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NIRSpec Mission Scenario

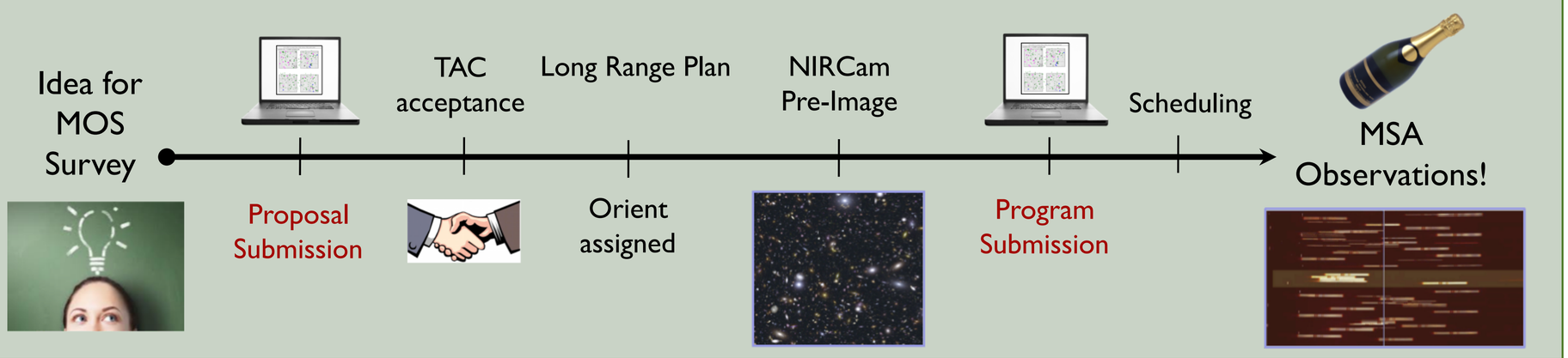
Observing High Redshift Galaxies in the Hubble Ultra-Deep Field

with the Micro Shutter Array

Abstract

The JWST's Near Infrared Spectrograph (NIRSpec) will enable multi-object spectroscopy through the Micro Shutter Array (MSA). The MSA is capable of observing up to ~200 sources at once using ~250,000 individually configurable shutters. The Space Telescope Science Institute has developed an MSA Planning Tool (MPT) to facilitate the complex observation planning process for a variety of observing cases. The tool finds optimal positions on the sky where many (high-valued) sources can be observed through a series of user-constrained dithers, and it designs the associated MSA configurations for each position. The MPT is included in the Astronomer's Proposal Tool (APT), an integrated software package developed by STScI for the preparation of observing proposals.

Proposal Timeline for Multi-Object Spectroscopic Observations



MOS spectroscopy will routinely require a two-phase approach:

Proposal Submission: Observers must provide details about exposure depths and the number of dither positions desired for their exposures. Most dithers will require MSA reconfigurations, which use a limited-lifetime mechanism, and are therefor constrained. The MSA Planning tool (MPT) can be used with simulated or existing catalogs to explore the effects of plan parameters on the number of observable targets and the number of MSA configurations needed to attain desired exposure depths. Observing overheads are also estimated in APT.

Program Submission: After program acceptance, an Orient is determined by the schedulers. NIRCam pre-images are then obtained to be able to supply the positional accuracies needed for placing targets into the tiny shutters. Armed with the selected Orient and pipeline-produced NIRCam pre-image and Catalog, the user can select Primary and Filler targets and create detailed observation plans (pointings and MSA configurations) needed for scheduling.

Mission Scenario

Context

Multi-object spectroscopy is a powerful way to study the formation and evolution of galaxies at high redshift. An observing case selected from the Science Operations Design Reference Mission (SODRM, 2012) is explored below. The program's goals are to confirm candidates for very high-redshift galaxies and look for spectral signatures of young, extremely-metal-poor stellar populations. Using a catalog derived from ACS imaging of the HUDF, we describe the effect of observational design choices in the MSA Planning Tool on the efficiency achieved in an MSA plan. Approximately 60-70 targets can be observed in one MSA configuration with a 3 shutter slitlet.

SODRM #90560 JWST Ultra-Deep Spectroscopy, PI H. Ferguson

Grating	R	gap?	Wavelengths	Rationale
Prism	~100	No	0.6 μm ≤ λ ≤ 5.0 μm	Continuum, spectral breaks
G140M	~1000	Yes	0.6 μm ≤ λ ≤ 1.8 μm	Spectral signatures of young stars
G235M	~1000	Yes	1.7 μm ≤ λ ≤ 3.0 μm	``
G395M	~1000	Yes	2.9 μm ≤ λ ≤ 5.0 μm	``

Primaries Z>6, predominantly point-like, a few extended up to ~1 shutter width
Fillers Z>4, a range of different half-light radii

