STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

Coordinated Parallels Level 2

Paul Goudfrooij

JWST Master Class

November 2019

Thanks to: Bill Blair, Karla Peterson, Tea Temim, Crystal Mannfolk, Shelly Meyett, & Amber Armstrong

JWST Science Parallels: Project History

- JWST Project and budget originally not include support for science parallels
  - However, parallel observations *were* planned for calibrations (darks, "sky flats")
    - Hence, ground and flight systems were designed all along to handle parallel SI Ops and visit planning
  - HST demonstrated that science parallels do deliver major gains to science impact and efficiency
    - Over HST Cycles 11-21, science parallels increased total observatory efficiency from ~50% to ~70%
    - Many large HST programs would not be feasible without science parallels (e.g., GOODS, GHOSTS, HUDF, 3D-HST, PEARS, Orion Treasury Program, Multi-Cycle Treasury Programs, Frontier Fields)
- 2013-2014: JWSTMO chartered Efficiency WG to look into gains to typical science cases, implementation options, and potential technical barriers
  - Supported by NASA, since JWST's design goal of 70% efficiency wasn't met without parallels
- Efficiency WG report on JWST science parallels released in 2014
  - Estimated total efficiency gain of 16-26%
    - Gain depending on fraction of prime visits that will allow "useful" parallels (exp. times / dithers)
  - Preliminary estimate on increase of Data Volume looked manageable
    - With some restrictions

JWST Science Parallels: Project History & Modes Implemented

- June 2015: NASA releases funding for JWST science parallels (engineering only)
- May 2016: Working Group put in charge of science input into APT implementation
  - Left only 5 months to get to implementation into APT for the GTO teams (!)
  - *Coordinated Parallel* modes implemented:

SI Mode 1	SI Mode 2	Both Ways?
NIRCam Imaging	MIRI Imaging	Yes
NIRCam Imaging	NIRISS WFSS	Yes
MIRI Imaging	NIRISS WFSS	Yes
NIRSpec MOS	NIRCam Imaging	No
NIRCam Imaging	NIRISS Imaging	No

  - 2018 launch delay allowed us to implement three more combinations:
    - Will be in place in APT 2020.1
    - Not further discussed here
    - Usage similar to cases mentioned above

SI Mode 1	SI Mode 2	Both Ways?
NIRCam WFSS	MIRI Imaging	No
NIRCam WFSS	NIRISS Imaging	No
NIRSpec MOS	MIRI Imaging	No

JWST Science Parallels: Coordinated vs. Pure Parallels

Coordinated Parallels	Pure Parallels
Science case in proposal needs to **justify parallel as well as prime observations**. Science goals need to call for both.	Distinct proposal type, **using parallel slots derived from separate (primary) programs**.
Proposer can craft exposure times, number of exposure specifications, dithers etc. to make things work for their science with the prime ***and*** parallel observations.	Pure parallel observations **cannot change the properties of primary observations** to which the proposed parallel ones will be attached.
Coordinated parallel proposal specifies ***all parallel exposures*** in detail.	• Proposal specifies ***one Observation per type of proposed exposure*** (e.g., different filters or grisms). • **Exposure times need to specify the minimum allowable lengths** for the proposed science. • Scientific Justification needs to specify **minimum number of distinct primary targets per observation** to fulfill science goals.
APT templates for coordinated parallels are **based on the "normal" templates** of the prime observing modes.	APT templates for pure parallels are **distinct from the "normal" observing templates**, selected in Proposal Information section of APT.

JWST Science Parallels: Pure Parallels

- Pure parallels ***not*** covered here in detail
- Dedicated articles in JDox
  - JWST Parallel Observations
  - JWST APT Pure Parallel Observations
- After acceptance by the TAC, and when the available parallel slots are known, successful proposers will develop a “Phase II” APT proposal using dedicated tool
  - Or: STScI will provide a listing of observing slots and their properties
  - Details will depend on the severity of competition for the available slots
  - Calibration Parallels (i.e., darks) will get access to the parallel slots before science pure parallels do
  - Formally, pure parallel observations are not guaranteed until visits have been scheduled

Filling out APT forms for pure parallel proposals

1. In the ***Proposal Information*** section, check box ***Pure Parallel Proposal***.

2. In the ***Observations*** section, click on ***New Observation Folder***.

3. Create one observation for each type of observation and exposure required to execute the proposed pure parallel science. In this context, "type of observation and exposure" means a combination of instrument, observing mode, optical element selection (filter(s) or grism), and minimum exposure duration. **Note that if more than one exposure setup is proposed to be obtained at a given position on the sky** (e.g., imaging with more than one filter per filter wheel, or WFSS observations with a grism as well as direct images), **one observation needs to be created for each of those exposure setups.** This is different from regular observation template specifications where multiple filters could just be listed sequentially within a given instance of the observation template.

4. For each of the observations specified, fill out the exposure specifics. This is done as follows for the observing modes available for pure parallel observations:
   1. For the *NIRCam Imaging* template (Instrument = NIRCam, Template = NIRCam Imaging):
      1. Select desired ***Module*** and ***Subarray***.
      2. Select desired ***Short Filter***, ***Long Filter***, ***Readout Pattern***, ***Groups/Int***, and ***Integrations/Exp***.
      3. Read off duration of Observation in "Total Charged" box in top area of the template. *Note down this value for this Observation.*
   2. For the *MIRI Imaging* template (Instrument = MIRI, Template = MIRI Imaging):
      1. Select desired ***Subarray***.
      2. Select desired ***Filter, Readout Pattern, Groups/Int***, and ***Integrations/Exp***.
      3. *Select* ***Exposures/Dith = 1***.
      4. Read off duration of Observation in "Total Charged" box in top area of the template. *Note down this value for this Observation.*
   3. For the *NIRISS Imaging* template (Instrument = NIRISS, Template = NIRISS Imaging):
      1. Select ***Subarray = FULL***.
      2. Select desired ***Filter, Readout Pattern, Groups/Int***, and ***Integrations/Exp***.
      3. Read off duration of Observation in "Total Charged" box in top area of the template. *Note down this value for this Observation.*
   4. For the *NIRISS WFSS* template (Instrument = NIRISS, Template = NIRISS Wide Field Slitless Spectroscopy):
      1. Select ***Mode*** ("DIRECT", "GR150C", or "GR150R"). *Note that for NIRISS WFSS Pure Parallel proposals, one of the Observations needs to specify a Direct Image exposure.* (To direct the user in this respect, the ***Mode*** is defaulted to "DIRECT".) For Cycle 1, we recommend that one Direct Imaging Observation be created for each Filter used in the proposal.
      2. Select desired ***Filter, Readout Pattern, Groups/Int***, and ***Integrations/Exp.***

5. For each of the Observations created as described above, evaluate how many distinct pointings (meaning distinct targets of the primary observations, i.e., *ignoring dithers*) will be required at a minimum to fulfill the science goals laid out in the proposal. Make sure these numbers are mentioned and justified in the *Description of Observations* section of the proposal PDF attachment.

6. Calculate the grand total duration of the pure parallel observations proposed. Calling the durations of the *m* different Observations "Dur_i" and the associated minimum number of pointings for each Observation "N_i", this grand total duration is equal to the following: $\Sigma_{i=0}^{m} N_i \; Dur_i$

7. In the "Proposal Information" section in APT, click on "Request custom time allocation" button.

8. In the "Requested Time" box that shows up, enter the grand total duration value calculated in the previous step. Make sure you choose the correct time unit (which is currently defaulted at "Days"). You can ignore the accounting numbers produced by APT automatically, as they are not relevant for pure parallel proposals.

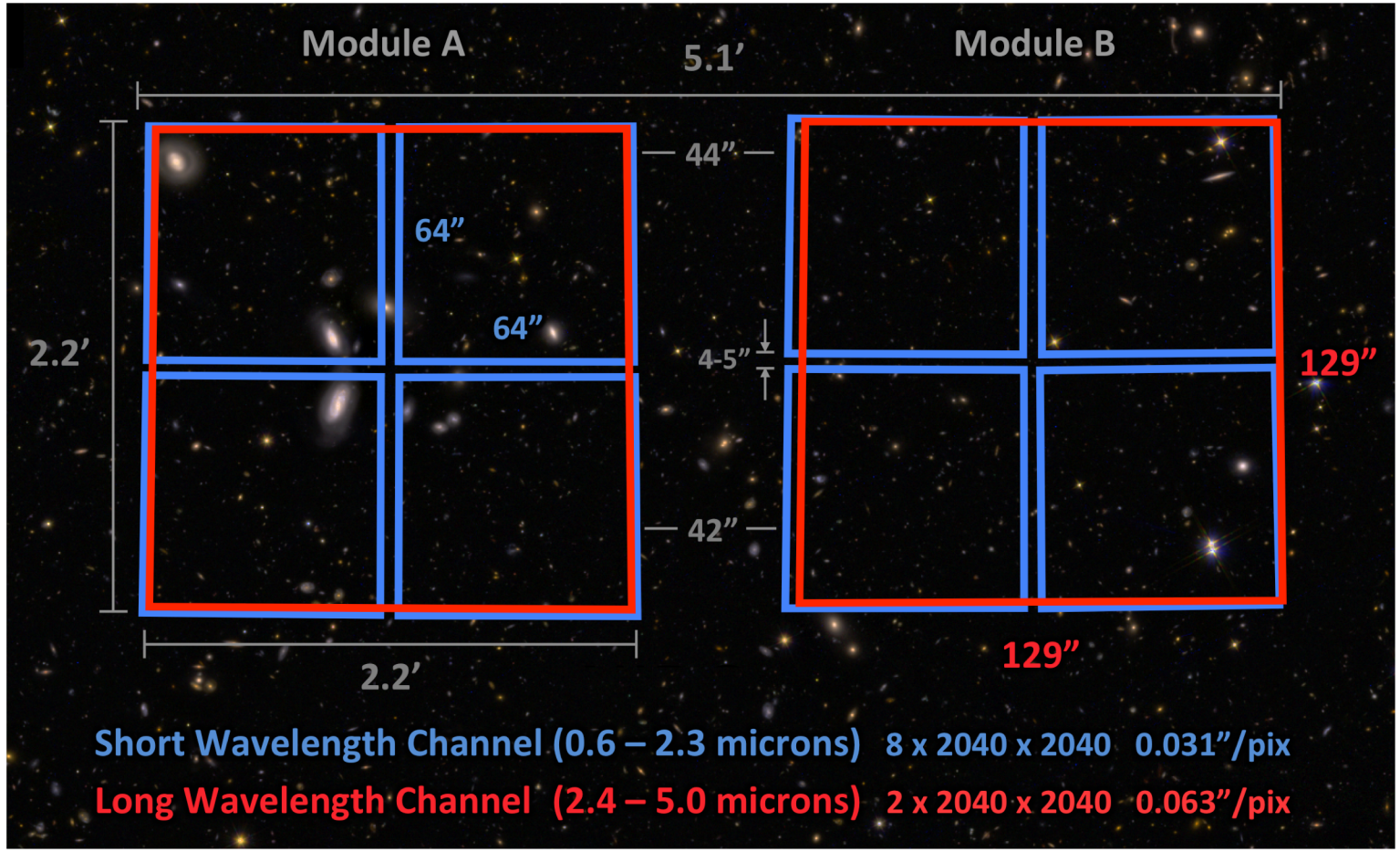
9. In the "Time Req Explanation" box, enter the following: "Pure Parallel proposal. Allocation value entered following prescription given in the **JWST APT Pure Parallel Observations** article."

