STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

Planning MOS Observations

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Gary Curtis and the team of APT developers

JWST Master Class
November 2019

The MOS Observing Process

Multi-Step Process

To accurately align science sources within the small 0.2" × 0.46" MSA shutters, NIRSpec MOS mode observations must be planned and executed at a fixed instrument aperture position angle (APA), assigned by STScI.

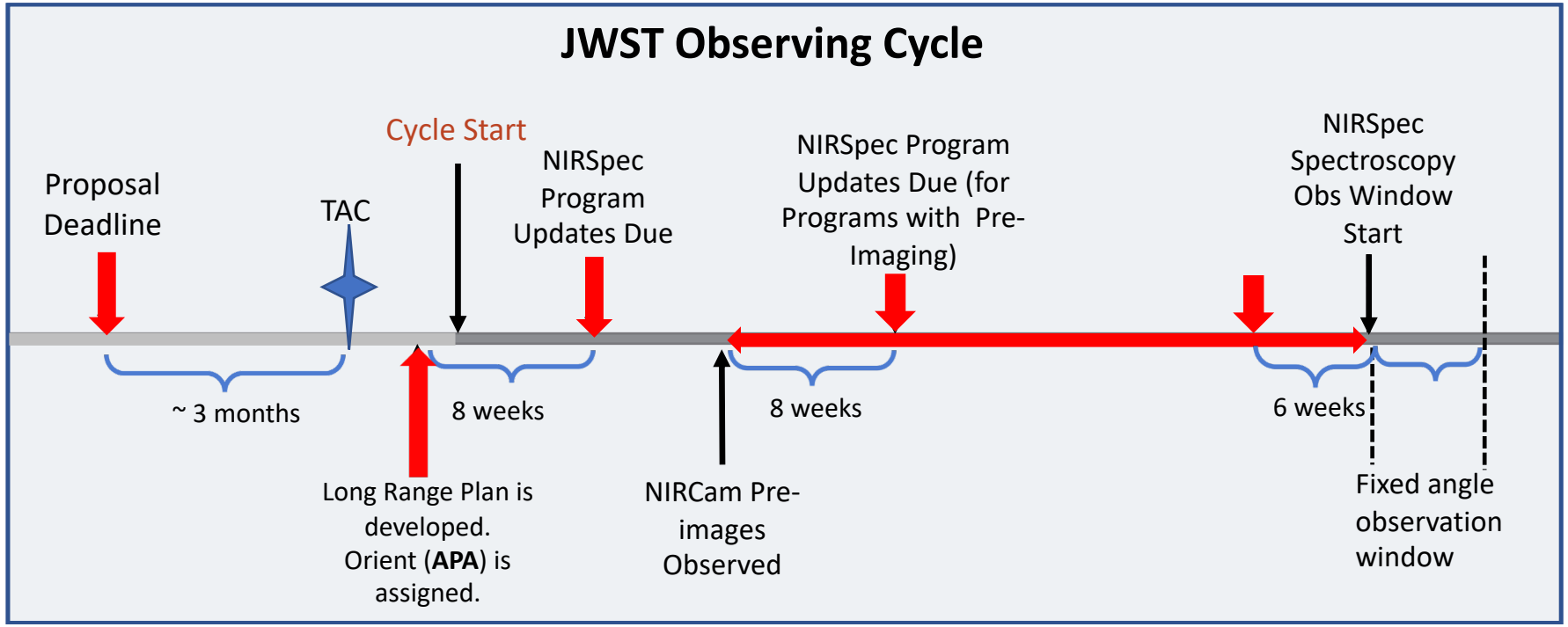
NIRSpec MOS observers must follow a multi-step planning process.

For the Proposal deadline, MPT should be used to create placeholder visits to accurately estimate the overheads for the strategy used.

After the TAC, an APA will be assigned by STScI.

Flight ready programs using MPT are due 8 weeks after the APA is assigned (if there is no NIRCam pre-imaging)

If NIRCam pre-imaging is requested, flight ready program updates are due 8 weeks after the NIRCam pre-imaging is observed.



For best success, users should consider placing their NIRCam pre-imaging and NIRSpec observations in different visibility windows (in Cycle 1) to allow for enough time to reduce and analyze the NIRCam astrometry.

When that's not possible, program updates will be due a min of 6 weeks in advance of the NIRSpec observation window.

Positional Accuracies, Target Acq, and Pre-imaging

Positional Accuracies

Does your science require accurate astrometry delivered by MSATA (using reference stars)?
Note that TA accuracy depends on input Catalog relative astrometric accuracy

TA Type	Delivered Pointing Accuracy	Catalog Relative Accuracy	Science Goal
Optimal (MSATA)	20 - 25 mas (20 mas is 1/10th shutter)	5 - 15 mas (HST: ~ 10 mas is possible. NIRCam: 5 mas is the goal)	Best possible photometric accuracy
Relaxed (MSATA)	< 50 mas	< 40 mas	Extended sources, or reduced flux accuracy w/ MSA
VERIFY_ONLY	~ 100 mas (TBD)	No ref stars required	Special cases – extended source

If accurate astrometry is required, and if HST imaging does not exist – request NIRCam pre-imaging in your Proposal

Target Acquisition Options

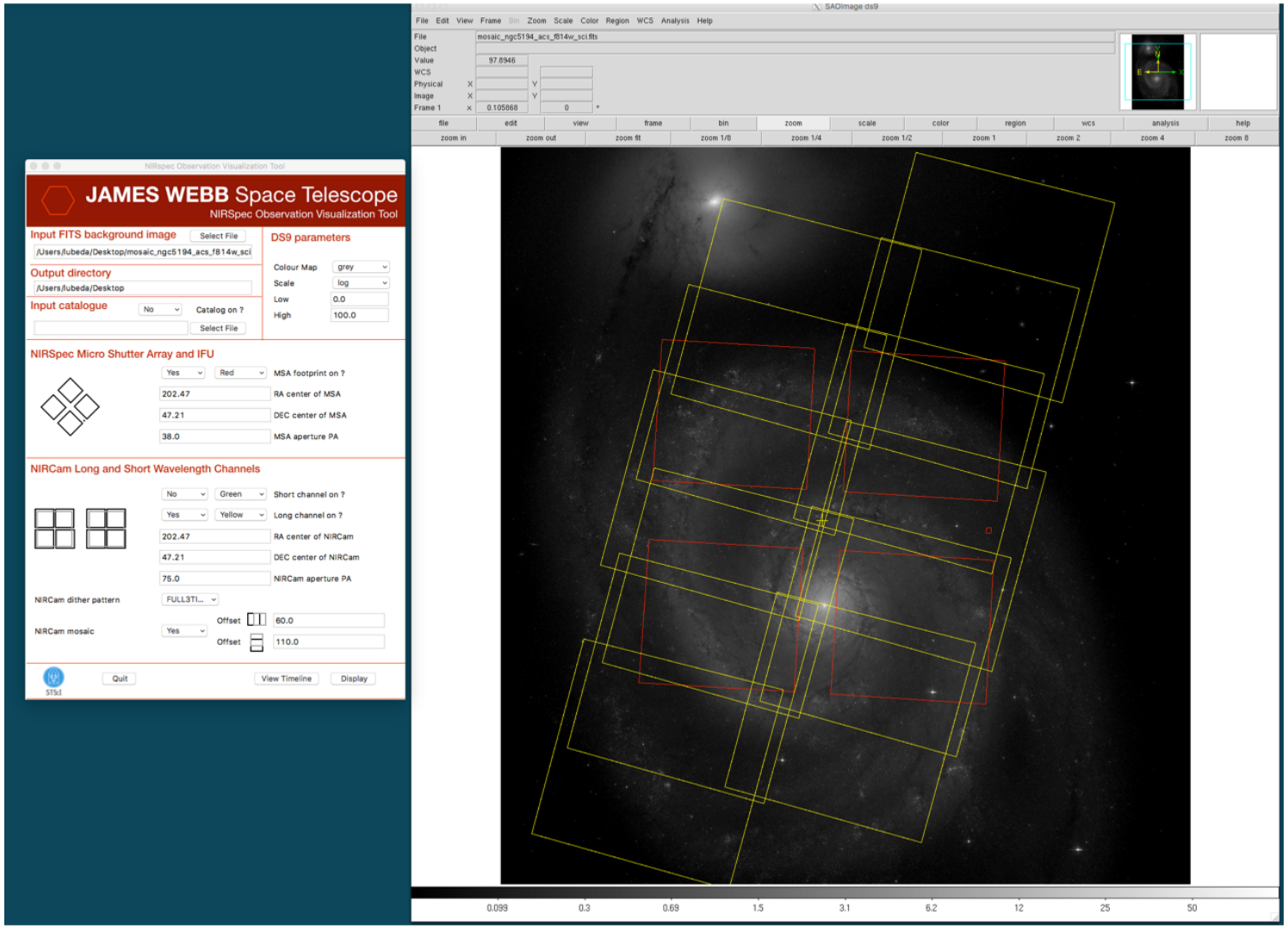
- **Moving targets** cannot use MSATA – **use WATA** instead. WATA does not require pre-imaging, only a good ephemeris.
- For **Program Updates** - **MPT will be used to select reference stars** at the assigned APA that will not be behind MSA bars or in failed shutters. This vetting is done at the Visit level at the first pointing.
- **MSATA** requires defining 5-8 reference stars. Programs using MSATA will be charged a **fixed overhead** equivalent to an average charge for 8 reference stars.
- **8 reference stars** have been determined to be optimal – tradeoffs between increased accuracy and overheads. Will be adjusted if needed. Can be increased with permission.

