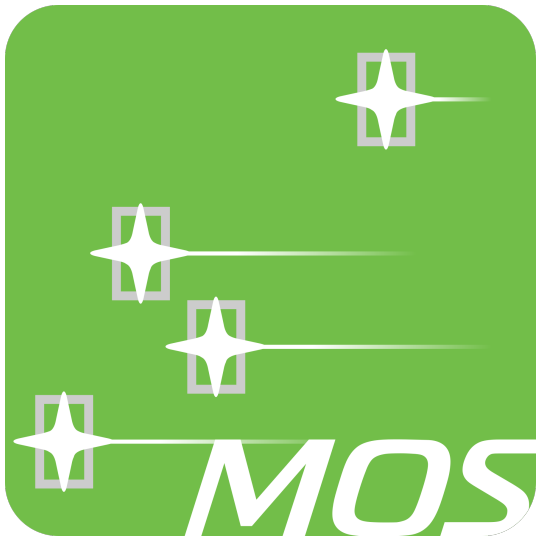
ESAC 2017 JWST Workshop



NIRSpec Multi-Object Spectroscopy of distant galaxies

Science case 3.2

Acknowledgements

This guide makes a heavy use of the ETC workbook and APT files generated by members of the NIRSpec STScI team for the JWST proposal planning workshop that took place at STScI in May 2017

https://jwst.stsci.edu/news-events/events/events-area/stsci-events-listing-container/jwst-proposal-and-planning-workshop

Tools used throughout this specific guide

In this guide you will be asked to used the following tools:

- The JWST Exposure Time Calculator (ETC).
- The Astronomer's Proposal Tool (APT) and more specifically the NIRSpec MOS Planning Tool (MPT).

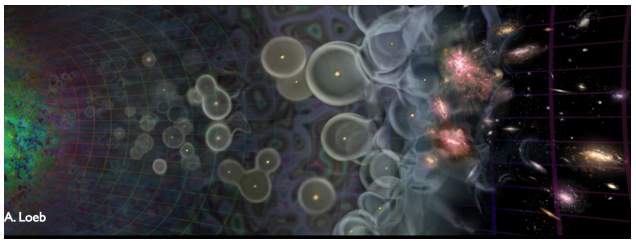
The MPT, which is part of the APT, got its dedicated demonstration and hands-on session during this workshop (D. Karakla).

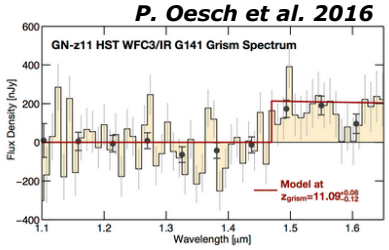
We will not have the time to exercise the visibility tools.

Overview

Goal: This program aims at studying the evolution of galaxies from its first steps (z>10), through the end of the dark ages (z=7-9) and down to the epoch of galaxy assembly (z=2-6).

- Understanding the very early stages of galaxy formation.
- Probing the epoch of reionization and the role of galaxies in the reionization.
- Tracking and understanding the build-up of stellar masses, metals and the build-up of quiescent populations (feedback, quenching).
- Understanding the role of AGNs.
- And look for surprises…





Overview

Methodology: an in-depth program of this type would combine deep imaging (NIRCam) and follow-up spectroscopy (NIRSpec MOS) like the NIRCam-NIRSpec GTO galaxy assembly survey.

In the following, we will use a much simpler example of deep NIRSpec MOS observations at a single "pointing" using an input source catalog derived from existing HST imaging.

Planned observations: single-pointing NIRSpec MOS observations at low and medium spectral resolution.

Type of sources: galaxies over a wide range of redshifts handled as compact objects.

Observation strategy: combination of "nodding" and dithering; 1x3 micro-shutter slitlets.

Instrument configurations

Low spectral resolution (CLEAR/PRISM): sensitivity to continuum; wavelength coverage (0.6 to 5.3 microns in one shot); higher-multiplex MOS thanks to the short spectra (more room).

Main drawback(s): lack of spectral resolution…

Medium spectral resolution (F100LP/G140M, F170LP/G235M, F290LP/G395M): clean separation of emission lines; accurate information on the position of the position of the centroid of the lines.