JWST Coordinated Parallels: Implementation within APT

- Operational Constraints & Limitations
  - No mechanism motions while other SI is exposing
  - No simultaneous mechanism motions (i.e., occurring serially) while FGS is in Fine Guide
- Observatory Constraints & Limitations implemented in APT (only):
  - Parallel SI same number of exposure *specifications* ("activities") as Prime SI
  - Data Volume constraints: *Calculated within APT and flagged when formal limit exceeded*
  - Data Rate constraints: *Imposed within APT through restrictions on available readout patterns*
    - ✓ ***ICDH must sustain up to five 2048x2048 frames plus FGS "postage stamp" into SSR every 10.7 s***
    - ✓ Using this as **upper limit** to data rate; only an issue when NIRCam is involved.
- Goals for the determination of ***dither patterns for coordinated parallels***:
  - Pixel phase sampling should be good for both SI's *(if their PSFs are undersampled)*
  - Dither step size should be large enough for PSFs of both SI's
  - Choice of dither step sizes for various target types (star field / distant galaxies / nearby galaxies)
  - However, science with Prime SI should not be compromised (e.g., NIRSpec MOS)

JWST Coordinated Parallels: Customized Dither Patterns

NIRCam

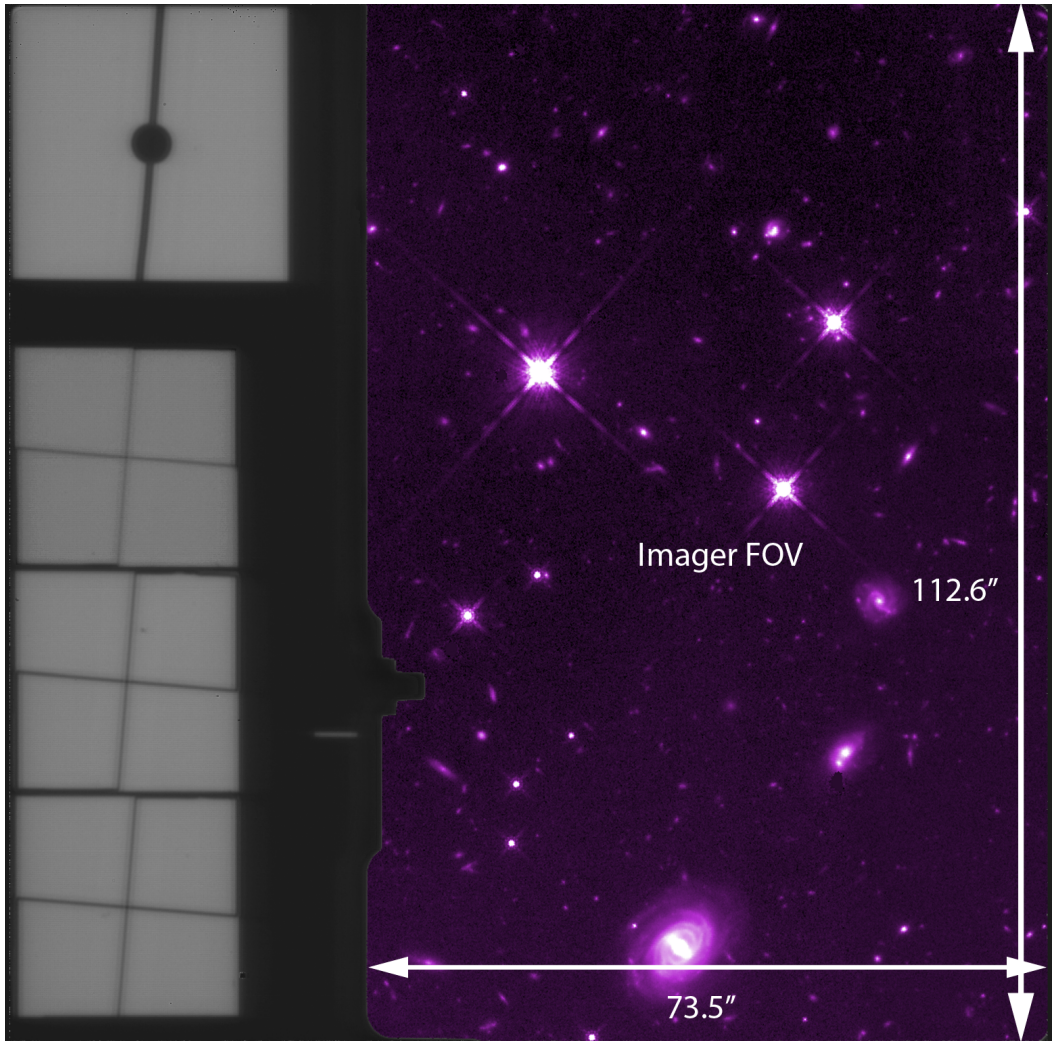


SW channel		LW channel	
Filter	λ / λ_{crit}	Filter	λ / λ_{crit}
F070W	0.35	F277W	0.69
F090W	0.45	F356W	0.89
F115W	0.58	F444W	1.11
F150W	0.75		
F200W	1.0		

- ***NIRCam dither patterns independent of filter***
- ***NIRCam sampling limited by SW channel***

JWST Coordinated Parallels: Customized Dither Patterns

MIRI

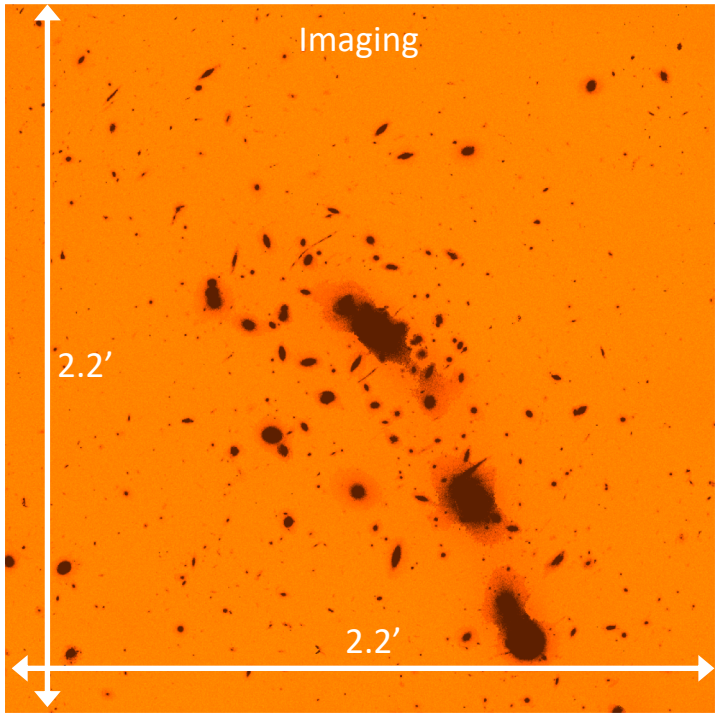


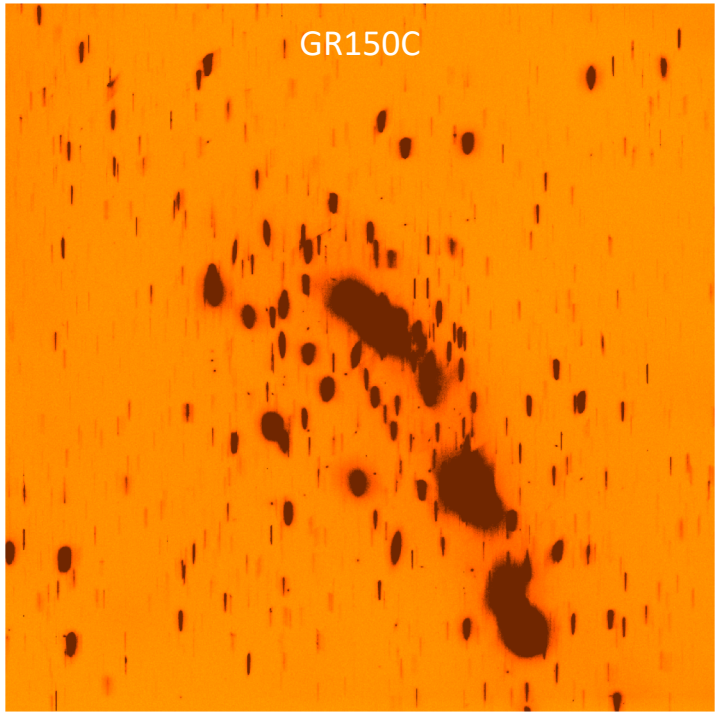
Filter	λ / λ_{crit}	Filter	λ / λ_{crit}
F560W	0.9	F1500W	2.3
F770W	1.2	F1800W	2.8
F1000W	1.5	F2100W	3.2
F1130W	1.7	F2550W	3.9
F1280W	2.0		

- ***MIRI dither patterns based on filter*** *(due to wide range of PSF FWHMs)*
- ***MIRI sub-pixel sampling constraints only enforced for F560W and F770W***

