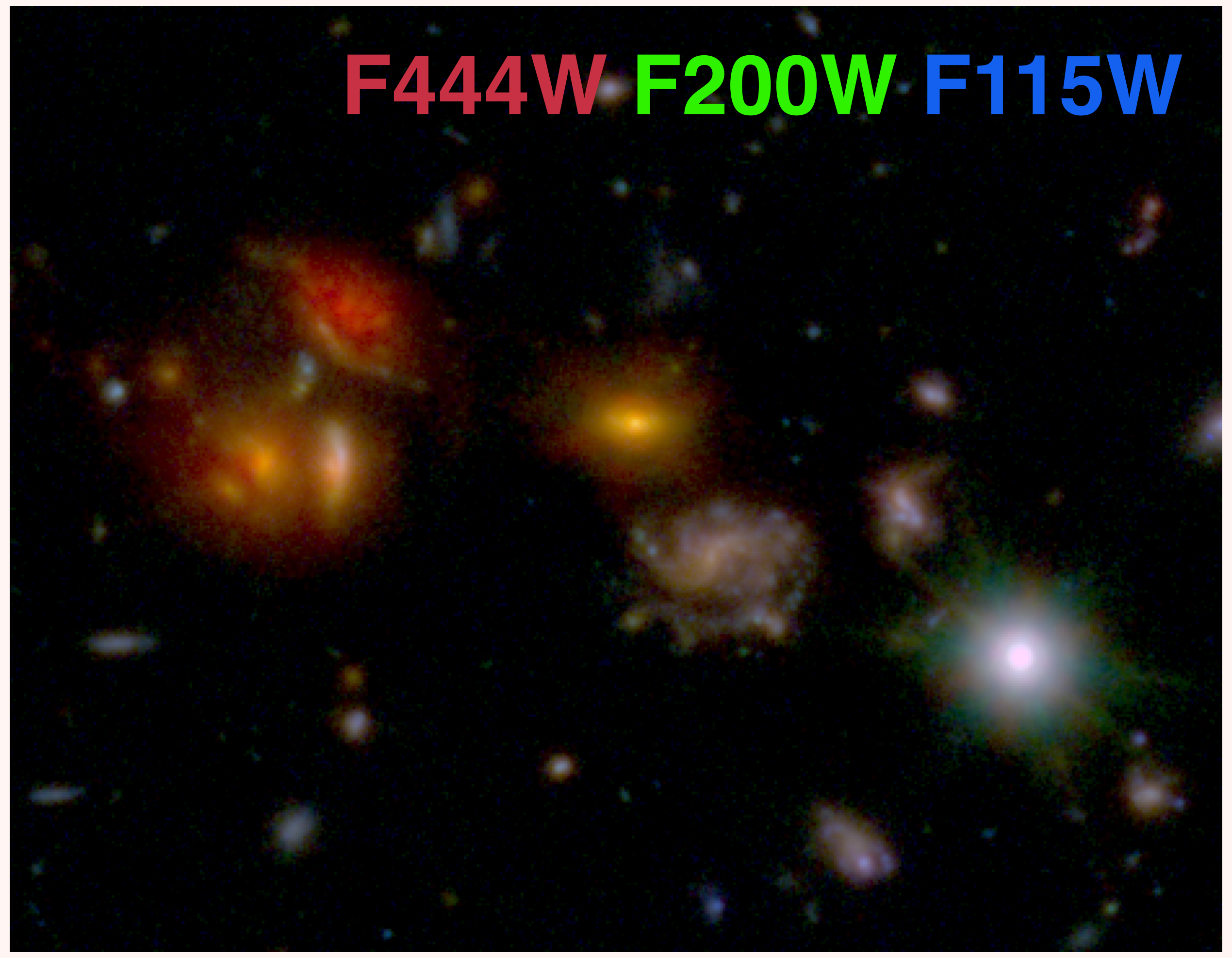
HST | NIRCam | MIRI F770W | Spitzer/ IRAC 8um

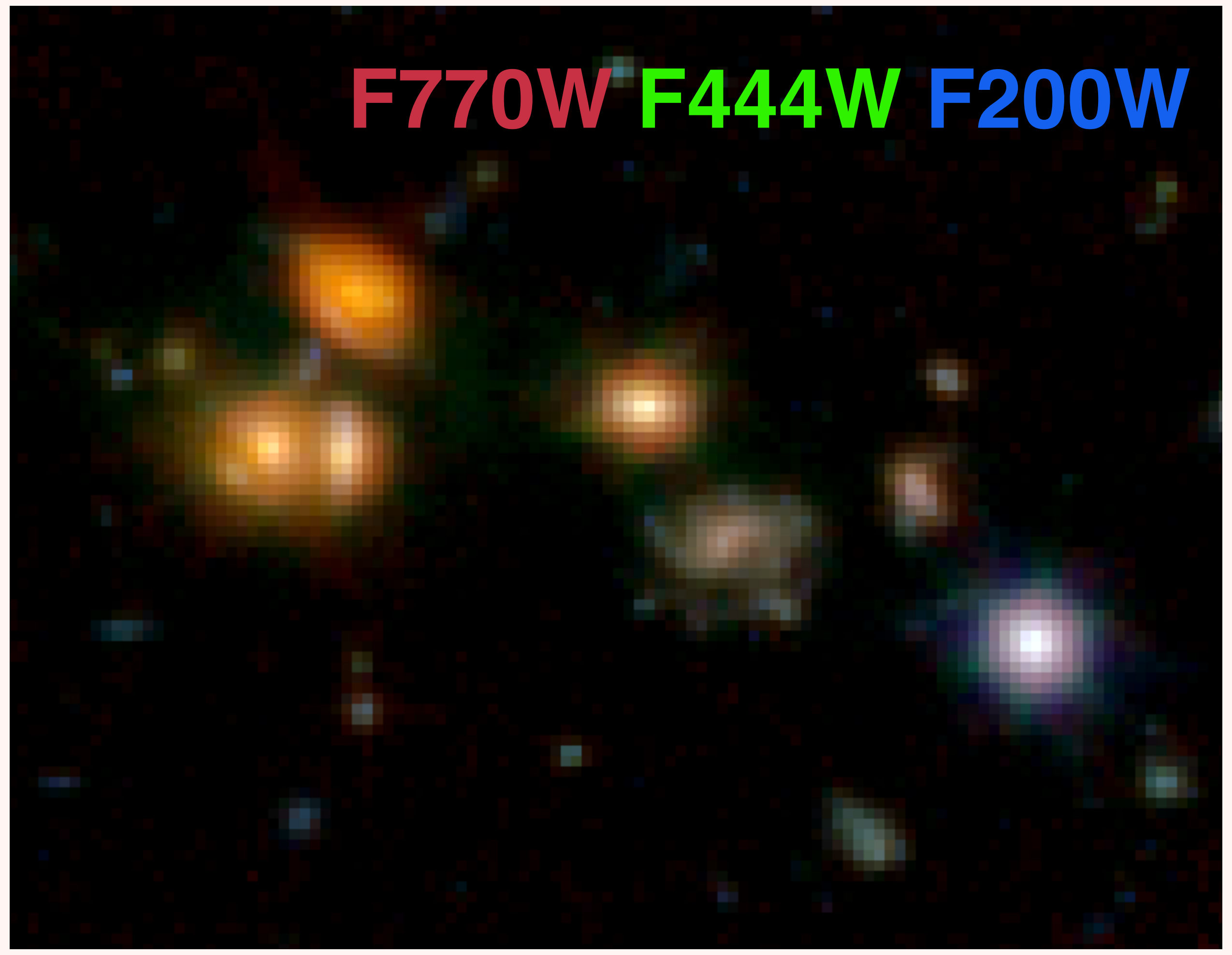


HST | NIRCam | MIRI F2100W | Spitzer/ MIPS 24um

RESOLUTION

HST vsNIRCam vs MIRI vs Spitzer IRAC/MIPS





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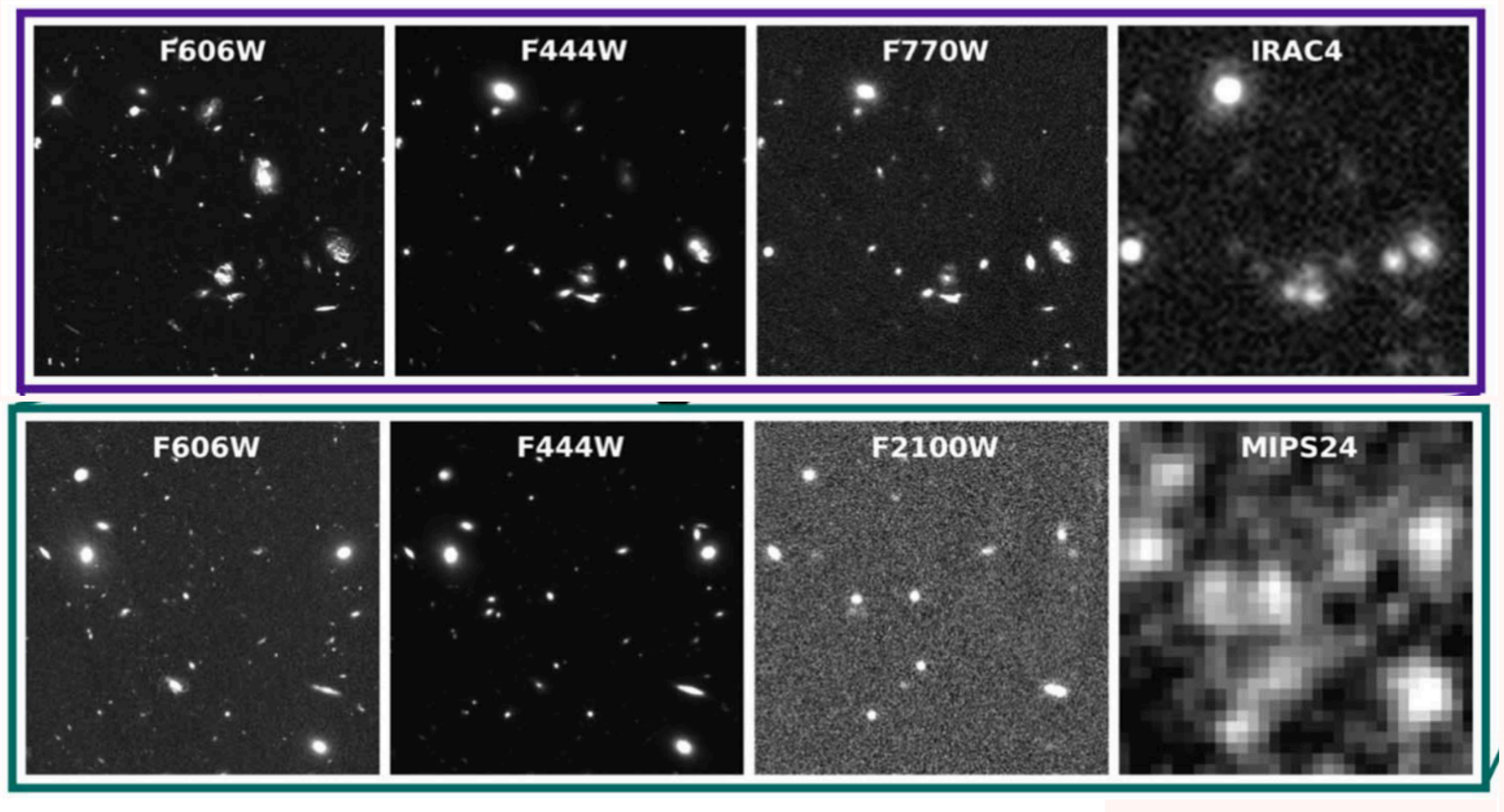


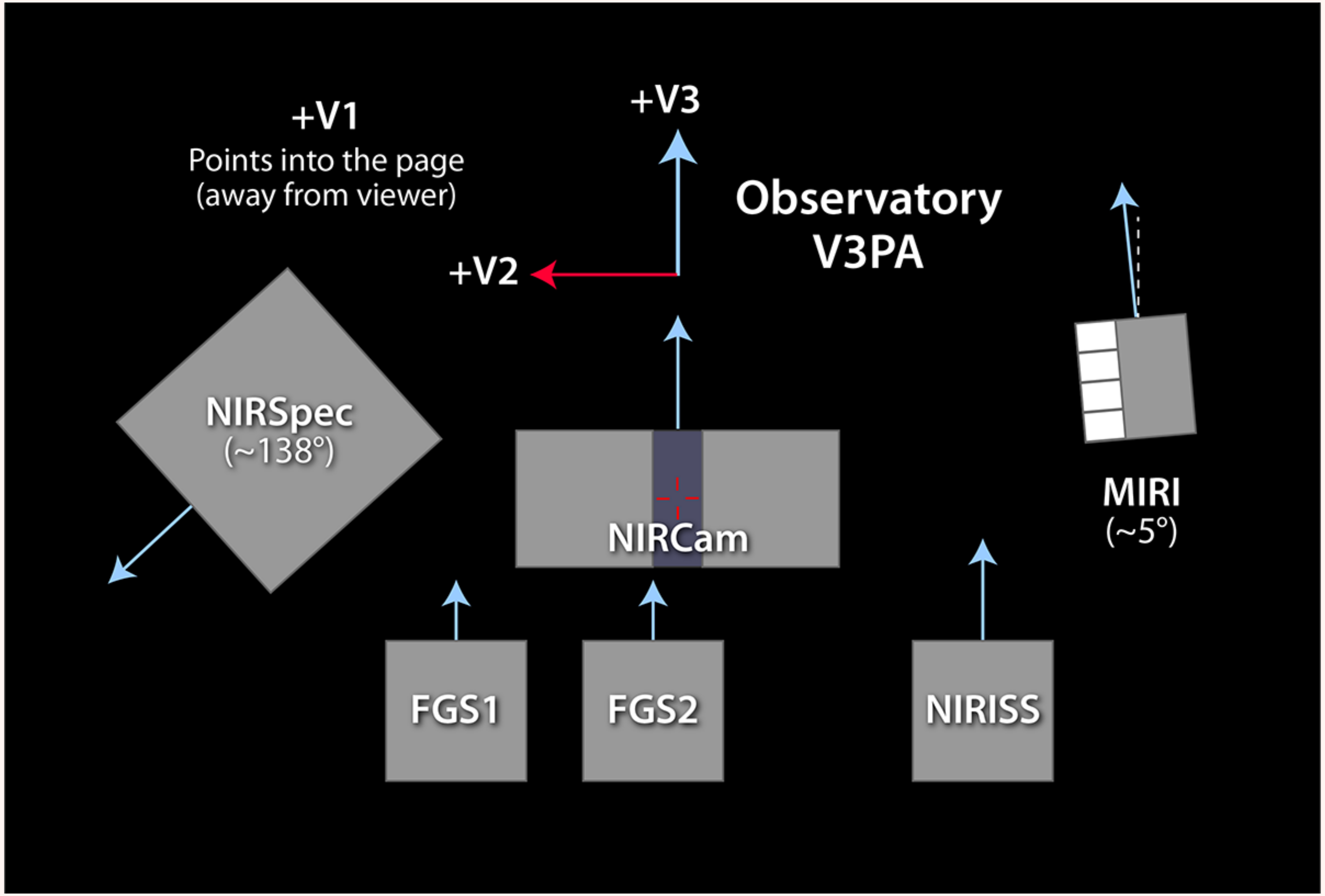
HST | NIRCam | MIRI F2100W | Spitzer/ MIPS 24um

WORKING WITH JWST [IMAGING] DATA

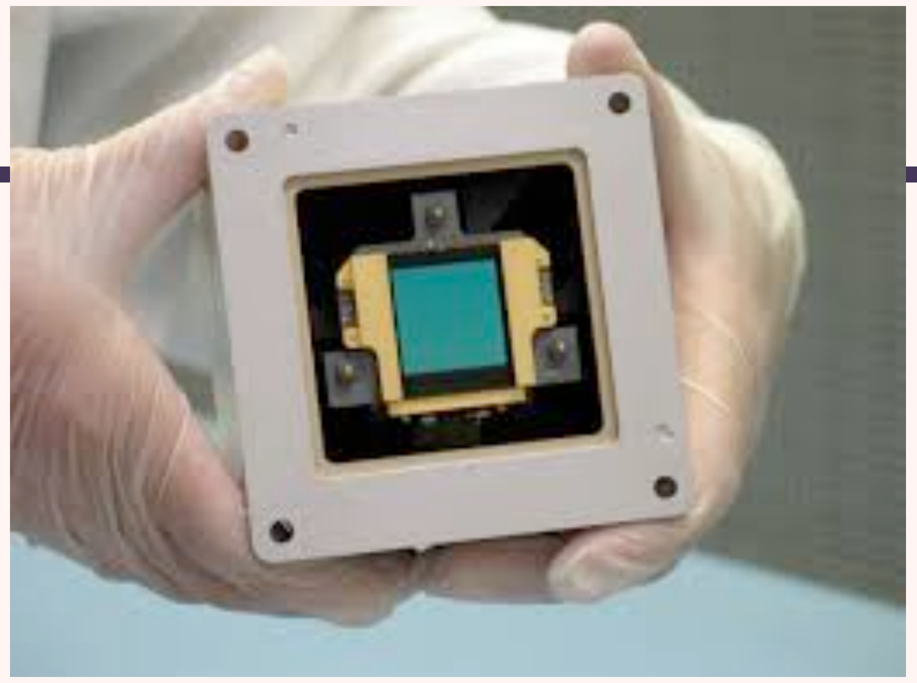
Aka how do the photons get from there to here

