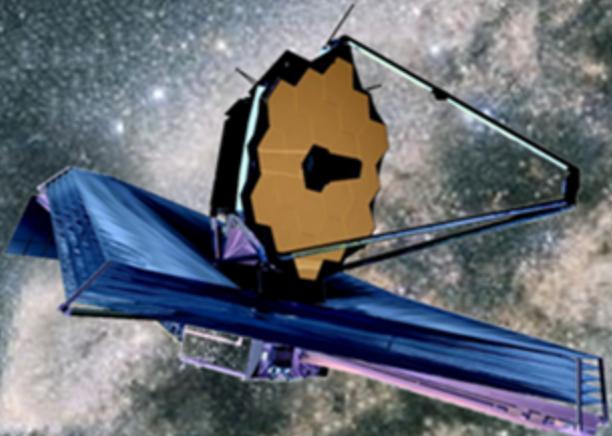
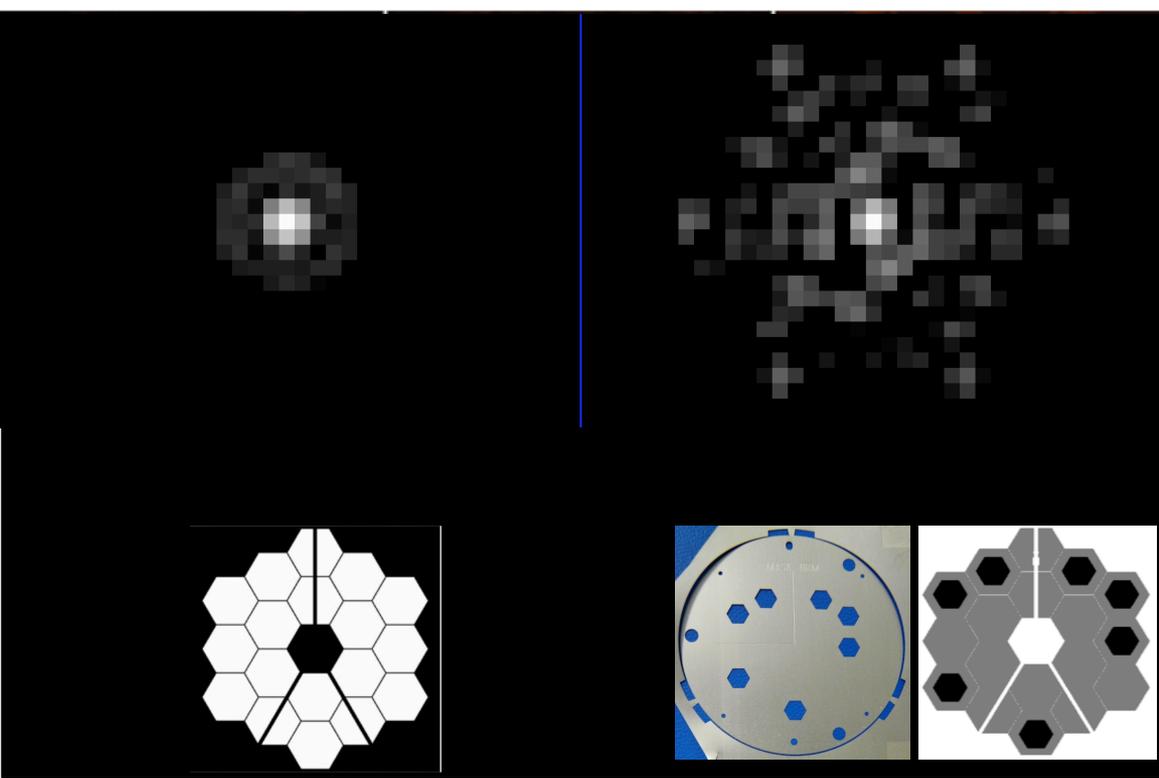


Université de Montréal  
 CSA ASC  
 James Webb Space Telescope  
**JWST**  
 NASA • ESA • CSA  
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**NRC - CNRC**  
**Honeywell**



**JWST Master Class**  
**November 2019**



# **NIRISS AMI OVERVIEW AND PROPOSAL PLANNING**

Deepashri Thatte, Anand Sivaramakrishnan and NIRISS team



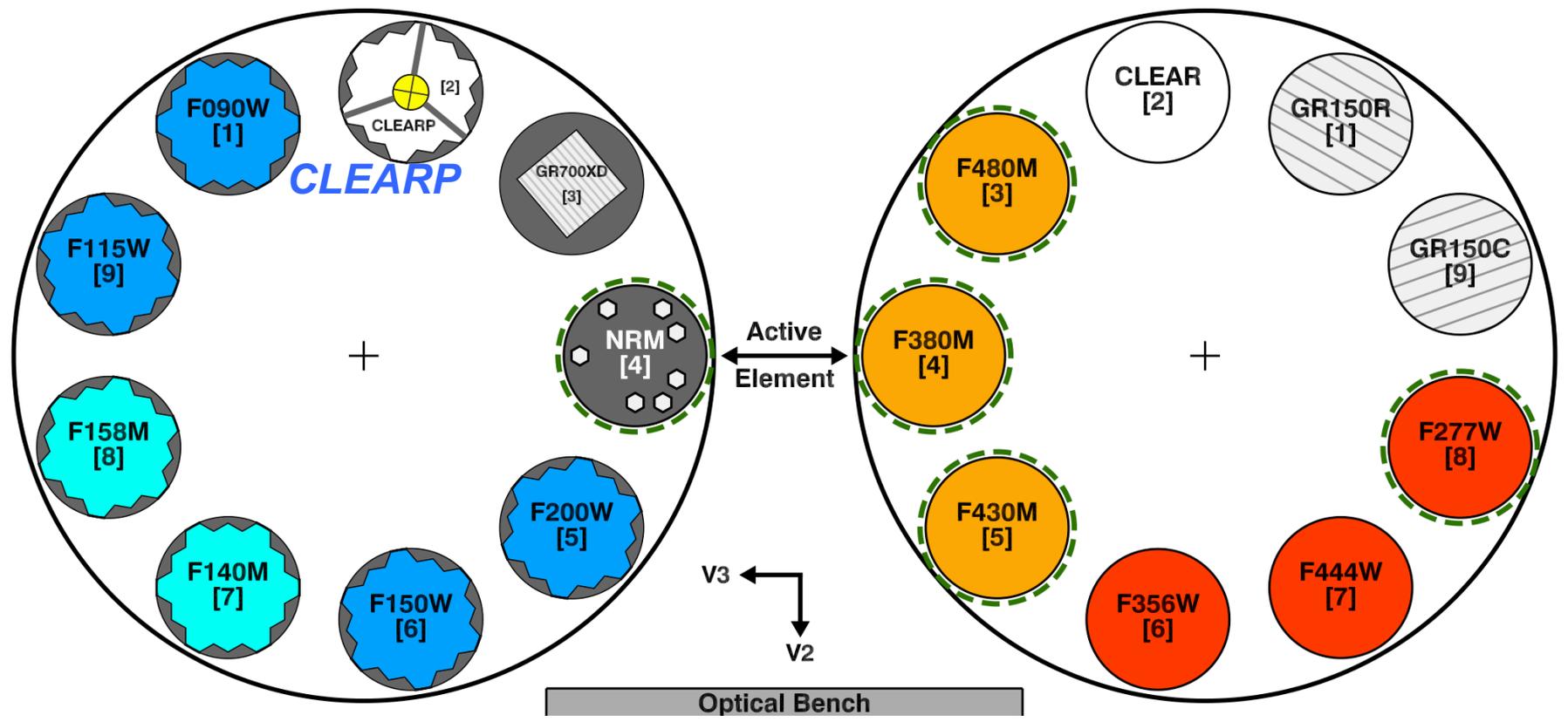
# HCI capability of NIRISS AMI

- Moderate-contrast, high angular resolution imaging for exoplanets, transition disks, AGN, Io volcanoes, exozodi disks
- Uses non-redundant mask (NRM) in the pupil wheel of NIRISS in conjunction with one of the 3x medium-band filters centered at 3.8, 4.3 and 4.8  $\mu\text{m}$  (F380M, F430M, F480M) or a wide-band filter centered at 2.77  $\mu\text{m}$  (F277W)
- Bright limit  $\sim 3$  to 4 magnitudes in medium filters. Goal is to reach binary point source contrast up-to  $10^{-4}$  at separations of  $\sim 70 - 400$  mas (“behind the spot” of NIRCам coronagraphs).
- Photon-noise limited, combination of flat-field error and placement can affect performance.
- Requires TA, observing calibrator star close in time to the target, dithers available but not recommended.

# Dual wheel optical elements

## Pupil Wheel

## Filter Wheel



~65 mas pixels are Nyquist sampled at ~4um  
 F277W: reduced performance but has water band  
 CLEARP for 'kernel phase' on fainter targets

# NIRISS NRM design

7 holes

$7 \times (7-1) / 2 = 21$  'baseline'  
interferometer, no vector baseline  
repeated

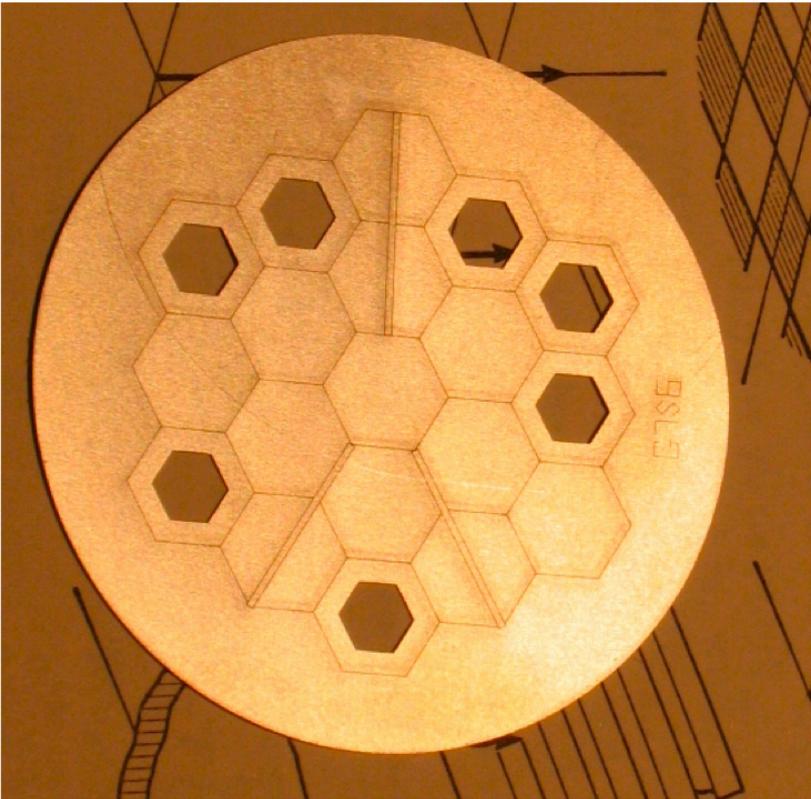
Highly calibratable images

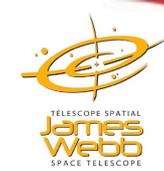
Undersized holes accommodate inexact  
pupil placement

15% throughput cf. full pupil  
Peak pixel  $\sim 1/40$  full pupil peak pixel

Used for target acquisition for bright  
NIRISS SOSS (exoplanet transit  
spectroscopy) targets

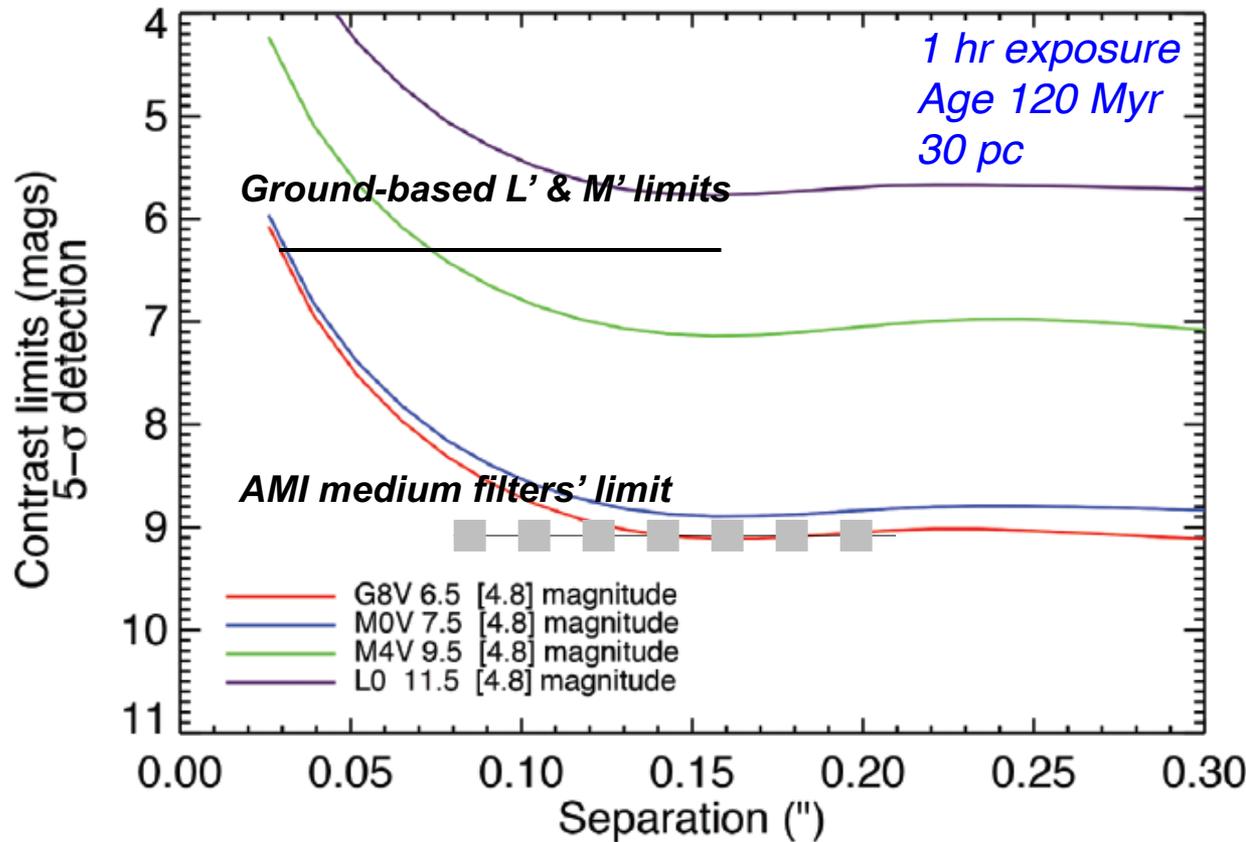
Enables coarse & fine wavefront sensing  
as back-up to NIRCam