JWST Coordinated Parallels: Customized Dither Patterns

NIRISS/WFSS



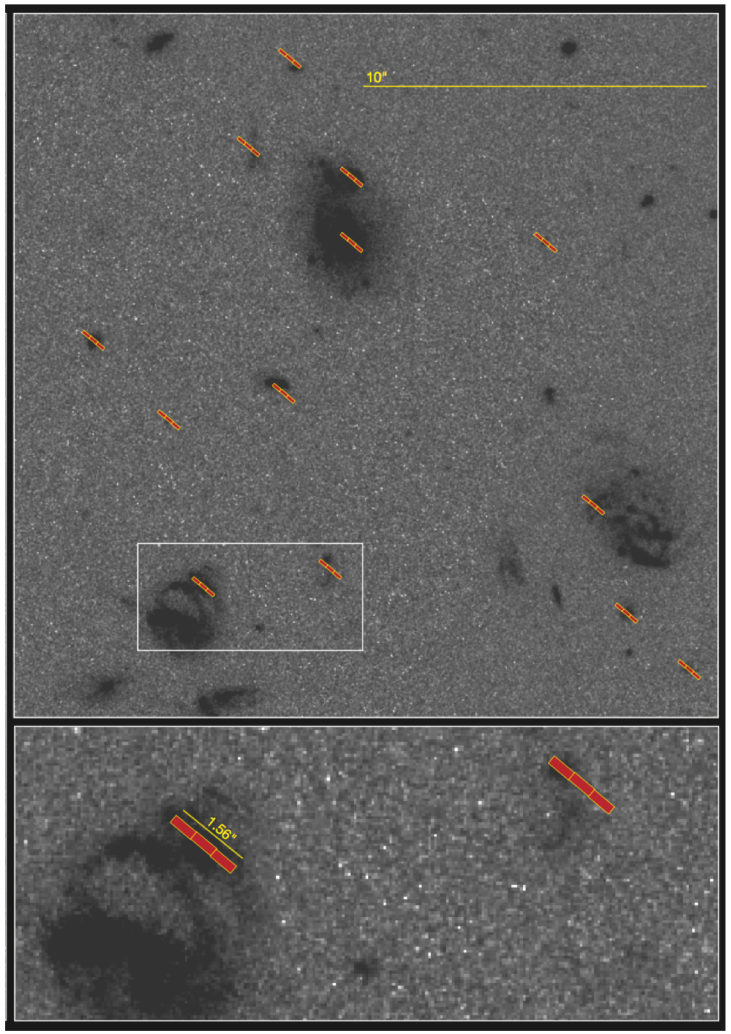


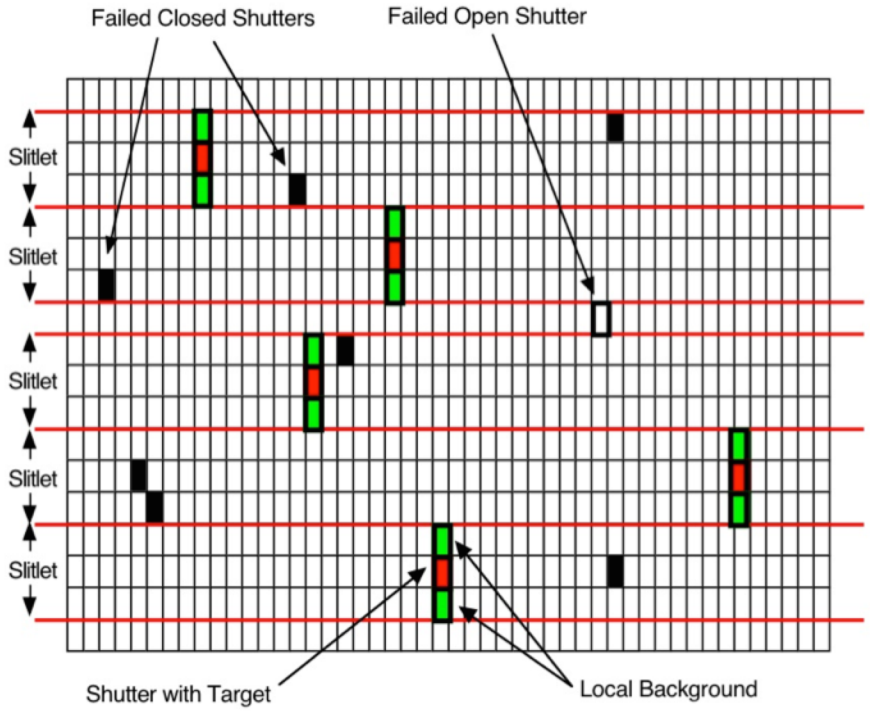
Filter	λ / λ_{crit}	Filter	λ / λ_{crit}
F090W	0.23	F150W	0.38
F115W	0.29	F200W	0.50

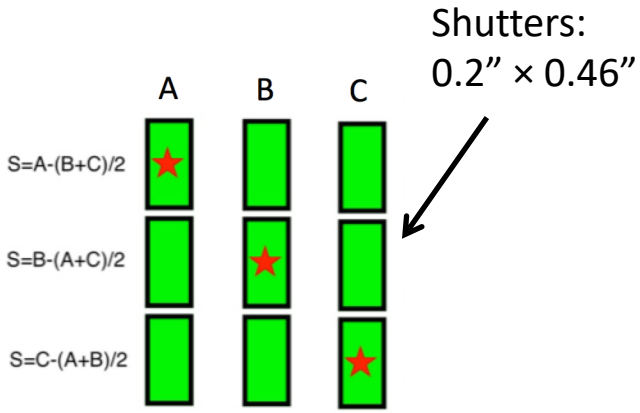
- ***NIRISS/WFSS strongly undersampled, dithering crucial***

JWST Coordinated Parallels: Customized Dither Patterns

NIRSpec MOS w/MSA



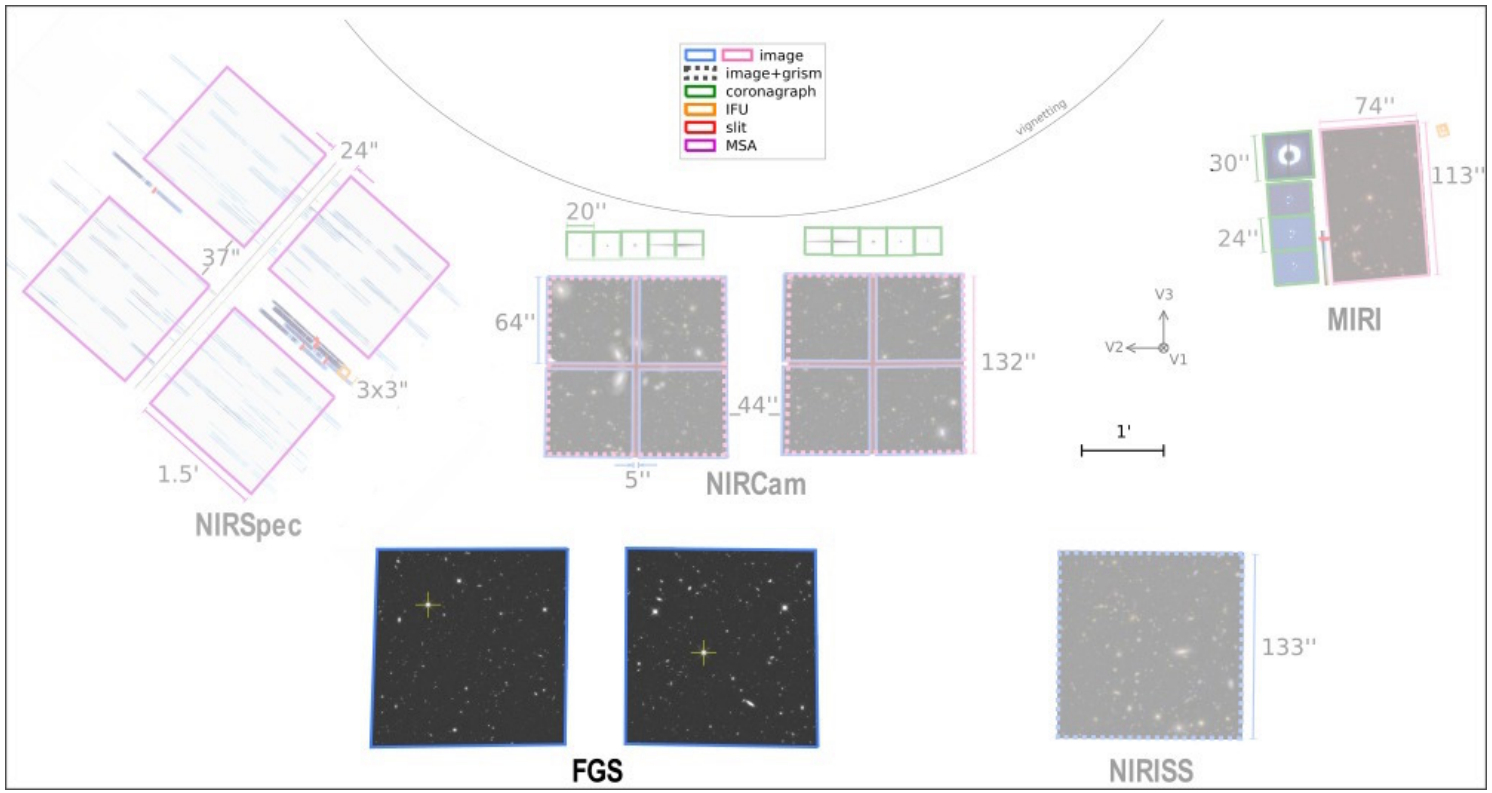




For comparison:
NIRCam SW pixel is 0.0317"

- ***"Nods"*** *(done mainly for background subtraction for compact sources)* ***allow some "wiggle room" for compromise w/NIRCam as parallel***
- ***Offering 2-pt and 3-pt dithers at each "nod" for 3 sub-pixel step sizes (plus "None"*** *as in* ***"no change to MOS setup")***

JWST Coordinated Parallels: Customized Dither Patterns

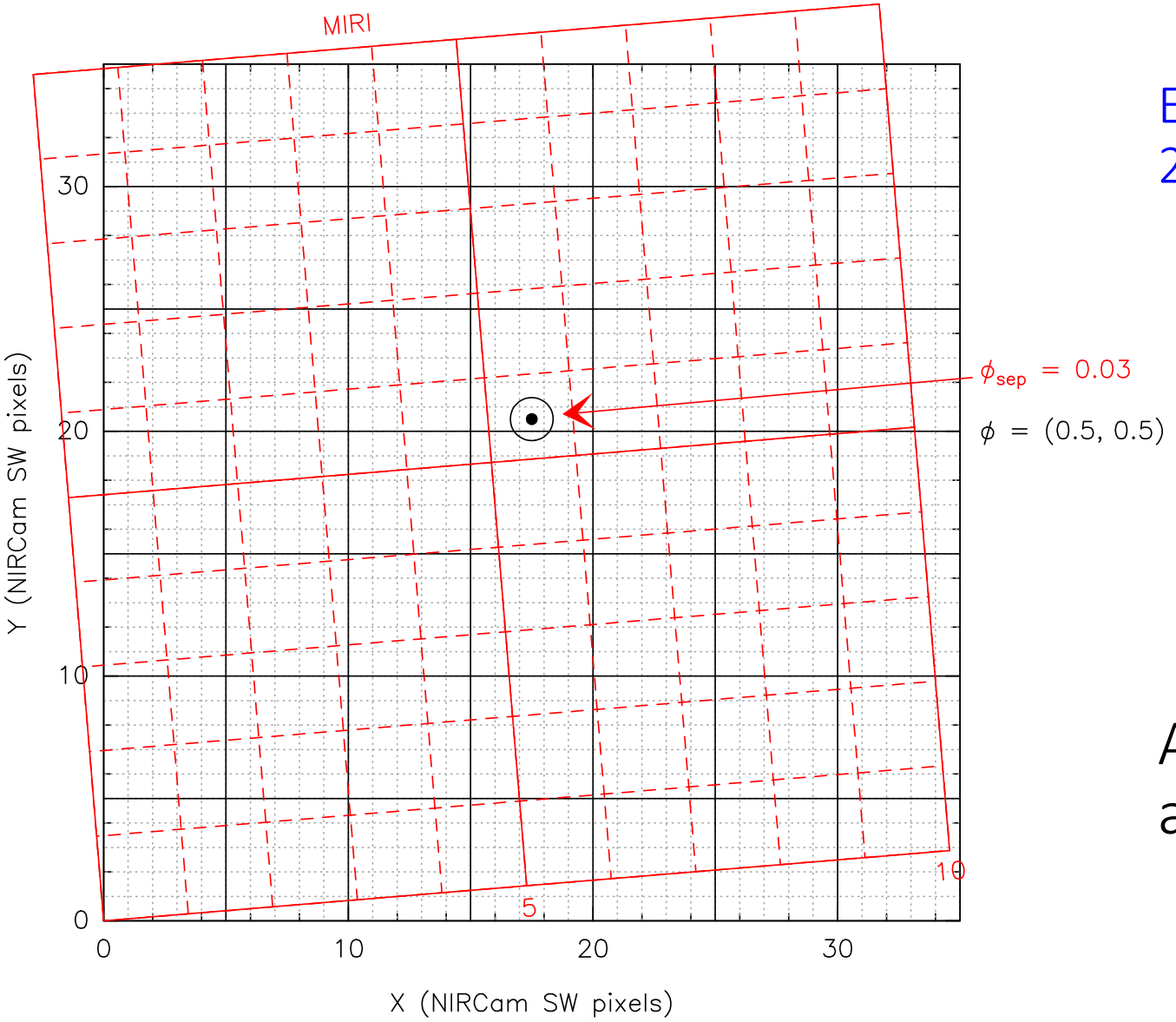


- Input parameters in determination of dithers for various combinations:
  - Pixel sizes
  - Mean angles of FOV w.r.t. (V2, V3) coordinate system (*determined from ground testing)*
  - PSF FWHM (mainly for MIRI; requirement is dither throw ≥ 3 × PSF FWHM)

