Observing Resolved Stellar Populations with the JWST Near Infrared Spectrograph

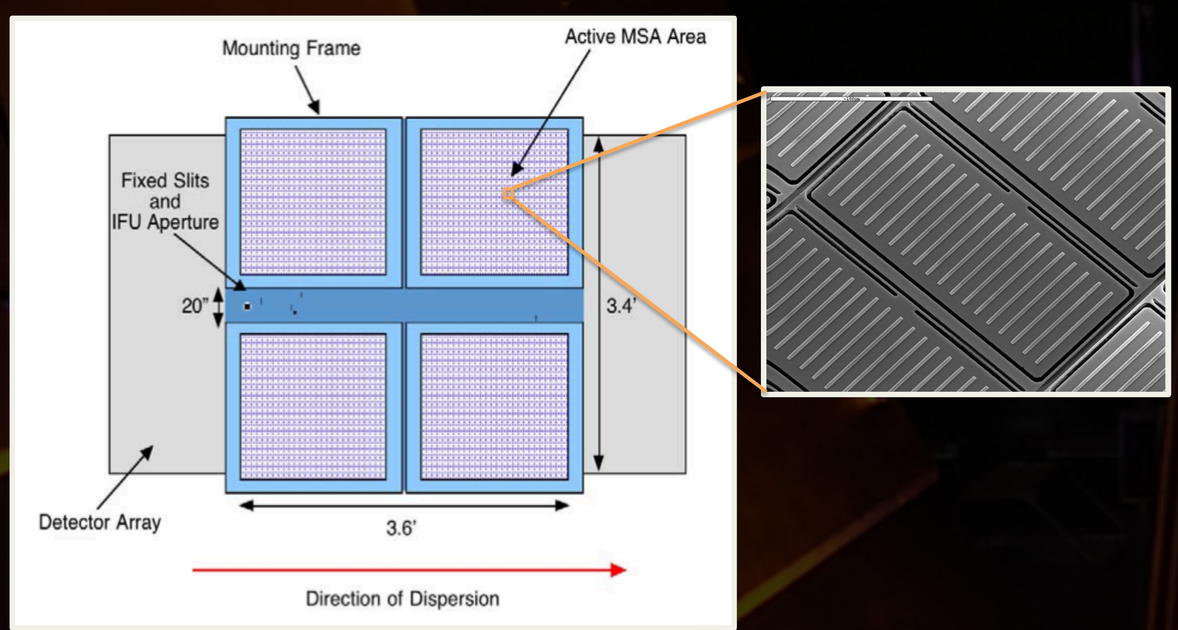
Karoline M. Gilbert, Tracy L. Beck, Diane M. Karakla
Space Telescope Science Institute

