NIRSpec MOS mode: an introduction

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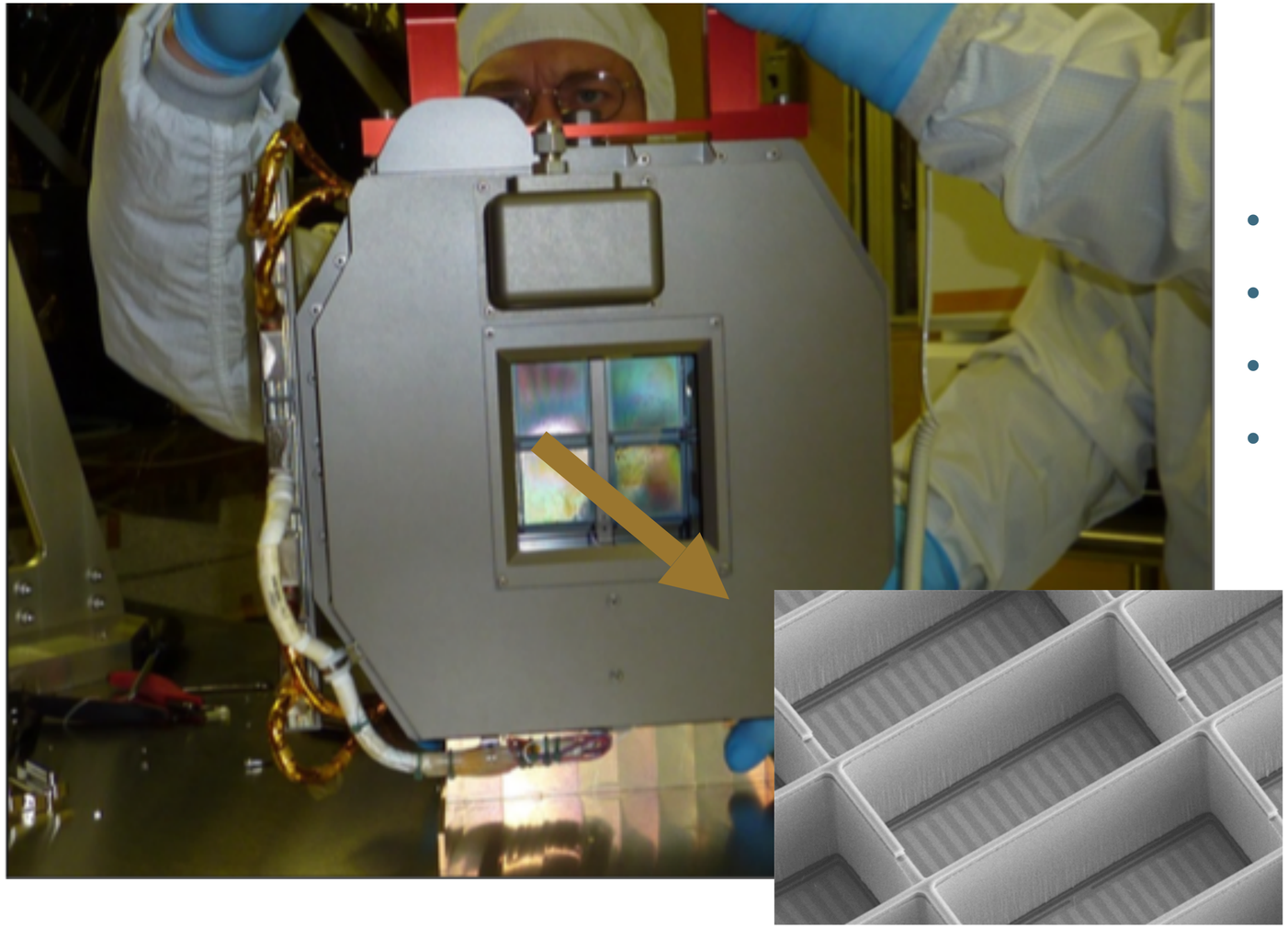
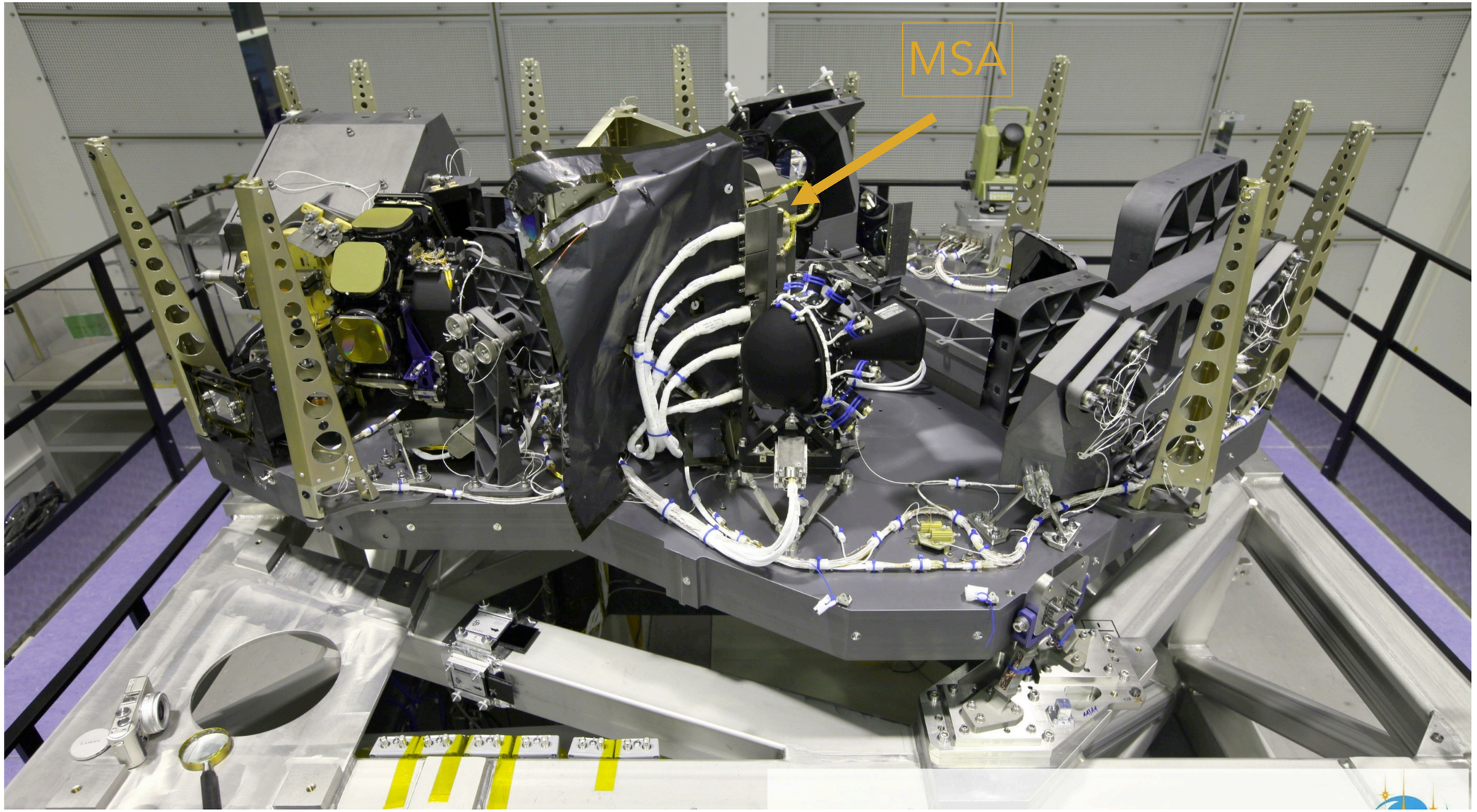
The Micro Shutter Assembly (MSA)