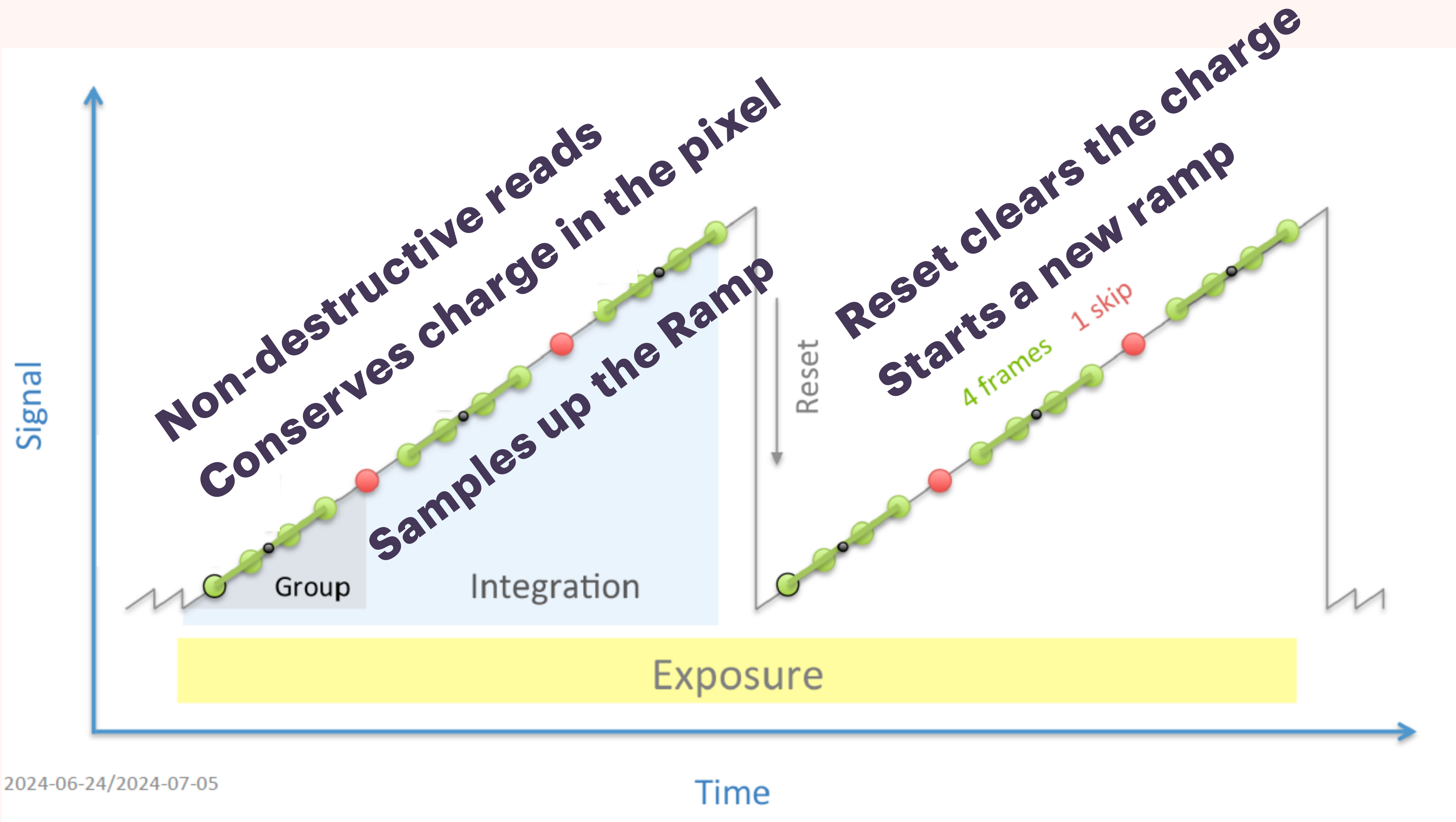
Where do these instruments live...

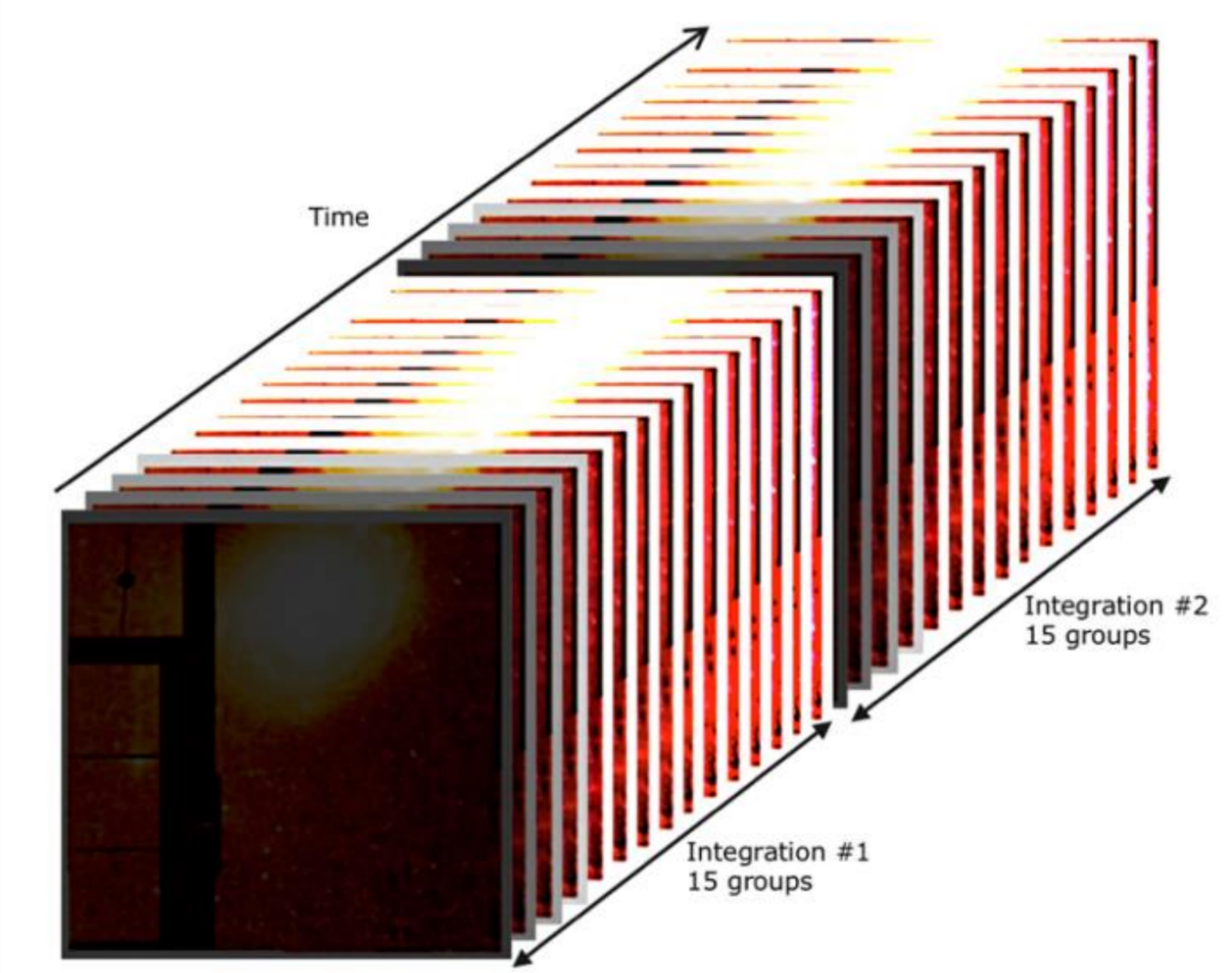
Two instruments can be run at once!



READOUT MODES AND EXPOSURE SETUP



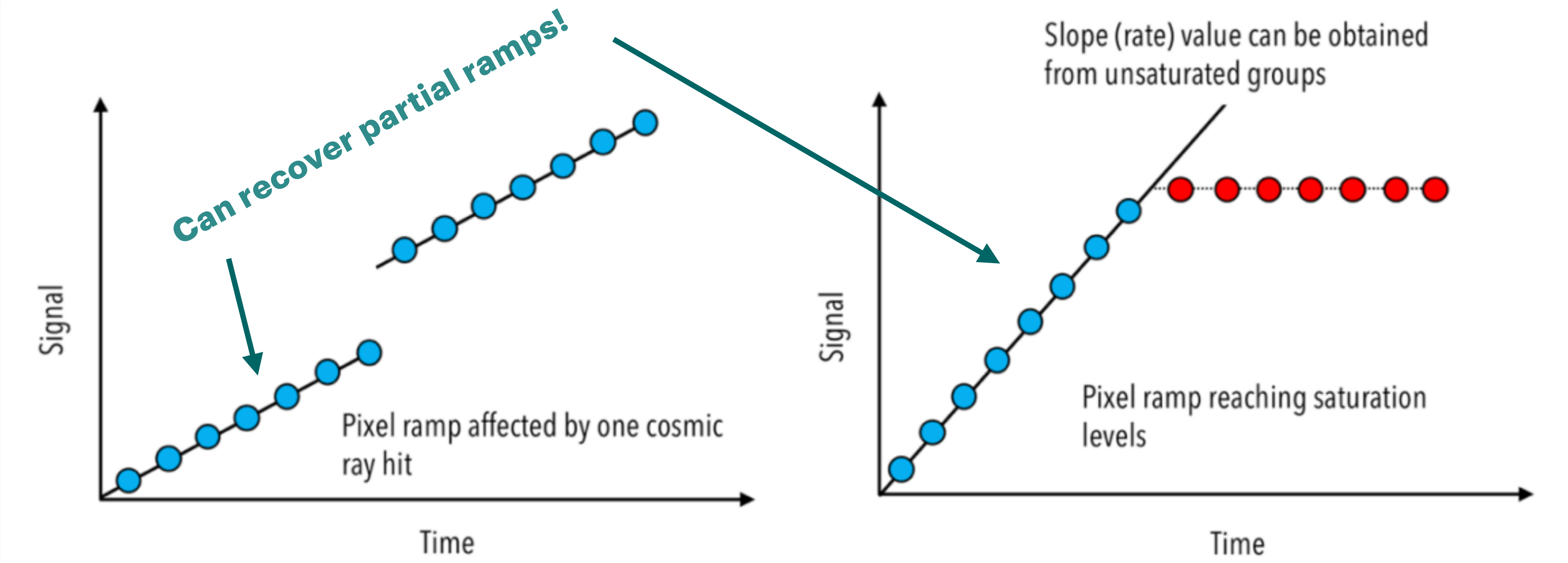




Longer ramps are better (except when they aren't)

READOUT MODES AND EXPOSURE SETUP

Cosmic rays cause jumps | **Saturation when the pixel well is full**

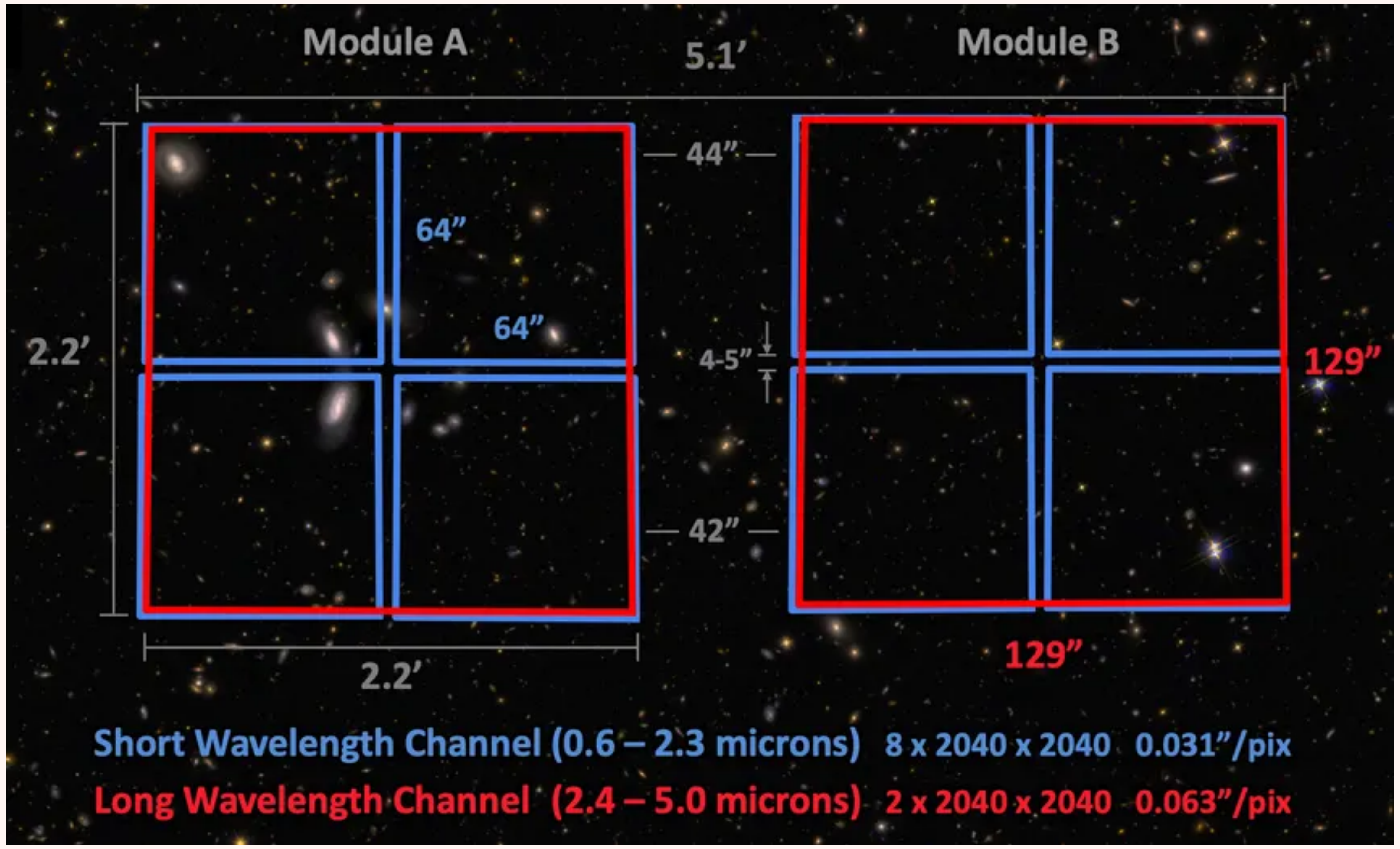


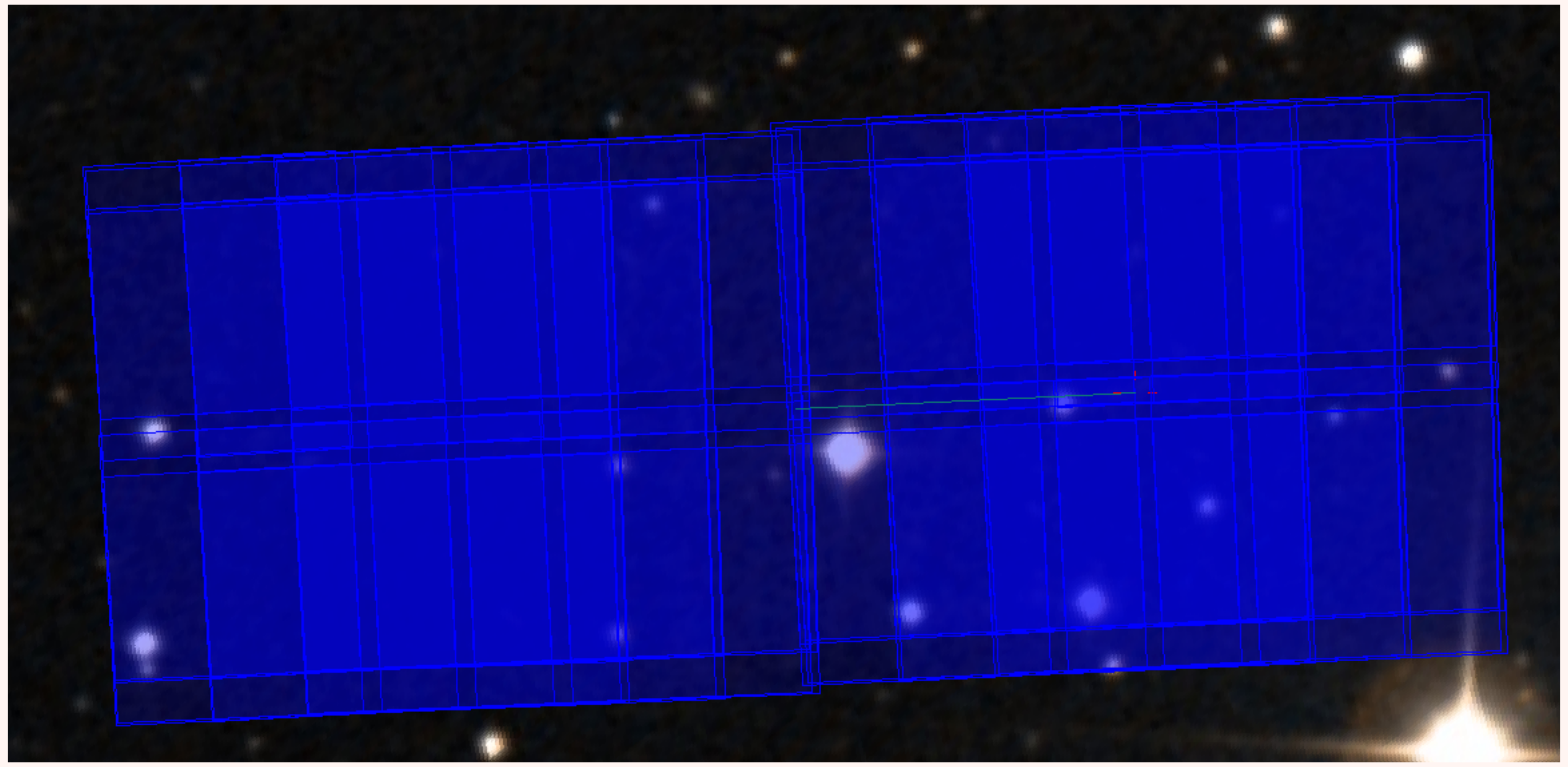
DITHERS

Mitigate artifacts (bad pixels, persistence, cosmic rays)