Pre-imaging with NIRCam

- Is imaging available that is
  - **deep enough** to identify interesting sources,
  - **wide enough** to plan ref stars, and
  - **accurate enough** to plan MOS observations?
- If not – request **NIRCam pre-imaging** in your initial Proposal submission
- If pre-imaging is needed: Coverage should be large enough to **allow for any APA** for NIRSpec obs: Ideally 5 x 5 arcmin: typically 2x1 mosaic + dithers to cover the gaps
- **NIRCam observations must be flight ready at proposal submission.**
- Pre-imaging in the **same cycle** is possible. **Program is due a minimum of 6 weeks before NIRSpec observations.**

[Video help available]

NIRSpec Observation Visualization Tool (L. Ubeda)

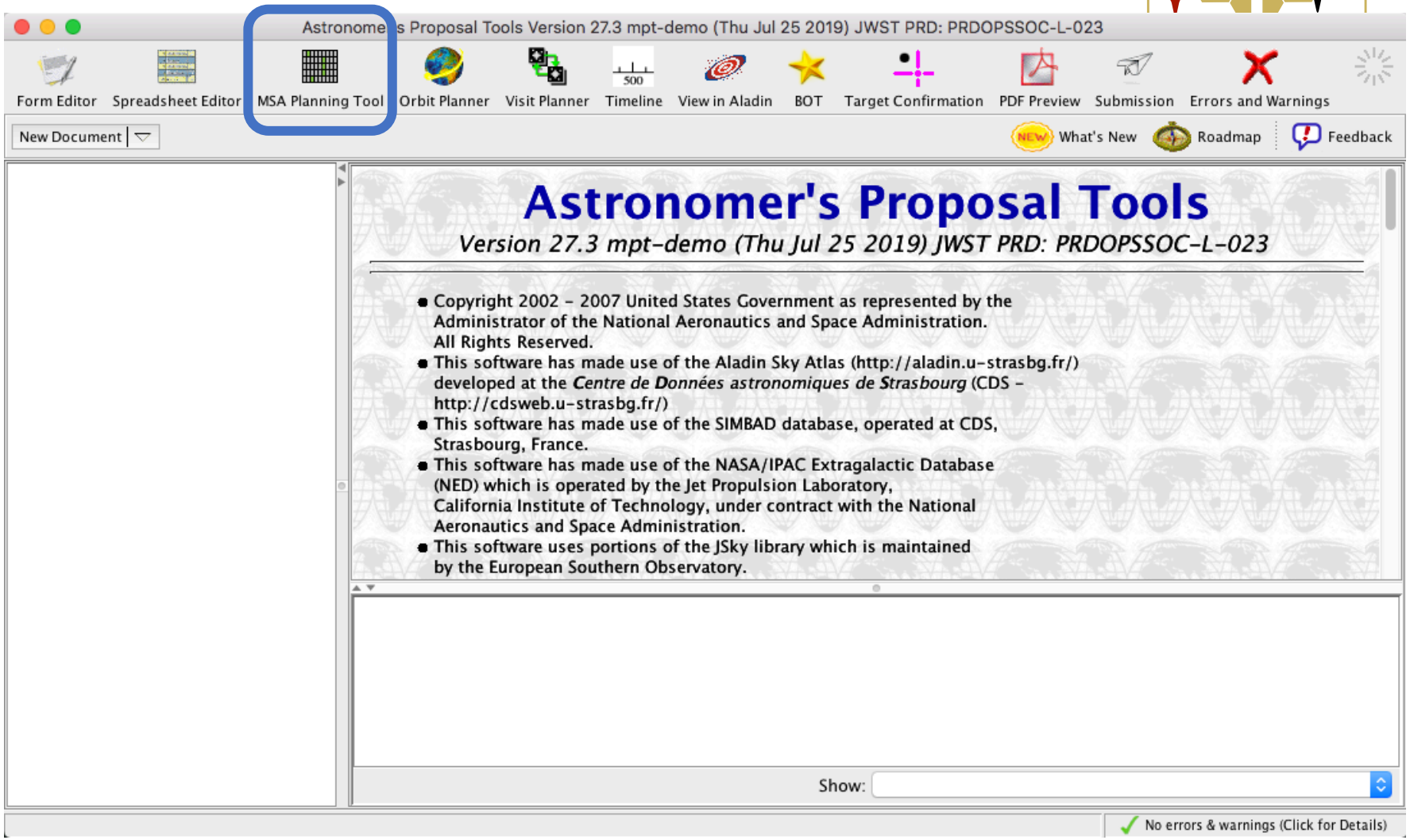


The MSA Planning Tool in APT

MSA Planning Tool (MPT)

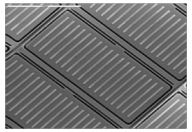
MOS Observing Mode

- NIRSpec MOS observing mode can collect spectra of tens to hundreds objects within a 3.6’ x 3.4’ FoV at the same time.
- The **MPT** has been designed to align science sources with the very small 0.2” x 0.46” shutters



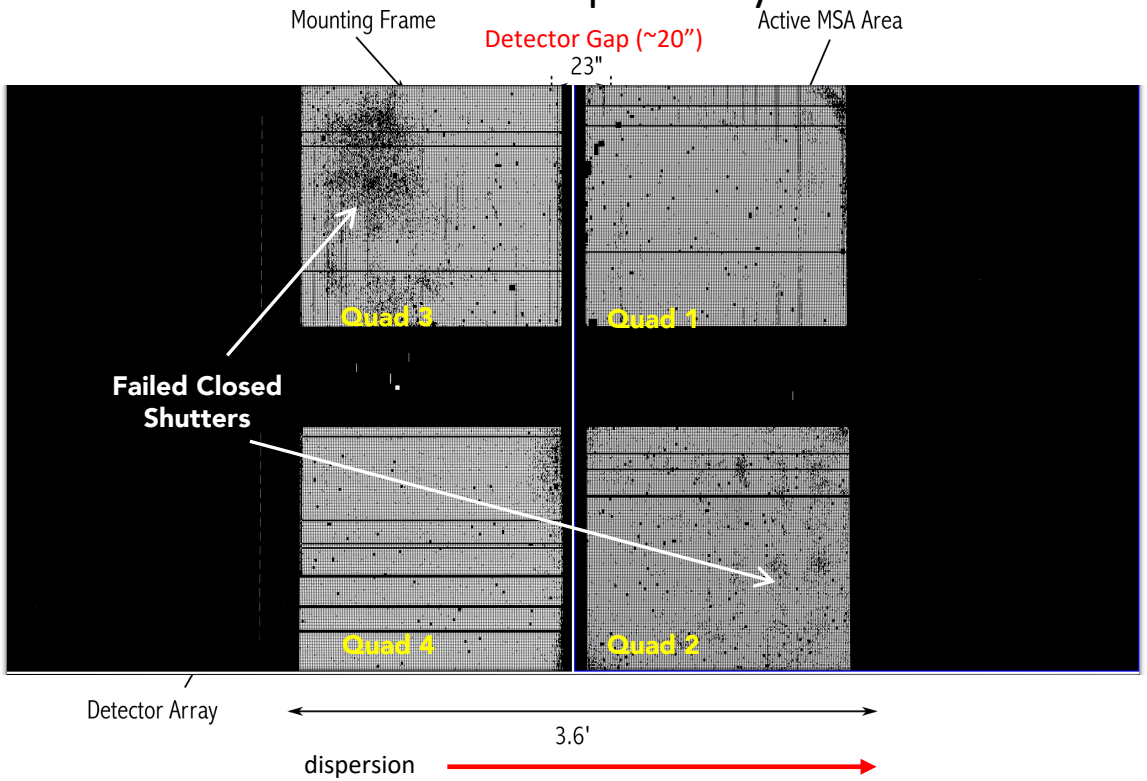
Why Use MPT?

- The MSA is a **fixed grid** (with bars that vignette light from sources behind them)



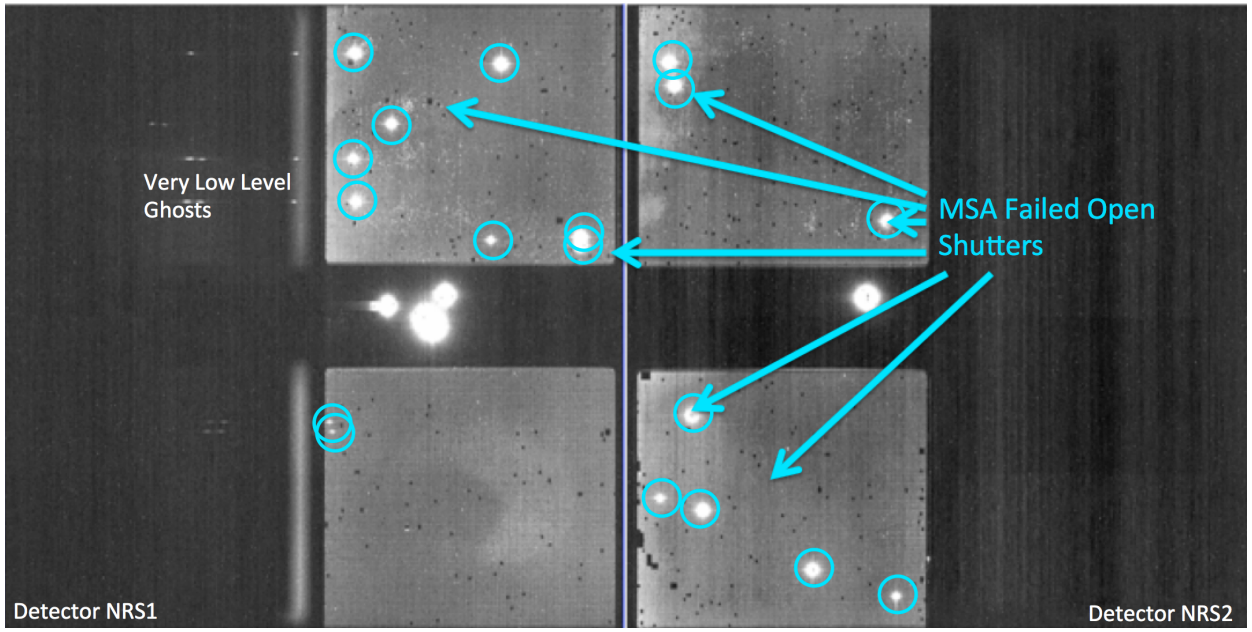
- There is a **gap** between the 2 detectors → missing wavelengths.

Shutter Operability



- The MSA has **Failed shutters, shorted rows/columns**. Shutter status evolves! MPT plans using the most up to date operability.
- Source positions in MSA require knowledge of **optical distortions/ velocity aberrations** at a planned Aperture Position Angle.

MSA failed open shutters



MSA Planning Tool Inputs/Outputs

- Internet connection to run MPT – to access the most up to date MSA shutter operability
- A complete and accurate astrometric **Catalog**
- Accurate source positions (< 15 mas relative accuracy) – Pre-Imaging with NIRCam?

- MOS Observations: Pointings, MSA configurations, Target Sets

The Source Catalog

Source Catalog

The first step to create a NIRSpec MOS observation is to create a complete catalog of sources.