# Science motivation

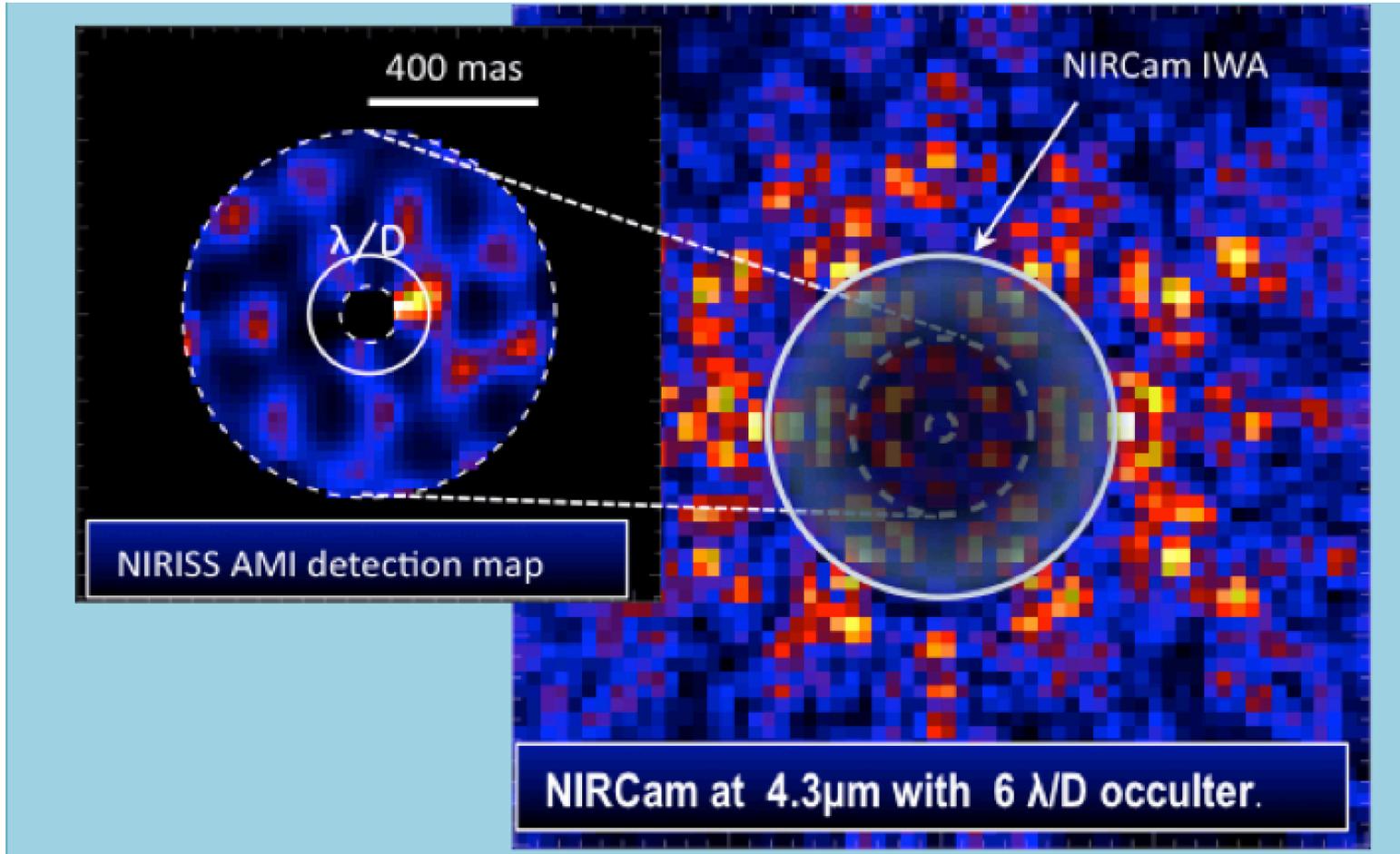
- Probe separations of ~40 to 400 mas
- At contrast of up to 9 mag
- Filters: F380M, F430M, F480M, (and F277W)



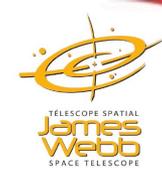
- ### Science goals
- Detection of planets very close (70-500 mas) to their parent star.
  - Study of feedback and fueling structures in AGNs.
  - Transition Disks  
Planets/structure
  - Ultracool star binarity
  - Exozodi detection
  - Io volcano photometry



# Complements NIRCams coronagraphy

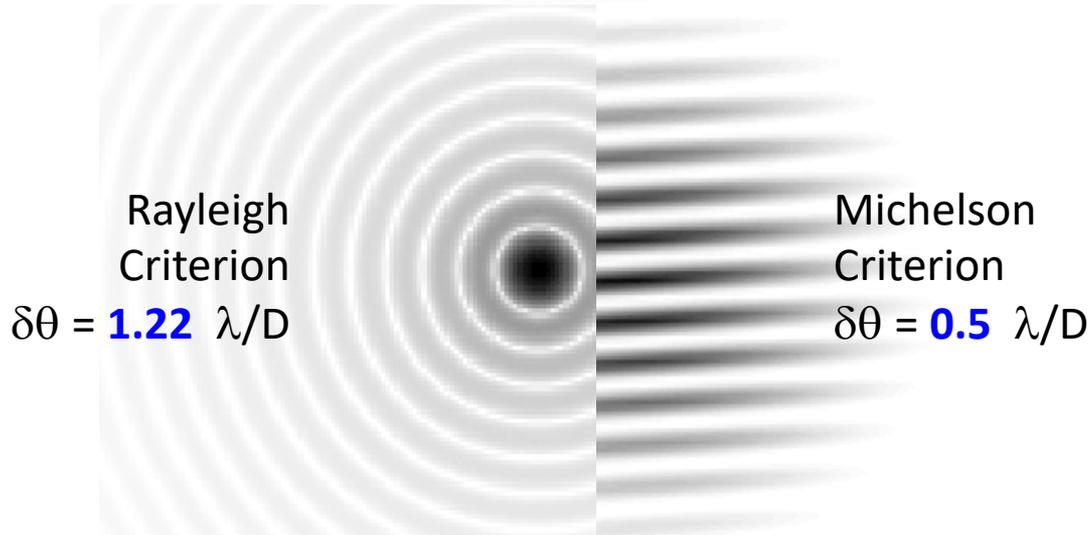


Simulation of 1-2 Jupiter mass planet at 1 AU around M0V host star at 10 pc (by NIRISS IDT). Observing time: 3 hr

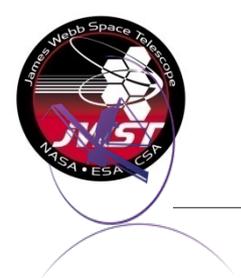


# Interferometric resolution, small IWA

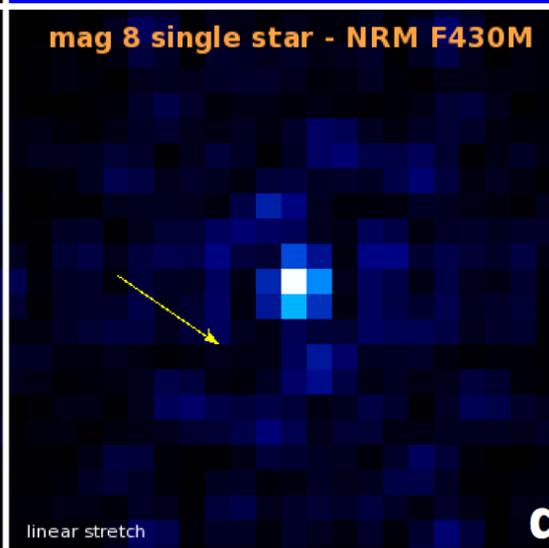
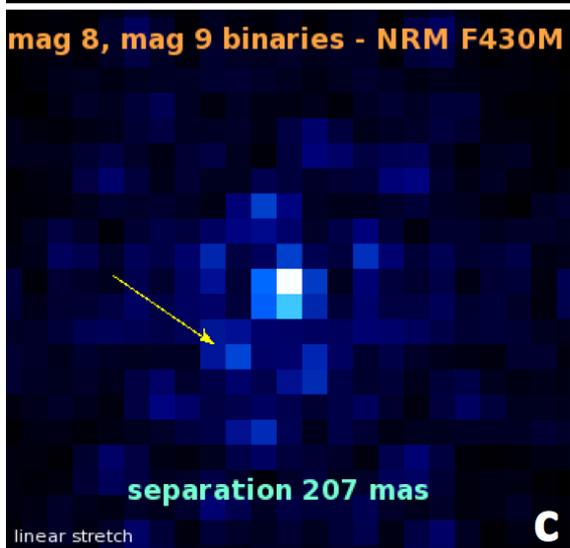
- $\delta\theta = 0.5 \lambda/D$  Michelson Criterion (NRM)
- $\delta\theta = 1.22 \lambda/D$  Rayleigh Criterion (Full aperture)
- $\delta\theta = 4\lambda/D$  NIRCcam coronagraph (Inner Working Angle)



Easier to calibrate out instrumental effects



# NIRISS AMI PSF

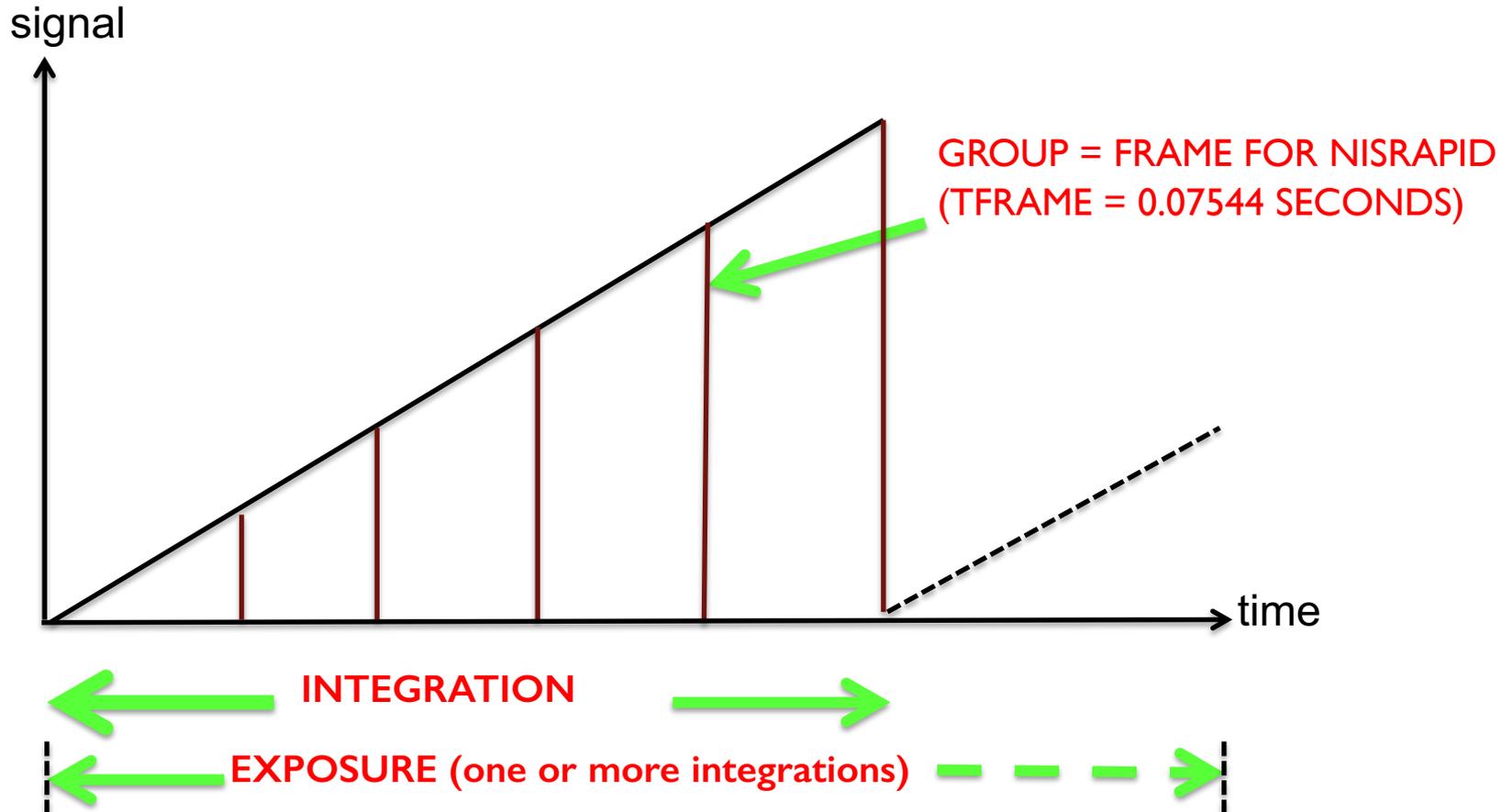




# Exposure Nomenclature

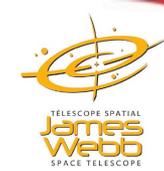


The NIRISS AMI subarray is SUB80 (FULL also available)  
One frame per group (NISRAPID readout pattern)

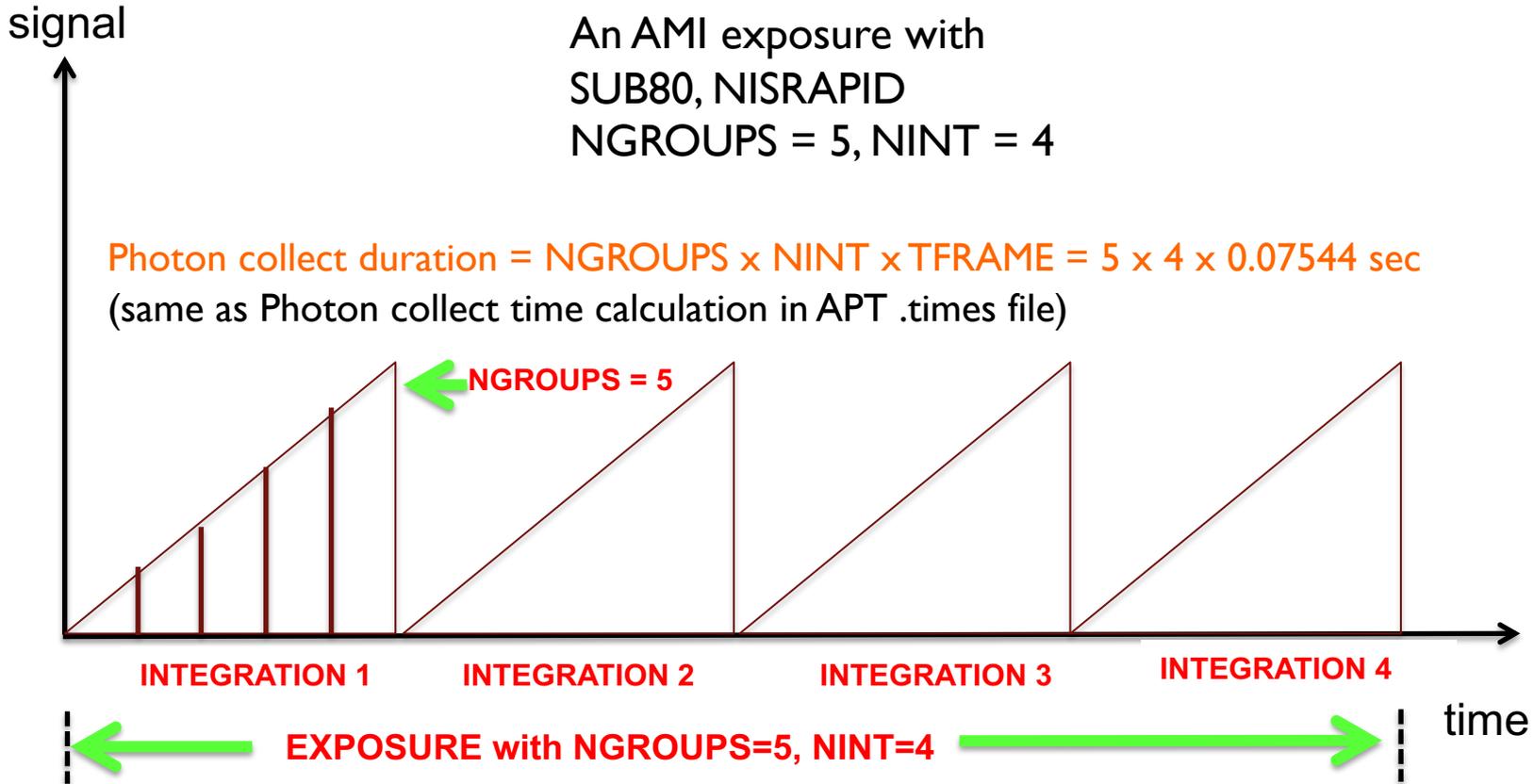




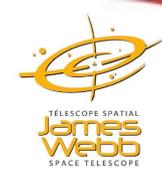
# NIRISS AMI Exposure



The NIRISS AMI subarray is SUB80 (FULL also available)  
One frame per group (NISRAPID readout pattern)



