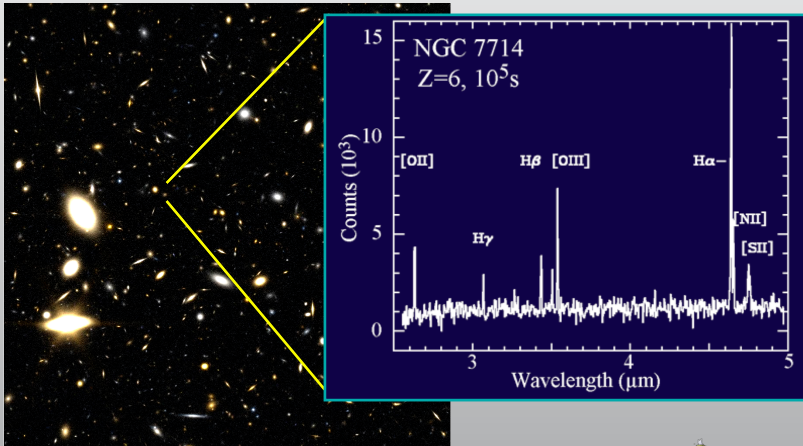
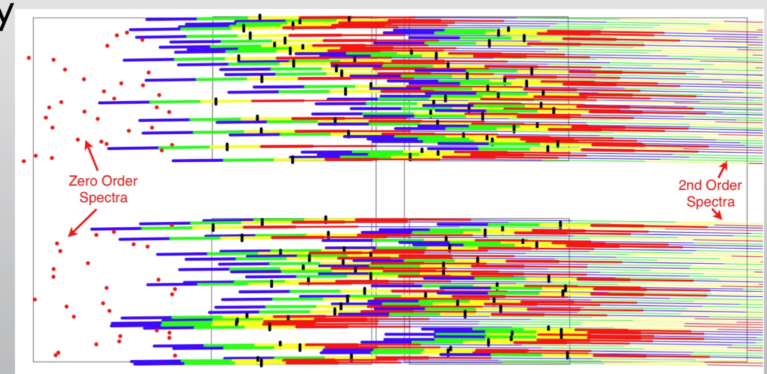
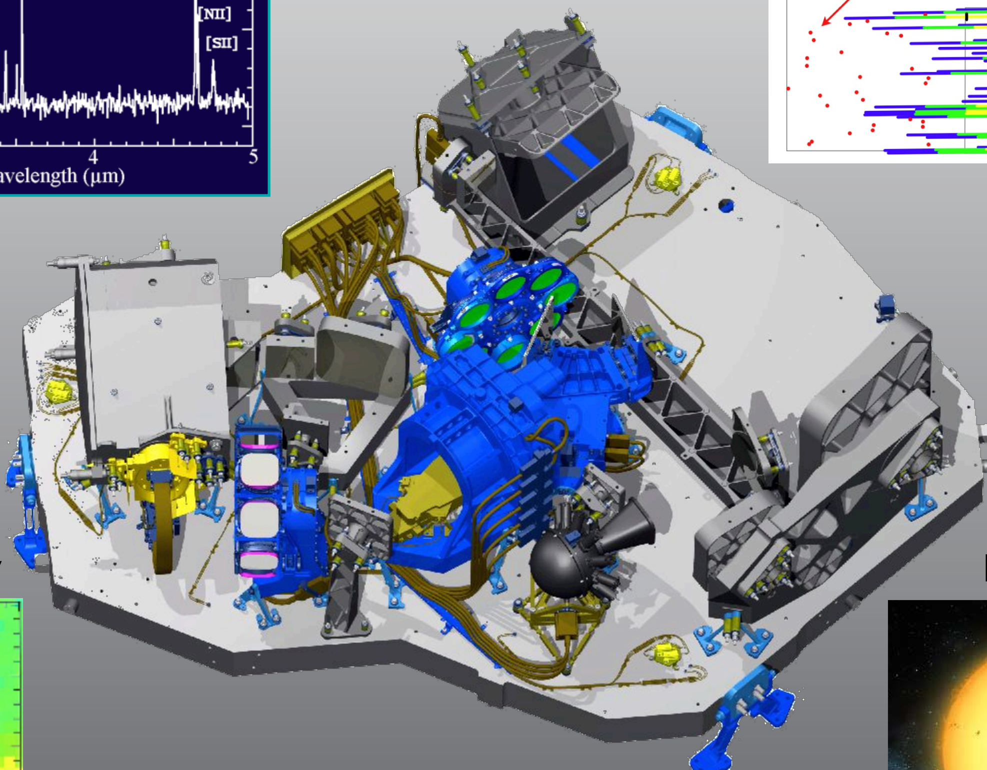
NIRSpec Target Acquisition

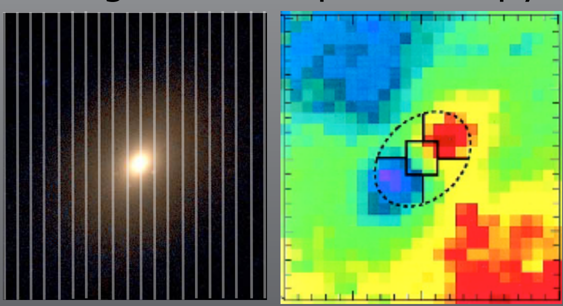


Multi-Object Spectroscopy

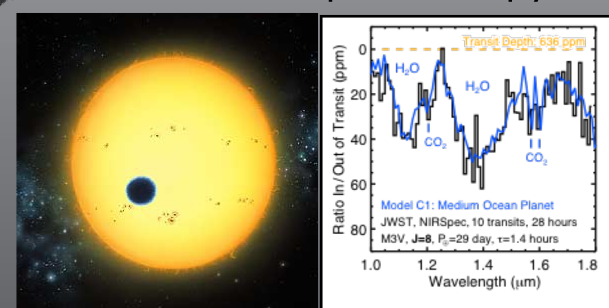




Integral-Field Spectroscopy



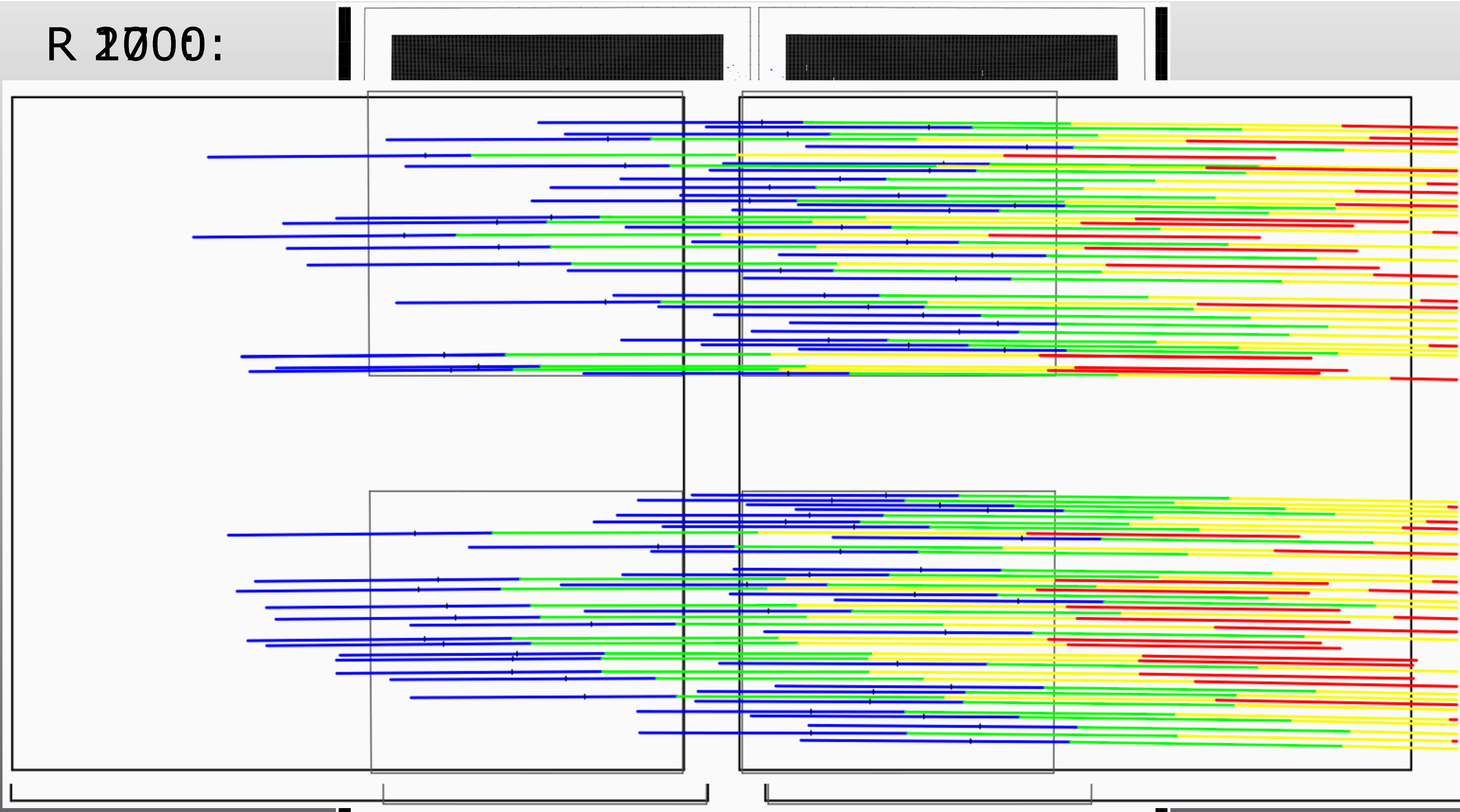
Fixed-Slit Spectroscopy



An Example: the HUDF

R 100:

