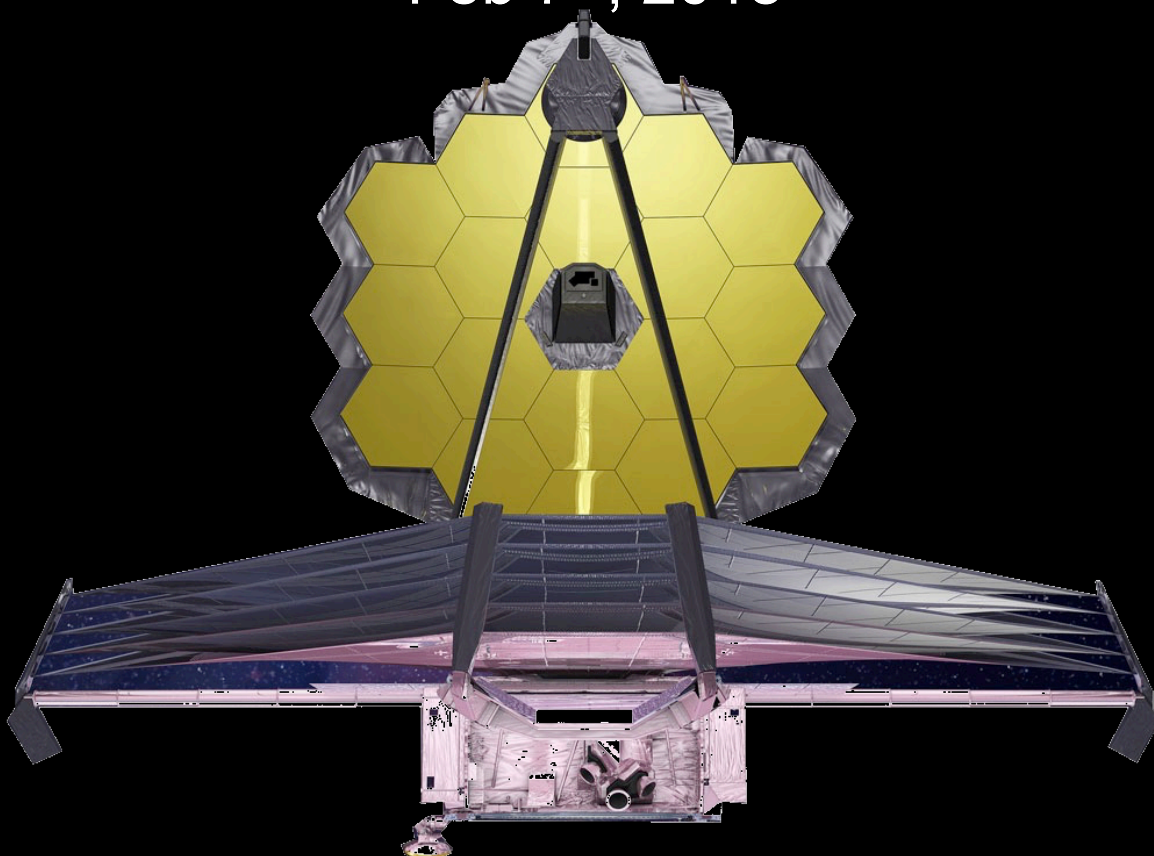
High Contrast Imaging with JWST

CSA webinar #8

Feb 7th, 2018



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OBSERVATOIRE DU MONT-MÉGANTIC

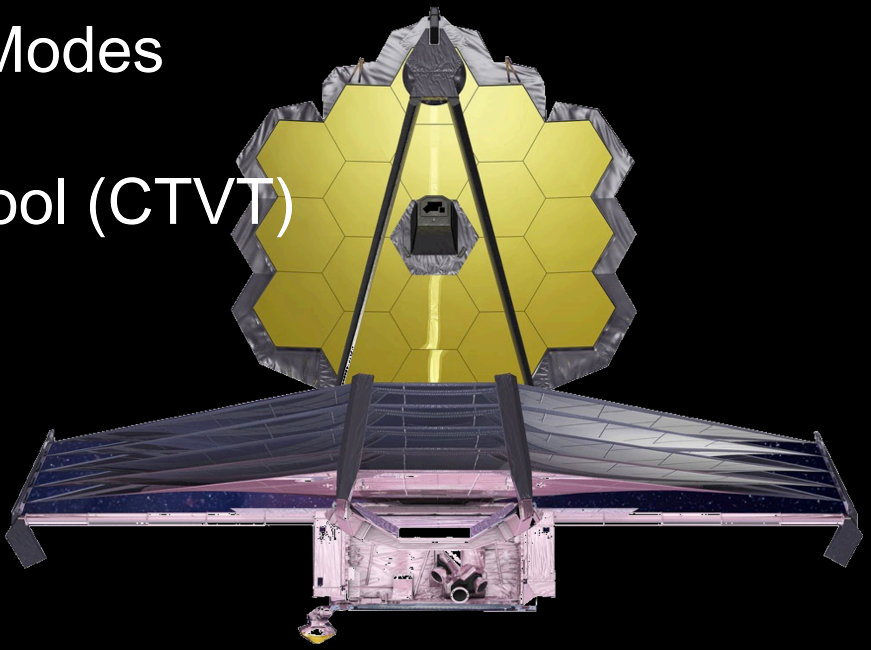
Outline

Recap of JWST Coronagraphic Modes

Coronagraphy Target Visibility Tool (CTVT)

Observing Strategies

APT Demo



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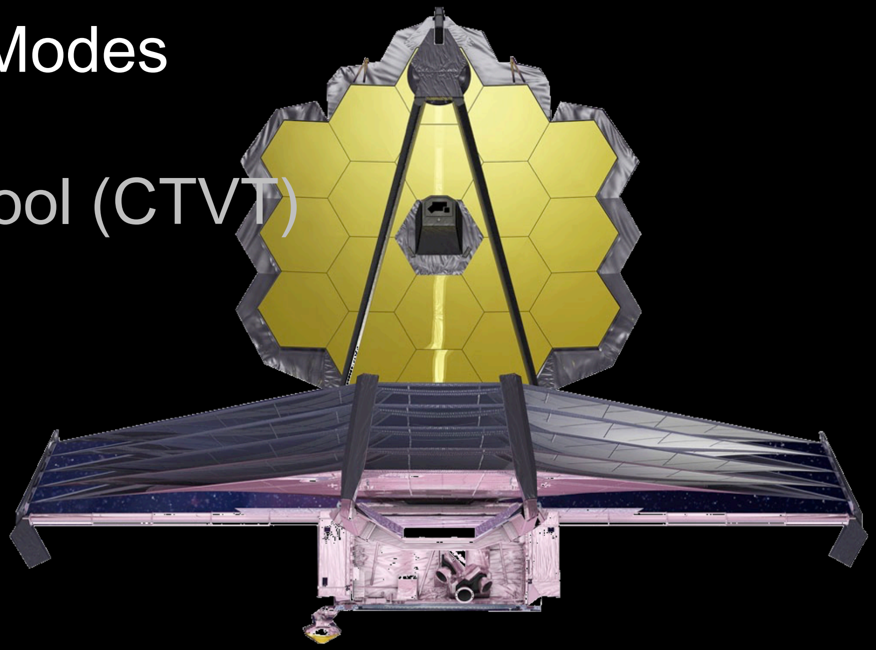


