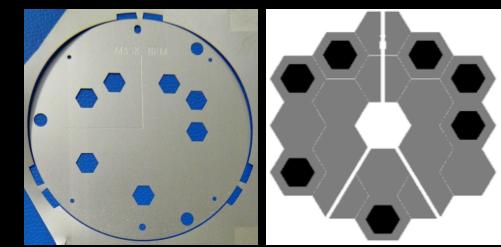
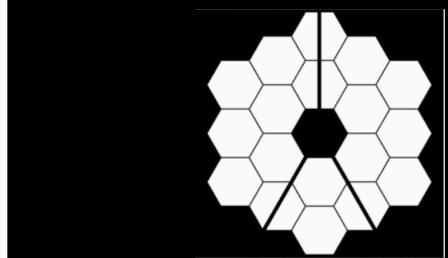
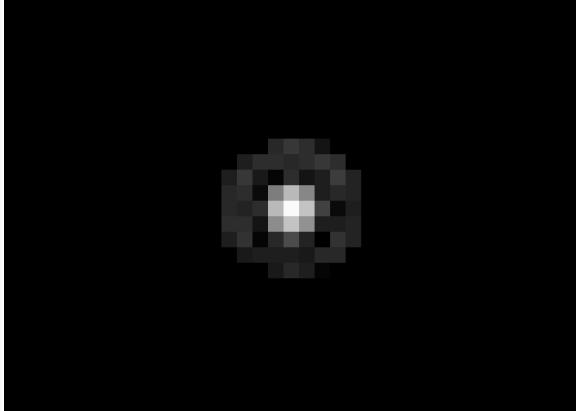


JWST Master Class
November 2019



NIRISS AMI OVERVIEW AND PROPOSAL PLANNING

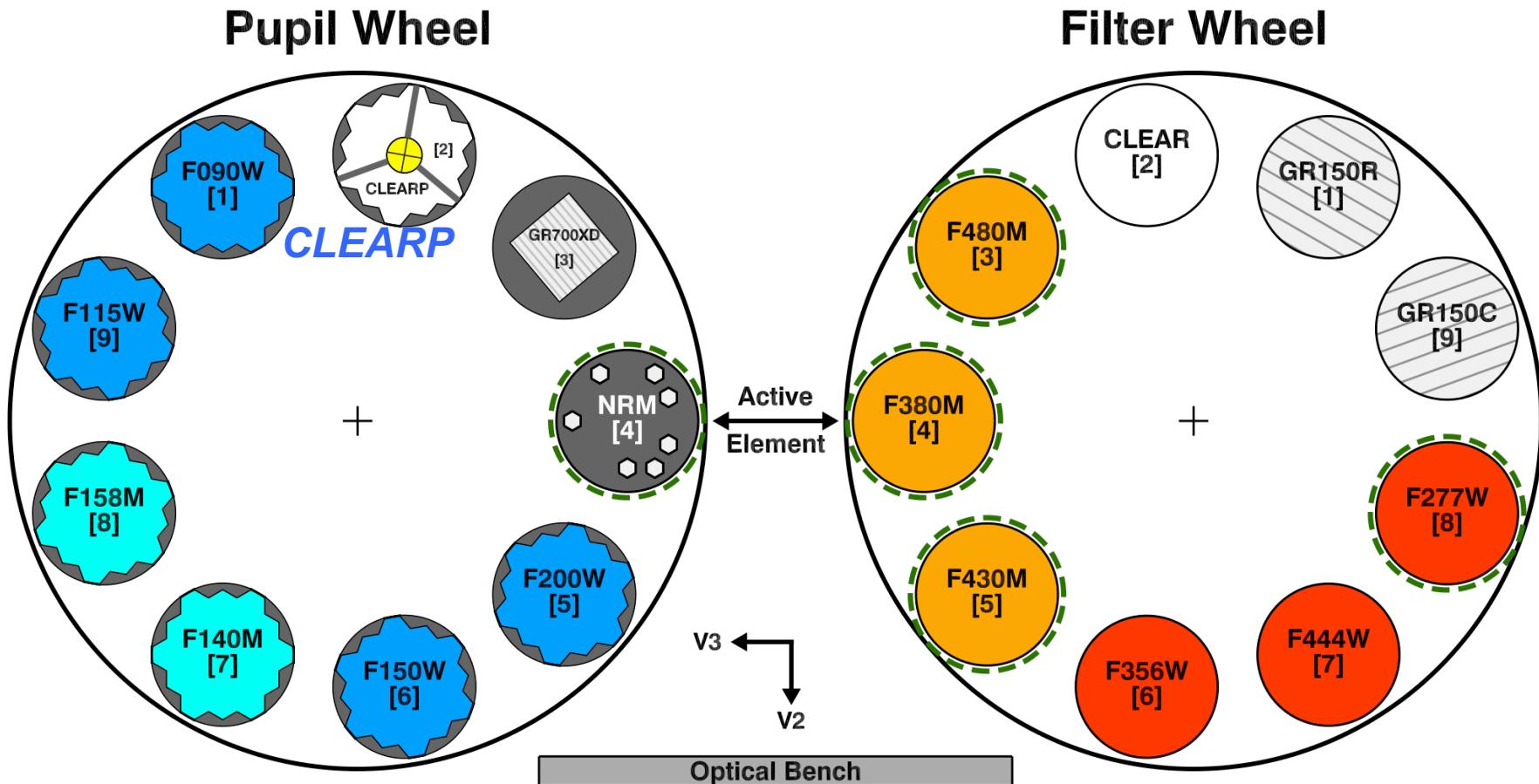
Deepashri Thatte, Anand Sivaramakrishnan and NIRISS team



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 μm (F380M, F430M, F480M) or a wide-band filter centered at 2.77 μm (F277W)
- Bright limit ~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 NIRCam 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

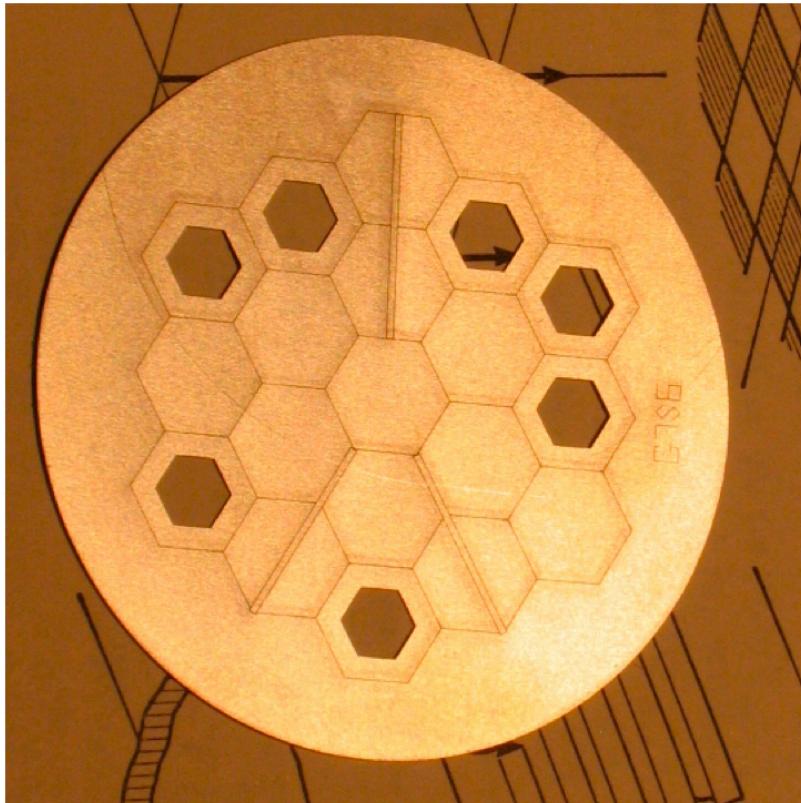


~65 mas pixels are Nyquist sampled at ~4um

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 accomodate inexact
pupil placement

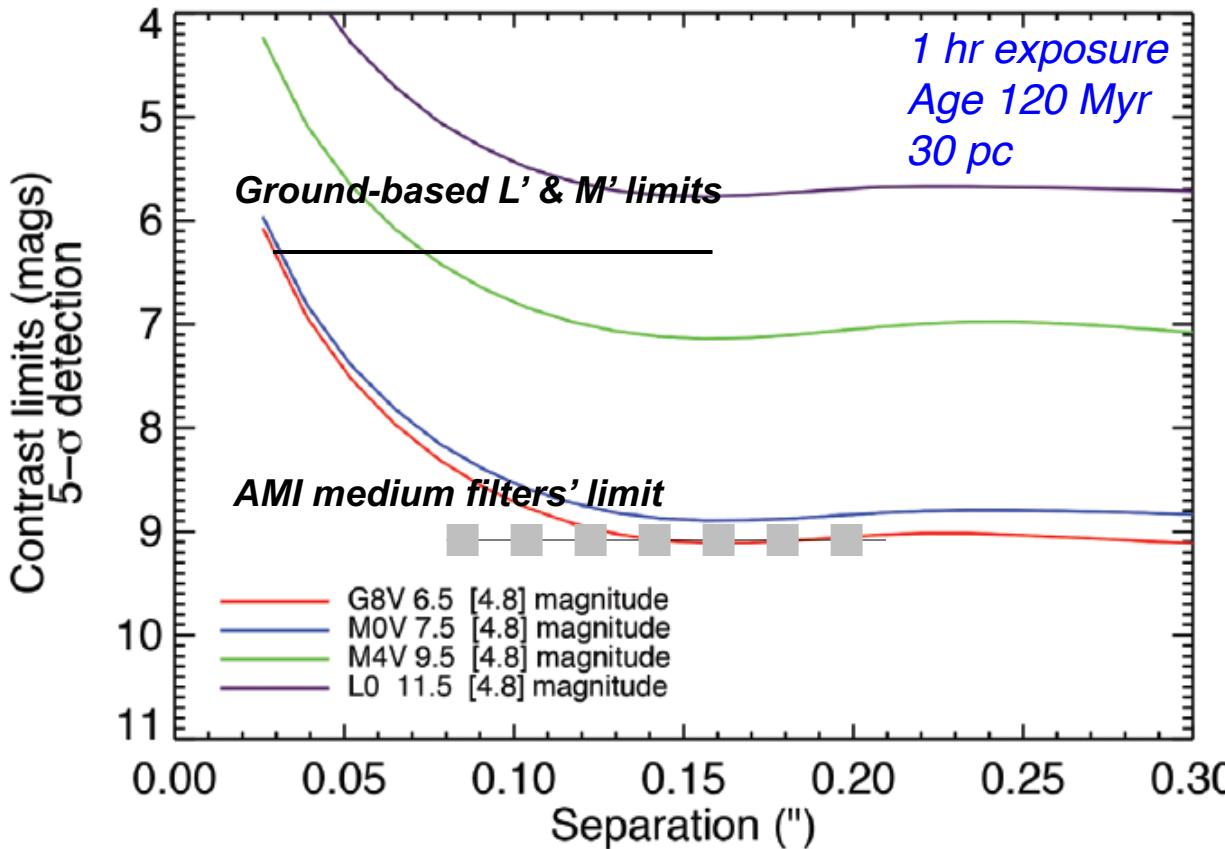
15% throughput cf. full pupil
Peak pixel $\sim 1/40$ full pupil peak pixel