JWST Coordinated Parallels: Customized Dither Patterns

- Approach:
  - MIRI, NIRCam, & NIRISS: Pixel phase sampling "ideal" for Prime SI, "close to ideal" for parallel SI
    - ✓ Define level of pixel phase mismatch φ_{sep} (= distance from ideal location in pixels)
    - ✓ For NIRCam & NIRISS combinations: *three dither step sizes (for three different typical target sizes)*
    - ✓ For combinations involving MIRI: *dither sizes provided for each (or almost each) MIRI filter*
      - ✓ This range of dither sizes will also allow one to select them based on *target* size (for extended targets)
  - NIRSpec MOS + NIRCam Imaging:
    - ✓ *Small sub-pixel dither patterns to be executed at each "nod" position*
    - ✓ *2-pt and 3-pt patterns, choice of 3 step sizes*
  - All: do not place dither within 2 pixels in X or Y from other dither in same pattern
  - In all cases, customized dither patterns are provided *in addition to* "normal" dithers/nods for prime SI

JWST Coordinated Parallels: Customized Dither Patterns



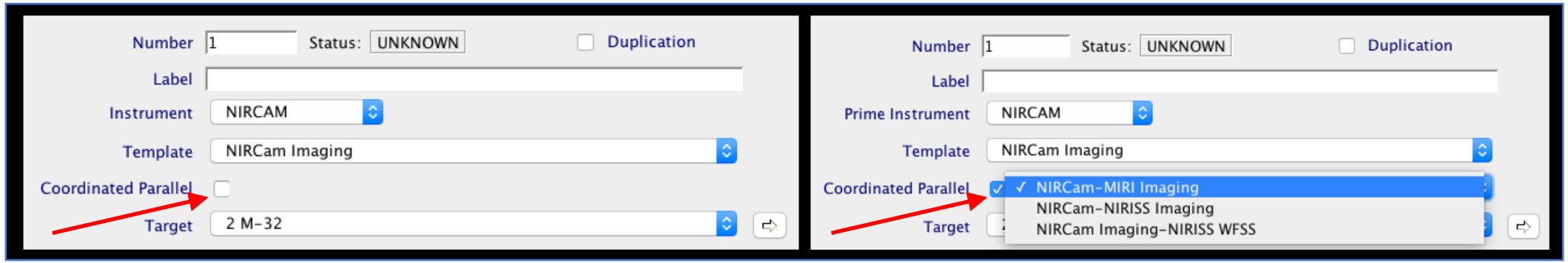
Example solution for NIRCam + MIRI/F560W 2-pt or 4-pt

- FOV orientations offset by ~5°
- $\varphi_{sep} < 0.05$ "when it counts" (i.e., NIRISS or MIRI @ < 10 µm as parallel)
- $\varphi_{sep} < 0.11$ when NIRCam [SW] is parallel
  - Still only 40% of JWST pointing uncertainty
- Compromise dithers typically have relatively large pixel offsets for NIRCam SW

All custom dither patterns described and available on JDox

JWST Coordinated Parallels: APT implementation

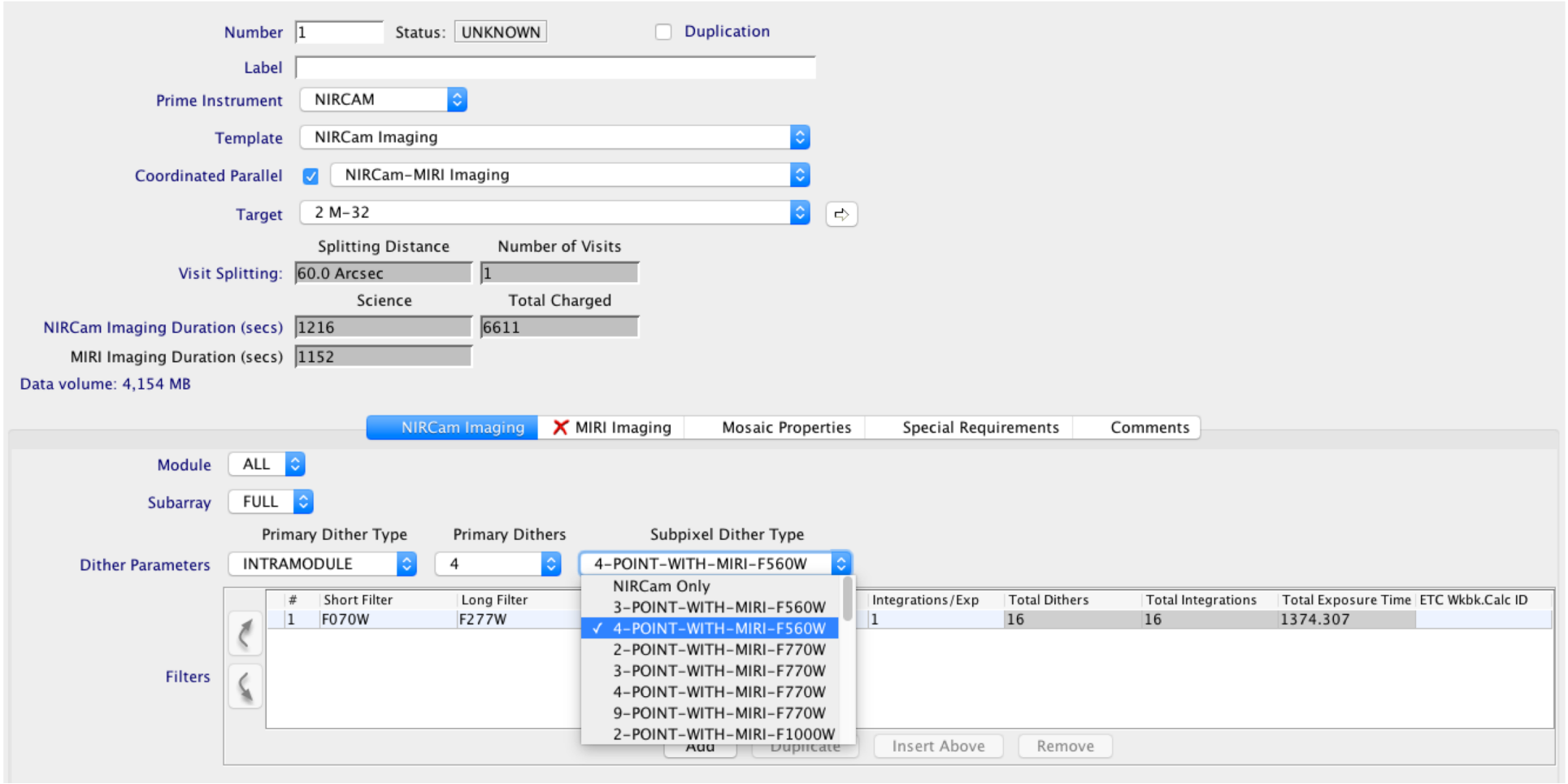
- Coordinated Parallel option appears in appropriate templates; combo options come up



Ref no.	Template combination	Comments
1	MIRI Imaging – NIRCam Imaging	Either can be primary
2	NIRCam Imaging – NIRISS WFSS	Either can be primary
3	MIRI Imaging – NIRISS WFSS	Either can be primary
4	NIRSpec MOS – NIRCam Imaging	NIRSpec MOS must be primary
5	NIRCam Imaging – NIRISS Imaging	NIRCam must be primary

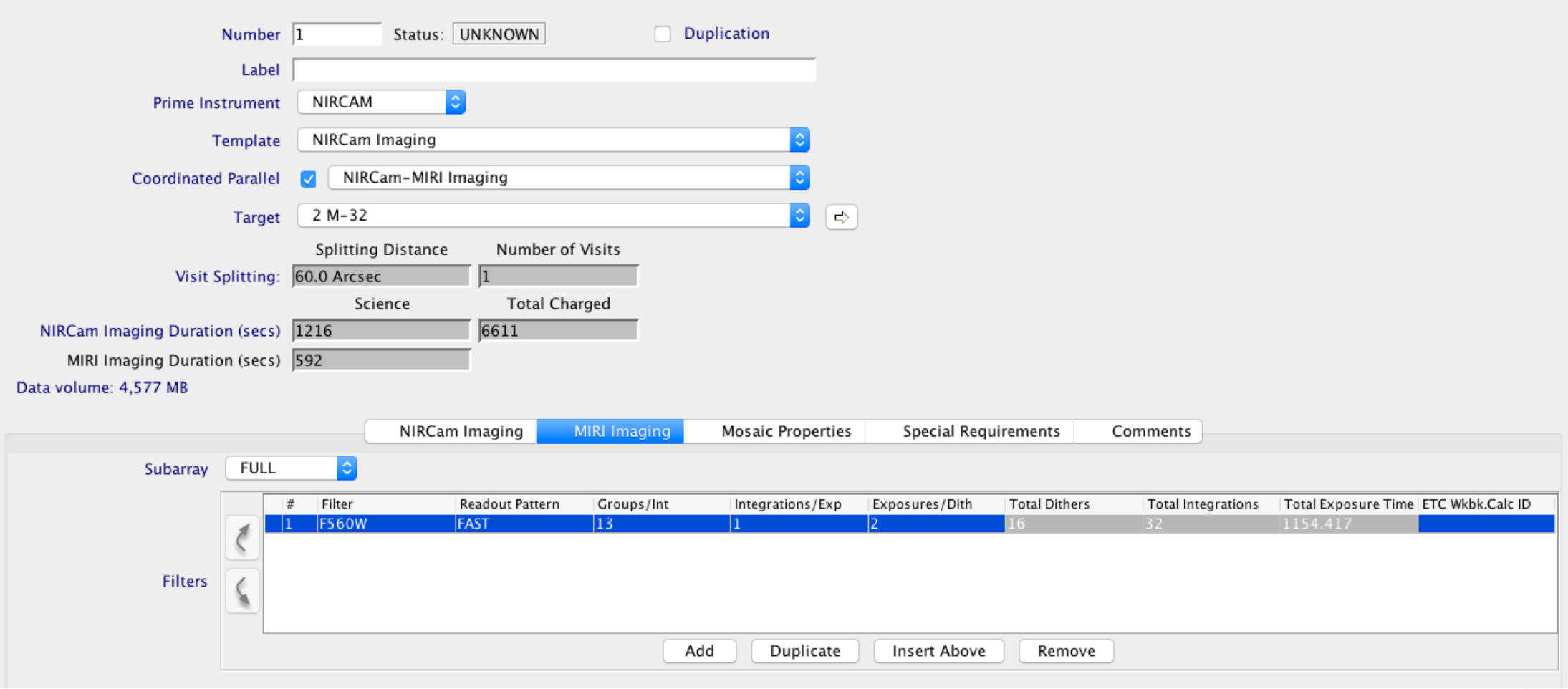
JWST Coordinated Parallels: APT implementation

