JWST Master Class Workshop

Available proposal tools: MPT, ETC & JIST

Pierre Guillard

MSA Planning Tool (MPT)

A guide to JWST MOS terminology

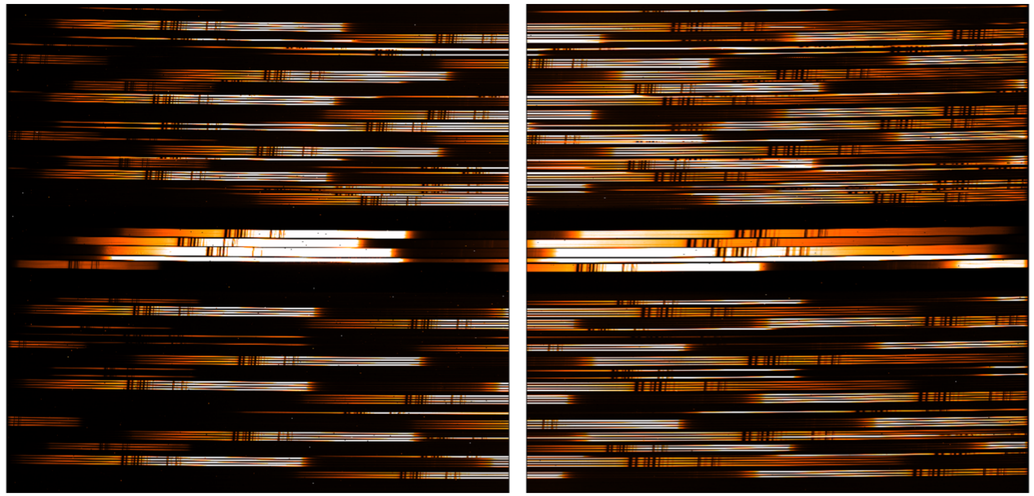
- **MOS** - Multi-Object Spectroscopy
  - the NIRSpec mode for obtaining spectra of 10-100s of specific targets simultaneously

- **MSA** - Micro-Shutter Assembly
  - the array of very small shutters (0.2x0.46 arcsec) within NIRSpec that allows specific targets to be selected and contaminants to be blocked

- **MPT** - MSA Planning Tool
  - the tool within APT for planning and optimising the MOS observations with the NIRSpec MSA

Why use MPT?

- NIRSpec MOS can obtain spectra for 10s-100s of objects simultaneously
- Targets are selected by opening a few of a grid of 250,000 micro-shutters
- MPT optimises this “MOS mask” given your target catalogue



Example (flat-field test exposure) of 100 tightly-packed spectra (G395H grating)

- details on the MSA shutter array are in the “observing modes” session
- strategies are covered in the MOS hands-on session

MSA Planning Tool (MPT) in APT

What is needed to run MPT?

- An internet connection
  - access to the most up-to-date MSA shutter operability
  - checking for guide stars during planning

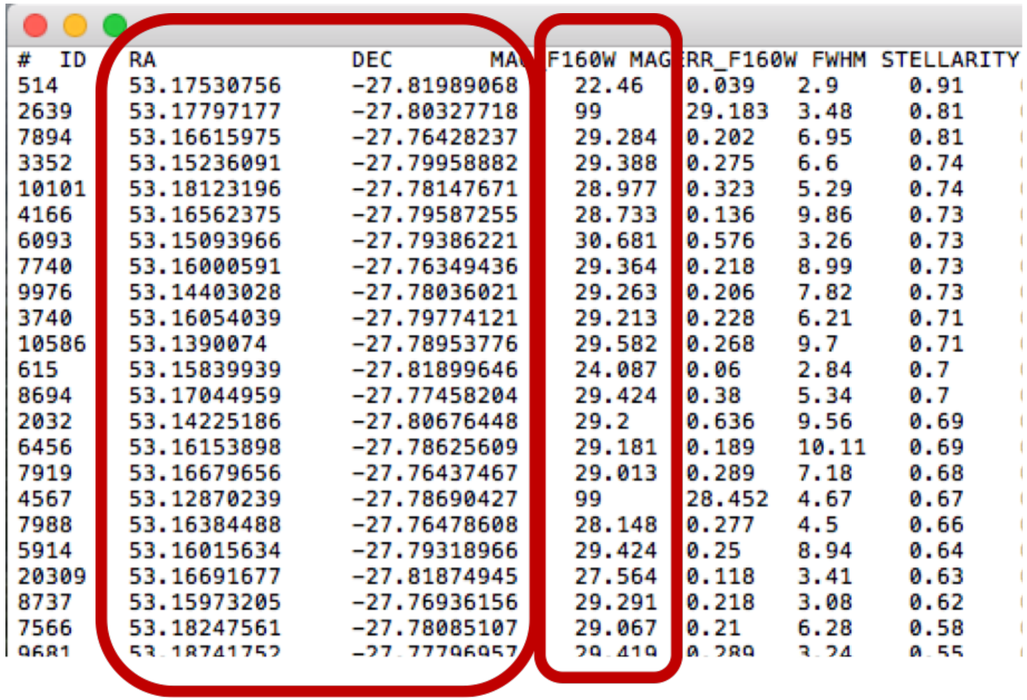
- A complete and accurate astrometric catalogue
  - accurate source positions (<15mas relative accuracy)… may require NIRCam pre-imaging

- MPT produces:
  - **plans** with 1 or more **pointings**
  - **MSA configurations**
  - target sets
- One or multiple **plans** can be selected for a given **observation**

The catalogue

- First step to create a MOS observation… upload complete catalogue of sources to the MPT
- Catalogue should include all known sources in the field, to properly identify contaminants

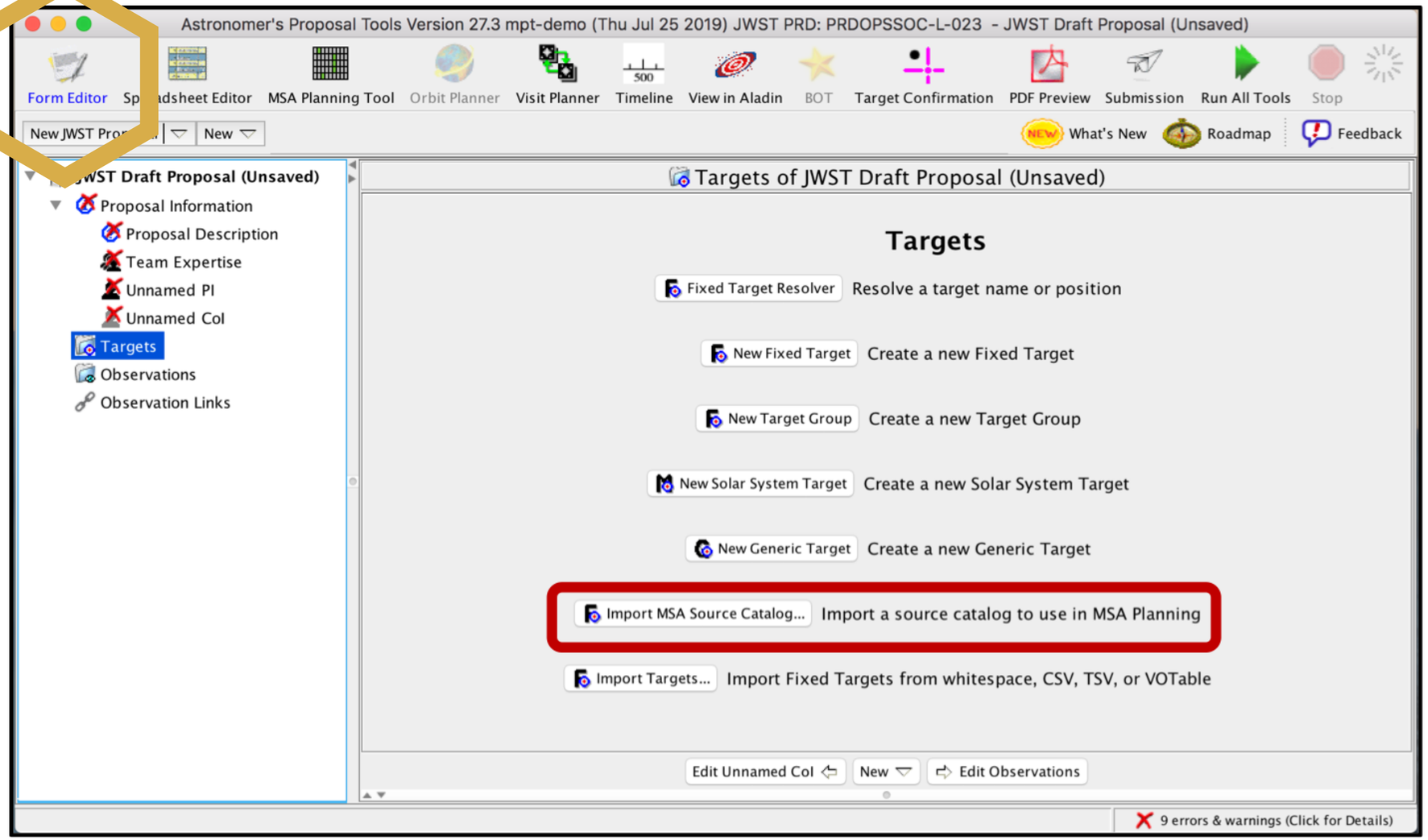
- Upload source catalogue as an ASCII file
- It **must** contains J2000 **RA** and **Dec** expressed in degrees or hexadecimal
- It **cannot** have duplicate **IDs** or NULL entries
- *Optional:* Fluxes or magnitudes for the sources helps
  - Magnitudes are needed to properly define reference stars
- *Optional:* Target priorities are recommended
- The file can have a header, marked by "**#**"
- Remember: the relative astrometric accuracy of the catalogue must be between 5 and 50 mas