Sample the Point Spread Function

Fill detector gaps





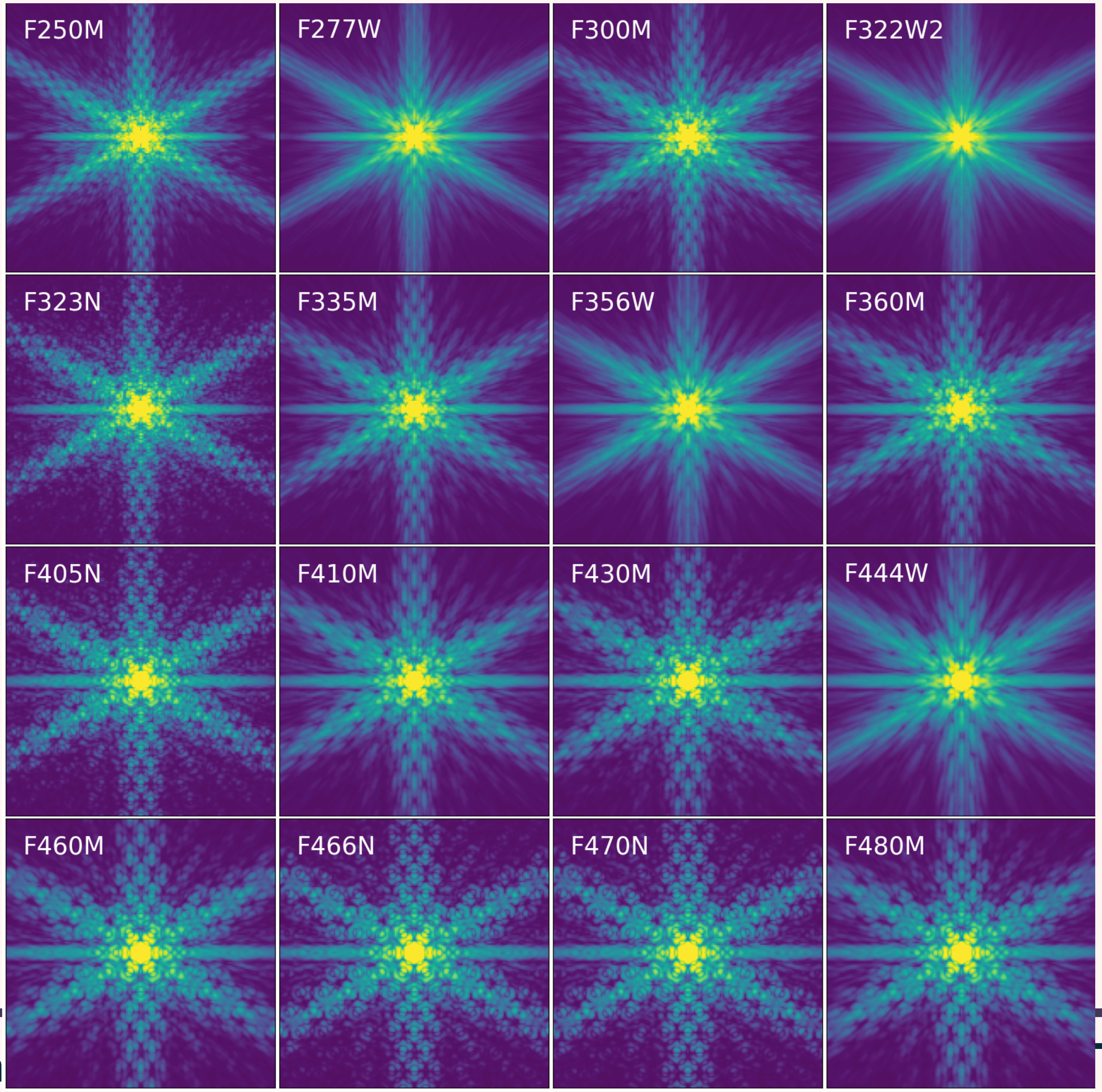
Always dither!
(Unless time series observation)

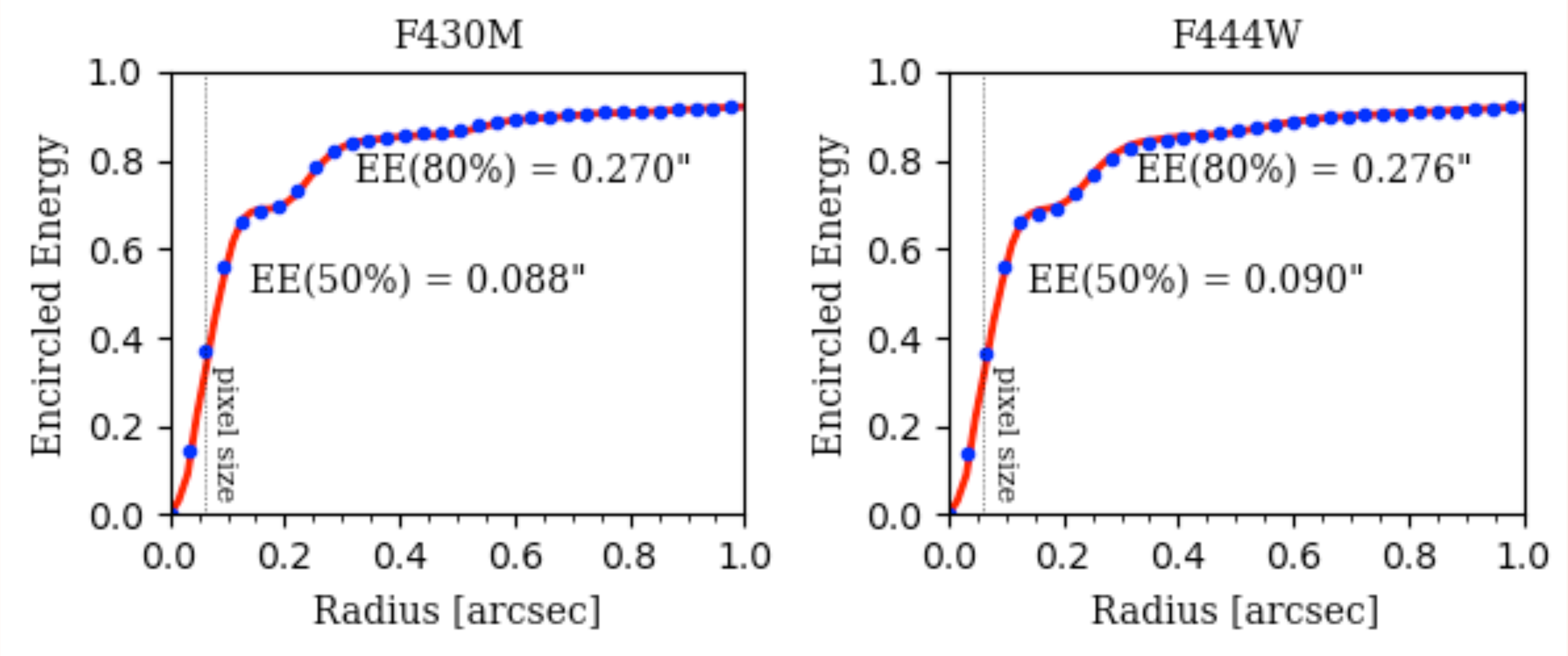
POINT SPREAD FUNCTION (PSF)

FWHM ~ λ/D

D = 6.5 m

At >2um, diffraction-limited. Below 2um, PSF is undersampled (FWHM<2 pixels).





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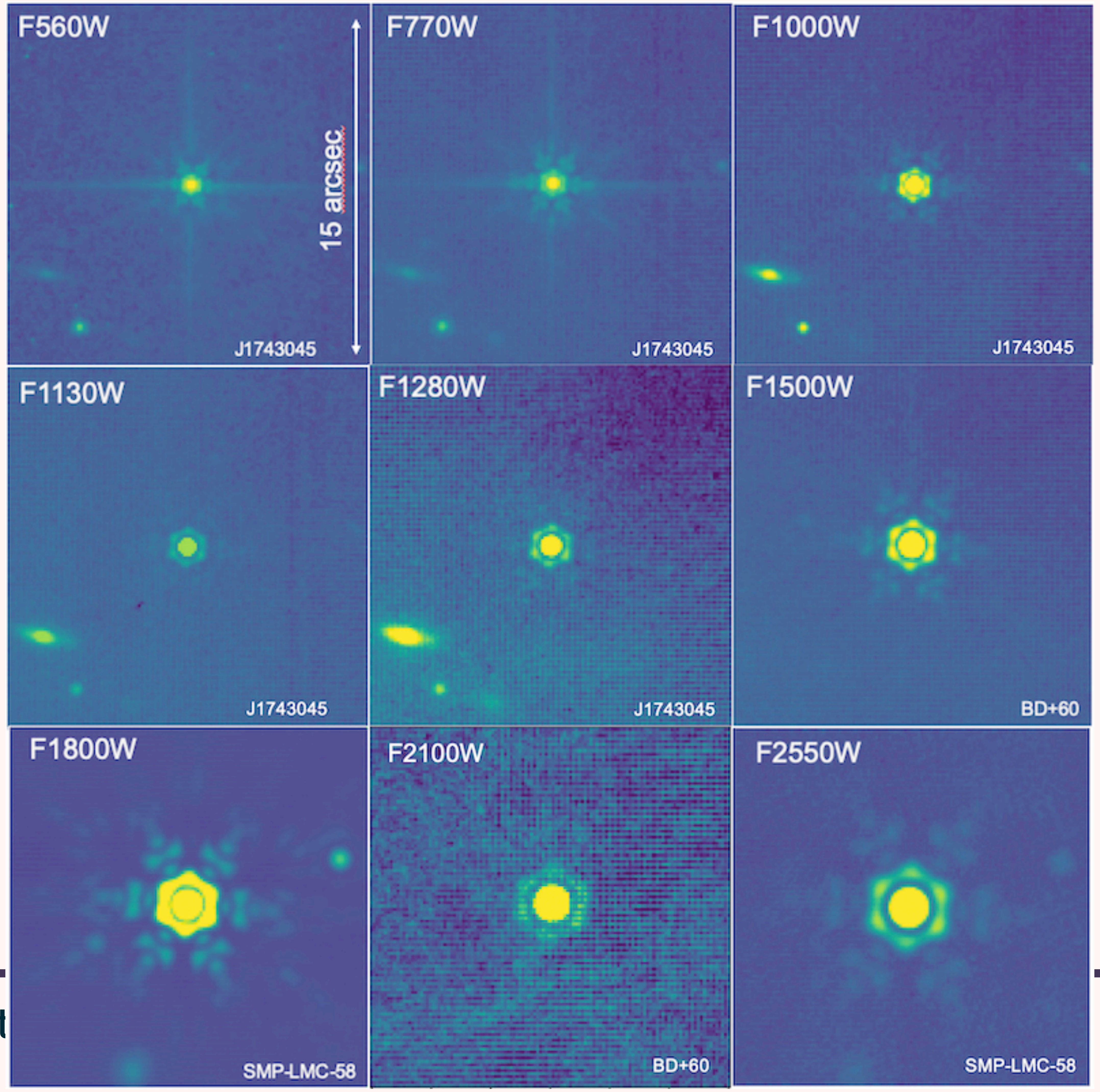
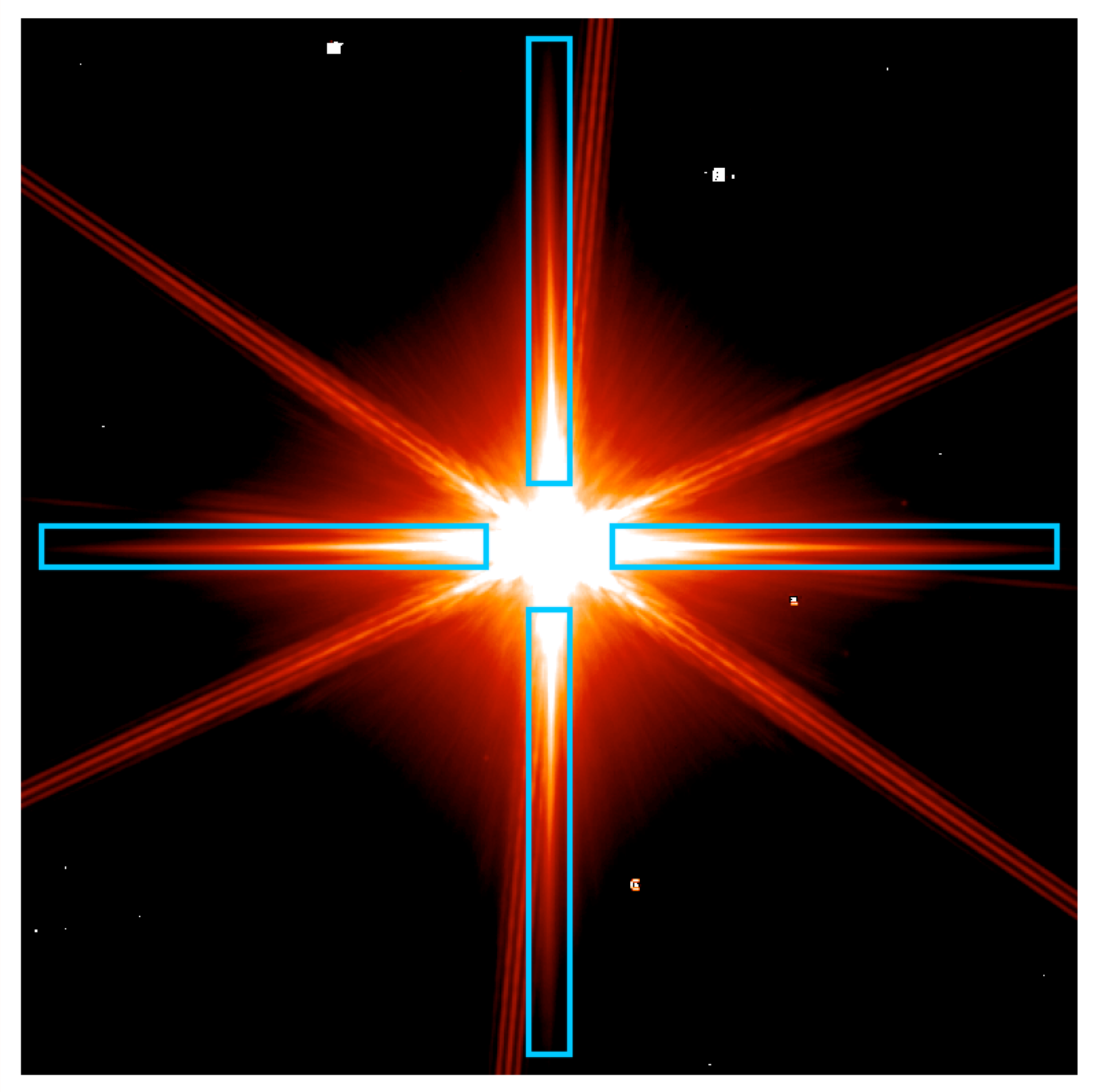


Cross Artifact (<10um)