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

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

Science motivation

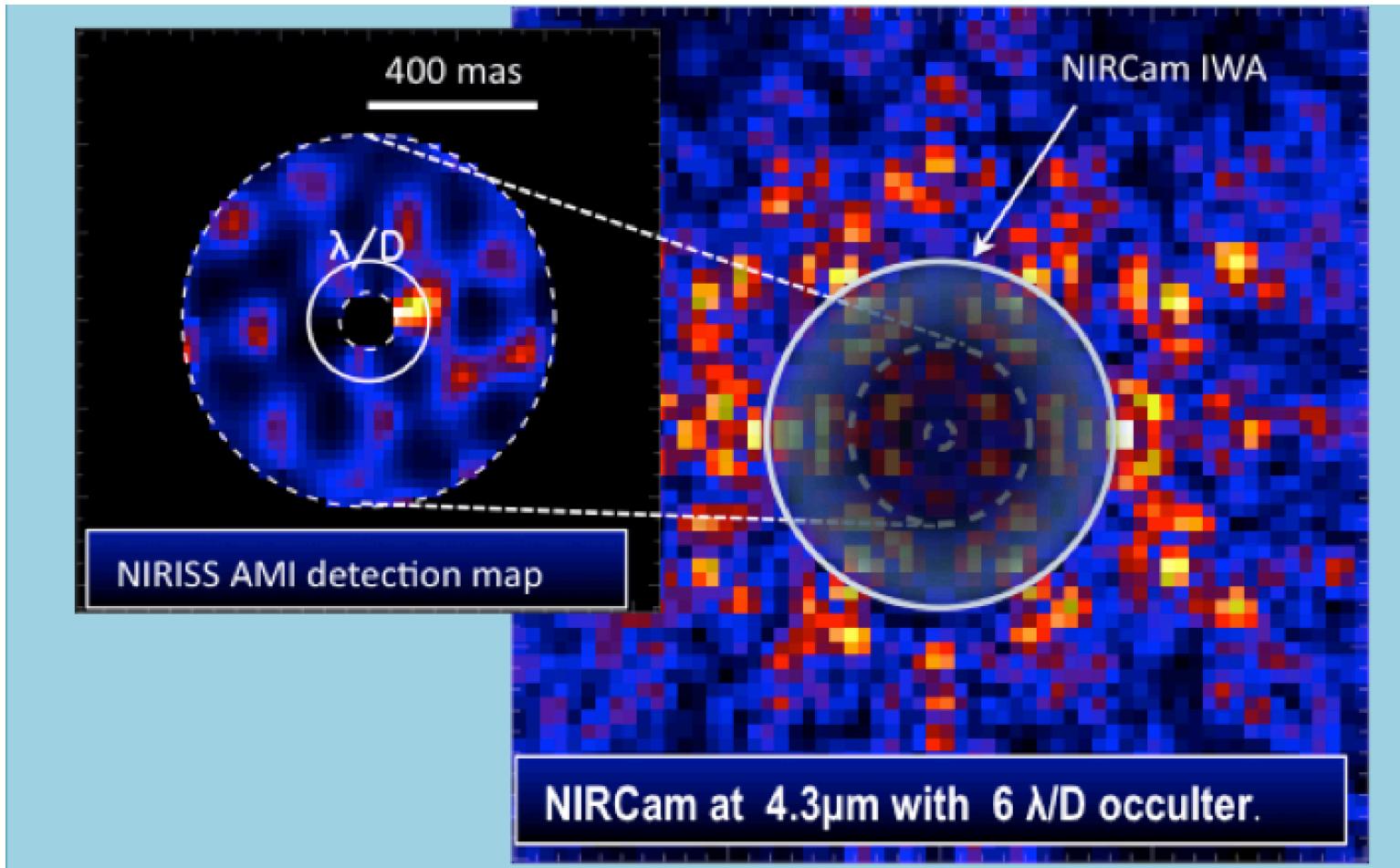
- Probe separations of ~40 to 400 mas
- At contrast of up to 9 mag
- Filters: F380M, F430M, F480M, (and F277W)



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

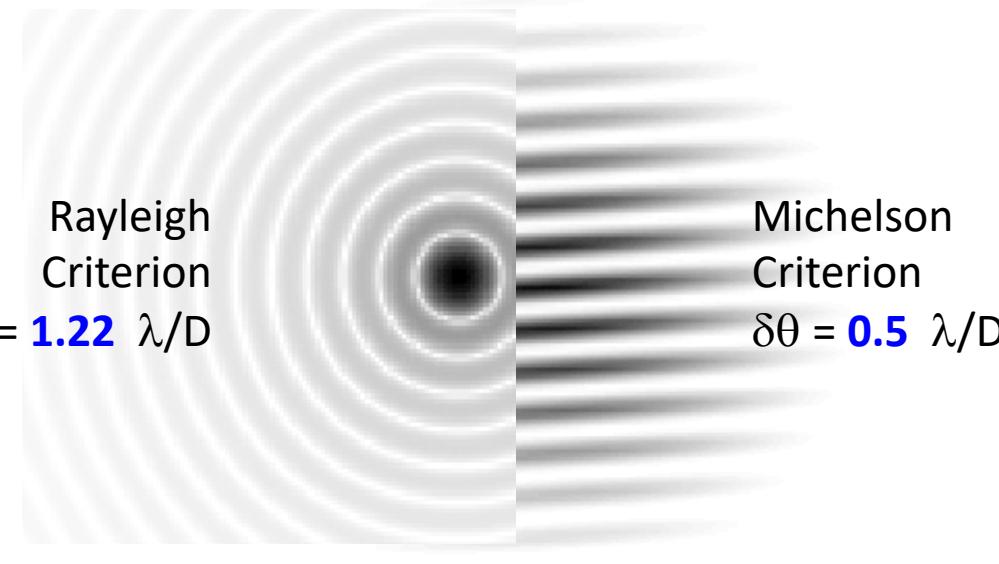
Complements NIRCam coronagraphy



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

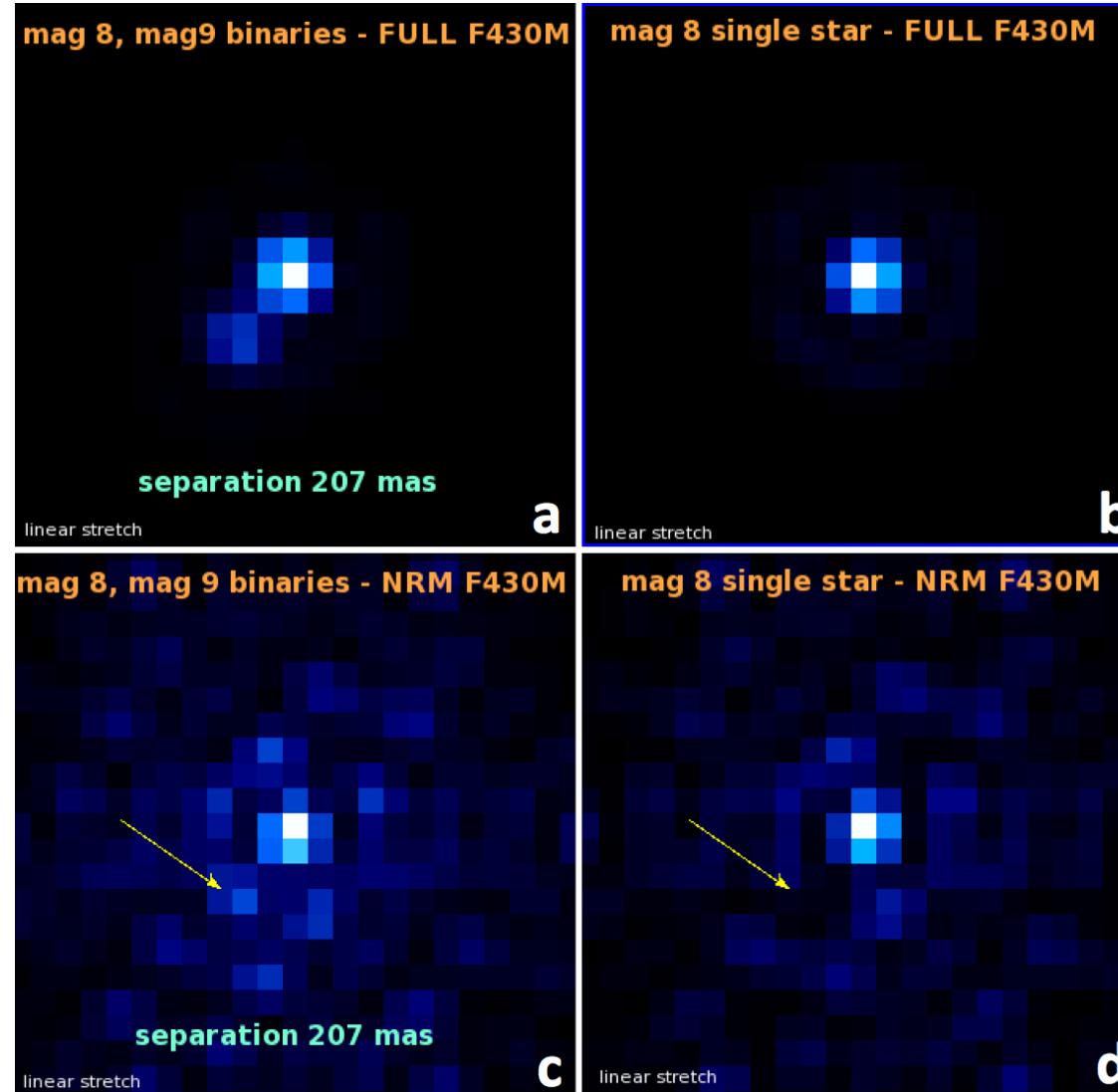
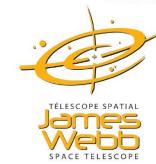
- $\delta\theta = 0.5 \lambda/D$ Michelson Criterion (NRM)
- $\delta\theta = 1.22 \lambda/D$ Rayleigh Criterion (Full aperture)
- $\delta\theta = 4\lambda/D$ NIRCam coronagraph (Inner Working Angle)