# ID	RA	DEC	MA	F160W MAG	RR_F160W	FWHM	STELLARITY
514	53.17530756	-27.81989068		22.46	0.039	2.9	0.91
2639	53.17797177	-27.80327718		99	29.183	3.48	0.81
7894	53.16615975	-27.76428237		29.284	0.202	6.95	0.81
3352	53.15236091	-27.79958882		29.388	0.275	6.6	0.74
10101	53.18123196	-27.78147671		28.977	0.323	5.29	0.74
4166	53.16562375	-27.79587255		28.733	0.136	9.86	0.73
6093	53.15093966	-27.79386221		30.681	0.576	3.26	0.73
7740	53.16000591	-27.76349436		29.364	0.218	8.99	0.73
9976	53.14403028	-27.78036021		29.263	0.206	7.82	0.73
3740	53.16054039	-27.79774121		29.213	0.228	6.21	0.71
10586	53.1390074	-27.78953776		29.582	0.268	9.7	0.71
615	53.15839939	-27.81899646		24.087	0.06	2.84	0.7
8694	53.17044959	-27.77458204		29.424	0.38	5.34	0.7
2032	53.14225186	-27.80676448		29.2	0.636	9.56	0.69
6456	53.16153898	-27.78625609		29.181	0.189	10.11	0.69
7919	53.16679656	-27.76437467		29.013	0.289	7.18	0.68
4567	53.12870239	-27.78690427		99	28.452	4.67	0.67
7988	53.16384488	-27.76478608		28.148	0.277	4.5	0.66
5914	53.16015634	-27.79318966		29.424	0.25	8.94	0.64
20309	53.16691677	-27.81874945		27.564	0.118	3.41	0.63
8737	53.15973205	-27.76936156		29.291	0.218	3.08	0.62
7566	53.18247561	-27.78085107		29.067	0.21	6.28	0.58
9681	53.18741752	-27.77796957		29.419	0.289	3.24	0.55

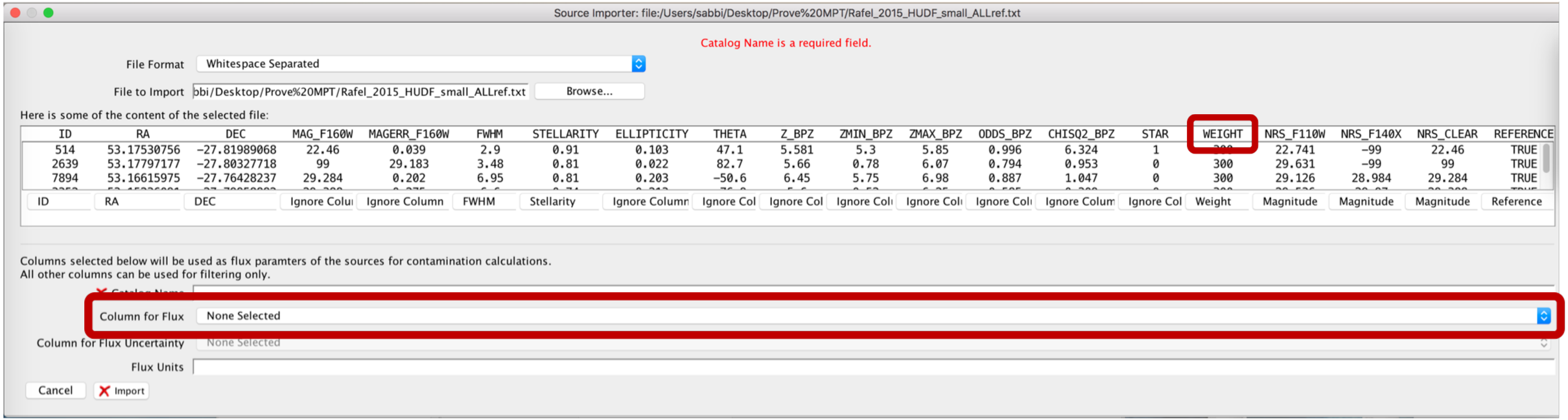
Load the catalogue as an MSA Source Catalogue Target

From the
Form Editor



Catalogue importer

- **Column for Flux** can be used for filtering sources when creating candidate sets
- **Weight** can be used to prioritise targets

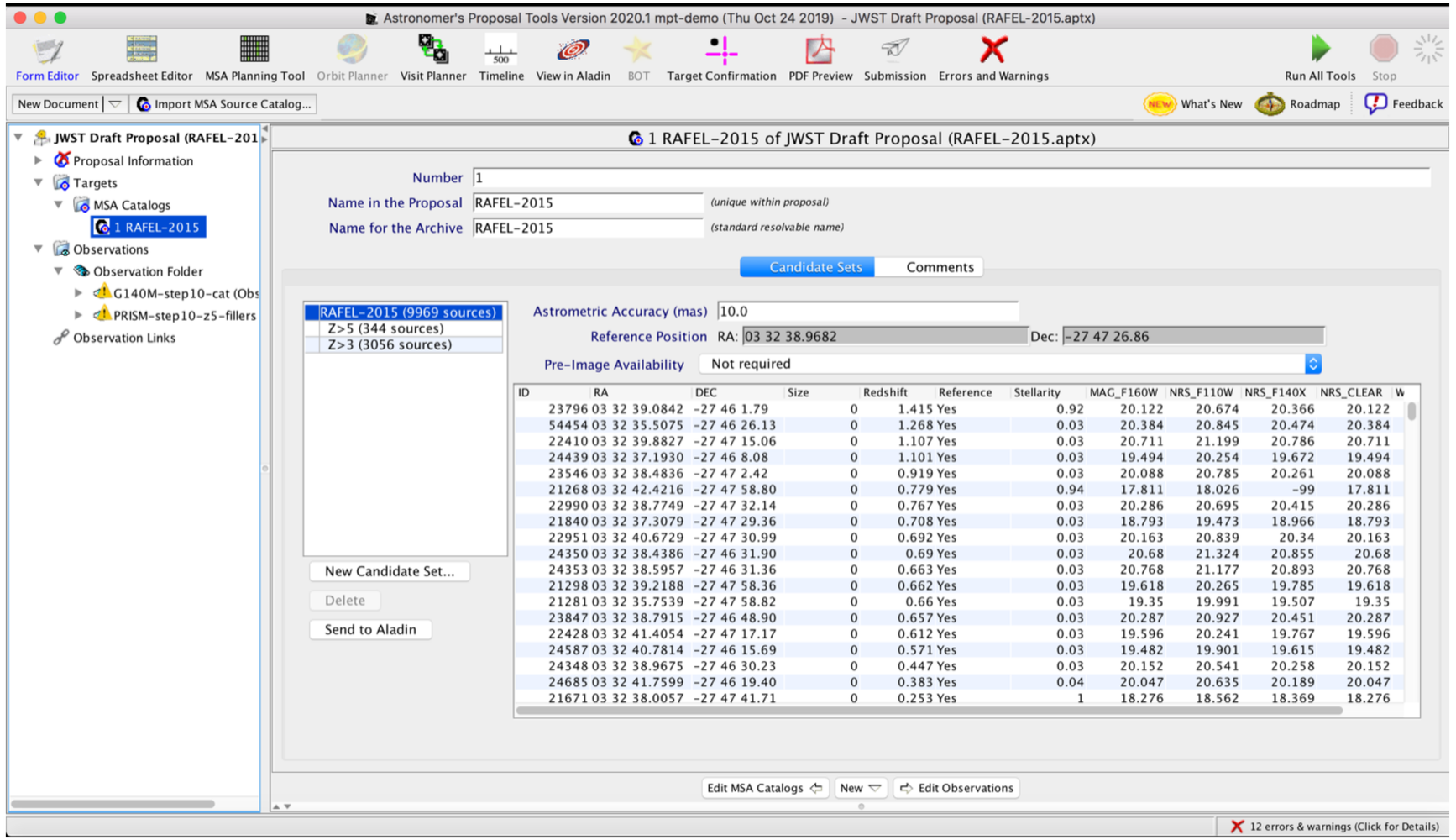


MSA Source Catalogue Target

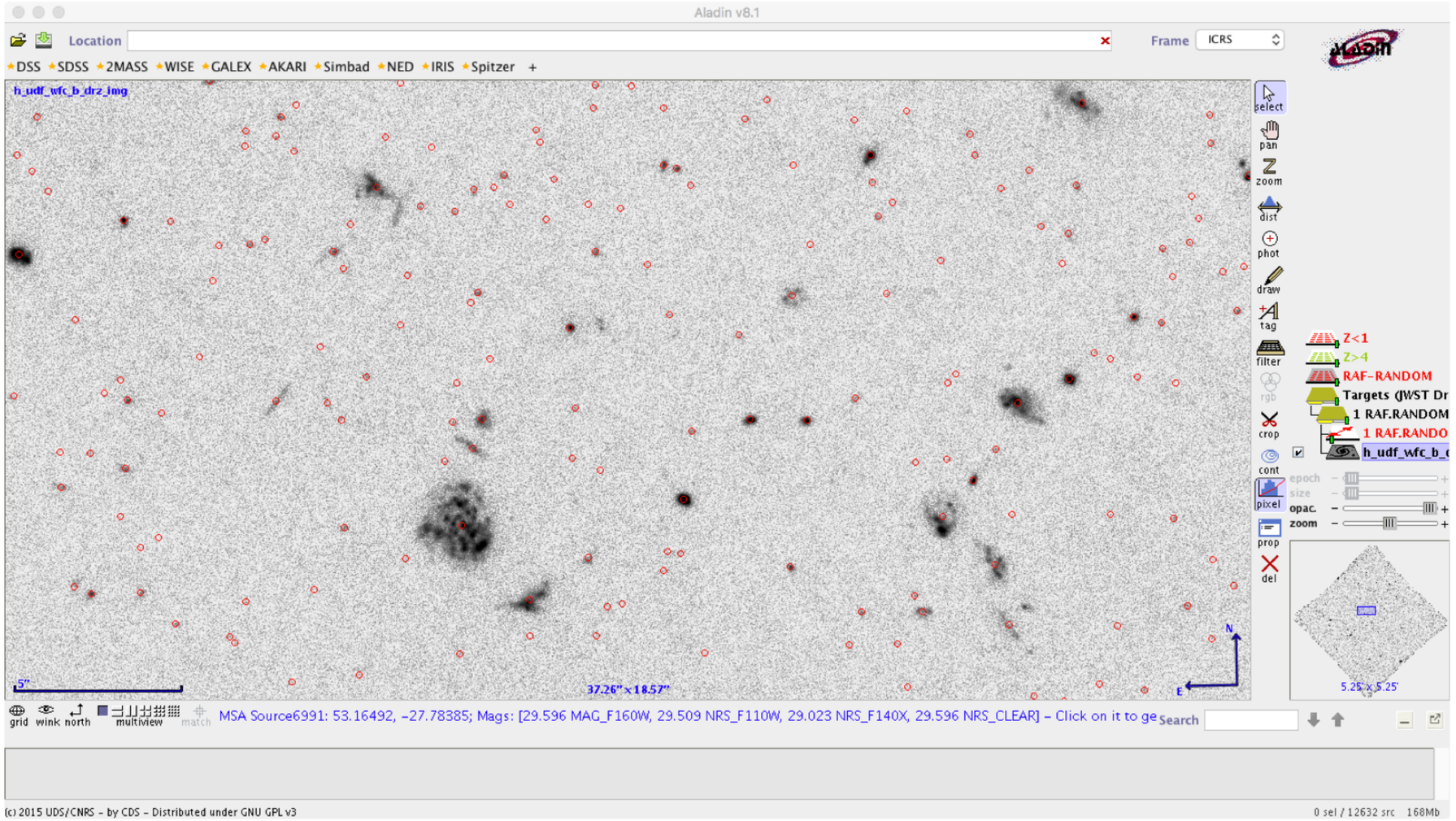
MSA Catalog is now in the **Targets Folder**