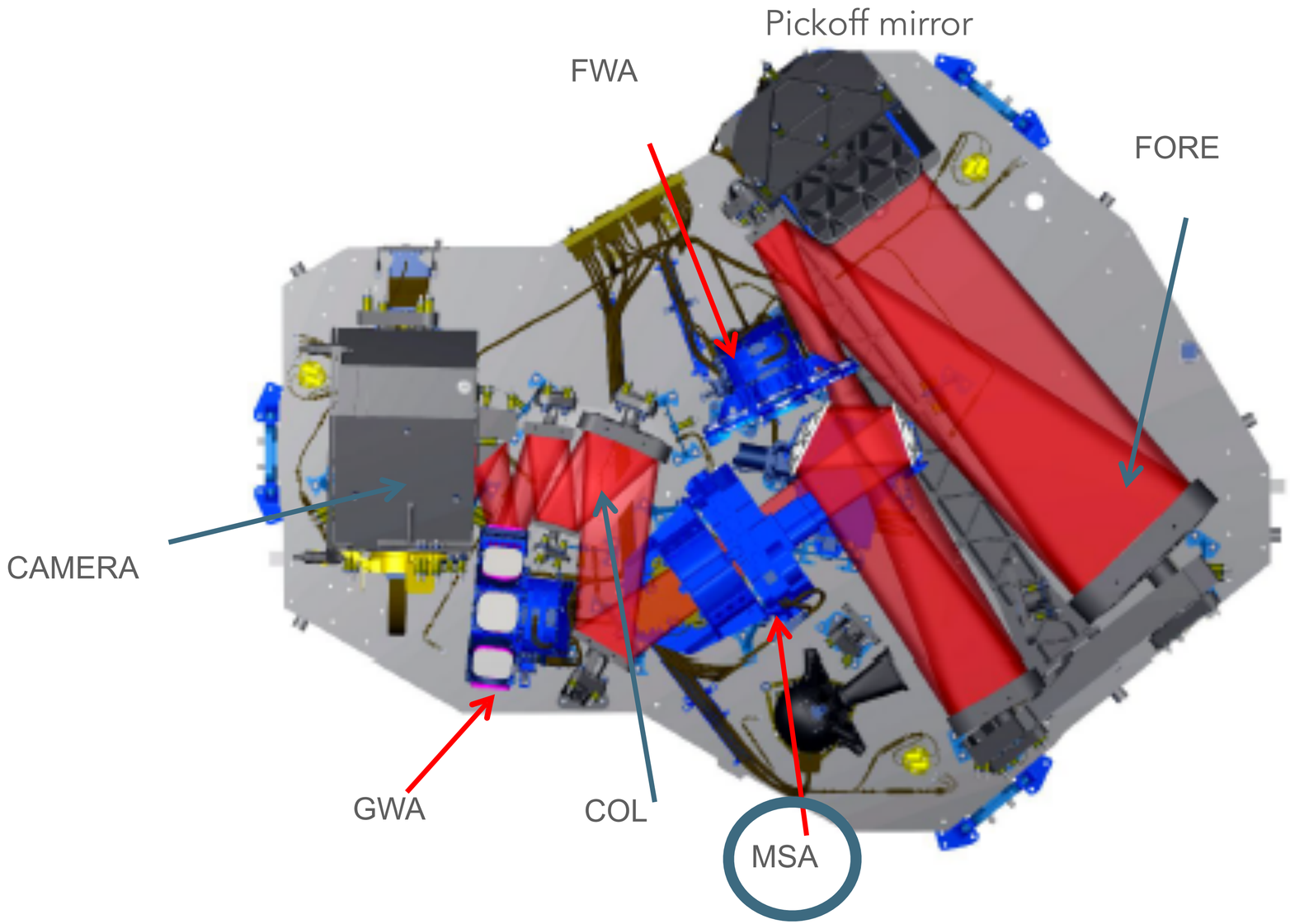


- 4 arrays of 365x171 micro-shutters
- 250,000 individually addressable shutters
- 3.6′x3.4′ field-of-view ~ 9 arcmin^2
- Each shutter 0.20"×0.46"
  (width in the dispersion direction
  × height)

