NIRSpec MOS Operations - Slit Losses

JWST NIRSpec MSA-based observations are affected by slit losses due to off-center target placement in the shutter and throughput calibration inaccuracies derived from target acquisition.

Introduction

Parent articles: NIRSpec Operations → NIRSpec MOS Operations

One of the main observing modes of NIRSpec is the multi-object spectroscopy (MOS) with the micro-shutter assembly (MSA). The MSA consists of a fixed grid of roughly a quarter million configurable shutters that are 0.20" × 0.46" in size. Its shutters can be opened in adjacent rows to create customizable and positionable spectroscopy slits (slitlets) on prime science targets of interest. At any given pointing, MSA targets will map to different positions within each target shutter. Properly accounting for the slit loss errors requires precise knowledge of those positions within the shutters. Because of the very small shutter size, NIRSpec MSA spectral data quality will benefit significantly from accurate catalog astrometry of planned science source positions.

NIRSpec MOS calibration slit loss uncertainties vs. planning catalog accuracy

See also: NIRSpec MOS Operations - Pre-Imaging Using NIRCam

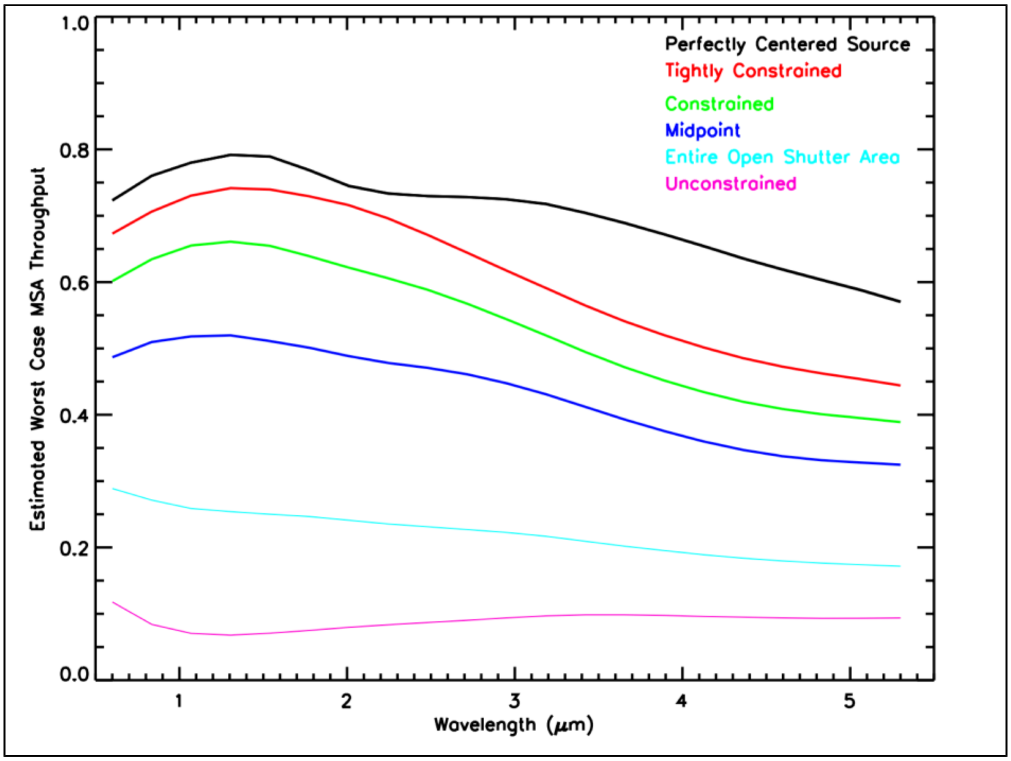
Slit losses in the MSA shutter and planning constraints

The NIRSpec MSA is comprised of a fixed grid of micro-shutters; science sources of interest cannot all be perfectly centered within their configured spectral slits and, as a result of the very small MSA shutter aperture size, moderate flux can be lost outside of the slit. Slit throughput loss is a function of wavelength, and it also changes with relative placement of the science sources within the MSA shutters (e.g., see Table 1 in NIRSpec MPT - Planner article.).