High Contrast Imaging (HCI) with JWST

Strengths

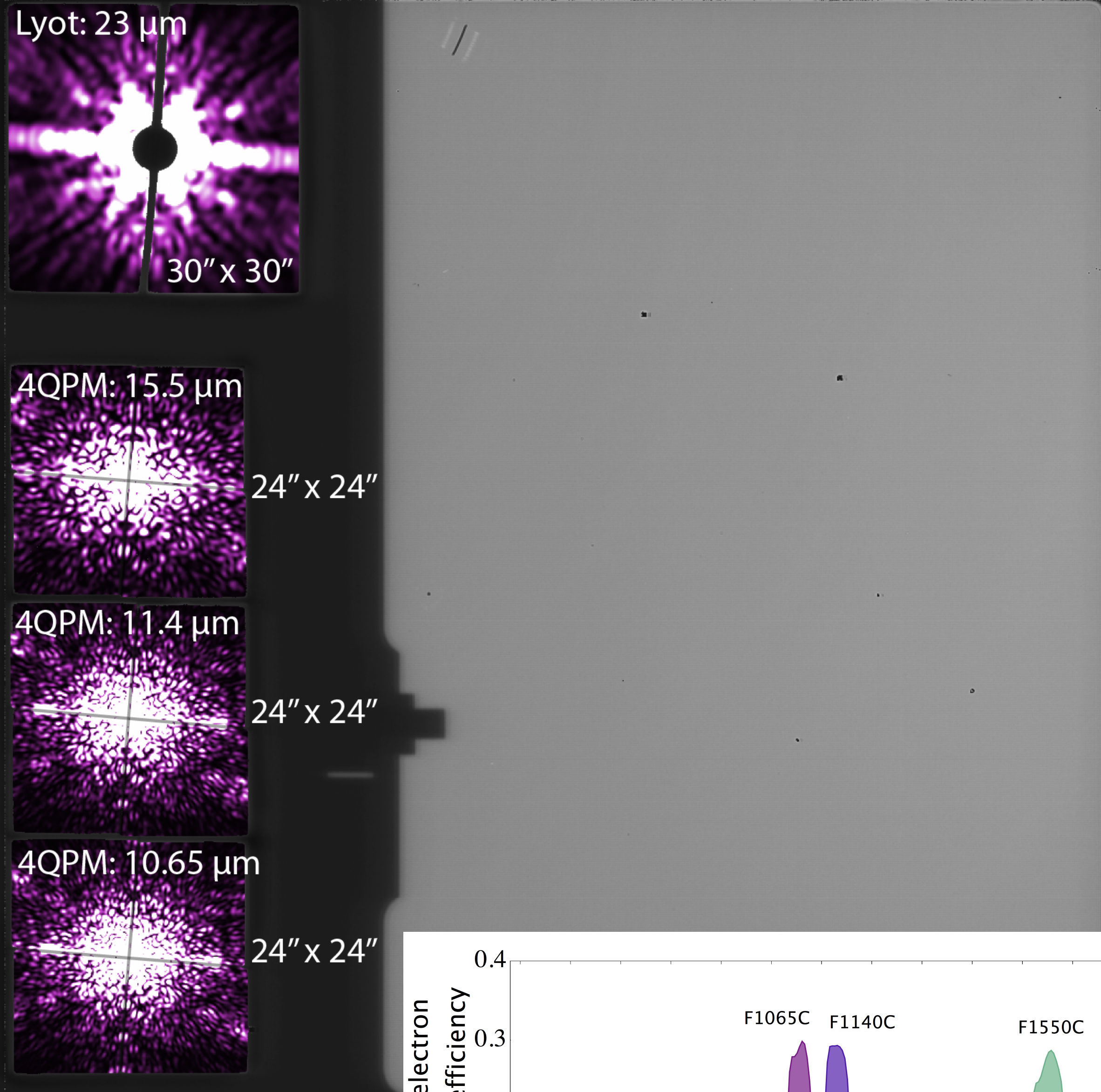
- Large FOV (~20"x20")
- Access to λ>5 μm
- low background (2-15 μm)

Three Instruments Offer HCI

- MIRI
  - 4 masks
  - 10, 11, 15 or 23 μm
- NIRCam
  - 5 coronagraphic masks, ~20 filters 1.8-5 μm
- NIRISS
  - Aperture Masking Interferometry (AMI) using a Non-Redundant Mask (NRM)
  - 2.77, 3.8, 4.3 or 4.8 μm

Performance/Expected Contrasts

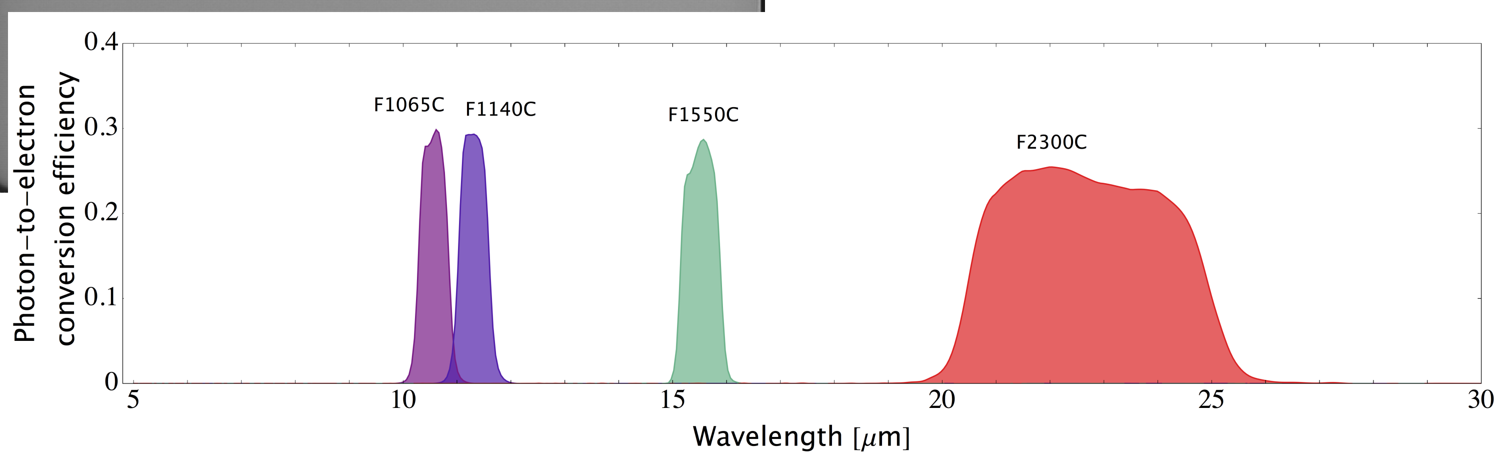
- Requires very detailed simulations and various poorly constrained input parameters, especially wave front (WF) variations.
- The telescope WF was expected to change on time scales of ~days. Rephasing every 2 weeks. Latest OTIS test showed <1h time scale WF variations but changes were made. Commissioning will tell.
- JWST ETC is not the best tool at the moment. Good for saturation check.
- Pandeia-Coronagraphy is better (links provided at the end)
- Roll + Reference PSF close to science observation are the recommended strategy.