WORKING WITH JWST [IMAGING] DATA

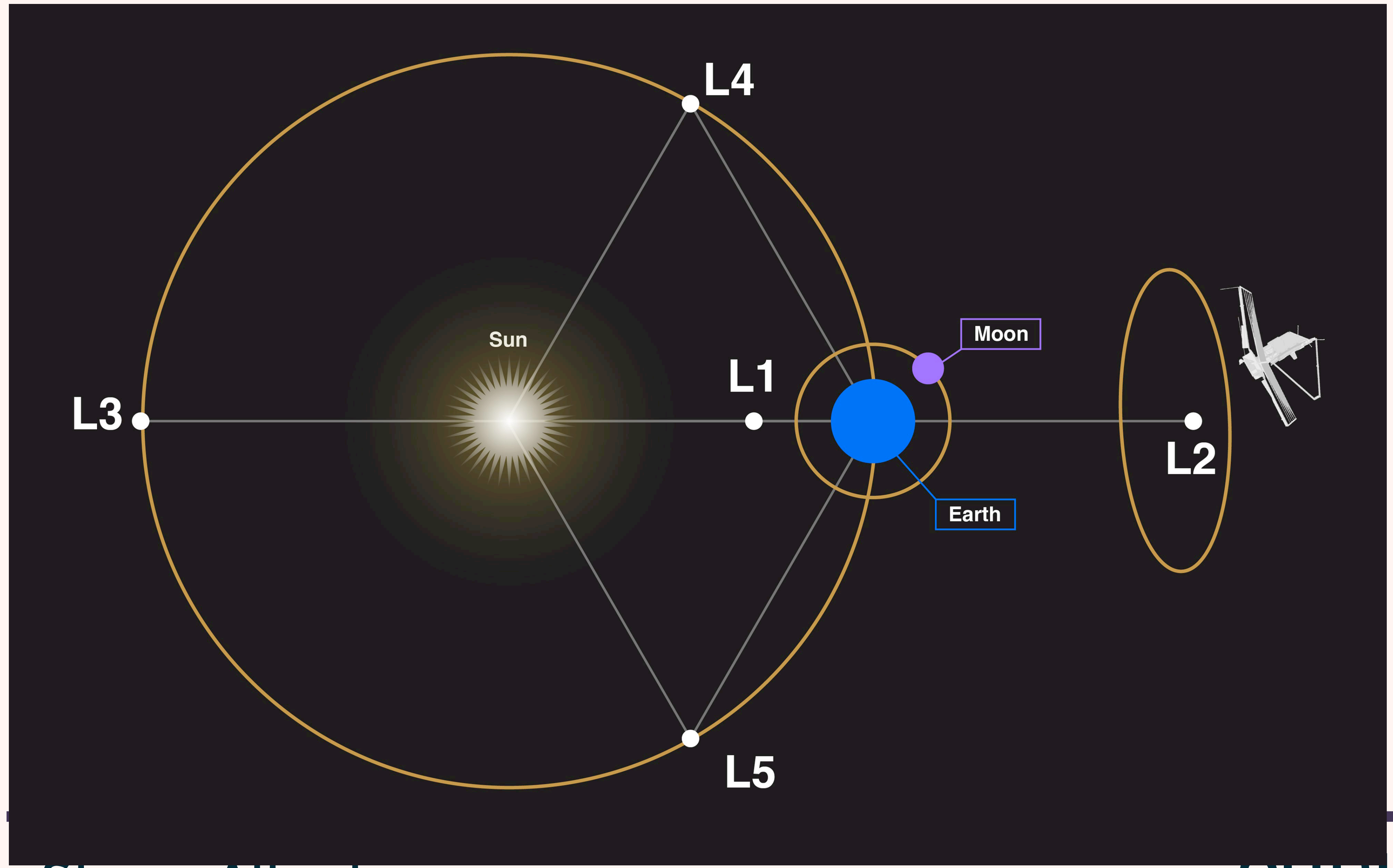
Aka why are my detectors doing that

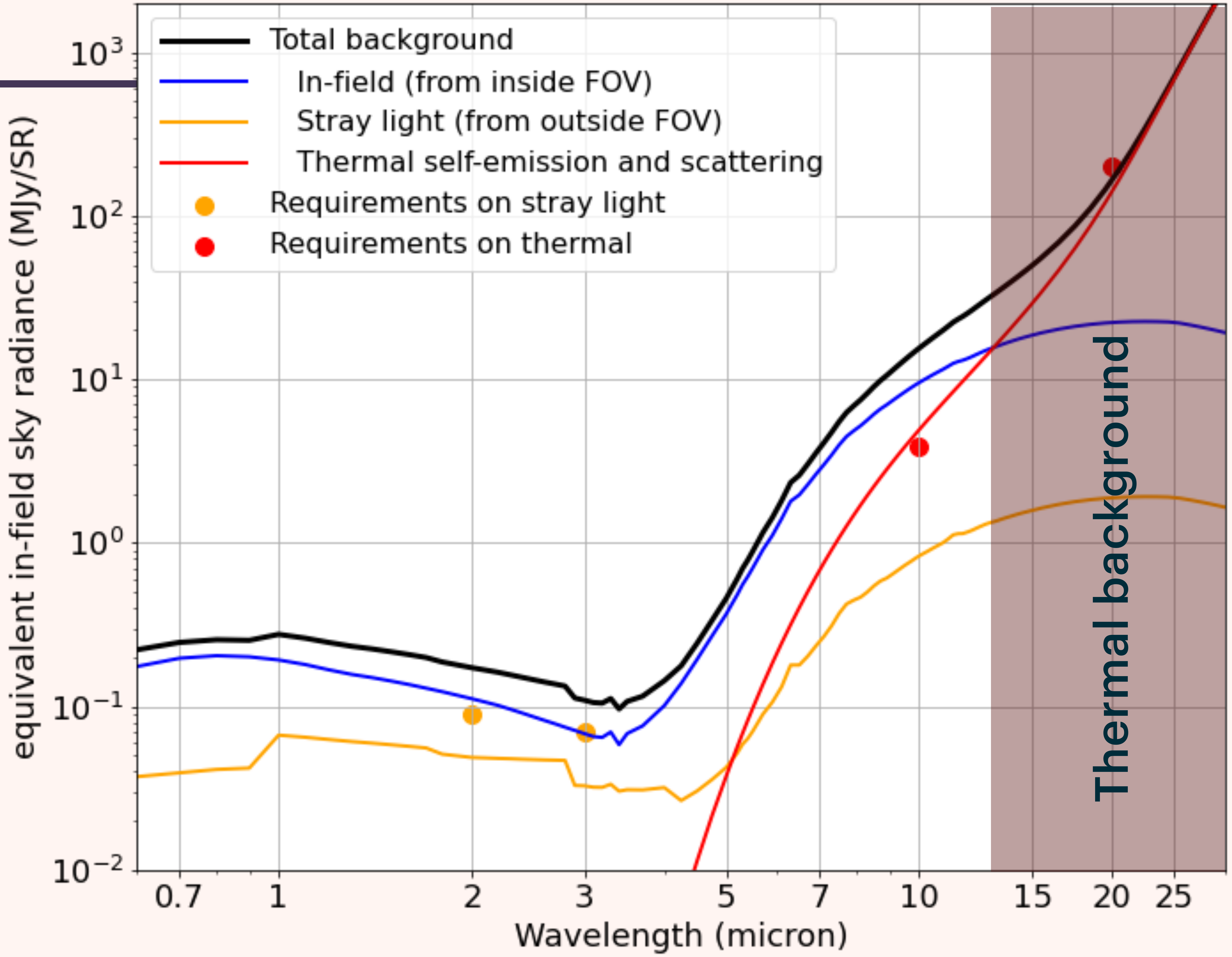
Background, cosmic rays, and artifacts, oh my!

Imaging Modes: Considerations

At this sensitivity, each detector is a special snowflake…

Space is an unforgiving environment…

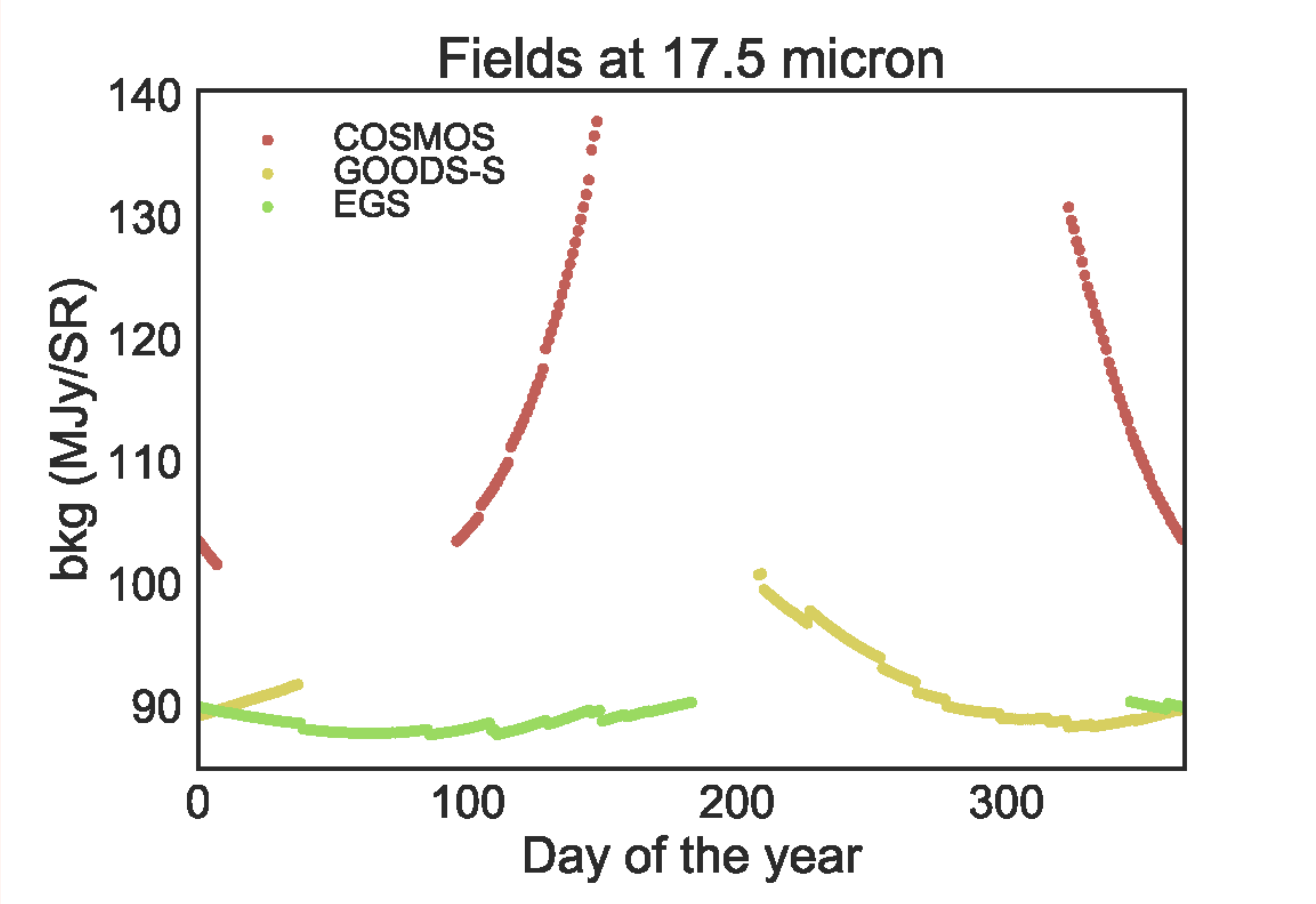


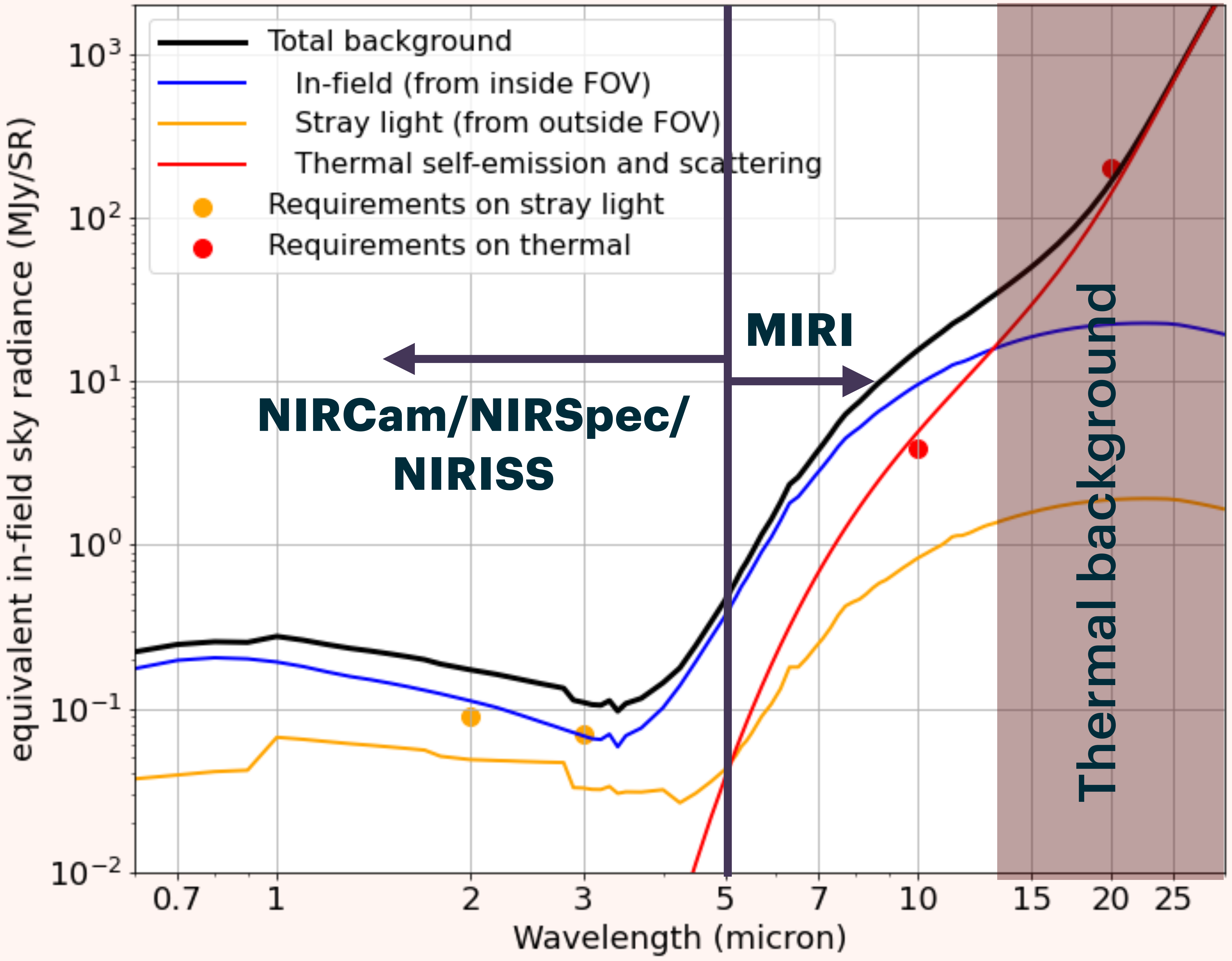


…even our own telescope is fighting us.