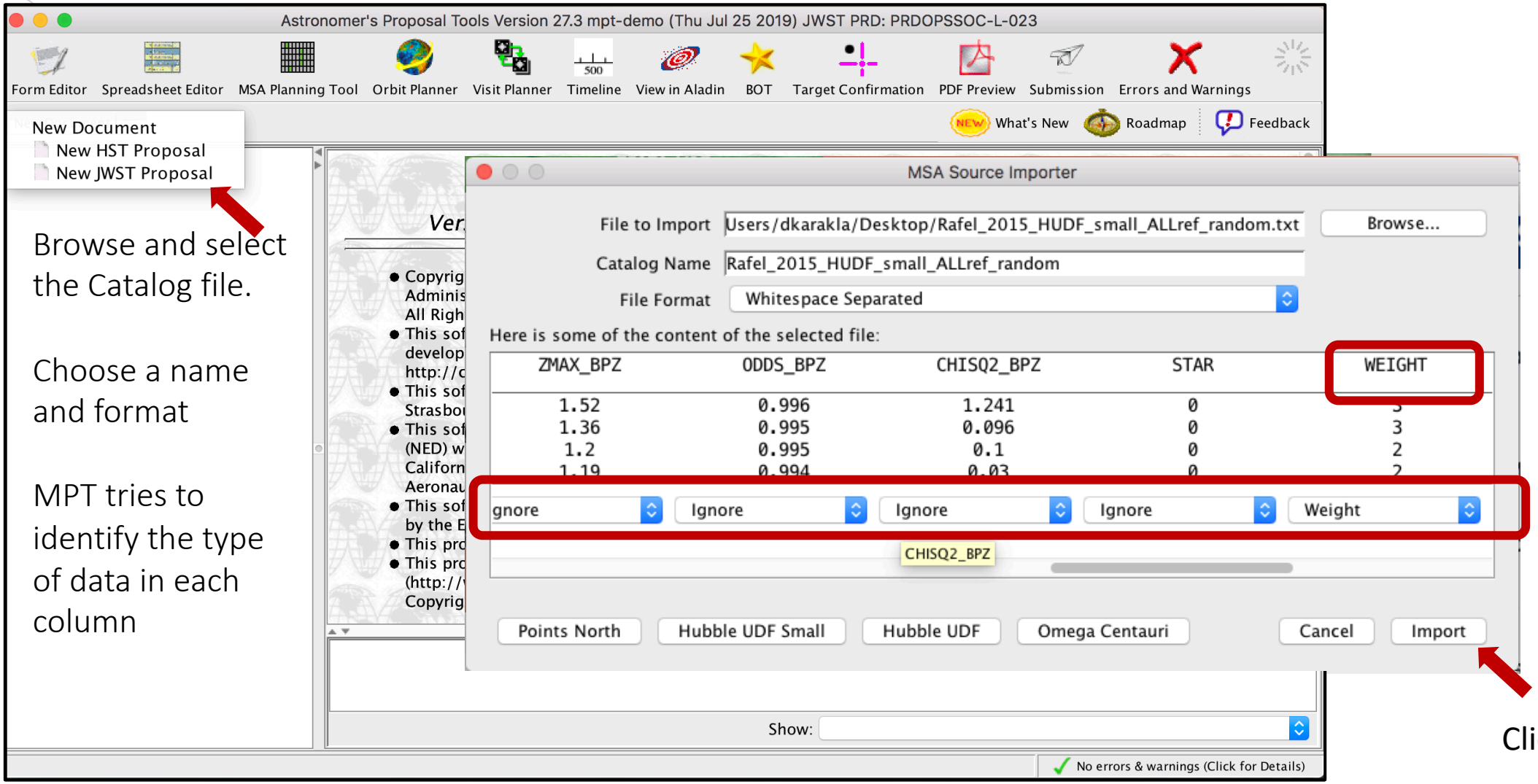
- The source catalog is an **ASCII file**
- It **MUST** contain J2000 **Ra and Dec** expressed in degrees or hexadecimal units
- It **CANNOT** have **duplicate IDs nor NULL entries**
- Fluxes or magnitudes for the sources help (but are optional at submission.)
- Target weights help (but are optional).
- Optional header. The header is marked with "#"

ID	RA	DEC	Size	Redshift	Reference	Stellarity	MAG_F160W	NRS_F110W	NRS_F140X	NRS_CLEAR	W
23796	03 32 39.0842	-27 46 1.79	0	1.415	Yes	0.92	20.122	20.674	20.366	20.122	
54454	03 32 35.5075	-27 46 26.13	0	1.268	Yes	0.03	20.384	20.845	20.474	20.384	
22410	03 32 39.8827	-27 47 15.06	0	1.107	Yes	0.03	20.711	21.199	20.786	20.711	
24439	03 32 37.1930	-27 46 8.08	0	1.101	Yes	0.03	19.494	20.254	19.672	19.494	
23546	03 32 38.4836	-27 47 2.42	0	0.919	Yes	0.03	20.088	20.785	20.261	20.088	
21268	03 32 42.4216	-27 47 58.80	0	0.779	Yes	0.94	17.811	18.026	-99	17.811	
22990	03 32 38.7749	-27 47 32.14	0	0.767	Yes	0.03	20.286	20.695	20.415	20.286	
21840	03 32 37.3079	-27 47 29.36	0	0.708	Yes	0.03	18.793	19.473	18.966	18.793	
22951	03 32 40.6729	-27 47 30.99	0	0.692	Yes	0.03	20.163	20.839	20.34	20.163	
24350	03 32 38.4386	-27 46 31.90	0	0.69	Yes	0.03	20.68	21.324	20.855	20.68	
24353	03 32 38.5957	-27 46 31.36	0	0.663	Yes	0.03	20.768	21.177	20.893	20.768	
21298	03 32 39.2188	-27 47 58.36	0	0.662	Yes	0.03	19.618	20.265	19.785	19.618	
21281	03 32 35.7539	-27 47 58.82	0	0.66	Yes	0.03	19.35	19.991	19.507	19.35	
23847	03 32 38.7915	-27 46 48.90	0	0.657	Yes	0.03	20.287	20.927	20.451	20.287	
22428	03 32 41.4054	-27 47 17.17	0	0.612	Yes	0.03	19.596	20.241	19.767	19.596	
24587	03 32 40.7814	-27 46 15.69	0	0.571	Yes	0.03	19.482	19.901	19.615	19.482	
24348	03 32 38.9675	-27 46 30.23	0	0.447	Yes	0.03	20.152	20.541	20.258	20.152	
24685	03 32 41.7599	-27 46 19.40	0	0.383	Yes	0.04	20.047	20.635	20.189	20.047	
21671	03 32 38.0057	-27 47 41.71	0	0.253	Yes	1	18.276	18.562	18.369	18.276	

Because of the small size of the shutters (0.2" x 0.46") the coordinate accuracy of the planning catalog must be between 5 and 50 mas.

The catalog should include all known sources in the field, to properly identify contaminants in MPT.

Loading the Catalog as an MSA Catalog Target



Browse and select the Catalog file.

Choose a name and format

MPT tries to identify the type of data in each column

Click

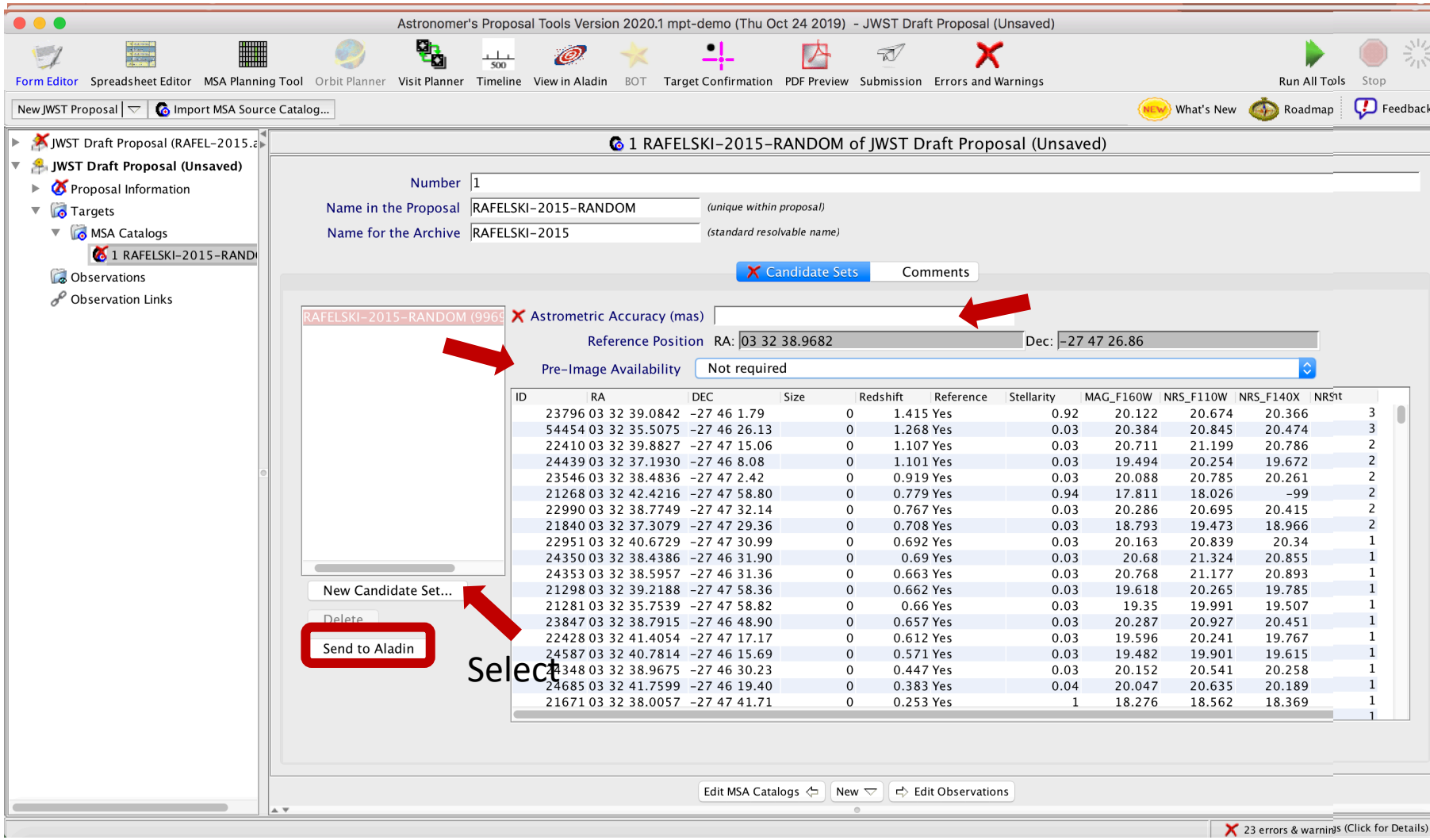
MSA Catalog and Candidate Sets

MPT complains because:

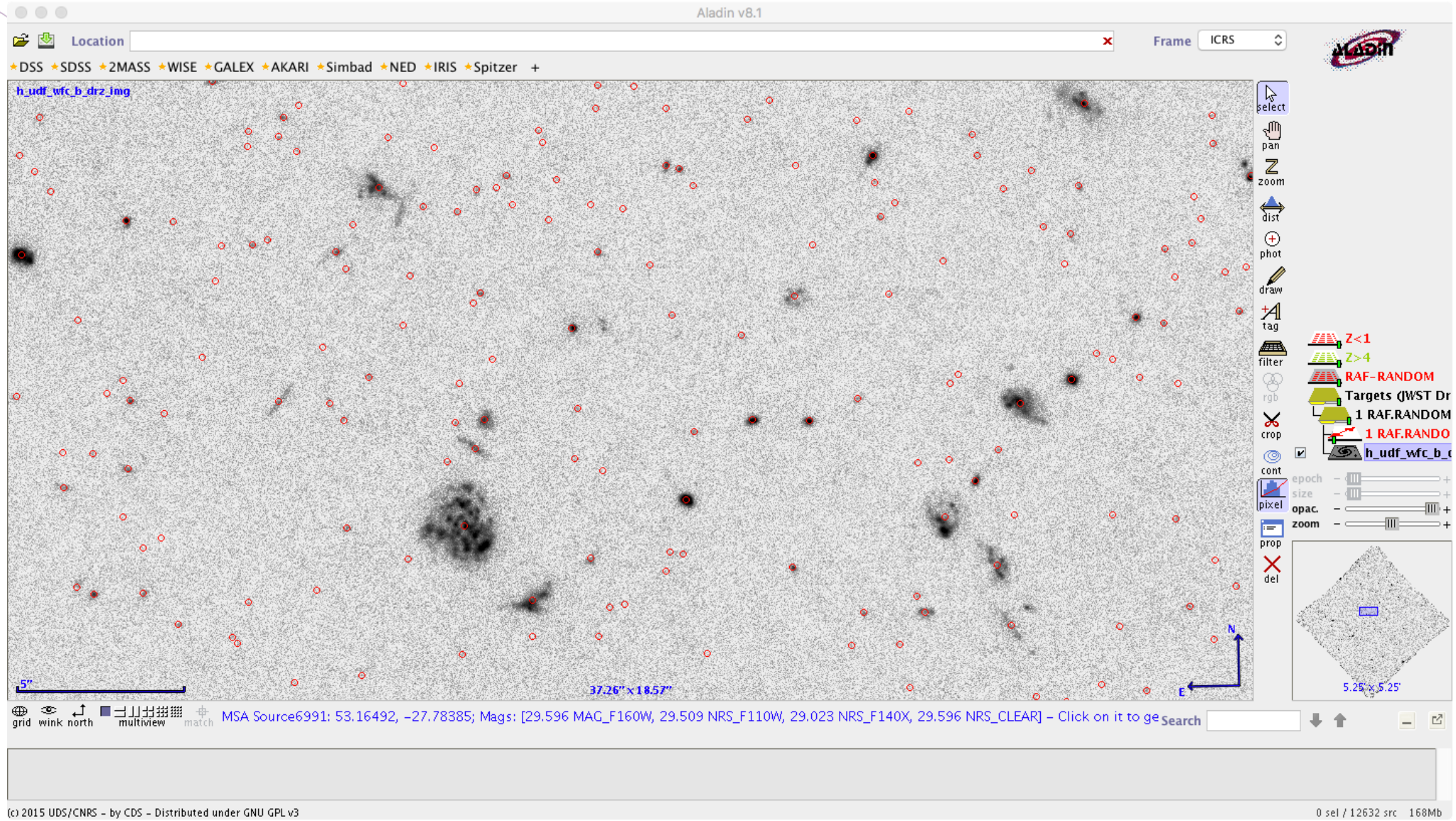
1) The target is not used in the proposal (yet) (just a warning)
2) We must specify the astrometric accuracy

3) We must tell MPT if we need pre-imaging or not:

- Already obtained (using NIRCam)
- Will be obtained external to this program (i.e. new HST program or an upcoming NIRCam program)
- Will be done in this program (NIRCam pre-imaging or NIRCam coordinate parallel)
- Not required (i.e. have previous HST observations, or you are just testing)



Sources seen in Aladin

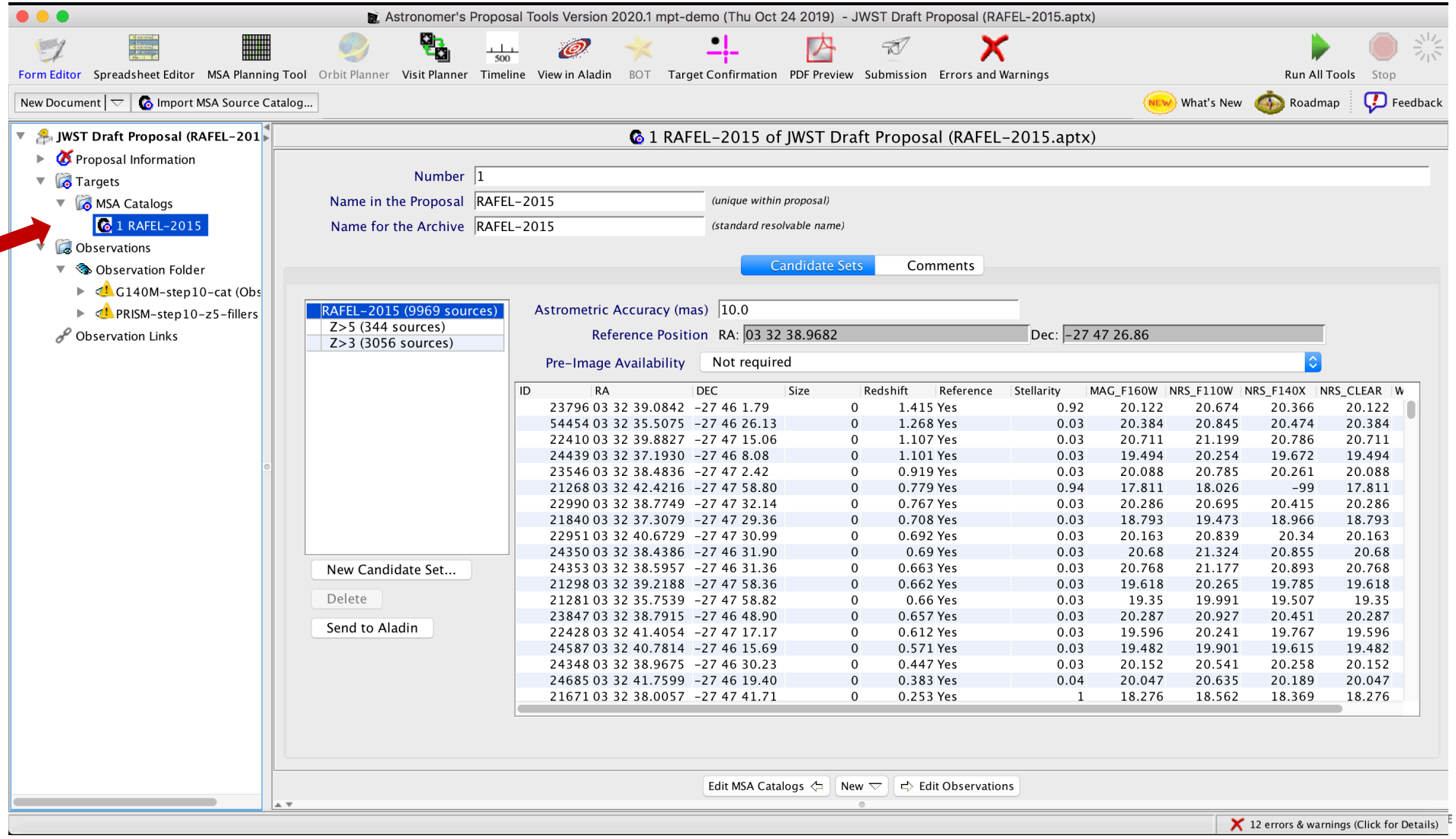


MSA Catalog Target

The next step to create a NIRSpec MOS observation is to ingest the catalog of sources in APT