Can create multiple **candidate sets** from a single catalogue

Visualisation of the catalogue via **Aladin**



Catalogue sources displayed in Aladin

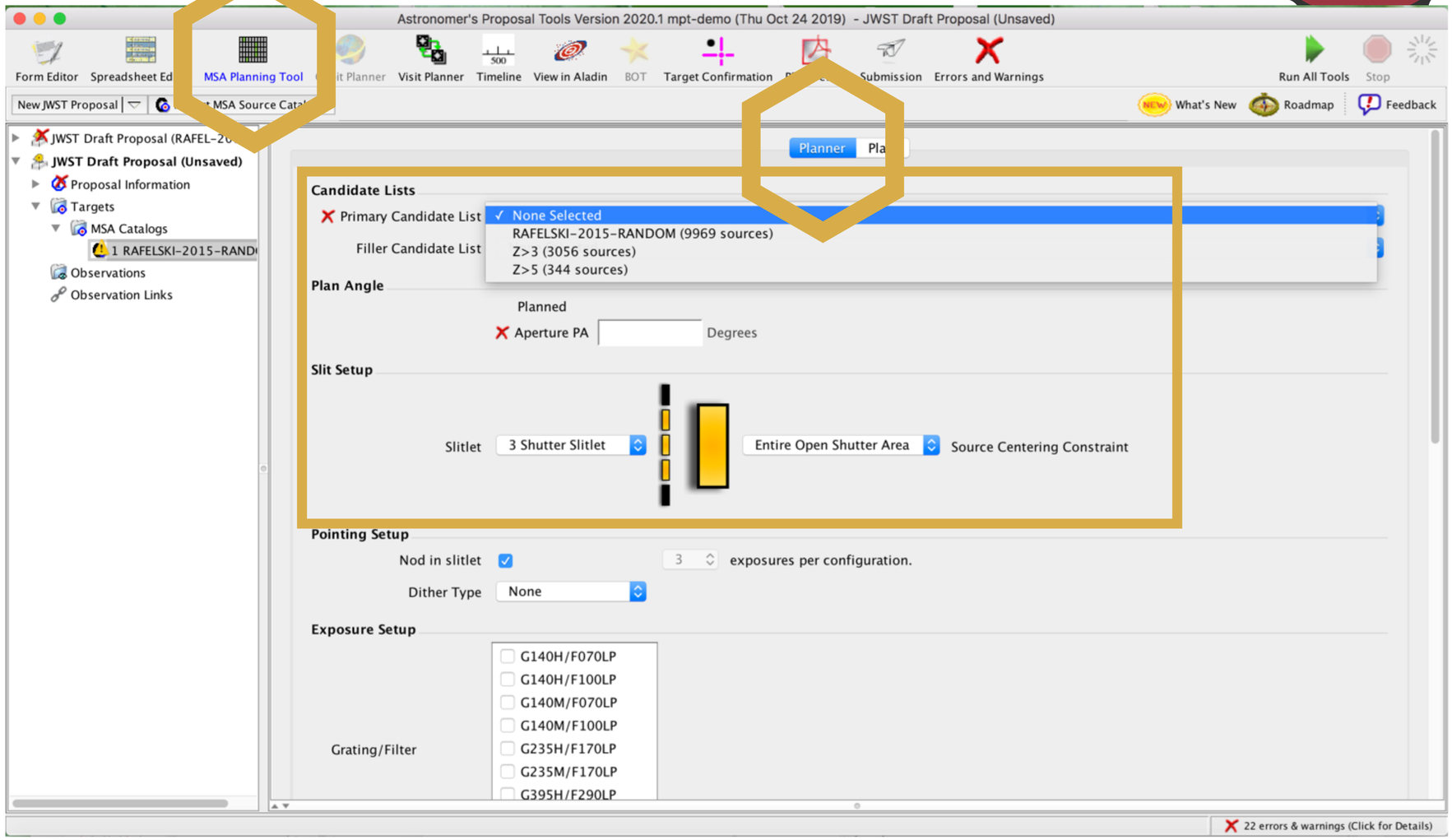


The MSA Planning Tool

MSA Planning Tool in the APT toolbar

The **Planner** tab is where you design MOS plans

- Select candidate lists from your MSA Catalog
- **Aperture PA** (position angle) is either a placeholder, or assigned to you by STScI (after acceptance)
- **Slitlet** configuration and **Centering Constraint** should be chosen

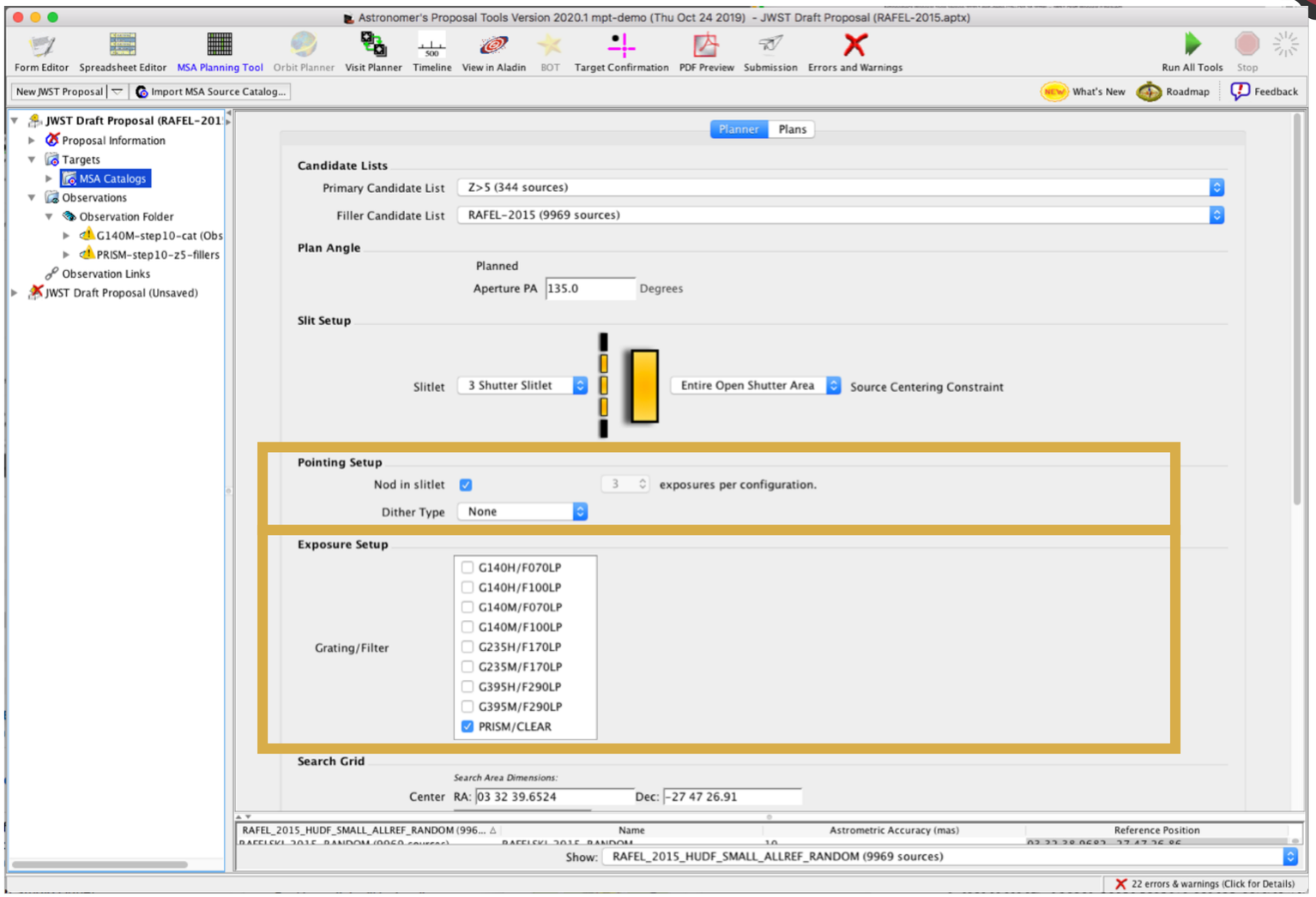


The MSA Planning Tool

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

- **Nodding** moves the sources within the slitlet – no shutter reconfiguration
- **Fixed Dither** moves the sources by a finite number of shutters specified by the user along the dispersion and/or the cross-dispersion direction.