Easier to calibrate out instrumental effects



NIRISS AMI PSF

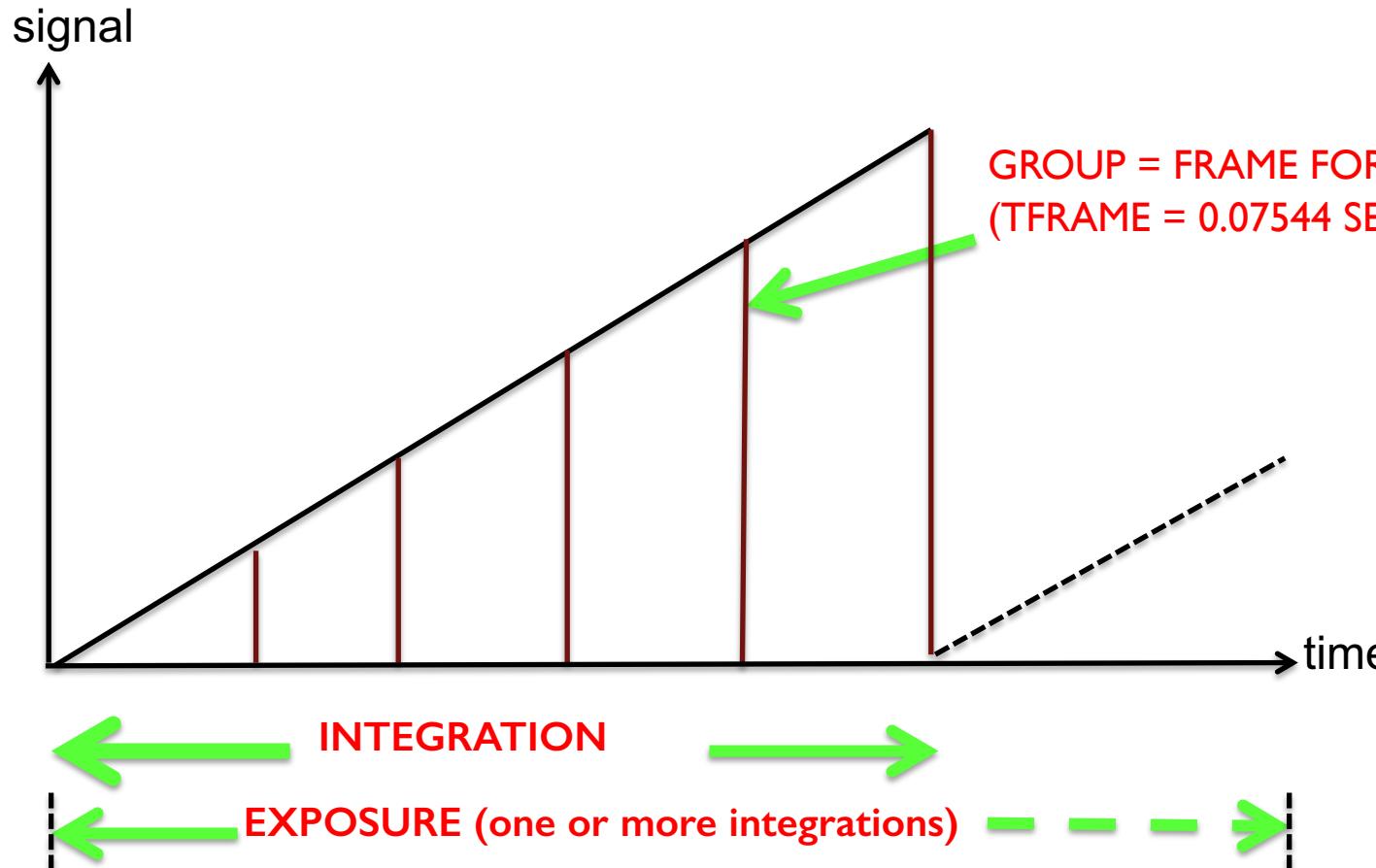




Exposure Nomenclature



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

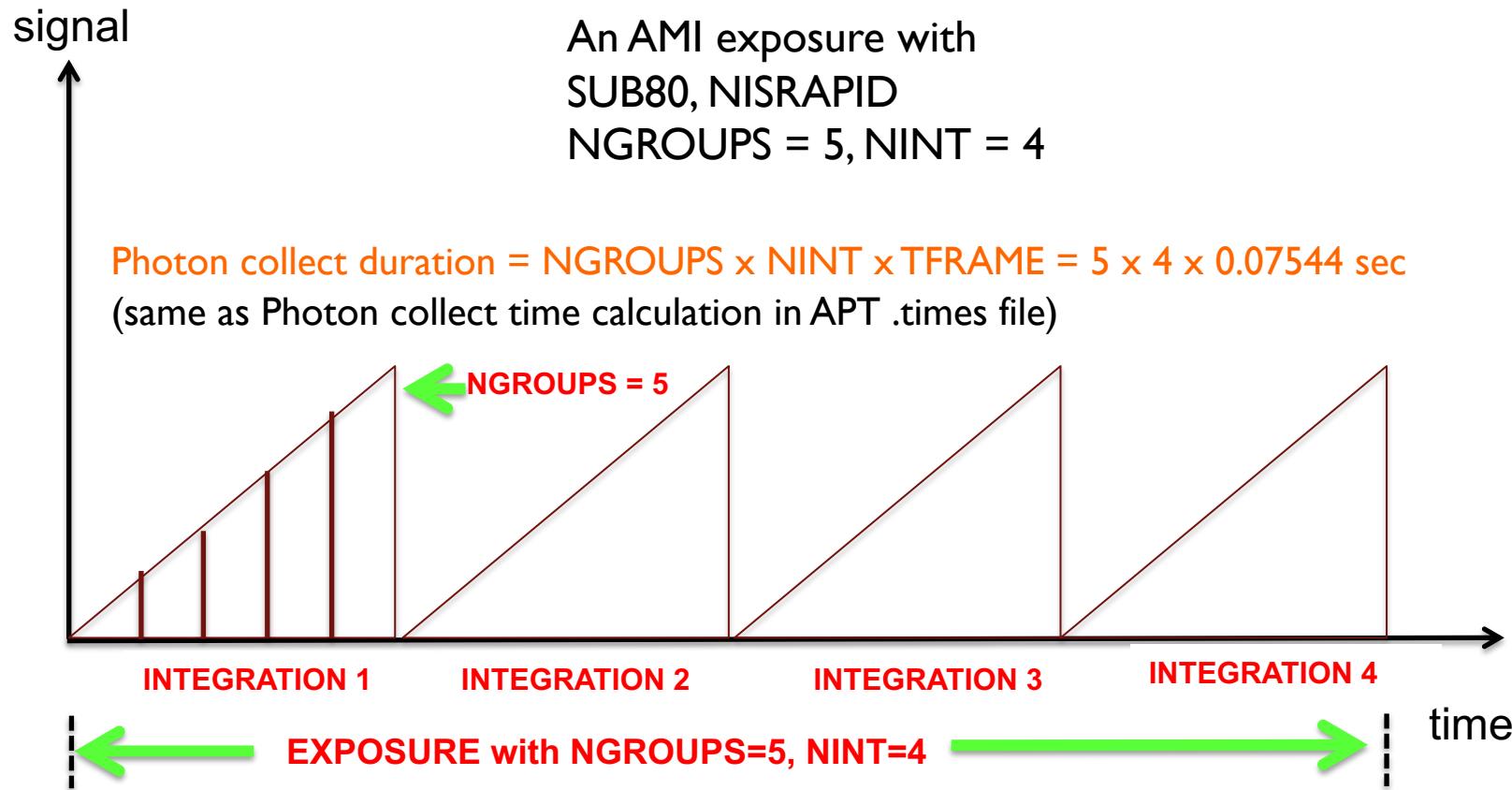




NIRISS AMI Exposure



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⁻ pixel signal limit, pixel-centered PSF

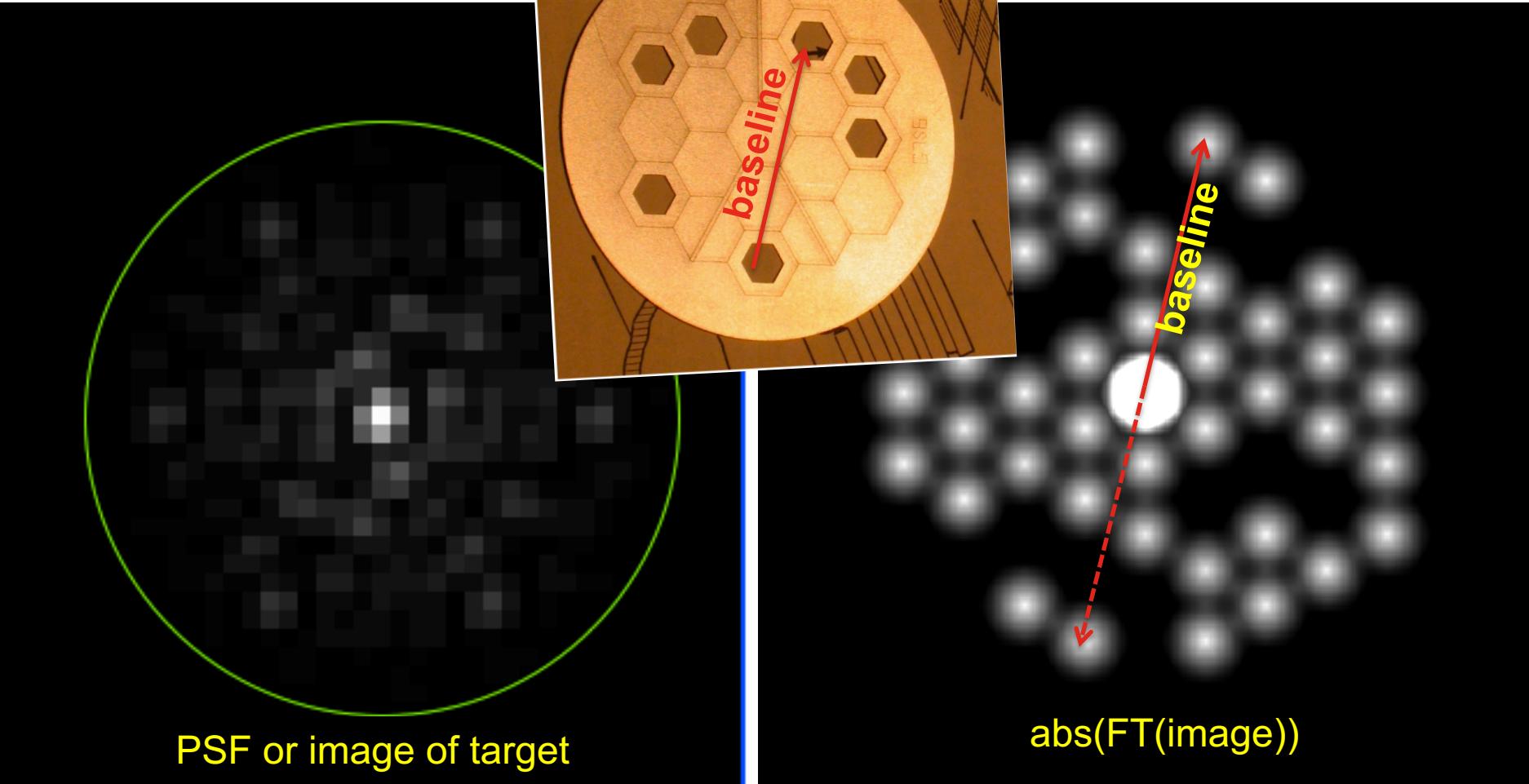
Add ~4 mag to these to get CLEARP SUB80 brightness limit (cf NRM)

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

Add ~9.5 mag to get FULL CLEARP brightness limit

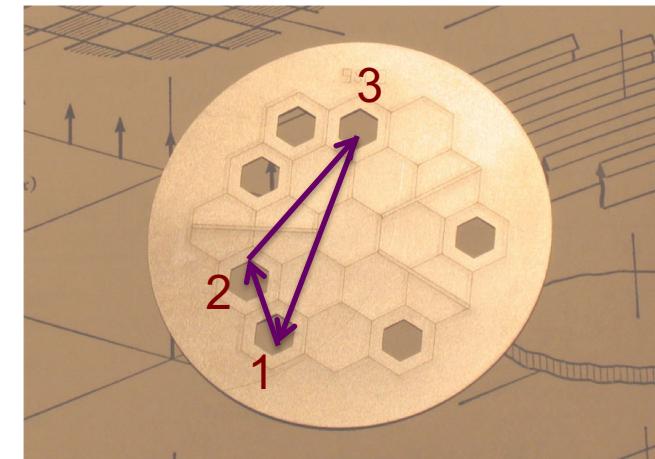
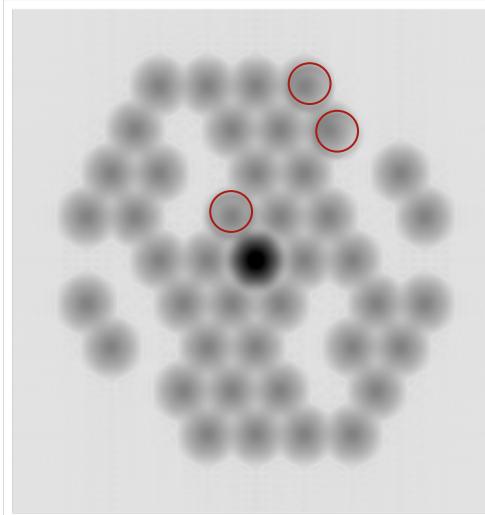
Fringe phases & amplitudes