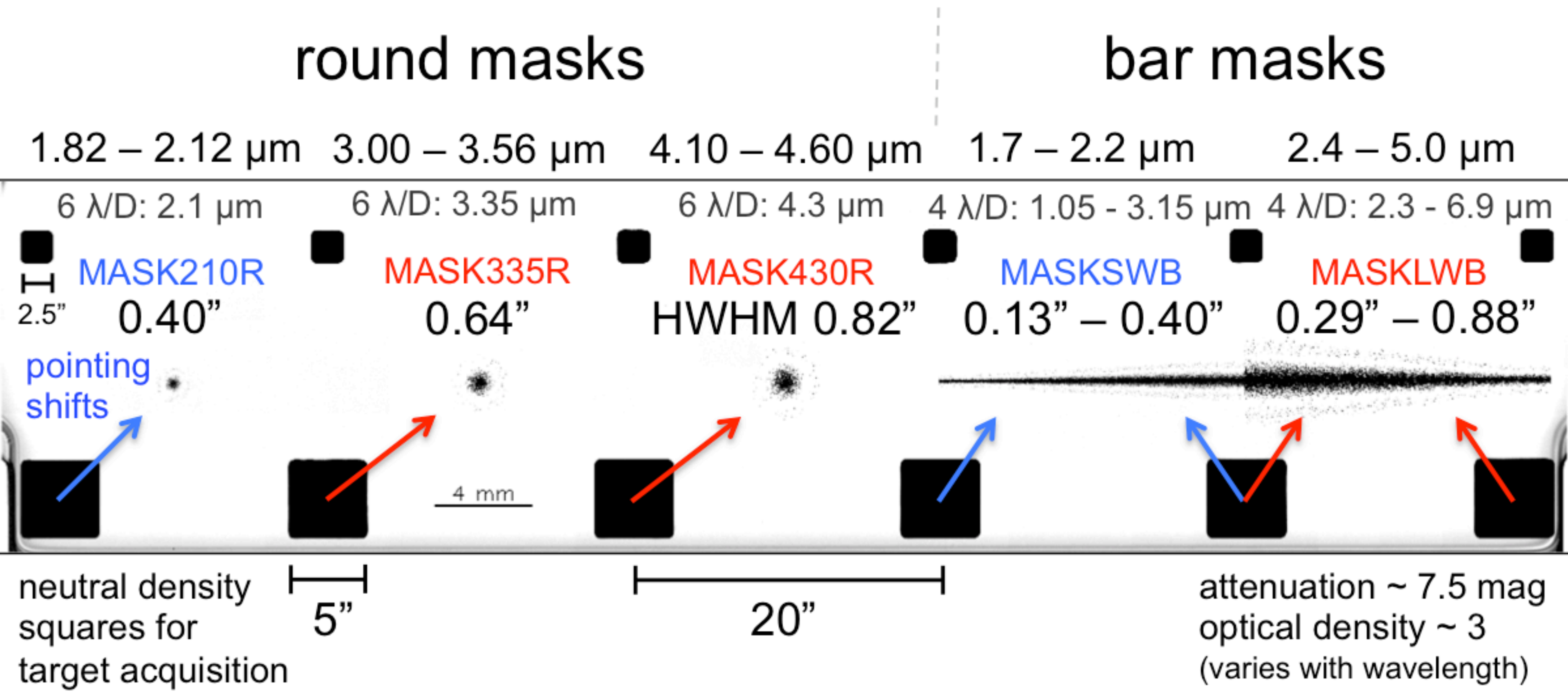
MIRI

4QPM designed to have
small IWA of 1 λ/D to compensate
for larger PSF due to larger λ

T= ~60%



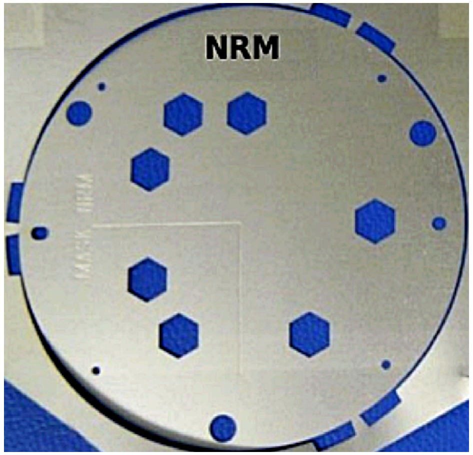
NIRCam

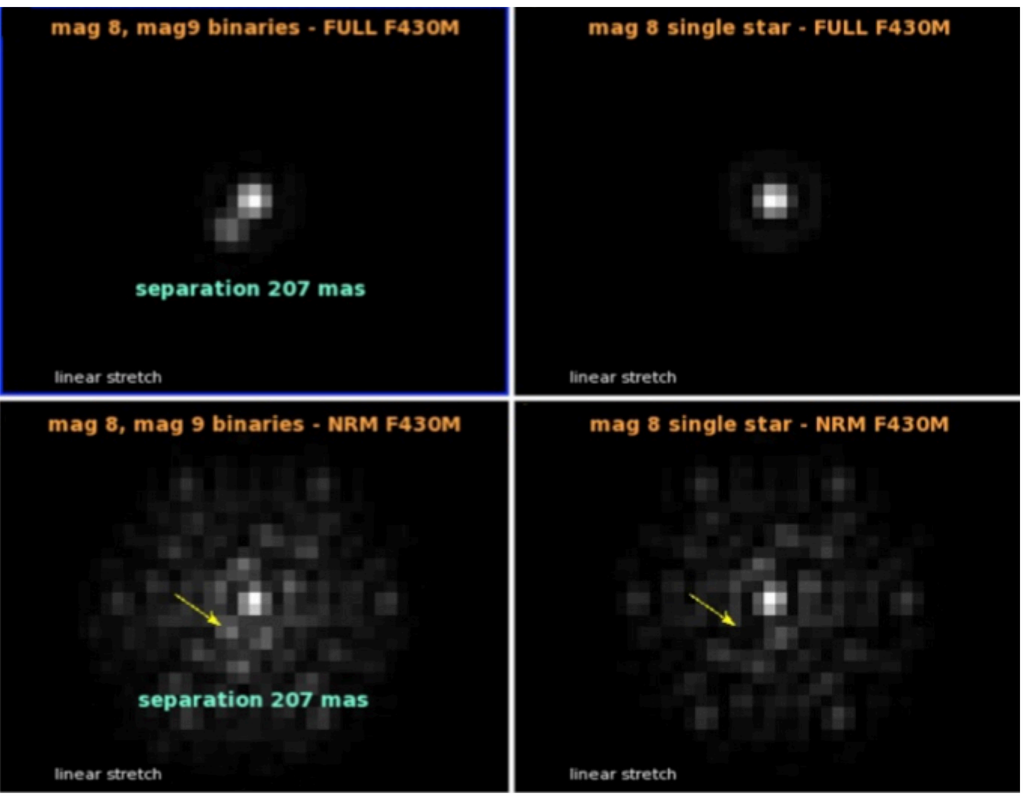


5 filters available	8 filters available	10 filters available	5 filters available	11 filters available

