JWST Master Class Workshop

NIRSpec Slit hands-on

Elena Puga for the ESA JWST SOT team

NIRSpec and MIRI LRS Slit hands-on

- **Infrared spectroscopy of Y dwarfs**
  - NIRSpec
  - MIRI LRS

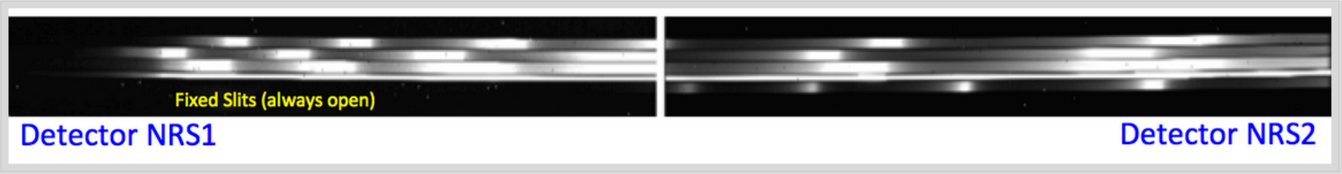
- In this hands-on session you will be asked to use:
  - The Exposure Time Calculator (ETC) for the NIRSpec
  - The Astronomer's Proposal Tool (APT) for NIRSpec

- The MIRI LRS science case may be an extension to this exercise.

Thinking about strategies

NIRSpec Subarrays and Readout patterns

- **Subarray:**
  - FULL
  - Tailored subarrays per individual slit: SUBS200A1, SUBS200A2, SUBS200B1, SUBS400A1
  - S1600 subarrays: SUB2048, SUB1024A, SUB1024B, SUB512
  - ALLSLITS (S200A1 and S200A2 combined to bridge the detectors gap, but not only. It can also be used to estimate background)



- FULL: only traditional readout mode
- **Readout patterns:** NRS, NRSRAPID, NRSIRS2, NRSIRS2RAPID
- Note: maximum exposure duration is 10,000 seconds

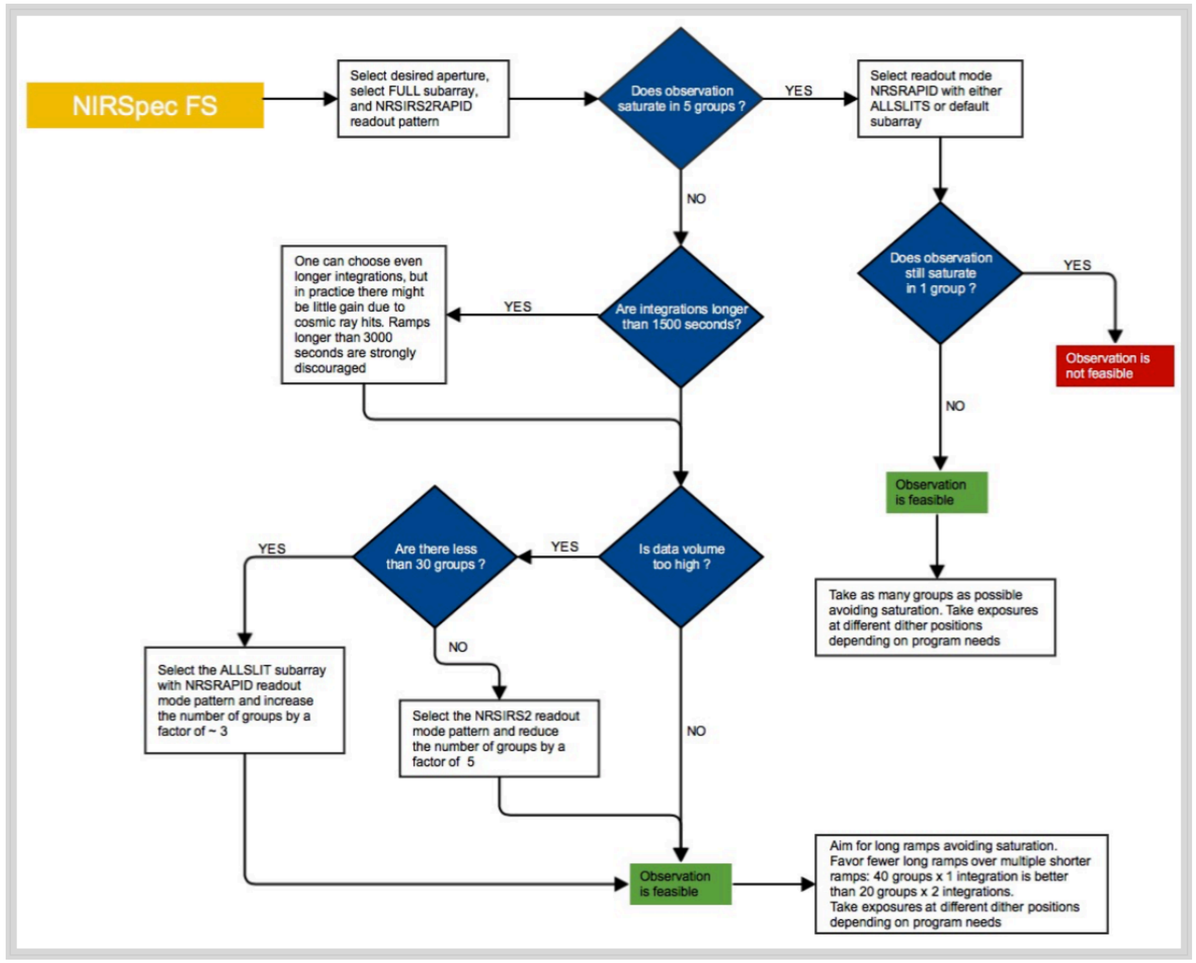
Table 1. NIRSpec subarrays for the FS observing mode