Interferometric view

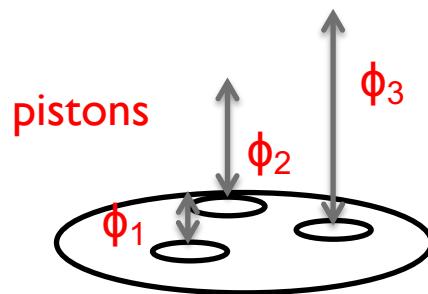


7 hole mask: 21 independent baselines. FT has central splodge + 42 splodges
Get fringe visibilities & (Fourier) phases of each of the 21 fringes (42 numbers)

Closure phase measures structure



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



$$\begin{aligned}\phi_{i,j} &= \phi_j - \phi_i \\ \phi_{1,2} + \phi_{2,3} + \phi_{3,1} &= 0\end{aligned}$$

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

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

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

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

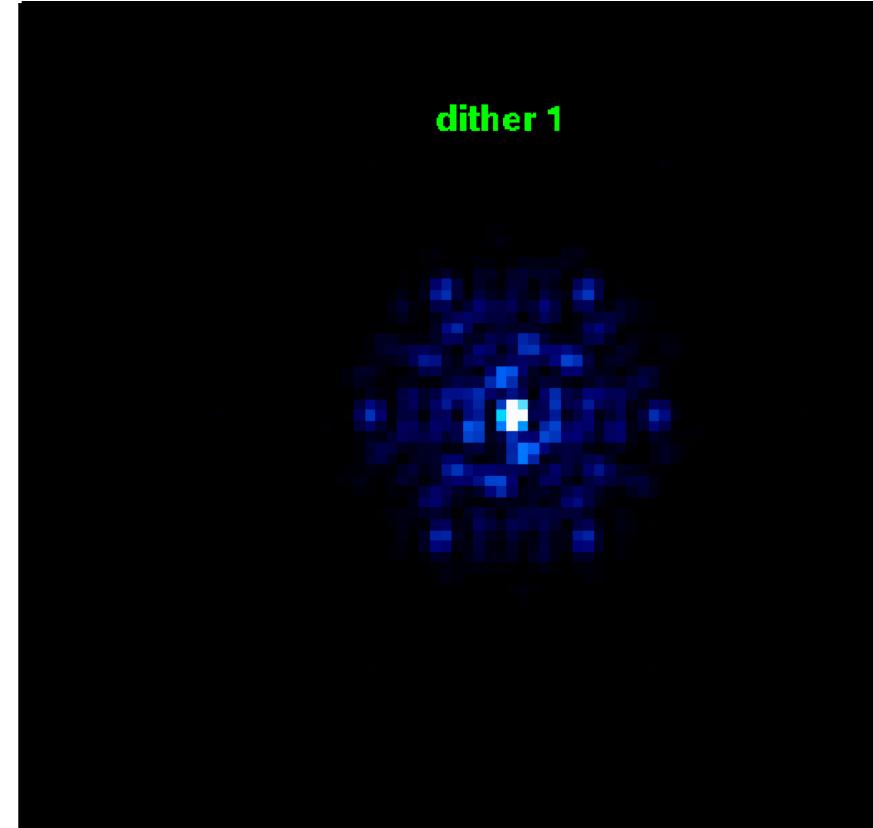
- AMI Target Acquisition in **64 × 64** subarray (**SUBTAAMI**)
 - NGROUPS – odd numbers between 1 & 19 (avoid saturation)
 - NISRAPID readout
 - Acquire in F480M, MASK_NRM for bright, CLEARP faint
 - Small Angle Maneuver to SUB80 science subarray POS 1
- AMI data acquisition in **SUB80: 80 × 80** subarray
 - 80 × 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 × 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

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

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

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

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

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

- 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

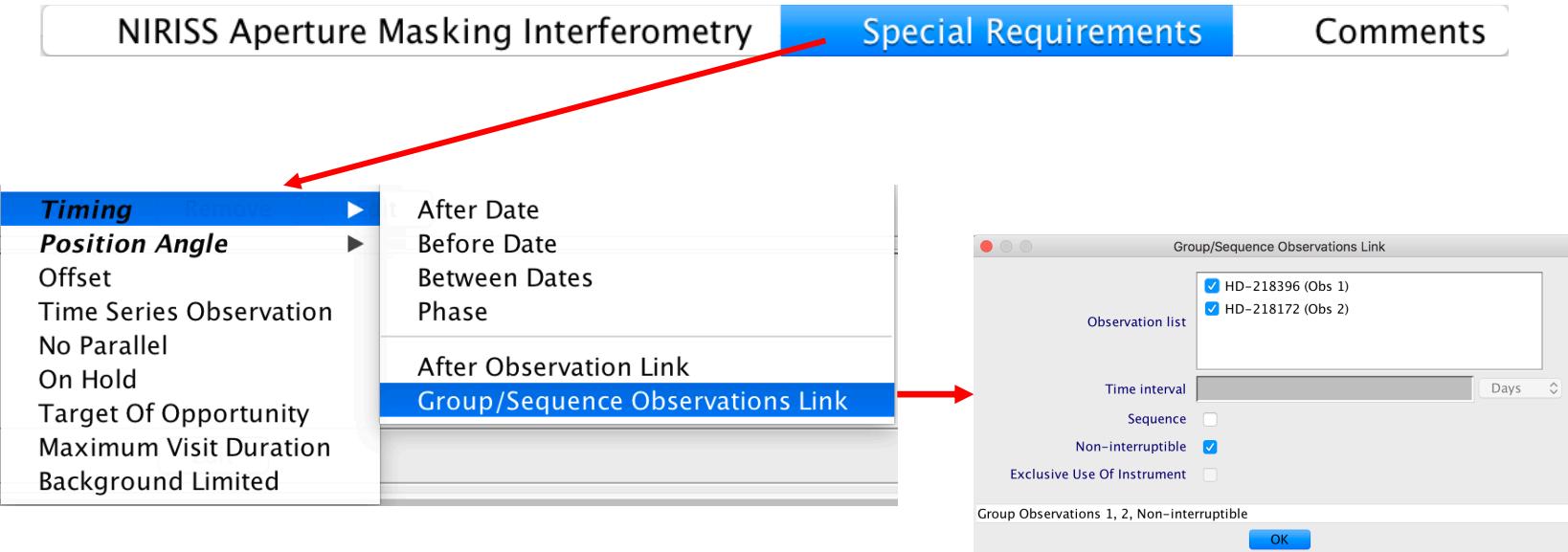
Step 4 – AMI specific steps in JWST APT continued...

- 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
<div style="border: 1px solid #ccc; padding: 5px;"> Timing ▶ Position Angle ▶ Offset Time Series Observation No Parallel On Hold Target Of Opportunity Maximum Visit Duration Background Limited </div>	<div style="border: 1px solid #ccc; padding: 5px;"> After Date Before Date Between Dates Phase After Observation Link Group/Sequence Observations Link </div>	<div style="border: 1px solid #ccc; padding: 5px;"> Group/Sequence Observations Link <div style="border: 1px solid #ccc; padding: 5px; margin-top: 5px;"> Observation list <input checked="" type="checkbox"/> HD-218396 (Obs 1) <input checked="" type="checkbox"/> HD-218172 (Obs 2) </div> <div style="margin-top: 10px;"> Time interval <input type="text"/> Days </div> <div style="margin-top: 10px;"> Sequence <input type="checkbox"/> </div> <div style="margin-top: 10px;"> Non-interruptible <input checked="" type="checkbox"/> </div> <div style="margin-top: 10px;"> Exclusive Use Of Instrument <input type="checkbox"/> </div> </div>





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

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

PSF Reference Observations

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)

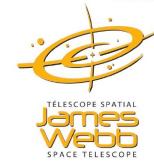
← For calibrator observation

- 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



The figure shows the APT software interface with the following details:

- File Menu:** File, Edit, Tools, Form Editor, HST Help, JWST Proposals, Export...
- Export Dialog:** Shows various export options including Diagnostic Summary, PDF, Anonymized TAC PDF, TAC PDF, XML file, SQL file, NIRSpec MSA Catalog Associated Images, Target Confirmation Charts, Visit Coverage, Visit Positions/Coverage to MAST, MSA Target Info, times file (selected), pointing file, MOSS files to proposal directory, Smart Accounting visit sequences, Approved SQL file, SPAR SQL file, and timing.json file.
- Text File Content:**

```
# 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

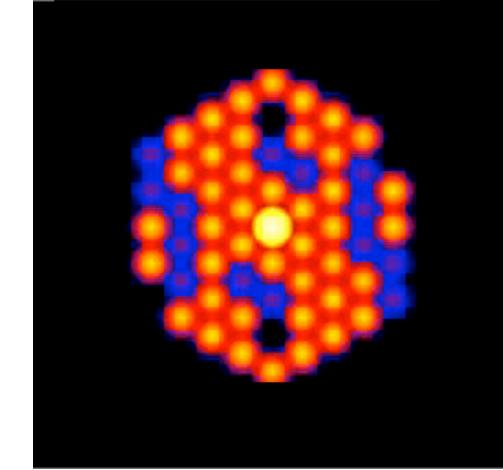
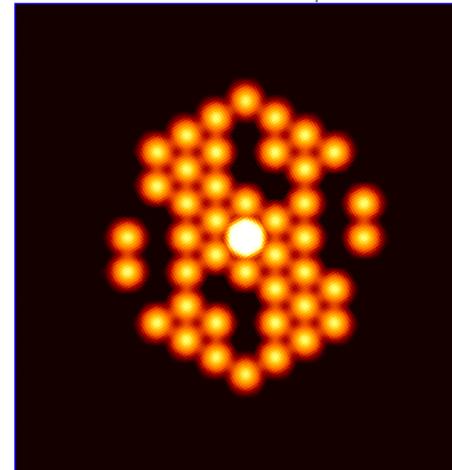
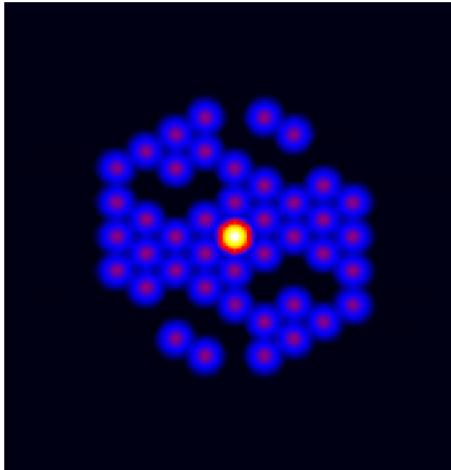
  Exposure Specifications:
  Exp SUBARRAY READOUT FrameRead Groups NFrame GrpGap Ints PhotonCollect Diths PrimDiths SecDiths NumExp TotalPhoton ExposureDuration ExposingDuration
  ACG SUBTAAMI NIRRAPID  0.050      3     1     0      1    0.150      1       1       1       1       0.150          16            2
  ACG SUB80  NIRRAPID  0.075      9     1     0    6504    4415.956      1       1       1       1    4415.956          5054            5040

  Visit Durations:
  Pointing Science Instrument (GS) (Targ) (Exp) (Mech) (OSS) (MSA) (IRS2) (Visit) Slew Observatory Direct Sched Total Time
  Visit Dist Duration Overhead (SAMs) (Acp) (Acq) (Ovh) (Ovh) (Mech) (OSS) (MSA) (IRS2) (Ovh) Time Overheads Overhead Sched 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

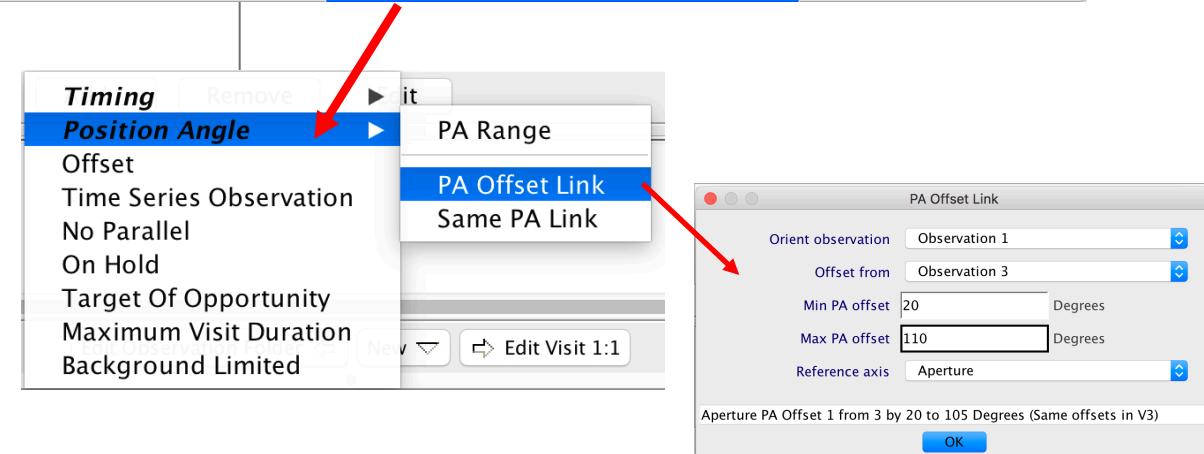
Rotation helps fill uv plane coverage



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.



The screenshot shows the 'Special Requirements' tab selected in the NIRISS software interface. A red arrow points from the 'Position Angle' option in the dropdown menu to a sub-menu titled 'PA Offset Link'. Another red arrow points from the 'PA Offset Link' option in the sub-menu to a detailed configuration dialog box titled 'PA Offset Link'.

PA Offset Link

- Orient observation: Observation 1
- Offset from: Observation 3
- Min PA offset: 20 Degrees
- Max PA offset: 110 Degrees
- Reference axis: Aperture

Aperture PA Offset 1 from 3 by 20 to 105 Degrees (Same offsets in V3)

OK



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>

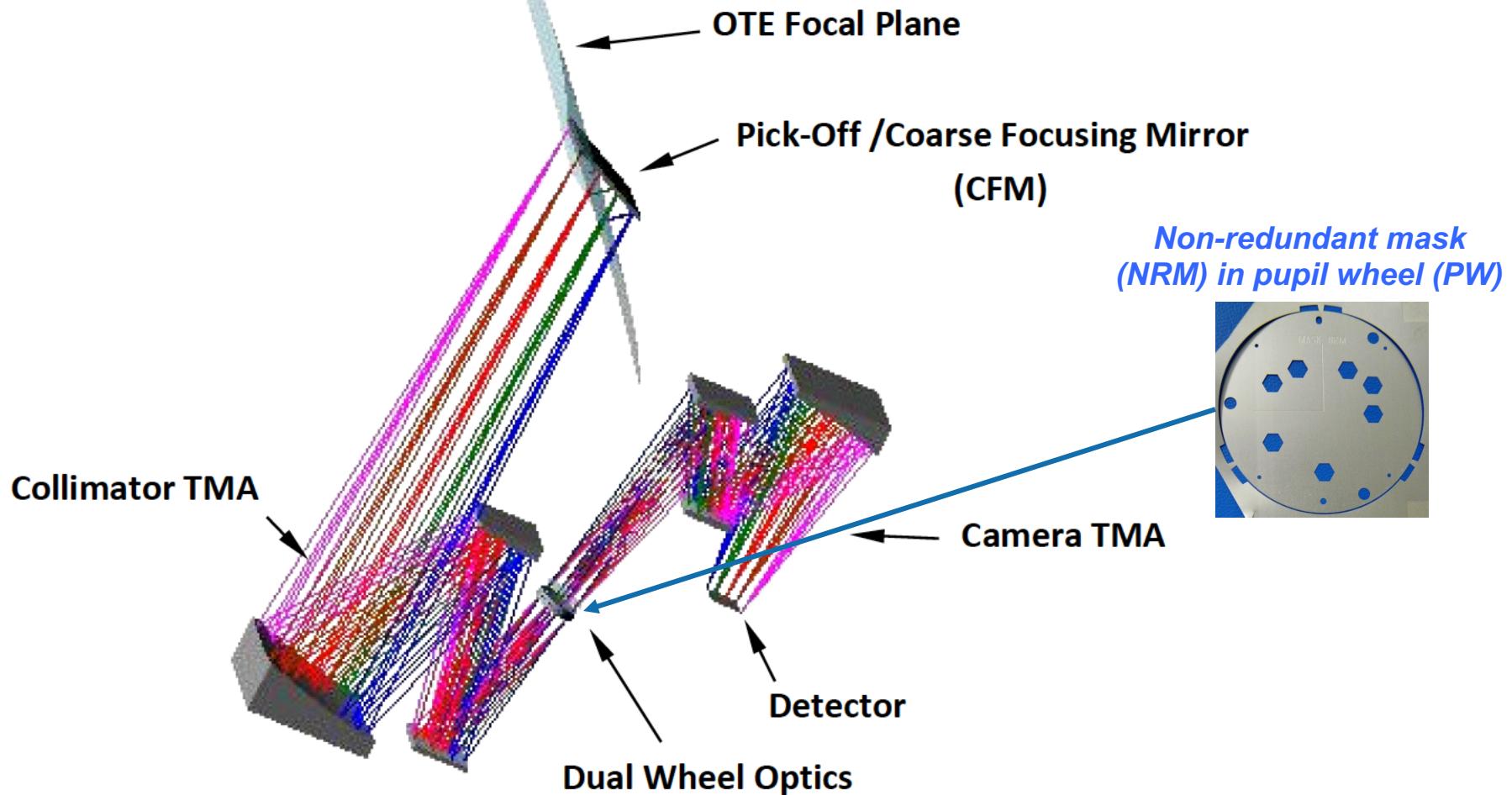
NIRISS AMI backup slides

NIRISS optical design layout

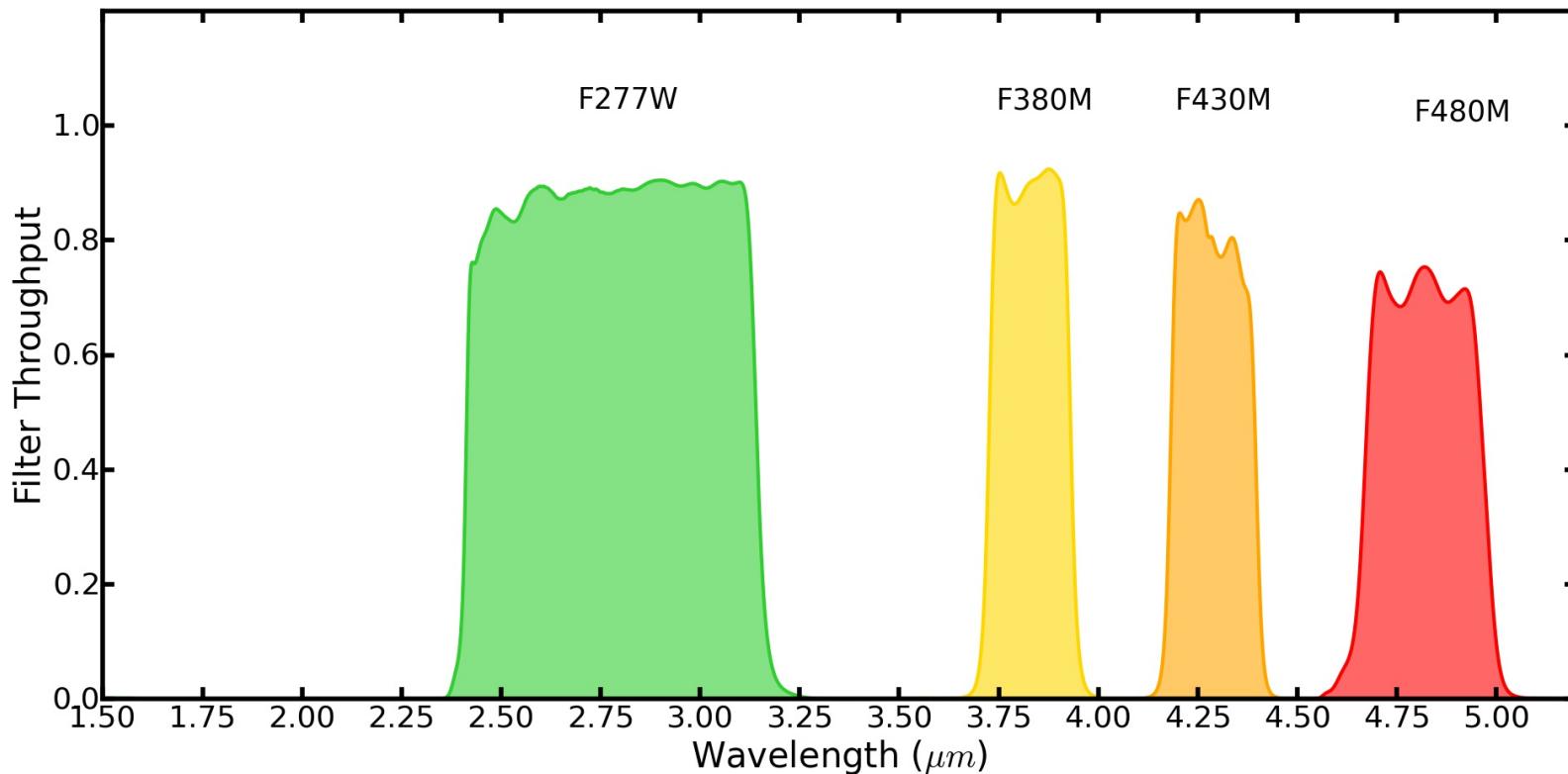
All-reflective design - no chromatic aberration

Space – no atmospheric differential refraction

Space – stable photometry (fringe visibility)



AMI filter bandpasses



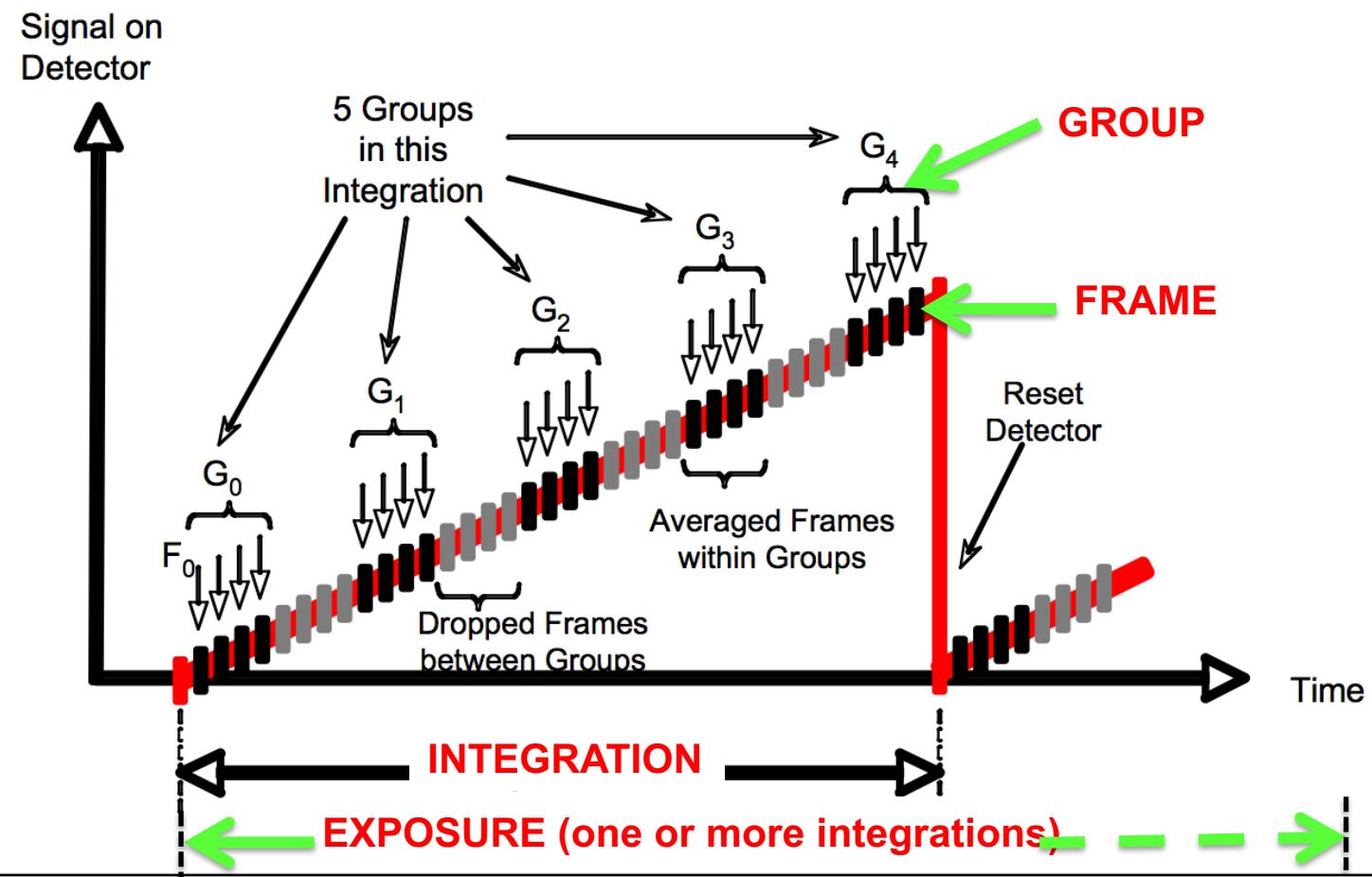
Binary point source contrast ~9+ magnitudes for F380M, F430M, F480M

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**

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:**

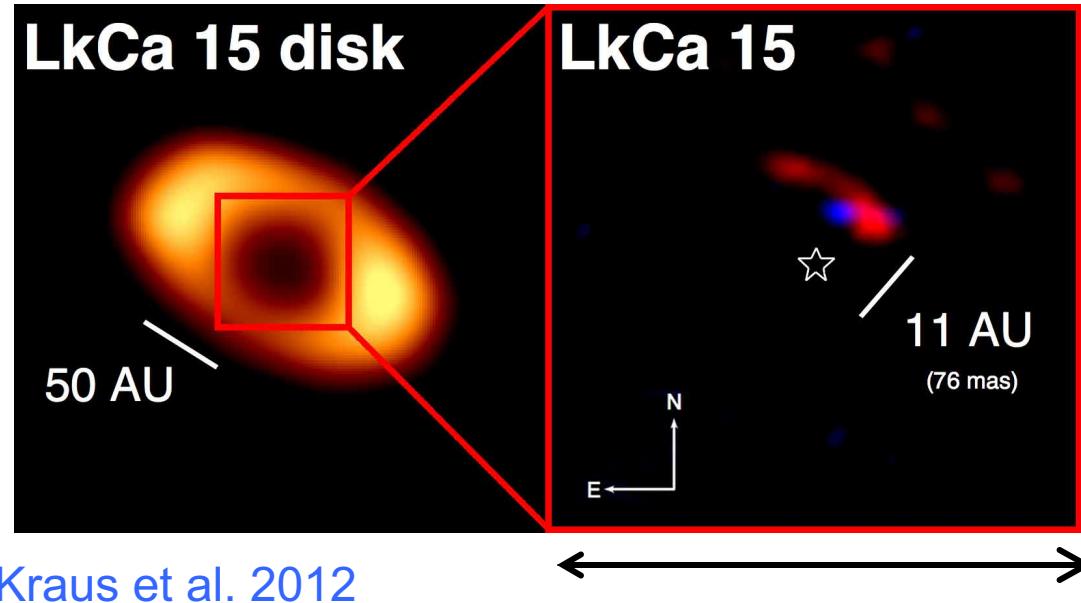
- **EITHER Case A:** Fringe amplitudes (visibilities) & phases, flux
 - Binary or multiple star model fitting
- **OR Case B:** Use image data for image reconstruction
 - CAL PSF and Target image

Fringe phases & amplitudes

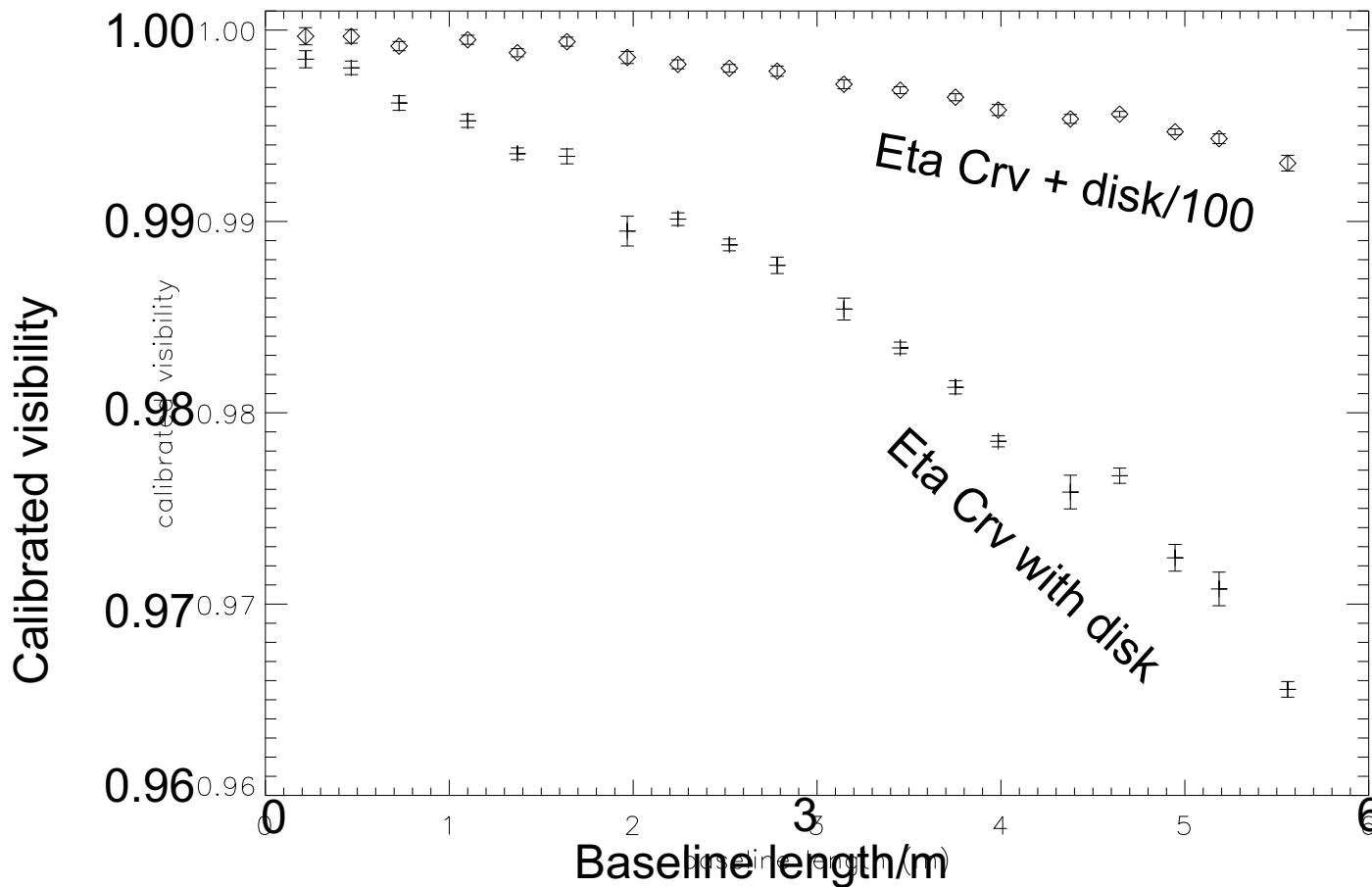
- Numerical Fourier transform to a complex number array
 - Conceptually easier to understand but not what we do
 - Measure splodge heights (fringe visibilities), splodge phases in FT(data)
 - Bad pixels corrupt an FT
 - Fix bad pixels then FT? Tricky.
- Fit analytical model to image (recommended)
 - 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 μm
 - Provide good constraints on $\log g$ and Teff