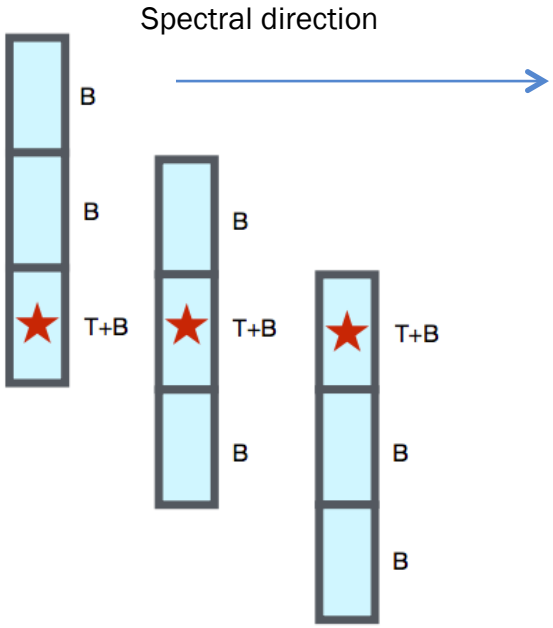
Main drawback(s): 3 configurations required to cover the 1.0-5.2 micron range; high multiplex only possible at the cost of allowing some overlap between the spectra.

➔ Complementary information, going for all 4 configurations.

Observation strategy – basic building block

3-shutter nodding pattern: in MOS mode, the recommended basic pattern for faint and compact sources is called a 3-shutter nodding pattern. It will constitute the basic building block for our observation program.

Each object is assigned a slitlet made of 3 shutters.



The baseline observation strategy is to "nod" i.e. to move the object in each shutter in three consecutive exposures, hence the name of "3-shutter nodding pattern".

For compact objects, this strategy allows powerful exposure-level background subtraction:
[T+B] – 0.5 * ([B] + [B])

In this scheme, the number of exposures is a multiple of 3.

ETC: S/N for an AB=26.5 mag z~6 galaxy observed during 100ks in CLEAR/PRISM

Task: prepare an ETC simulation for a ~100ks NIRSpec MOS CLEAR/PRISM observation of a z~6 galaxy of AB=27.5 (or ~50 nJy) around 2 microns.

Scene and source: single point source; use the Blue Compact Dwarf template spectrum from Brown et al, redshift it to z=6 and normalize it either to AB=27.5 (over NIRCam/F150W) or to 50 nJy at 2 microns.

Observation strategy: medium background at 03:32:28.0 -27:48:30; MSA full shutter extraction.

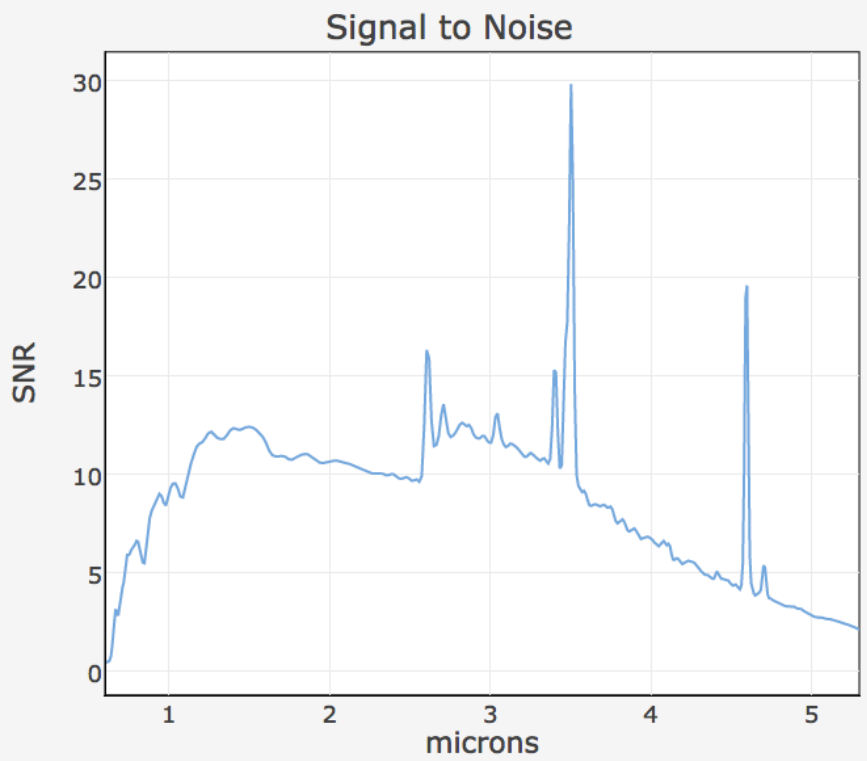
Instrument setup: NIRSpec MOS; CLEAR/PRISM; 3-shutter slitlet; target centered in the micro-shutter