R 2700:

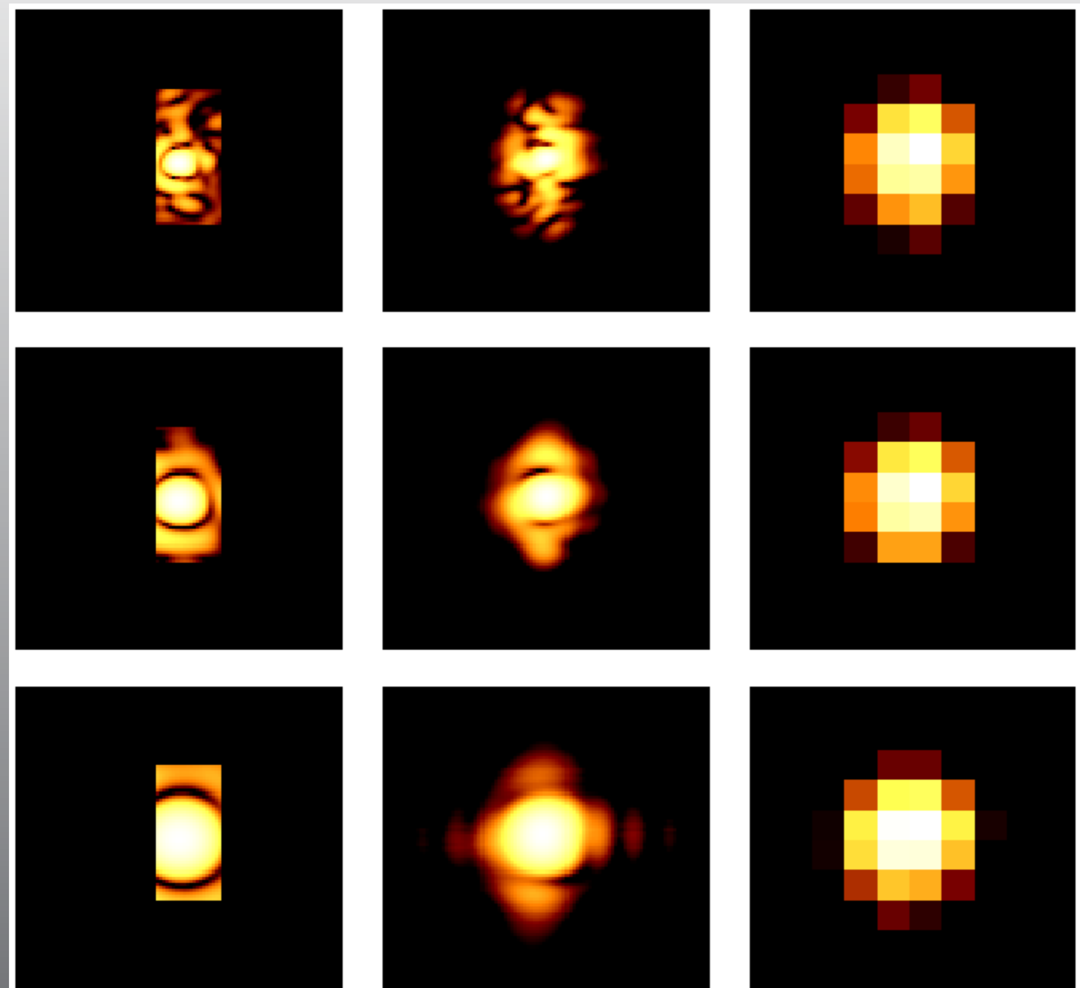


PSF Size

1.4 µm

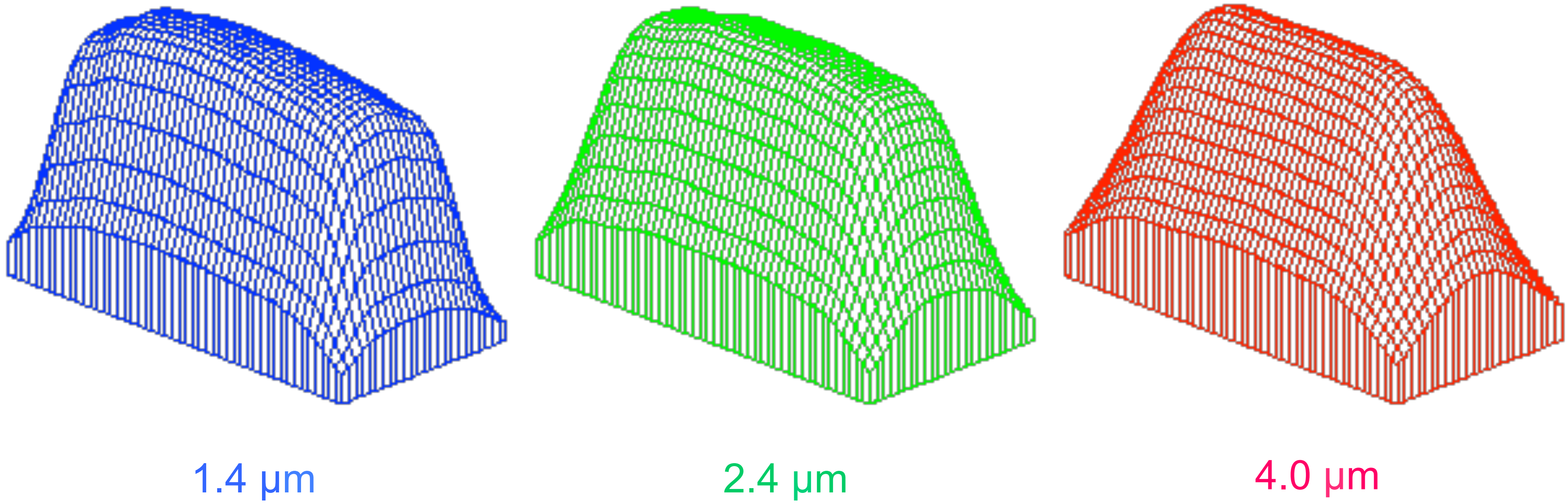
2.4 µm

4.0 µm



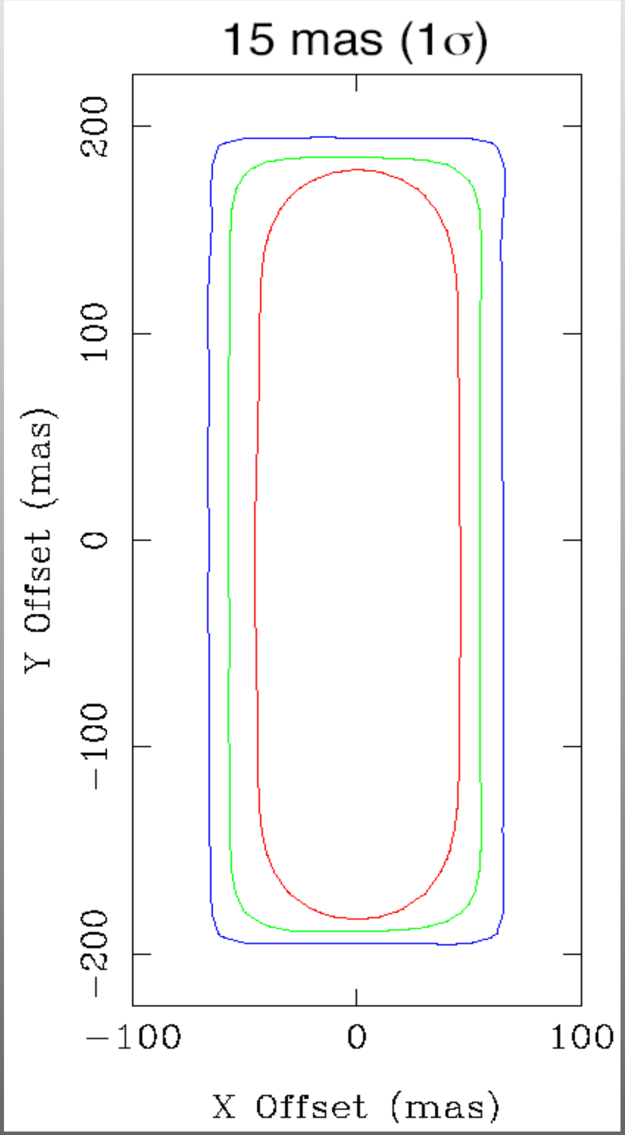
@ MSA @ Detector Pixels

Slit Throughput



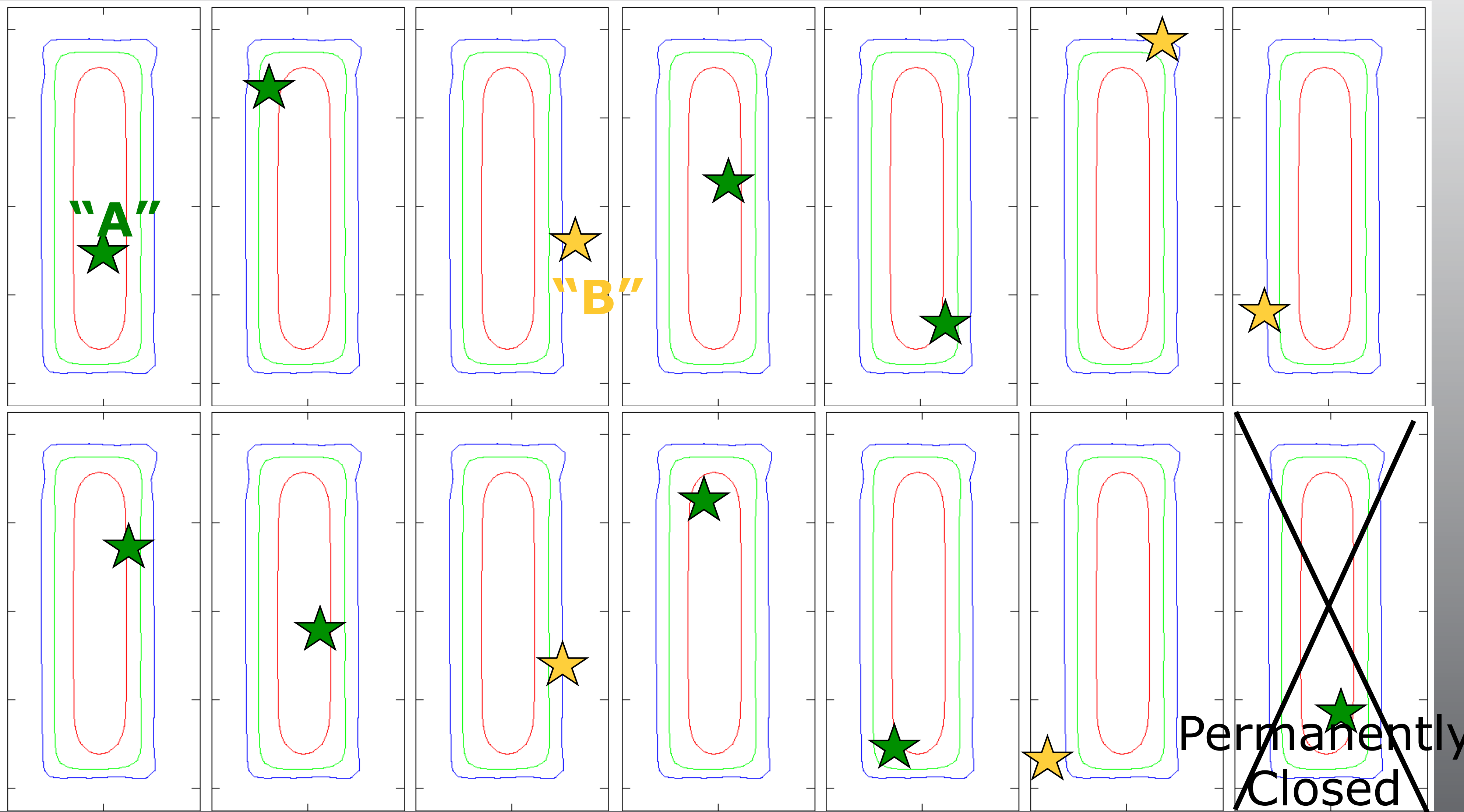
Throughput varies strongly across the slit.

Acceptance Zone (a.k.a "Sweet Spot")