- Follow-up of GPI/SPHERE planets with separation less than ~ 0.5 arcsec and contrast $> 10^{-4}$ @ 4 μm .
 - 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)

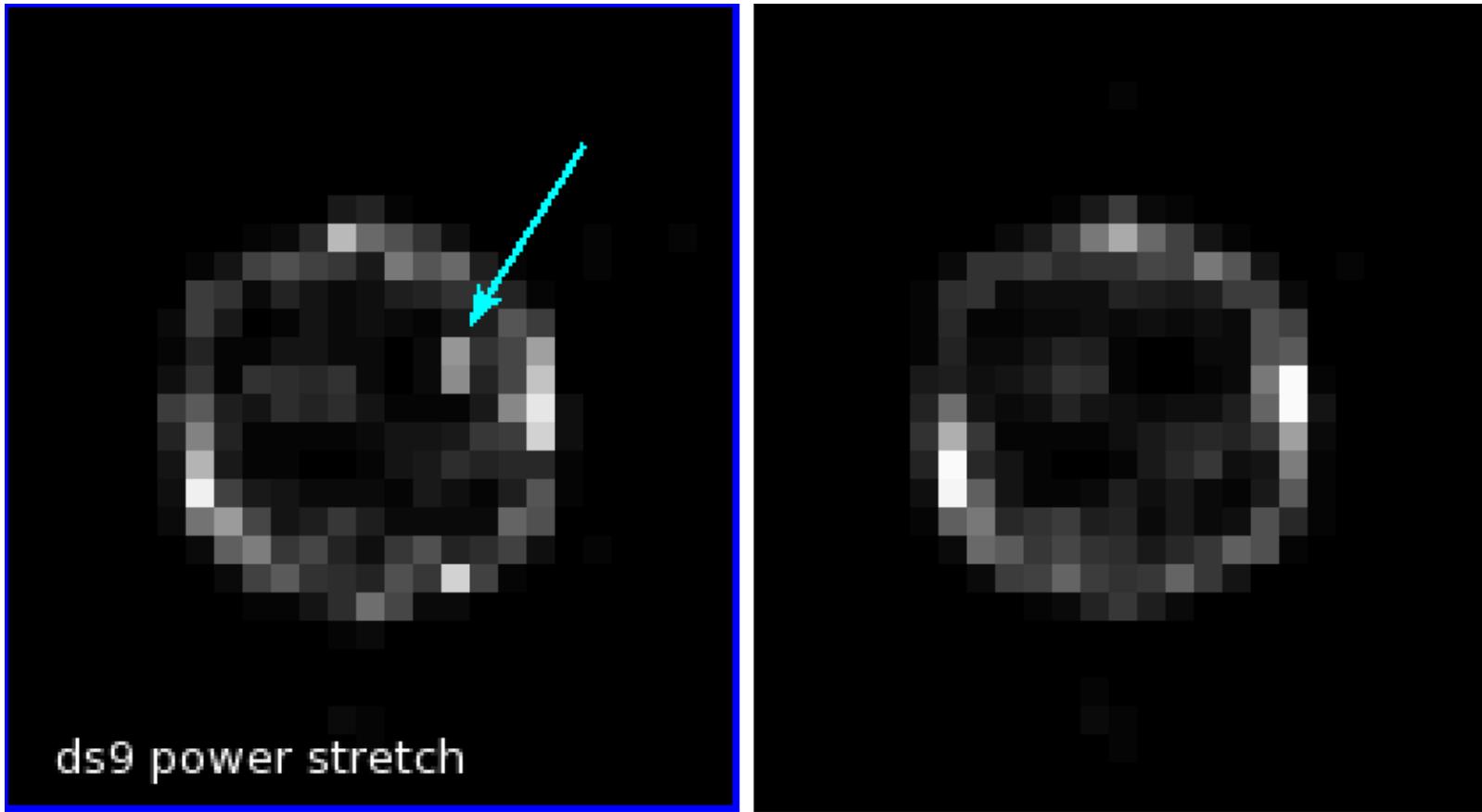


Exozodi measurement



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

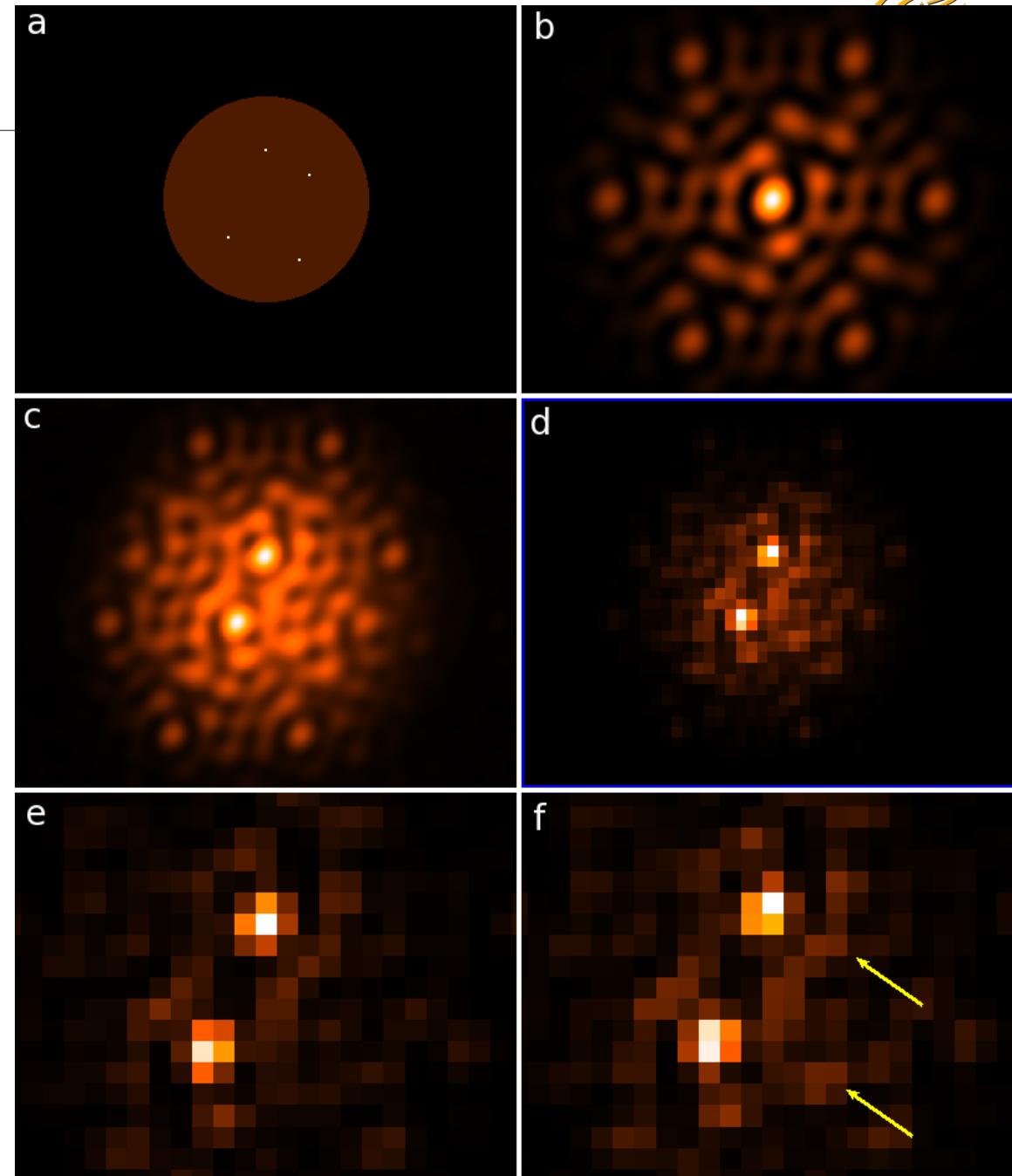
Io vulcanism



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 New Workbook Sample Workbooks ▾ Example Science Program Workbooks ▾

User Access Permissions for #23: NIRISS AMI Observations of Extrasolar Planets Around a Host Star ?

User ▾

#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

Email Add User by Email Revoke

Create a scene with another target with spectral type F0V, vega $mag=6.5$, 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

Select a Workbook ?

User ?

- #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

Add User by Email

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'

Source Editor ?

ID Continuum Renorm Lines Shape Offset

Spectral Energy Distribution Redshift 0

Extinction Law Milky Way R_V=3.1

Ext. Magnitude 0

Ext. Bandpass J

Uploaded File

Select

No Continuum

Source selected: 3

Reset Save

Source Editor ?

ID Continuum Renorm Lines Shape Offset

Scene Identity Information Target 2 Scene

No comment

Source Identity Information Target 2

Source selected: 3

Reset Save

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 mJy λ 2 μm

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 ★ Default 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

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

- 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?

Calculations

ID	Mode	λ	Scn	(s)	SNR	Δ
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	1	0.22	0.00	!

Scenes and Sources

ID	Mode	λ	Scn	(s)	SNR	Δ
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	1	0.22	0.00	!

Instrument Setup

Scene ★ Backgrounds Instrument Setup Detector Setup Strategy

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

Sources in that Scene: 3: Target 2

Normalize Source Flux Density
Renormalization applied after redshift
Normalize at wavelength: 0.001 flam μm
Normalize in bandpass: 6.5 vegamag

JWST NIRISS/IMAGING F430M

HST WFC3/IR F098M

Calculation selected: 8, Mode: niriss target_acq

Detector Setup

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

Strategy

Reset Calculate

Backgrounds

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

Background configuration: None Low Medium High
Date: Jul 1 2020

NIRISS Target Aquisition

Acq Mode: SOSS or AMI Bright
Filter: F480M

Detector Setup

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

Instrument Setup

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

Detector Setup

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

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

Backgrounds

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

Instrument Setup

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

Detector Setup

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

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



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	Imaging		(s)	SNR -	▲			
1	<input type="checkbox"/> niriss amri	SOSS		0.85	1007.77	!			
2	<input type="checkbox"/> niriss amri	WFSS		0.62	507.22	✓			
3	<input type="checkbox"/> niriss amri	AMI		5039.82	7831.05	✓			
4	<input type="checkbox"/> niriss amri	Target Acquisition		4.81	2	8050.99	7836.49	✓	
5	<input type="checkbox"/> niriss target_acq	4.81	1	0.22	104.87	✓			