Subarray name	Apertures available	Height (pixels)	Width (pixels)	Frame time (s)
FULL †	All FSs	2048	2048	10.73677 14.58889 (IRS2)
ALLSLITS	All FSs, option: ***S200A1*** and ***S200A2*** **	256	2048	5.49400
SUBS200A1	***S200A1***	64	2048	1.55800
SUBS200A2	***S200A2***	64	2048	1.55800
SUBS200B1	***S200B1***	64	2048	1.55800
SUBS400A1	***S400A1***	64	2048	1.55800
SUB2048	***S1600A1***	32	2048	0.90200
SUB1024A ‡*	***S1600A1***	32	1024	0.45144
SUB1024B	***S1600A1***	32	1024	0.45144
SUB512	***S1600A1***	32	512	0.22616

NIRSpec FS detector recommendations

- Decision flow to specify detector parameters for a FS observation:

- Saturation
- Lower limit
- Data volume



Background removal strategies

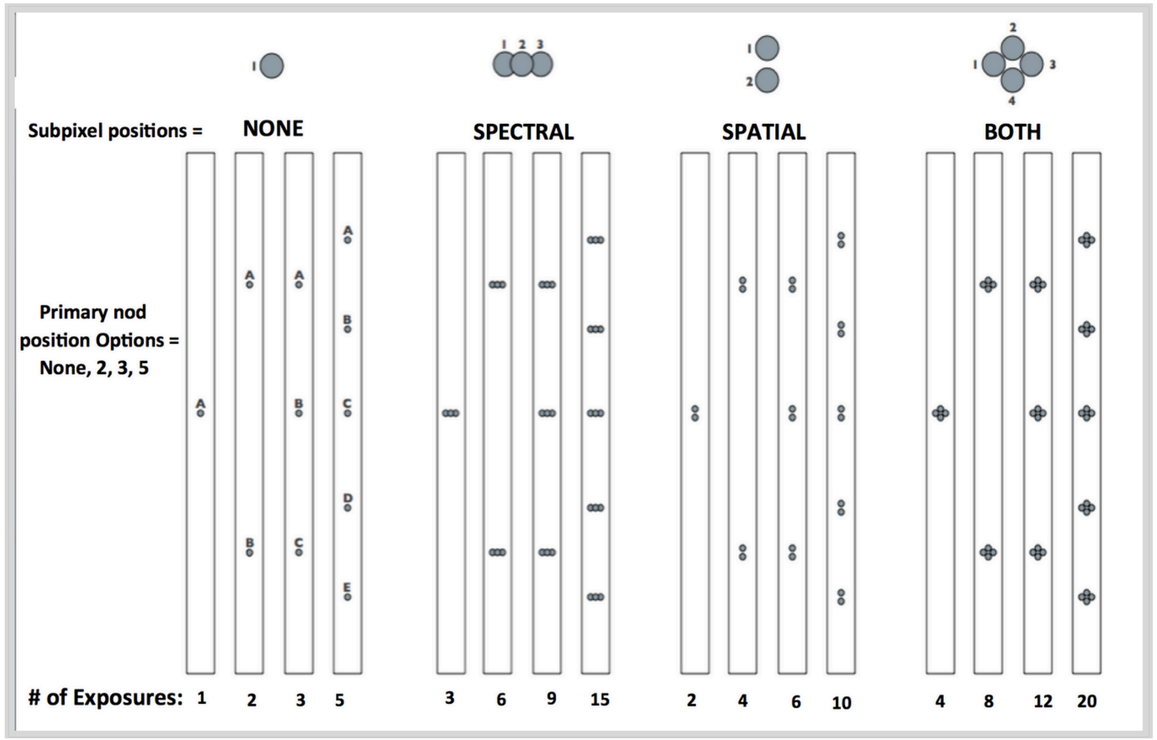
- **Pixel-to-pixel subtraction**
  - Compact sources: using nodding
  - Extended sources: associated dedicated "blank sky" observation at off-scene position
    - for NIRSpec: performed only if grating wheel has not moved between the target and off-scene exposures
- **Master background subtraction**
  - Standard for extended sources
  - created from:
    - associated exposure, creating an independently flux-calibrated 1D background spectrum
    - list of background elements (like off-source pixels)
  - for NIRSpec: is set by pipeline processing if the grating wheel has moved

- In ETC, FS nod/dithers are accounted for at detector level, setting the number of exposures.
- APT: Dedicated observations for background must be linked to science observations in order to create an association list. This is defined at Target Level in APT. Necessary for pipeline processing flow.
- APT: If the background signal is time variable throughout the year, dedicated "blank-sky" observations should be scheduled consecutively to ensure pixel-to-pixel subtraction. Special requirements: Non-interruptible