Technical Challenges

Slitlet Shape

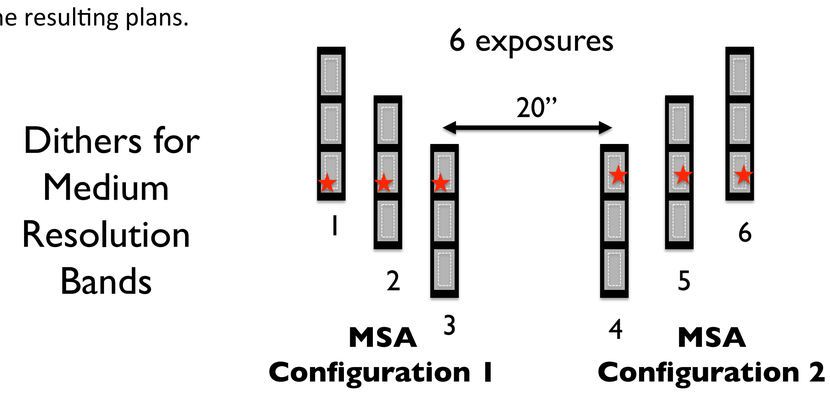
Slitlet shape and dithering have a strong impact on the number of targets observed. We selected a three-shutter slitlet for all targets to be able to have two background shutters per target shutter in each exposure. Slit losses are constrained by using a large slit margin that restricts the slit loss to ~50% due to positional uncertainties, but improved throughput comes at the cost of observing efficiency.

Dithers and Plan Merging

Detector QE variations and artifacts can be mitigated by performing dithers of at least a few shutters in the spatial or dispersion directions. In this program, the PI identified many key wavelengths of interest, so the medium bands will additionally need large dithers to cover the wavelength gap in the detectors. This requires use of the "Flexible Dithers" algorithm, with a minimum constraint (~ 20 arcsec) on the separation between exposures in the dispersion direction to recover wavelengths lost in the gap.

Problem: For deep observations of faint sources it is especially important to dither, however the algorithm prohibits more than about 3 or 4 large dithers. Dithering also impacts the S/N on a given target, since fewer targets can be observed at all dither points. But, the multiplexing efficiency of the MSA remains about the same - other sources from the candidate lists will be observed.

Solution: Try different grid cell sizes on the sky for the same grating, then merge the resulting plans.



For the PRISM spectra, more targets per row are possible, and gap dithering is not needed. Hence, the PRISM plan was made separately, then merged with the medium band observations.

Different Exposure Depths for Different Target Flux

Problem: For the faintest, high-priority candidates, exposures at many different dither positions are recommended. Secondary targets, typically brighter, require less total exposure time, hence fewer (or shorter) exposures. How can we plan this in the MPT?

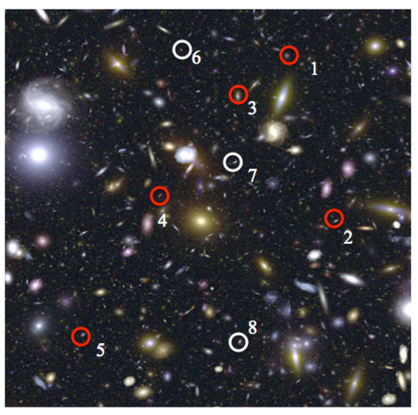
Solutions: Specify the secondary sources as Fillers. Primary sources drive the pointing selection, and MPT attempts to complete these sources through all specified dithers to attain the desired exposure depth. If more control is needed over the exposure times on individual sources, one must either develop independent plans with different exposure times, or apply initial weights to the candidates used in the plan in accordance with desired exposure time.

Ensure Same Targets in Different Plans

Problem: It is desirable to develop independent plans for the medium resolution gratings and the Prism, yet there is no guarantee of observing the same targets in two independently-developed MOS observation plans.

Solution: It will soon be possible to select the targets of one plan as primary candidates for a new plan, but until then, one can alter target weights in the input Catalog to help drive the target/pointing selection for the next observation plan. Since the medium resolution bands requiring a gap dither are more constrained, that plan was developed first. The weights of the resulting targets were then increased to plan the PRISM observations. One can then merge plans with the medium resolution bands. This approach takes advantage of the increased multiplexing in the PRISM mode.

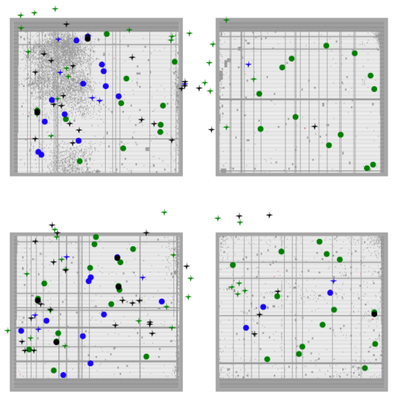
Medium-Resolution Plan
observed targets shown in red



Prism Plan
input list

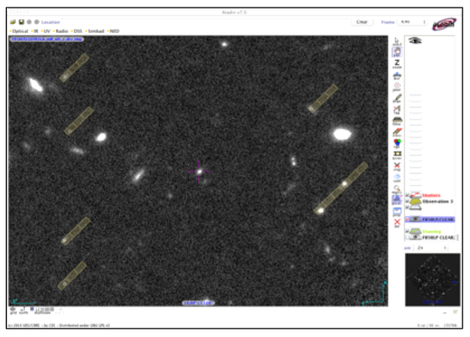
Source ID	Weight
1	100
2	100
3	100
4	100
5	100
6	1
7	1
8	1
9	…

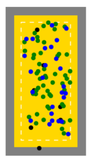
Plan Assessment Tools



Left: MSA shutter view. Primary (green) and filler (blue) targets are shown on a sketch of the MSA for one exposure. Users can select subsets of targets for cross-examination with other views.

Below: MSA slitlets displayed on an image of the HUDF field in Aladin.





Left: Collapsed shutter view showing target centering results

Come to a demo of the NIRSpec MSA Planning Tool, find me at coffee, or contact me at dkarakla@stsci.edu to discuss the planning and reduction needs of your observing scenario.