6	<input type="checkbox"/> niriss target_acq	4.81	2	0.22	72.26	✓			
7	<input type="checkbox"/> niriss target_acq	4.81	2	0.32	117.41	✓			
8	<input checked="" type="checkbox"/> niriss target_acq	4.81	3	0.72	157.37	✓			
-	-	---	-	-	-	-			

		Calculations		Scenes and Sources		Upload Spectra		Caveats and Limitations	
MIRI	NIRCam	NIRISS	NIRSpec						
ID	Mode	λ	Scn	(s)	SNR -	SNR -	▲	△	
1	<input type="checkbox"/> niriss amri	4.81	1	0.85	1007.77	!			
2	<input type="checkbox"/> niriss amri	4.81	2	0.62	507.22	✓			
3	<input type="checkbox"/> niriss amri	4.81	1	5039.82	7831.05	✓			
4	<input type="checkbox"/> niriss amri	4.81	2	8050.99	7836.49	✓			
5	<input type="checkbox"/> niriss target_acq	4.81	1	0.22	104.87	✓			
6	<input type="checkbox"/> niriss target_acq	4.81	2	0.22	72.26	✓			
7	<input type="checkbox"/> niriss target_acq	4.81	2	0.32	117.41	✓			
8	<input type="checkbox"/> niriss target_acq	4.81	3	0.72	157.37	✓			
9	<input checked="" type="checkbox"/> niriss amri	4.28	3	0.85	520.97	✓			
-	-	---	-	-	-	---		---	

Calculation selected: 9, Mode: niriss amri
Reset
Calculate



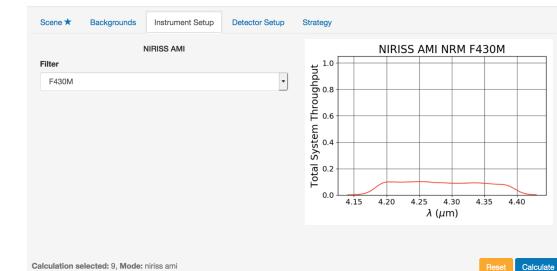
AMI calculations in JWST ETC

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

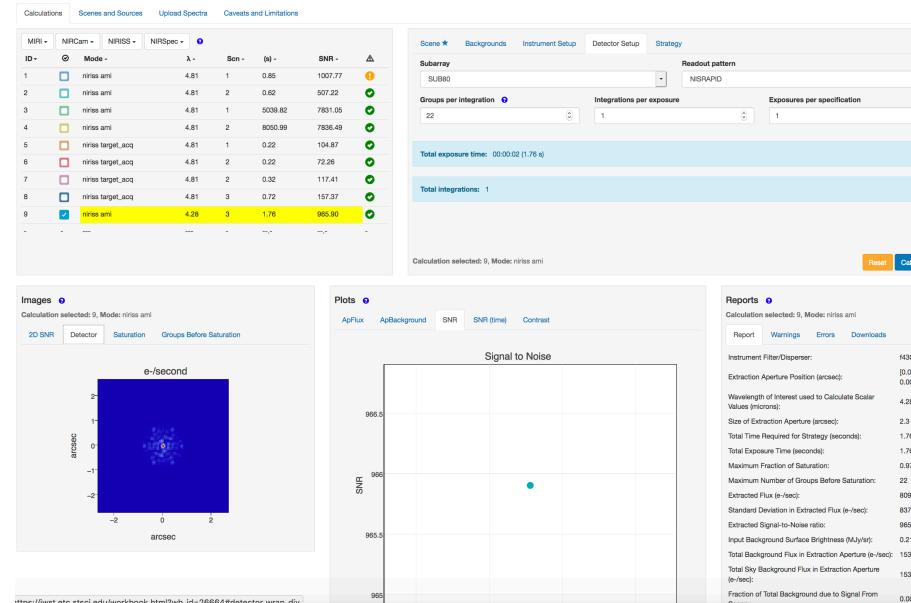


AMI calculations in JWST ETC

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



The screenshot shows the JWST ETC interface with three main panels:

- Calculation:** Shows a table of observations. The last row (ID 9) is highlighted in yellow and corresponds to the 'niris amr' entry in the other panels.
- Strategy:** Displays the readout pattern for SUB90. It shows 'Groups per integration' set to 22, 'Integrations per exposure' set to 1, and 'Exposures per specification' set to 1. The total exposure time is 00:00:02 (1.76 s).
- Reports:** Provides detailed reporting for the selected calculation. Key values include:
 - Instrument Filter/Dispenser: F430M/nisl
 - 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 (MAU/arcsec²): 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

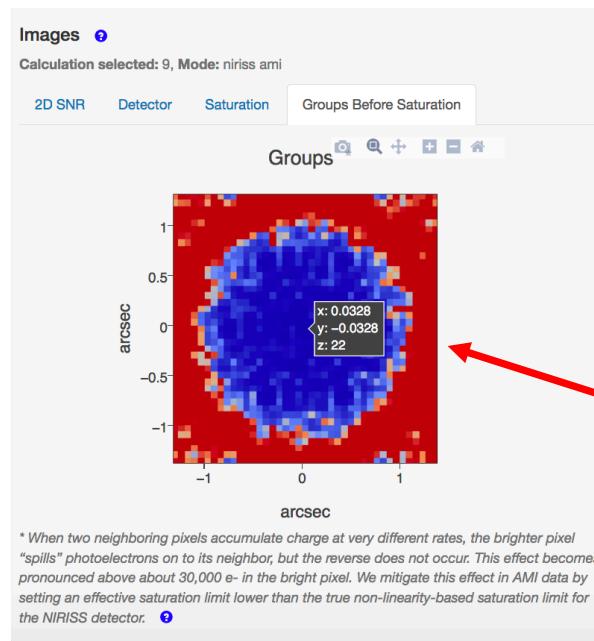
Maximum Number of Groups Before saturation value is 22 from the Reports panel. Therefore set Groups per integration to 22. (NGROUPS)

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/Disperser:	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 Jy/arcsec ²):	0.21

Total photons = flux × NGROUPS × NINT × TFRAME

$$\text{NINT} = \text{Total photons} / (\text{flux} \times \text{NGROUPS} \times \text{TFRAME})$$

$$= 10^9 / (809296.80 \text{ e-/sec} \times 22 \times 0.07544 \text{ sec})$$

$$= 744.5 \rightarrow \text{Round up to } 745$$



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

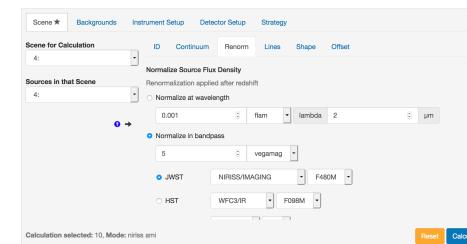
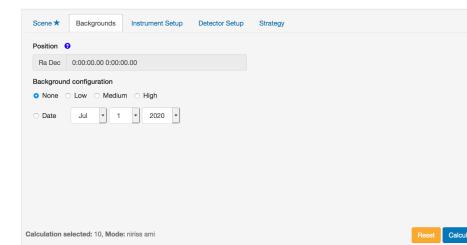
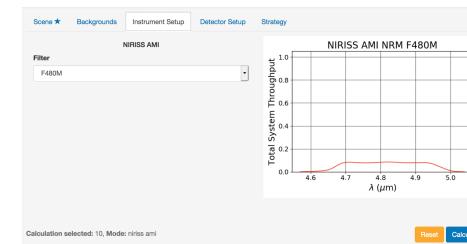
Vegamag = 5 gives maximum number of Groups Before Saturation as 7.

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

Reports	
Calculation selected: 10, Mode: niriss ami	
Report	Warnings
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

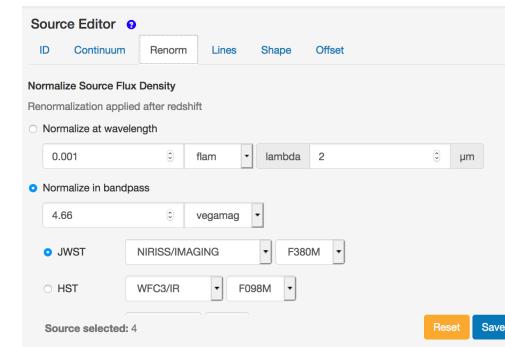
4. Calculate NGROUPS=1 and NGROUPS=2 bright limits (Vegamag) for A0V star observed with F380M.

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

**NGROUPS=2 bright limit
For F380M**

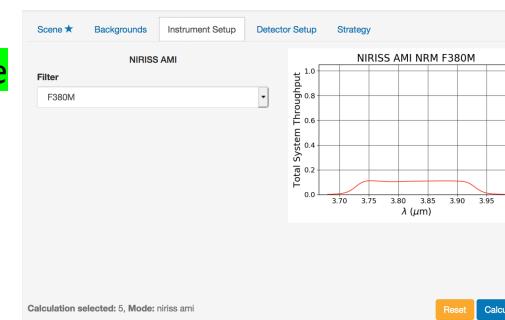
4.66

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



The Source Editor interface shows the following settings:

- ID: Continuum
- Renorm: Renorm at wavelength (0.001 μm)