Figure 1 presents the worst-case point source flux throughput in an MSA shutter as a function of wavelength for the different ***Source Centering Constraints*** [1] in NIRSpec MSA Planning Tool (MPT).

The ***Tightly Constrained*** curve (red) means that science sources will only be observed if their planned position within the shutter would result in observing at least 85% of the total possible flux that can be acquired through an open shutter (at 2.95 µm). The ***Constrained*** source placement (green) restricts sources to planned positions that result in at least 75% of the total possible flux throughput. The ***Midpoint*** position (blue) will have at least 62% of the throughput possible within an open shutter area. The ***Entire Open Shutter Area*** constraint (cyan) will plan the source anywhere within the open 0. 2 × 0.45 shutter region, and the ***Unconstrained*** plan constraint (magenta) could have a science source centered precisely behind the ~69 mas wide MSA mounting bars (recommended only for extended science objects).

Figure 1. NIRSpec MSA shutter throughput as a function of wavelength for different source centering constraints



These are the worst case throughputs resulting from geometrical slit loss for a point source observed through an MSA shutter plotted as a function of wavelength. The curves are anchored to the Source Centering Constraint (Table 1) at 2.95 m. The larger PSF at 5 m results in more slit loss through the shutters. The colored curves represent different planning shutter centering constraints for a target (in the NIRSpec MSA Planning Tool). The tightly constrained, constrained, and midpoint curves correspond to 85%, 75%, and 62% of the flux, respectively, compared to a perfectly centered source at 2.95 m. The unconstrained curve (magenta) refers to positions anywhere inside the mid-bar area of the shutter.

The NIRSpec MSA science sources could be located anywhere within their planned shutter centering constraint. As a result, the actual slit throughput for a given source observed through the NIRSpec MSA can be in the range from the appropriate colored curve in Figure 1 to the perfectly centered point source curve presented in black. The worst case shutter throughput occurs when sources are centered near to the corners of the allowed shutter area, since the PSF is truncated on two sides. In the ***Unconstrained*** case (magenta), a science source of interest might be centered behind both the horizontal and vertical MSA bars in the shutter corner. In this situation only a small fraction of the flux of a point source will make it into the open shutter to be measured by the spectrograph. The ***Unconstrained*** position option is recommended only for spatially extended targets where additional flux would make it into the slit, compared to the point source calculation presented in Figure 1.

[1] ***Bold italics*** font style is used to indicate parameters, parameter values, and/or special requirements that are set in the APT GUI.

Slit loss uncertainty as a result of catalog astrometric accuracy

The NIRSpec calibration pipeline will apply a slit loss throughput correction for point sources based on the planned position within an MSA shutter. A perfectly centered point source with optimal TA astrometric accuracy (5 mas) will have no excess flux error; the slit loss can be calibrated at the optimal level achievable by the pipeline (estimated to be approximately a ~6% term). However, if the TA astrometric accuracy is relaxed, the slit loss correction will also carry a greater uncertainty.