BACKGROUND SUBTRACTION

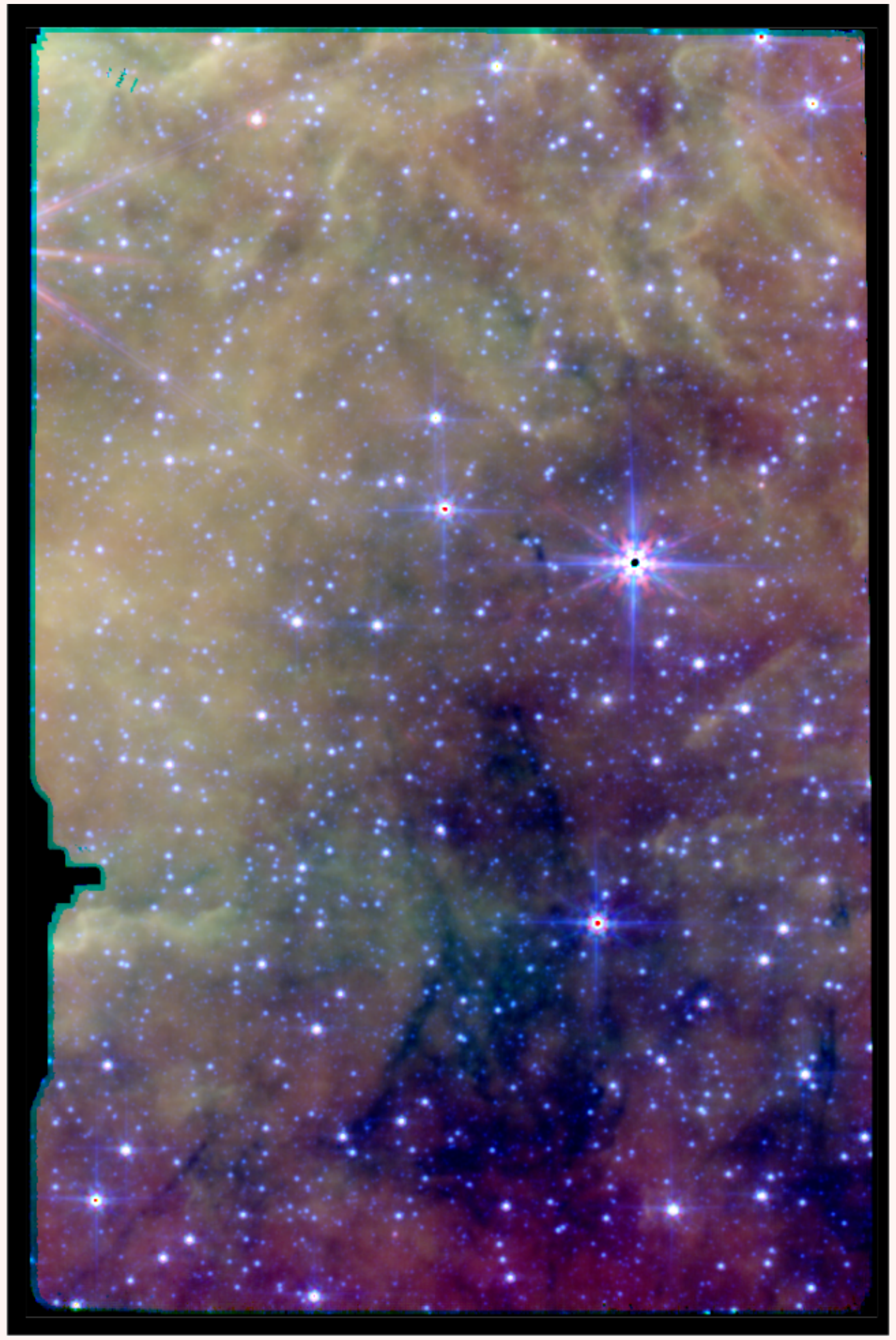
Backgrounds are space, time and wavelength varying





BACKGROUND SUBTRACTION

Natively supported by the pipeline



Galactic center (F560W, F770W, F1280W) [Dicken+]

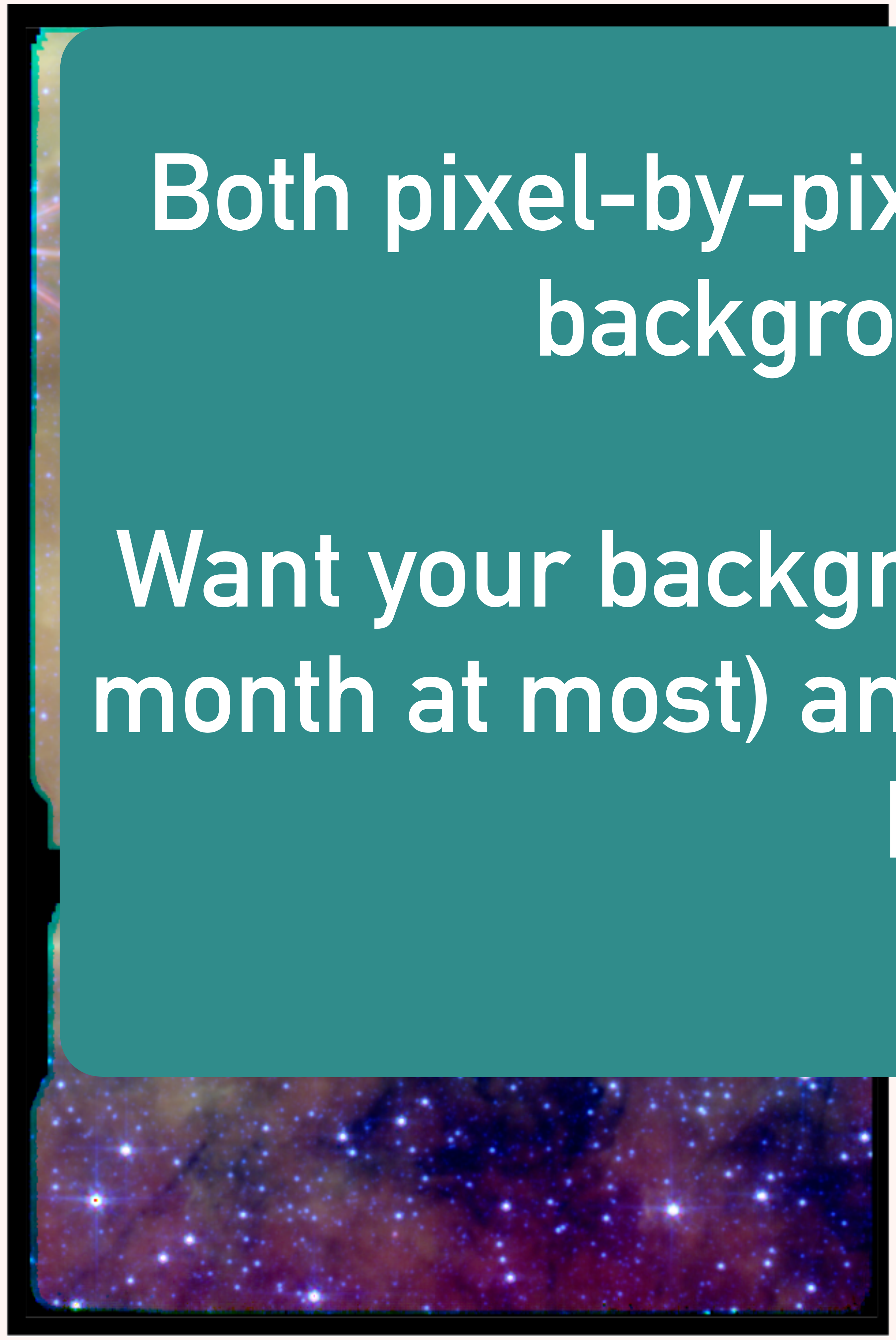
Designated "empty" background from nearby

Multiple background exposures will be averaged with sigma-clipping

Then subtracted from each science exposure

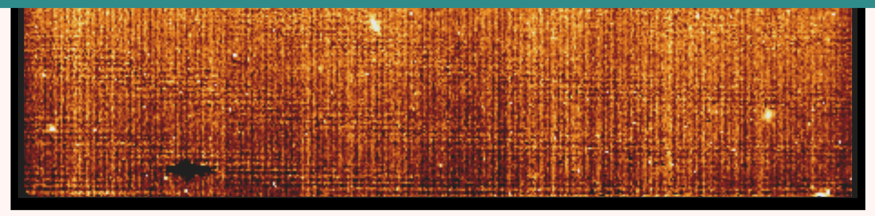
BACKGROUND SUBTRACTION

Natively supported by the pipeline



Both pixel-by-pixel background and sky (zodi or thermal) background vary with time and location.

Want your background exposures to be within ~2 weeks (a month at most) and nearby (several arcminutes) for optimal background subtraction!



Galactic center (F560W, F770W, F1280W) [Dicken+]

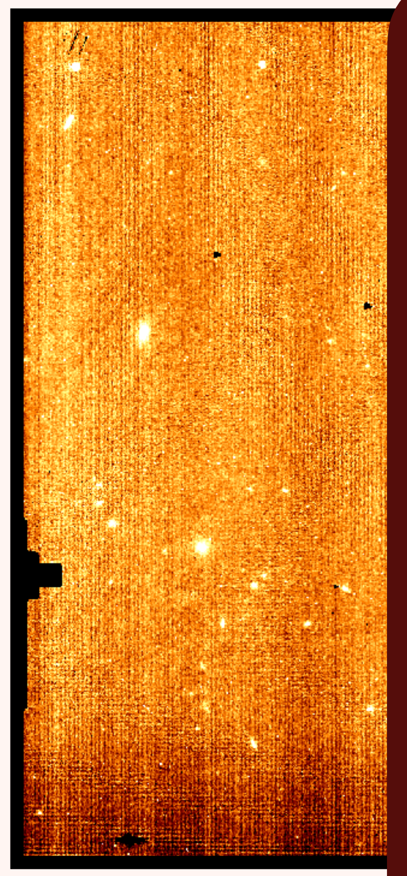
BACKGROUND SUBTRACTION

BACKGROUND SUBTRACTION

Mask/clip, scale, stack, and median combine

Dither 1 Dither 2 Dither 3 Dither 4

SINGLE POINTING (POINT/COMPACT SOURCES)



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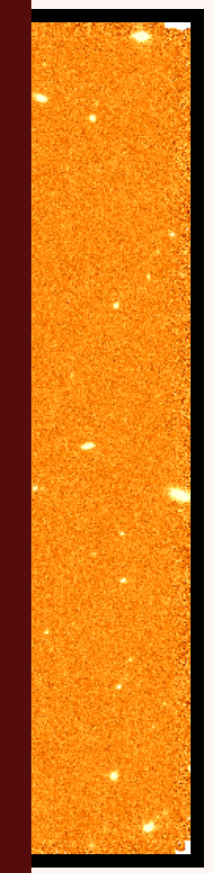


NOT natively supported by the pipeline

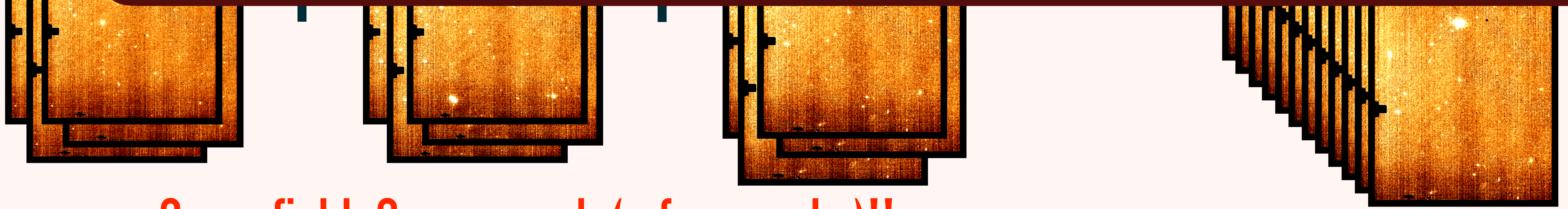
See resources:
https://github.com/STScI-MIRI/Imaging_ExampleNB/blob/main/Pipeline_demo_subtract_imager_background.ipynb

Alberts et al., 2024, ApJ, 976, 224

MULTI-POINTING MOSAIC

Poir

(4 c



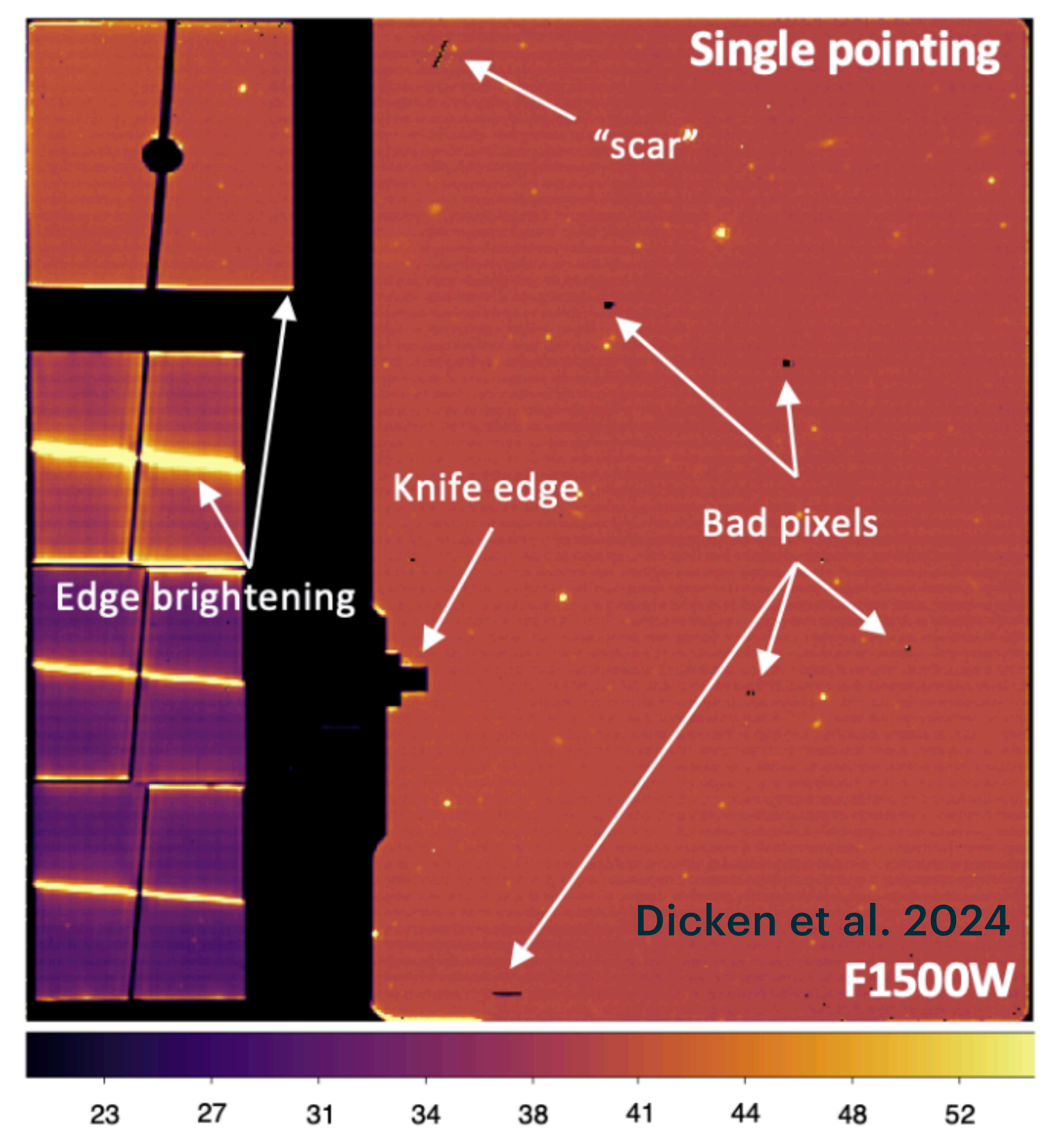
Same field, Same epoch (~few weeks)!!

BAD PIXELS

BOTH

Warm/hot pixels, changing with time

How to reduce: dither!!



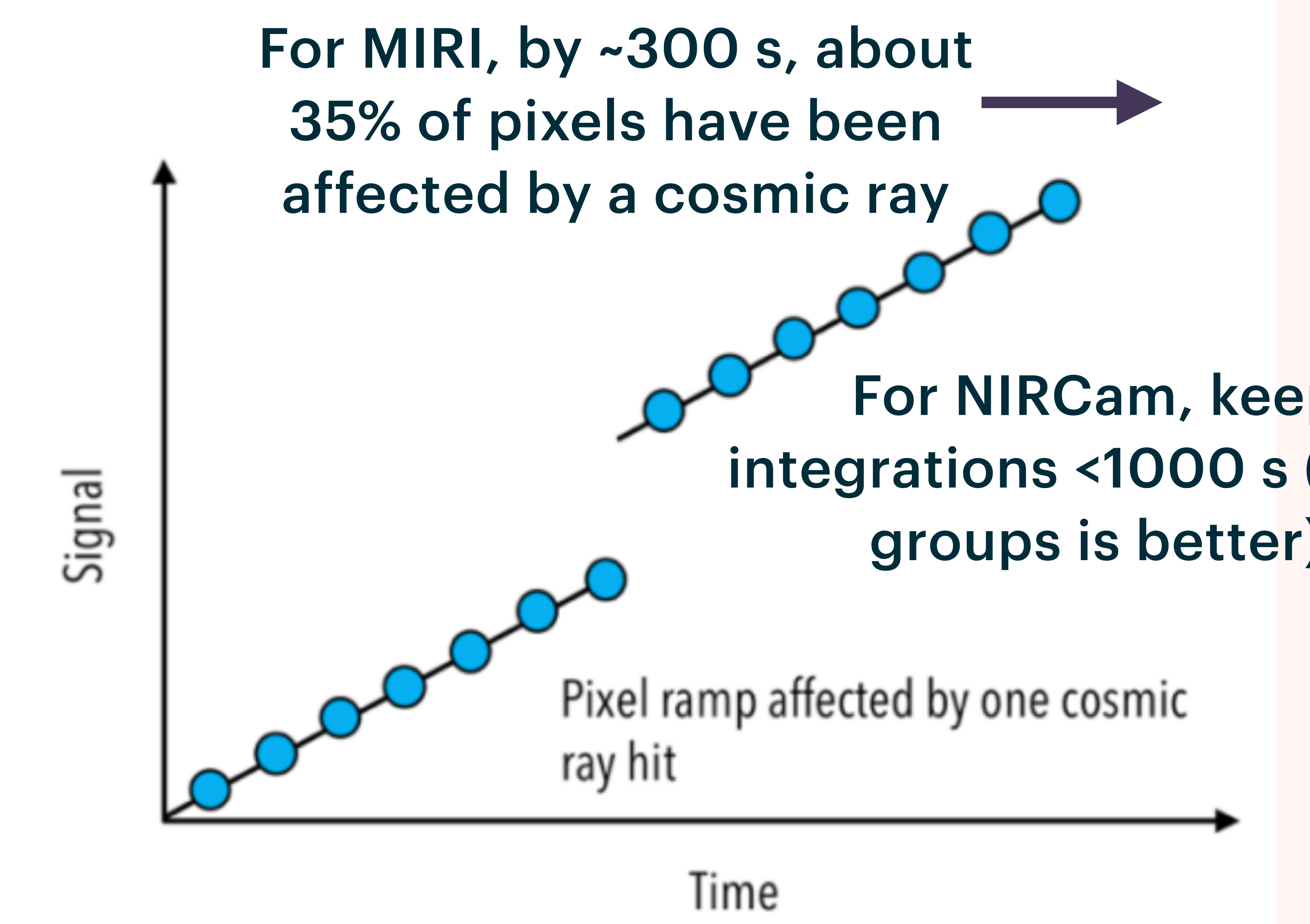
COSMIC RAYS

BOTH

High energy particles that hit the detectors and deposit excess charge in a pixel or group of pixels

How to reduce: optimize ramps and dither!!