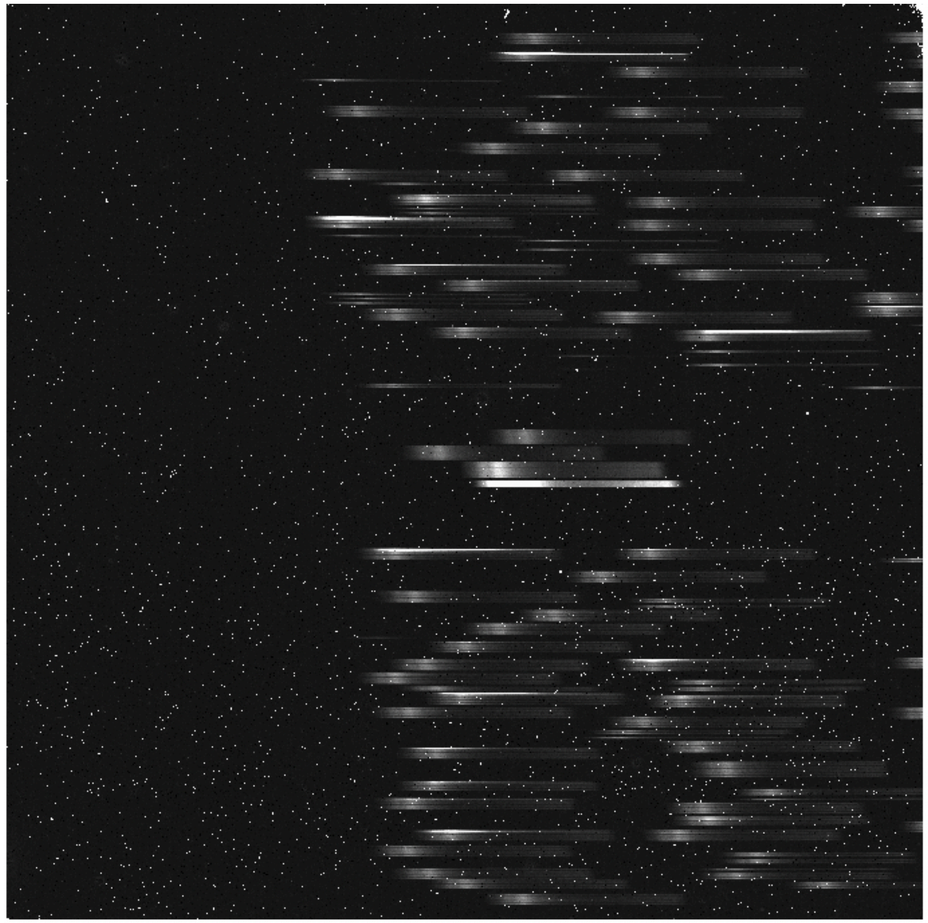
NIRSpec

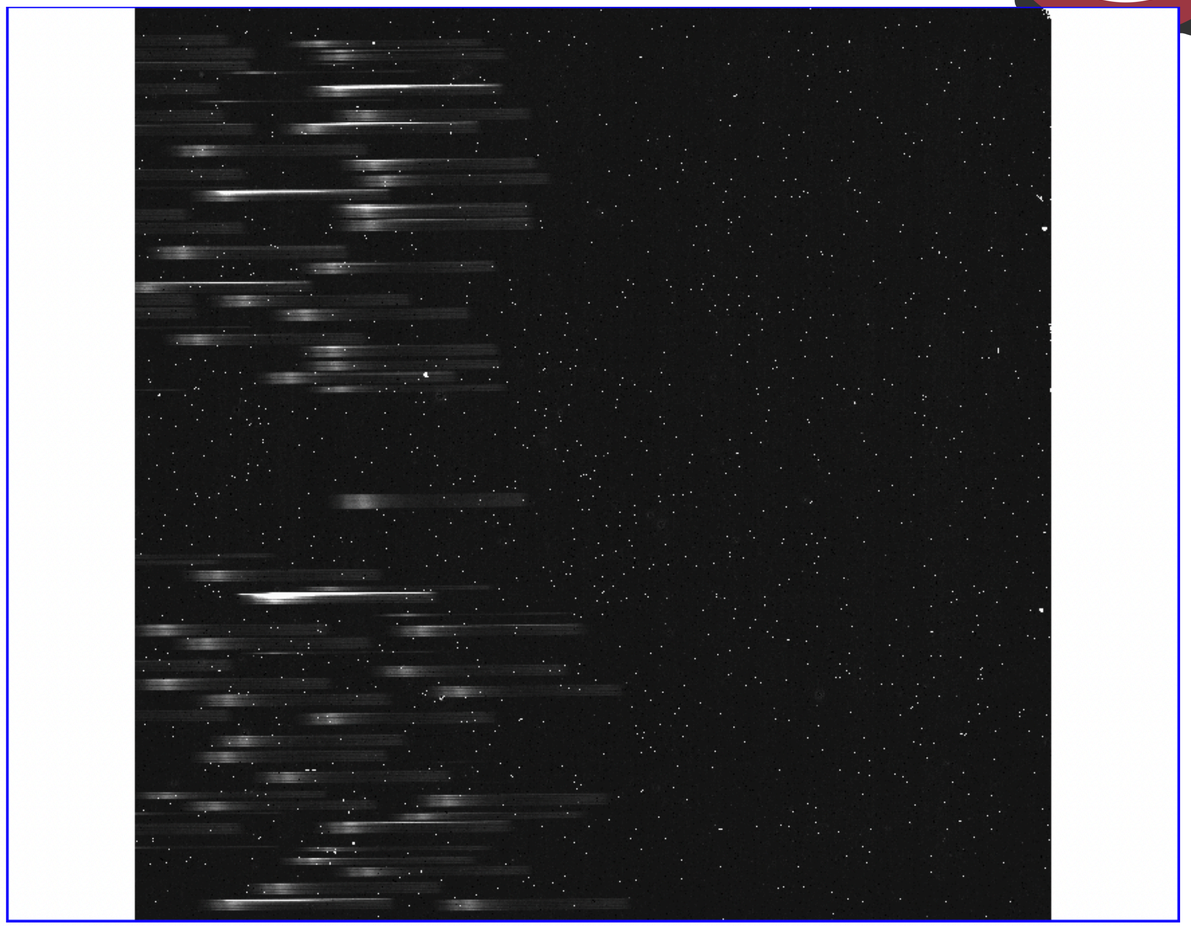


NIRSpec – light path

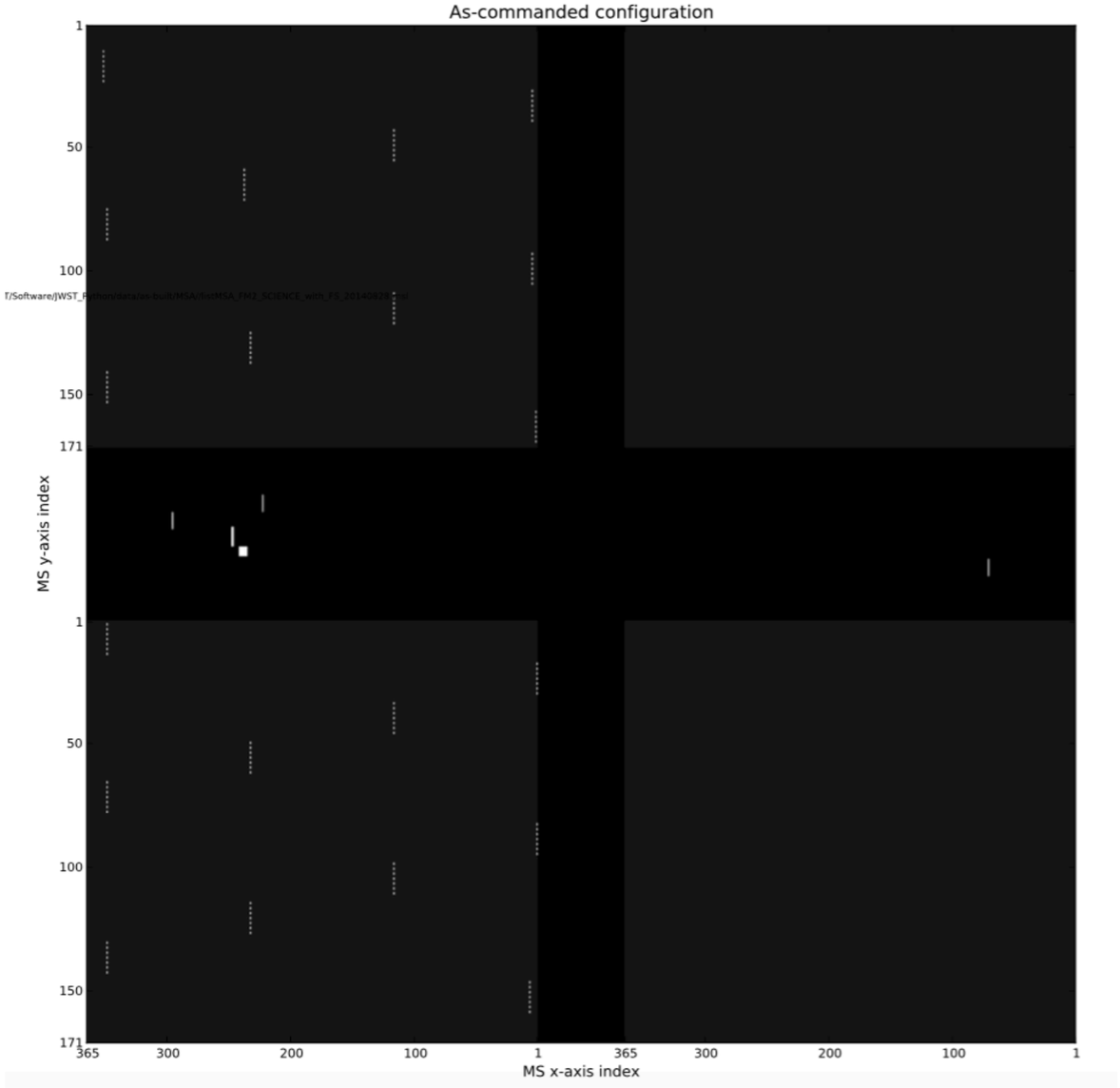


Example MOS data -#2565