The **MSA Catalog Target** is now in the **Targets Folder**

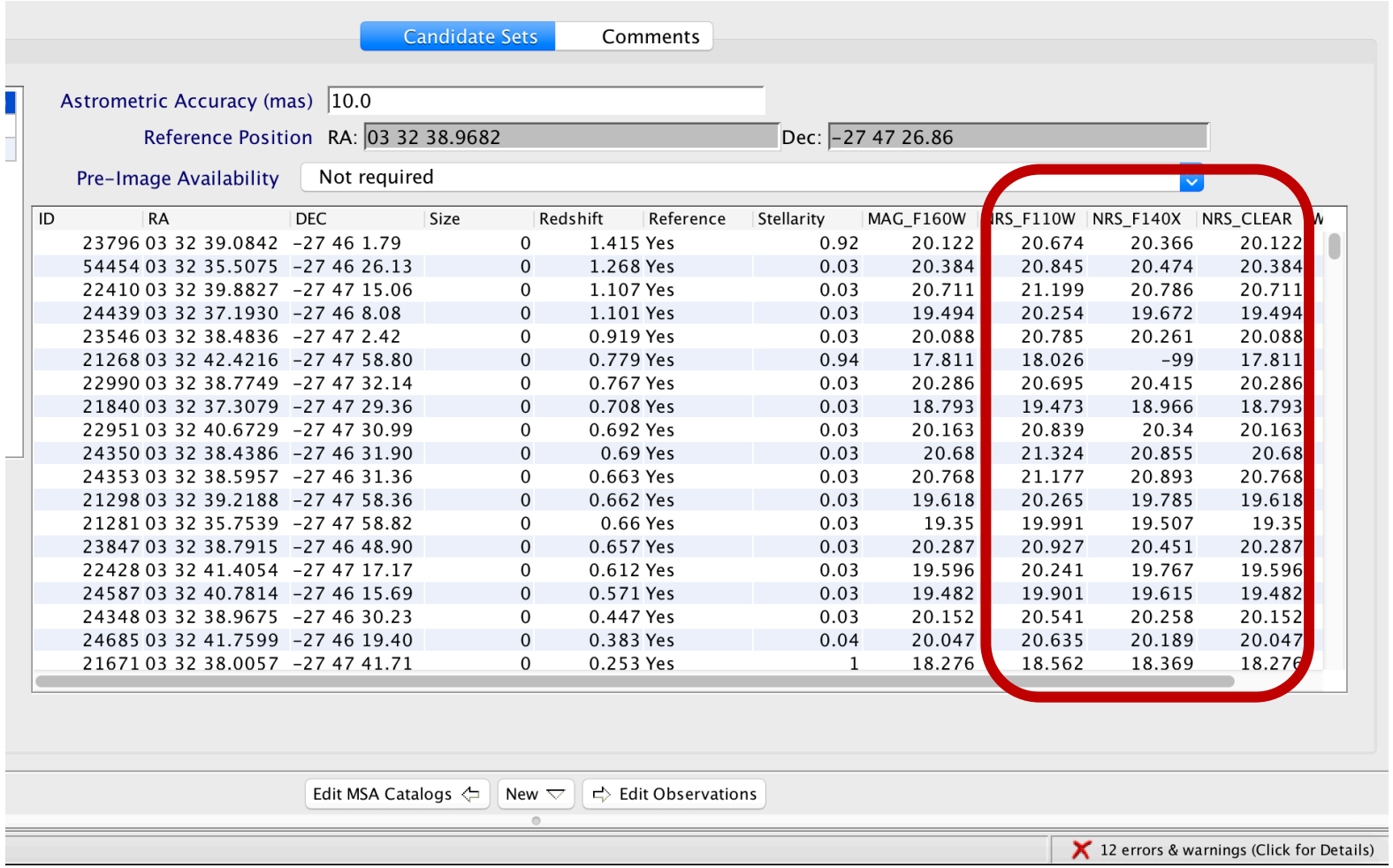
Highlight the Catalog to see its data



Source Catalog at Program Update

The first step is to create a NIRSpec MOS observation is to upload a complete catalog of sources in MPT

- For (later) program update submission
  MPT needs magnitudes in TA filters to properly define the reference stars
- There will be a tool for creating this data by converting HST magnitudes (when available).



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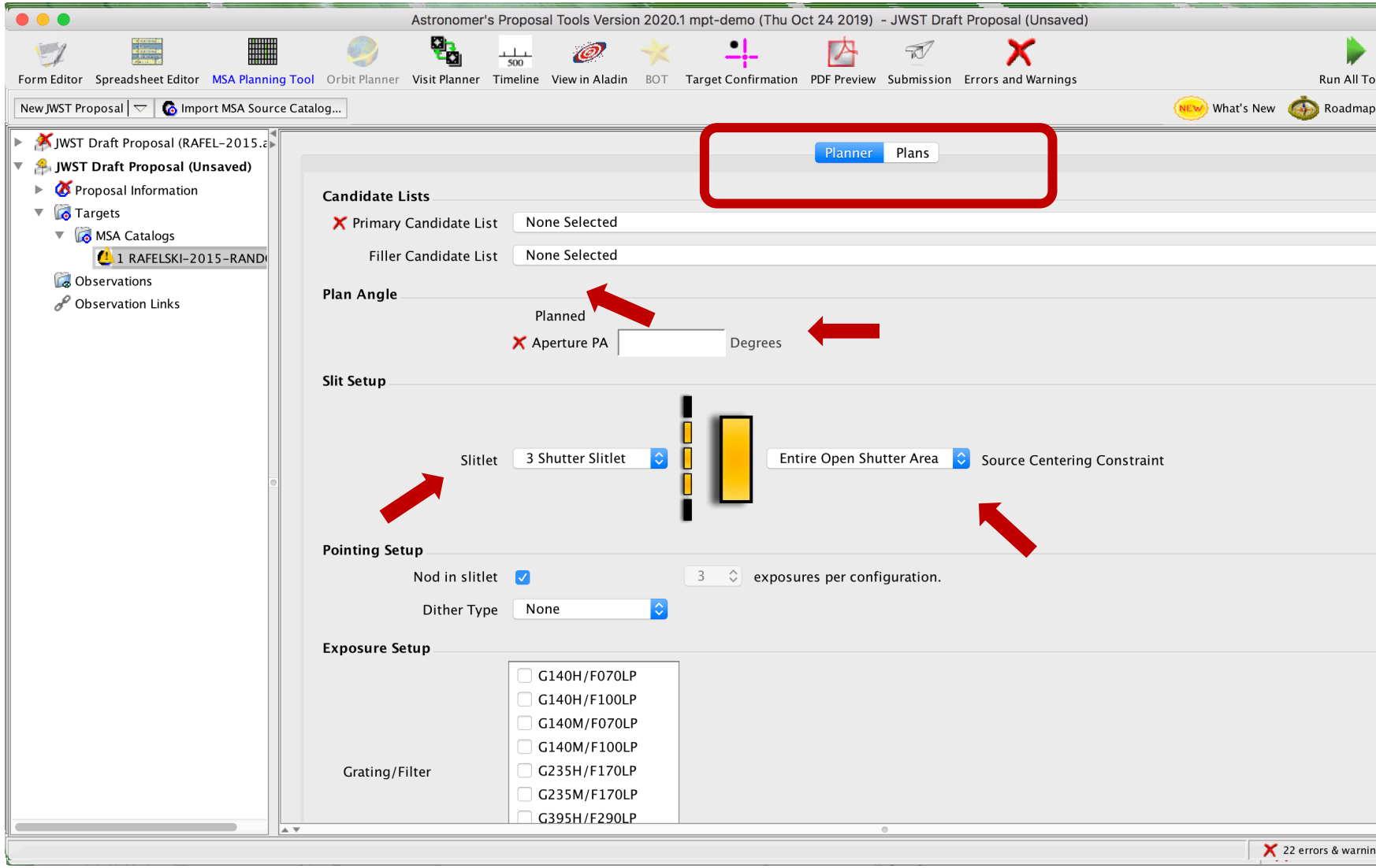
The MPT Planner

Planner Parameters

The **Planner** in the MSA Planning Tool is where you can design your observations

- Choose the Primary Candidates
- (Choose Filler Candidates)
- Choose an APA (place holder or assigned from STScI)
- Choose the slitlet configuration
- Choose the source centering constraints

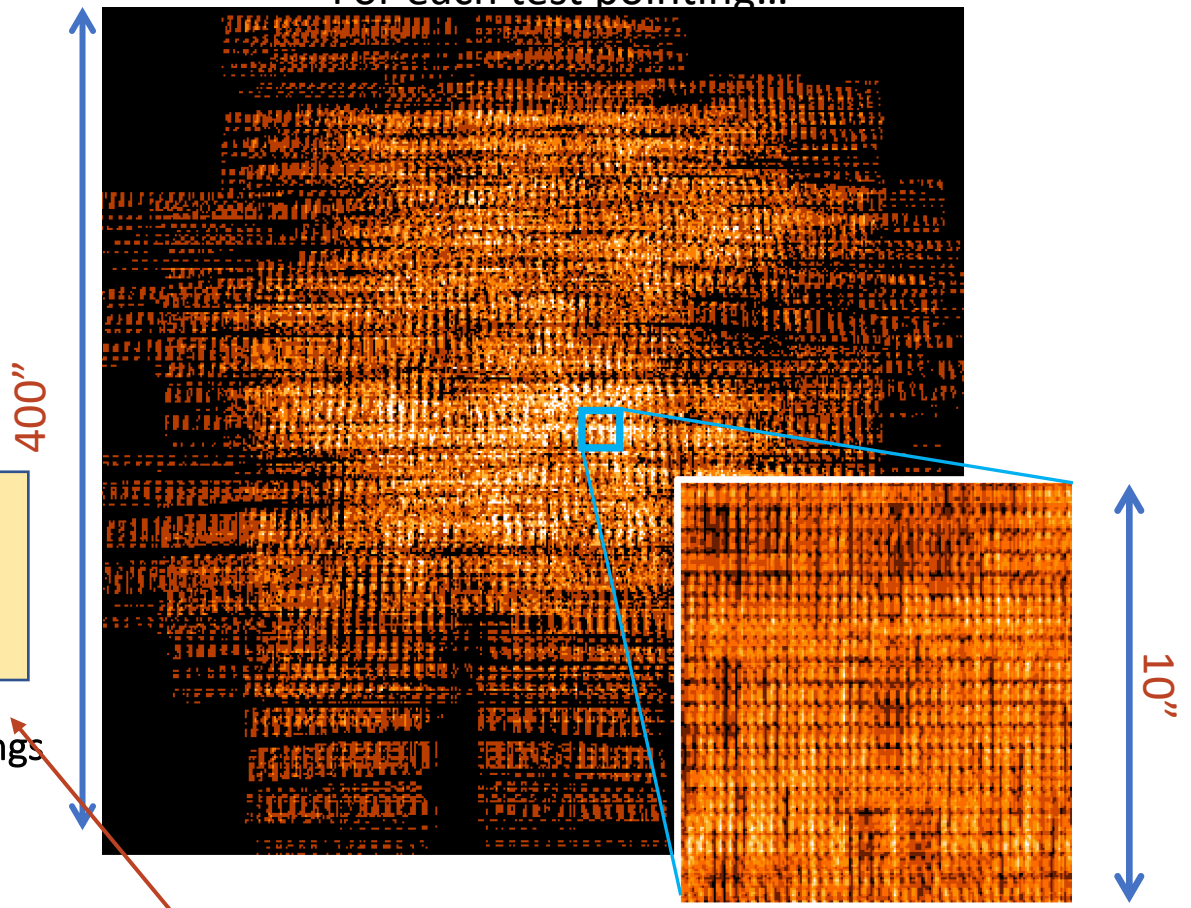


How MPT works

- The Catalog is loaded and Primary and optional Filler candidate lists are defined. Sources are mapped to the MSA plane.
- User runs the Planner: He/she selects an APA, a slit shape, a centering constraint, and dithers in dispersion and/or spatial directions. User also specifies search grid extent and step size.
- MPT creates a grid of test pointings over the area of the Primary Candidate list. MPT will find the Primary sources at each user-specified dither.
- At each pointing, weights of all observable primary sources in an MSA configuration are summed. The order of the Catalog and Candidate lists impacts the target selection. The result is a Heatmap.
- The "best" pointing with the largest score is selected. (a set of pointings if dithers were specified)
- A Plan is created in MPT. Plans have Pointings, a set of Targets, and associated MSA configurations.
- One or more Plans are selected and made into an Observation.