NIRSpec Nods and dithers

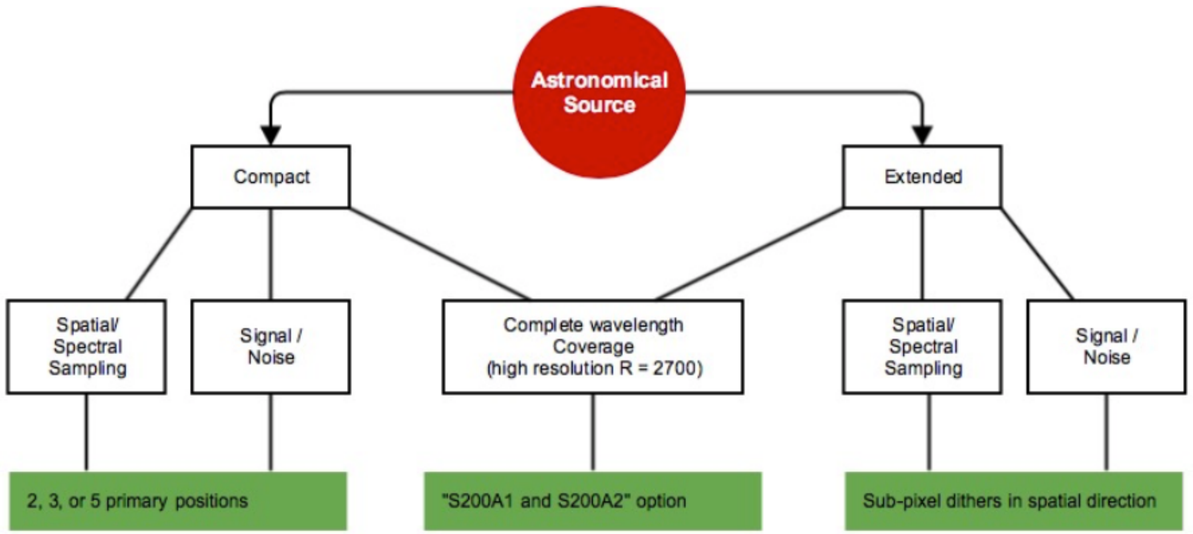
- **Nods:** offsets that produce data to be subtracted in pipeline processing, in order to cancel in-field background flux. Nod options are typically best used for targets that are not significantly spatially extended. (2, 3, or 5 points), depending on the number of exposures needed/possible.
- **Dithers:** offsets of the target position over multiple exposures, to even out or mitigate detector effects, help remove cosmic rays, improve spatial sampling, and increase signal-to-noise and flux accuracy.

- APT
  - **Primary dithers:** nod along the slit used to subtract background flux. Recommended 3, 5.
  - **Sub-pixel dithers:** to improve spatial and/or spectral pixel sampling, only in addition to Primary Dither pattern for point sources. Not recommended in spectral dimension.
  - **Across gap SAM.** Offset executed by selecting the option "S200A1 and S200A2" only in the high resolution gratings



NIRSpec Nods and dithers

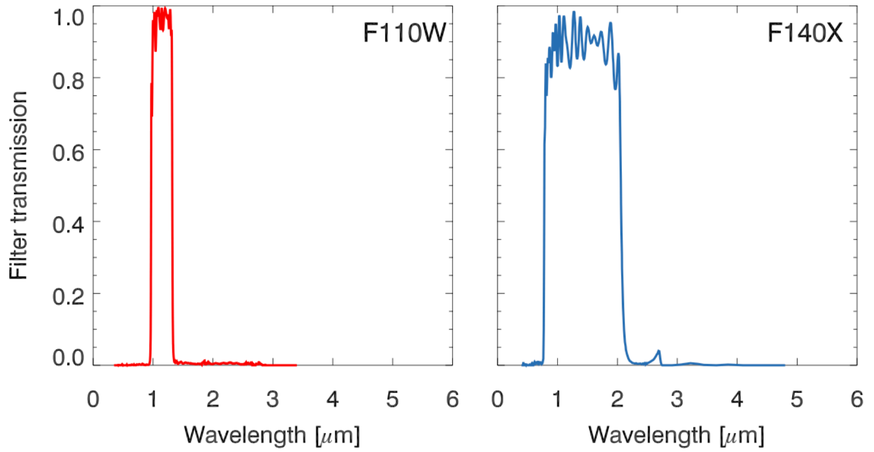
- Decision tree for choosing the right nod/dither pattern for FS observations based on the source compactess.



NIRSpec FS Target Acquisition

- FS TA methods:
  - **WATA (recommended)** using science or offset target centred in S1600A1. 11-18 minutes. Expected accuracy: 20 mas, and depends on centroiding accuracy of the target (ephemeris).
  - **MSATA** requires defining 5-8 reference stars (may require pre-imaging). It is specified at the visit level of the observation, not directly at the observation template. 24-30 minutes. Expected accuracy: 20 – 25 mas (optimal), <50 mas (relaxed), depending on the catalogue relative accuracy.
  - **NONE** is not recommended for FS. The resulting pointing accuracy will be that delivered by the GS acquisition at the start of the observation. For reference, the absolute pointing performance of JWST for NIRSpec is expected to be 100 mas