- Field of view: 20"x20"
- All masks coupled with a Lyot with T=19%

NIRISS





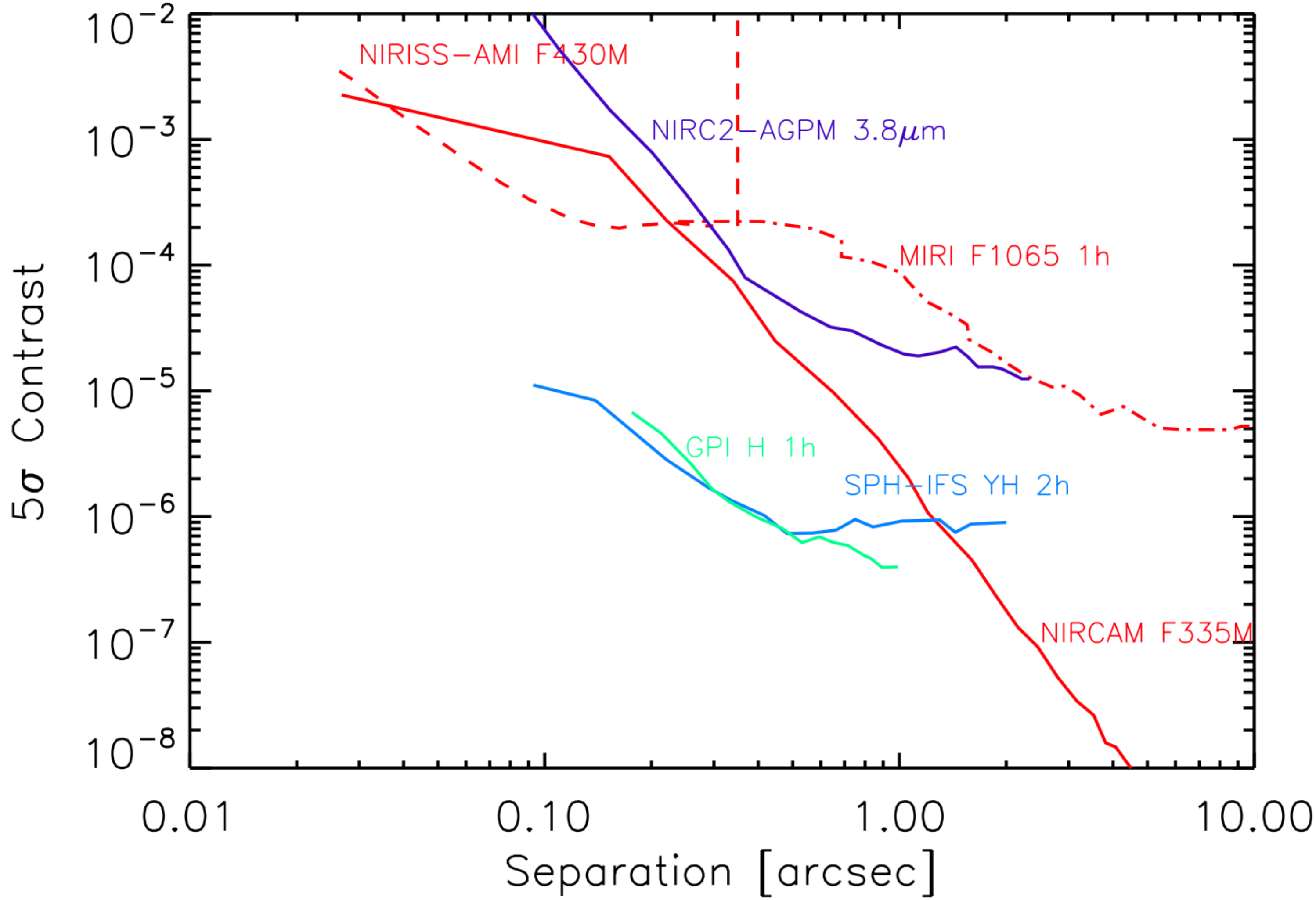
- 21 non-redundant baselines allow to play interferometry tricks to recover information at 0.5 λ/D.
- Final product is a model check of the scene rather than a clearer image (works for simple scenes).
- Needs a calibrator star to calibrate the WF phases.
- 15% throughput.
- Possible alternative is the kernel phase imaging (clear pupil)

Inner Working Angle (IWA)

Definition: Radial angle at which occulter transmission drops below 50%

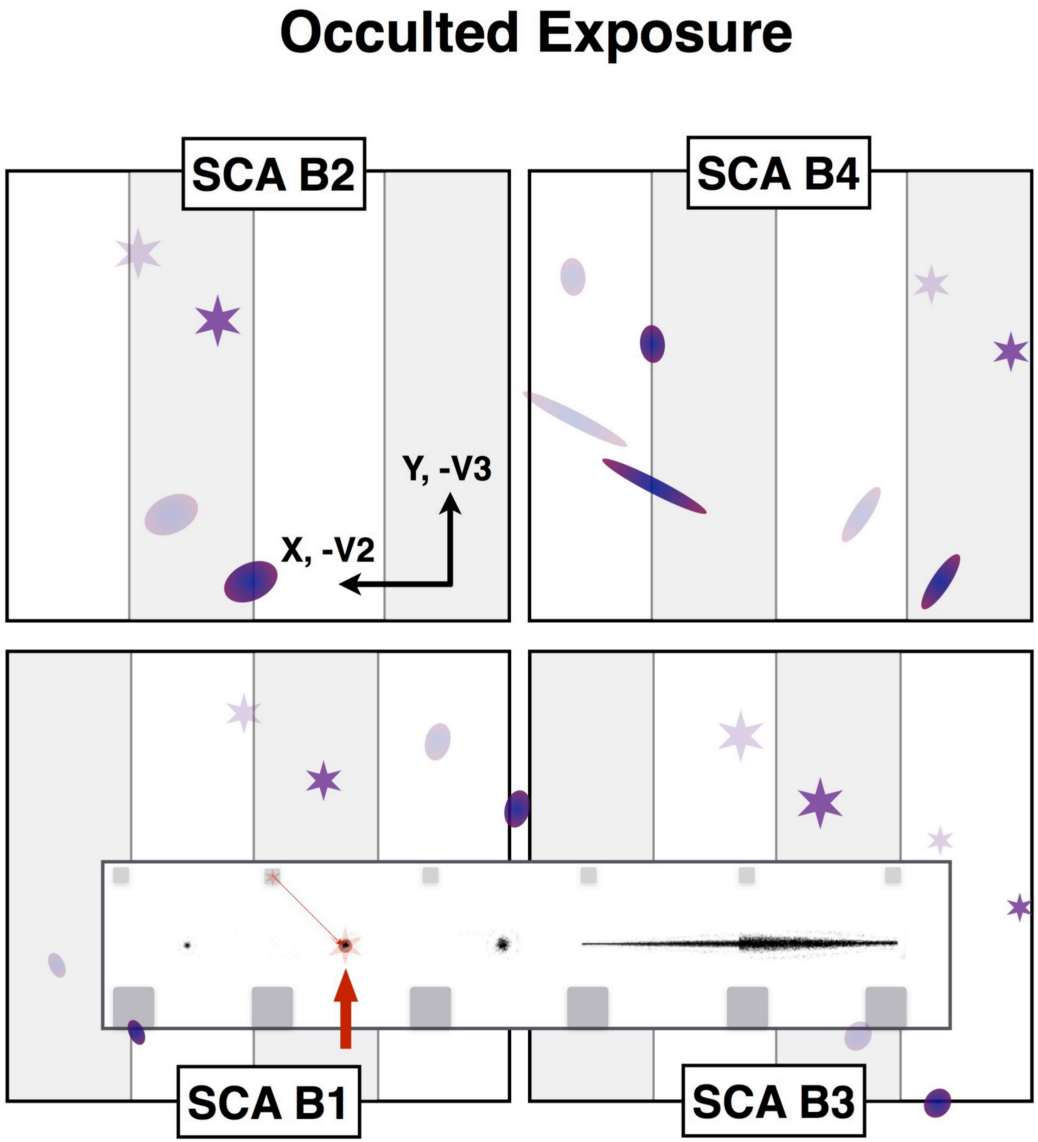
Instrument	Mask type	Mask name	fiducial λ (μm)	N (λ/D)	IWA (arcsec)
NIRCam	round	MASK210R	2.1	6	0.40"
		MASK335R	3.0		0.57"
		MASK430R	4.6		0.87"
	short-λ bar	MASKSW	2.1	2	0.14"
				4	0.27"
				6	0.41"
	long-λ bar	MASKLW	4.6	2	0.30"
				4	0.59"
				6	0.89"
MIRI	4-quadrant phase mask	4QPM1	10.65	1	0.34"
		4QPM2	14.40		0.46"
		4QPM3	15.50		0.49"
	Lyot	LYOT	23	3	2.19"
NIRISS	aperture-masking interferometer	non-redundant mask on pupil plane	2.77	1	0.089"
			3.8		0.12"
			4.3		0.14"
			4.8		0.15"