**Note: The Total Exposure Time shown by JWST ETC includes resets, do not use it to calculate signal. Use photon collect time instead.**



# AMI Brightness limits (Vegamag) SUB80

Filter	NGROUPS 1	NGROUPS 2
F277W	7.0	7.6
F380M	4.1	4.7
F430M	3.4	4.0
F480M	3.1	3.7

30,000 e<sup>-</sup> pixel signal limit, pixel-centered PSF

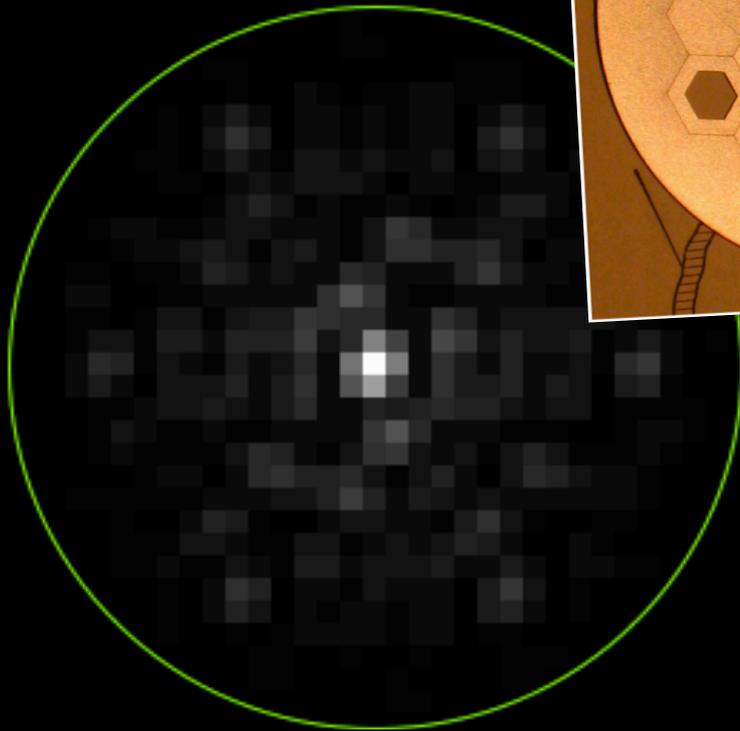
Add ~4 mag to these to get CLEARP SUB80 brightness limit (cf NRM)

Add ~5.5 mag to get FULL detector NRM brightness limit (cf SUB80)

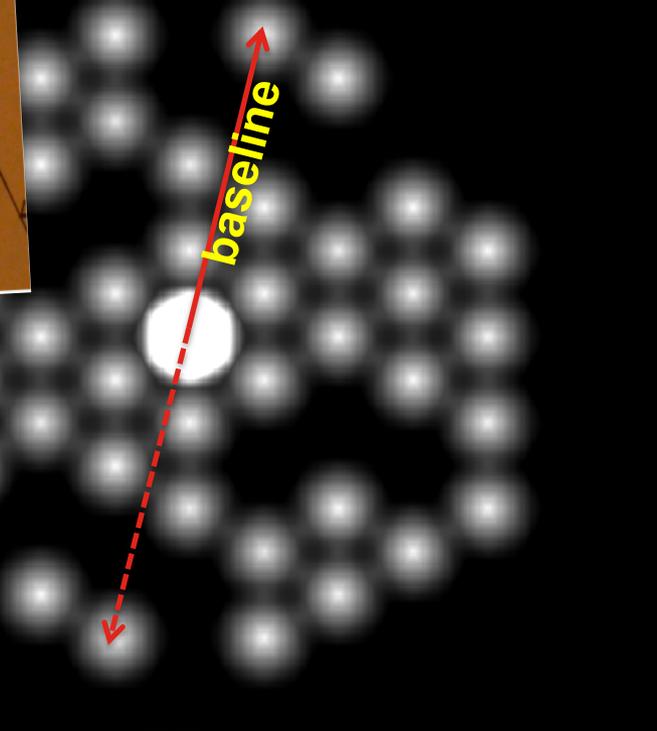
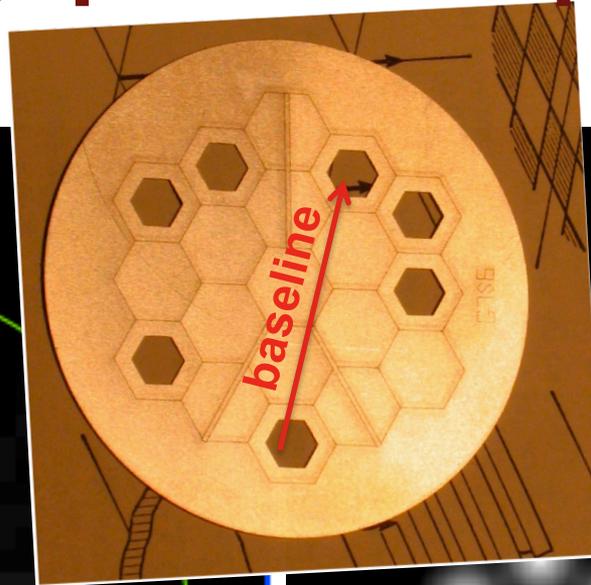
Add ~9.5 mag to get FULL CLEARP brightness limit

# Fringe phases & amplitudes

Interferometric view



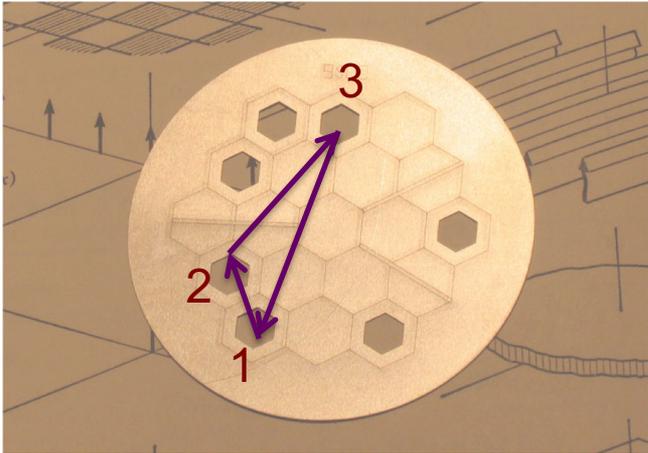
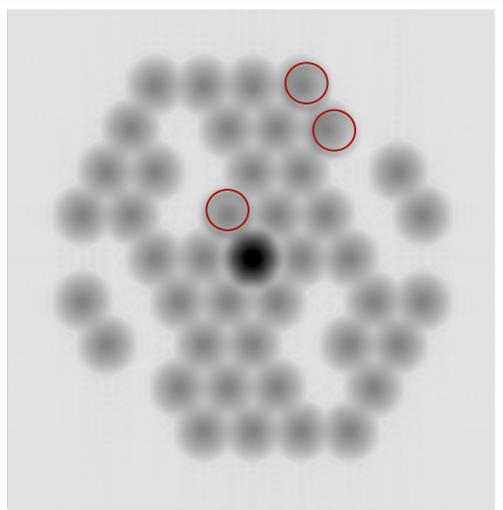
PSF or image of target



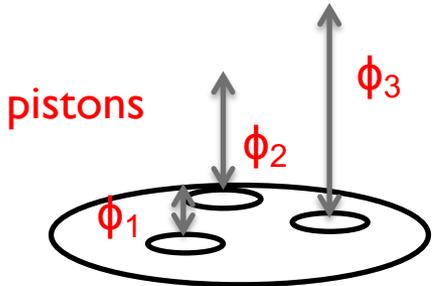
$\text{abs}(\text{FT}(\text{image}))$

7 hole mask: 21 independent baselines. FT has central splodge + 42 splodges  
 Get fringe visibilities & (Fourier) phases of each of the 21 fringes (42 numbers)

# Closure phase measures structure



For three holes, sum of 3 fringe phases = closure phase



pistons

$$\phi_{i,j} = \phi_j - \phi_i$$

$$\phi_{1,2} + \phi_{2,3} + \phi_{3,1} = 0$$

Non-zero closure phases are a result of structure or measurement errors

$$\text{Contrast} \sim 1/\sigma_{CP}$$



# Calibrating Closure phases & SqV



For a point source;

Closure phase (CP) should be 0

square visibility (SqV) should be 1

Remove residual error/instrumental contribution to closure phases by calibrating with the point source calibrator star

Subtract CAL CPs from Target CPs

$$CP_{\text{target}} = (CP_{\text{target}} + CP_{\text{instrument}}) - (CP_{\text{calibrator}} + CP_{\text{instrument}})$$

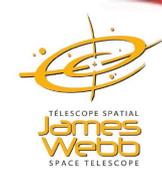
Any non-zero closure phase is due to asymmetry in the source.

*CPs do not measure centro-symmetric structure, but SqV's do*

Divide target visibilities by calibrator visibilities

Square calibrated visibilities to get SqV

**Fit science data to fringe quantities**



# AMI Operations

- **AMI Target Acquisition in 64 x 64 subarray (SUBTAAMI)**
  - NGROUPS – odd numbers between 1 & 19 (avoid saturation)
  - NISRAPID readout
    - Acquire in F480M, MASK\_NRM for bright, CLEARP faint
    - Small Angle Maneuver to SUB80 science subarray POS 1
- **AMI data acquisition in SUB80: 80 x 80 subarray**
  - 80 x 76 light sensitive, 4 rows of reference pixels
  - NISRAPID readout only for SUB80 (select NGROUPS, NINT)
    - Recommend POS 1 only (default is pixel center)
      - Expected POS 1 placement to ~5 mas per axis
      - User-selected offset possible
      - Dithers possible but not recommended
- **SUB80 frame time 0.07544 s (approx 1 / 15 s)**
- **Full detector possible (optional TA), NISRAPID, 10.7 s frame time**
  - NIS available for FULL



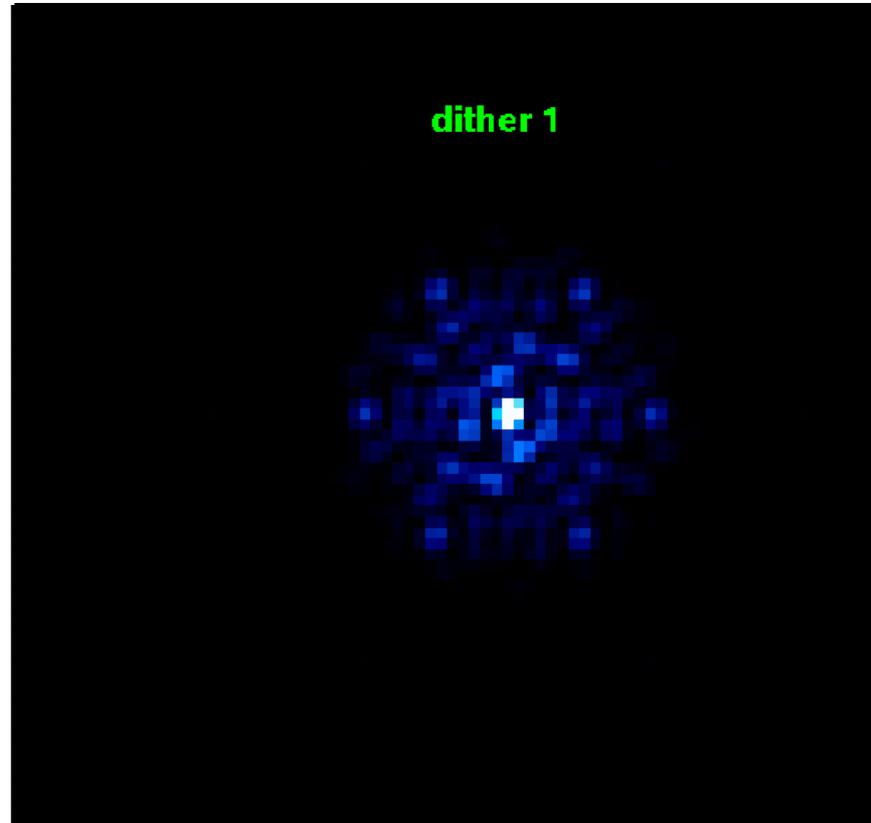
# SUB80 AMI subarray 5.2" × 4.9"

76 x 80 light sensitive pixels



Target placement  
at POS 1

Sub-dithers  
available, use with  
caution



*Dithers possible but not recommended.*



# NIRISS AMI Observation planning:

## Step I Select science targets(s) and calibrator(s)

- Select Science Target & (optional) PSF CAL[ibrator] star
  - Check if target and calibrator are visible using JWST General Target Visibility Tool (GTVT) or APT.
  - Similar spectral type & brightness
- Vet potential calibrators for IR excess, strong spectral lines, binarity
  - Catalog searches, 8m-class ground NRM, VLT & LBT interferometry (e.g. SearchCal)
- Shared CALs save time
  - For low required contrast (eg BD binaries) – use existing/simulated CAL
  - Cooperate across programs to select & share CALs



# NIRISS AMI Observation planning:

## Step 2 Exposure depth estimation

- Binary point source

$$\begin{aligned} N_{\text{photons}} &= 1.5 \times N_{\text{hole}}^2 / (\text{contrast ratio})^2 \quad \text{----- Ireland (2013)} \\ &= 73.5 / (\text{contrast ratio})^2 \end{aligned}$$

Considering the fact that NRM has not been used in space before, we use a slightly more conservative value of:

$$N_{\text{photons}} = 100 / (\text{contrast ratio})^2$$

For example, to detect a contrast ratio of  $10^{-3}$

$$N_{\text{photons}} = 100 / (0.001)^2 = 10^8$$

- Therefore we need  $10^8$  photons from the target (and also the calibrator) with NRM and the F480M in the ETC



# NIRISS AMI Observation planning

## Step 3 – JWST ETC



- Estimate exposure parameters using JWST ETC
  - Stay below a signal limit of 30000 electrons in the peak pixel of an integration
    - When two neighboring pixels accumulate charge at very different rates, photoelectrons from the brighter pixel migrate to its neighboring pixels (charge migration)
    - ETC issues a warning when this signal limit is exceeded
    - This signal limit is lower than the true non-linearity based saturation limit for the NIRISS detector
  - Calculate exposure parameters to reach required exposure depth (total photons) needed to detect contrast
- The extended wings of the AMI PSF can be used for data analysis
  - Strategy tab: Choose noiseless sky background when defining the extraction parameters for the source flux and for the background to be used for background subtraction. The extended PSF makes background subtraction difficult and AMI analysis handles background in the data.
  - Use the following aperture extraction radius for point sources
    - F480M: 2.5", F430M: 2.3", F380M: 2.0", F277W: 1.6"
- A note about Total Exposure Time in ETC
  - The exposure time reported by ETC includes reset time, equivalent to one tframe, between each integration and the time for full-frame reset of pixels outside the subarray, which occurs before every integration when the detector is in subarray mode. No photons are recorded during this reset time, so these reset times should not be included when calculating the total number of photons.
  - Use Photon collect time =  $NGROUPS \times NINT \times TFRAME$  to estimate signal



# NIRISS AMI Observation planning

## Step 4 AMI specific steps in JWST APT

- Use [JWST ETC](#) to calculate [NGROUPS](#) and [NINT](#) needed to reach the required exposure depth. Input to APT.
- A [target acquisition \(TA\)](#) is required when using a subarray and strongly recommended for full frame readout to ensure that the target is always placed on the same detector pixel.
- We recommend using [GAIA DR2 archive](#) to get coordinates and proper motion of the sources and [2015.5](#) for epoch in APT
- TA is performed with the F480M filter prior to the start of science observations. Therefore [starting an exposure sequence with the F480M filter is most efficient](#). If using all the filters the sequence [F480M, F380M, F430M, and F277W](#) produces the least motion of the Filter Wheel.