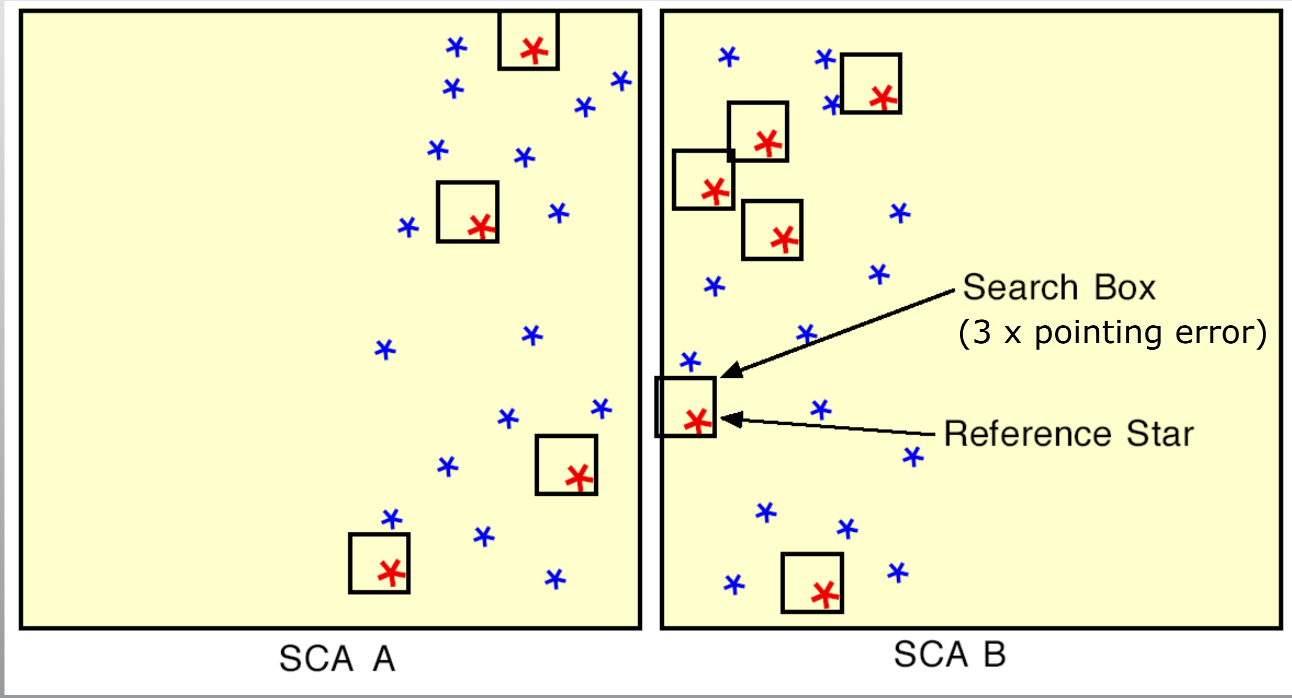


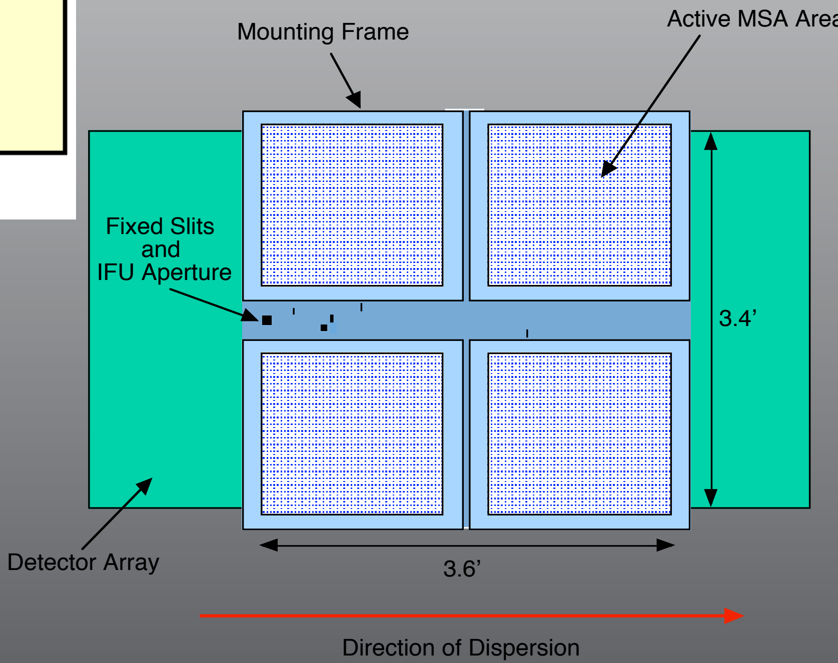
1.4 µm
2.4 µm
4.0 µm

Target Sets



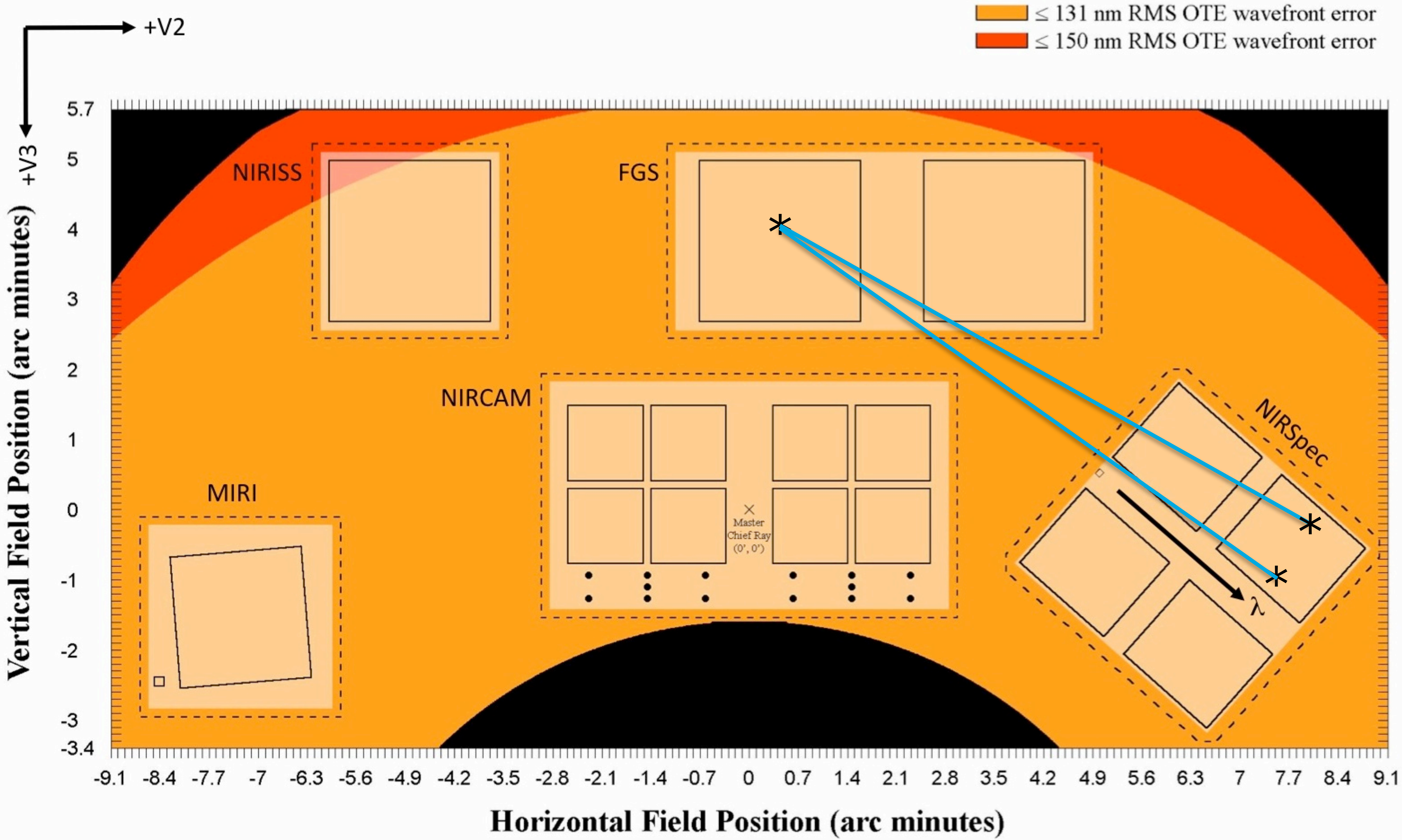
Problem 1: Limited Slew Accuracy



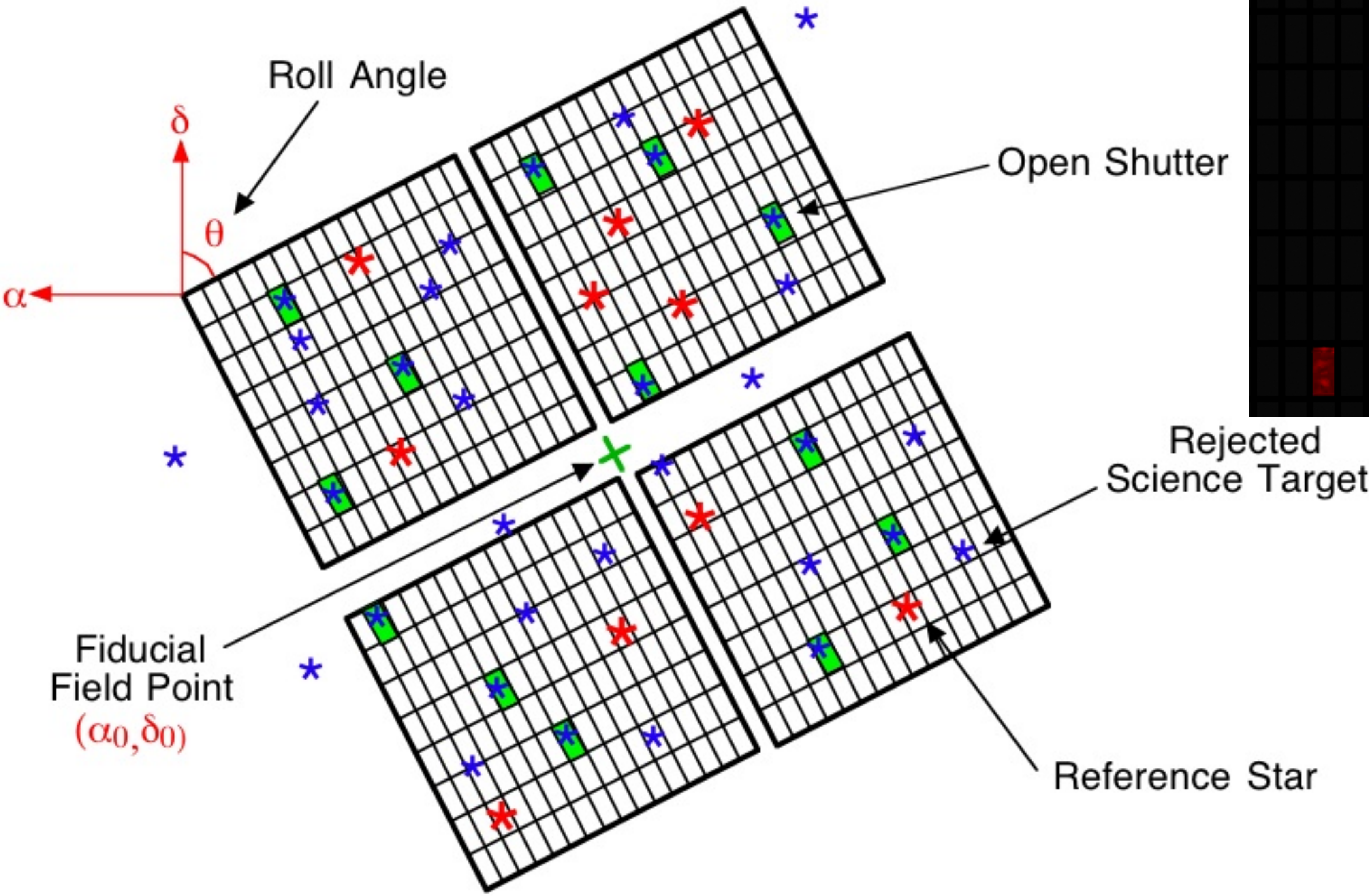


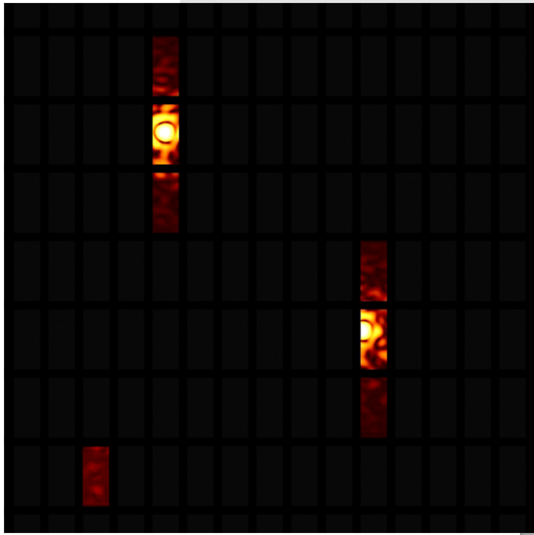
corrective "delta"-slew has to be computed on board, and without human intervention

Problem 2: Limited Roll Control



Problem 3: Finding Reference Stars





The details....

The NIRSpec Target Acquisition Concept
Peter Jakobsen
Version 1.0, 12 March, 2004

1. Introduction and Background

This document aims to establish the mathematical framework for the target acquisition procedure for NIRSpec, as outlined in the NIRSpec Operations Concept Document (STScI-JWST-R-2003-0003). The conceptional elements of only the most basic and simplest conceivable acquisition concept are discussed with emphasis on identifying the various processing tasks that need to be handled in an autonomous manner by the NIRSpec flight software. It is entirely likely that further studies will demonstrate the necessity to expand on the bare bones capabilities identified here. Other important practical considerations such as reference star availability, acquisition image exposure times, impact of failed MSA shutters and detector pixels, and the overall error budget will be discussed in later separate notes.

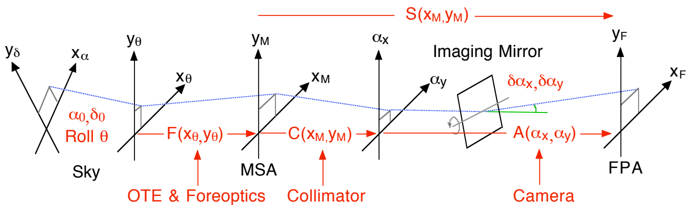


Figure 1: Coordinate systems and transformations.

2. Coordinate Systems and Transformations

Recall that NIRpec has two internal focal planes; the first one is at the Micro Shutter Array (MSA) and the second one at the detector or Focal Plane Array (FPA).

NIRSpec target acquisition will be carried out in so-called imaging mode, wherein the MSA is configured in the all-open configuration and a flat mirror on the grating wheel is rotated into the beam. In this configuration, NIRSpec acts as a camera projecting an undispersed image of the target field as seen through the open MSA onto the FPA.

The key challenge for NIRSpec target acquisition is that the targets to be observed need to be placed extremely accurately over pre-determined slits in the MSA focal plane, whereas the actual spacecraft pointing can only be monitored in the FPA focal plane – and that only through the MSA grid and off the movable imaging mirror. This means that the significant optical distortions that occur between the sky, the MSA and the FPA need to be accurately determined and taken into account by the flight software.

The relevant NIRSpec coordinate systems of interest and the transformations between them are shown schematically in Figure 1.

The orientation of the JWST spacecraft during a given observation is described by the celestial coordinates of a fiducial point within the NIRSpec FOV (nominally the field center), α_0, δ_0, and the roll or position angle, θ, of the NIRSpec FOV measured about the fiducial point (Section 3.1).