""Comparative"" Contrasts



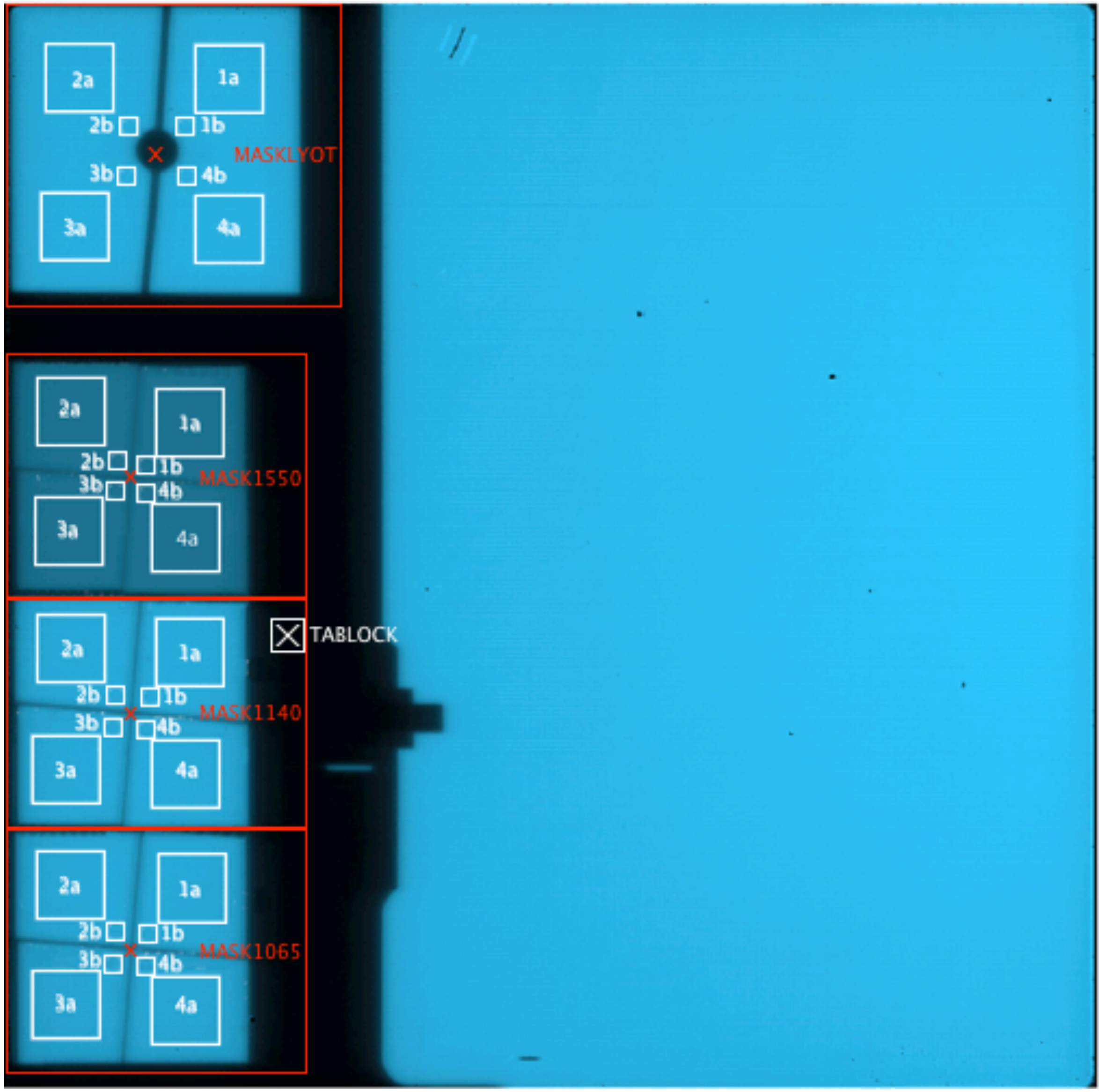
Target Acquisition - NIRCam

- If K<7, put target on ND filter subarray (large)
- If K>7, use the smaller subarray
- Measure centroid then do a small angle manoeuvre (SAM) to center of occulter (uses opaque mask during move to prevent persistence)
- Otion to obtain a science image at both positions for astrometry reference



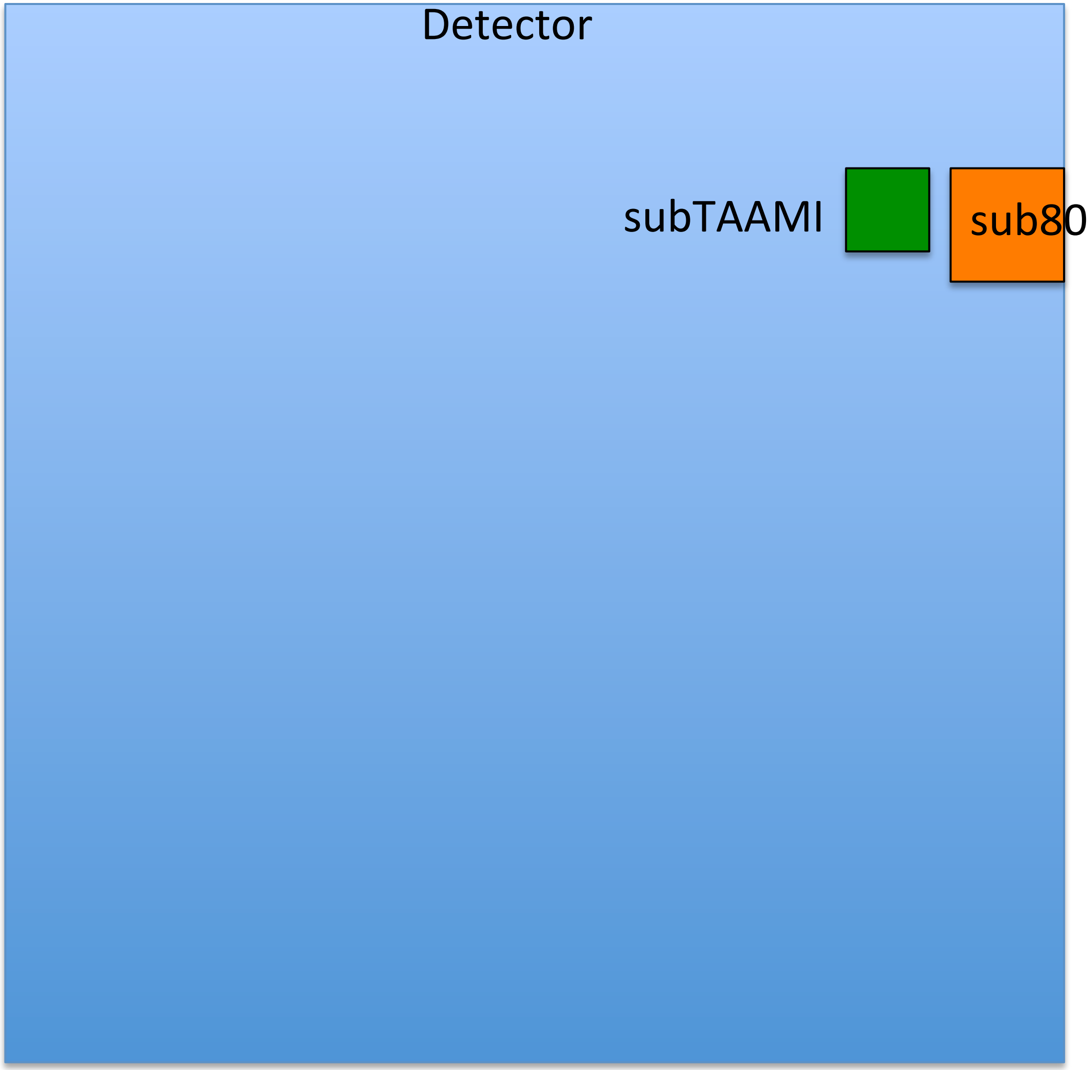
Target Acquisition - MIRI

- Use of a neutral density filter to allow Vega to not saturate
- 2 steps to maximize centering accuracy
- First image is 64x64 pixels, second is 16x16
- Choose one of 4 quadrants to avoid persistence on science targets
- Option to split observation in two sets so as to do TA twice on opposite quadrants, to discriminate against persistence



Target Acquisition - NIRISS

- TA uses F480+CLEAR (faint targets) or F480+NRM (bright targets)
- Images in SUBTAAMI (64x64") then SAM to SUB80.