Also see the posters by Karakla and Muzerolle

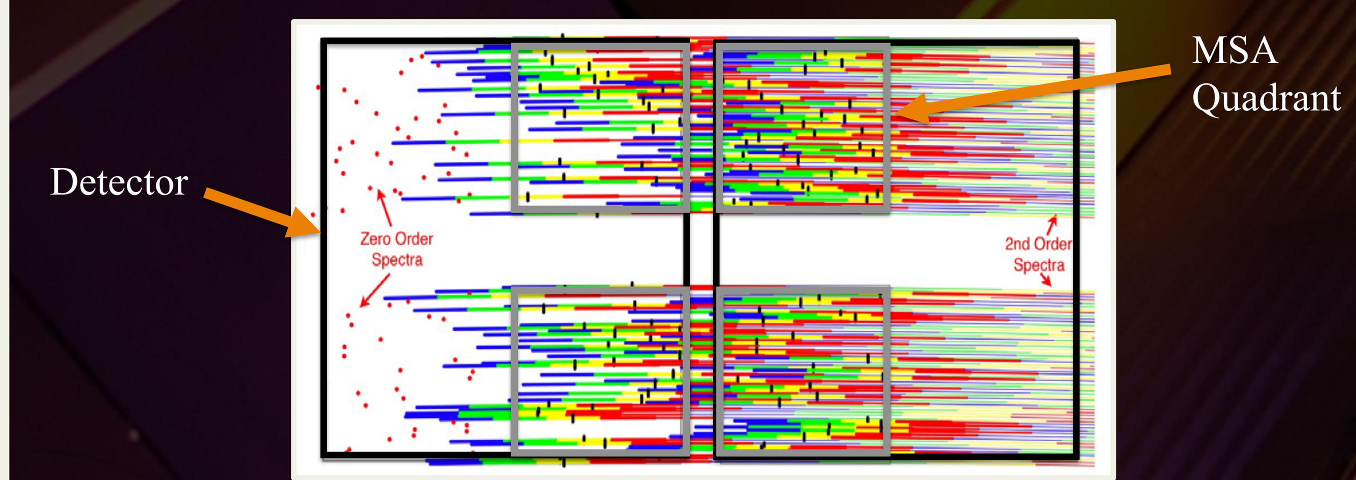
The James Webb Space Telescope's (JWST) Near Infrared Spectrograph (NIRSpec) will provide a multi-object spectroscopy mode through the Micro-Shutter Array (MSA). Each MSA quadrant is a grid of contiguous shutters that can be configured to form slits on more than 100 astronomical targets simultaneously. The combination of JWST's sensitivity and superb resolution in the infrared and NIRSpec's full wavelength coverage over 0.6 to 5 μm will open new parameter space for studies of galaxies and resolved stellar populations alike. We describe a NIRSpec MSA observing scenario for obtaining spectroscopy of individual stars in an external galaxy, and investigate the technical challenges posed by this scenario. This use case and several others, including a deep galaxy survey (see talk by Giardino) and observations of Galactic H II regions, are guiding development of the NIRSpec user interfaces including proposal planning and pipeline calibrations. Please approach me to discuss your science, and we can determine how well the planned user interfaces will meet your needs.

Multi-object Spectroscopy with the NIRSpec MSA

The 4 MSAs on NIRSpec are each comprised of a grid of more than 62000 shutters, configured in 365 rows and 171 columns. Each shutter can be individually commanded open or closed, resulting in an extraordinarily flexible multi-object spectrograph.

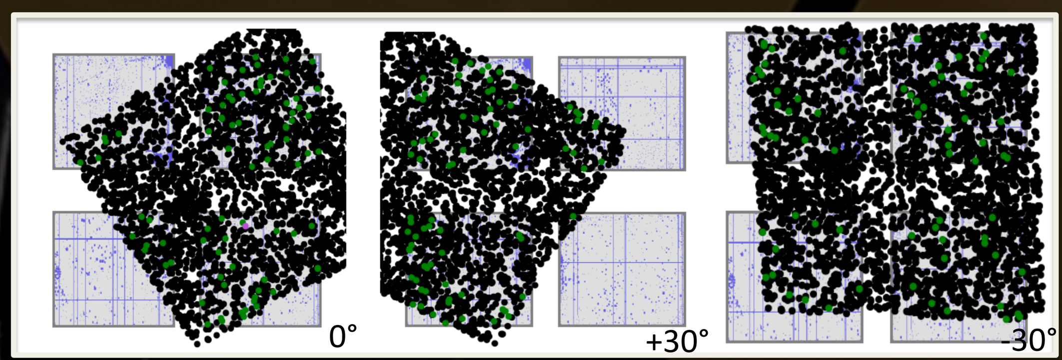


NIRSpec's gratings and prism each provide contiguous wavelength coverage from 0.6 to 5 μm at R~100, 1000, and 2700. For the R~1000 and 2700 gratings, only one source can be observed per MSA row. This can be seen in the diagram below, which illustrates the approximate spectral locations on the detector array for a configuration of opened MSA shutters and the R~2700 grating.