# NIRISS AMI Observation planning

## Step 4 – AMI specific steps in JWST APT continued...

- Use same positioning (eg POS 1, because of flat-field error)
- For higher contrast needs science target and calibrator should be observed close in time and without PM/SM adjustments between observations.

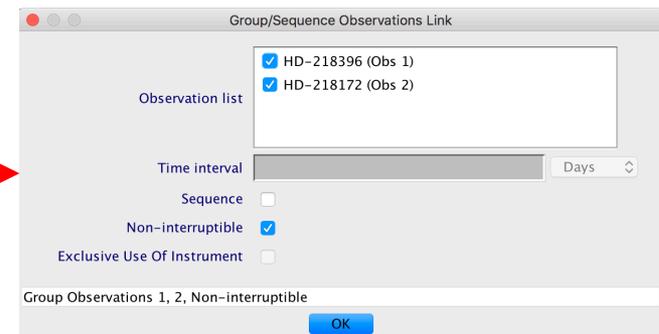
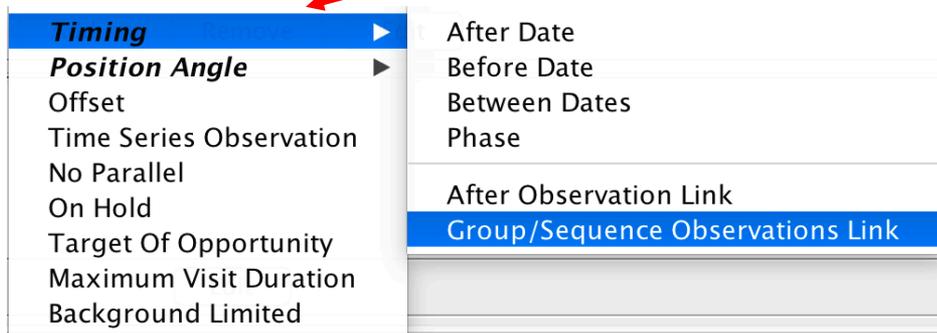
### Special Requirement tab,

- Timing requirement of Group/Sequence Observations Link, selecting target(s) and calibrator(s) from the Observation list box
- Non-interruptible option

NIRISS Aperture Masking Interferometry

Special Requirements

Comments





# NIRISS AMI Observation planning

## Step 4 – AMI specific steps in JWST APT continued...

- Small slews between target and calibrator improves efficiency and stability
- Under PSF Reference Observation in Form Editor select PSF reference star to associate target with the calibrator for target observation. Choose 'This is a PSF Reference Observation' for calibrator observation. This tells the JWST pipeline to calibrate target with a specific calibrator(s).

PSF Reference Observations

This is a PSF Reference Observation

PSF Reference Observations

HD-218172 (Obs 2) (PSF Reference; Filters [F480M])

Additional justification  Additional justification of self reference survey will be provided in the science justification.

← For target observation

PSF Reference Observations

This is a PSF Reference Observation  (exclusive access period will be 0 months)

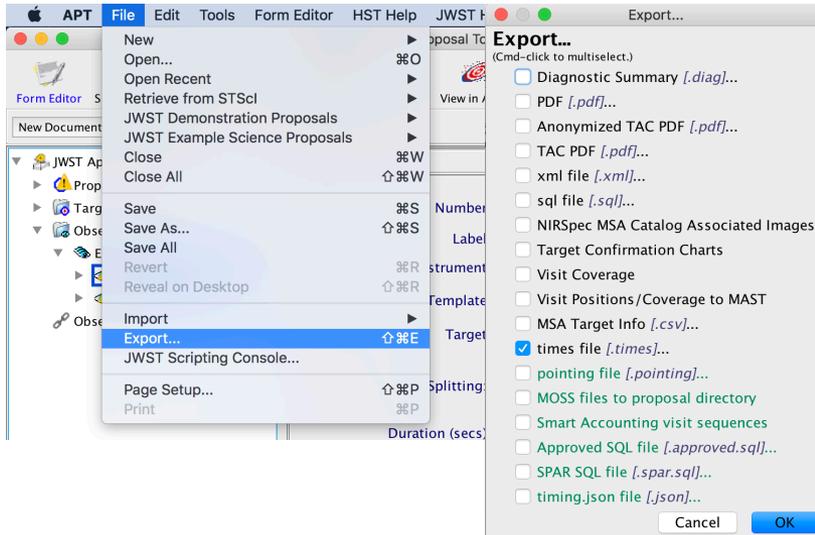
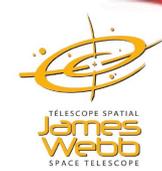
← For calibrator observation

- Verify that you entered correct coordinate information by creating target confirmation charts, view observation in Aladin
- Run visit planner
- Run Smart Accounting



# NIRISS AMI Observation planning

## APT timing report



```

ami_times.txt — Edited
# APT Output Product
#
# APT Version: Version 27.3.1 JWST PRD: PRDOPSSOC-M-025
# Date: Mon Nov 18 16:09:14 GMT 2019

JWST Times Report for JWST Approved Proposal 23 (Unsaved)

Note: Glossary of terms and column headers at bottom of this report

=====
* HD-218396 (Obs 1)
  Science   Total Time
  Duration  Charged
  4416      9169

Exposure Specifications:
  Exp  SUBARRAY  READOUT  FrameRead  Groups  NFrame  GrpGap  Ints  PhotonCollect  Diths  PrimDiths  SecDiths  NumExp  TotalPhoton  ExposureDuration  ExposingDuration
  Acq  SUBTAAAMI  NISRAPID  0.050      3       1       0      1       0.150          1       1           1       1       4415.956      16              5054              2
  SUBB00  NISRAPID  0.075      9       1       0      6504      4415.956      1       1           1       1       4415.956      5054              5040

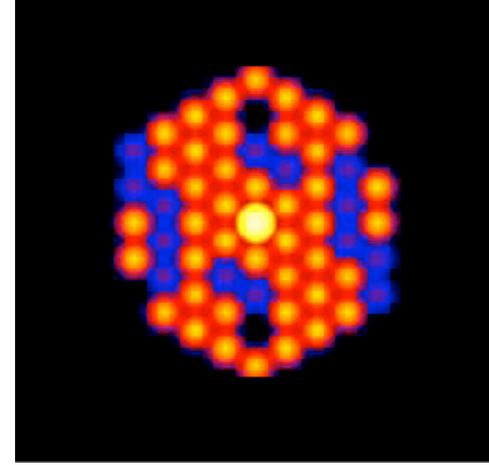
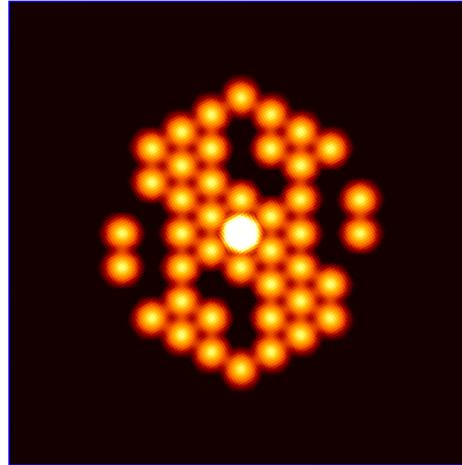
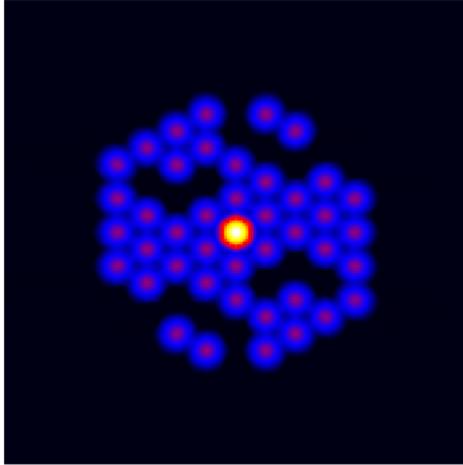
Visit Durations:
  Visit  Pointing  Science  Instrument  (GS  (Targ  (Exp  (Visit  Slew  Observatory  Direct  Sched  Total Time
  Dist  Duration  Overhead  (SAMS)  (Acq)  (Acq)  (Ovhd)  (Mech)  (OSS)  (MSA)  (IRS2)  (Ovhd)  Time  Overheads  Overhead  Charged
  1      0.00      4416     1688      ( 48)  ( 284)  ( 602)  ( 638)  ( 24)  ( 30)  ( 0)  ( 0)  ( 62)  1800      1265      0          9169

=====
* HD-218172 (Obs 2)
  Science   Total Time
  Duration  Charged

```

# Rotate for good uv-coverage

Rotation helps fill uv plane coverage



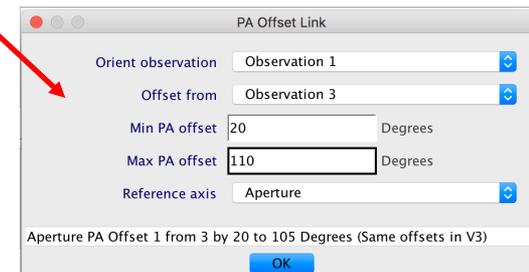
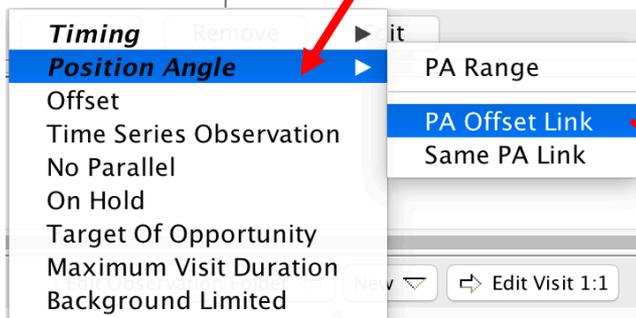
60 deg  
rotation

NIRISS Aperture Masking Interferometry

Special Requirements

Comments

Use Special Requirement tab, to select Position Angle and then PA Offset Link to rotate an observation with respect to another observation. Sun angle constraints limit possible rotations.

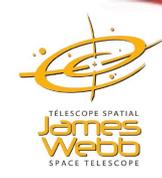




# Summary



- Moderate-contrast, high angular resolution imaging using NRM+Filter (F480M, F430M, F380M, F277W)
- Exoplanets, AGNs, Transition Disks Planets/structure, Exozodi disks, Io volcano photometry
- Bright limit ~3 to 4 magnitudes in medium filters.
- Binary point source contrast goal: up-to  $10^{-4}$  at separations of ~70–400 mas
- Complementary to NIRCam coronagraph
- AMI TA 64x64, SUB80 array with NISRAPID readout for data acquisition, FULL array available
- Calculate exposure parameters (NGROUPS, NINT) using JWST ETC, use those as an input to JWST APT.
- Send your questions to JWST help desk <https://stsci.service-now.com/jwst>