Detector Readout Modes & Sub Arrays

- Readout mode
  - NIRCam: All allowed. Rec. rapid, bright or shallow
  - MIRI – Fast (all reads are kept)
  - NIRISS – NISRAPID (all reads are kept)
- Subarray for science observation
  - NIRCam: FF or 640x640 (blue)/320x320 (red) subarray (~20"x20")
  - MIRI: 224x288 or 304x320 subarrays (~24"x24")
  - NIRISS: FF or 80x80 (~5"x5")

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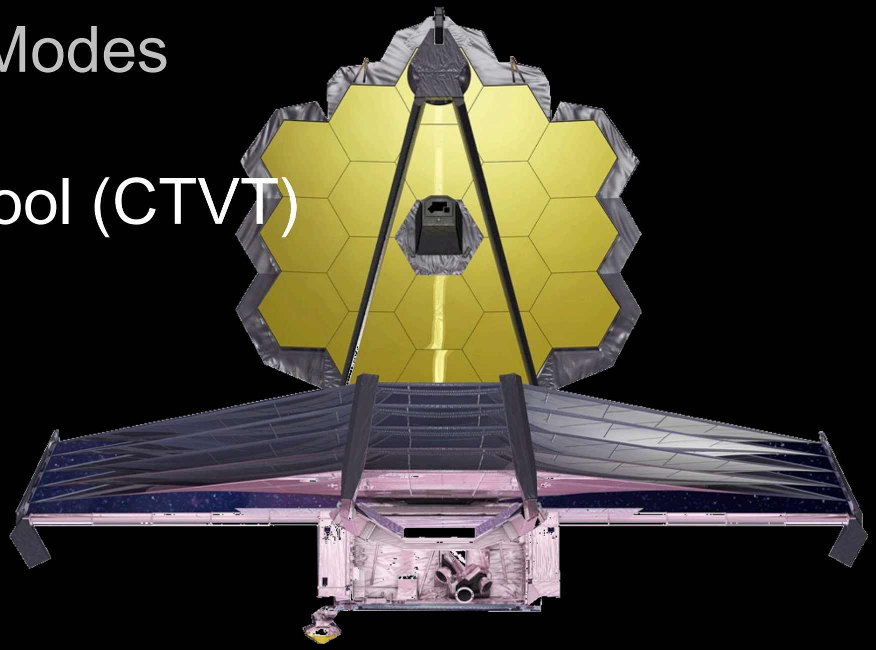
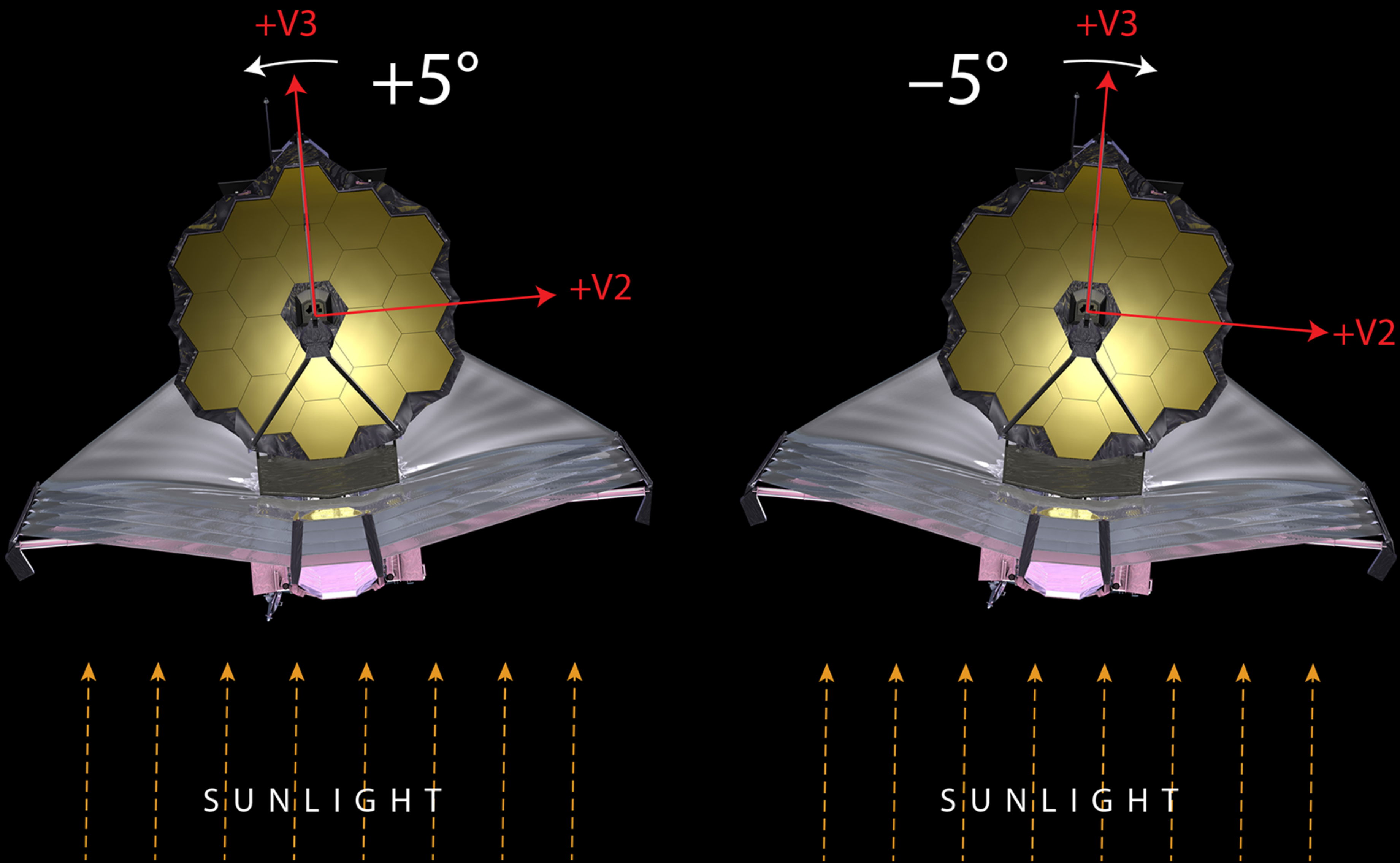
APT Demo





+V3
+5°
+V2
SUNLIGHT
+V3
−5°
+V2
SUNLIGHT

Coronagraphy Target Visibility Tool

Downloading and installing the CVT

The CVT is distributed as part of the AstroConda package from STScI. AstroConda is the preferred release channel for JWST Python-related tools. For more information, see the AstroConda installation instructions. Also note that AstroConda runs from the bash shell, not CSH or TCSH.

Further information on setting up AstroConda for your machine is availble in the AstroConda documentation. Help can also be obtained by contacting the JWST Help Desk.

If you've already installed AstroConda for macOS or Linux, you can install CVT as follows in the AstroConda environment:

```
$ source activate astroconda
(astroconda)$ conda install jwst_coronagraph_visibility
# ... installation output ...
(astroconda)$ jwst-coronagraph-visibility-gui &    # to launch the GUI
```

If you're running macOS and want a double-clickable app:

1. Download the double-clickable app archive (e.g. `jwst_coronagraph_visibility_calculator_macos_v0.1.0.zip`) from https://github.com/spacetelescope/jwst_coronagraph_visibility/releases/latest
2. Extract the .zip file to get the .app bundle
3. Double-click the .app bundle

If you see a message warning you about opening an app from an unidentified developer, right-click (or control-left click) the icon and choose "Open". This is a security feature of macOS.