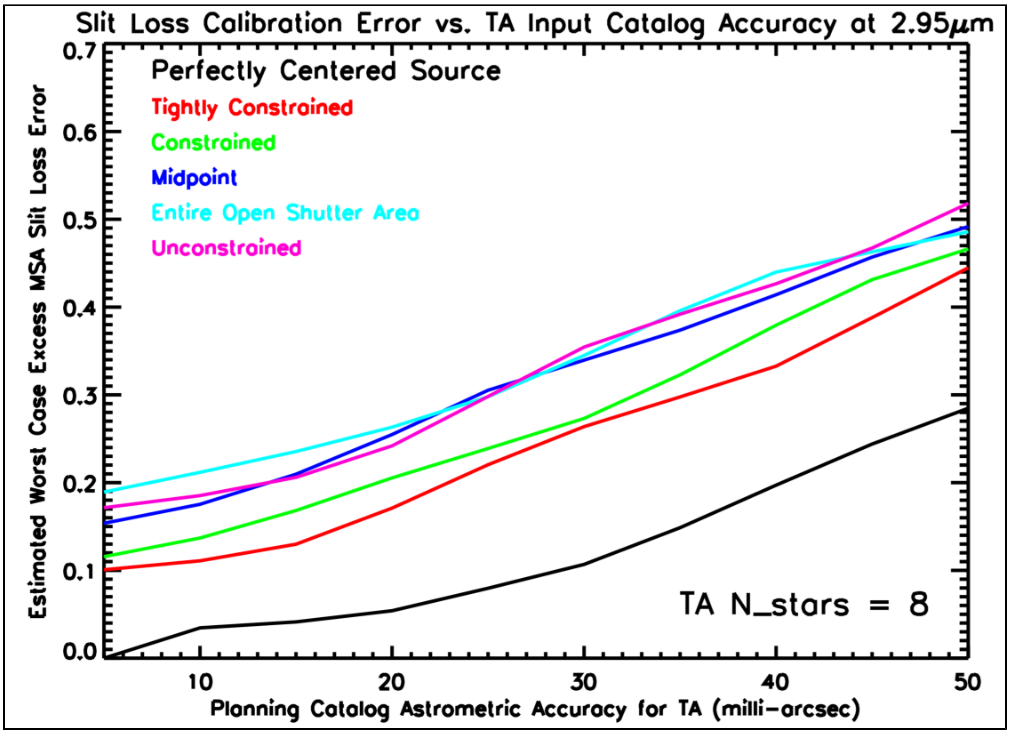
Figure 2 presents the possible excess flux calibration uncertainty due to slit losses as a function of the astrometric accuracy of the catalog used for TA planning. These calculations are done assuming a point source, resulting in worst case slit loss throughput uncertainty. The curves are anchored to wavelength defining the source centering constraint: 2.95 μm. The figure describes the *geometrical* slit throughput only, and does not represent the total end-to-end instrument throughput or sensitivity. Note that the figure throughput curves represent the worst-case scenario of a point source observed in the corners (highest flux loss regions) of an MSA shutter margin.

> Figure 2 shows that the accuracy of the flux calibration of the science sources will depend on the catalog relative astrometric accuracy. The ability to effectively limit slit losses using the different ***Source Centering Constraints*** in MPT will also depend on the catalog relative astrometric accuracy. These factors should be taken into consideration when deciding whether or not pre-imaging with NIRCam would benefit the spectroscopic observations.

The purpose of Figure 2 is to present the excess flux calibration uncertainties that can result from the imperfect knowledge of the position of point sources in NIRSpec spectral slits from relaxed TA catalog constraints. This “estimated worst case excess MSA slit loss error” is the excess calibration error that would result if a point source target is planned to be at the edge position in its *Source Centering Constraint* area, but uncertainties in target acquisition result in slightly offset placement compared to the planned position. For example, a point source planned using 20 mas relative astrometric catalog planning accuracy in a ***Tightly Constrained*** plan could have an excess MSA slit loss throughput calibration error of ~15% because of the position uncertainty from target acquisition. These worst-case excess calibration errors are very difficult to correct because of imprecise knowledge of the final source centering in a NIRSpec MSA slit.

For NIRSpec MSA science observations and target acquisition, very high quality planning astrometry will limit calibration errors that result from uncertain spectral source positioning. As seen from Figure 2, in field-relative astrometry of 5–10 mas or better is needed to limit the excess flux calibration error for point source observations.

Figure 2. NIRSpec MSA slit loss calibration error vs. input catalog accuracy at 2.95 m



The estimated excess slit loss calibration error is plotted against input astrometric catalog planning accuracy. These plots present the worst case calibration slit loss error that can result based on the accuracy of the target acquisition. The colored curves represent shutter centering constraints used in the planning process. A point source at the center of an MSA shutter planned using 30 mas of relative astrometric catalog accuracy can have up to 10% of excess slit loss calibration error because of imperfect TA that results from the relaxed catalog constraints.

References

Beck et al. 2016, SPIE, 9910, 12
Planning JWST NIRSpec MSA spectroscopy using NIRCam pre-images