- Lines, Shape, Offset: Not selected
- Normalize Source Flux Density: Renormalization applied after redshift
- Normalize at wavelength: 0.001 μm
- Normalize in bandpass: 4.66 vegamag
- JWST: NIRISS/IMAGING, F380M
- HST: WFC3/IR, F098M
- Source selected: 4
- Buttons: Reset, Save



Reports	
Calculation selected: 5, Mode: niriss ami	
	Report
Instrument Filter/Disperser:	f380>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

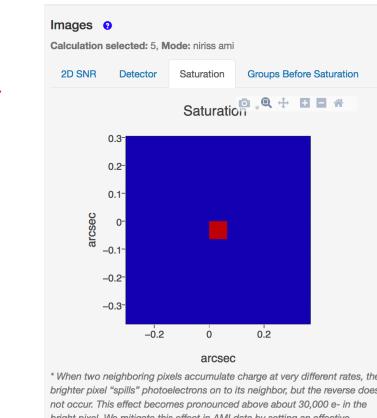
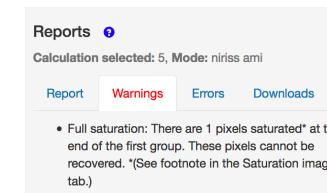
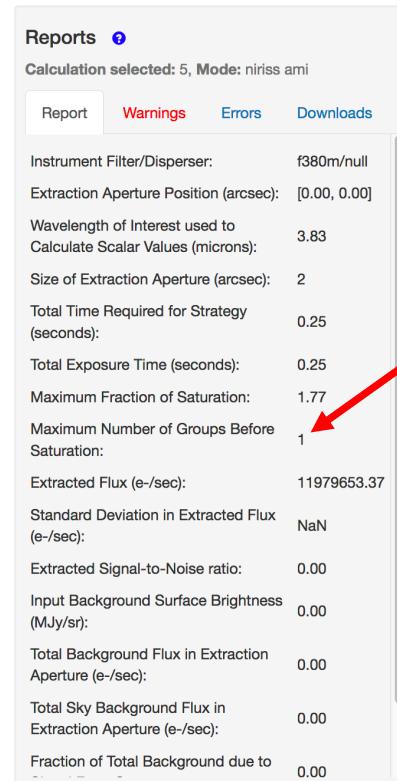
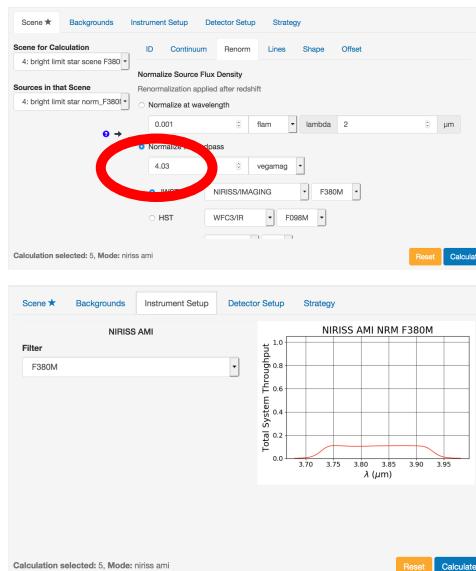
AMI calculations in JWST ETC

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.

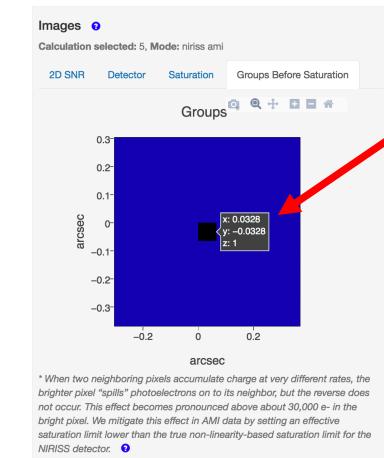
NGROUPS=1 bright limit for F380M is 4.03. Change the magnitude to 4.02 and look at the central pixel in Groups Before Saturation image.



Saturation image

* When two neighboring pixels accumulate charge at very different rates, the brighter pixel "spills" photoelectrons on to its neighbor, but the reverse does not occur. This effect becomes pronounced above about 30,000 e- in the bright pixel. We mitigate this effect in AMI data by setting an effective saturation limit lower than the true non-linearity-based saturation limit for the NIRISS detector.

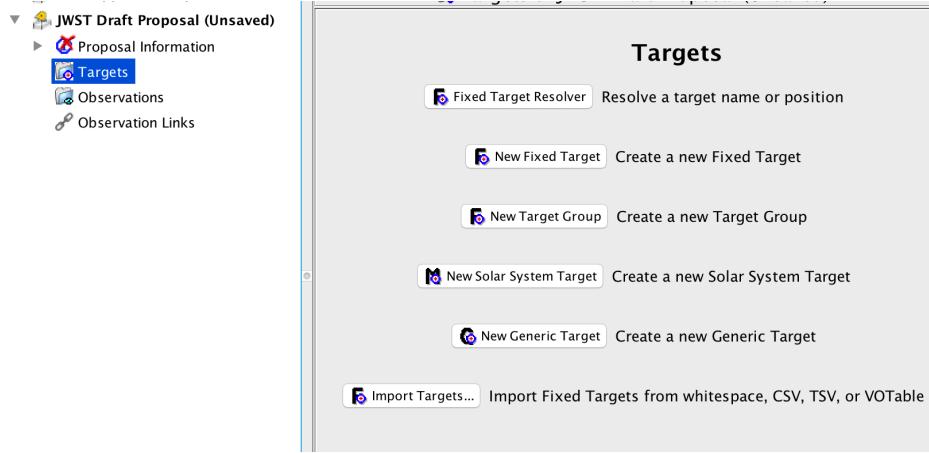
Signal limit exceeded in group 2 but not in group 1



Groups Before Saturation image

Example science program in JWST APT

AMI Specific strategies



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.

The screenshot shows the 'Form Editor' window for 'JWST Approved Proposal 23 (Unsaved)'. The 'Proposal Information' section includes fields for 'Number' (1), 'Name in the Proposal' (HD-218396), 'Name for the Archive' (HD 218396), 'Category' (Star), and 'Description' (Exoplanet Systems: F stars). The 'J2000 Coordinates' section shows RA: 23 07 28.8327 and Dec: +21 08 2.53. The 'Proper Motion' section shows RA: 108.30 mas/yr and Dec: -49.48 mas/yr. The 'Epoch' is set to 2015.5. A red arrow points from the 'Category' field to the 'Description' field.



Example science program in JWST APT

Astronomer's Proposal Tools Version 27.3.1 JWST PRD: PRDOPSSOC-M-025 - 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 sole reference exposure will be provided in the science investigation.

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)

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

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

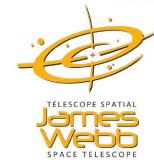
Show: Observation

2 errors & warnings (Click for Details)



Example science program in JWST APT

AMI Specific strategies



Adding Special Requirements

Screenshot of Astronomer's Proposal Tools Version 27.3.1 showing the "Group/Sequence Observations Link" dialog box.

The dialog box is titled "Group/Sequence Observations Link" and shows the following settings:

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

At the bottom, there are tabs for "NIRISS Aperture Masking Interferometry", "Special Requirements", and "Comments". A purple arrow points upwards from the "Comments" tab towards the "Group/Sequence Observations Link" dialog.

A callout box with the text "Click on Add" points to the "Add" button in the "Special Requirements" tab.

The "Special Requirements" tab dropdown menu is open, showing the following options:

- 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** (highlighted in blue)

The status bar at the bottom right indicates "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.