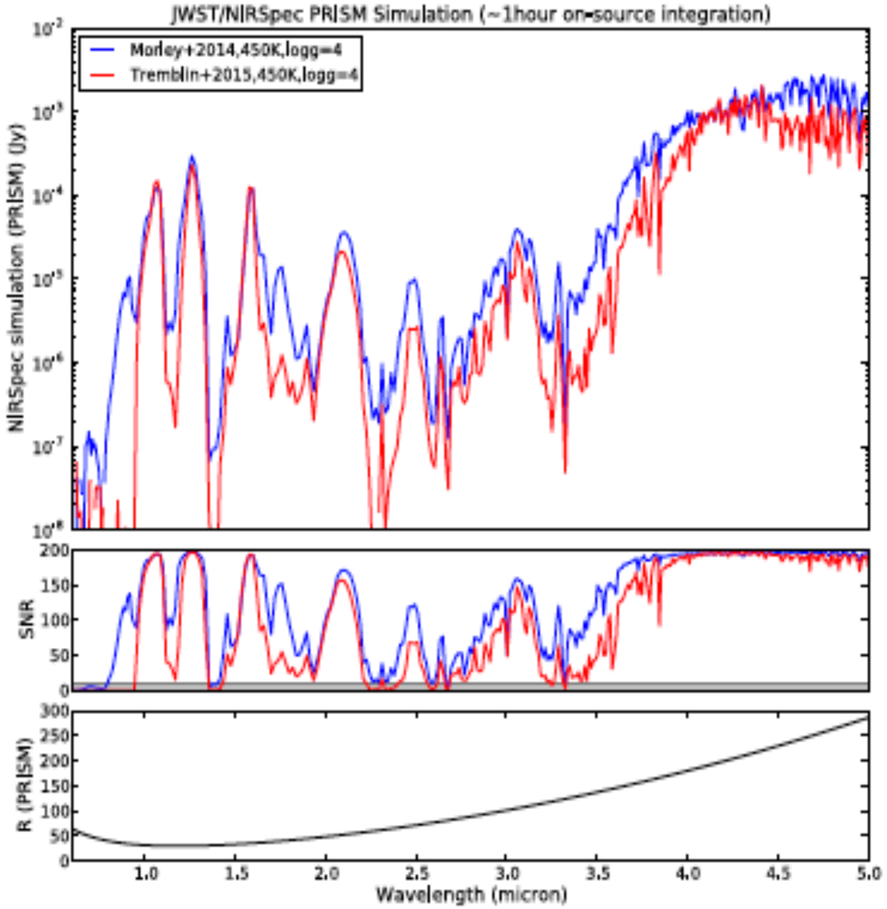
- **Strategies and parameters:**
  - WATA:
    - Subarray configurations: SUB32, SUB2038, FULL (increasing frame time)
  - MSATA:
    - Subarray configuration: FULL
  - Filters: F110W, F140X, CLEAR
  - Readout pattern: NRSRAPID, NRSRAPIDD1, NRSRAPIDD2, NRSRAPIDD6
  - Groups/Integrations are fixed
  - TA readout mode switch with respect to science parameters costs extra in time.



Science case

Science Overview

- **Goal**
  - To obtain spectroscopic observations of a Y dwarf across the entire JWST NIRSpec and MIRI LRS wavelength ranges to understand whether these atmospheres are shaped by chemical disequilibrium driven by vertical transport or the formation of water clouds, and constrain the object's gravity, hence mass.



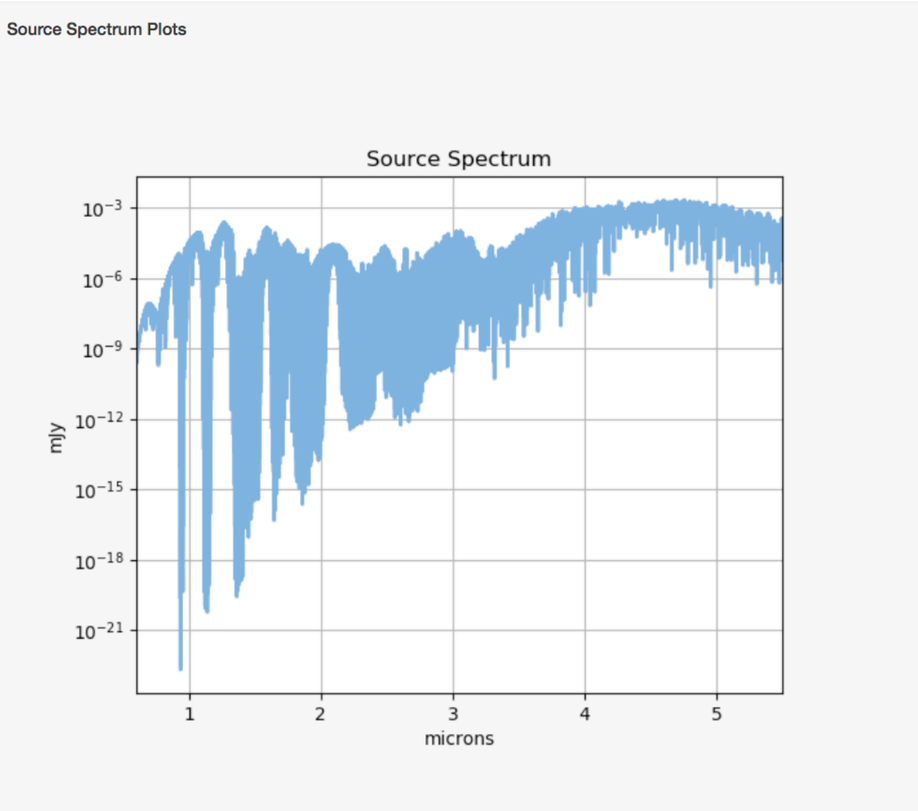
Observations Methodology

- **Methodology**
  - Compare high-quality low and medium resolution Infrared spectra from 0.6 to 13 microns, to models of cool atmospheres at different temperatures, gravity, degrees of turbulence, chemical equilibrium or disequilibrium driven by vertical transport, and clouds.
- **Planned observations**
  - NIRSpec fixed slit spectroscopy
  - MIRI LRS slit spectroscopy
- **Source Type**
  - Point source
- **Observation strategy**
  - PRISM and G395M dispersers for NIRSpec to obtain R~100 and R~1000, respectively and MIRI LRS R~100
  - 3-point nod NIRSpec / 2-point nod MIRI
  - TA on science source

Getting started ETC
NIRSpec WB ID: 30896
MIRI LRS WB ID: 30989

Scenes and Sources

- NIRSpec:
  - 1 source with user supplied model spectrum morley_spec_ETC_noscale.txt renormalized to measured Vega magnitudes HST/ WFC3 F140X.
- MIRI
  - Workbook: 30989