For MIRI, by ~300 s, about 35% of pixels have been affected by a cosmic ray



For NIRCam, keep integrations <1000 s (more groups is better)

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High energy particles that hit the detectors and deposit excess charge in a pixel or group of pixels

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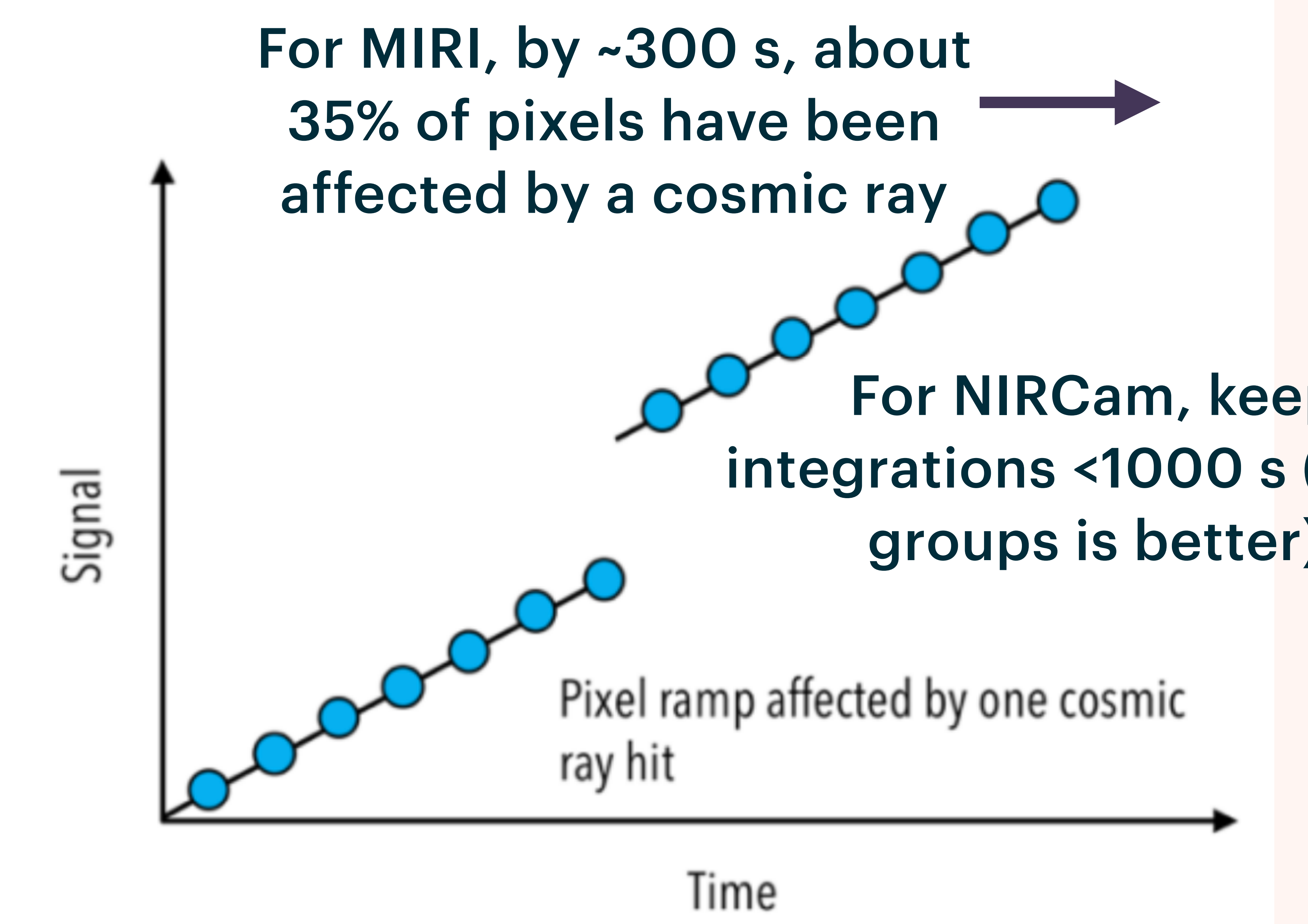
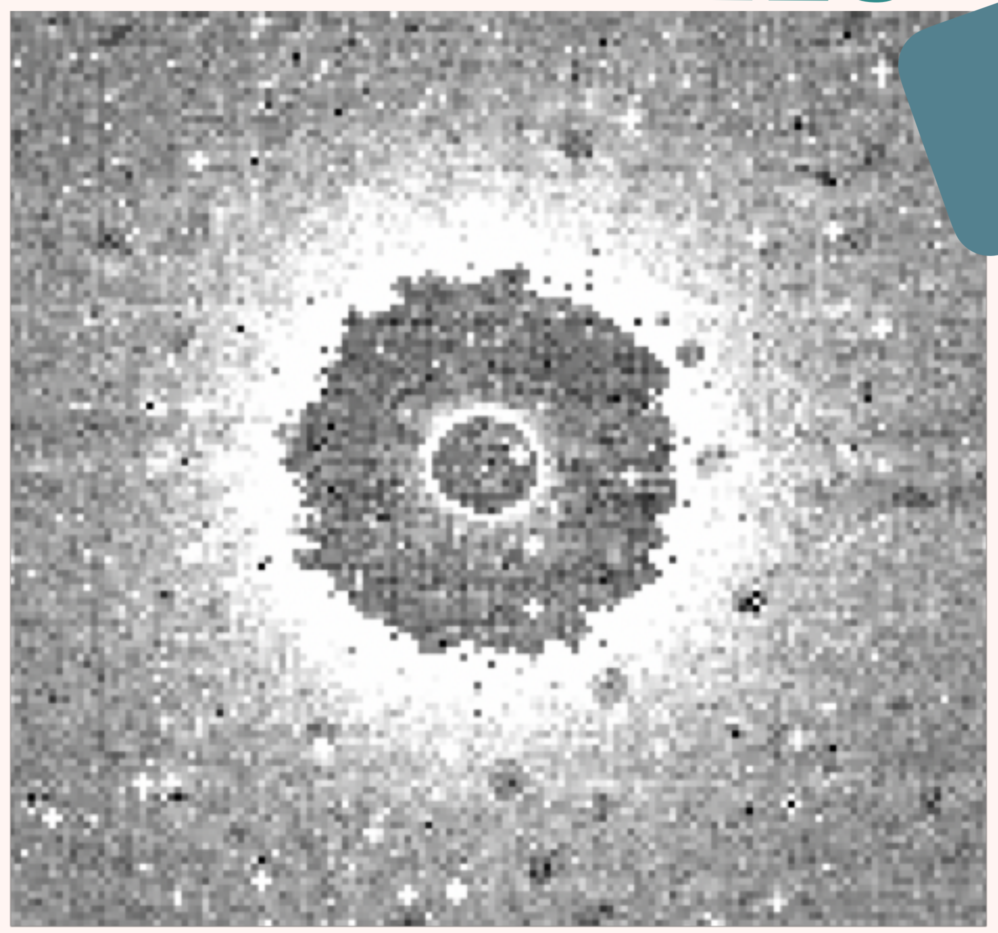


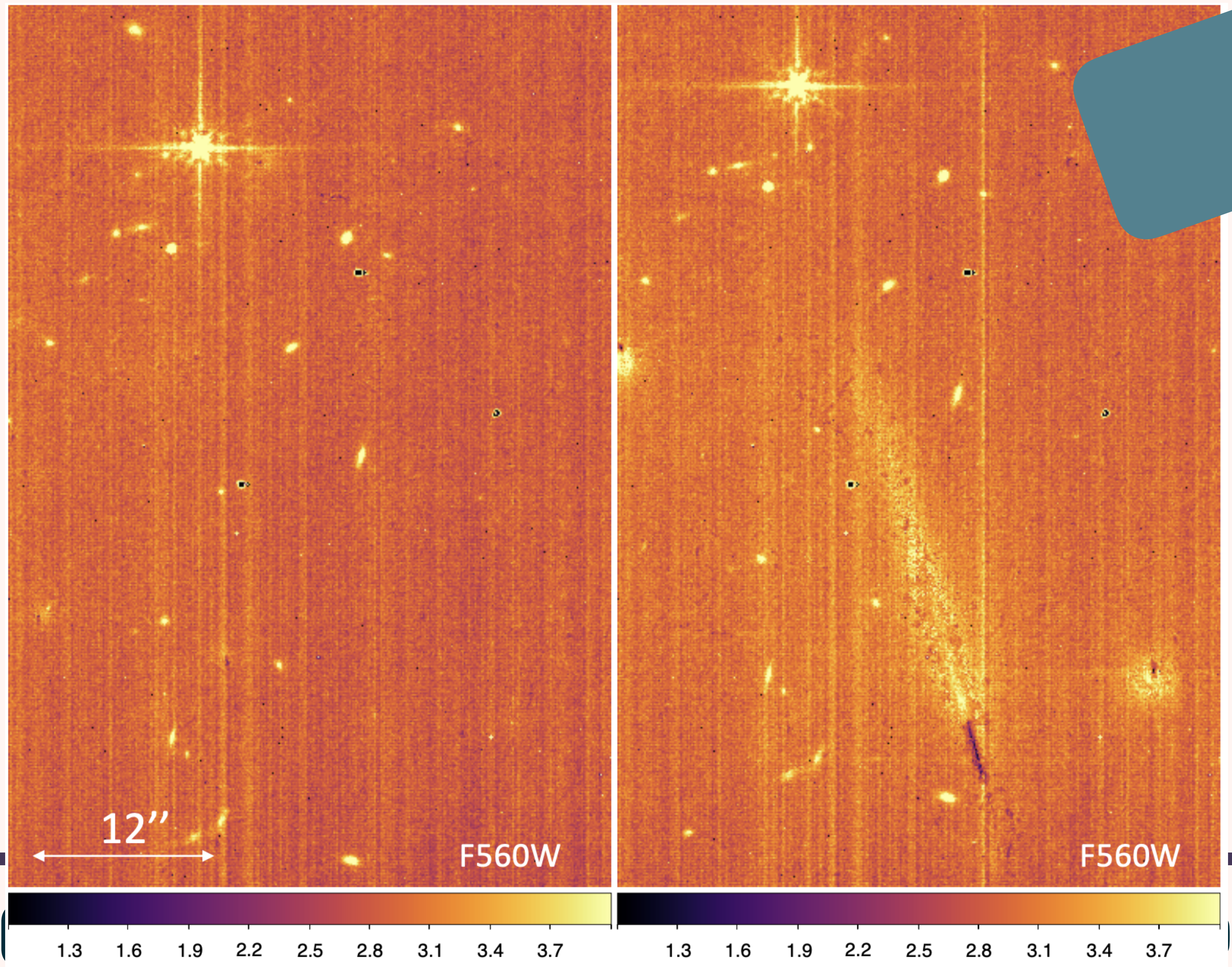
SNOWBALLS

NIRCAM



COSMIC RAY SHOWERS

MIRI

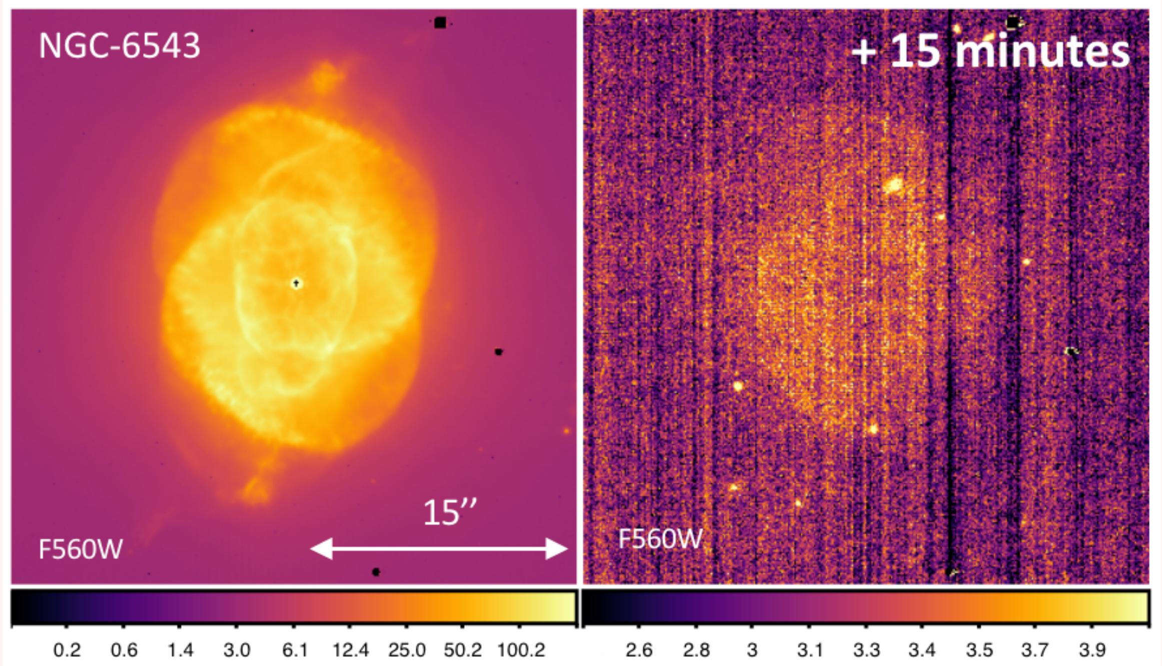


PERSISTENCE

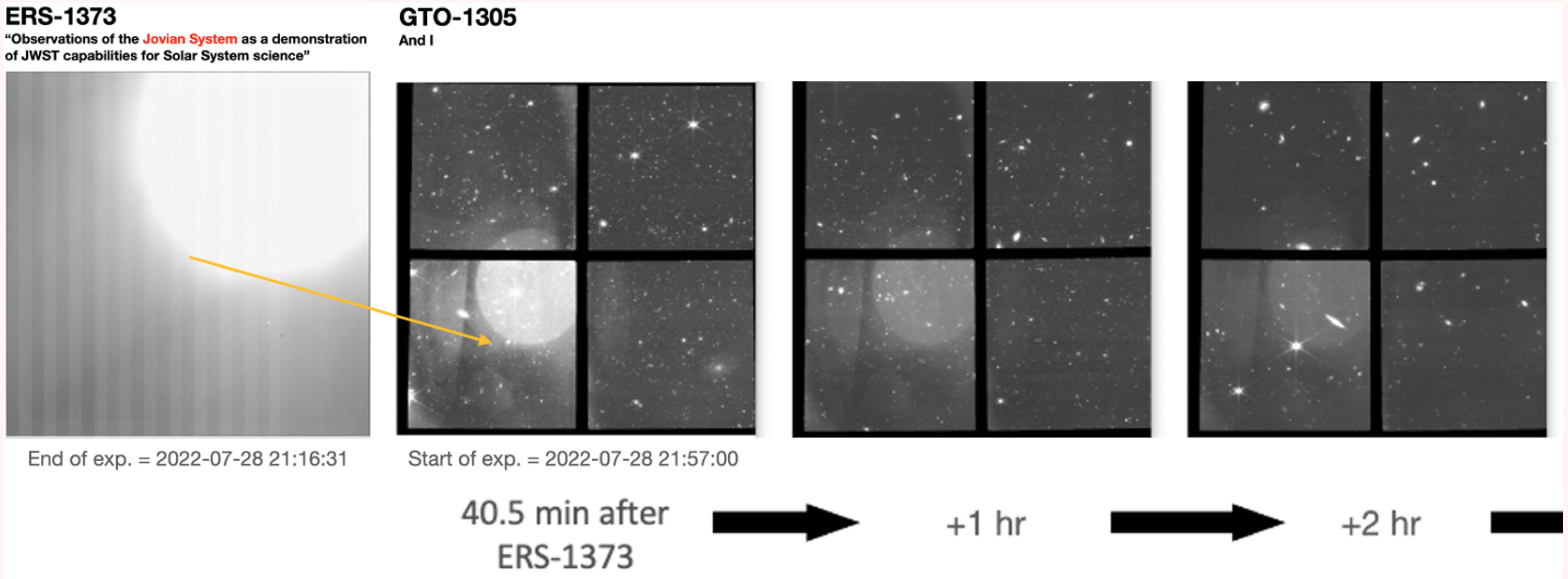
BOTH

Small amounts of charge that remain in a pixel after observing a bright target or being hit by a cosmic ray or saturating, can be long-term

How to reduce: dither!!