- Template then adds second tab for the parallel SI mode; custom dithers added to prime template



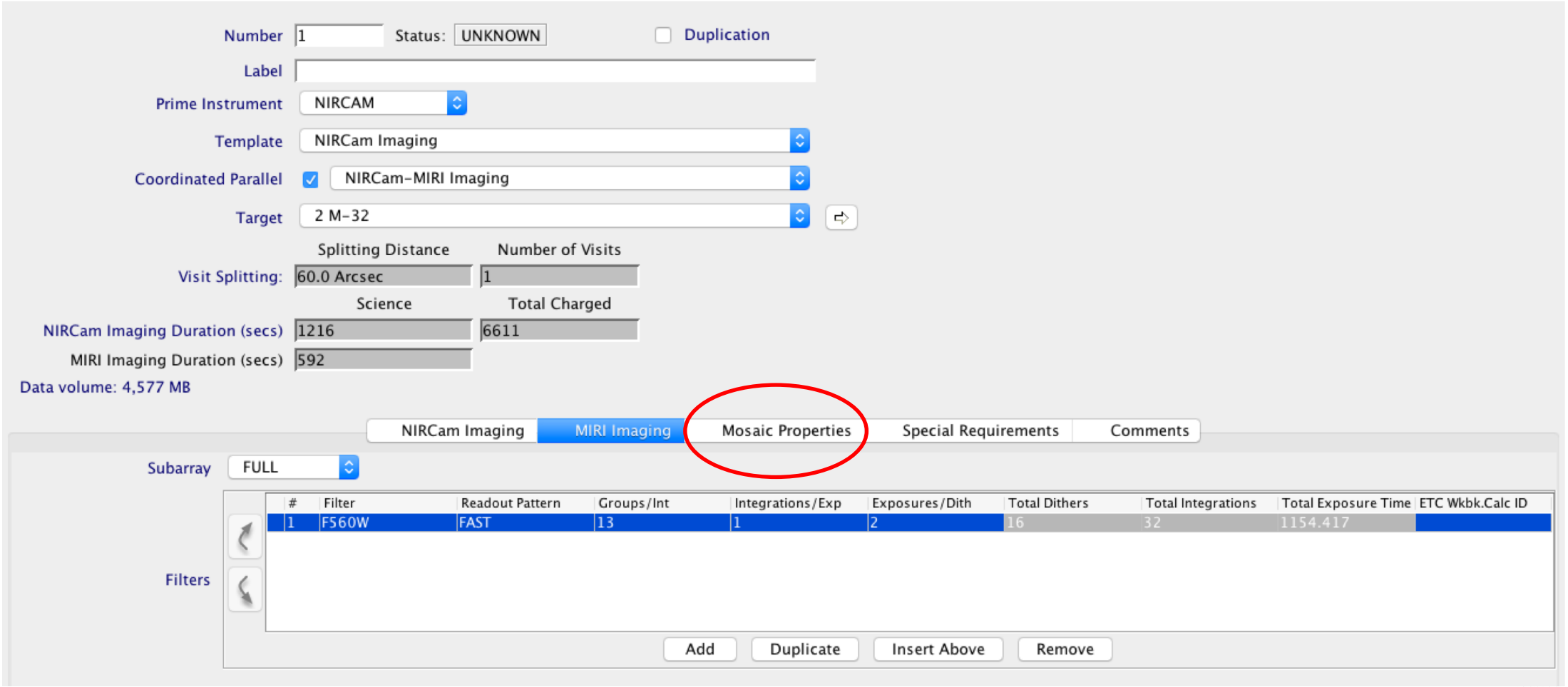
JWST Coordinated Parallels: APT implementation

- Parallel SI mode shows up as usual *but without dither interface*
  - *Exposure duration must be ≤ that of prime SI*



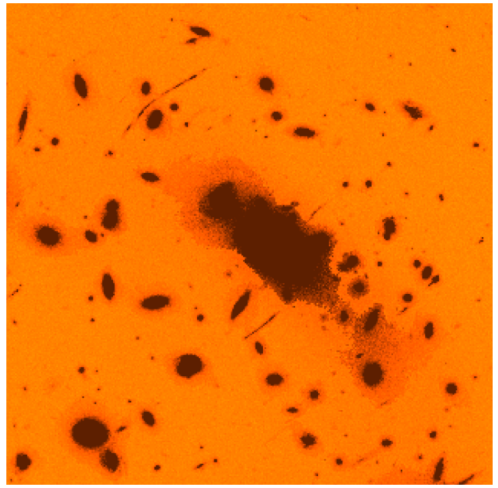
JWST Coordinated Parallels: APT implementation

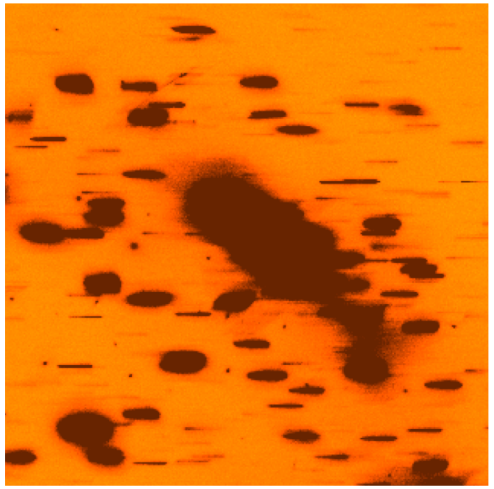
- *Mosaic Properties* tab unchanged from "normal" templates (w/o coordinated parallels)
  - *Mosaics can be relevant for parallels involving NIRCam Imaging, e.g., to cover gaps between detectors.*



JWST Coordinated Parallels: APT implementation

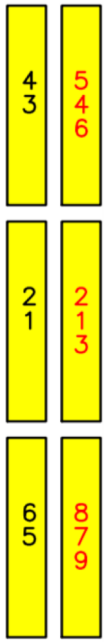
- Special Case #1: Coordinated Parallels with NIRISS/WFSS
  - NIRISS/WFSS exposure specification results in 3 “activities”:
    1. Direct image at first dither position
    2. Grism exposures (one at each dither position)
    3. Direct image at last dither position
  - Thus, each NIRISS/WFSS exp. spec needs to be accompanied by ***3 exp. spec’s of the other SI***
    - *Even when NIRISS/WFSS is the parallel SI mode (!)*
    - Breaks paradigm of “parallel SI shall not influence prime SI”
    - But: Only way to implement NIRISS/WFSS in current APT architecture
  - Created dedicated, illustrated JDox article on how to set up NIRISS/WFSS as Coordinated Parallel
  - We will cover the opposite-but-similar case of NIRISS/WFSS as Prime with NIRCam Imaging as Coordinated Parallel in this Class





JWST Coordinated Parallels: APT implementation

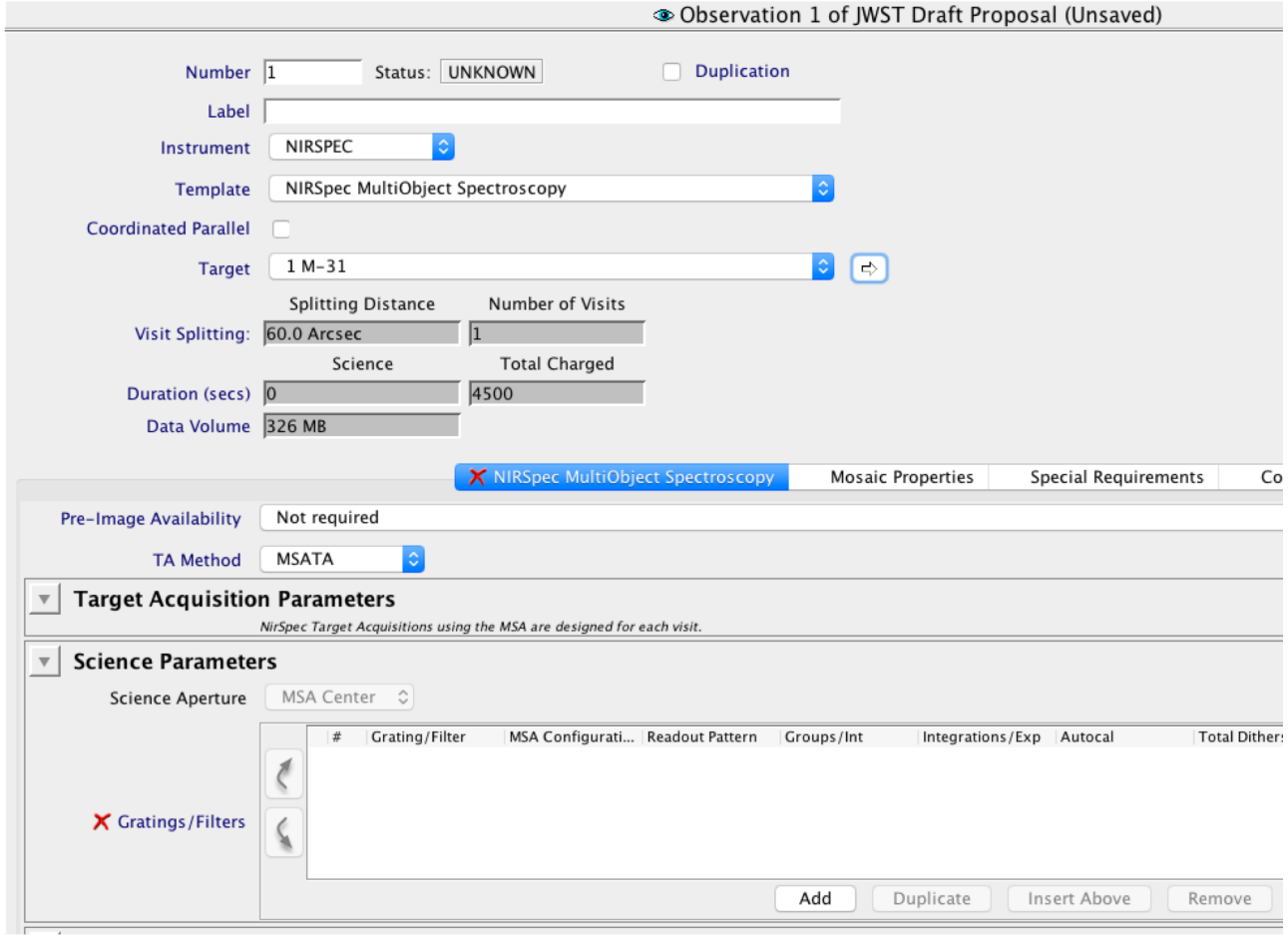
- Special Case #2: NIRSpec MOS + NIRCam Imaging
  - Small sub-pixel dither patterns to be executed at each “nod” position (i.e., MSA shutter)
  - 2-pt and 3-pt patterns, choice of 3 step sizes (10, 15, 20 mas/step – can be executed while guiding!)