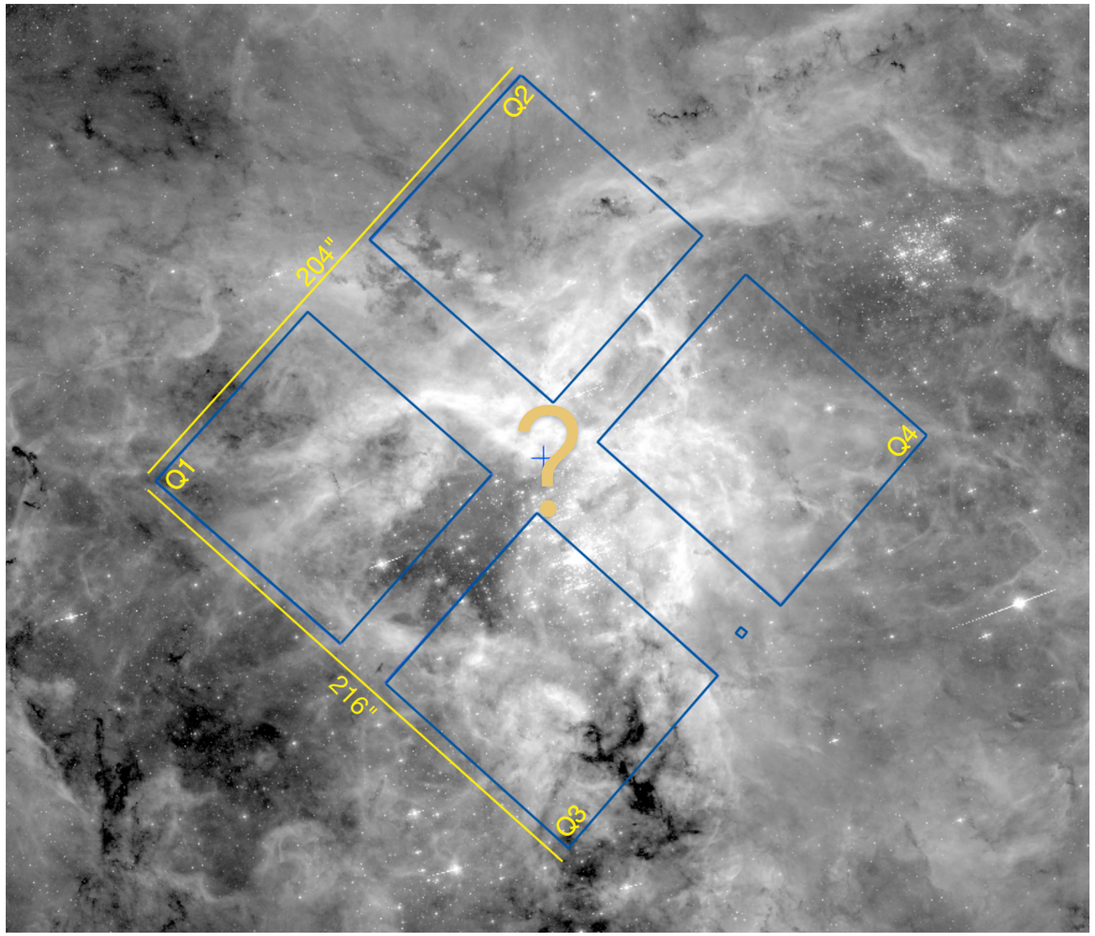


MSA configuration - Testing



Regular pattern of open micro-shutters used with flat-field illumination: Easy ☺

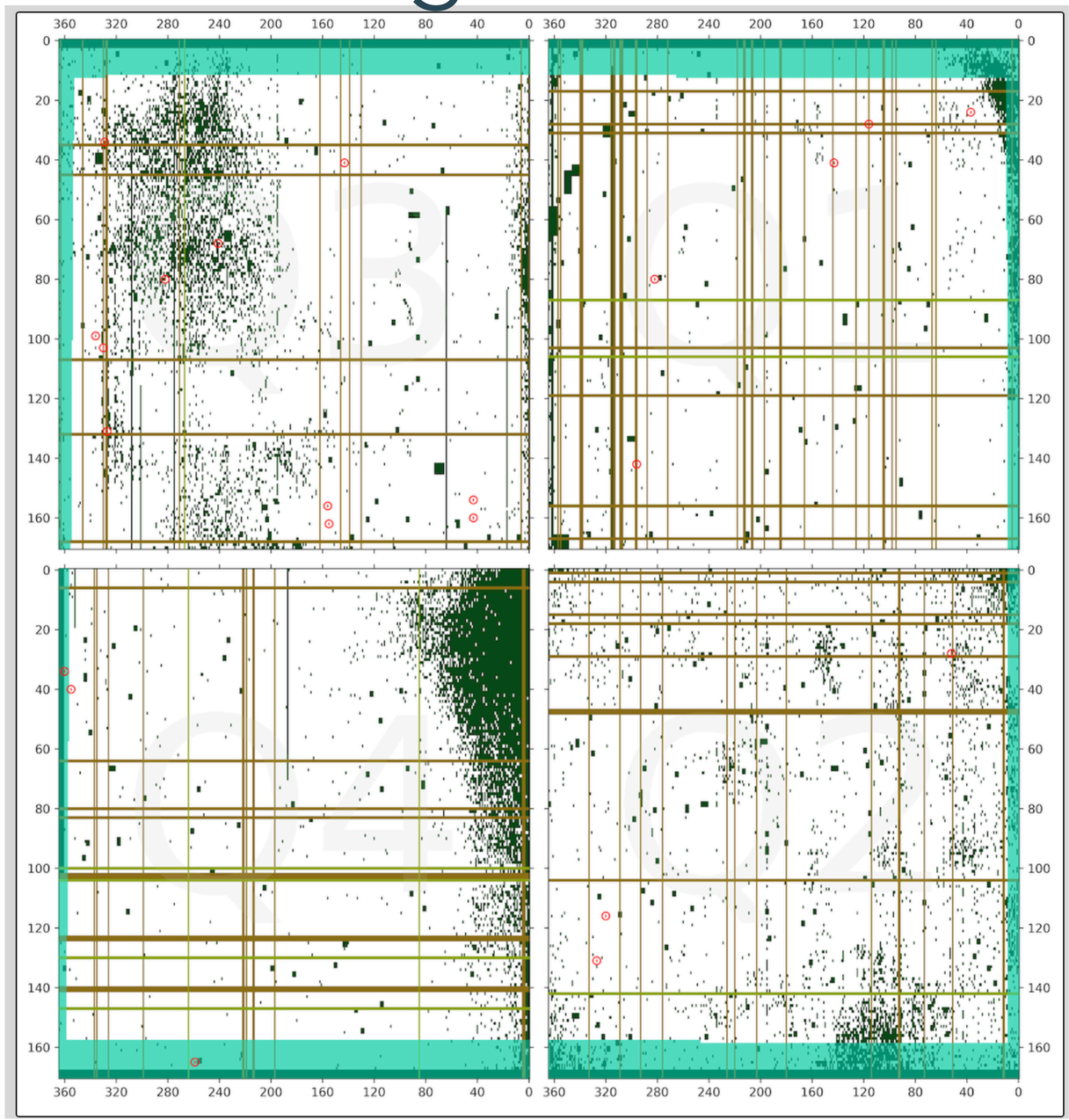