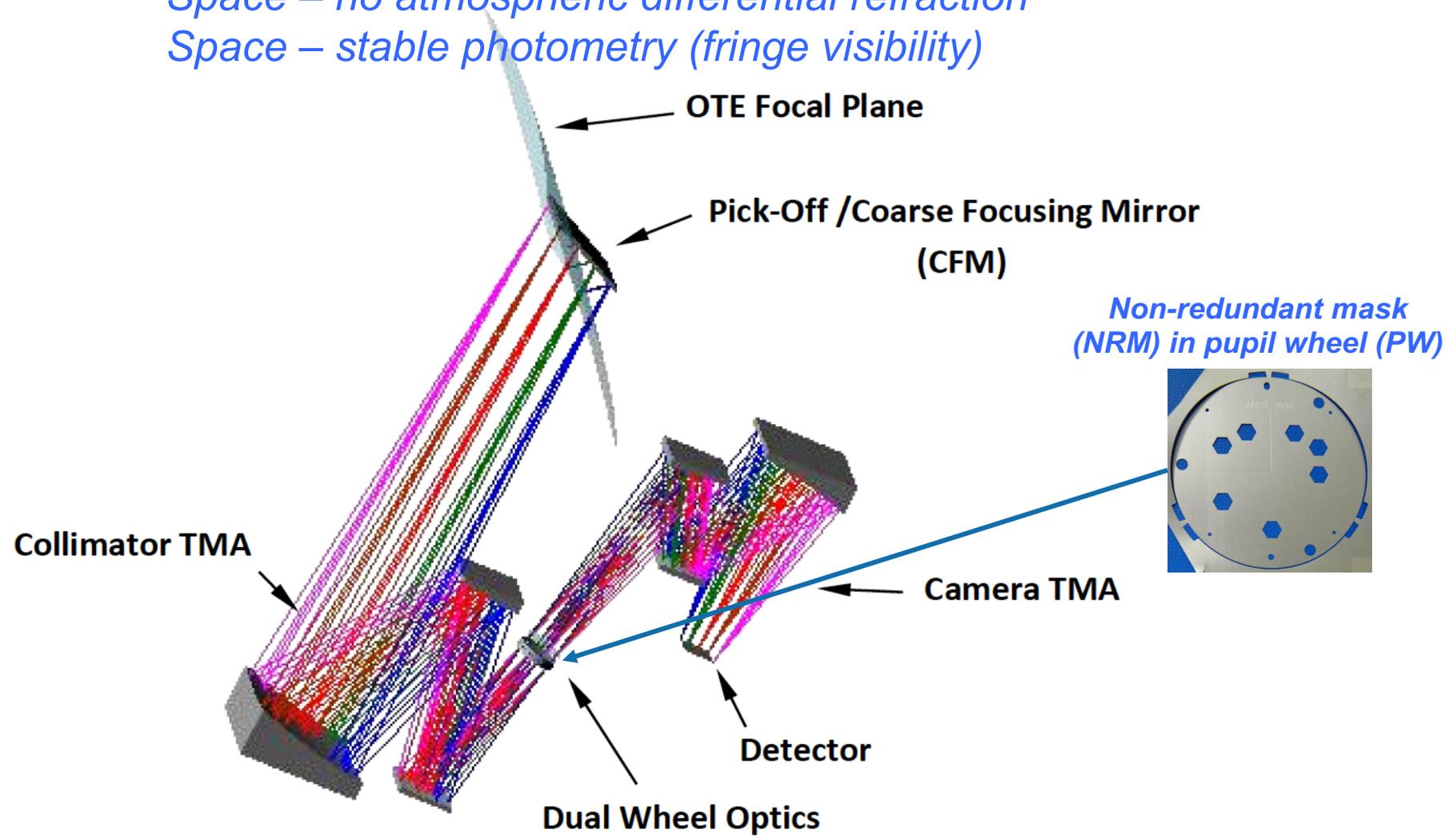
# **NIRISS AMI backup slides**



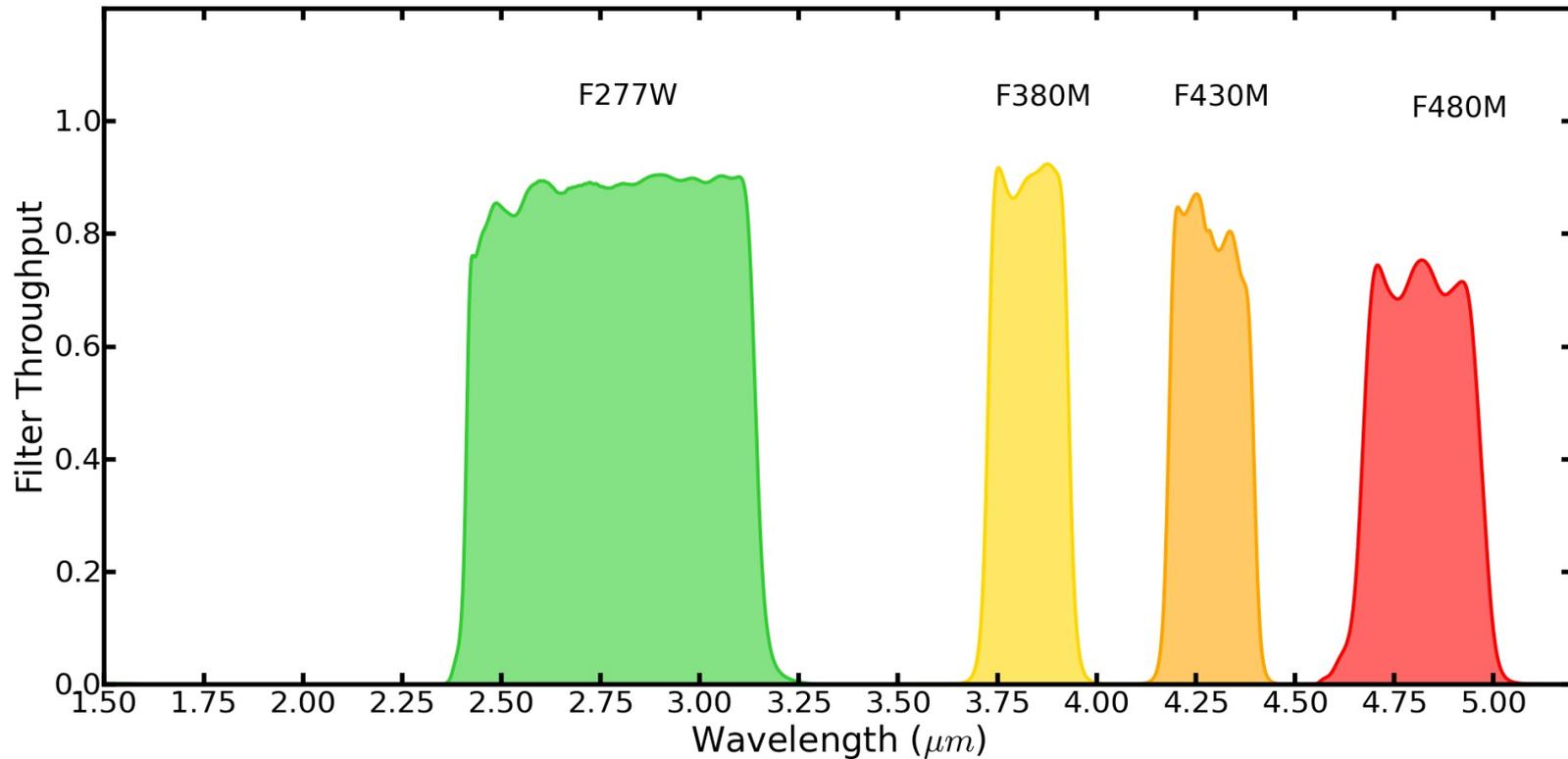
# NIRISS optical design layout



*All-reflective design - no chromatic aberration*  
*Space – no atmospheric differential refraction*  
*Space – stable photometry (fringe visibility)*



# AMI filter bandpasses



Binary point source contrast  $\sim 9+$  magnitudes for F380M, F430M, F480M

Reduced performance with F277W (not Nyquist sampled) – but good for breaking Brown Dwarf/Jovian Log  $g$ /Teff degeneracy to constrain bulk physical properties (Artigau et al. SPIE 2012)



# Data Structure

## Readout pattern, NGROUPS, NINT



For NIRISS AMI subarray is SUB80,  
readout pattern is NISRAPID (one frame per group)

**NGROUPS:**

number of groups in an integration

**NINT:**

number of integrations in an exposure

**EXPOSURE:** The end result of one or more INTEGRATIONS over a finite period of time.

**EXPOSURE** defines the contents of a single FITS file

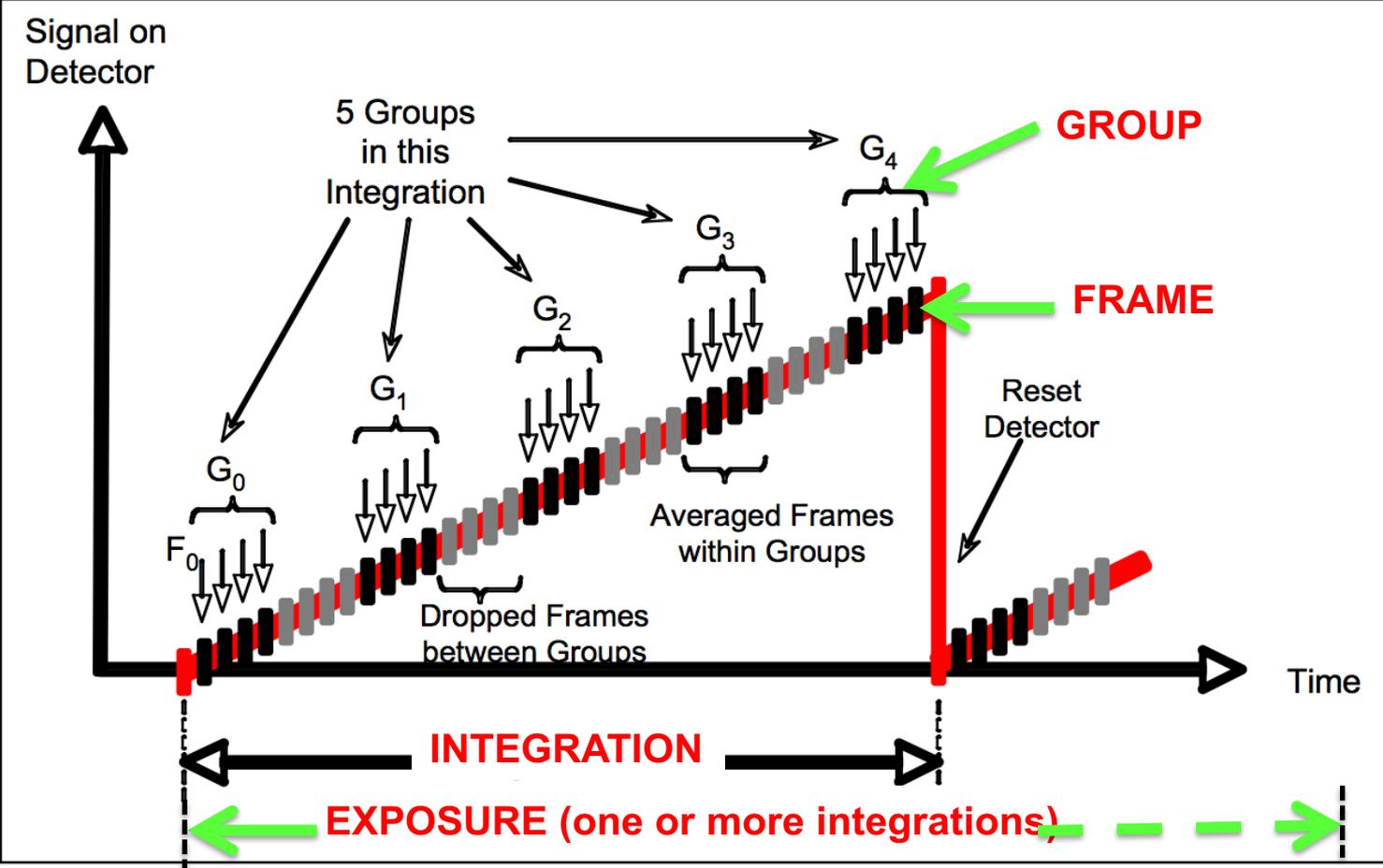


Figure adapted from JWST Mission Operations Concept Document JWST-OPS-002018 Revision E 2014



# Post-observations: Calibrate imaging data



- **JWST imaging data analysis on Target or CAL**

- Common to other JWST imaging, eg NIRCam imaging
- Correct for non-linearity, flat field, cosmic rays, etc

***To be determined from on-sky performance:***

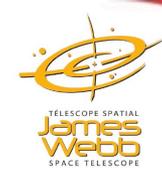
- ***EITHER*** Average all exposures
  - One final image
- ***OR*** Average all groups (recommended)
  - NINT images (per exposure – might need multiple exposures)
  - Better for statistics, image quality/stability monitoring

- **Extract observables:**

- ***EITHER Case A:*** Fringe amplitudes (visibilities) & phases, flux
  - Binary or multiple star model fitting
- ***OR Case B:*** Use image data for image reconstruction
  - CAL PSF and Target image



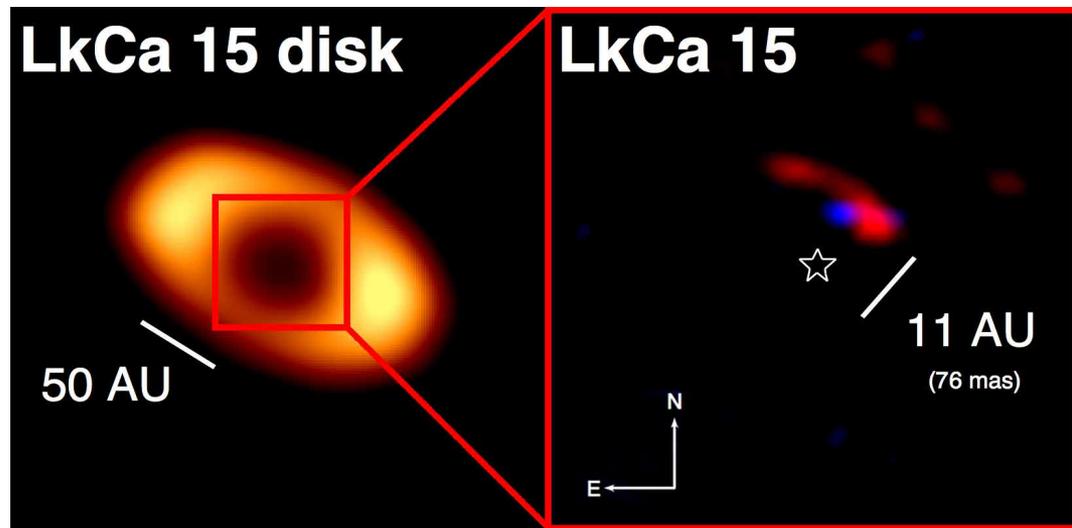
# Fringe phases & amplitudes



- **Numerical Fourier transform to a complex number array**
  - Conceptually easier to understand but not what we do
  - Measure splodge heights (fringe visibilities), splodge phases in FT(data)
  - Bad pixels corrupt an FT
  - Fix bad pixels then FT? Tricky.
- **Fit analytical model to image (recommended)**
  - Fit analytical fringe model to image, ignore bad pixels
    - Determine *pupil rotation* from image
  - Least squares extraction of 21 fringe phases & visibilities, flux, pedestal
  - Calculate:
    - Closure Phases (CPs)
    - Squared visibilities (SqV)
  - See Greenbaum et al. ApJ 2015 for algorithm
  - Implemented in JWST pipeline
- **Fit model of science data to fringe quantities**

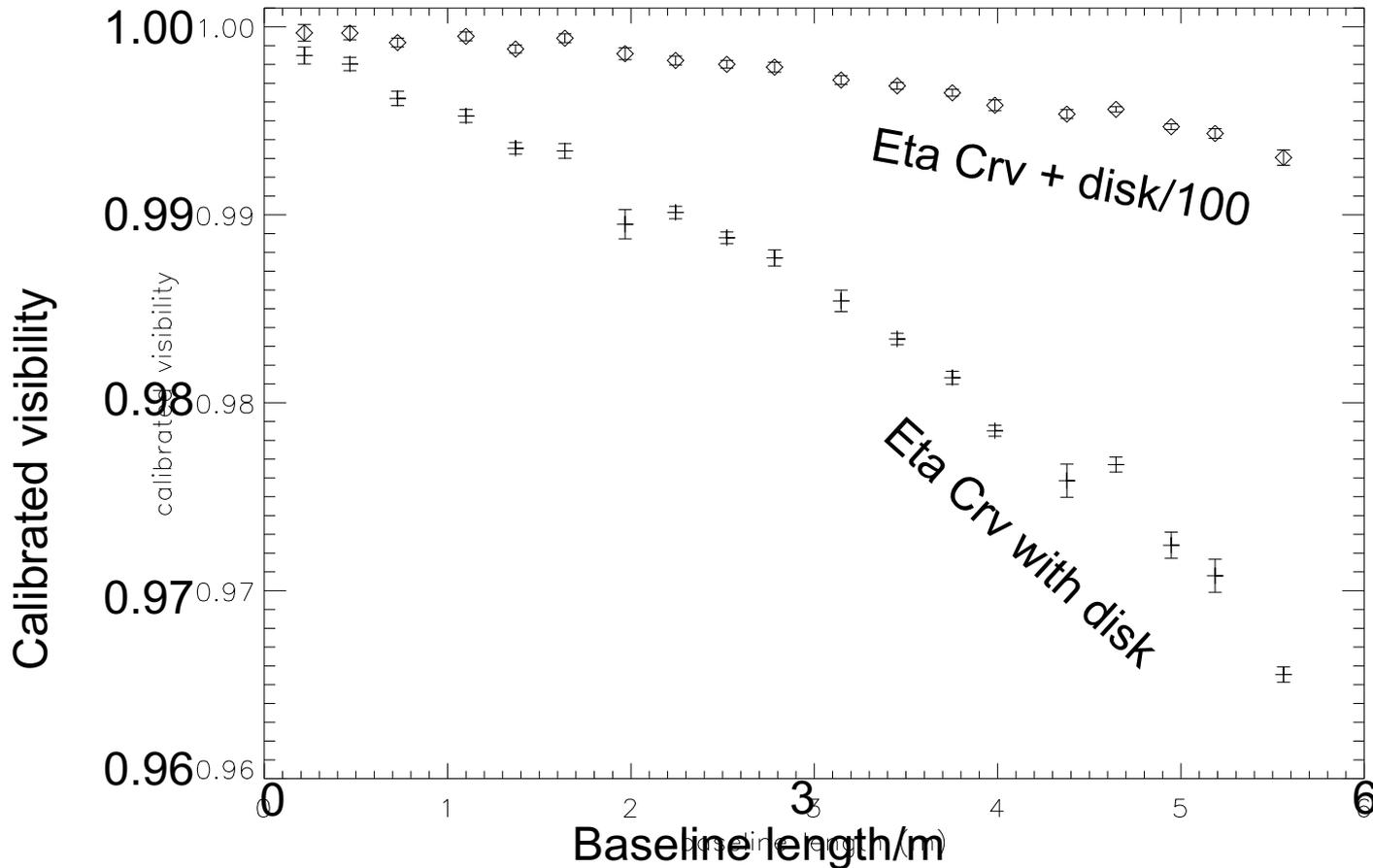
# Exoplanet Imaging with AMI

- Three medium-band filters: 3.8, 4.3 & 4.8  $\mu\text{m}$ 
  - Provide good constraints on  $\log g$  and  $T_{\text{eff}}$
- Follow-up of GPI/SPHERE planets with separation less than  $\sim 0.5$  arcsec and contrast  $> 10^{-4}$  @ 4  $\mu\text{m}$ .
  - Photometry and astrometry (e.g. Beta Pic b) (on flip side of FGS)
- Detection/confirmation/disambiguation/follow-up of suspected protoplanets in transitional disks (e.g. LkCA 15 disk)