POSITIVE PERSISTENCE



PERSISTENCE

BOTH

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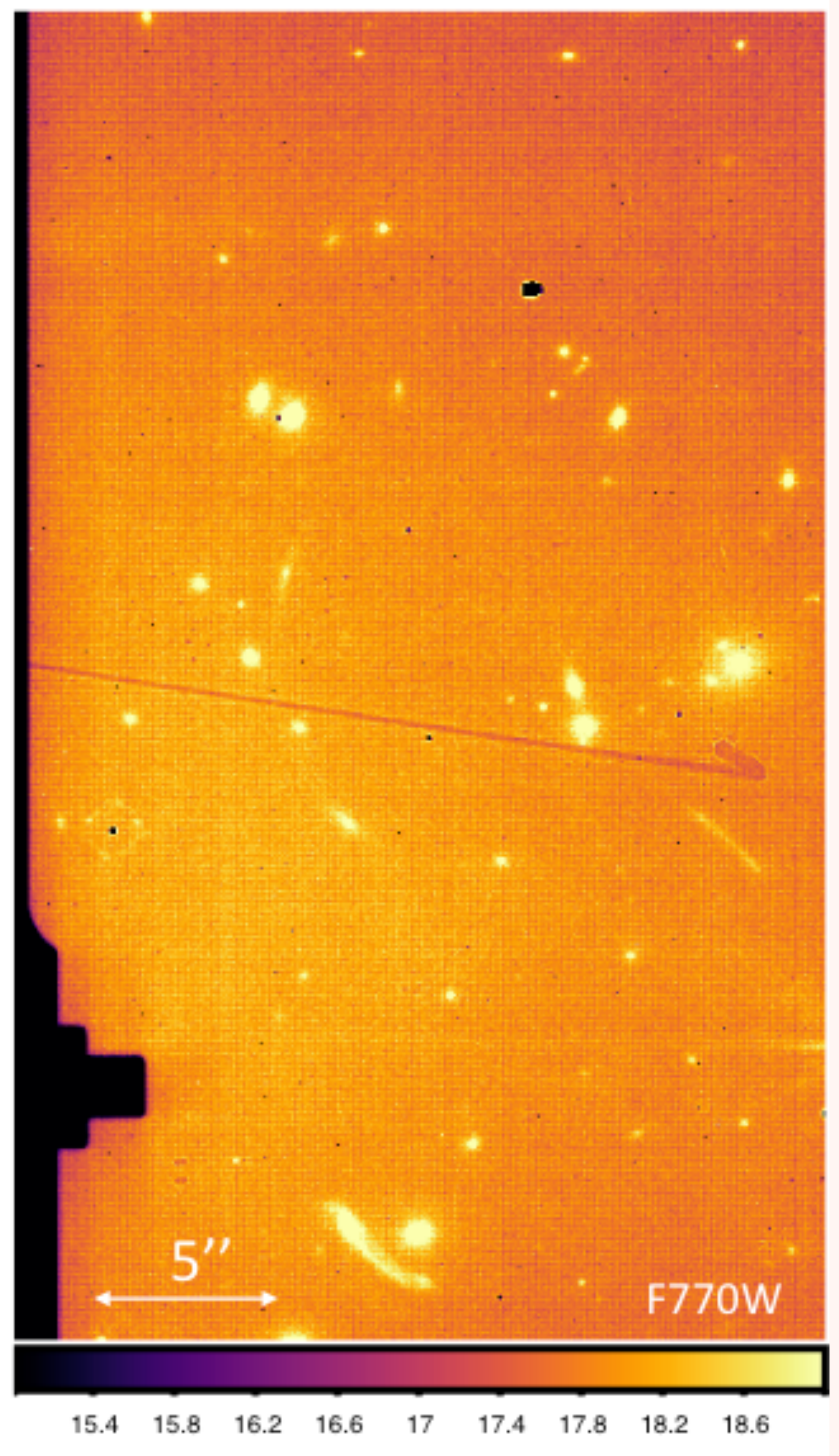
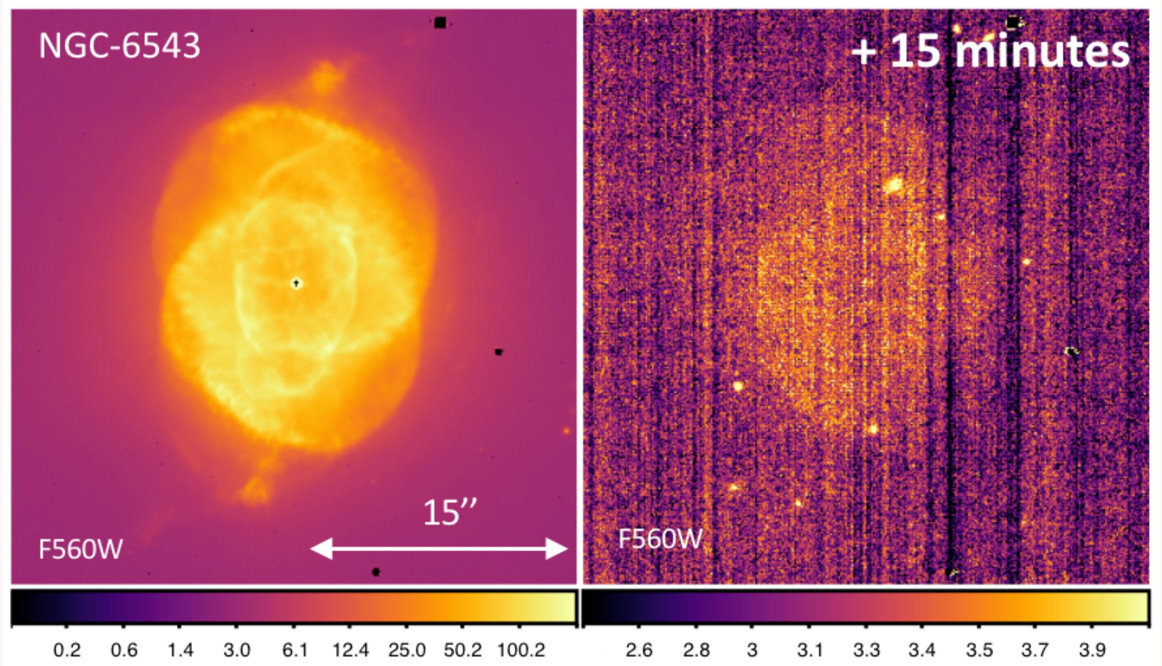
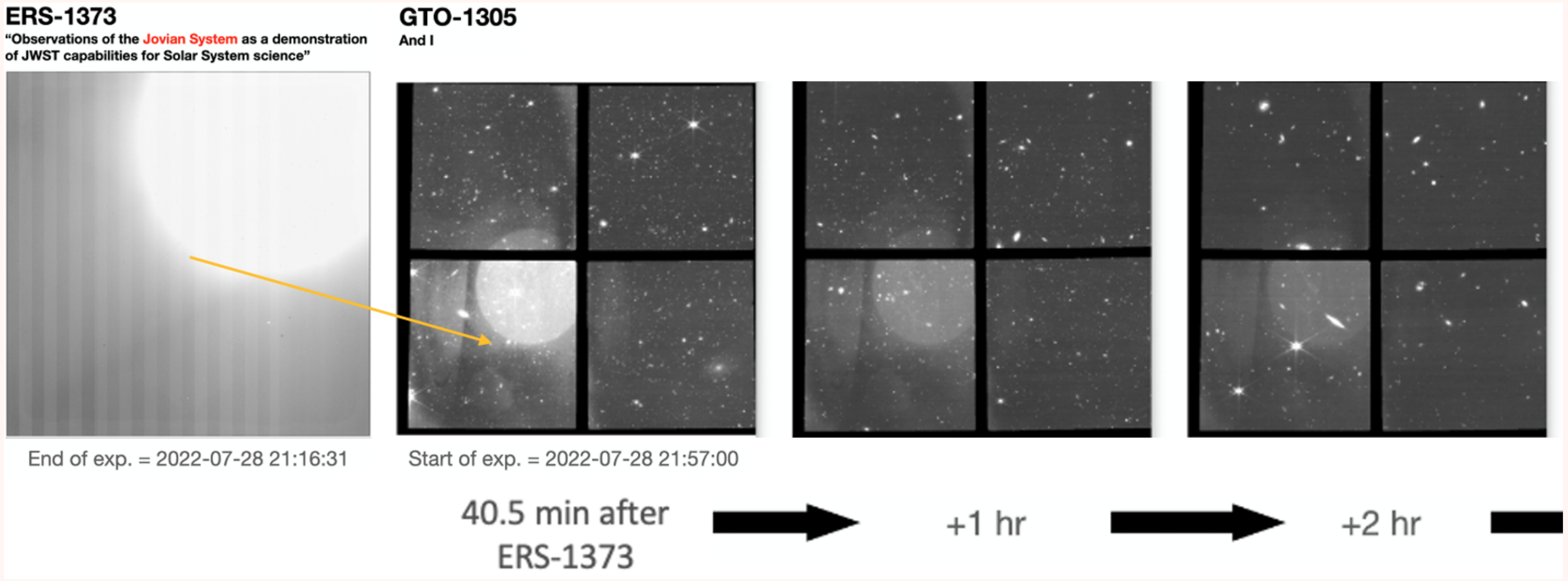
How to reduce: dither!!