Detector setup: NRSIRS2 (recommended for long exposure and faint-object observations); ~1.5ks per exposure = 18 groups; total of 72 integrations or exposures (multiple of 3…).

ETC: S/N for an AB=26.5 mag z~6 galaxy observed during 100ks in CLEAR/PRISM

Plots

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



Bounds/Scale:

X: 0.6 | 5.3 | Linear | Clear

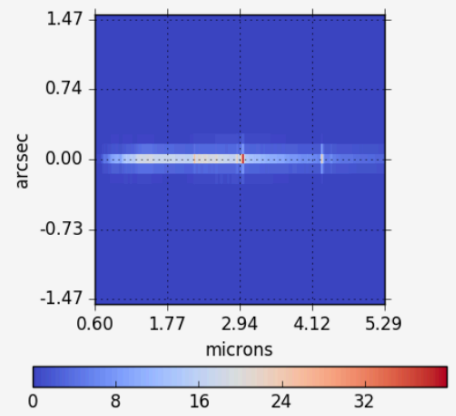
Y: -1.22 | 31.42 | Linear | Clear

Apply

Images

Calculation selected: 1, Mode: nirspec msa

2D SNR | Detector | Saturation



2D SNR Image

ETC: S/N for emission-lines observed at medium spectral resolution

Task: prepare an ETC simulation made of 3 calculations for NIRSpec MOS F100LP/G140M+F170LP/G235M+F290LP/G395M observations of emission lines for a total exposure time of ~100ks

Scene and source: single point source. Create a scene with a single source containing 3 (manually) redshifted emission lines (see at the bottom of the slide)