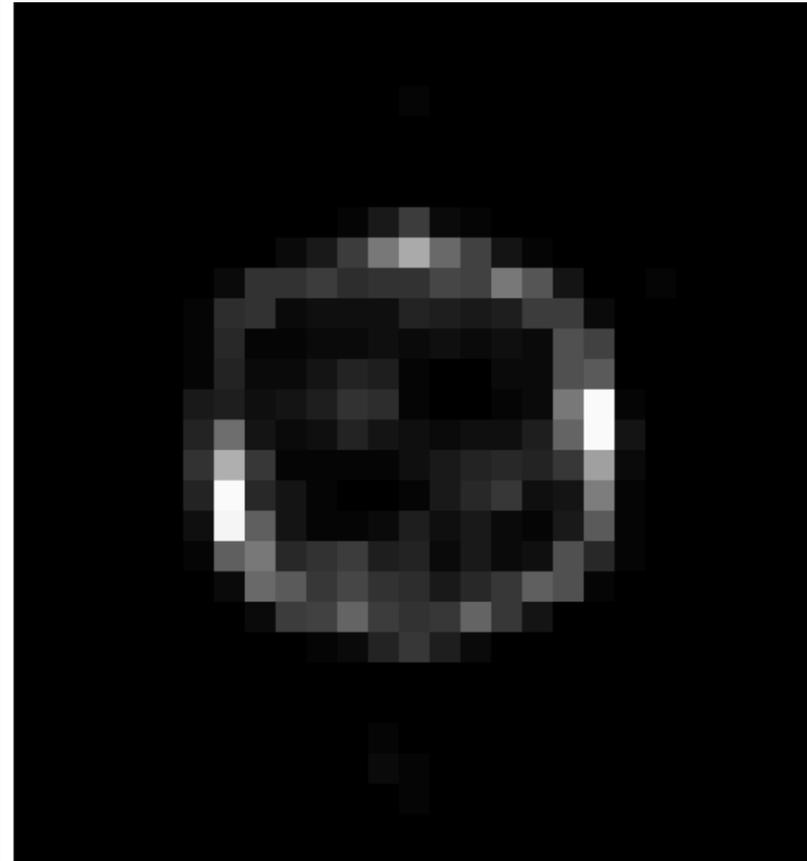
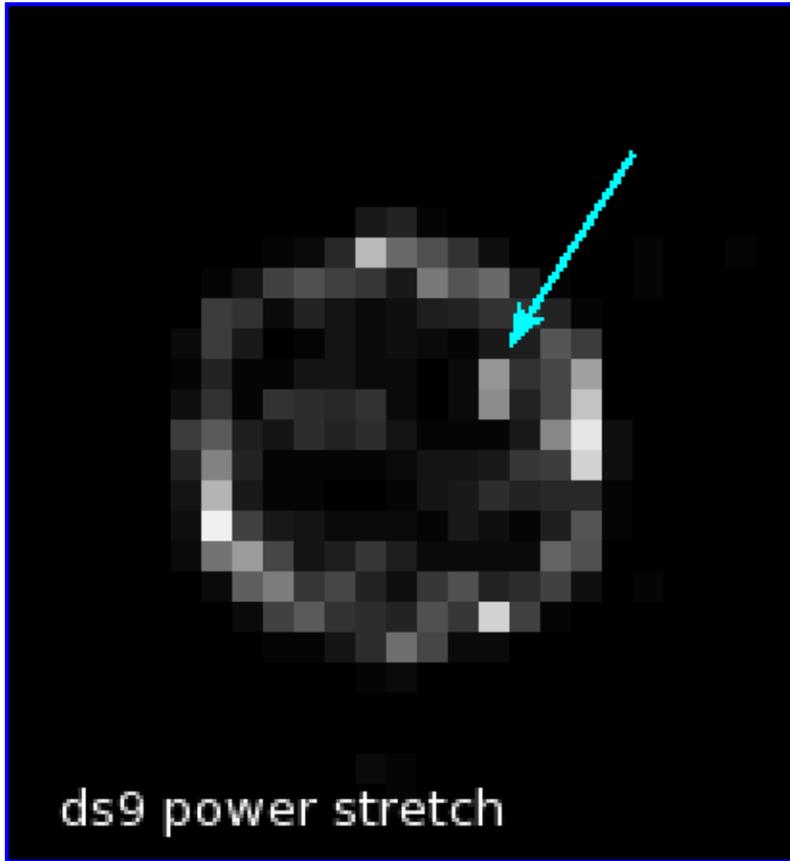
Kraus et al. 2012

# Exozodi measurement



Simulated F480M and F380M visibility of Eta Crv + MCFOST disk model and Eta Crv with 1/100 the dust mass in the disk (Tuthill & Sivaramakrishnan). NIRISS photometric and JWST pointing stability should enable this measurement. Cf. ground > ~5% visibility errors

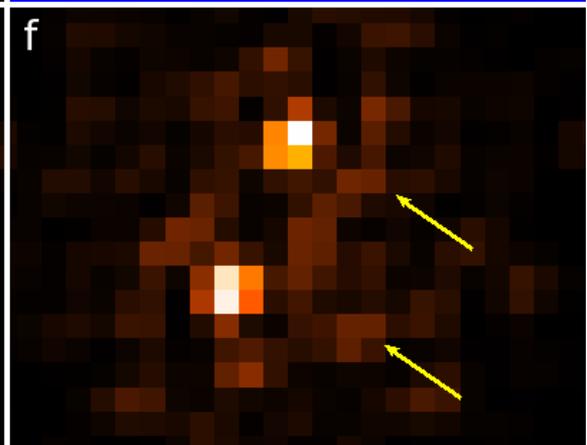
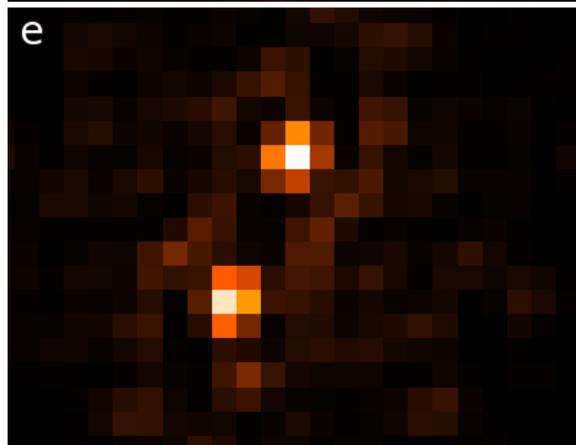
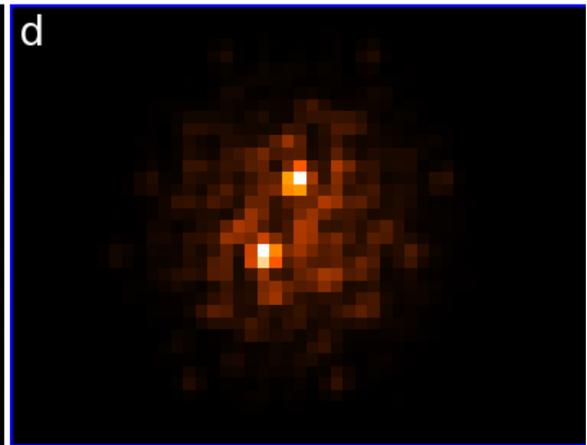
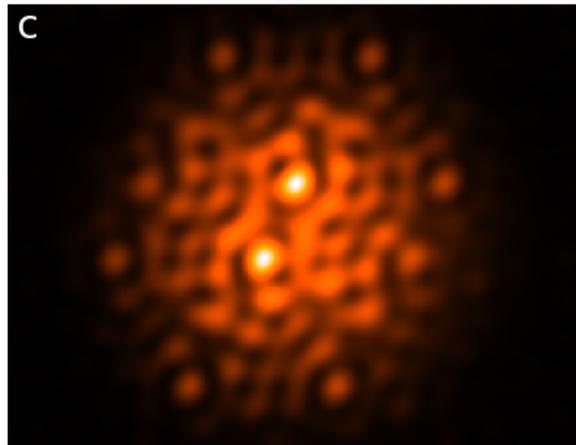
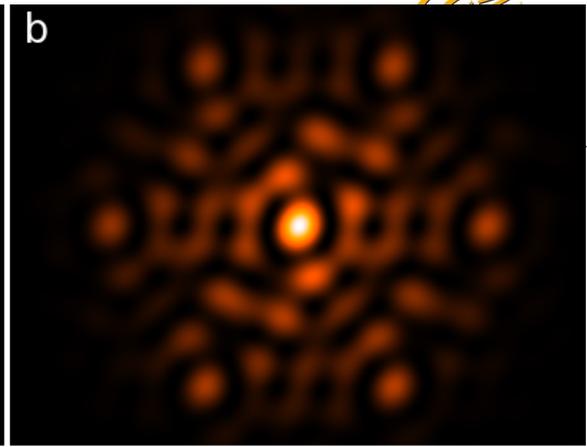
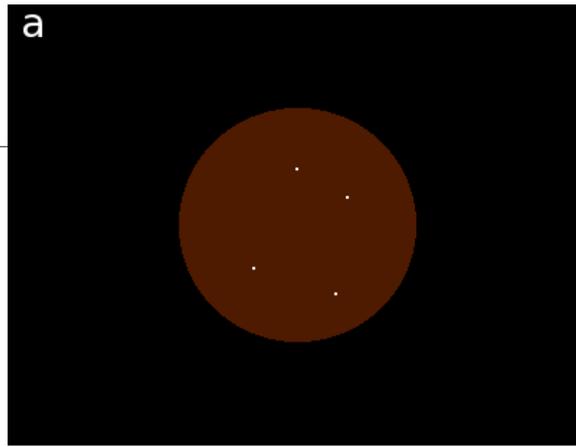
# Io volcanism

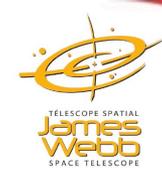


Simulated F430M images of Jupiter's closest Galilean moon, Io, with and without a typical volcanic event, after a Laplacian-like filter is applied to the simulated data. Space-based **photometry** of such a volcanic event should improve upon ground-based adaptive optics photometry (Thatte et al. LPSC 2015)



# Simulated volcanoes on Jupiter's moon Io



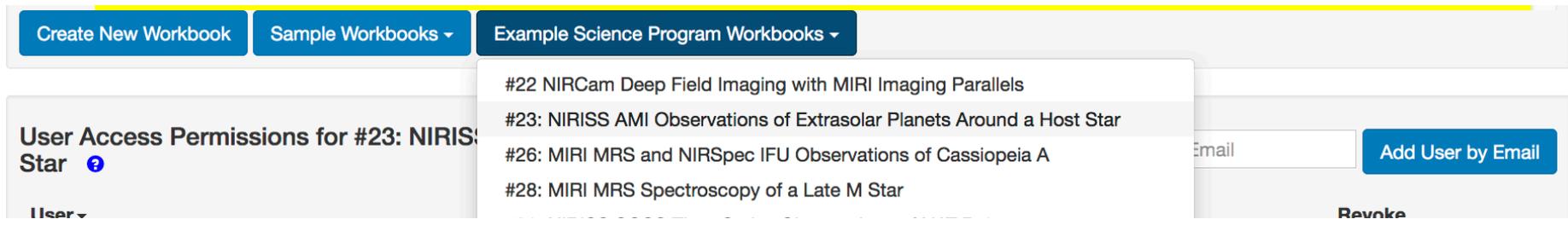


# NIRISS AMI hands-on exercises



# Example science program in JWST ETC

## 1. Log in to JWST ETC and Open program #23



Create a scene with another target with spectral type F0V, vegamag=6.5, normalized in NIRISS F430M. Name the source 'Target 2' and name the scene 'Target 2 Scene'

- i. Create a Target Acquisition calculation for this source
- ii. Create a new calculation to use this scene
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?



# AMI calculations in JWST ETC



2. What is the magnitude (Vegamag) of the brightest F0V star that you can observe with NGROUPS=7 in F480M, F380M?
3. Create calculations to calculate NGROUPS and NINT required to get  $10^7$  photons from HD37093. Use Vegamag = 5.47 normalized in F380M and vegamag=5.46 normalized in F430M and F480M
4. Calculate NGROUPS=1 and NGROUPS=2 bright limits (Vegamag) for a A0V star observed with F380M.

# AMI calculations in JWST ETC

## Answers to questions

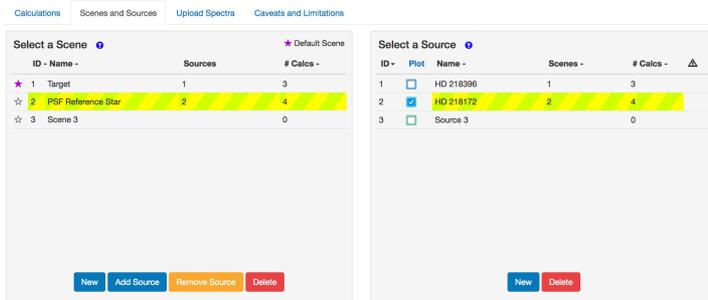
### 1. Log in to JWST ETC and Open program #23



The screenshot shows the 'Example Science Program Workbooks' dropdown menu with the following items:

- #22: NIRCam Deep Field Imaging with MIRI Imaging Parallels
- #23: NIRISS AMI Observations of Extrasolar Planets Around a Host Star
- #26: MIRI MRS and NIRSpec IFU Observations of Cassiopeia A
- #28: MIRI MRS Spectroscopy of a Late M Star
- #31: NIRISS SOSS Time-Series Observations of HAT-P-1
- #33: NIRISS WFSS and NIRCam Imaging of Galaxies Within Lensing Clusters
- #34: NIRSpec IFU and Fixed Slit Observations of Near-Earth Asteroids

### 2. Create a scene with another target with spectral type F0V, vegamag=6.5, normalized in NIRISS F430M. Name the source 'Target 2' and name the scene 'Target 2 Scene'



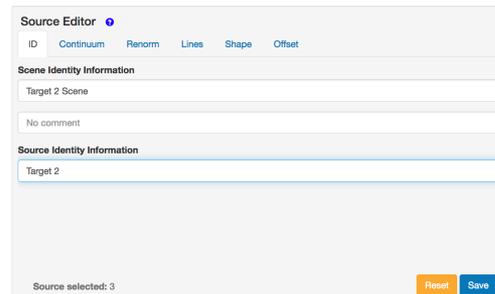
The screenshot shows two panels: 'Select a Scene' and 'Select a Source'.

**Select a Scene:**

ID - Name -	Sources	# Calcs -
★ 1 Target	1	3
☆ 2 PSF Reference Star	2	4
☆ 3 Scene 3	0	0

**Select a Source:**

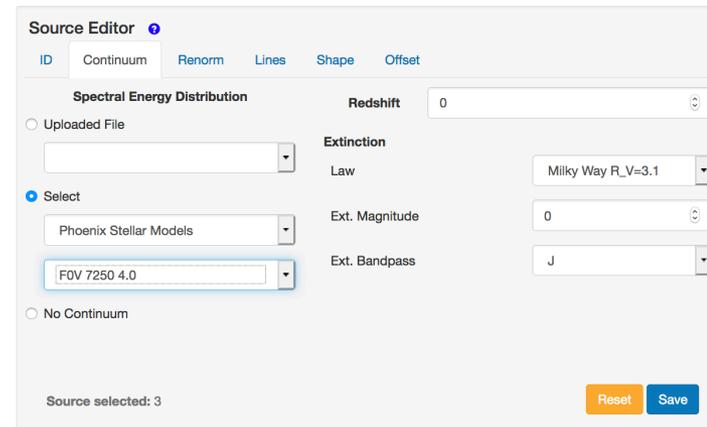
ID -	Plot	Name -	Scenes -	# Calcs -	Δ
1	<input type="checkbox"/>	HD 218396	1	3	
2	<input checked="" type="checkbox"/>	HD 218172	2	4	
3	<input type="checkbox"/>	Source 3	0	0	



The screenshot shows the 'Source Editor' interface with the following fields:

- Scene Identify Information:** Target 2 Scene
- Source Identify Information:** Target 2

Buttons: New, Delete, Save, Reset



The screenshot shows the 'Source Editor' interface with the following settings:

- Spectral Energy Distribution:** Select, Phoenix Stellar Models, F0V 7250 4.0
- Extinction:** Milky Way R\_V=3.1, Ext. Magnitude: 0, Ext. Bandpass: J
- Redshift:** 0
- Buttons:** Reset, Save

Source selected: 3

# AMI calculations in JWST ETC

## Answers to questions



2. Create a scene with another target with spectral type F0V, vegamag=6.5, normalized in NIRISS F430M. Name the source 'Target 2' and name the scene 'Target 2 Scene' continued...