What about the planning of a real observation?



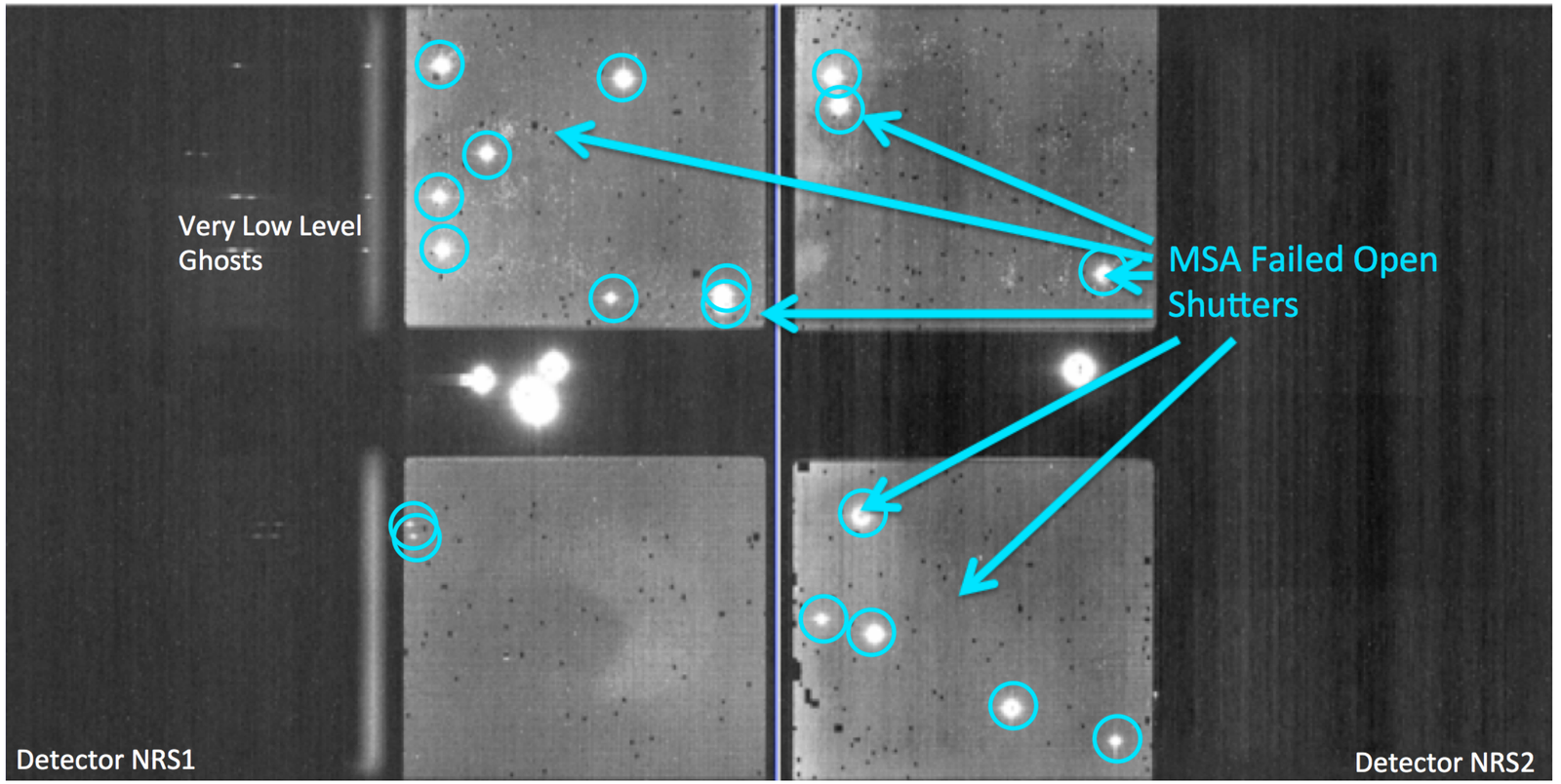
What are the considerations of such a plan?

What does the observer need to know?