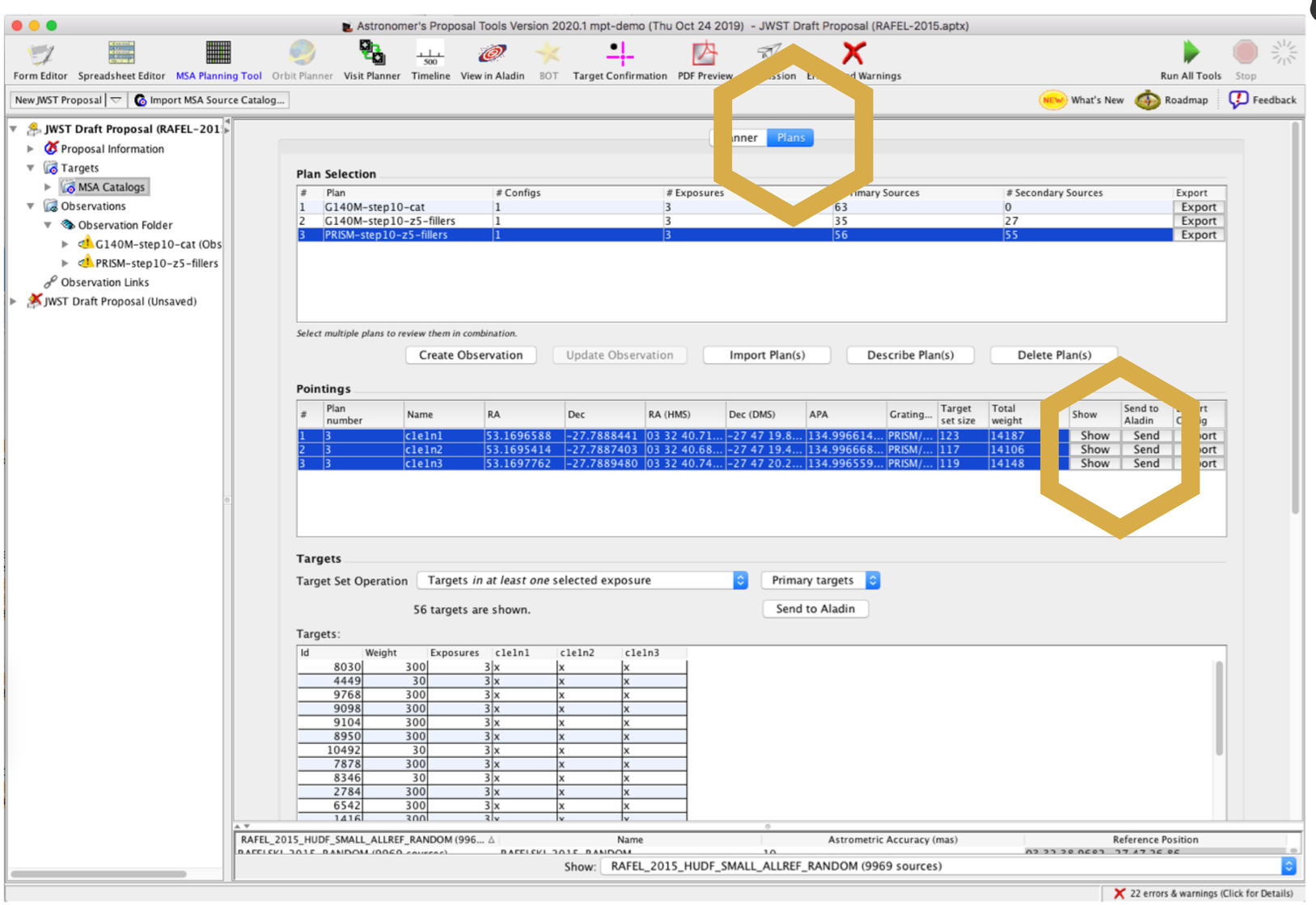
Grating/Filter combination(s) must be selected to prevent spectral overlap in the chosen configurations



Examine and visualise a plan

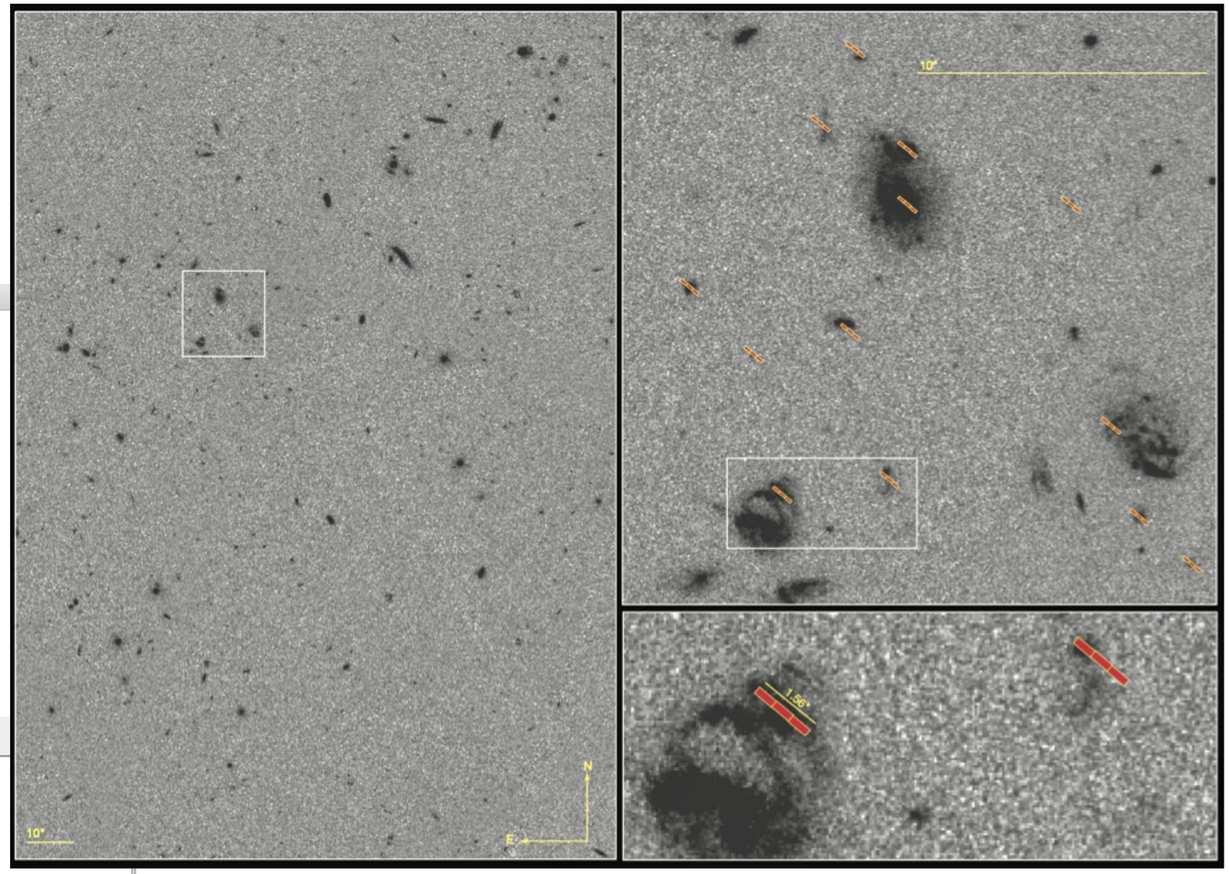
The **Plans** tab is where you examine and visualise MOS plans

- MSA shutter view
- Collapsed shutter view
- Send to Aladin (on-sky visualisation)