If you're using Python with pip:

```
$ pip install jwst-coronagraph-visibility
# ... installation output ...
$ jwst-coronagraph-visibility-gui &    # to launch the GUI
```

CTVT Demo

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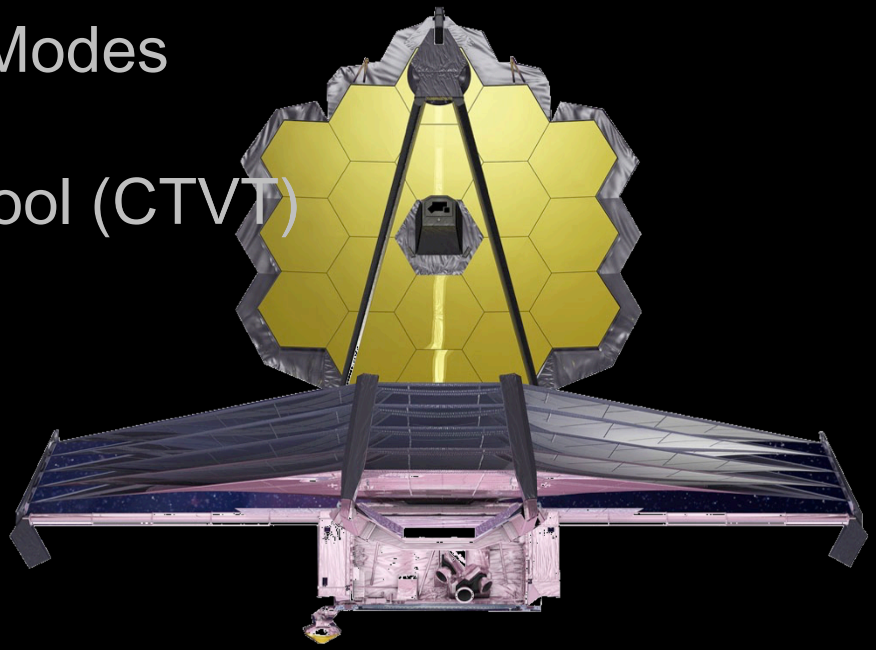


Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy
3. Estimate exposure time with ETC
4. Choose PSF reference star
5. Estimate visibility and orients
6. Design with APT

Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask

   Science-driven, mostly depends on the contrast and separation of interest

2. Choose PSF subtraction strategy
3. Estimate exposure time with ETC
4. Choose PSF reference star
5. Estimate visibility and orients
6. Design with APT

Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy

   Recommanded: Target at 2 rolls + reference star all back-to-back

   NIRCAM/MIRI:

   NIRISS-AMI:

   Mitigate PSF degradation by wavefront drifts, PSF star color difference, self-subtraction biases, imperfect target acq. and jitter

3. Estimate exposure time with ETC
4. Choose PSF reference star
5. Estimate visibility and orients
6. Design with APT

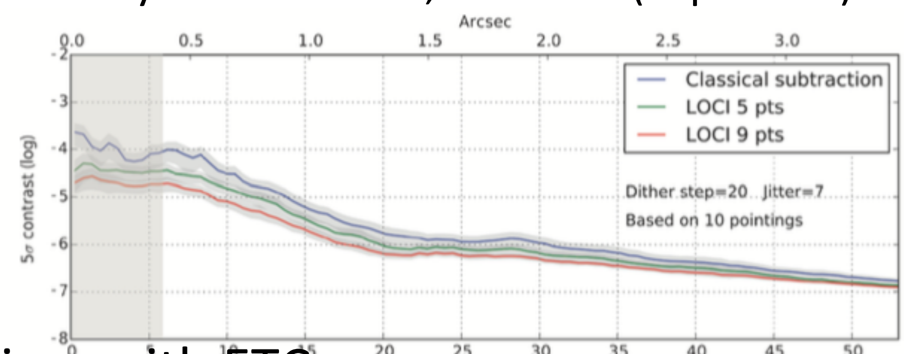
Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy

NIRISS-AMI: staring recommanded

Option NIRCAM/MIRI: Small Grid dithers for PSF ref

=> improve contrast < 1'' by x3-5 NIRCAM, x10 MIRI (expensive)



3. Estimate exposure time with ETC
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Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy

   Option:

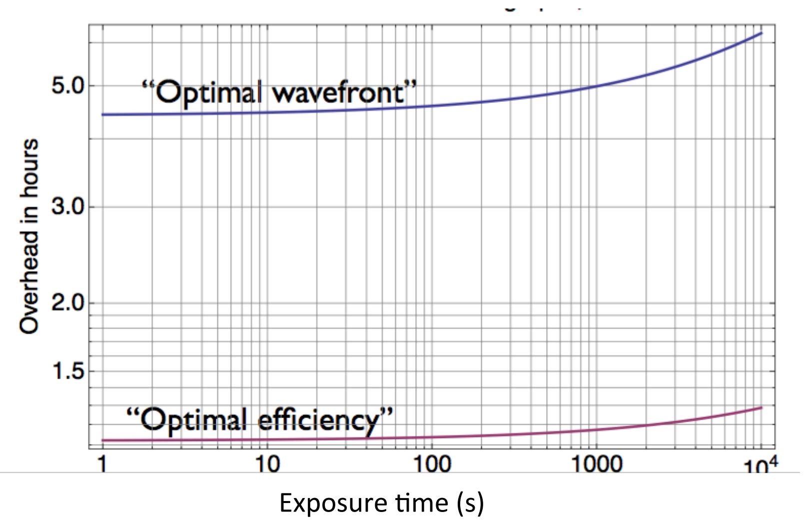
   optimal efficiency (default):

   all filters/masks then move

   optimal wavefront (expensive):

   sequence per filter/mask

   then change filter



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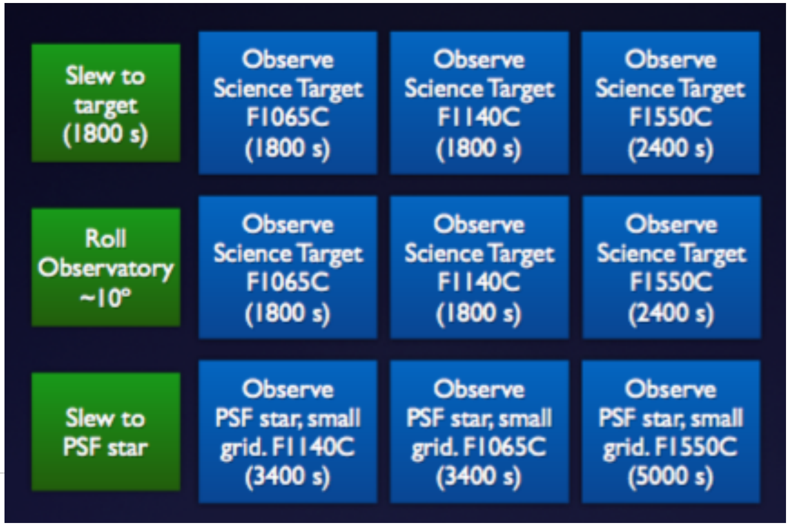

3. Estimate exposure time with ETC
4. Choose PSF reference star
5. Estimate visibility and orients
6. Design with APT

Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy
3. Estimate exposure time with the ETC
   - Limited skills of the ETC: TA, saturation & photon-noise (assume perfect subtr.)
   - NIRCAM/MIRI: advanced Python tools:
     - https://github.com/spacetelescope/pandeia-coronagraphy
     - https://github.com/JarronL/pynrc
   - NIRISS-AMI: advanced Python tools and precomputed contrast curves:
     - https://github.com/agreenbaum/ami_sim
     - http://maestria.astro.umontreal.ca/niriss/AMIcontrast/index.php
4. Choose PSF reference star
5. Estimate visibility and orients
6. Design with APT

Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy
3. Estimate exposure time with ETC
4. Choose PSF reference star

   Nearby, same spectral type (color match), similar brightness/brighter, single

   Use SIMBAR/Vizier/SearchCal

5. Estimate visibility and orients
6. Design with APT

Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
2. Choose PSF subtraction strategy
3. Estimate exposure time with ETC
4. Choose PSF reference star
5. Estimate visibility and orients
   - NIRCAM bar/MIRI 4QPM: use the coronagraphic target visibility tool
6. Design with APT