Source Editor

ID Continuum Renorm Lines Shape Offset

Normalize Source Flux Density

Renormalization applied after redshift

Normalize at wavelength

0.001 m $\mu$ y lambda 2  $\mu$ m

Normalize in bandpass

6.5 vegamag

JWST NIRISS/IMAGING F430M

HST WFC3/IR F098M

Source selected: 3

Reset Save

Calculations Scenes and Sources Upload Spectra Caveats and Limitations

Select a Scene

ID Name	Sources	# Calcs
★ 1 Target	1	3
☆ 2 PSF Reference Star	2	4
☆ 3 Target 2 Scene	3	0

Select a Source

ID Plot Name	Scenes	# Calcs
1 HD 218396	1	3
2 HD 218172	2	4
3 Target 2	3	0

Select new scene, new source and then add source

New Add Source Remove Source Delete

New Delete

Source Editor

ID Continuum Renorm Lines Shape Offset

Position of Source in Scene

X offset 0 arcsec

Y offset 0 arcsec

Orientation 0 degrees

Source selected: 3

Reset Save

Source Editor

ID Continuum Renorm Lines Shape Offset

Shape of source:  Point  Extended

Source selected: 3

Reset Save

# AMI calculations in JWST ETC

## Answers to questions



- Create a Target Acquisition calculation for this source
- Create a new calculation to use this scene
- Calculate NGROUPS for an observation with NRM + F430M
- Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- What contrast can you reach with  $10^9$  total photons?

Calculations Scenes and Sources Upload Spectra Caveats and Limitations

ID	Mode	λ (nm)	Scn (s)	SNR
1	niriss ami		0.85	1007.77
2	niriss ami		0.85	717.74
3	niriss ami		5039.82	7831.05
4	niriss ami	4.81	2	8050.99
5	niriss target_acq	4.81	1	104.87
6	niriss target_acq	4.81	2	72.26
7	niriss target_acq	4.81	2	117.41

Calculations Scenes and Sources Upload Spectra Caveats and Limitations

ID	Mode	λ (nm)	Scn (s)	SNR
1	niriss ami	4.81	1	0.85
2	niriss ami	4.81	2	0.62
3	niriss ami	4.81	1	5039.82
4	niriss ami	4.81	2	8050.99
5	niriss target_acq	4.81	1	0.22
6	niriss target_acq	4.81	2	0.22
7	niriss target_acq	4.81	2	0.32
8	niriss target_acq	4.81	1	0.22

Scene ★ Backgrounds Instrument Setup Detector Setup Strategy

1: Target  
2: PSF Reference Star  
3: Target 2 Scene

Normalize Source Flux Density  
Renormalization applied after redshift

Sources in that Scene  
3: Target 2

Normalize at wavelength  
0.001 flam

lambda 2 μm

Normalize in bandpass  
6.5 vegmag

JWST NIRISS/IMAGING F430M

HST WFC3/IR F098M

Calculation selected: 8, Mode: niriss target\_acq

Reset Calculate

Scene ★ Backgrounds Instrument Setup Detector Setup

Position  
Ra Dec 0:00:00.00 0:00:00.00

Background configuration  
None Low Medium High

Date Jul 1 2020

NIRISS Target Acquisition

Acq Mode  
SOSS or AMI Bright

Filter  
F480M

Calculations Scenes and Sources Upload Spectra Caveats and Limitations

ID	Mode	λ (nm)	Scn (s)	SNR
1	niriss ami	4.81	1	0.85
2	niriss ami	4.81	2	0.62
3	niriss ami	4.81	1	5039.82
4	niriss ami	4.81	2	8050.99
5	niriss target_acq	4.81	1	0.22
6	niriss target_acq	4.81	2	0.22
7	niriss target_acq	4.81	2	0.32
8	niriss target_acq	4.81	3	0.72

Scene ★ Backgrounds Instrument Setup Detector Setup Strategy

Subarray  
SOSS or AMI TA

Readout pattern  
NISRAPID

Groups  
13

Integrations  
1

Exposures  
1

Total exposure time: 00:00:01 (0.72 s)

Total integrations: 1

Calculation selected: 8, Mode: niriss target\_acq

Reset Calculate



# AMI calculations in JWST ETC

## Answers to questions



- i. Create a Target Acquisition calculation for this source
- ii. **Create a new calculation to use this scene**
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?

ii

Calculations   Scenes and Sources   Upload Spectra   Caveats and Lin

MIRI	NIRCam	NIRISS	NIRSpec	ID	Mode	(s)	SNR
		Imaging		1	niriss ami	0.85	1007.77
		SOSS		2	niriss ami	0.62	507.22
		WFSS		3	niriss ami	5039.82	7831.05
		AMI		4	niriss ami	4.81	2
		Target Acquisition		5	niriss target_acq	4.81	1
				6	niriss target_acq	4.81	2
				7	niriss target_acq	4.81	2
				8	niriss target_acq	4.81	3

Calculations   Scenes and Sources   Upload Spectra   Caveats and Limitations

MIRI	NIRCam	NIRISS	NIRSpec	ID	Mode	$\lambda$	Scn	(s)	SNR
				1	niriss ami	4.81	1	0.85	1007.77
				2	niriss ami	4.81	2	0.62	507.22
				3	niriss ami	4.81	1	5039.82	7831.05
				4	niriss ami	4.81	2	8050.99	7836.49
				5	niriss target_acq	4.81	1	0.22	104.87
				6	niriss target_acq	4.81	2	0.22	72.26
				7	niriss target_acq	4.81	2	0.32	117.41
				8	niriss target_acq	4.81	3	0.72	157.37
				9	niriss ami	4.28	3	0.85	520.97

Scene ★   Backgrounds   Instrument Setup   Detector Setup   Strategy

Scene for Calculation: 3: Target 2 Scene

Sources in that Scene: 3: Target 2

Scene Identity Information: Target 2 Scene

Source Identity Information: Target 2

Calculation selected: 9, Mode: niriss ami

[Reset](#) [Calculate](#)

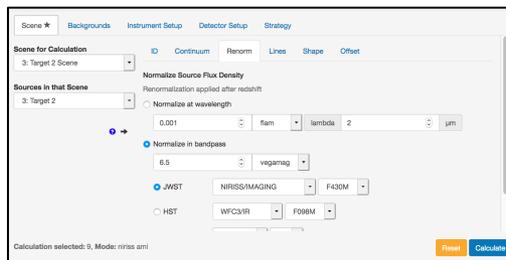
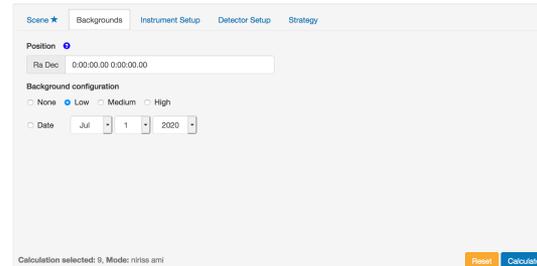
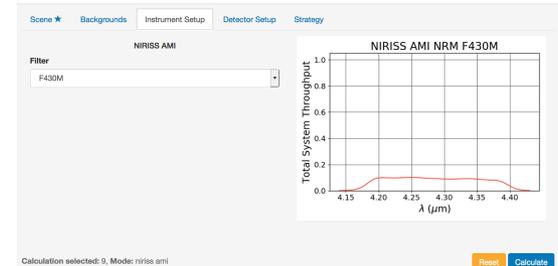
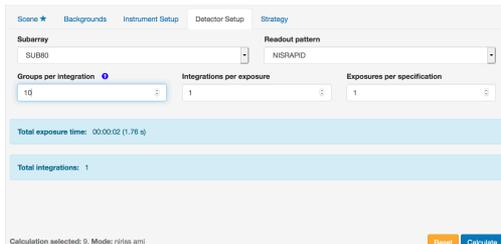
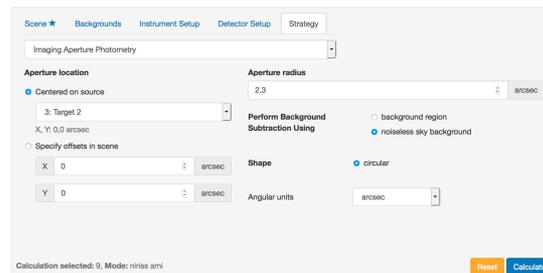
# AMI calculations in JWST ETC

## Answers to questions

- i. Create a Target Acquisition calculation for this source
- ii. Create a new calculation to use this scene
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?

iii

Update Scene, background, Instrument Setup and Strategy and run the calculation with default Detector Setup

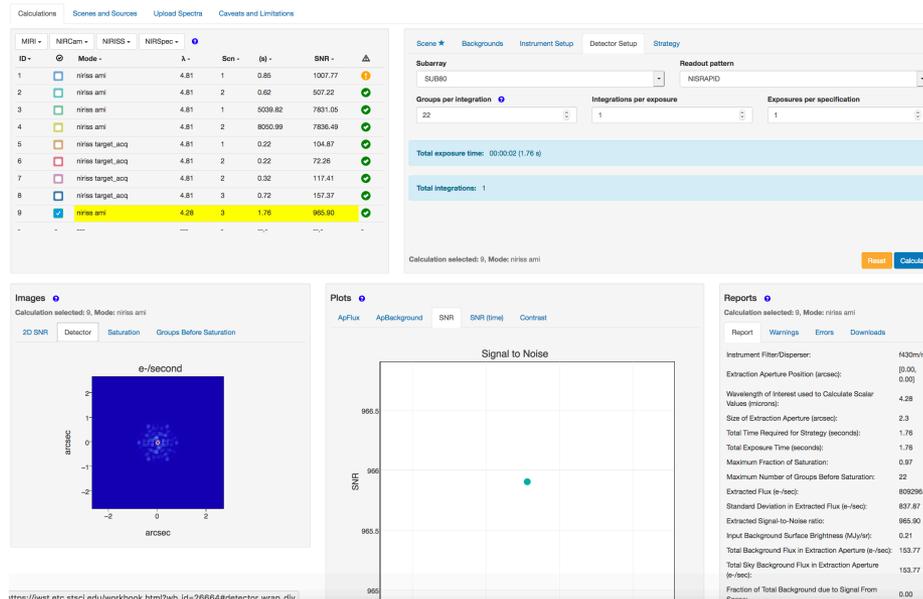






# AMI calculations in JWST ETC

## Answers to questions

- i. Create a Target Acquisition calculation for this source
- ii. Create a new calculation to use this scene
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?

iii  
continued



Maximum Number of Groups Before saturation value is 22 from the Reports panel. Therefore set Groups per integration to **22**. (NGROUPS)



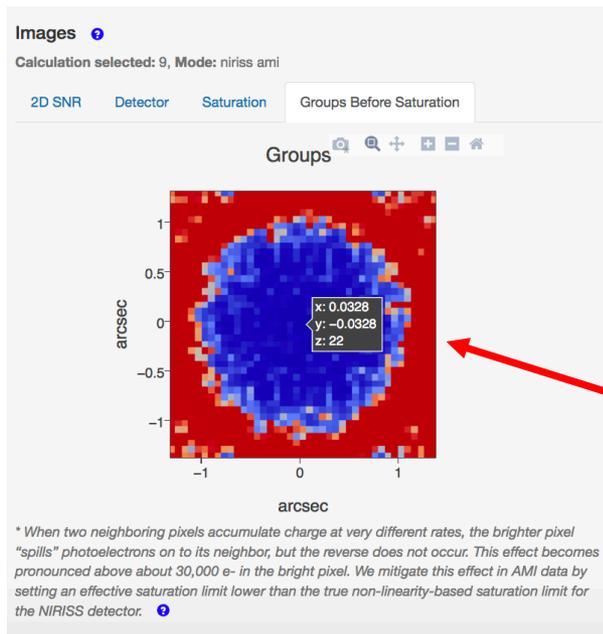
# AMI calculations in JWST ETC

## Answers to questions



- i. Create a Target Acquisition calculation for this source
- ii. Create a new calculation to use this scene
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?

iv



Reports ⓘ

Calculation selected: 9, Mode: niriss ami

Report Warnings Errors Downloads

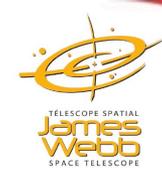
Instrument Filter/Dispenser:	f430m/null
Extraction Aperture Position (arcsec):	[0.00, 0.00]
Wavelength of Interest used to Calculate Scalar Values (microns):	4.28
Size of Extraction Aperture (arcsec):	2.3
Total Time Required for Strategy (seconds):	1.76
Total Exposure Time (seconds):	1.76
Maximum Fraction of Saturation:	0.97
Maximum Number of Groups Before Saturation:	22
Extracted Flux (e-/sec):	809296.80
Standard Deviation in Extracted Flux (e-/sec):	837.87
Extracted Signal-to-Noise ratio:	965.90
Input Background Surface Brightness (MJy/sr):	0.21
Total Background Flux in Extraction Aperture (e-/sec):	153.77
Total Sky Background Flux in Extraction Aperture (e-/sec):	153.77
Fraction of Total Background due to Signal From Scene:	0.00
Average Number of Cosmic Rays per Ramp:	1.3e-4

Maximum number of Groups Before saturation in the brightest pixel of AMI PSF.



# AMI calculations in JWST ETC

## Answers to questions



- i. Create a Target Acquisition calculation for this source
- ii. Create a new calculation to use this scene
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?

v

Total Time Required for Strategy (seconds):	1.76
Total Exposure Time (seconds):	1.76
Maximum Fraction of Saturation:	0.97
Maximum Number of Groups Before Saturation:	22
Extracted Flux (e-/sec):	809296.80
Standard Deviation in Extracted Flux (e-/sec):	837.87
Extracted Signal-to-Noise ratio:	965.90
Input Background Surface Brightness (M <sub>v</sub> /sr):	0.21

$$\begin{aligned}\text{Total photons} &= \text{flux} \times \text{NGROUPS} \times \text{NINT} \times \text{TFRAME} \\ \text{NINT} &= \text{Total photons} / (\text{flux} \times \text{NGROUPS} \times \text{TFRAME}) \\ &= 10^9 / (809296.80 \text{ e-/sec} \times 22 \times 0.07544 \text{ sec}) \\ &= 744.5 \rightarrow \text{Round up to } 745\end{aligned}$$



# AMI calculations in JWST ETC

## Answers to questions



- i. Create a Target Acquisition calculation for this source
- ii. Create a new calculation to use this scene
- iii. Calculate NGROUPS for an observation with NRM + F430M
- iv. Compare the 'Maximum number of Groups Before Saturation' value with the central pixel value in Groups Before Saturation image
- v. Calculate NINT to get  $10^9$  total photons in the exposure.
  - Use photon collect time formula and Extracted Flux in the Reports panel
- vi. What contrast can you reach with  $10^9$  total photons?