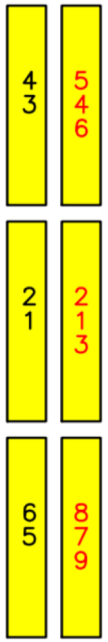


Shutters:
0.2” × 0.46”

JWST Coordinated Parallels: APT implementation

- Special Case #2: NIRSpec MOS + NIRCam Imaging
  - Small sub-pixel dither patterns to be executed at each “nod” position
  - 2-pt and 3-pt patterns, choice of 3 step sizes (10, 15, 20 mas/step – can be executed while guiding!)

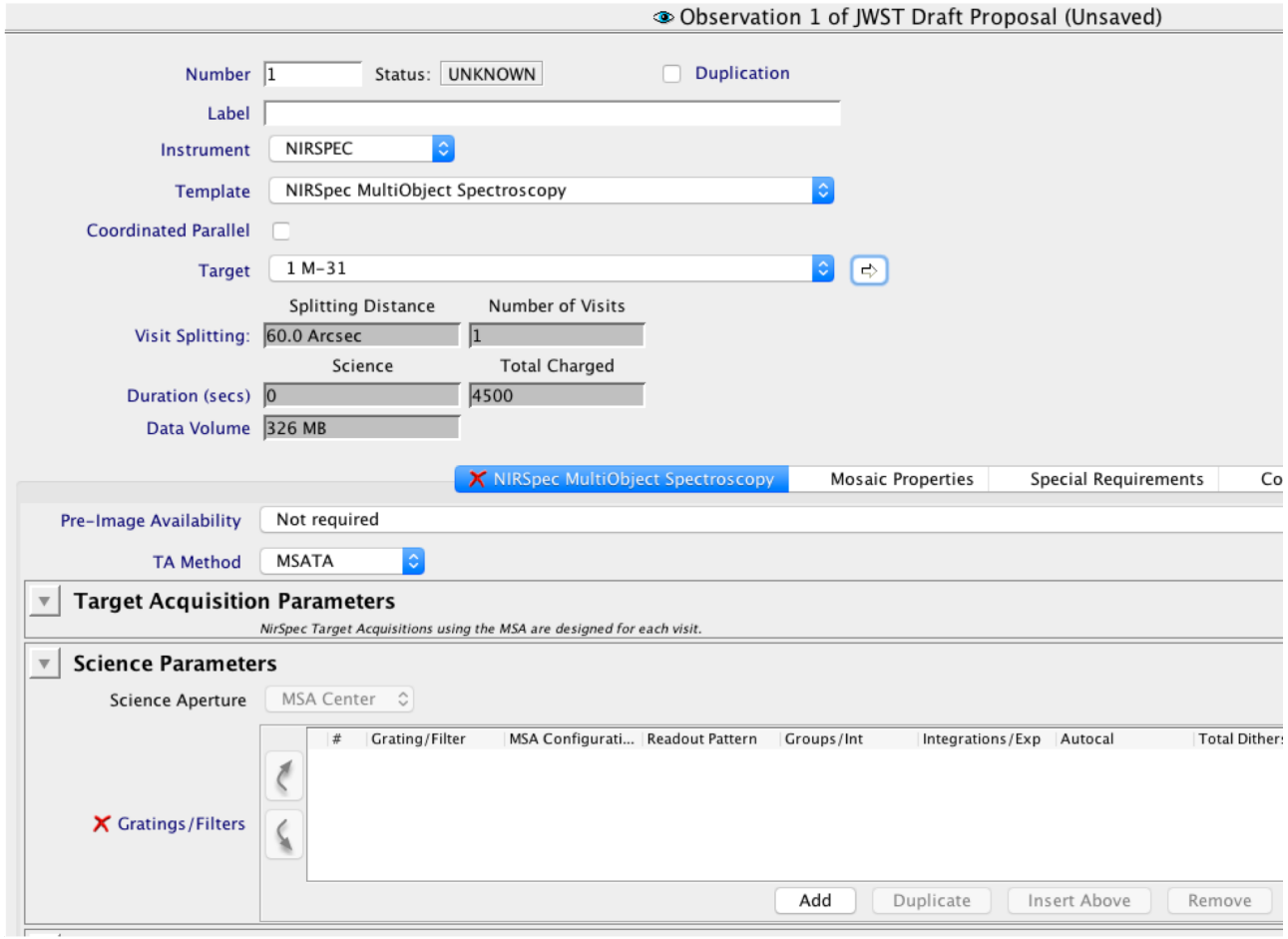


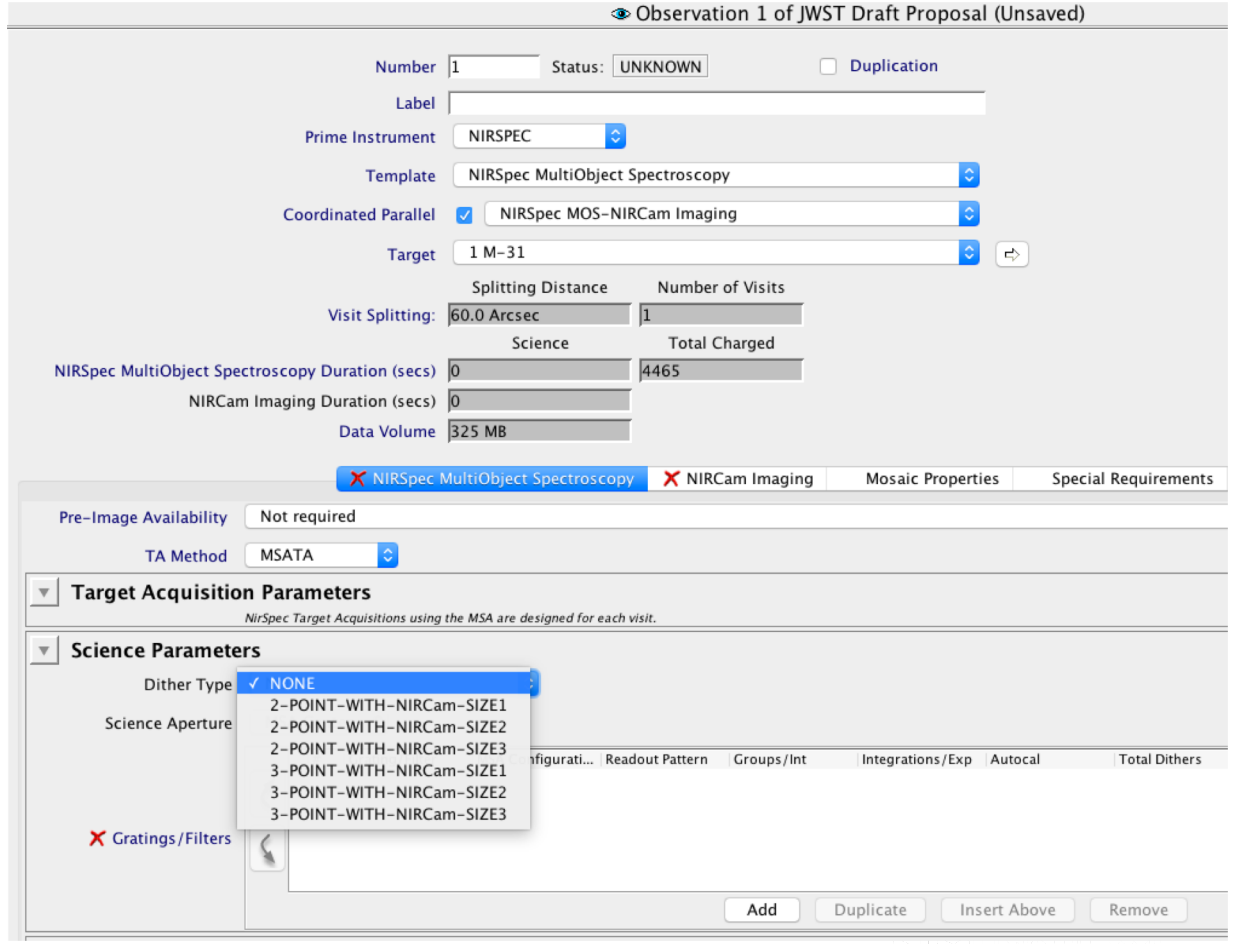


Shutters:
0.2” × 0.46”

JWST Coordinated Parallels: APT implementation

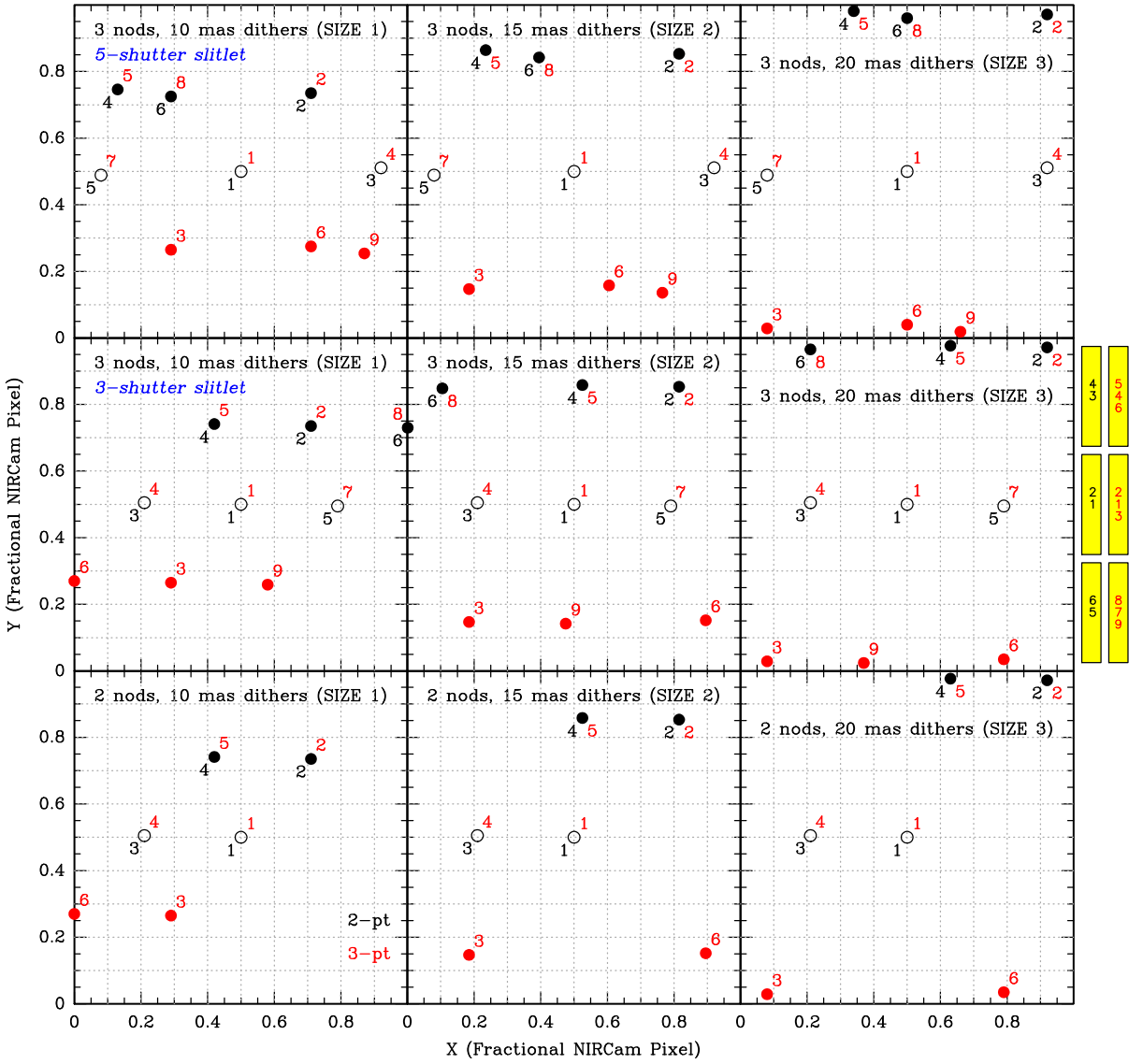
- Special Case #2: NIRSpec MOS + NIRCam Imaging
  - Small sub-pixel dither patterns to be executed at each “nod” position
  - 2-pt and 3-pt patterns, choice of 3 step sizes (10, 15, 20 mas/step)