Calculations

- Overview

Calculations | Scenes and Sources | Upload Spectra | Caveats and Limitations

MIRI | NIRCam | NIRISS | NIRSpec

ID	✓	Mode	λ	Scn	(s)	SNR	⚠
3	☐	nirspec target_acq	1.27	1	42.95	21.60	✓
2	☐	nirspec fixed_slit	1.00	1	1318.19	25.24	✓
1	☑	nirspec fixed_slit	4.70	1	5618.27	103.62	✓
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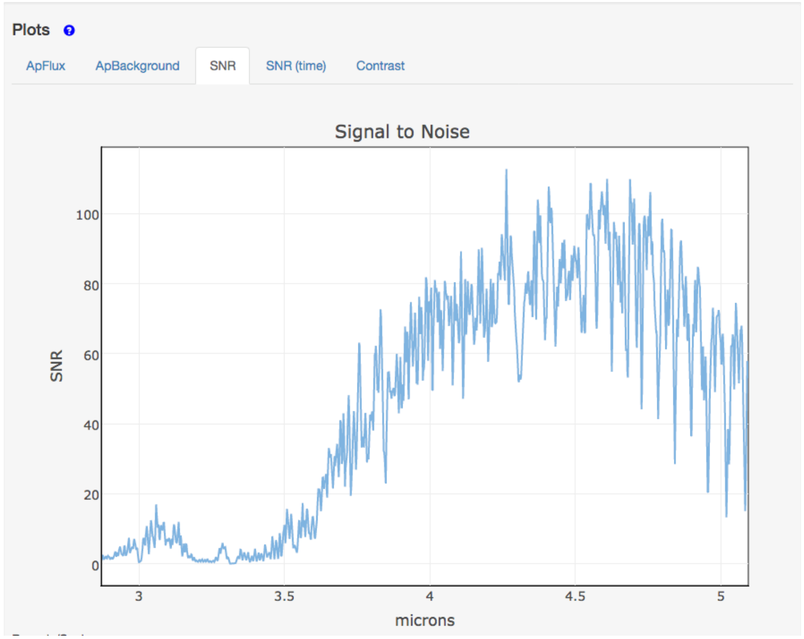
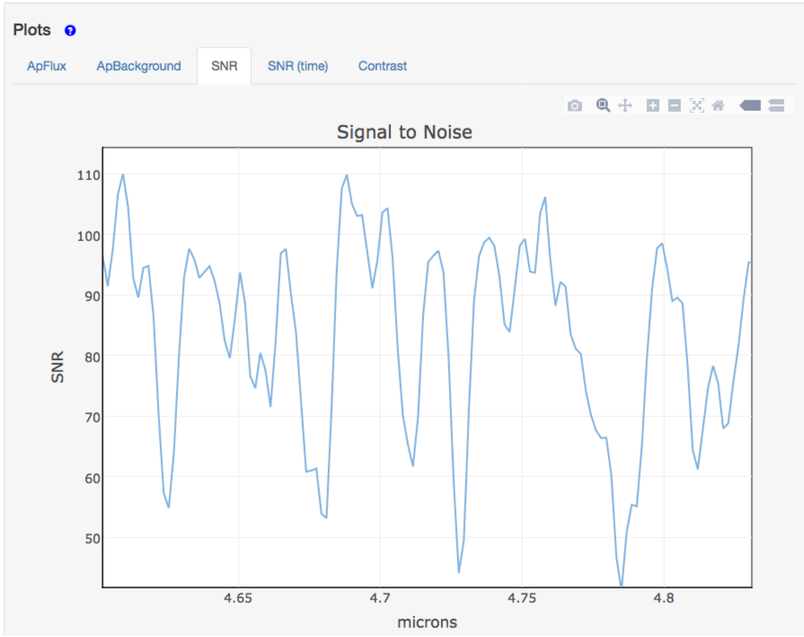
Plots