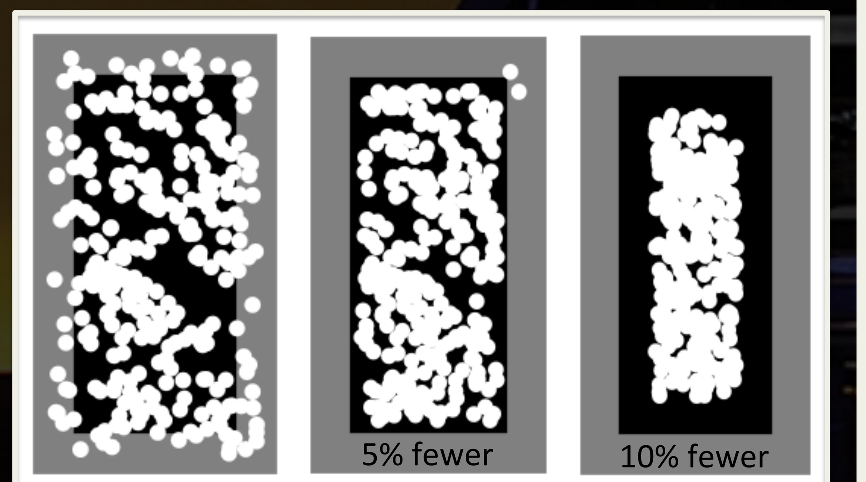
Multiplexing in Crowded Stellar Fields

Context: Multi-object spectroscopy is a powerful way to study the dynamics and chemical abundances of stellar systems. The NIRSpec MSA mode will enable observations of crowded and dust-obscured stellar populations in the nearby universe. Below, we explore the effect of observational design choices on the multiplexing achieved in an MSA plan, using a stellar catalog derived from ACS imaging of the inner region of M33's disk. The primary targets are bright red giant branch and asymptotic giant branch stars. The results will be applicable to any field with similar source density (the primary target density is 275 stars arcmin^{-2}). With this source density, ~72 primary targets can be observed in one MSA configuration with a 3 shutter slitlet.

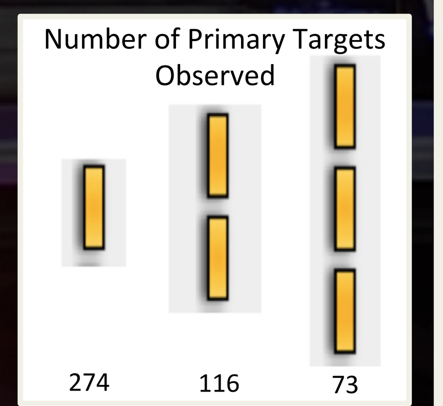


Orientation: The available roll angles for a given date and sky location will be significantly more constrained for JWST than for HST. Fortunately, for crowded fields the orientation has a small effect on the number of observed sources. Even for source catalogs (black circles) with spatial extents well matched to the field of view of the MSA, there is less than a 10% difference in the number of observed sources (green circles) in the 3 orientations shown here.

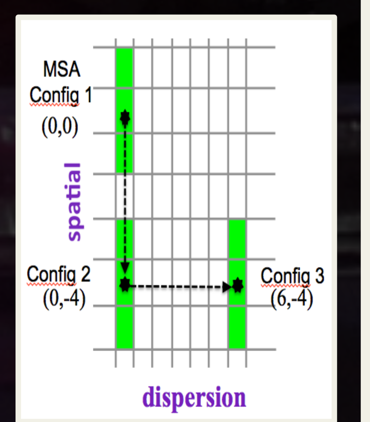
Restricting source location in shutters: If a source is offset from the center of a shutter, the observed flux of the source is reduced. Users can restrict the location of sources to ensure a limited loss of flux. The graphic overplots the position of each observed source in its respective shutter, with an increasingly large constraint on source location in the shutter from left to right. In the crowded field considered here, restricting the location of the source in the shutter results in roughly 5% and 10% fewer observed sources compared to the unconstrained case.



Slitlet Shape: For crowded stellar fields, many primary targets are available in every MSA row and the slitlet shape has a strong impact on the number of targets observed. In this example, the stellar density is high enough that using a one shutter slitlet instead of a three shutter slitlet results in a factor of 3.7 increase in the number of observed primary targets.