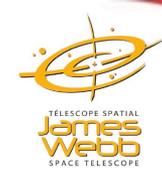
vi

$$\text{sqrt}(100/(10^{**9})) = 0.0003$$



# AMI calculations in JWST ETC

## Answers to questions



2. What is the vegamag magnitude of the brightest F0V star that you can observe with NGROUPS=7 in F480M, F380M?

• F480M

Vegamag = 5 gives maximum number of Groups Before Saturation as 7.

Vegamag = 5.1 gives maximum number of Groups Before Saturation as 8.

Therefore **vegamag=5** is the NGROUP=7 bright limit for F480M

• F380M

**vegamag = 6**

for NGROUPS=7

Scene \* Backgrounds Instrument Setup Detector Setup Strategy

Scene for Calculation: 4

Normalize Source Flux Density

Normalize at wavelength: 0.001

Normalize in bandpass: 5 vegamag

Instrument: JWST Filter: NIRISS/MAGING Filter: F480M

Calculation selected: 10, Mode: niriss ami

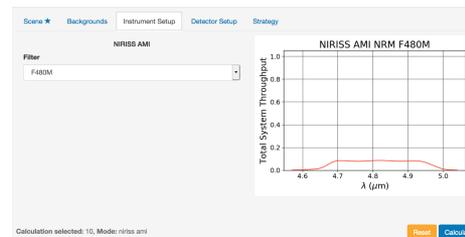
Scene \* Backgrounds Instrument Setup Detector Setup Strategy

Position: RA Dec: 0:00:00.00 0:00:00.00

Background configuration: None Low Medium High

Date: Jul 1 2020

Calculation selected: 10, Mode: niriss ami

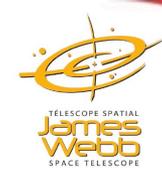


### Reports

Calculation selected: 10, Mode: niriss ami

Report Warnings Errors Downloads

Instrument Filter/Disperser:	f480m/null
Extraction Aperture Position (arcsec):	[0.00, 0.00]
Wavelength of Interest used to Calculate Scalar Values (microns):	4.81
Size of Extraction Aperture (arcsec):	2.5
Total Time Required for Strategy (seconds):	0.62
Total Exposure Time (seconds):	0.62
Maximum Fraction of Saturation:	0.91
Maximum Number of Groups Before Saturation:	7
Extracted Flux (e-/sec):	2877649.50
Standard Deviation in Extracted Flux (e-/sec):	3275.57
Extracted Signal-to-Noise ratio:	878.52
Input Background Surface Brightness (MJy/sr):	0.00
Total Background Flux in Extraction Aperture (e-/sec):	0.00
Total Sky Background Flux in Extraction Aperture (e-/sec):	0.00
Fraction of Total Background due to Signal From Scene:	0.00



# AMI calculations in JWST ETC

## Answers to questions

3. Create calculations to calculate NGROUPS and NINT required to get  $10^7$  photons from HD37093. Use Vegamag = 5.47 normalized in F380M and vegamag=5.46 normalized in F430M and F480M

Answer:

This is similar to calculations 2, 3 and 4 in NIRISS AMI Examples sample workbook. The only difference is in the total number of photons which will change the number of integrations.

F480M NGROUPS=11, NINT = 7

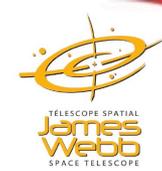
F430M NGROUPS=8, NINT = 8

F380M NGROUPS=4, NINT = 11



# AMI calculations in JWST ETC

## Answers to questions



4. Calculate NGROUPS=1 and **NGROUPS=2 bright limits (Vegamag)** for A0V star observed with F380M.

This is similar to Example 3 in NIRISS AMI Examples. Only the filter is different.

**NGROUPS=2 bright limit**  
**For F380M**

**4.66**

**Change the magnitude to**  
**4.65 and look at the warning message**

Source Editor

Normalize Source Flux Density

Renormalization applied after redshift

Normalize at wavelength

0.001 | flam | lambda 2 |  $\mu\text{m}$

Normalize in bandpass

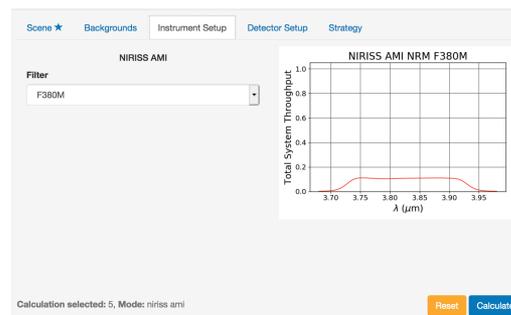
4.66 | vegamag

JWST | NIRISS/IMAGING | F380M

HST | WFC3/IR | F098M

Source selected: 4

Reset Save



Reports

Calculation selected: 5, Mode: niriss ami

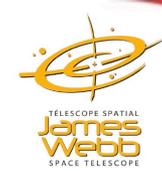
Report Warnings Errors Downloads

Instrument Filter/Disperser:	f380m/null
Extraction Aperture Position (arcsec):	[0.00, 0.00]
Wavelength of Interest used to Calculate Scalar Values (microns):	3.83
Size of Extraction Aperture (arcsec):	2
Total Time Required for Strategy (seconds):	0.25
Total Exposure Time (seconds):	0.25
Maximum Fraction of Saturation:	0.99
Maximum Number of Groups Before Saturation:	2
Extracted Flux (e-/sec):	6705701.97
Standard Deviation in Extracted Flux (e-/sec):	15015.28
Extracted Signal-to-Noise ratio:	446.59
Input Background Surface Brightness (MJy/sr):	0.00
Total Background Flux in Extraction Aperture (e-/sec):	0.00
Total Sky Background Flux in Extraction Aperture (e-/sec):	0.00
Fraction of Total Background due to	0.00



# AMI calculations in JWST ETC

## Answers to questions



4. Calculate **NGROUPS=1** and NGROUPS=2 bright limits (Vegamag) for A0V star observed with F380M.

This is similar to Example 3 in NIRISS AMI Examples. Only the filter is different.

**NGROUPS=1 bright limit for F380M is 4.03. Change the magnitude to 4.02 and look at the central pixel in Groups Before Saturation image.**

Scene # Backgrounds Instrument Setup Detector Setup Strategy

Scene for Calculation  
4: bright limit star scene F380M

Sources in that Scene  
4: bright limit star norm\_F380M

Normalize Source Flux Density  
Renormalization applied after redshift

Normalize at wavelength  
0.001 5.0 fltm lambda 2 5 μm

Normalized classes  
4.03 vegmag

Filter  
F380M

Calculation selected: 5, Mode: niriss ami

Reset Calculate

Filter  
F380M

NIRISS AMI

NIRISS AMI NRM F380M

Total System Throughput

λ (μm)

Calculation selected: 5, Mode: niriss ami

Reset Calculate

Reports

Calculation selected: 5, Mode: niriss ami

Report Warnings Errors Downloads

Instrument Filter/Dispenser: f380m/null

Extraction Aperture Position (arcsec): [0.00, 0.00]

Wavelength of Interest used to Calculate Scalar Values (microns): 3.83

Size of Extraction Aperture (arcsec): 2

Total Time Required for Strategy (seconds): 0.25

Total Exposure Time (seconds): 0.25

Maximum Fraction of Saturation: 1.77

Maximum Number of Groups Before Saturation: 1

Extracted Flux (e-/sec): 11979653.37

Standard Deviation in Extracted Flux (e-/sec): NaN

Extracted Signal-to-Noise ratio: 0.00

Input Background Surface Brightness (MJy/sr): 0.00

Total Background Flux in Extraction Aperture (e-/sec): 0.00

Total Sky Background Flux in Extraction Aperture (e-/sec): 0.00

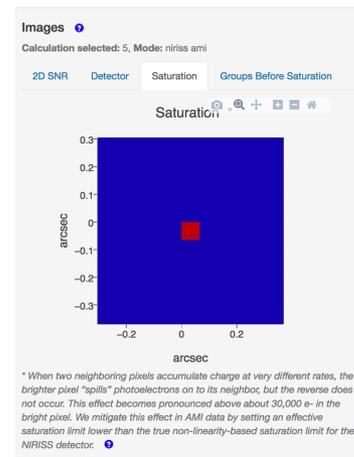
Fraction of Total Background due to

Reports

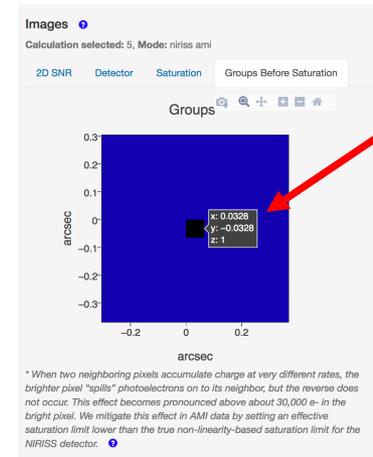
Calculation selected: 5, Mode: niriss ami

Report Warnings Errors Downloads

Full saturation: There are 1 pixels saturated\* at the end of the first group. These pixels cannot be recovered. \*(See footnote in the Saturation image tab.)



Saturation image



Groups Before Saturation image

Signal limit exceeded in group 2 but not in group 1

# Example science program in JWST APT

## AMI Specific strategies



**JWST Draft Proposal (Unsaved)**

- Proposal Information
- Targets**
- Observations
- Observation Links

### Targets

Resolve a target name or position

Create a new Fixed Target

Create a new Target Group

Create a new Solar System Target

Create a new Generic Target

Import Fixed Targets from whitespace, CSV, TSV, or VOTable

Get coordinates from GAIA DR2 archive, enter epoch as 2015.5

- Use Fixed Target Resolver to search for target and then manually update coordinates OR
- Select New Fixed target and update information.

Astronomer's Proposal Tools Version 27.3.1 JWST PRD: PRDOPSSOC-M-025 - JWST Approved Proposal 23 (Unsaved)

Form Editor | Spreadsheet Editor | Orbit Planner | Visit Planner | Timeline | View in Aladin | BOT | Target Confirmation | PDF Preview | Submission | Errors and Warnings | Run All Tools | Stop

New Document | New

**JWST Approved Proposal 23 (Unsaved)**

- Proposal Information
- Proposal Description
- Team Expertise
- PI: William Blair
- Targets
  - Fixed Targets**
    - 1 HD-218396**
    - 2 HD-218172
- Observations
- Observation Links

**1 HD-218396 of JWST Approved Proposal 23 (Unsaved)**

Number: 1

Name in the Proposal: HD-218396 (unique within proposal)

Name for the Archive: HD 218396 (standard resolvable name)

Category: Star

Description: +/- Exoplanet Systems F stars

Choose 1 to 5 items after selecting a category.

J2000 Coordinates (ICRS) RA: 23 07 28.8327 Dec: +21 08 2.53

Uncertainty RA: [ ] Arcsec Dec: [ ] Arcsec

Proper Motion RA: 108.30 mas/yr Dec: -49.48 mas/yr

Epoch: 2015.5

Annual Parallax (arcsec): [ ]

Extended: Unknown Recommended for spectroscopy (for advice to data reduction pipeline)



# Example science program in JWST APT



Astronomer's Proposal Tools Version 27.3.1 JWST PRD: PRDOPSSOC-M-025 - JWST Approved Proposal 23 (Unsaved)

Form Editor | Spreadsheet Editor | Orbit Planner | Visit Planner | Timeline | View in Aladin | BOT | Target Confirmation | PDF Preview | Submission | Errors and Warnings | All Tools | Stop

New Document | New

JWST Approved Proposal 23 (Unsa...  
▶ Proposal Information  
▶ Targets  
▶ Observations  
    ▶ Exoplanets in HD 218396 with  
        ▶ HD-218396 (Obs 1)  
        ▶ HD-218172 (Obs 2)  
    ▶ Observation Links

HD-218396 (Obs 1) of JWST Approved Proposal 23 (Unsaved)

**Direct Imaging Parameters**  
Direct Image  True  False

**PSF Reference Observations**  
This is a PSF Reference Observation   
 HD-218172 (Obs 2) (PSF Reference; Filters [F480M])

PSF Reference Observations

Additional justification  Additional justification of self-reference observations will be provided in the science justification

Edit Exoplanets in HD 218396 with NIRISS AMI | New | Edit Visit 1:1

Astronomer's Proposal Tools Version 27.3.1 JWST PRD: PRDOPSSOC-M-025 - JWST Approved Proposal 23 (Unsaved)

Form Editor | Spreadsheet Editor | Orbit Planner | Visit Planner | Timeline | View in Aladin | BOT | Target Confirmation | PDF Preview | Submission | Errors and Warn | Run All Tools | Stop

New Document | New

JWST Approved Proposal 23 (Unsa...  
▶ Proposal Information  
▶ Targets  
▶ Observations  
    ▶ Exoplanets in HD 218396 with  
        ▶ HD-218396 (Obs 1)  
        ▶ HD-218172 (Obs 2)  
    ▶ Observation Links

HD-218172 (Obs 2) of JWST Approved Proposal 23 (Unsaved)

Filters

Add Duplicate Insert Above Remove

**Direct Imaging Parameters**  
Direct Image  True  False

**PSF Reference Observations**  
This is a PSF Reference Observation  (exclusive access period will be 0 months)

Edit Visit 1:1 | New | Edit Visit 2:1

Observa...	Number	Status	Duplication	Label	Science	Total Char...	Data Volume	Parallel Slo...	Instrument	Ter
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Show: Observation

2 errors & warnings (Click for Details)



# Example science program in JWST APT AMI Specific strategies



## Adding Special Requirements

The screenshot shows the JWST APT software interface. The main window displays observation details for HD-218396 and HD-218172. A dialog box titled "Group/Sequence Observations Link" is open, showing a list of observations with checkboxes. A purple arrow points to the "Add" button in the dialog. A context menu is open over the "Add" button, listing various special requirements options.

**Observation Details:**

- Number: 1
- Status: IMPLEMENTED
- Label: HD-218396
- Instrument: NIRISS
- Template: NIRISS Aperture Masking Interferometry
- Target: 1 HD-218396
- Splitting Distance: 50.0 Arcsec
- Number of Observations: 1
- Science Time (secs): 4416
- Total Time (secs): 9169
- Volume: 899 MB

**Special Requirements Dialog:**

- Observation list: HD-218396 (Obs 1), HD-218172 (Obs 2)
- Time interval: [ ] Days
- Sequence:
- Non-interruptible:
- Exclusive Use Of Instrument:
- Group Observations 1, 2, Non-interruptible
- OK button

**Special Requirements Context Menu:**

- Timing
- Position Angle
- Offset
- No Parallel
- On Hold
- Target Of Opportunity
- Maximum Visit Duration
- Background Noise
- After Date
- Before Date
- Between Dates
- Phase
- After Observation Link
- Group/Sequence Observations Link

**Table:**

Observa...	Number	Status	Duplication	Label	Science	Total Char...	Data volume	Parallel SIO...	Instrument	Template	COO
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2 errors & warnings (Click for Details)



# Example science program in JWST APT AMI Specific strategies



Create 'NIRISS AMI Observations of Extrasolar Planets around a Host Star' proposal and compare with the existing program.

- Select target HR8799(or HD218396) and calibrator (HD218172).
- Enter/update coordinates, proper motion using information from Gaia DR2 archive, use 2015.5 epoch.
- Create observations for each source using NIRISS AMI template.
- Update exposure parameters using calculations 5 and 7 for Target Acquisition and calculations 3 and 4 for science observations in JWST ETC example science program workbook #23: NIRISS AMI Observations of Extrasolar Planets Around a Host Star.
- Create Group non-interruptible Special Requirement for the target and the calibrator.
- Update PSF Reference Observations field for the target and the calibrator.
- Run visit planner
- Run Smart accounting
- Create the times report (via APT File – Export) to look at an ASCII listing of charged times
- Create Target Confirmation Charts and view the observations in Aladin.