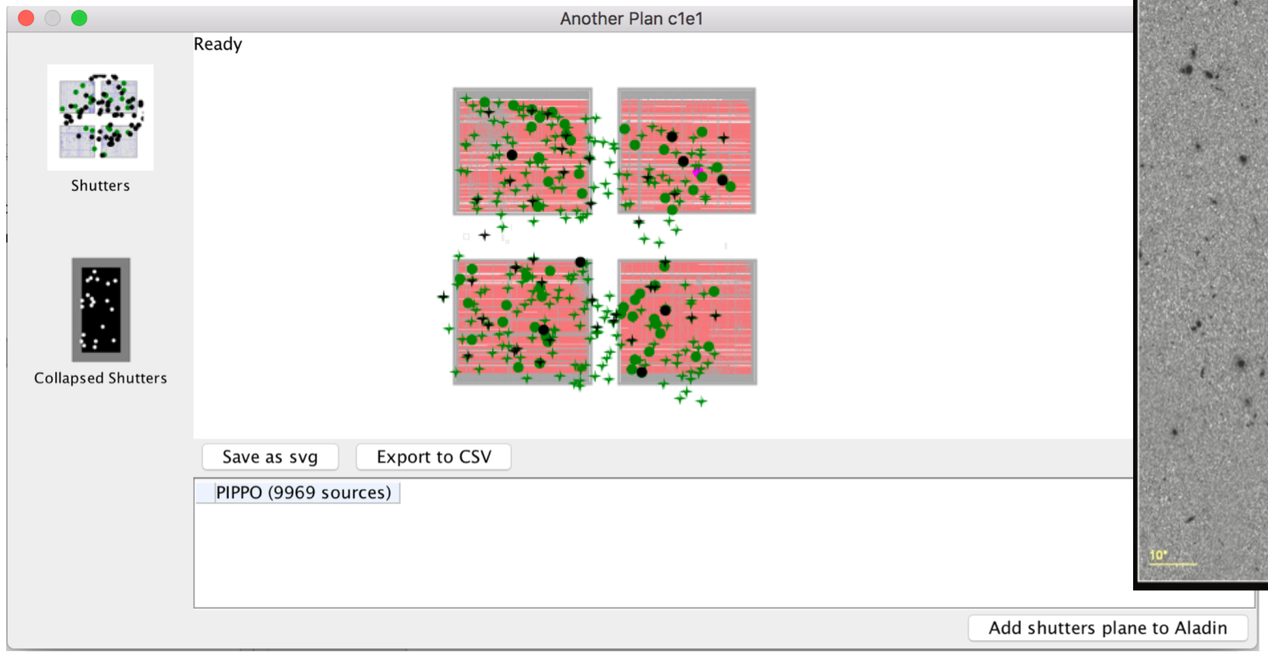


Examine and visualise a plan

Shutters projected onto the sky in Aladin



Targets on the MSA

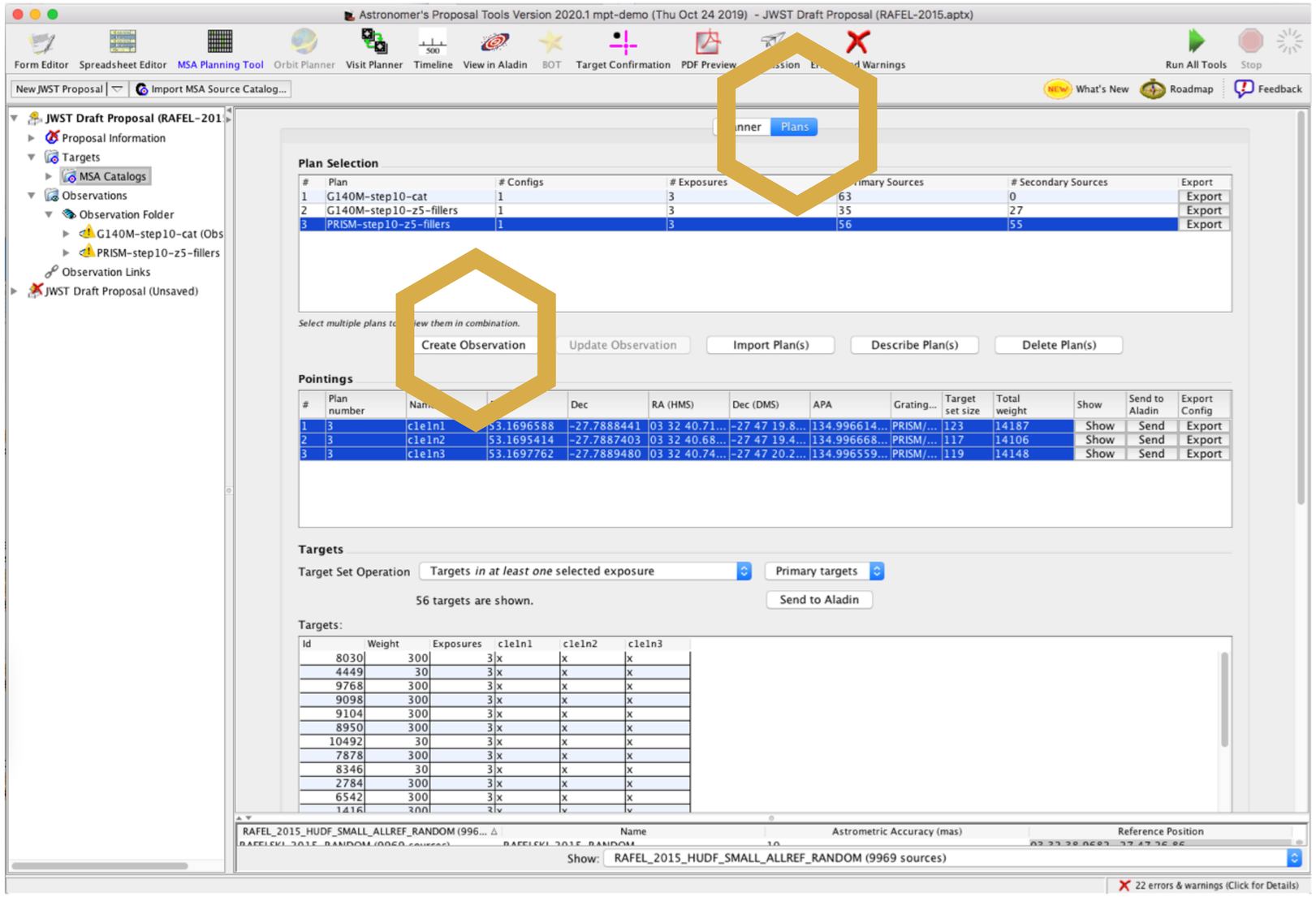


Create an observation

From the **Plans** tab

- Highlight a plan or plans
- Select the pointings

- **Create Observation**

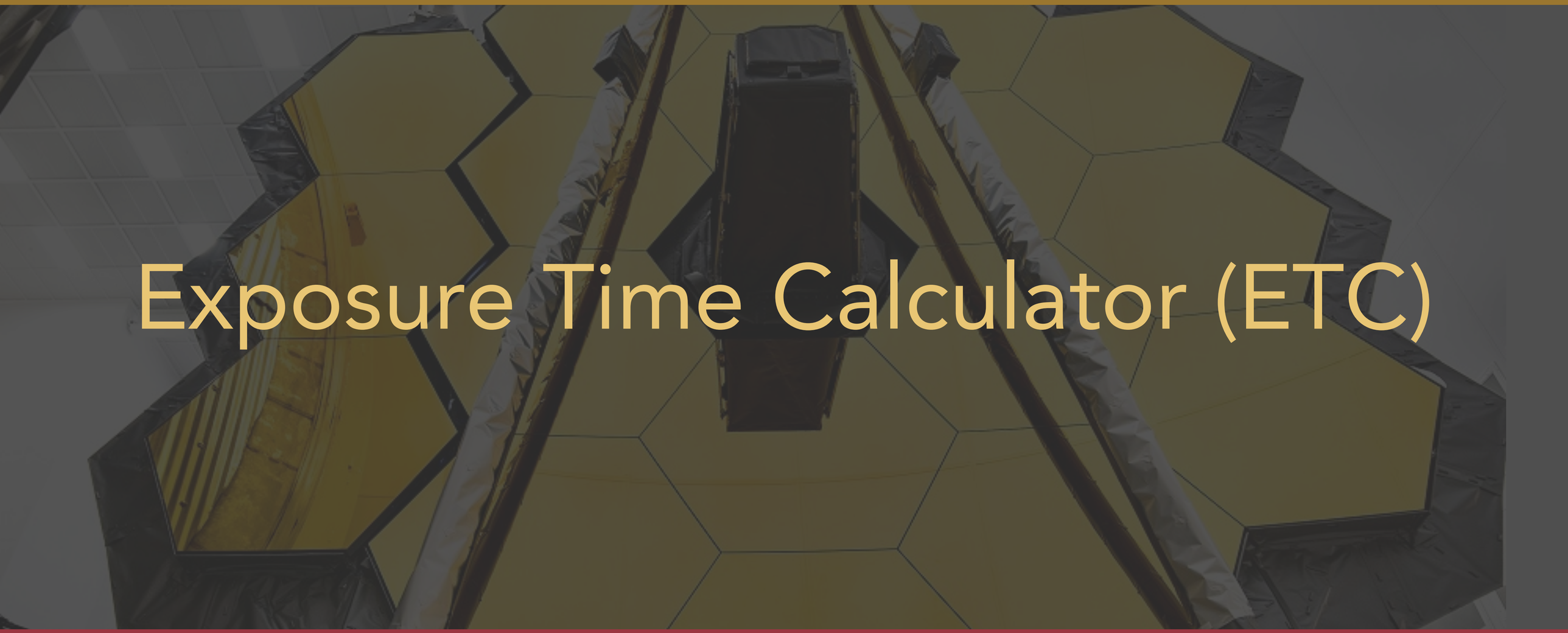


Proposing for MOS

- New version of the MPT available for the Cycle 1 call
- Remember: need a catalogue with accurate relative astrometry
  - <15mas relative accuracy
- MOS will have a multi-step planning process
  - Final plans not possible until the program is accepted and scheduled (giving the actual Aperture PA)
  - A particular APA can be requested in a proposal, but must be strongly justified
- Instrument overheads are not negligible - use APT/MPT for the estimate

Additional helpful hints

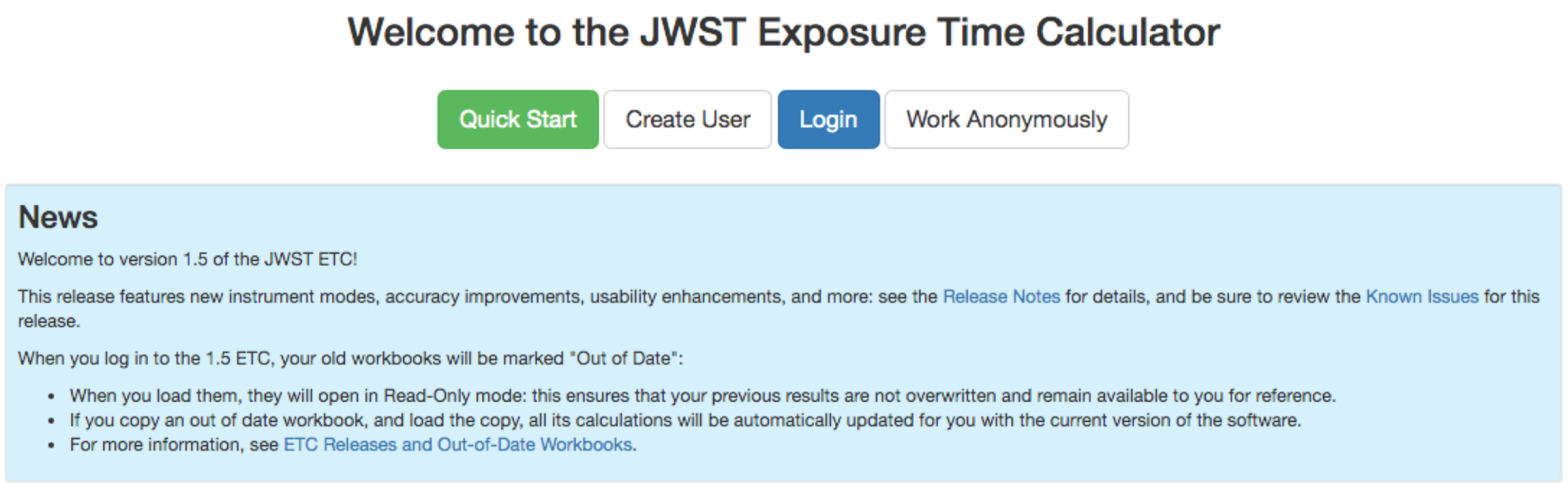
- **Dither!!!** …to improve background subtraction, wavelength coverage, etc
- Order your input catalogue by weight… during optimisation, MPT adds sources in the catalogue order
- Use a **Filler Set** to maximise efficiency/multiplexing
- Include **Primary** candidates in the **Filler** list to obtain additional observations of important sources
- Weight only matters for **Primary** sources (not for **Fillers**)
- If observability window is large, test optimisation for several APAs… if multiplexing differs significantly, consider including an **Orient Special Requirement**, with a minimum range of 30 deg
- If using a high-res grating (GxxxH), attempt to place most sources on the leftmost quadrants (MPT orientation) to avoid detector cutoffs
- Use Aladin to show the position of NIRCam parallels during NIRSpec exposures
- Input catalogue should be as complete as possible to check for contaminants in commanded open (or known **Failed Open**) shutters
- The MSA Configuration Editor can be used to amend MPT-optimised configurations. It can be found at the **observation level** in APT