ApFlux | ApBackground | SNR | SNR (time) | Contrast



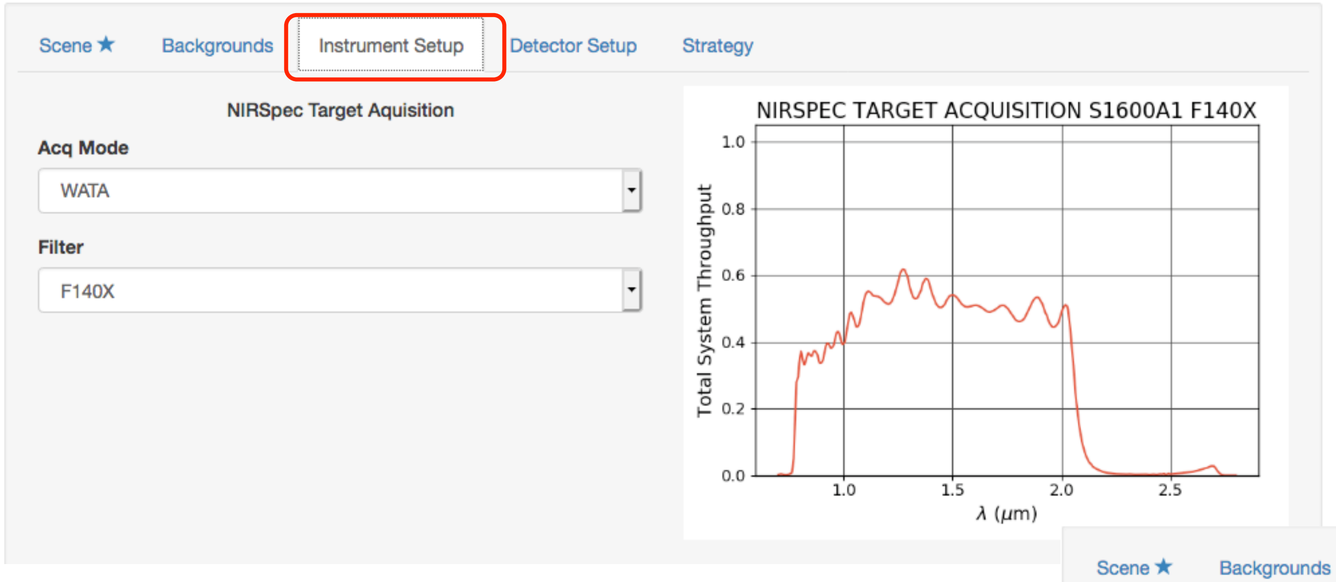
Plots

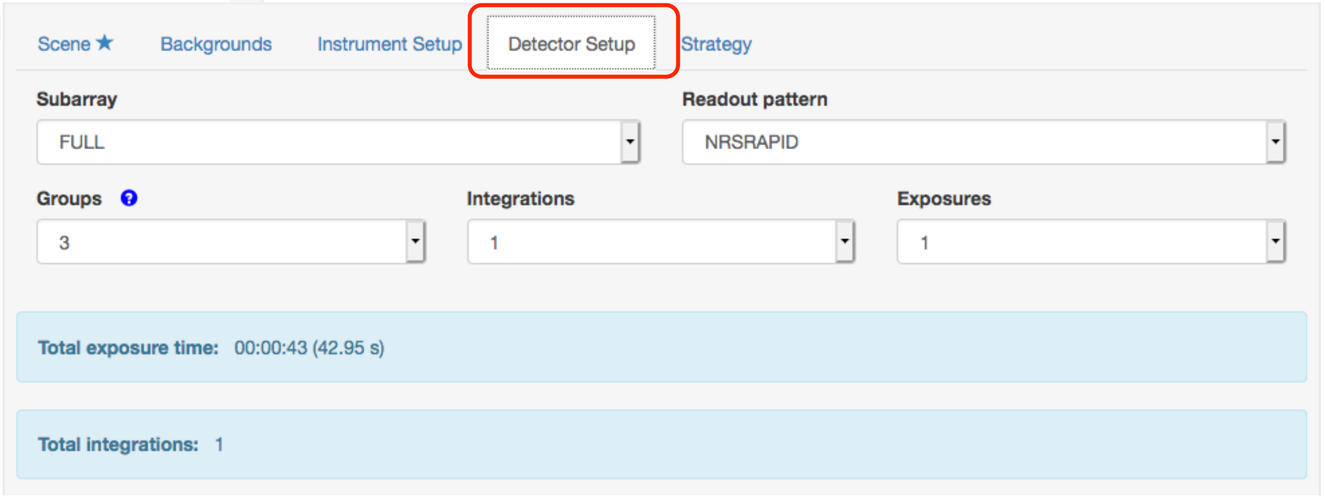
ApFlux | ApBackground | SNR | SNR (time) | Contrast



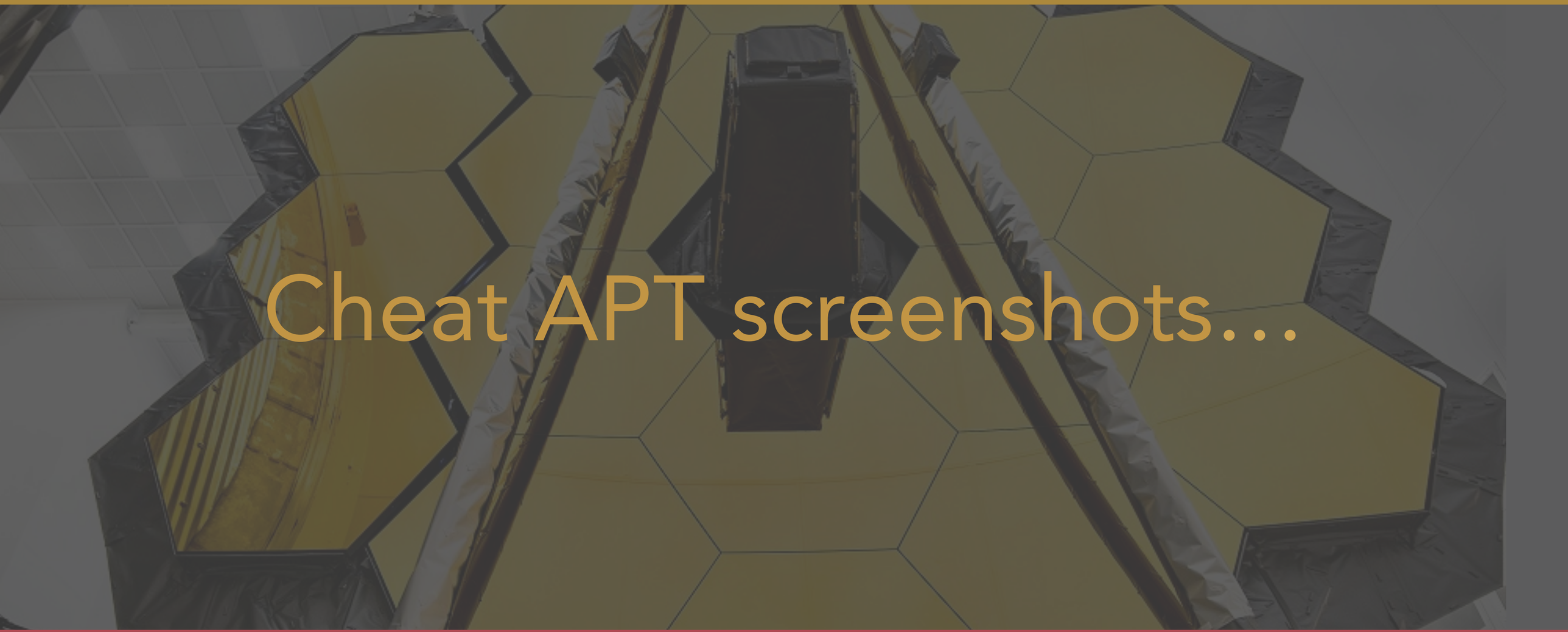
NIRSpec Calculation for Target Acquisition

- WATA in ETC is available.