The MSA is not an ‘ideal’ grid - I

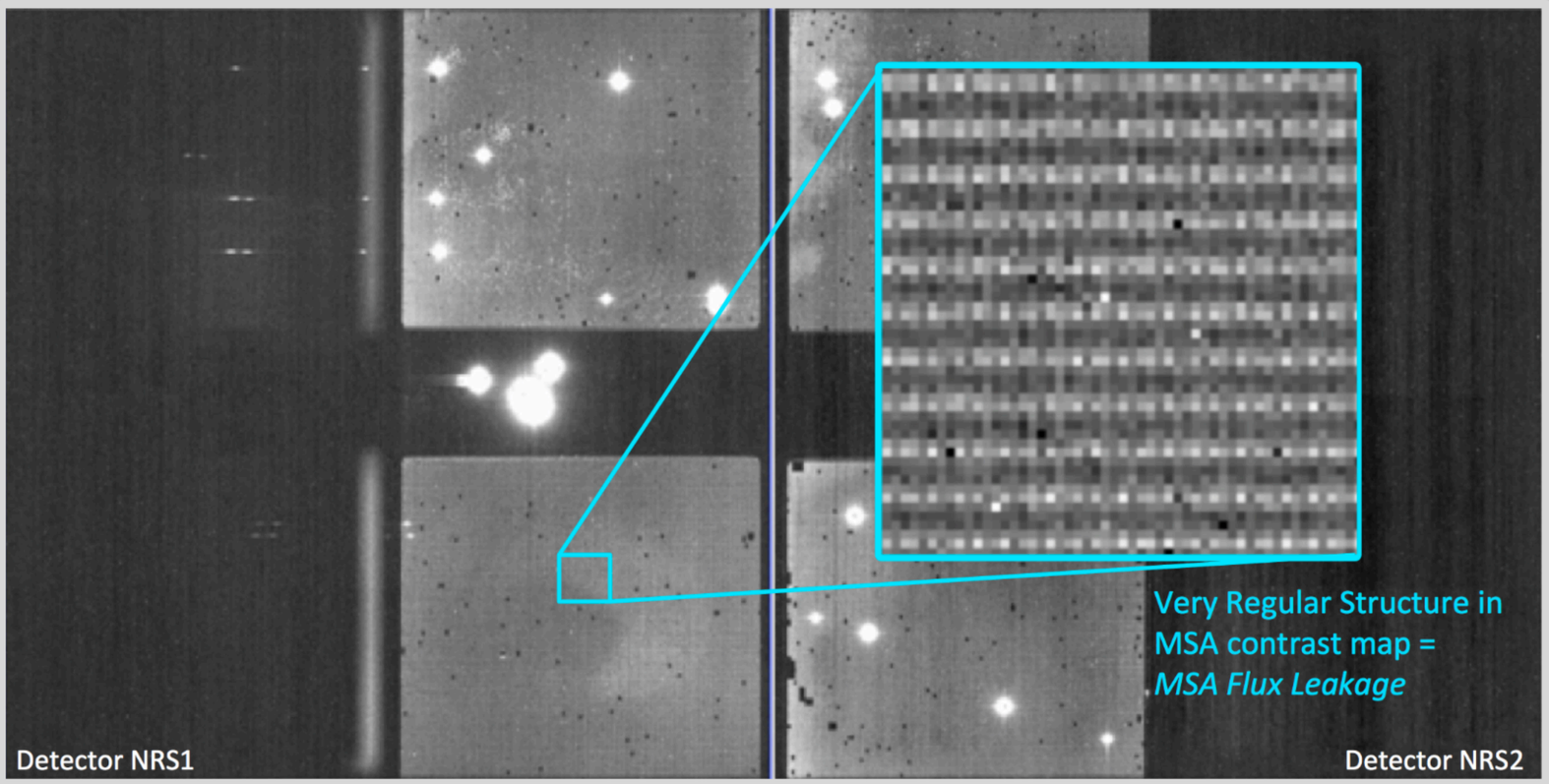


The MSA is not an ‘ideal’ grid - II

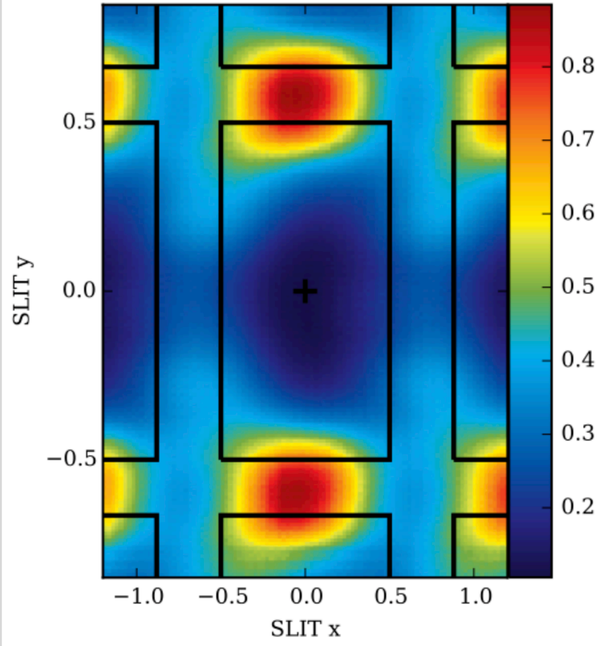


- Dispersed light falling on a failed-open shutter can contaminate spectrum of target
- Closed shutter are nor perfectly opaque
- The status of failed open/failed closed shutters can evolve