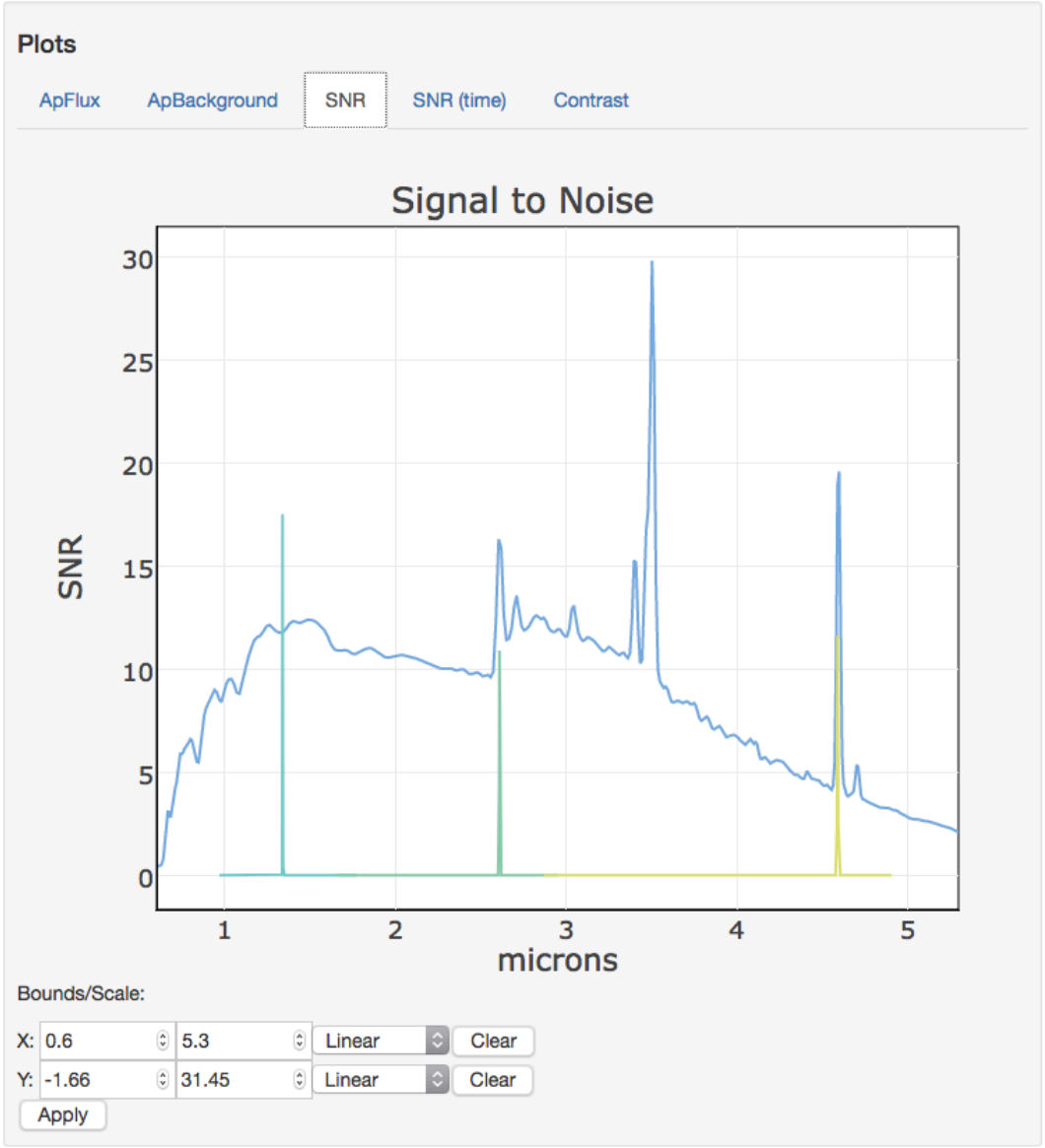
Observation strategy: medium background at 03:32:28.0 -27:48:30; MSA full shutter extraction.

Instrument setup: NIRSpec MOS; F100LP/G140M, F170LP/G235M, F290LP/G395M; 3-shutter slitlet; target centered in the micro-shutter

Detector setup: NRSIRS2 (recommended for long exposure and faint-object observations); ~1.5ks per exposure = 18 groups; total of 24+24+24 integrations or exposures.

Name	Center	Width	Strength
[OII] at z=6	2.61	40	7e-19
CIII[	1.34	40	2.1e-18
Ha at z=6	4.59	40	5.15e-19

ETC: S/N for emission-lines observed at medium spectral resolution



Plan your observation strategy before playing with APT/MPT (stop and think…)

Task: prepare an observation layout that you will implement in the APT/MPT.

Your inputs: basic building block of 3 exposures corresponding to a 3-shutter nodding scheme; 72 exposures in CLEAR/PRISM; 24 exposures in each of F100LP/G140M, F170LP/G235M and F290LP/G395M

Your not-so-compatible wishes when designing the observations:

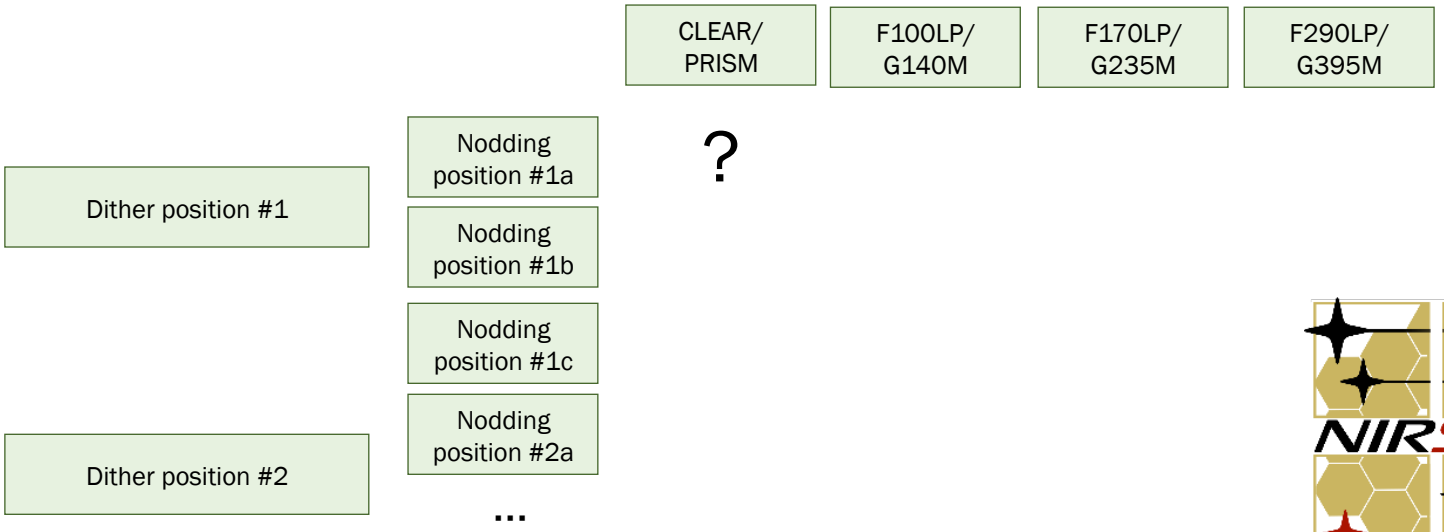
- Obtain each group of 3 nodding exposures at a different location on the detectors (i.e. in different slitlets) in order to minimize systematics (e.g. from the flat-field correction) and to work around detector defects (bad pixels…).
- Your goal is to get as many of your objects as possible in all exposures (i.e. your objects should see the complete integration time) and you want to get as many as possible (best possible mutliplex).

➔ When dithering, you reduce your effective field of view which is the intersection of the footprint of NIRSpec field of view at each dither positions.
➔ You are effectively reducing the number of objects you can observe in all exposures.

Plan your observation strategy before playing with APT/MPT

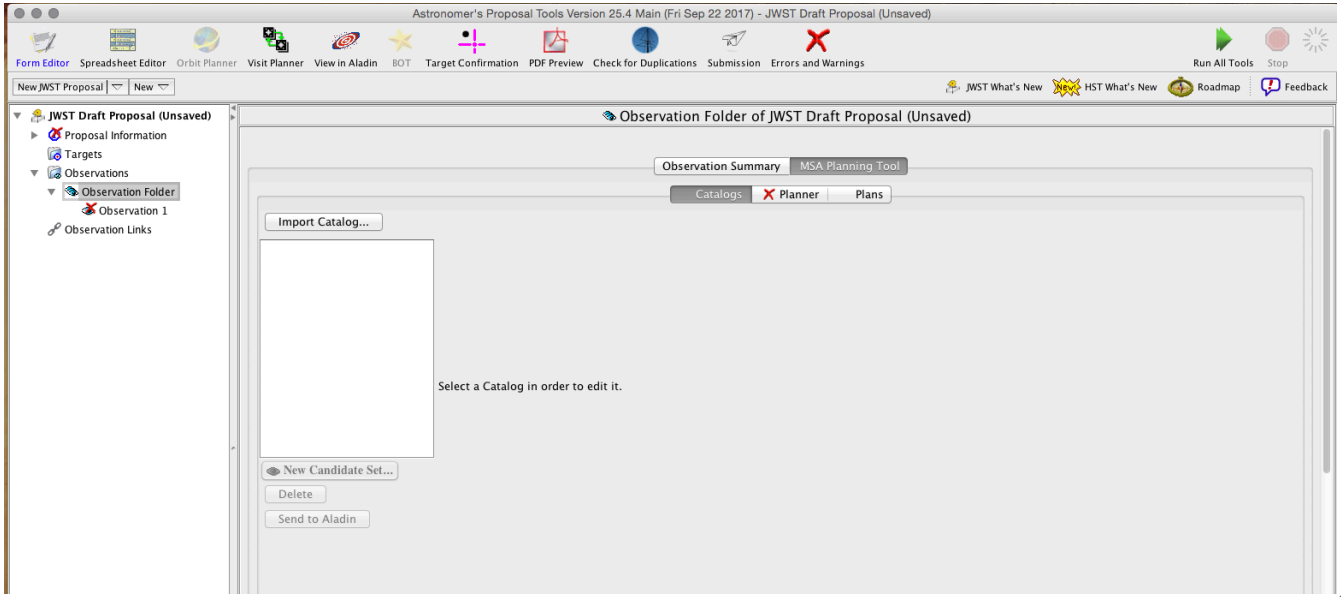
What you will choose will depend on your science case: here, depth is very important so we will chose to put more emphasis on getting as many common objects as possible between the exposures. We will therefore limit the number of dithers and used the fixed-dither option in MPT.