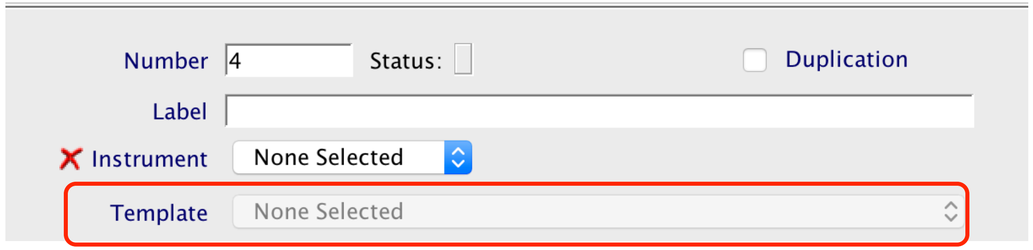
Getting started APT

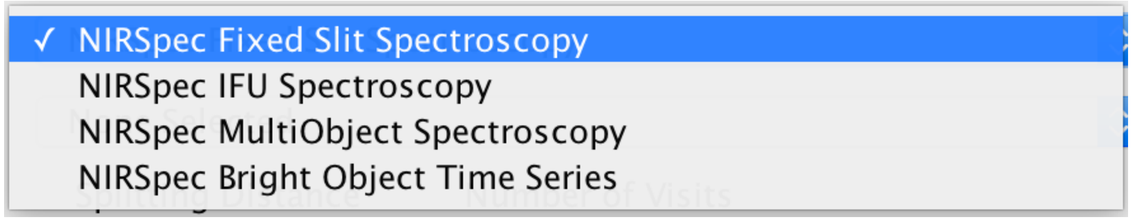


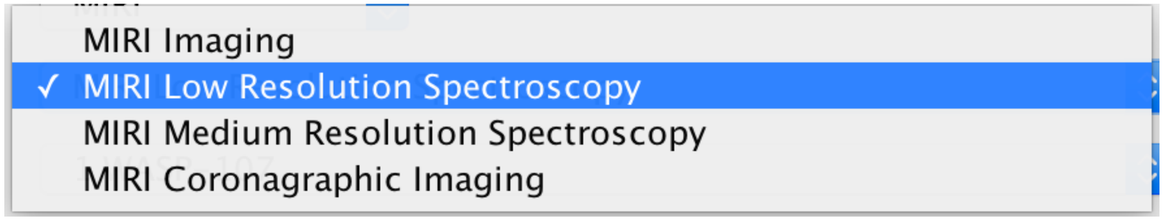
Cheat APT screenshots…

APT Fixed-slit spectroscopy templates

- When creating a new observation, the user defines the APT template



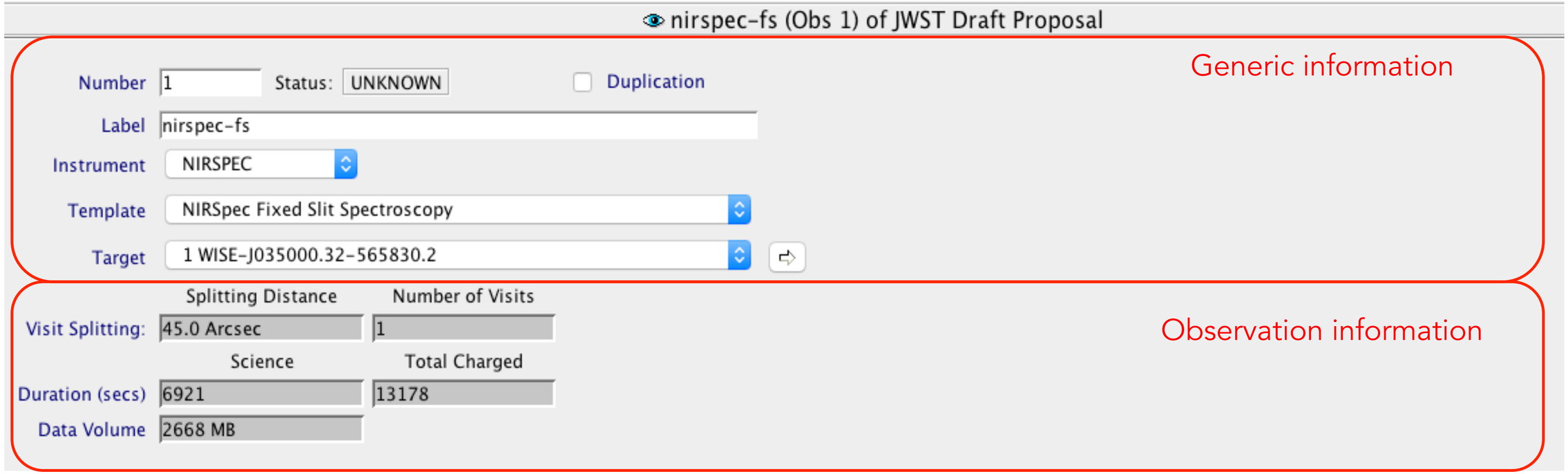




- APT fixed-slit spectroscopy templates are divided into four sections:
  - Generic information
  - Observation information
  - Target acquisition parameters
  - Science parameters