1

NIRSpec Target Acquisition: Fitting Algorithm Including Roll Correction

Peter Jakobsen
Version 1.2, 4 September, 2006

1. Introduction and Background

The task of the NIRSpec Target Acquisition process in the case of Multi-Object Spectroscopic (MOS) observations is to align the Multi Shutter Array on the sky as closely as possible to the pointing and orientation requested by the observer in setting up the observation. As outlined in the NIRSpec Target Acquisition Concept Document [1], the position of the MSA on the sky can be described by three parameters: the sky coordinates of the center of the NIRSpec field of view, α_0, δ_0, and the roll orientation or position angle, θ, of the MSA around this point.

Up until now, it has been assumed that the JWST spacecraft will orient NIRSpec to the desired roll value to sufficient accuracy such that only a small maneuver in pitch and yaw is required to correct for the finite initial setting accuracy of the observatory and move the MSA to its desired position. As an added side benefit, this pointing correction in pitch and yaw will also take out any systematic offsets due instrument drift or zero point errors in the absolute target sky coordinates employed by the observer in preparing the observation.

It has recently been realized, however, that while the stated absolute roll control of the JWST observatory of $\simeq 6''$ is adequate for NIRSpec's needs, it may be extremely difficult to achieve a matching high level of absolute roll accuracy when planning NIRSpec observations. Specifically, the preparation of all NIRSpec MOS observations will be based on high quality images of the target fields obtained either from the ground or with NIRCam. The absolute roll accuracy attainable with a current VLT image is reportedly of order $\simeq 1'$, an order of magnitude less accurate than that required to prepare NIRSpec observations. One expects to eventually be able to do better with NIRCam images, but there is no guarantee that the detailed mapping and relative orientation between the NIRCam and NIRSpec instruments will be known to sufficient accuracy before well into the JWST mission. It is also not a given that the inter-instrument mapping will remain stable to the required accuracy over time given the highly adjustable nature of the JWST telescope.

In light of these concerns, it has been proposed that the NIRSpec Target Acquisition Process, in addition to tweaking pitch and yaw as originally foreseen, be augmented to also perform the equivalent adjustment in roll in order to compensate for these potential sources of error.

The purpose of this note is to present a suitable algorithm to achieve this, and demonstrate that the additional computational burden on the relevant script in the flight software should not be an issue.

It is stressed that the introduction of roll correction does not affect the logic or flow of the NIRSpec target Acquisition sequence. The only change is that one additional parameter needs to be calculated from the comparison between the desired and the actual locations of the reference stars measured from the target acquisition image. This calculated roll correction then needs to be passed to the spacecraft for execution together with the matching corrective pitch and yaw maneuvers.

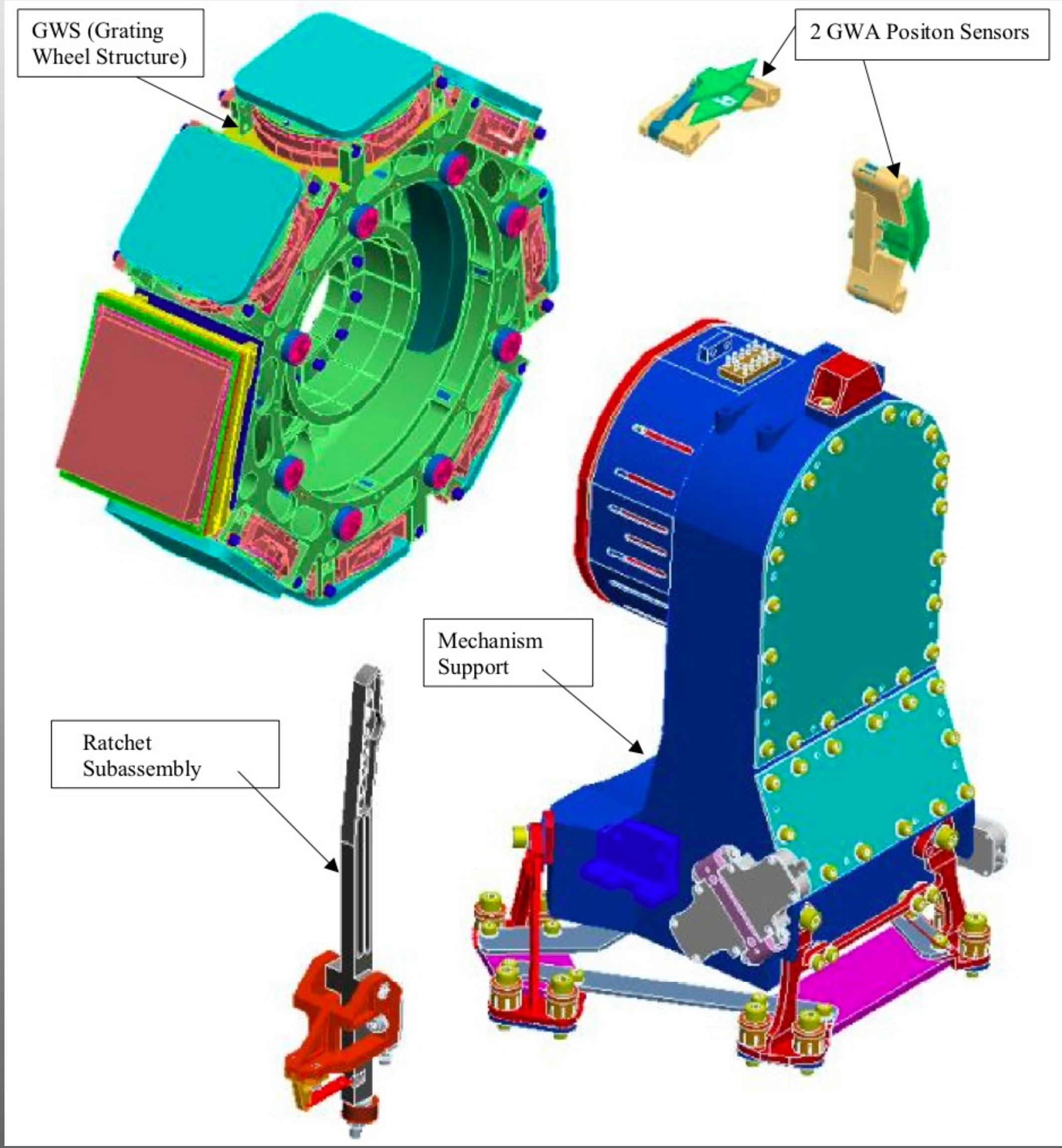
2. Calculation of the Offset Slew with Fixed Roll

To establish method and nomenclature, consider first the original case of fixed roll.

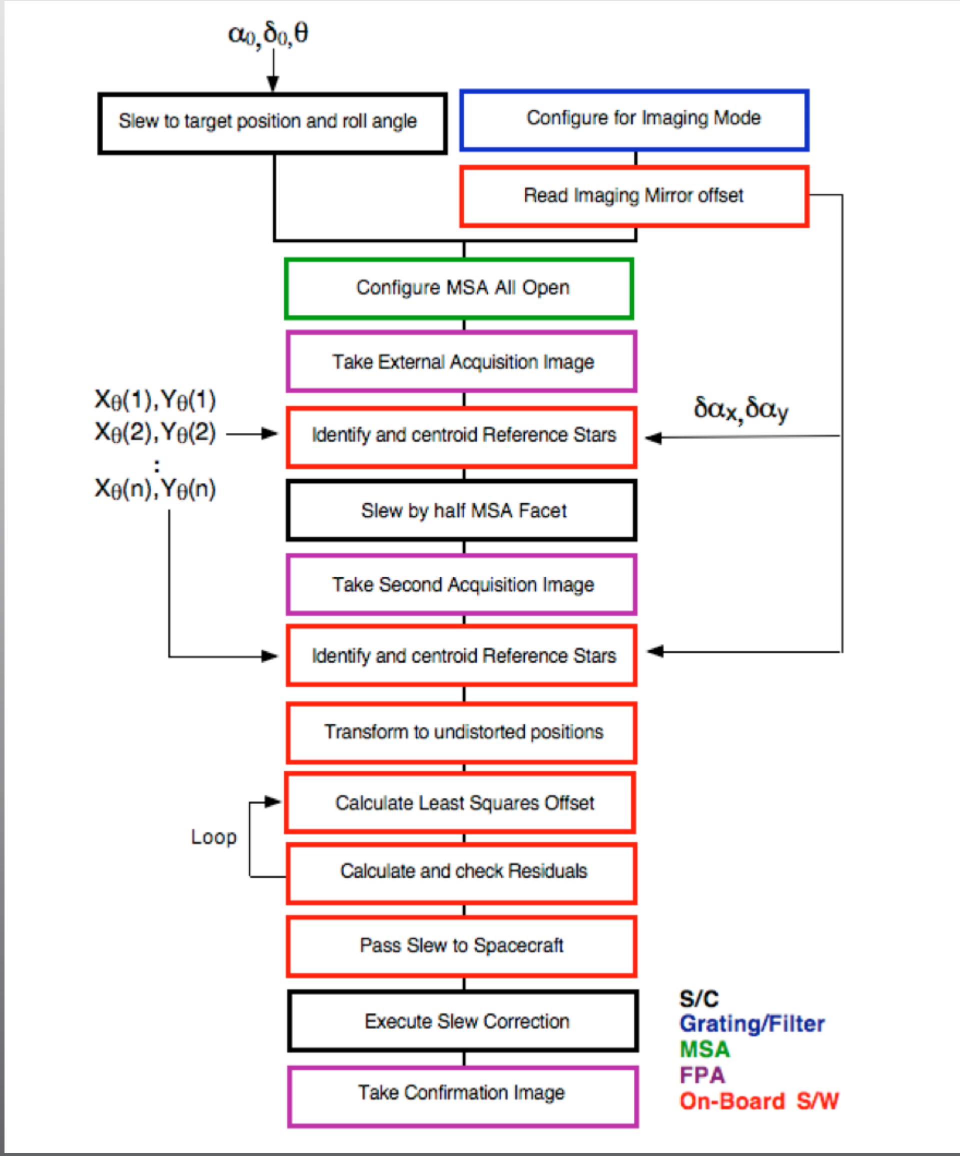
Recall that, as outlined in the NIRSpec Target Acquisition Concept [1], the basic input to the flight software following reference star identification and centroiding is the list of (undistorted) actual tangential coordinates, $\tilde{x}_\theta, \tilde{y}_\theta$, of the reference stars generated onboard from their measured positions on the FPA, and the corresponding prepared list of target positions x_θ, y_θ where the reference stars need to be placed for the fainter science targets to fall on their respective shutters:

1

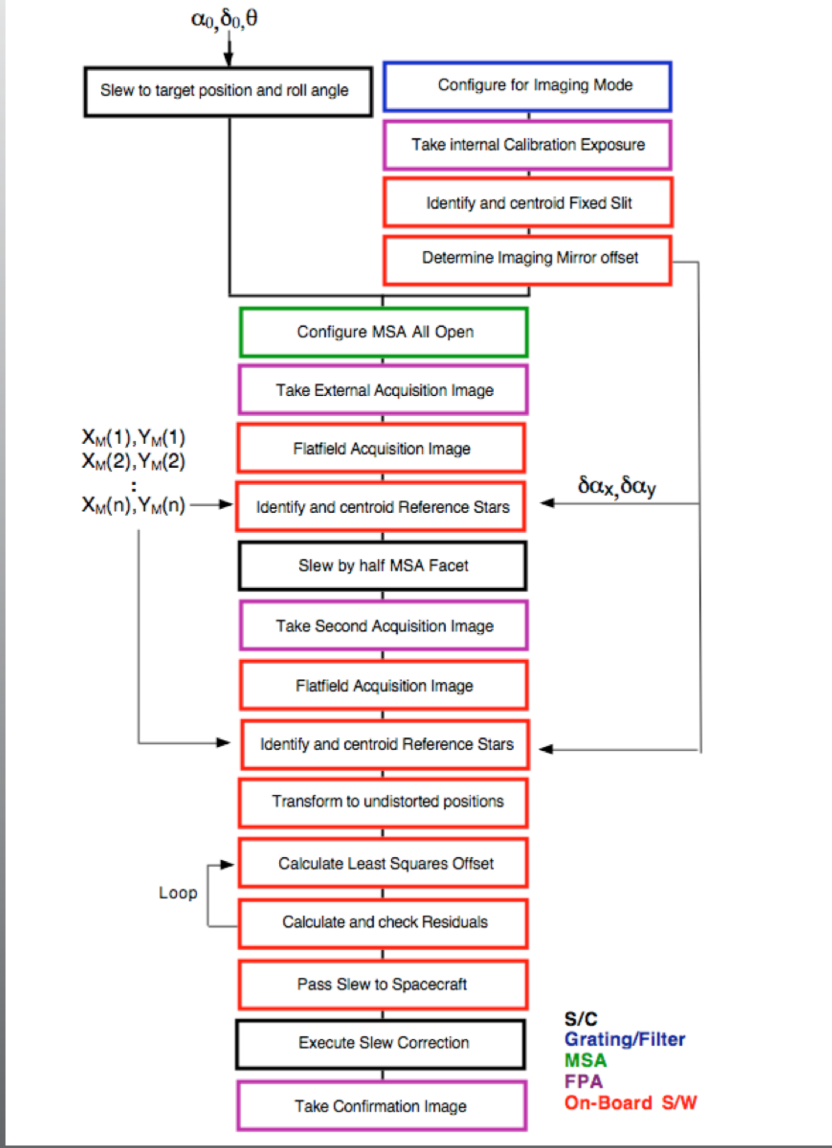
Problem 4: Grating Wheel Repeatability



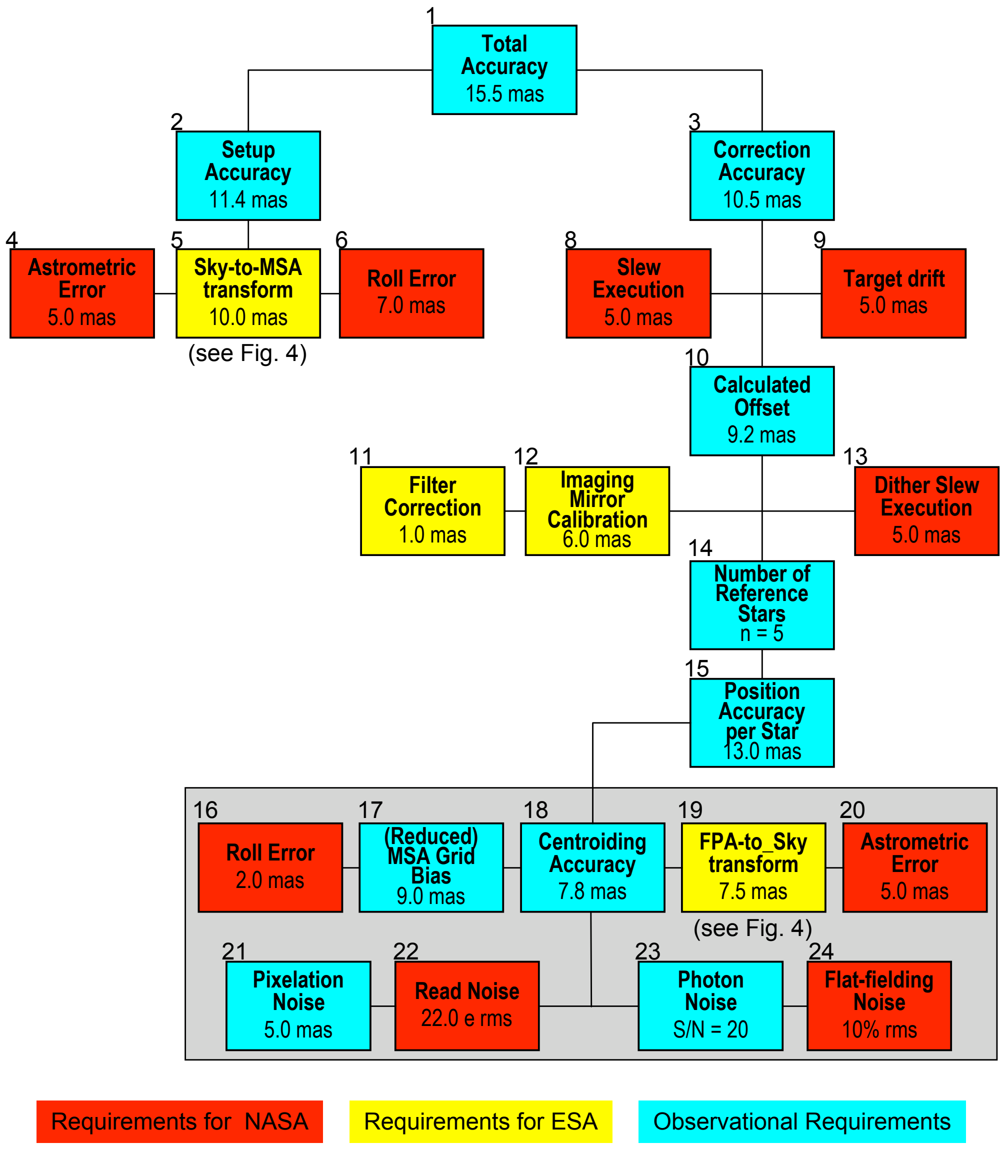
TA flow (best case)



TA flow (nominal)