Exposure Time Calculator (ETC)

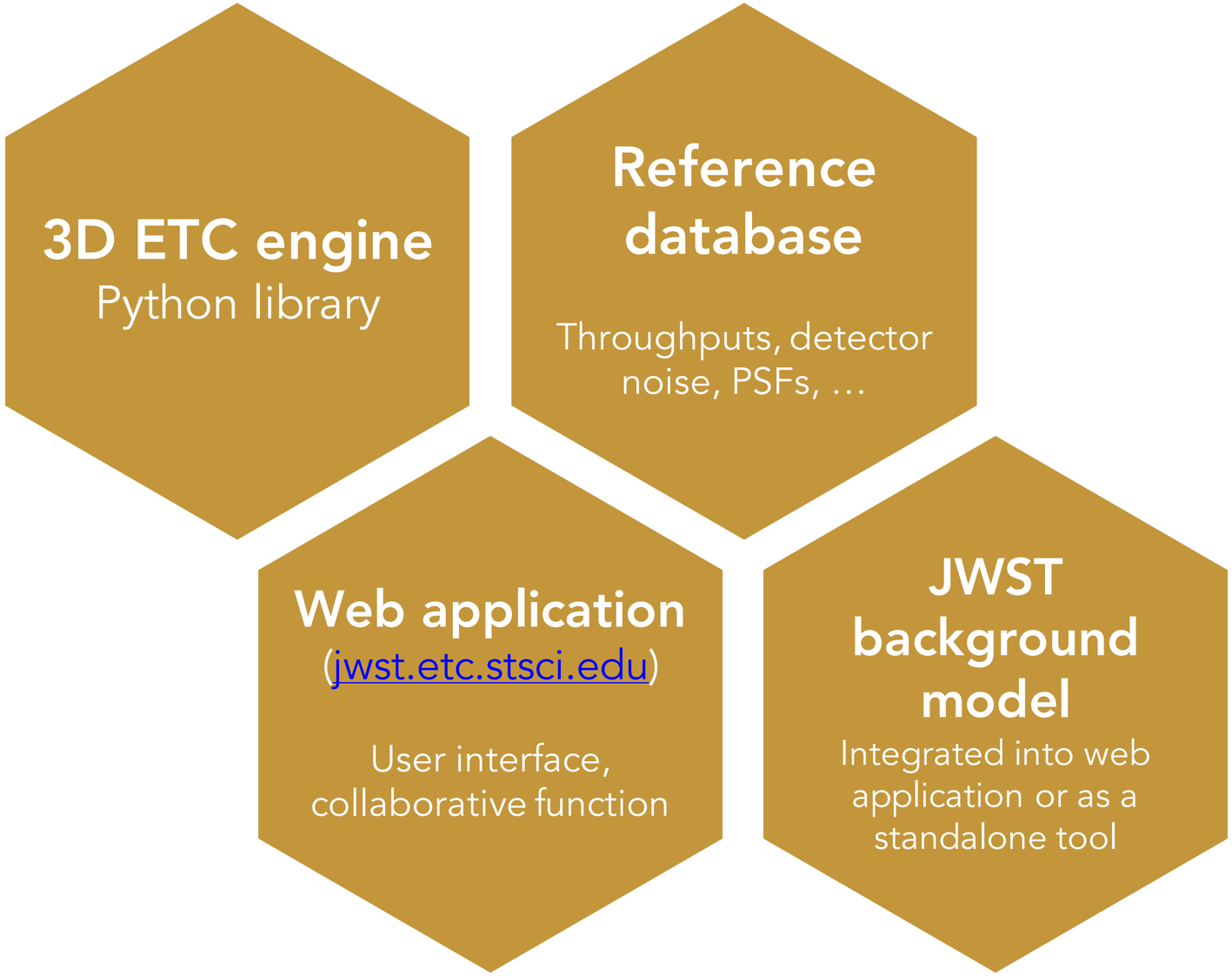
Where is ETC?

jwst.etc.stsci.edu

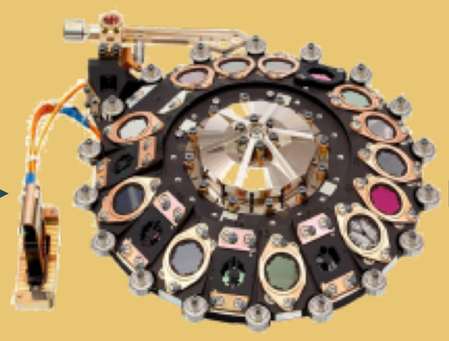


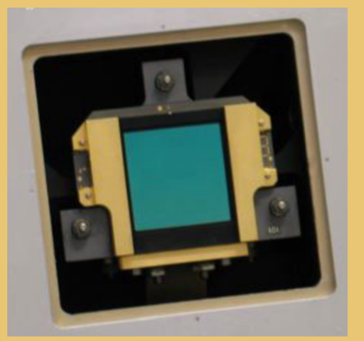
- Pontoppidan et al., Proc. SPIE. 9910, Observatory Operations: Strategies, Processes, and Systems VI, 991016. July 15, 2016 (https://arxiv.org/abs/1707.02202)