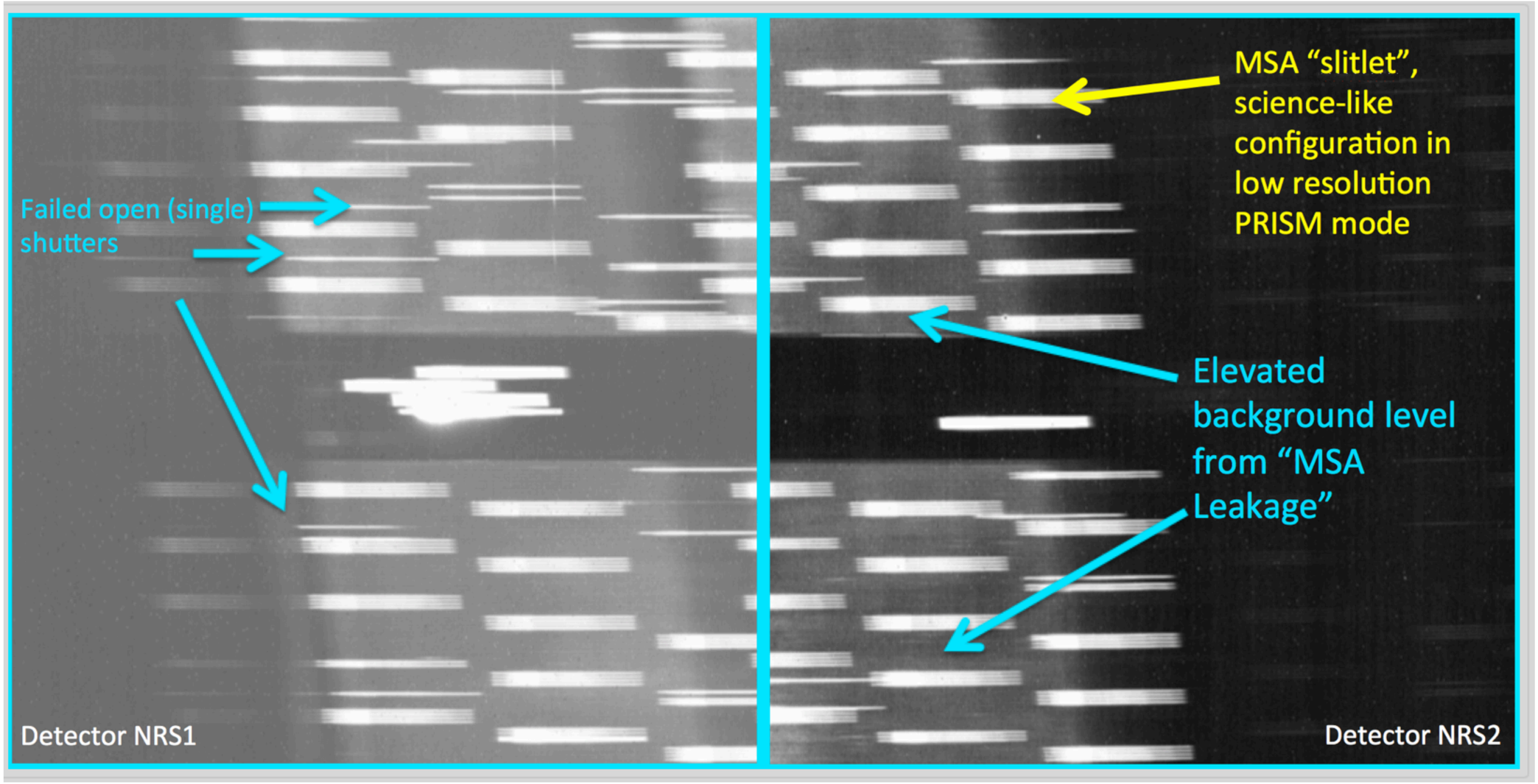
The MSA is not an ‘ideal’ grid - III



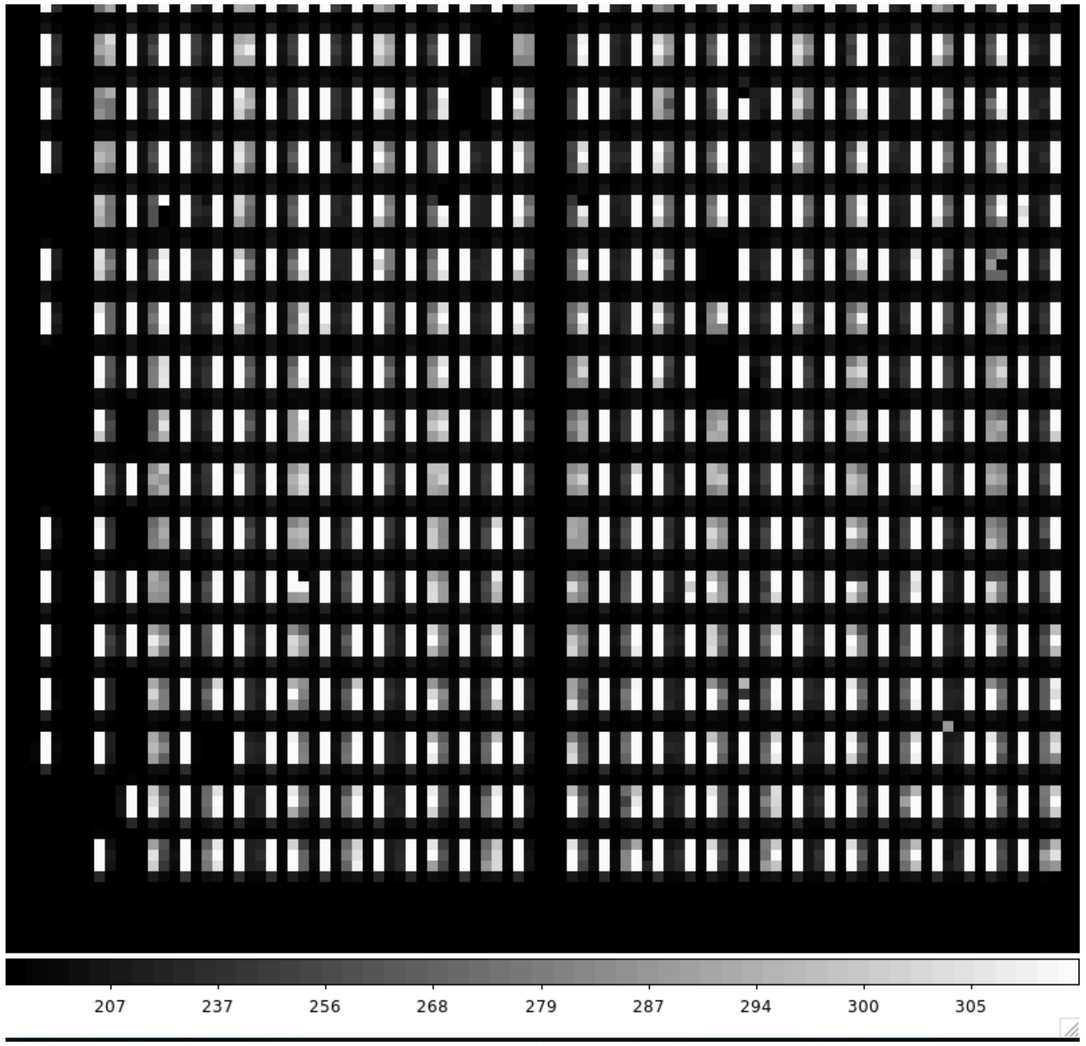
A zoomed view of the data acquired to determine the opaqueness of the MSA reveals very regular structure within the contrast map.