Get the layout of the observation: assume that we will limit ourselves to 3 dither positions and that at each of them we do a 3-shutter nodding. Allocate the exposures of each spectral configurations.



APT – Get started.

Get started: launch the APT and create the skeleton of a JWST proposal, going directly to create a new "Observation folder". In the observation folder, go directly to the "MSA planning tool" tab.



APT – Preparing your observation

Load the catalog provided for this exercise:

- "Rafelski_2015_HUDF_catalog_small.txt" (whitespace separated).
- Flux column: "MAG_F160W" (you will need to declare it as a magnitude column).
- Flux uncertainty: "MAGERR_F160W" (you will need to declare it as such also)
- Flux units: magnitudes

[declaring the columns is not really mandatory]

You will need to click on the catalog to fill some missing fields.

- Astrometric accuracy: must be <50mas, put 15 mas for this exercise.
- Pre-image: is already obtained as we are using an existing catalog derived from existing (HST) imaging.

No more red flag…

APT – Preparing your observation

Setup your observation in the planner (go to the "planner" tab):

- Select PA: 45 degrees (suitable for the selected field and orientation favorable given the footprint of the catalog on the sky).
  - In real life you will have to look at the visibility tools or use the PAT itself to determine the suitable range of PA.
  - IMPORTANT: one need to select a PA to run the MPT but this angle is NOT fixed for your proposal unless you specify it explicitly as a constraint for your observations. If you do not have any scientific or observational driver to constrain the PA in your proposal, do not constrain formally the PA at proposal submission stage. You will later be allocated a PA once your observation is scheduled.
- For this simple exercise only pick the Rafelski catalog as a primary candidate list.
- Put emphasis on multiplex and do not put strong constraints on the centering of your sources in the shutters ("Entire Open Shutter Area")
  - We have a fixed-grid of shutters to apply on a fixed distribution of objects on the sky (your catalog) so each object will have a different centering in the shutter. Here we specify that all the selected objects must be within the open aperture of a shutter.

APT – Preparing your observation

Setup your observation in the planner (continued):

- Dither setup. Try to select the parameters corresponding to what you have planned to do earlier.
  - We will use the fixed-dither scheme (this is now the recommended scheme) and we will keep the dither sizes small (5-shutters).
- Add the spectral configurations and try to get the right number of exposures.
  - You should have a problem for the medium resolution exposures where you need to distribute 8x3 exposures over 3 dither positions and you cannot do it simply in a single observation. You would have to create multiple observations (and may not get the same objects each time). As our time is limited, go for 27 exposures distributed in 9x3.
  - When assigning a large number of integrations (CLEAR/PRISM) you will get a red flag. Be aware that you can have several lines with the same spectral configuration in the exposure setup table (this should allow you to solve this problem).

APT – Preparing your observation

Setup your observation in the planner (continued):

- Define the search grid. Limit the search grid to 40”x40” and a step of 3”
  - The size of search grid and its step define the number of positions that will be explored. Be aware that this can quickly become VERY long. Try small numbers on your machine and increase progressively as you figure out how long this is going to take.
  - Once you tried a step of 3” and if it took a reasonable amount of time (~1min) try 1” and see the difference in the number of common objects.
- Additional parameters.
  - Set the number of configurations to 1 as you have fully constrained the observation sequence above (you do not want to repeat it several times)
  - For the overlap, set it to PRISM and the threshold to 1.2 (documentation on these values is not yet available but will be for the GO proposal; we are not discussing them here).

- Generate the plan and look at the results…
- Generate the associated observation and look at the number of visits, the overheads… Fiddle around if you have time.

The End

We hope you had fun and most of all that this session was useful.