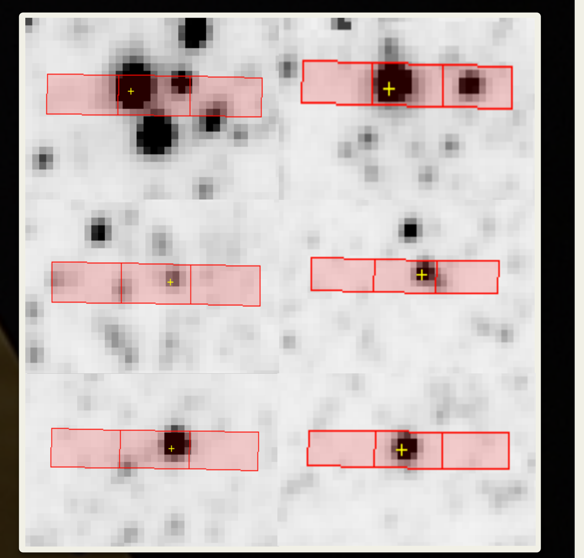


Dithers: Most observations will benefit from performing dithers of at least a few shutters in the spatial or dispersion directions. For small dithers such as these, multiplexing is decreased by ~20% as some targets will fall outside the slitlet in one of the dither positions. Large dithers, which are needed to cover the wavelength gap in the detectors, have a significantly larger effect.



Technical Challenges

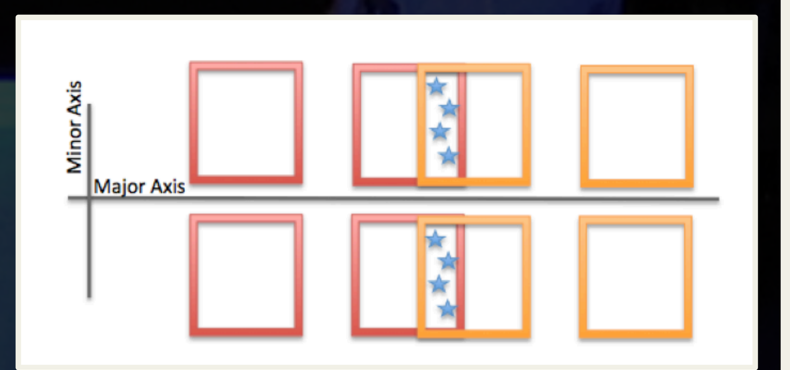
Identification of slitlets with only one source, and identification of background shutters: In dense fields, multiple sources in a single slitlet will be common, as seen to the right. Many of the faint sources visible in the F814W image are below the magnitude limit used for selecting targets, but will adversely affect either target or background measurements. Obtaining background shutters with no stellar sources will be challenging in dense fields. **Solution:** Implement a check for contamination within the slitlet during planning, and enable users to interactively open background shutters.



Stellar Kinematics: Pushing the Limits of the NIRSpec MSA. The NIRSpec MSA will be an excellent instrument for obtaining spectra of stars in crowded or highly extincted regions, including globular clusters, the Milky Way bulge, and dwarf galaxies. However, studying the velocity distributions in these systems will require extra care in obtaining and reducing the observations.

The location of the source in the shutter: The spectra of two sources with the same intrinsic velocity, but located on opposite edges of the shutter, will be shifted by 2 pixels with respect to each other. This results in an offset of 120 km s^{-1} in the measured velocities. Therefore, the location of each source in the shutter must be determined with an accuracy of ~0.1 pixels. One possibility is to obtain and analyze an image taken through the configured MSA after target acquisition. The position of each source in the shutter must be used by the data reduction pipeline when determining the wavelength solution for each target.

Relative Wavelength Calibration: The requirement on the accuracy of the absolute wavelength calibration is ~15 km s^{-1} for the R~2700 grating. However, the relative wavelength calibration for targets observed with a single target acquisition, and no movement of the grating wheel, will likely be significantly better and could reasonably attain ~3 km s^{-1} precision. For programs that require multiple target acquisitions, observers could force the MPT to observe sources from the first target set in the second, by placing a very high priority on those targets. This would allow an empirical calibration between the wavelength solutions for each target set.



We are giving demonstrations of the MSA Planning Tool! Find us during a coffee break, or contact us at kgilbert@stsci.edu and dkarakla@stsci.edu. The planning tool is still in development – discuss with us the technical challenges your science will pose.