Heatmap: Every point is the sum of source weights

For each test pointing…



A loaded step. MPT is checking limits provided in the Planner, and known instrument effects.

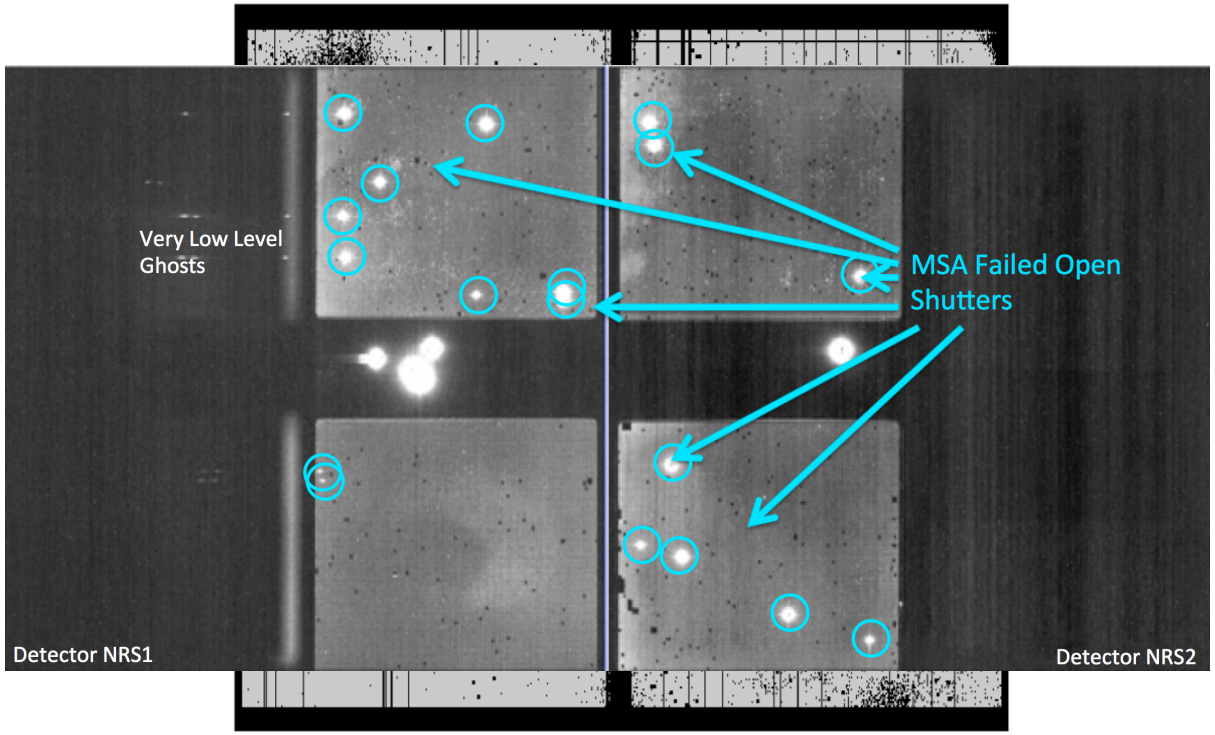
MSA Operability: Failed shutters and shorts

Some of the MSA shutters are not operable

Failed Closed shutters affect sources that may happen to fall into them

Shorts between columns and rows can occur, but are expected to be fairly stable.

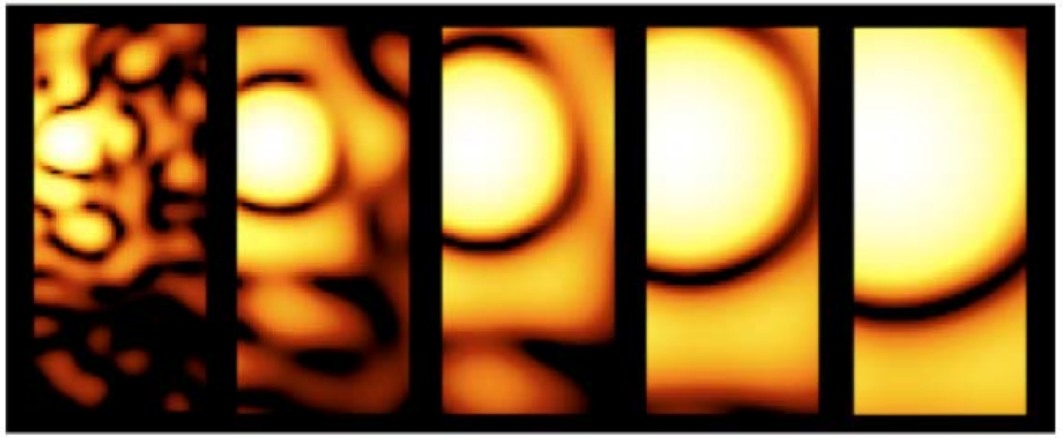
Failed Open shutters have the most severe impact on the observations, and can prohibit observing sources over a sizeable area. Unintended spoilers can contaminate spectra of planned sources.



MPT automatically plans around failed shutters and shorts and searches for the optimal configuration.

Source Centering and Slit Losses

A tighter constraint yields more accurate photometry and higher flux, but may reduce the number of observable targets.
Important for point sources.

Source Centering Constraint	Figure†	Minimum Relative Flux Transmission at 2.95 μm††	Margin (milli-arcsec)
			
	1 μm 2 μm 3 μm 4 μm 5 μm		
Constrained		75%	72
Tightly Constrained		85%	91

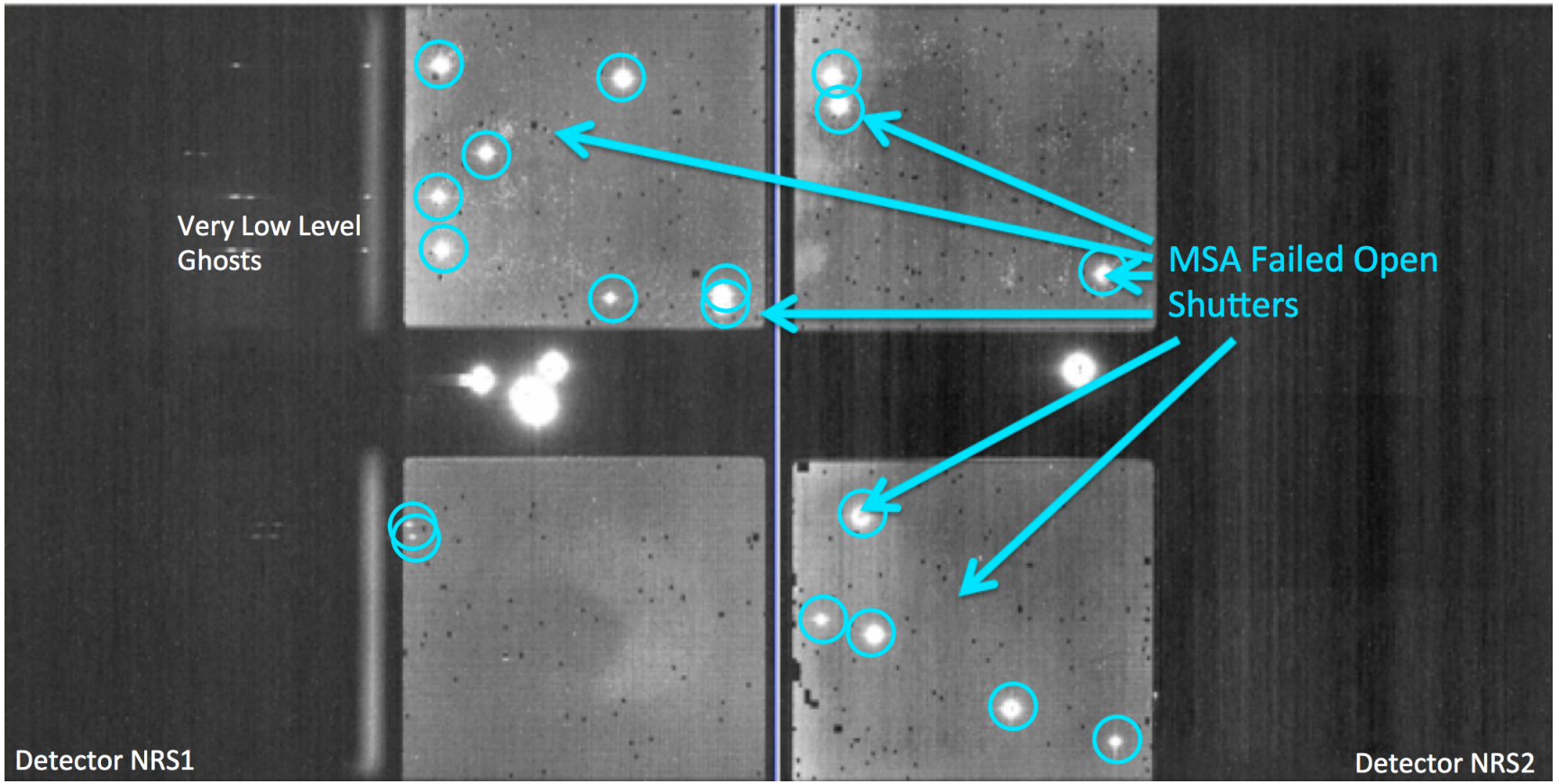
Slit throughput loss is a function of wavelength and the relative placement of the science source in the MSA shutter

Benefits of dithering

In addition to improving the sampling of the PSF and correcting for hot/bad pixels, dithering helps with:

- Better background subtraction (Nodding):
- Recover important wavelengths that could fall in the detector gap (Fixed dither)
- Mitigate effects of light leakage through the MSA
- **Dithers aslo** help mitigate detector artifacts, improve resolution, observe additional sources behind bars or mounting plate.