TA Error Budget

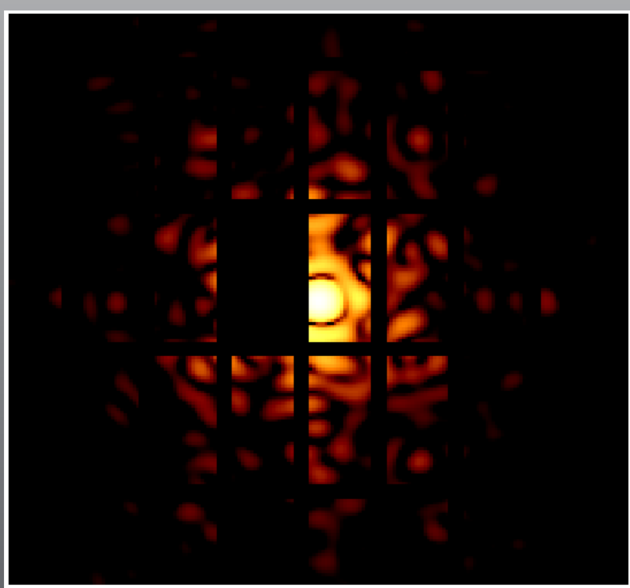


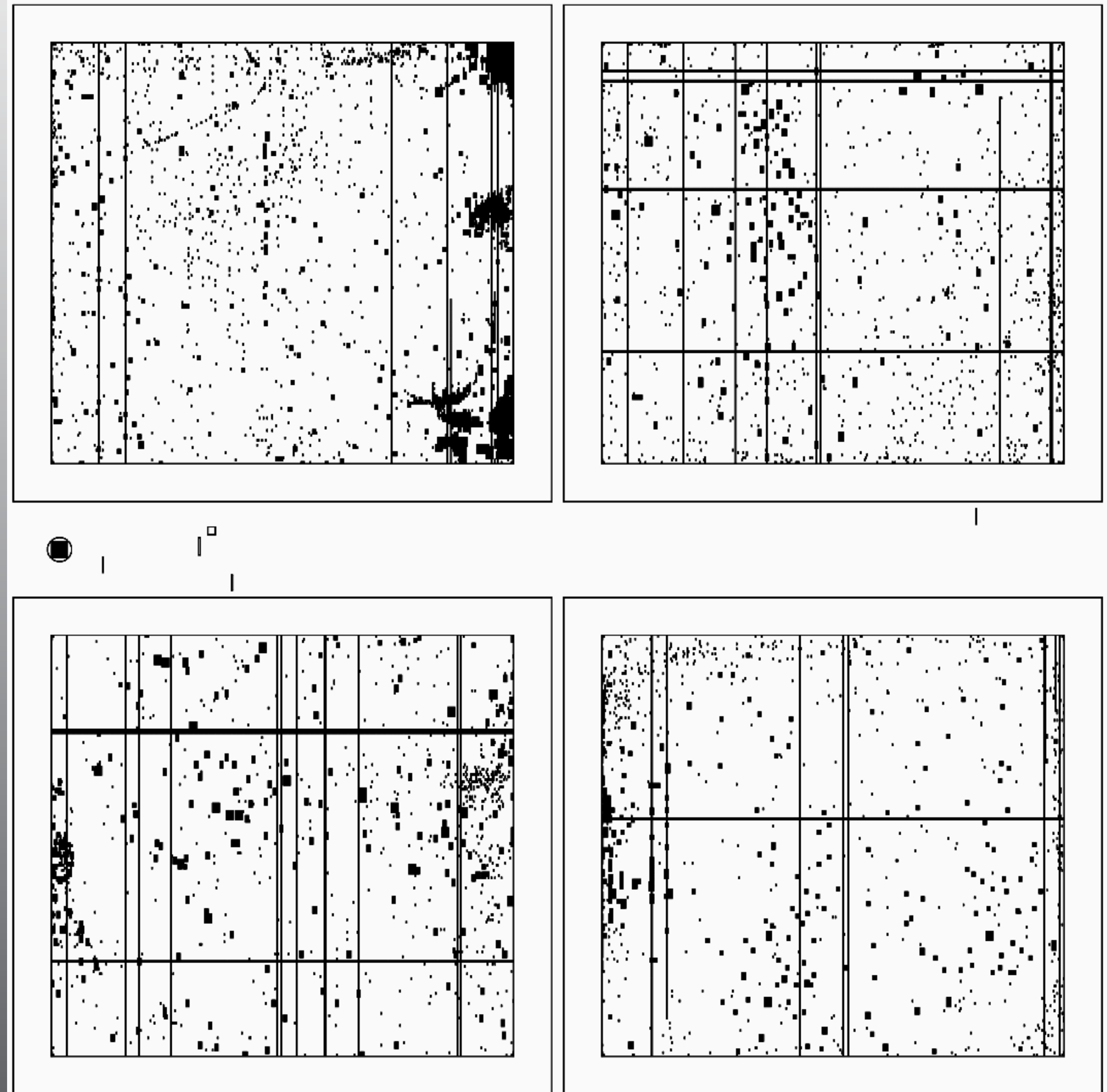
MSA performance: Closed Shutters

shutters that do not open
("failed closed"):

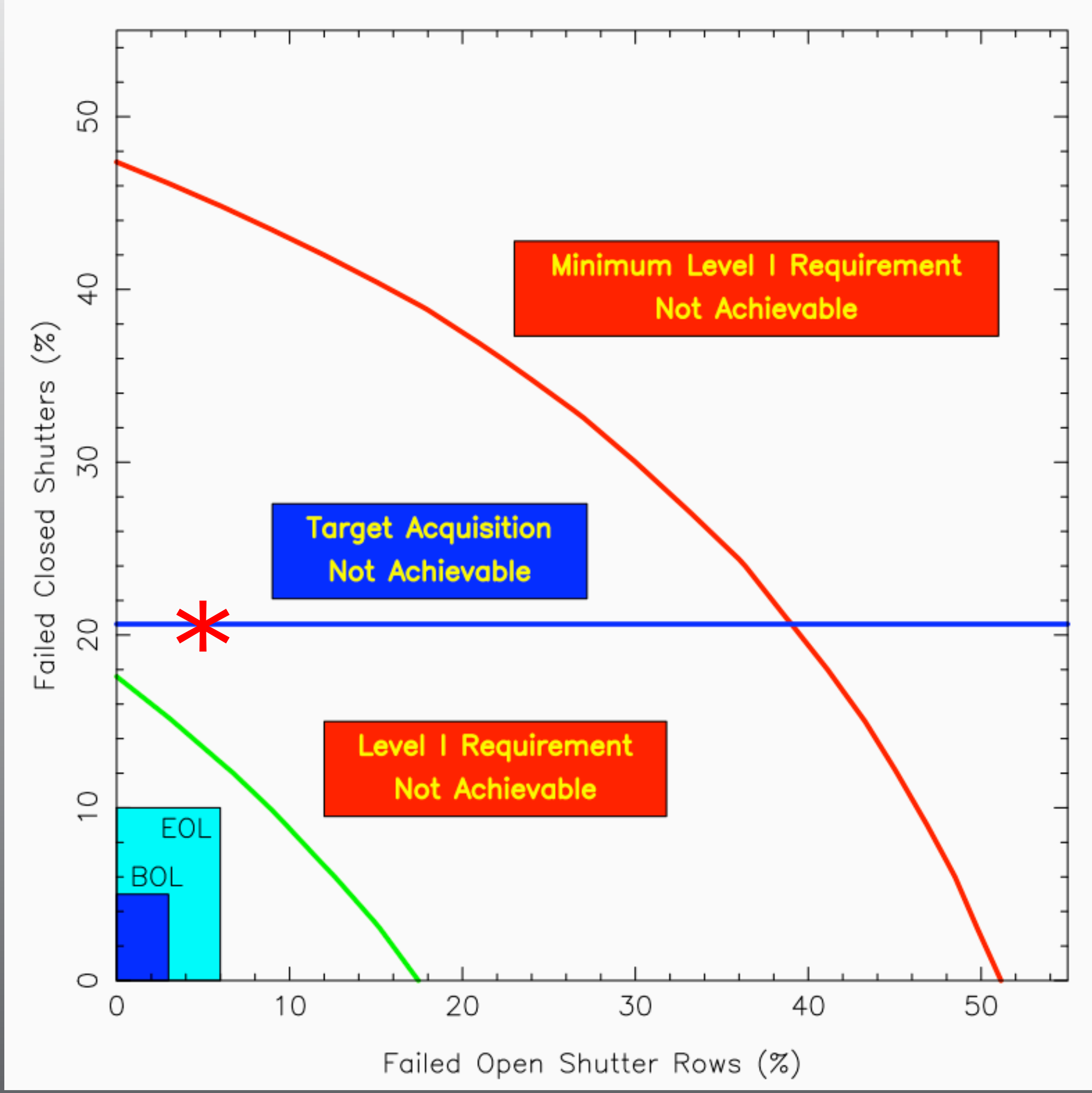
- cannot be used, but do not cause further harm (for science)

- electrical shorts cause entire columns/rows to fail in closed state





How many failed shutters are tolerable?