JWST Coordinated Parallels: Custom Dither Patterns

Dithers for NIRSpec MOS + NIRCam Imaging



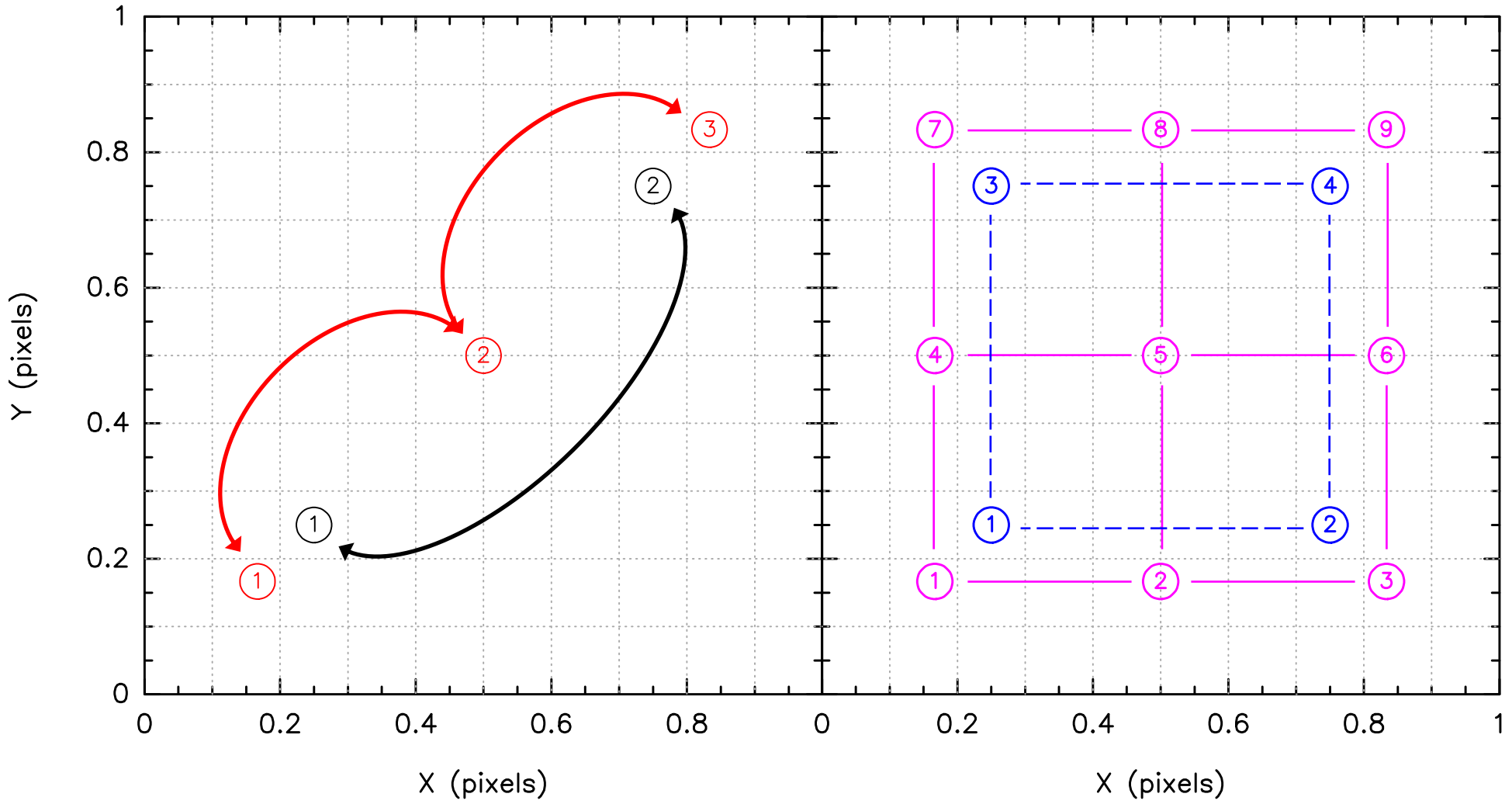
JWST Coordinated Parallels: Exercises

- Refer to Exercise handout
  - Contain steps to guide work
  - Hyperlinks to JDox articles at end of each exercise
- Exercise #1: NIRCam Imaging + MIRI Imaging
  - “Deep Field” imaging program (GOODS-South) using 2 sets of filters (SW/LW)
  - Adjusting mosaic to make MIRI parallels (with 2 filters) cover a contiguous area
- Exercise #2: NIRISS WFSS + NIRCam Imaging
  - Slitless spectroscopy of center of HST Frontier Field galaxy cluster (using 3 filters & 2 grisms)
  - Multi-filter NIRCam parallels to find candidate high-z emission-line galaxies

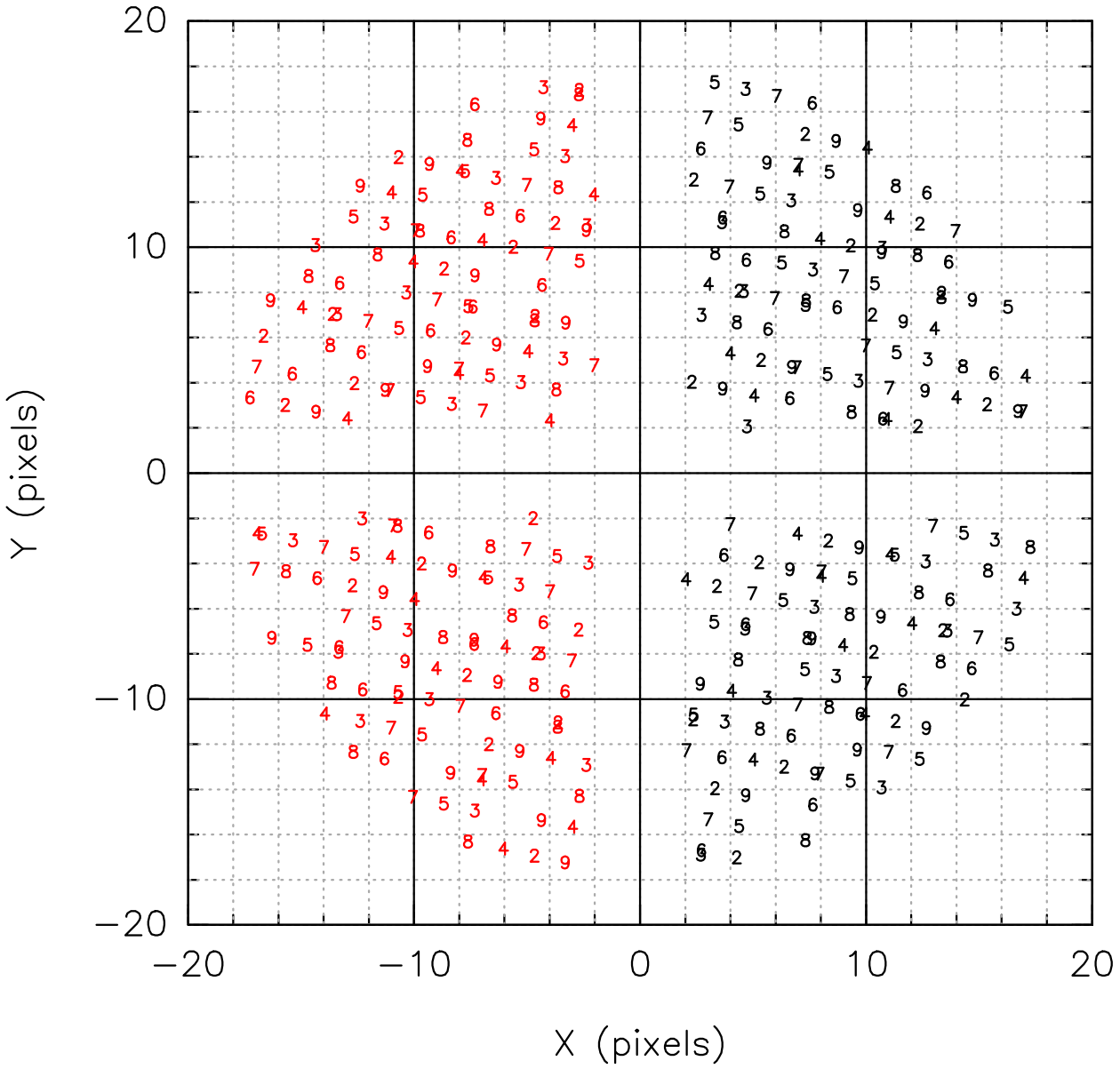
Backup Slides

JWST Coordinated Parallels: Custom Dither Patterns

“Optimal” dither positions (pixel phases)