NEGATIVE PERSISTENCE



POSITIVE PERSISTENCE



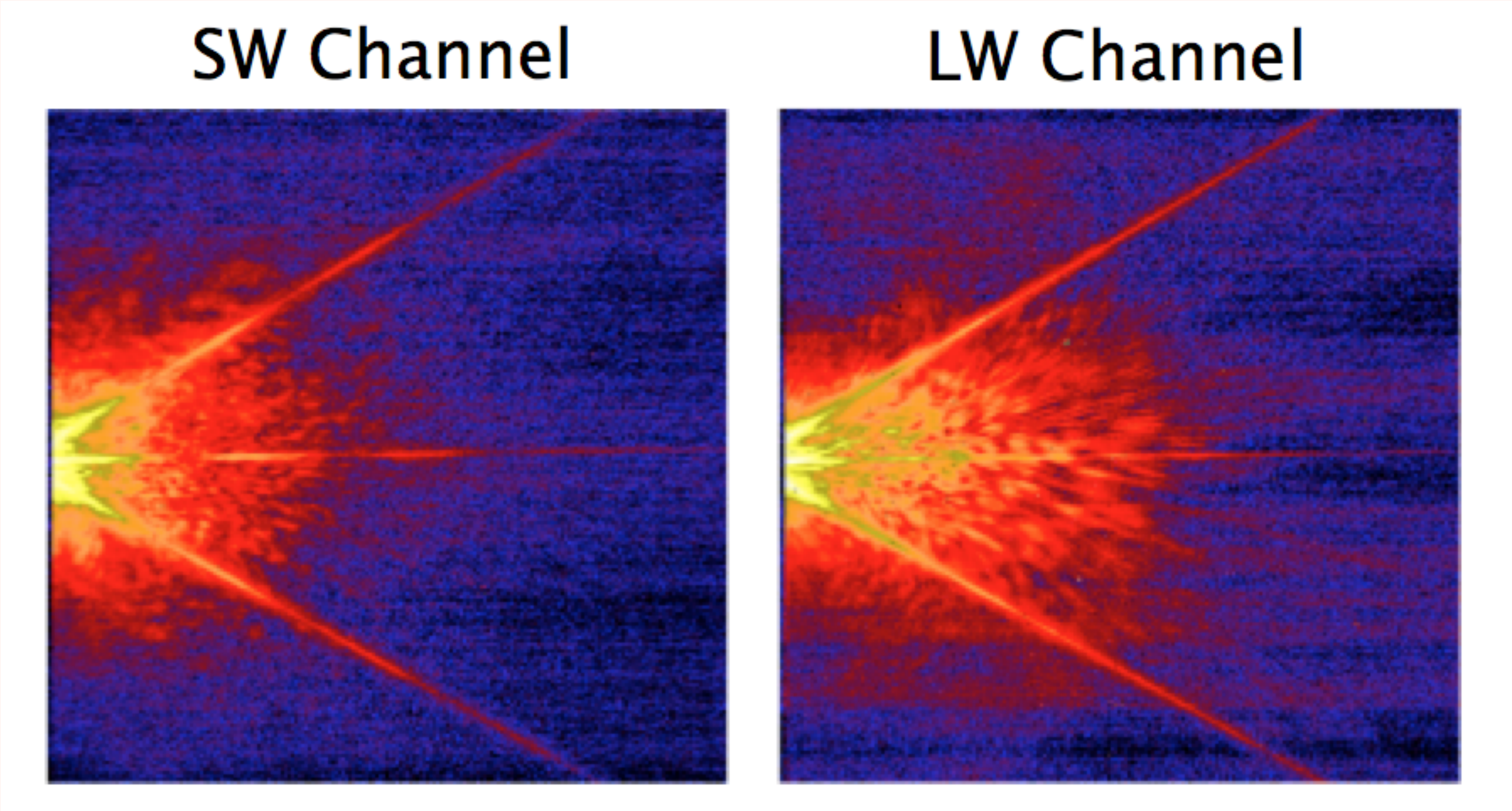


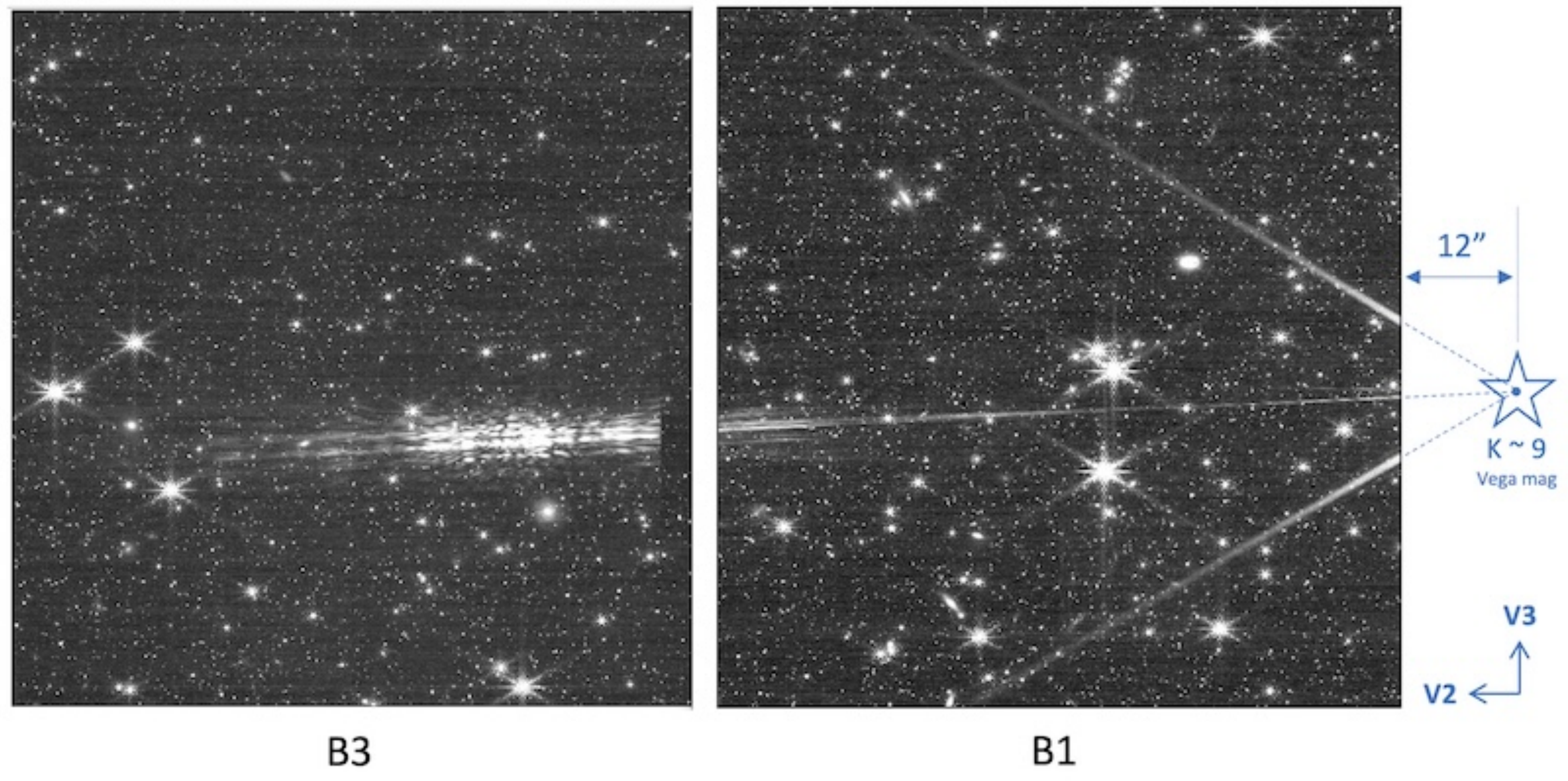
STRAYLIGHT ARTIFACTS

NIRCAM
**some MIRI

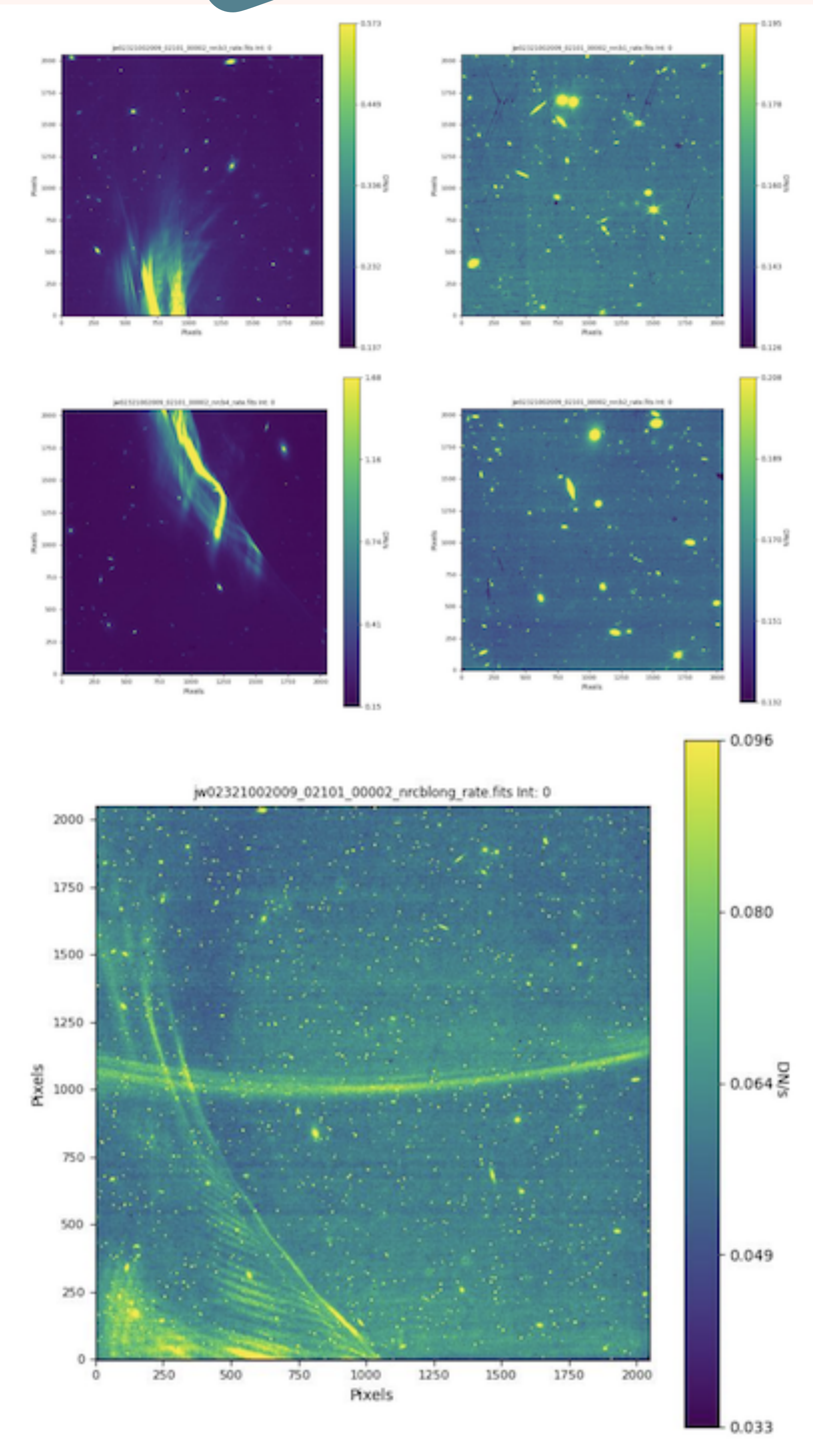
Light from outside the instrument FOV or reflections off telescope structures

DRAGON'S BREATH

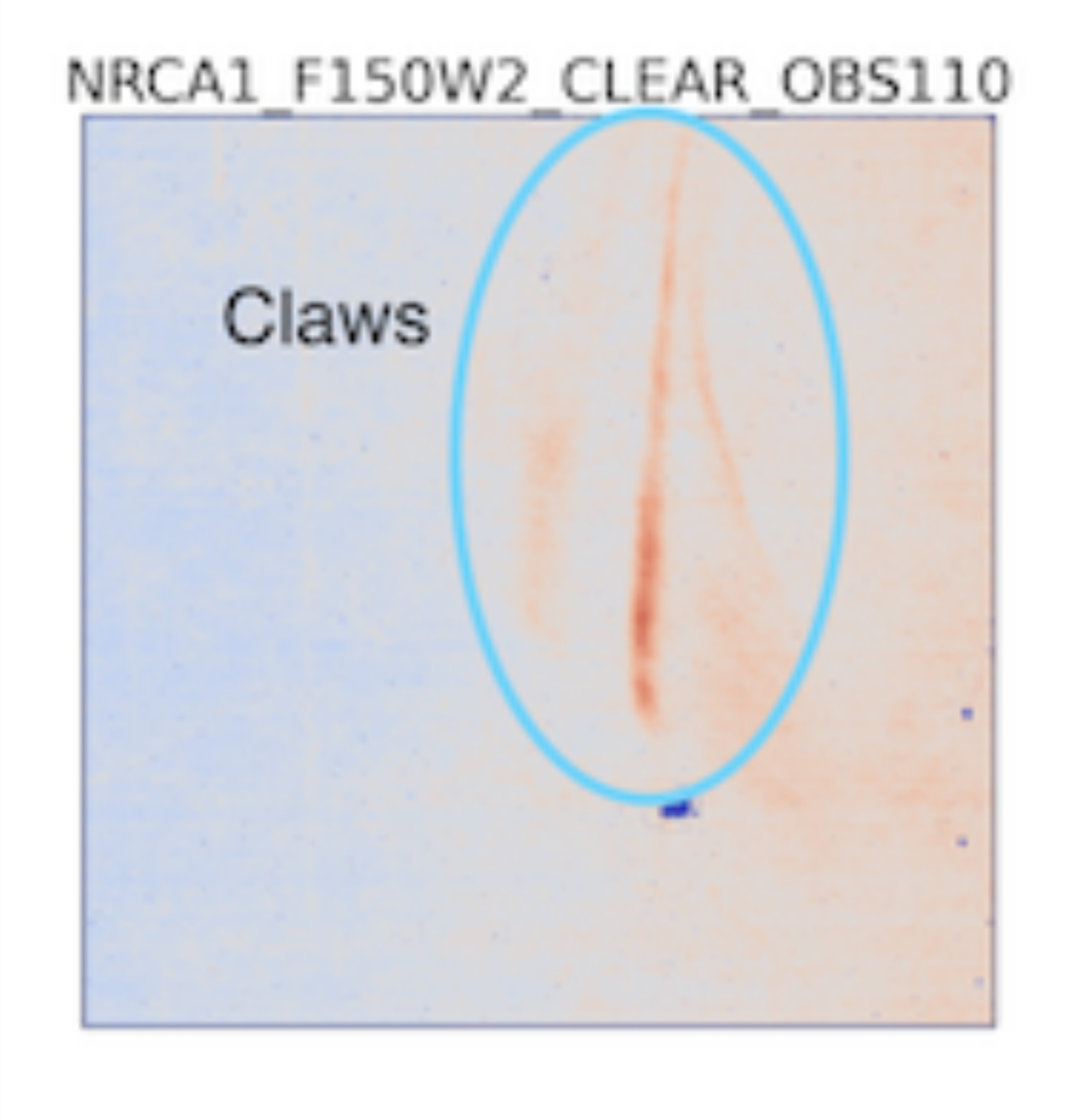




WISPS



CLAWS



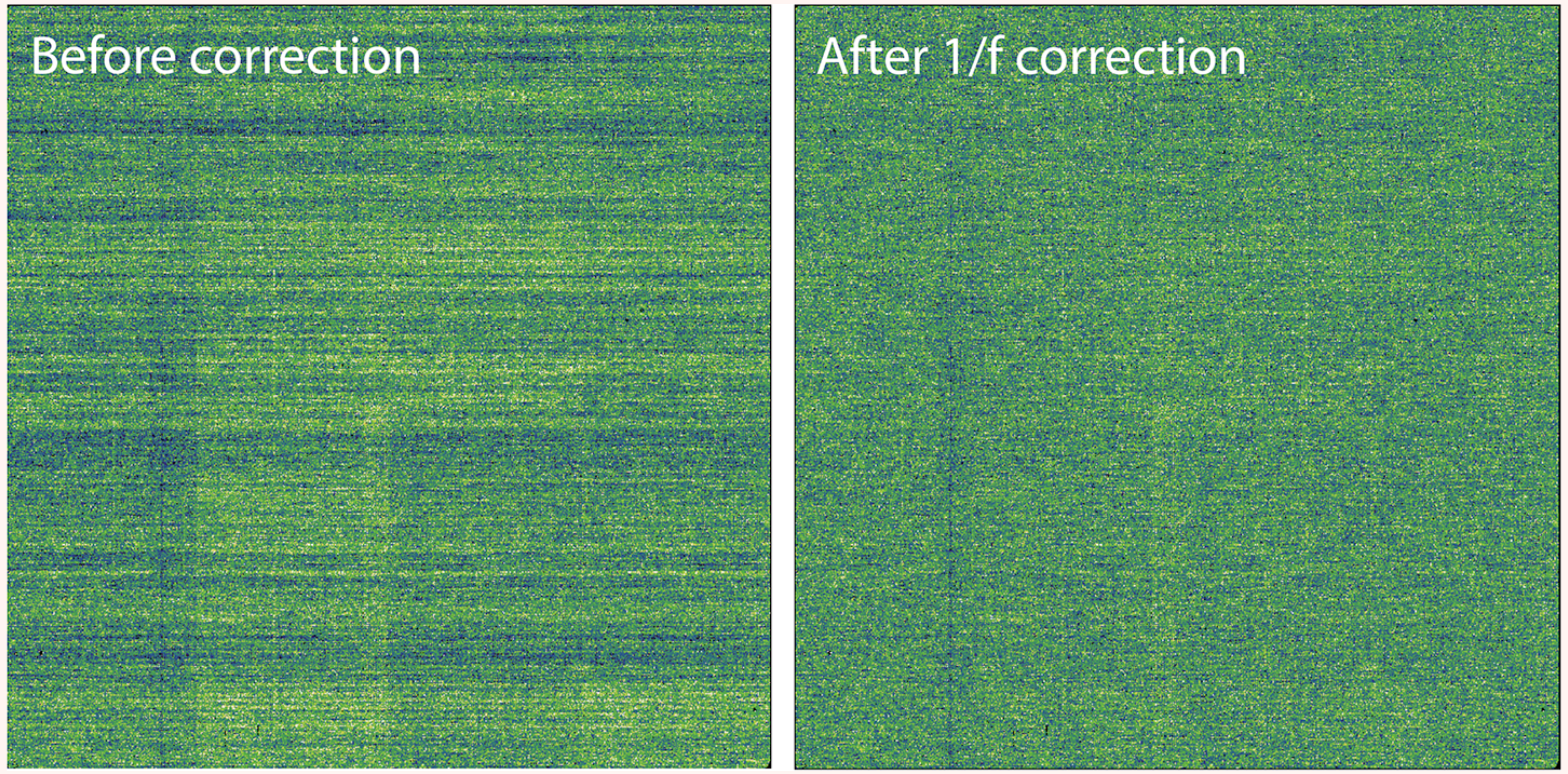
**For MIRI, less common but can cause offsets in the background level between MIRI dithers or glow at the detector edge

STRIPING

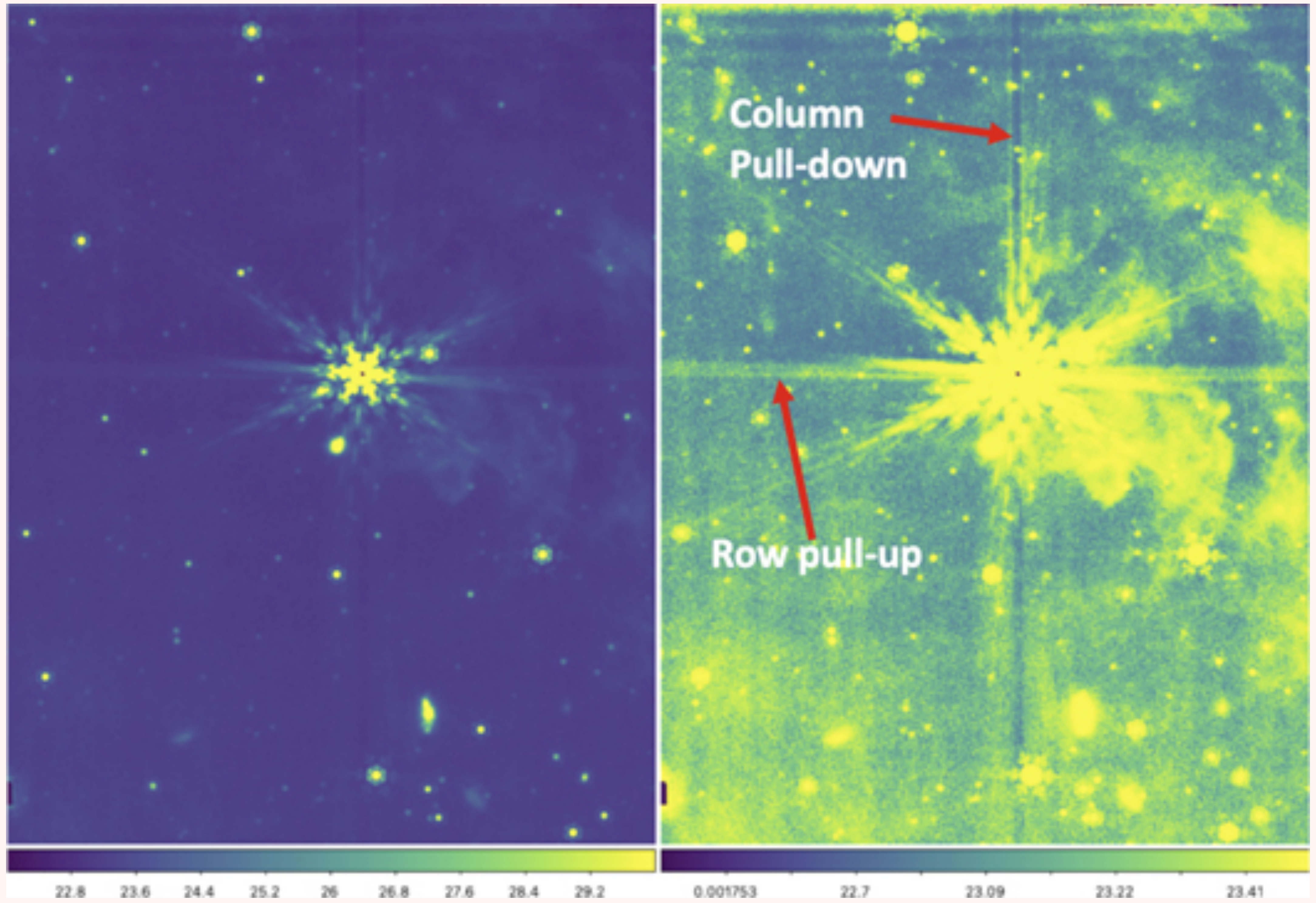
BOTH

How to reduce: different filtering techniques

NIRCam: 1/f noise



MIRI: column/row pull down



RECAP

ALWAYS CONSIDER WHEN PLANNING

- **Dithers**
  - you need them! (unless time-series observation [TSO])
- **Readout mode and exposure, i.e. groups vs integrations**
  - more groups is better, until you start getting too many cosmic rays or saturate or run into data volume issues
- **(MIRI) Background subtraction strategy**
  - Use science exposures IF you are looking at point or compact sources in an uncrowded field. Need dedicated background otherwise!

KEEP IN MIND WHEN USING

- **Cosmic Rays**
  - corrected by the pipeline, but not perfectly
- **Persistence**
  - can cause artifacts, with different correction strategies
- **Straylight**
  - Several artifacts in NIRCam, sometimes offsets between dithers or edge effects in MIRI

ALWAYS CHECK JDOX BEST PRACTICES AND KNOWN ISSUES PAGES