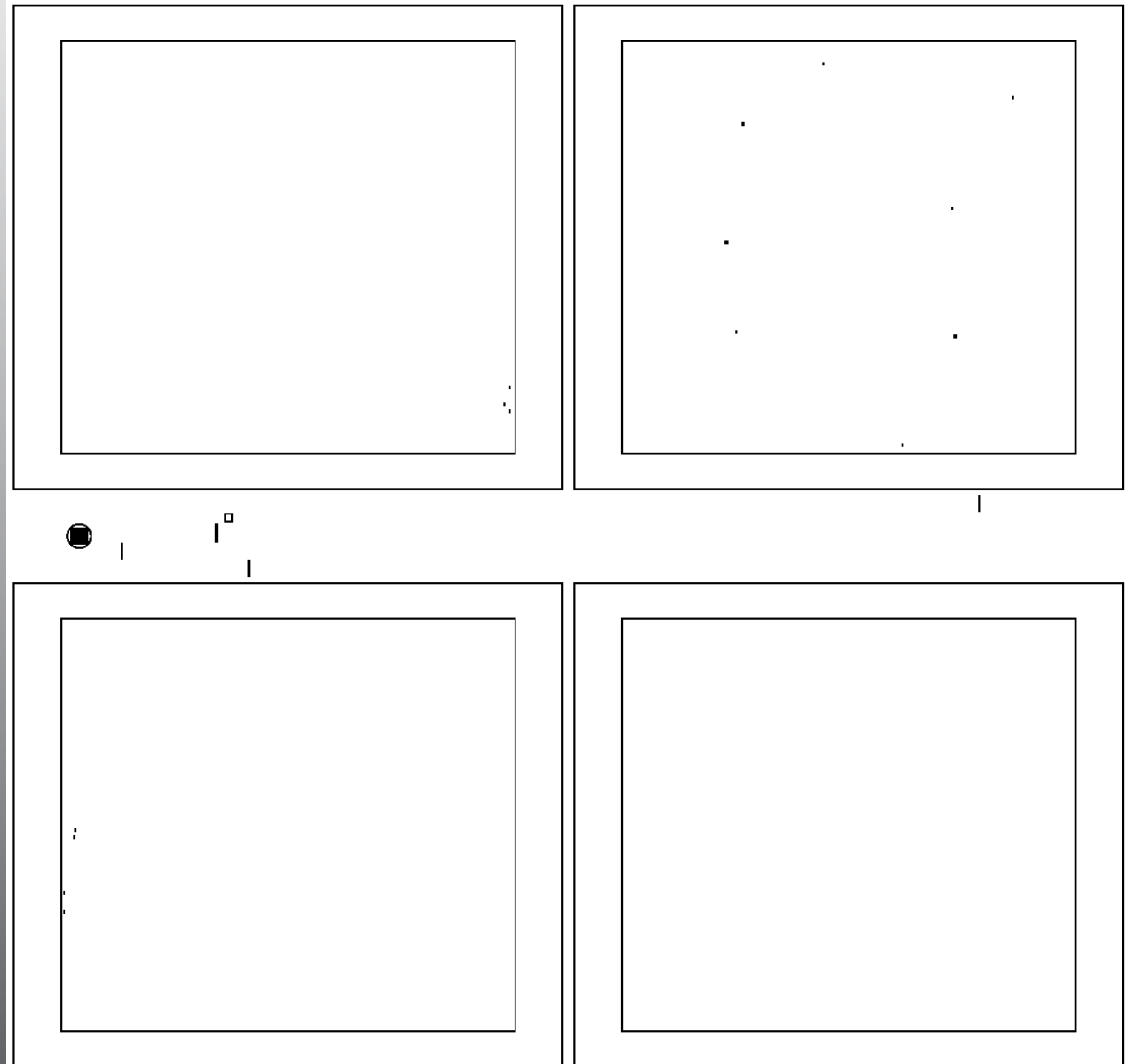


MSA Performance: Open Shutters

shutters that do not close
(“failed open”):

- are critical because they contaminate science spectra

- can mostly be plugged, turning them into “failed closed”



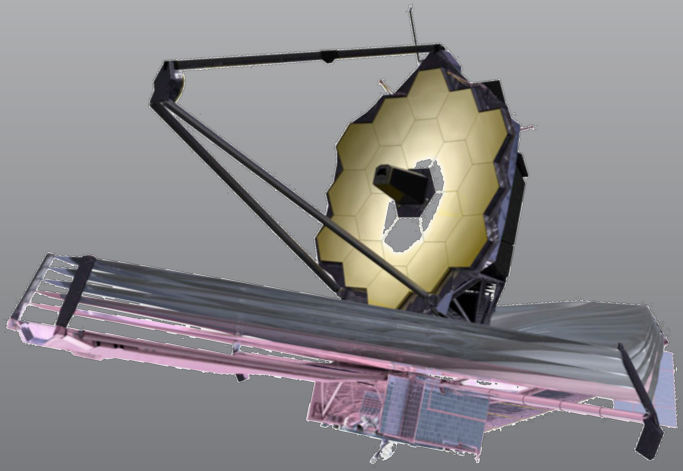
Alternative Strategies for Single Objects

- need backup method if no reference stars are available
- highest precision placement may not be needed for IFU/FS modes, and TA overhead may be reduced by simplified approach
- work in progress... some ideas:

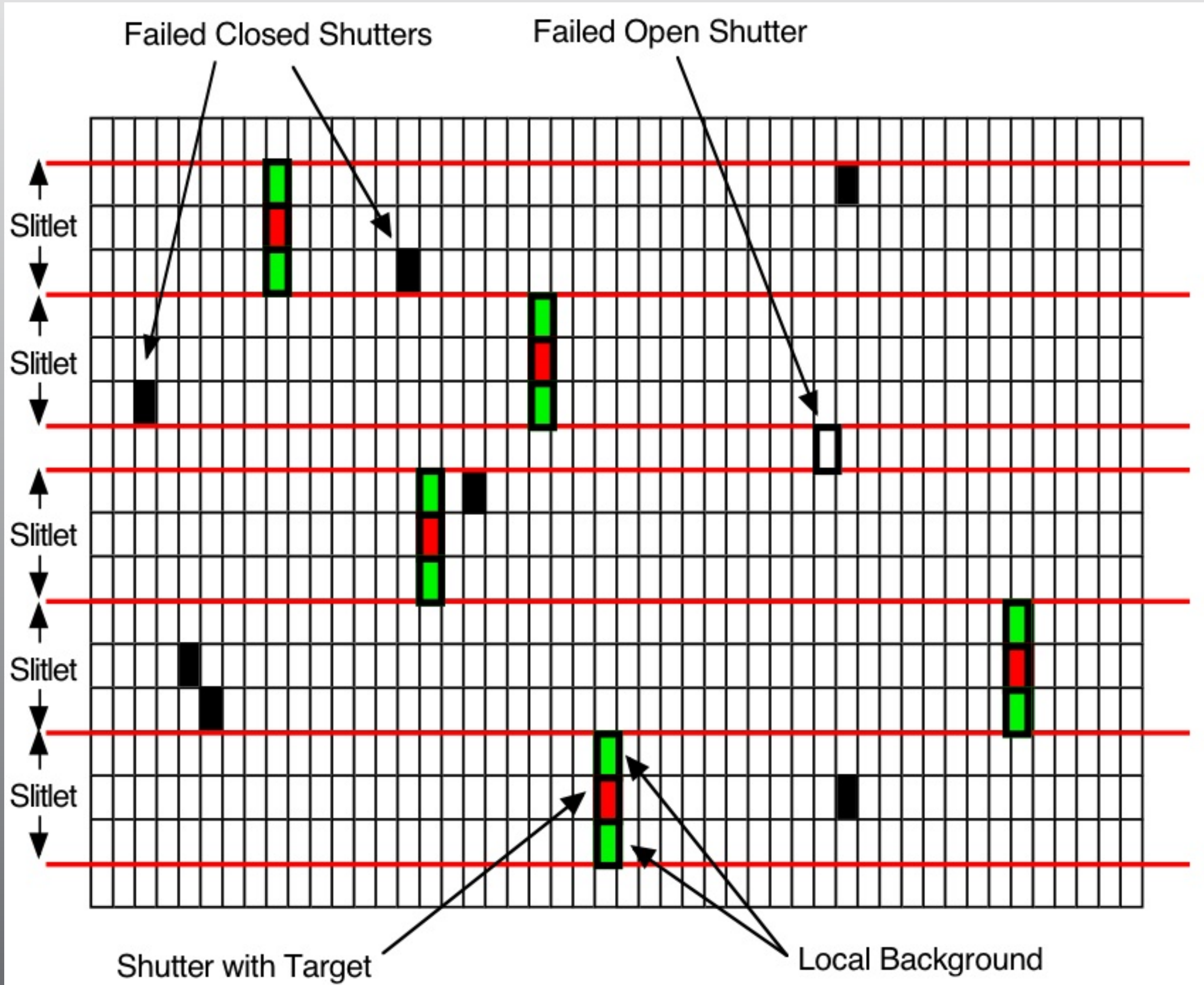
Name:	"Point and Shoot"	IFU		Fixed Slits		BigSquare	
Cases:		Ref stars good	Ref Stars not good	Bright	Faint	Bright	Faint
Method:	means slew+GSacq +conf image but no NIRSpec acq activities	coarse std	use "point and shoot"	dispersed peakup+xD centroid	imaging centroid	two options: see * below	imaging centroid
Precision:	as good as ~100 mas (depends on GS catalog)	varies	"	TBD	TBD	TBD	TBD
Application:	large IFU mosaics, MSA as long slit	many	"	bright stars	GRBs, highz gals	exoplanet hosts	stars/galaxies some ToOs

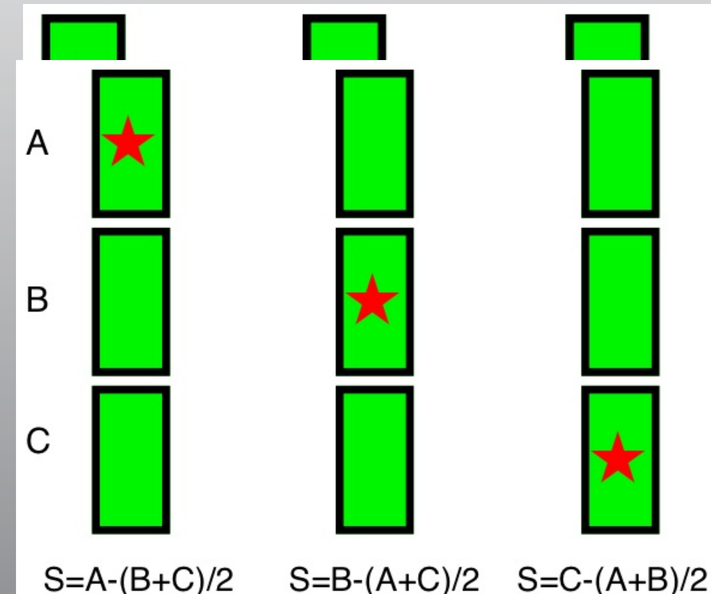
Conclusion

1) TA concept for MSA spectroscopy well understood
2) required on-board software is being developed
3) simplifications possible for IFU and FS modes



Removing the Sky Background





(extract, then subtract BG)
(subtract BG, then extract)