➢ MPT will observe as many sources as possible at all dithers



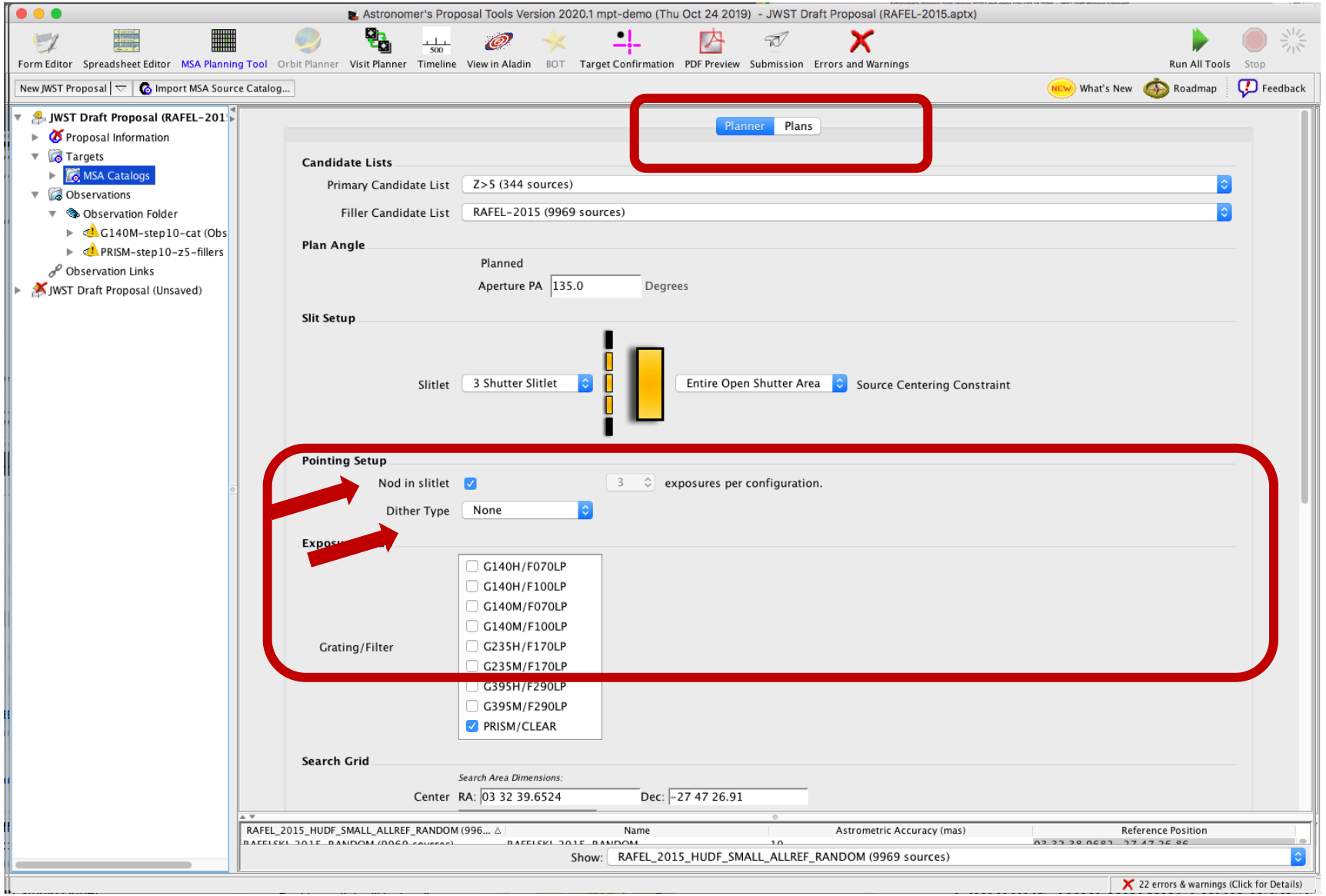
Specifying Dithers and Nods

The **Planner** is where you decide how to dither:

<u>Nodding</u> moves the sources within the slitlet – no shutter reconfiguration

<u>Fixed Dither</u> moves the sources by a finite number of shutters along the dispersion and/or the cross-dispersion direction

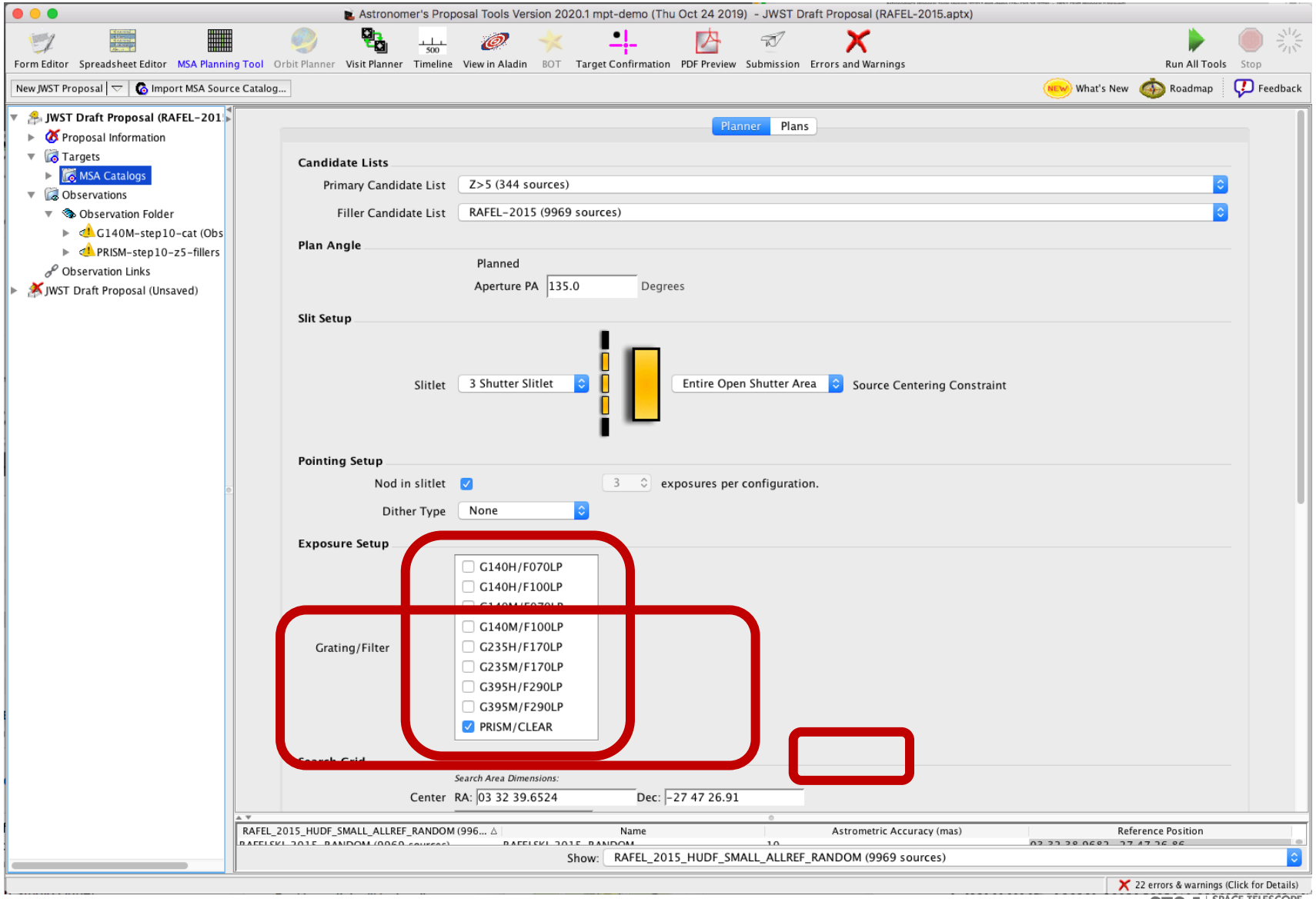
Nodding and dithering can be used together or independently



Create a Plan in MPT

Grating and Filter combination selected (each has different masking to prevent spectral overlaps)

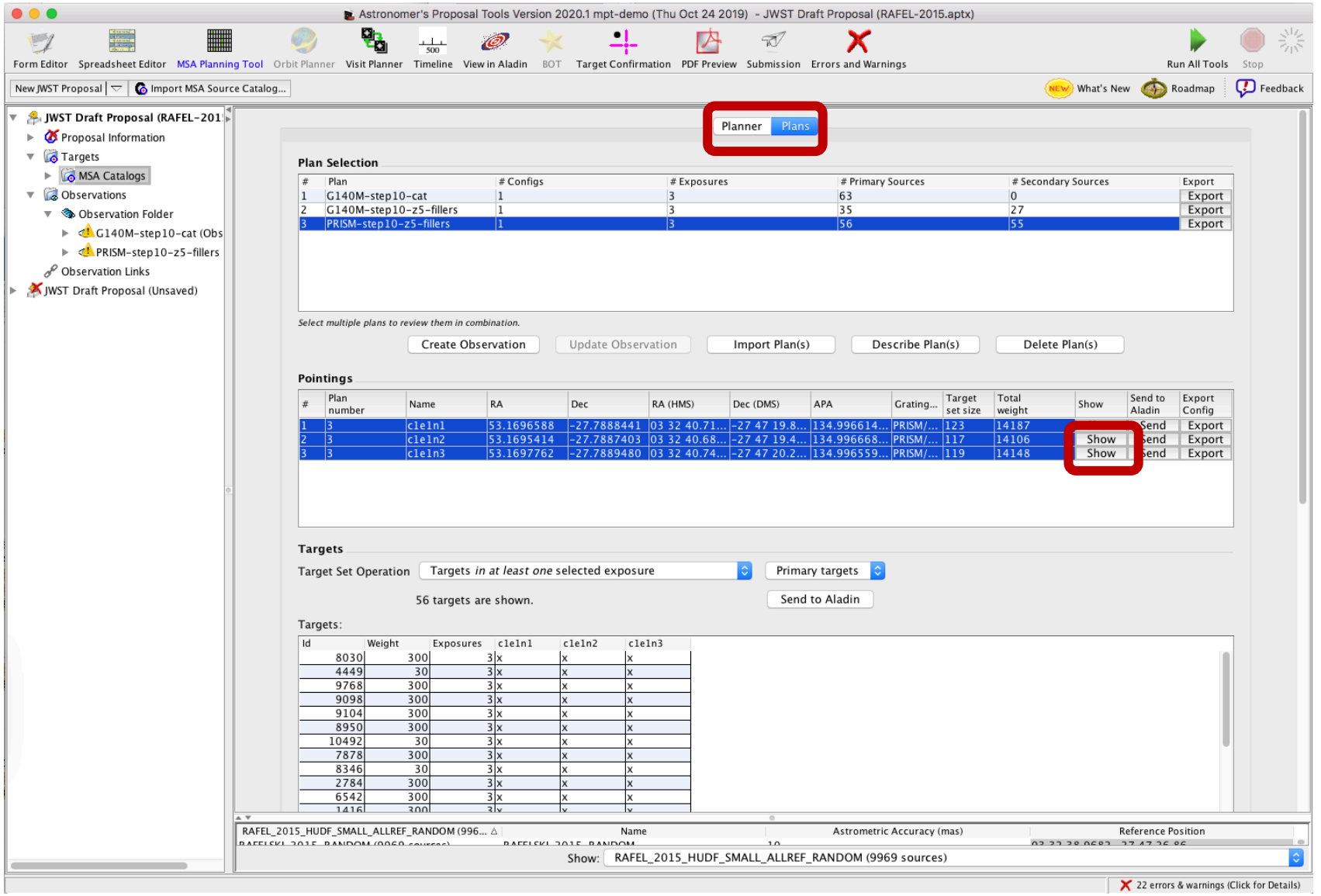
Use Weights and MC shuffling (Monte Carlo) Random ordering of sources tested for most sources in MSA