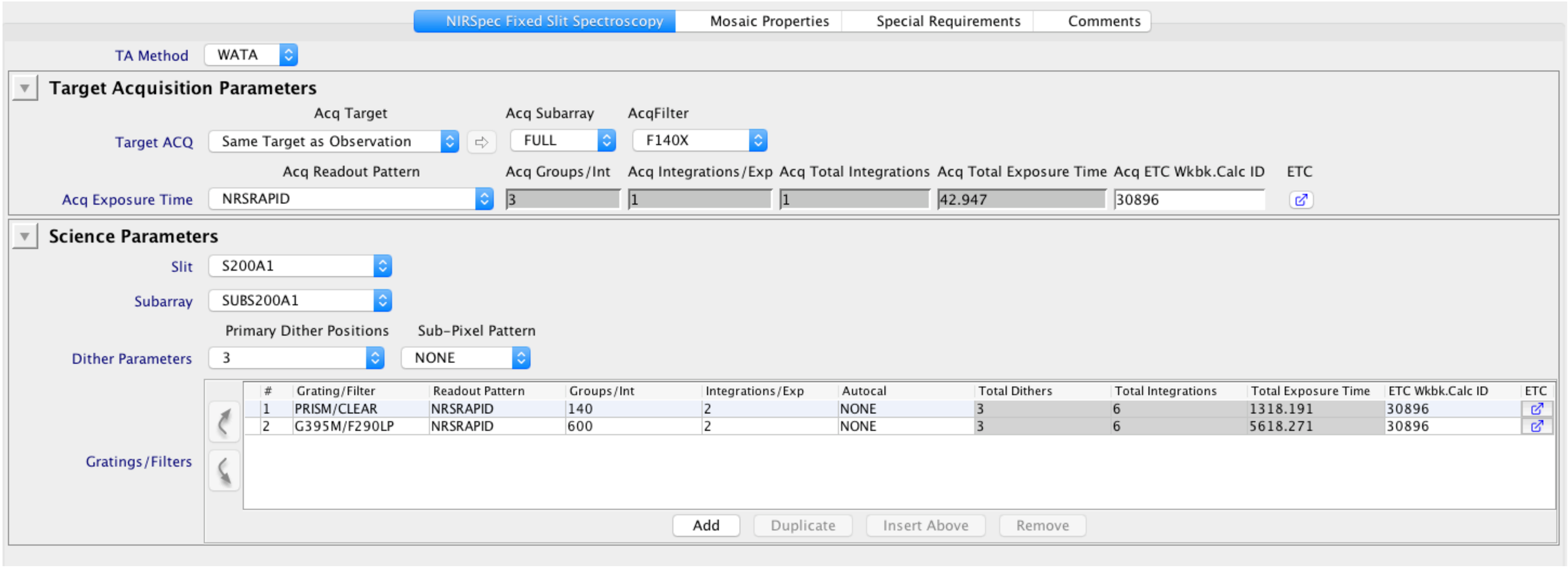
APT Fixed slit spectroscopy template

- NIRSpec



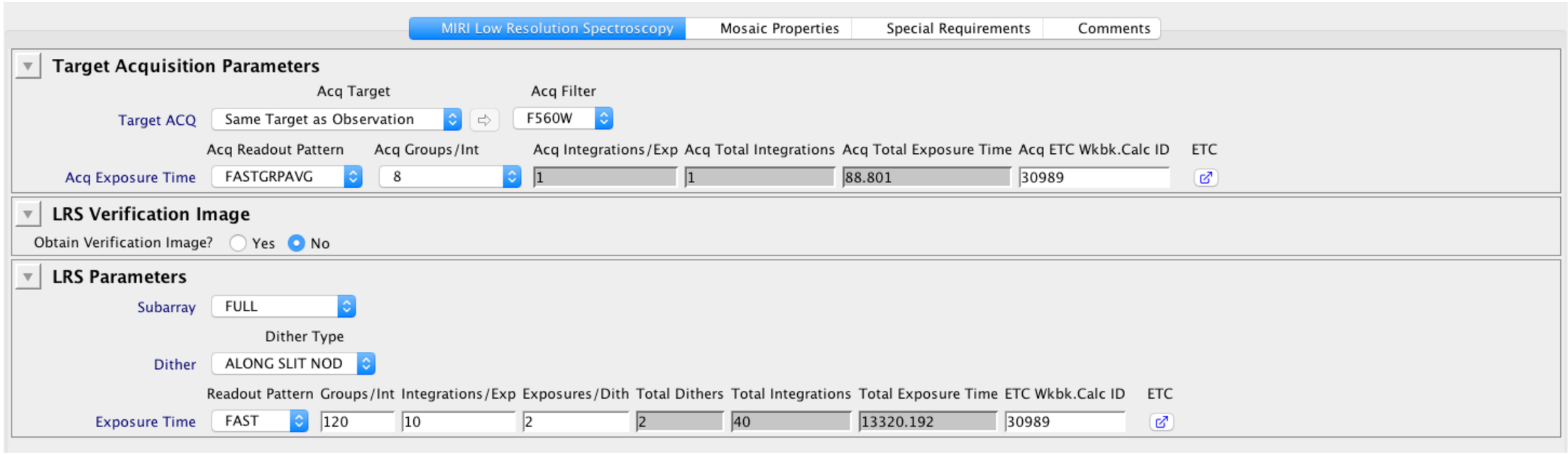
APT Fixed slit spectroscopy template

- NIRSpec



APT Fixed slit spectroscopy template

- MIRI



Further reading

Slit Help and JDOX

- Detector Strategies
  - NIRSpec detector recommended strategies
- NODS and Dithers
  - NIRSpec Background Recommended Strategies
  - MIRI LRS Recommended Strategies – Background observations
  - NIRSpec Dithering Recommended Strategies - FS
  - MIRI LRS Dithering Recommended Strategies
- Target Acquisition
  - NIRSpec Target Acquisition Recommended Strategies
  - MIRI Target Acquisition Generic Recommended Strategies
  - MIRI LRS Target Acquisition Recommended Strategies