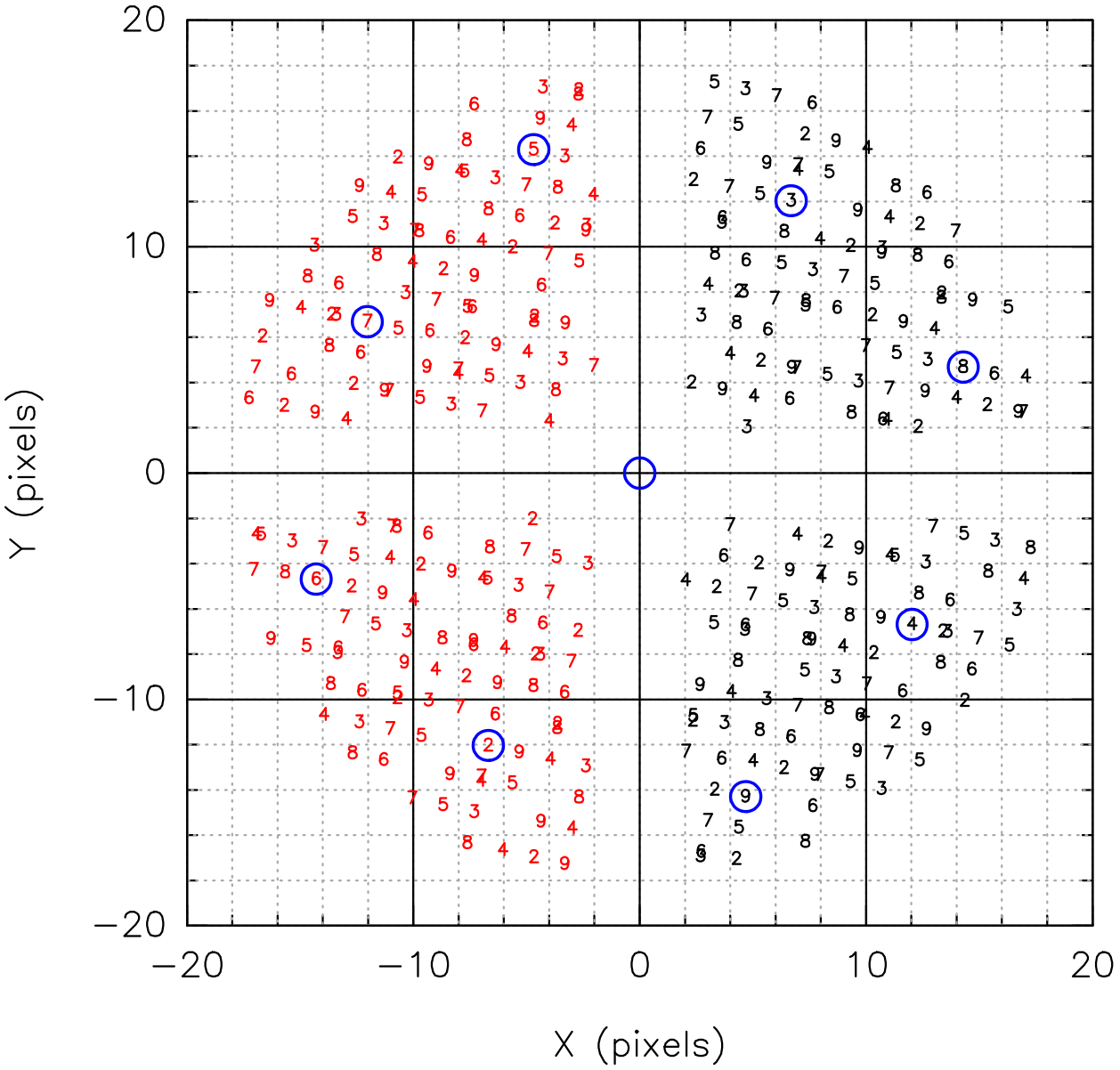
JWST Coordinated Parallels: Custom Dither Patterns



NIRISS + MIRI/F560W 9-pt

- $\varphi_{sep} < 0.05$
- 0.33 ≤ Radius/arcsec ≤ 2.0

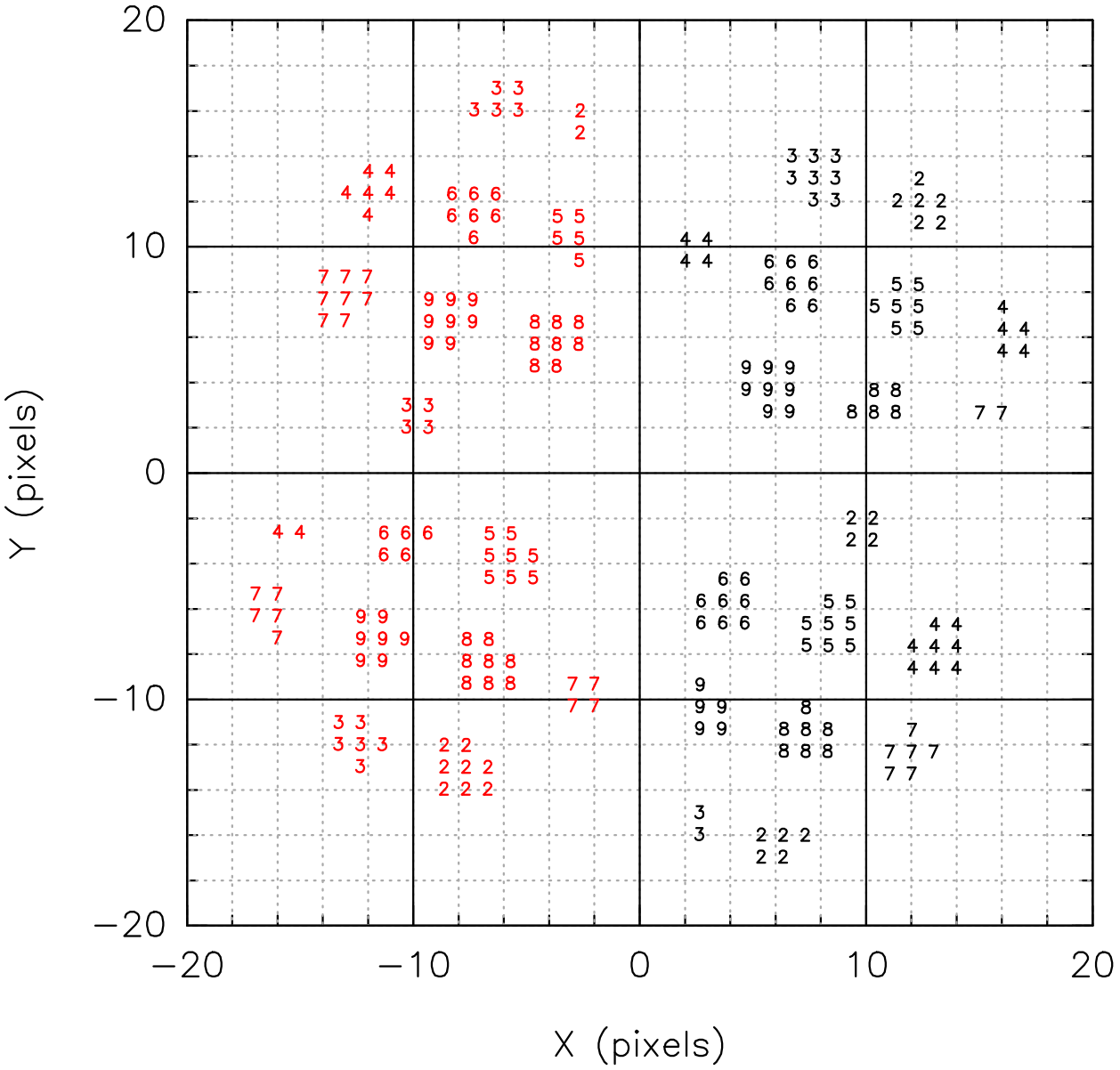
JWST Coordinated Parallels: Custom Dither Patterns



NIRISS + MIRI/F560W 9-pt

- $\varphi_{sep} < 0.05$
- 0.33 ≤ Radius/arcsec ≤ 2.0
- ΔX, ΔY ≥ 2 pixels from all other dithers
- Radius ≥ 0.33 arcsec from all other dithers

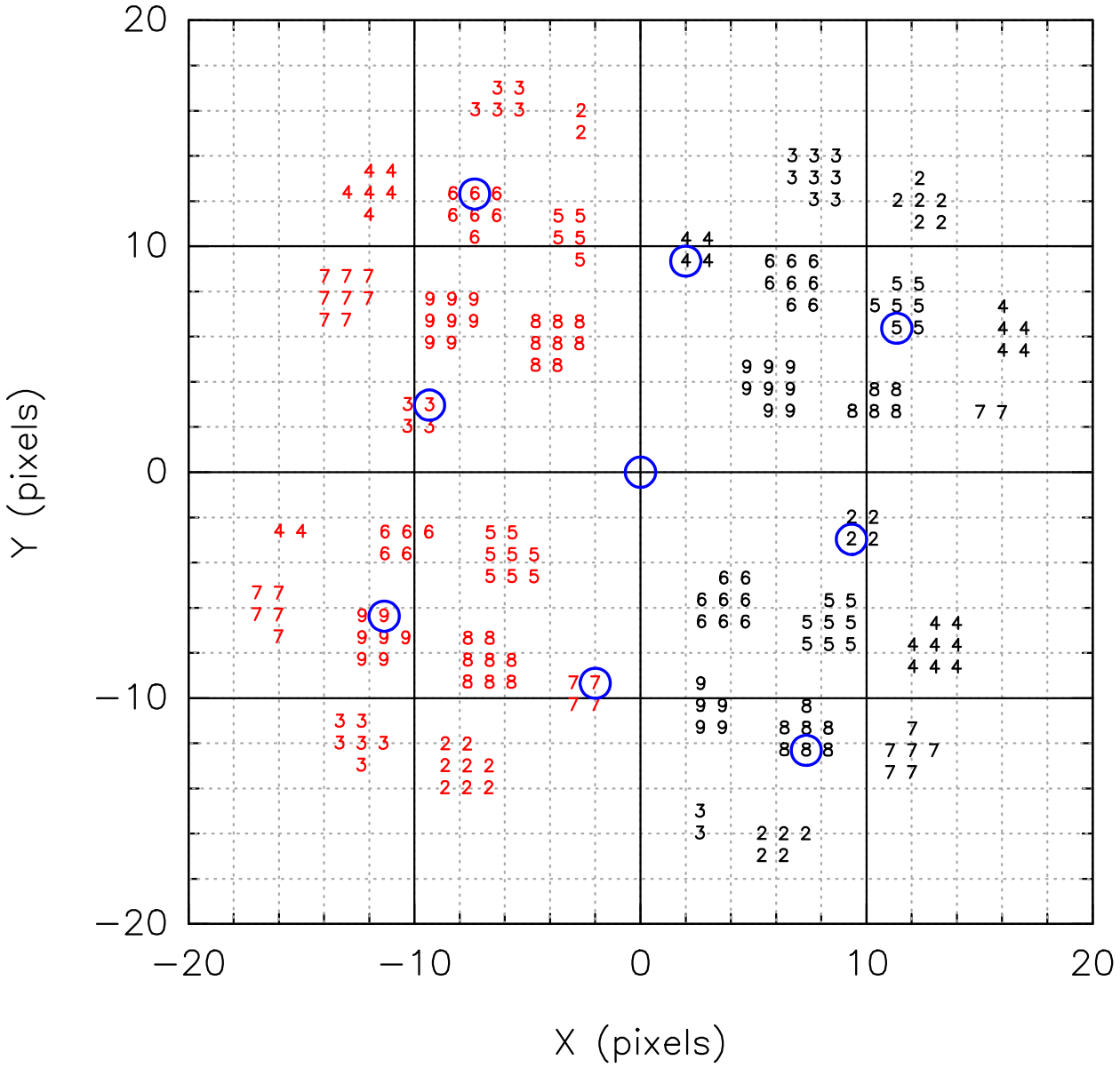
JWST Coordinated Parallels: Custom Dither Patterns



NIRCam SW + NIRISS 9-pt (medium throws)

- $\varphi_{sep} < 0.05$
- 0.2 ≤ Radius/arcsec ≤ 1.2

JWST Coordinated Parallels: Custom Dither Patterns



NIRCam SW + NIRISS 9-pt (medium throws)

- $\varphi_{sep} < 0.05$
- 0.2 ≤ Radius/arcsec ≤ 1.2
- ΔX, ΔY ≥ 2 pixels from all other dithers
- Radius ≥ 0.2 arcsec from all other dithers

JWST Coordinated Parallels: Custom Dither Patterns

- Wishes / aims
  - Pixel phase sa
  - Dither step siz
  - Choice of dith
  - However, scie
- Approach:
  - MIRI, NIRCam,
    - ✓ Introduce l
    - ✓ For NIRCa
    - ✓ For combi
  - NIRSpec MOS
    - ✓ *Sub-pixel d*
    - ✓ *Small 2-pt*

ed)

nearby galaxies)

NIRSpec MOS)

eal" for parallel SI

s

typical target sizes)

IRI filter

step sizes