The “Pandeia” project



The engine algorithm





Space

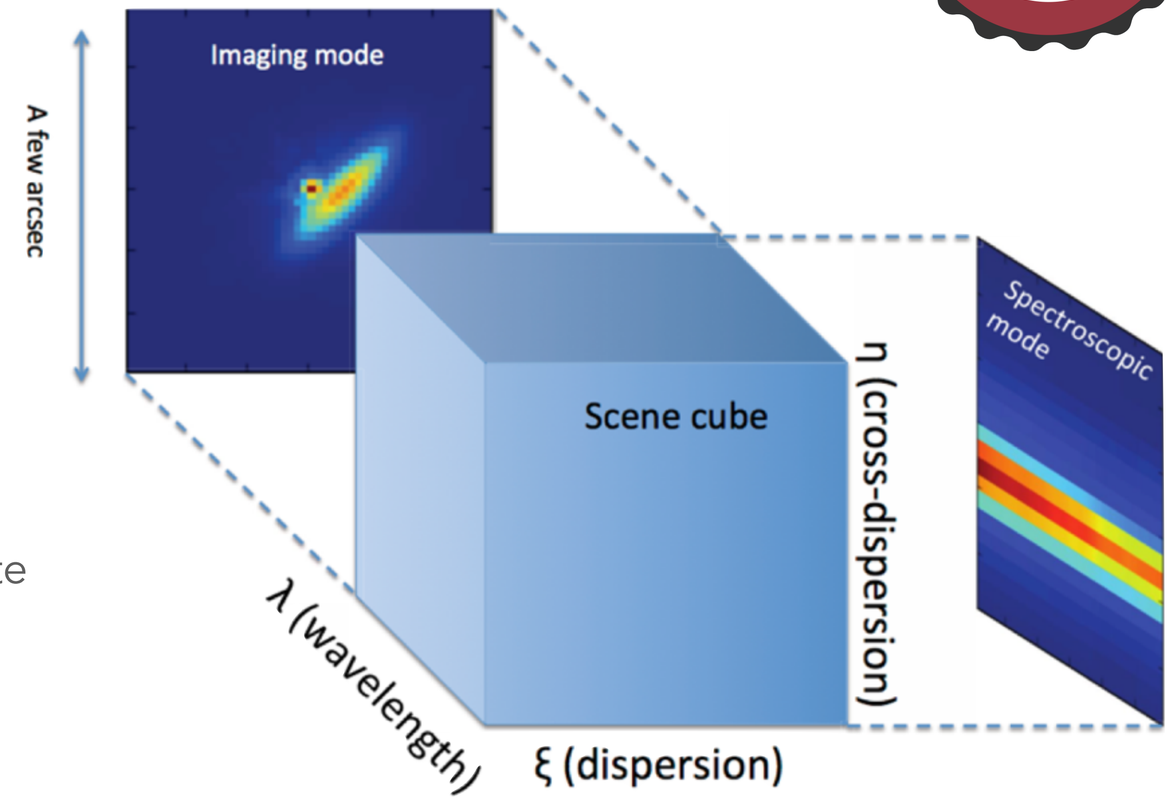
Telescope

Instrument

Detector

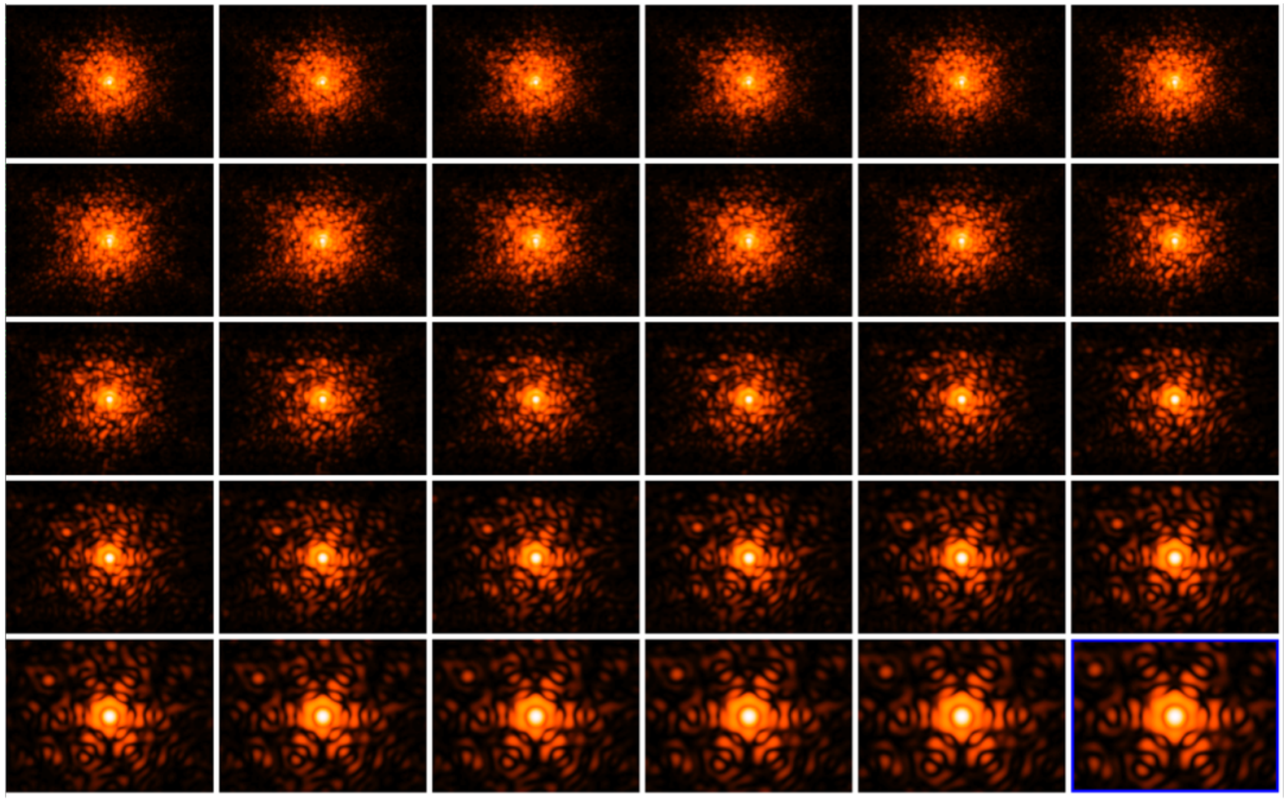
JWST ETC concept

- **Modern design**
  - Signal (source + background) modelled in 3D
    - conserves flux
    - resolve lines
    - oversample JWST resolution
  - Pixel based:
    - Models the detector (e.g. correlated noise)
    - Final S/N calculation includes data analysis and post-processing steps (“strategy”)
    - Allows the modelling of complex scenes (e.g. estimate contamination from bright sources)
- **Supports all JWST modes**



PSF library

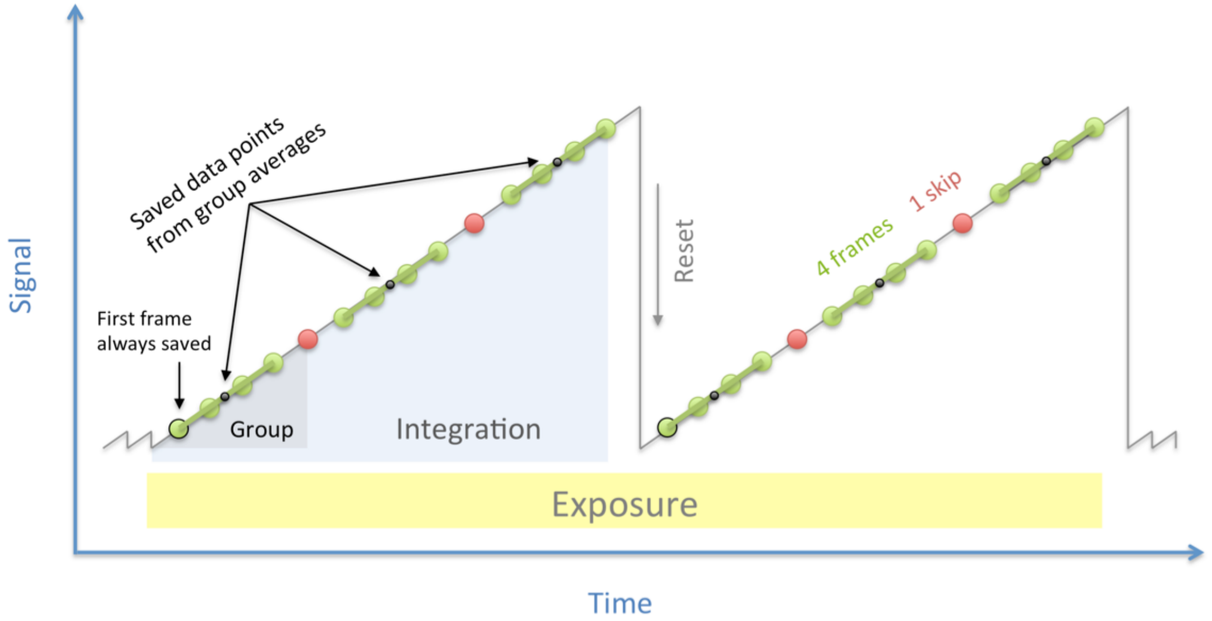
- Uses WebbPSF to calculate PSF including realistic wavefront errors
- Almost 5000 individual monochromatic PSFs
- Subsampled by integer factor of pixel size



NIRCam SW PSFs
(0.6-5.2 micron)

Readout terminology

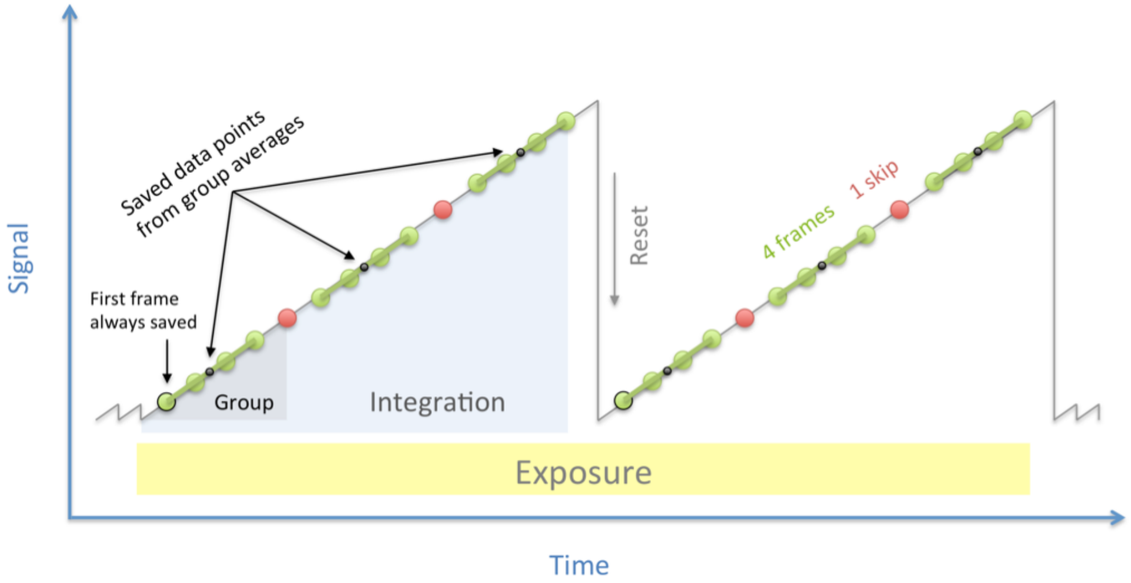
- **subarray**: the window on the detector being read out
- **frame**: one complete read of the detector or subarray
- **group**: a set of consecutive frames averaged onboard (some frames may be skipped)
- **integration**: one non-destructive ramp
- **exposure**: a set of consecutive integrations at the same pointing
- **dither**: an exposure at a new pointing

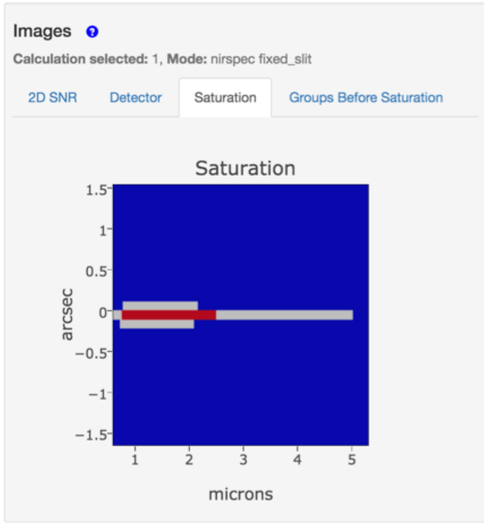


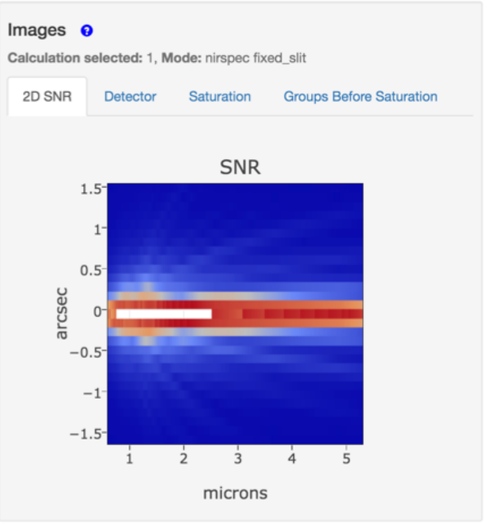
Time terminology

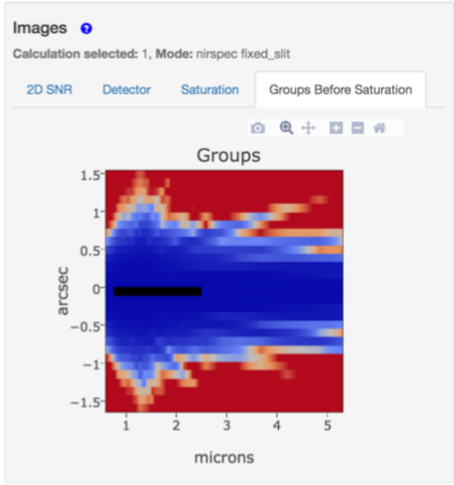
- **exposure time**: Time the detector is operating during a single exposure
  - includes resets
  - excludes initial synchronisation time
  - includes all integrations, but no repetitions per pointing, per tile, or per observation
- **measurement time**: For any individual pixel, the interval between first and last measurements during a single integration, multiplied by the number of integrations per exposure
  - used to determine count rate
- **saturation time**: For any individual pixel, the interval from reset to the final read of an integration, multiplied by the number of integrations per exposure
  - depends on exposure parameters, not target brightness or instrument throughput
- **exposure duty cycle**: measurement time divided by exposure time

How is saturation treated in ETC?