Examine Results

Examine plan results in the Plans pane of MPT

- MSA shutter view
- Collapsed shutter view



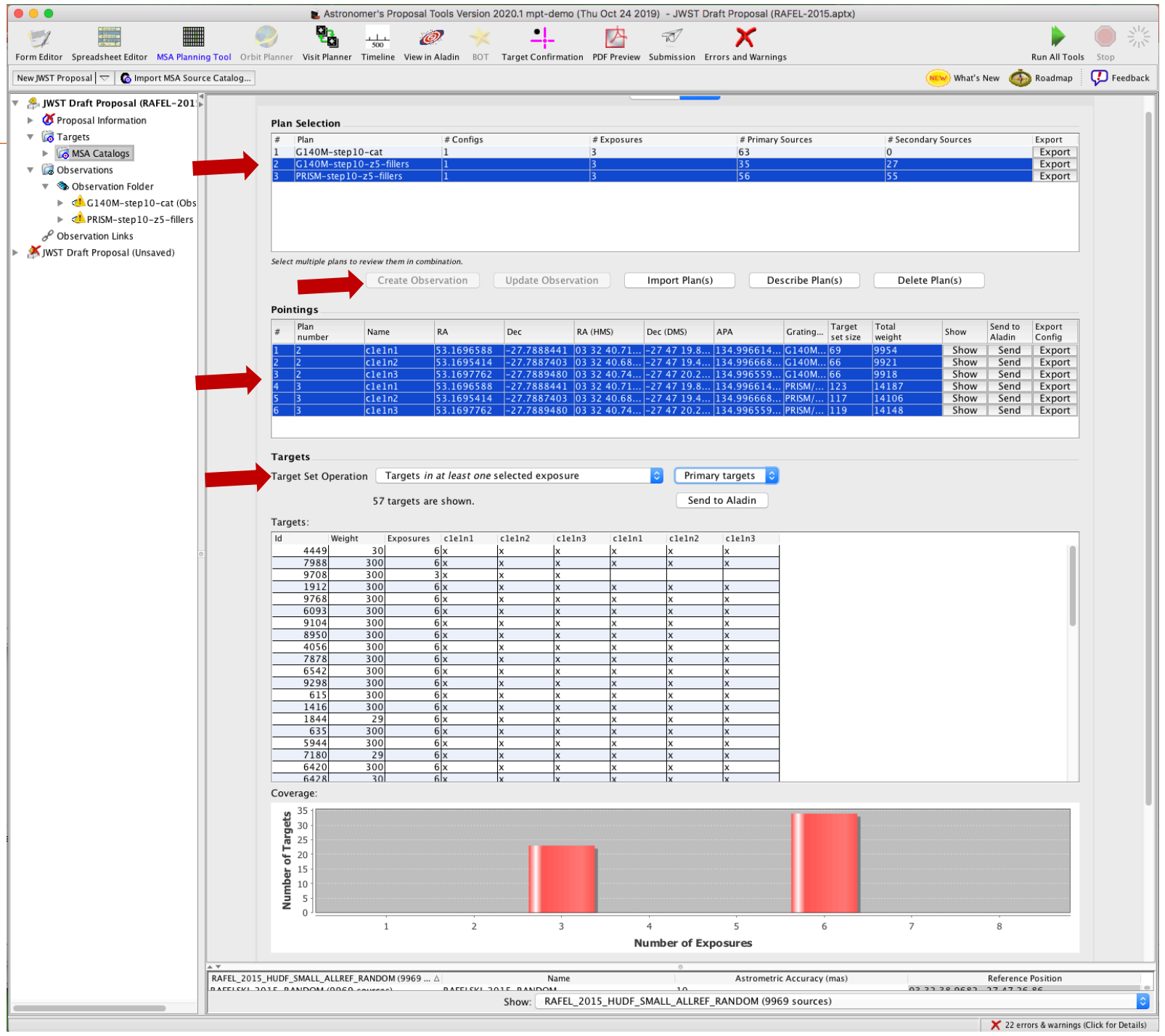
Create an Observation

Examine plan results in the Plans pane of MPT

Highlight a Plan or Plans and Exposures

Filter results

...and Create an Observation!



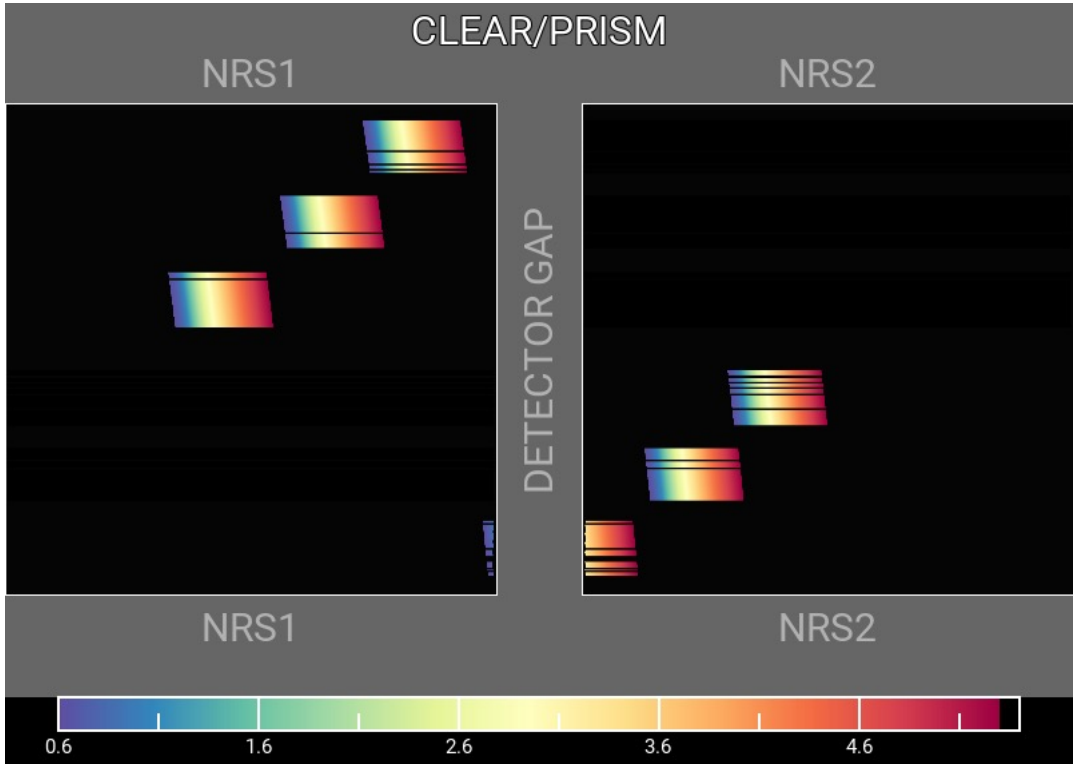
MSA Spectral Visualization Tool

MSAVis is a standalone too that can be downloaded from GitHub

It takes the ”MPT Target Info” output from MPT and projects the spectra of the observed targets on the 2 NIRSpec detectors for both visual inspection and a report for indicating wavelength cutoffs.

Instructions to download, install and run MSAVis can be found in the JDox NIRSpec section:

[The Near Infrared Spectrograph, NIRSpec]



Take Away

- New version of MPT will be available for the Cycle 1 call for proposal – easier to use, more intuitive and discoverable, lighter
- Need high precision relative astrometry – 5-20 mas for point sources – up to 50 mas for extended objects
- MOS is one of the very few observing modes o JWST that will follow a multi-step planning process
- MOS **requires** aperture position angle – it is assigned by STScI (although it may be requested at the time of call for proposals, but have to be strongly justified)
- NIRSpec overheads for MSA are considerable – USE MPT to have a good estimate
- You can use MSAVis to verify that wavelengths are properly sampled
- You can use NOVT to visualize NIRCam pre-imaging relative to MSA observations
- Dither! Dither!! Dither!!! It improves background subtraction, wavelength coverage, etc.

Helpful Hints

- Order the input Catalog by target weights prior to ingest into MPT. When building an MSA cpnfiguration, MPT tries adding sources in the order they appear in the Catalog.
- Include Primary candidates in the Filler list to obtain extra observations of them.
- Only the weights of the primaries matter (not the Fillers), so to help ensure observations of certain sources, include them in the Primary candidate list.
- Add Fillers to maximize efficiency/multiplexing
- If feasibility windows are large, test several APAs to see if it makes a statistical difference. If so, set conservative limits on requested exposure time. Add an Orient SR only if needed, with a min range of 30 deg.
- If using the high-res gratings (G140H, G235H, G395H), attempt to get most sources onto the leftmost quadrants to avoid detector cutoffs.
- Use Aladin FoV to show the position of NIRCam paralells wrt NIRSpec MSA.
- Your catalog should be **complete** to be able to check for contaminants getting into Failed Open shutters, or into planned target shutters/slitlets.
- The Manual Config Editor can be used to make changes to your MSA configurations designed automatically with MPT. It's found at the observation level in APT.