Preparing a JWST high-contrast proposal

1. Choose instrument+filter+mask
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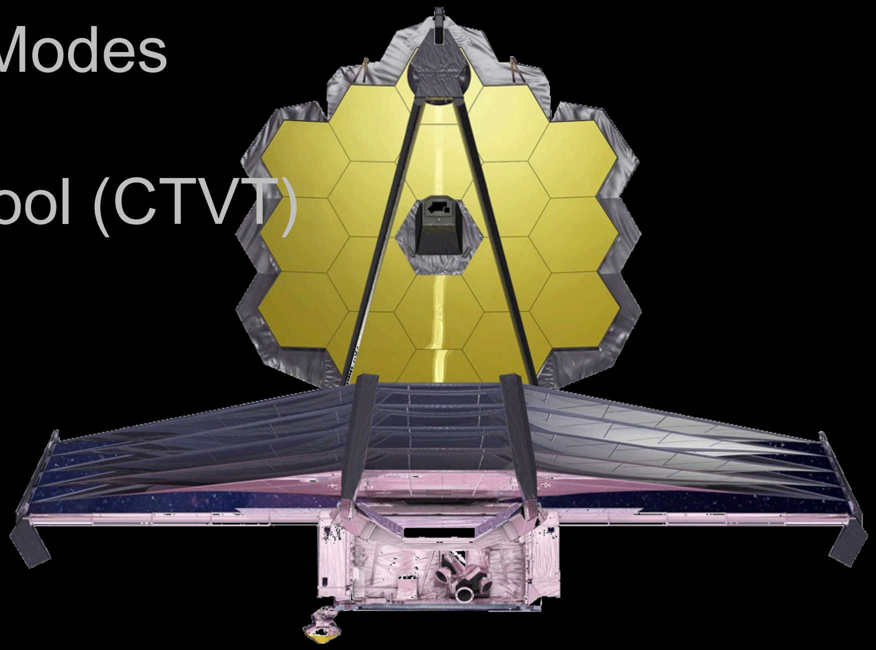


Demo: NIRISS AMI+MIRI 4QPM

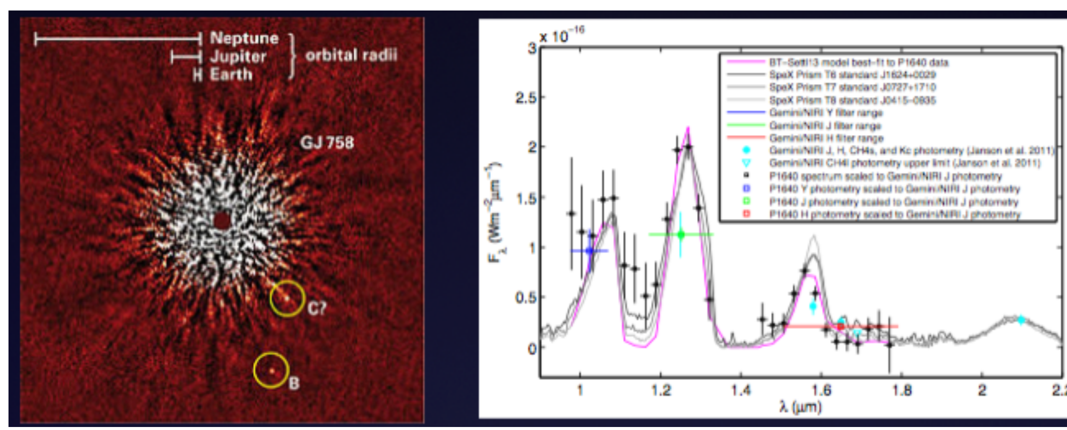
Characterizing the system around GJ 758

© JDox

Goal: Characterize the atmosphere of this cool benchmark brown dwarf at long wavelengths. Measure effective temperature and atmospheric ammonia absorption.
and probe the innermost separations for additional objects

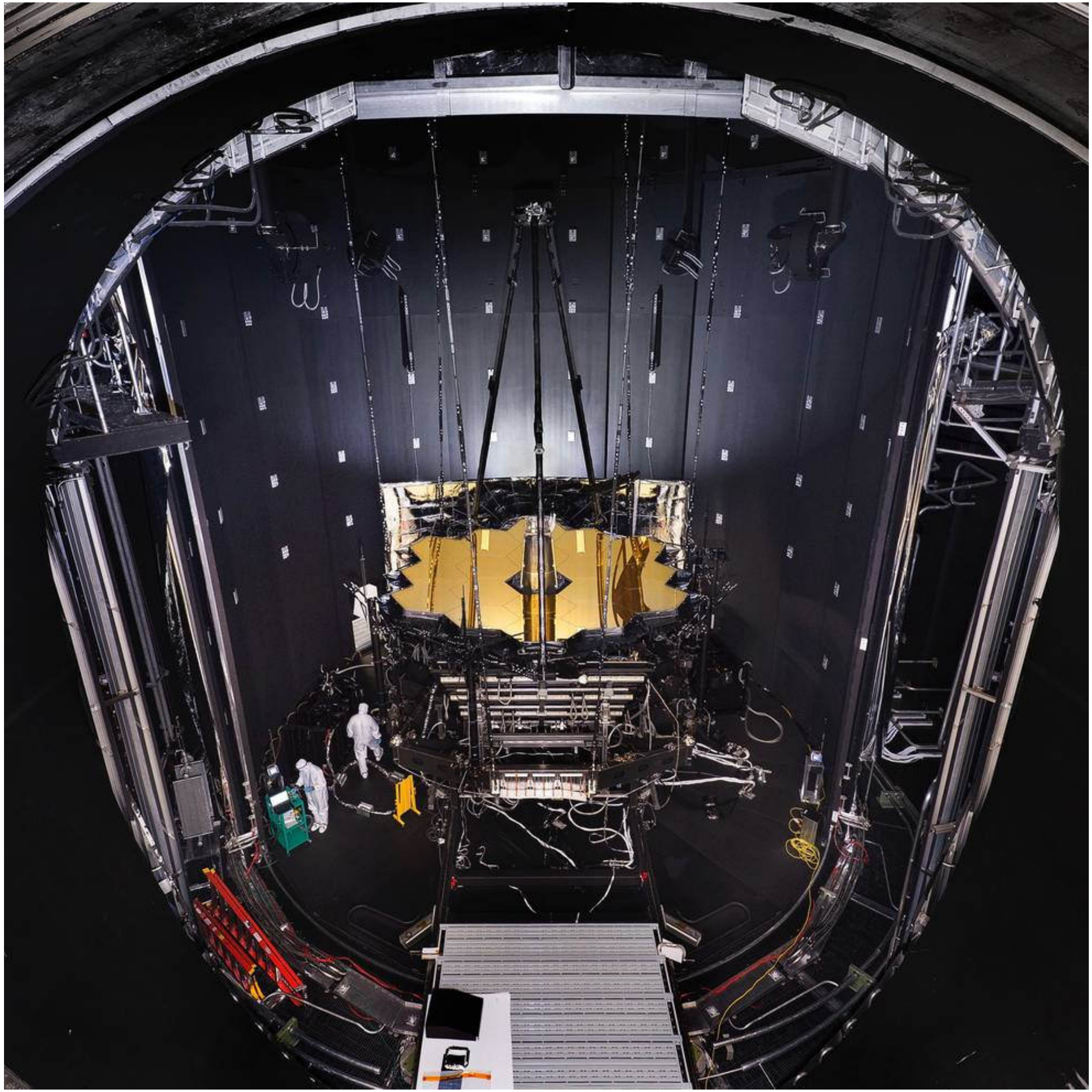
Method: NIRISS AMI in F430M and MIRI all 3 4QPM to sample the SED and amonia.

Source: Multiple point sources



APT Demo

Thank you



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