- Two types of saturation
  - **Partial saturation**: the integration saturates before it completes, but more than the minimum number of groups are unsaturated - DATA RECOVERED
  - **Full saturation**: the integration saturates before the minimum number of groups achieved - NO DATUM (for that pixel)
  - Usually, the minimum $n_{groups} = 2$

Tips for optimising detector set-up

- More frames per integration decreases read noise
- Longer groups decreases data volume
- Shorter groups decreases chance of cosmic ray hit per group
- More groups per integration make the cosmic ray correction better
- Longer integrations may make ramp fitting more certain
- More dithered exposures decreases flat-field errors and the impact of bad pixels

  Note: in ETC, all exposures are assumed to be dithers, except for time-series observations
- Readout patterns that skip lots of frames have higher read noise, but slightly better duty cycle

JWST ETC features

- **Workbooks**
  - Organise several ETC calculations into a workbook
  - A workbook can contain multiple sources, scenes and calculations
  - Workbooks remain in your MyST account, and are shareable

- **Reusability**
  - Calculations in a workbook start with reasonable defaults
  - Simply copy a calculation, modify the inputs as desired and recalculate

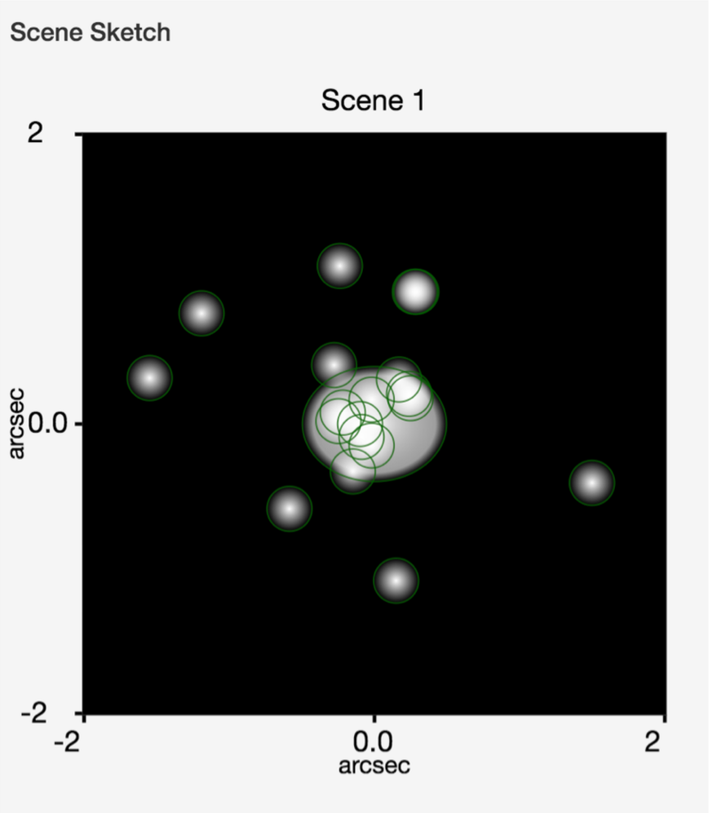
- **Batch expansion**
  - Efficiently run a batch of many calculations
  - Calculation is duplicated N times varying only the selected parameter
  - Expansion over e.g. Ngroups offers a way to show the behaviour of SNR as a function of “exposure” time

- **Auto-update**
  - Changes made to the input, flow through to associated forms and calculations

Scenes and sources

- **Scene**: small postage-stamp of the sky (a few arcsec on a side)
  - A scene can have no source (just background) or multiple sources
  - Scenes can be reused in multiple calculations

- **Source**: specify SED, normalisation, extinction, emission lines and shape
  - Each sources can be reused in multiple scenes
  - Location: x,y offset (with orientation) within the postage stamp scene
  - Shape: point source or extended (flat, Gaussian, Sersic, power law…)
  - Spectrum:
    - Continuum: flat, black body, power law, templates
    - Lines: centre, width, flux
    - Normalise to magnitude/flux in JWST or HST bandpass, or at a λ
    - Upload a spectrum (ASCII or FITS format)



Issues to think about when using ETC

- **ETC is a highly versatile tool**

- **There are many parameters affecting ETC sensitivities and program preparation**
  - Different read-out patterns change the read noise
  - Be aware of saturation
  - Which background subtraction scheme?
  - Is the background correct for your target?
  - What extraction aperture is optimal? (Point or extended source?)
  - Does your extraction aperture contain contaminating flux from other sources in the scene?

Remember: ETC approximates our current best knowledge and understanding of performance. There are remaining uncertainties associated with system throughputs, detector noise properties, etc., which will remain unknown until JWST is in flight.

BEWARE: The ETC is not intended to be a complete observation simulator

Useful links

- **JWST ETC (v1.5)**
  - https://jwst.etc.stsci.edu/

- **Documentation:**
  - ETC introduction
  - Links to all pages, video tutorials and more
  - https://jwst-docs.stsci.edu/jwst-exposure-time-calculator-overview

- **ETC release notes, known issues and FAQ (@ JWST Help Desk)**
  - JWST Help Desk ETC FAQ
  - JWST Help Desk ETC known issues

- **JWST Community Lecture Webcasts**
  - "The JWST Exposure Time Calculator" - Klaus Pontoppidan (Nov 2019)
  - "JWST ETC Demo" (interface demonstration) - Swara Ravindranath (Feb 2017)

JWST Interactive Sensitivity Tool (JIST)

JWST Interactive Sensitivity Tool (JIST)

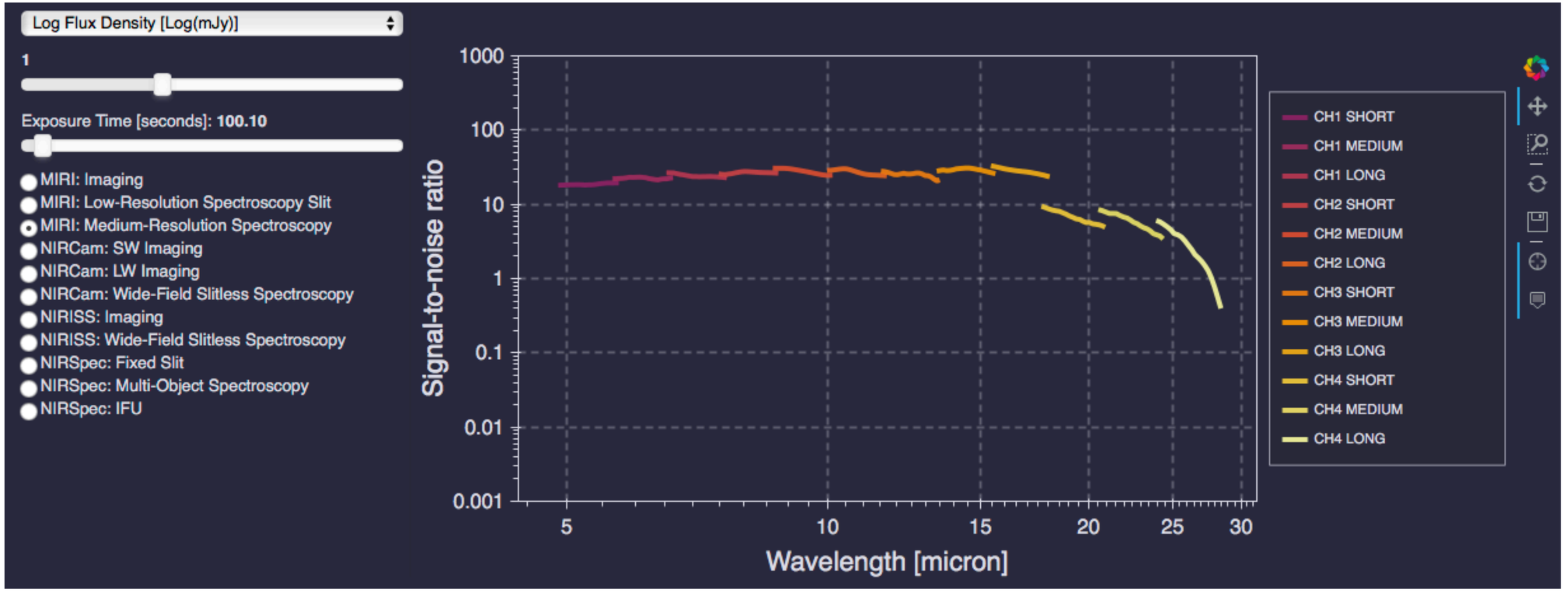
- Quick-look observation feasibility
- Runs directly in a browser window

  - Online tool: jist.stsci.edu
  - JDox: JIST

- For all basic observing modes, explore S/N values by adjusting source flux or telescope exposure parameters

JWST Interactive Sensitivity Tool (JIST)

- Example view of the interface



JWST Interactive Sensitivity Tool (JIST)

- Beware of the simplifying assumptions…
  - All calculations based on a point source:
    - Flat SED
    - Background spectrum set to 120% of minimum zodiacal background at a reference point (see usage notes for more detail)
  - Single integrations are considered. For multiple integrations (or dithers), SNR can be scaled by SQRT(N_{INTS})
  - Saturation simply handled by setting SNR=0 (JIST is not recommended for saturated data)
  - For WFSS modes, only R Grism values presented (C Grism assumed identical)

Accessing the tool - reminder

Accessing the tools

- Astronomer's Proposal Tool (APT)
- MSA Planning Tool (MPT)

→ apt.stsci.edu

- Exposure Time Calculator (ETC)

→ jwst.etc.stsci.edu

- JWST Interactive Sensitivity Tool (JIST)

→ jist.stsci.edu