The MSA is not an ‘ideal’ grid - IV

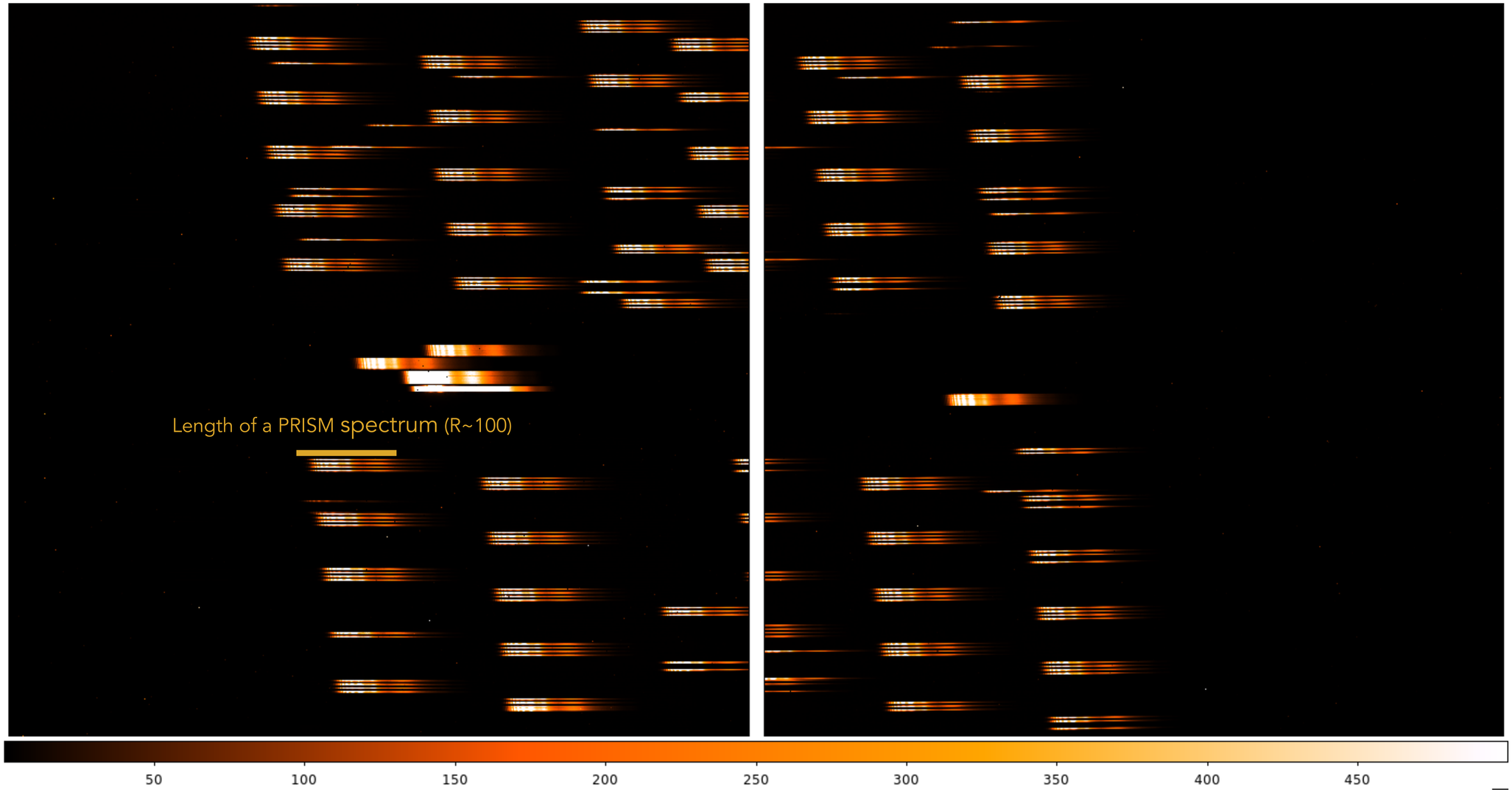


The MSA is a fixed grid

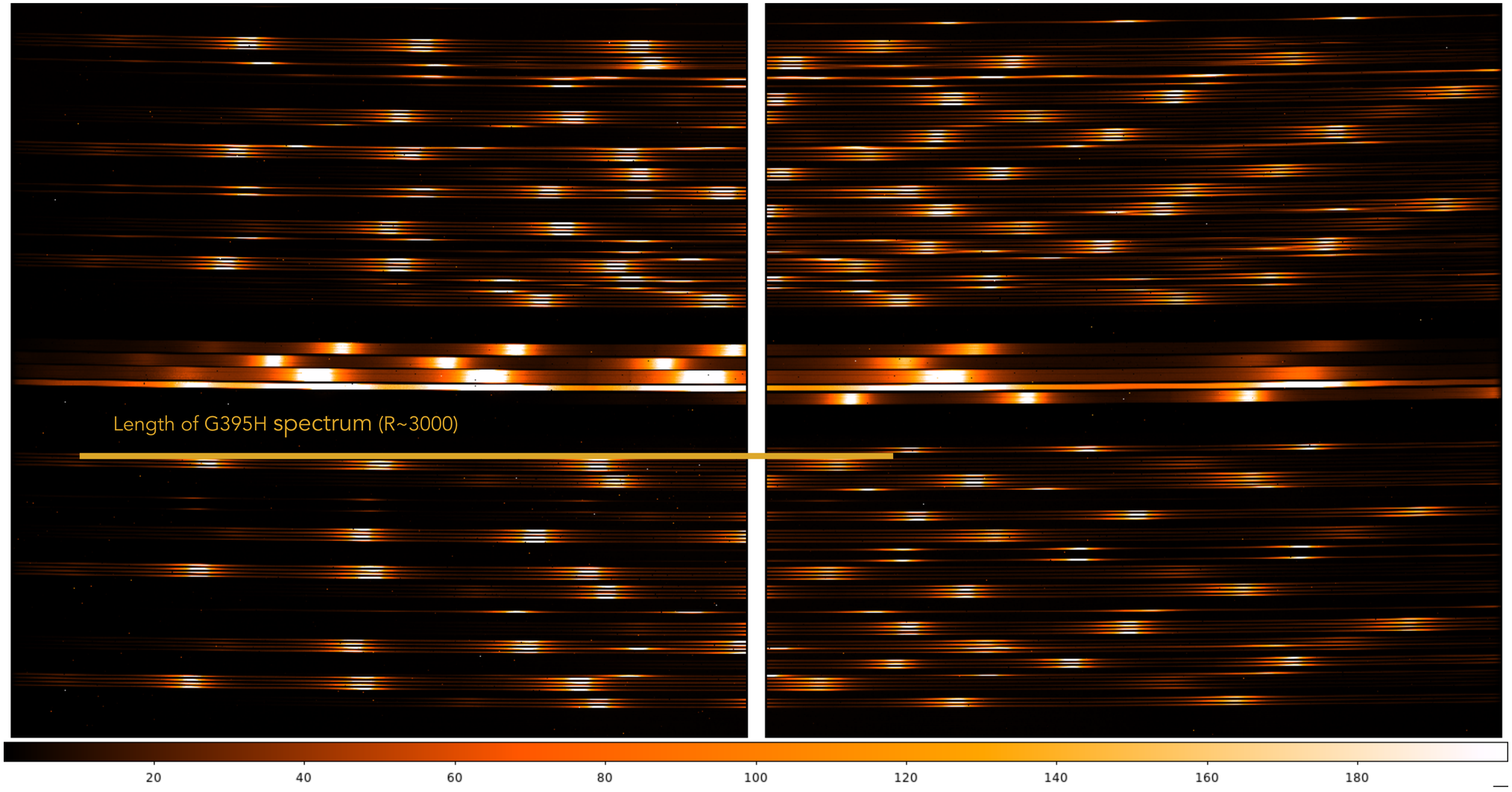


- Shutter bars vignette light from an extended sources
- Gap between the 2 detectors that leads to a gap in wavelength coverage
- In general sources will not be centered in the aperture
- Positioning sources in MSA require knowledge of optical distortions/ velocity aberrations

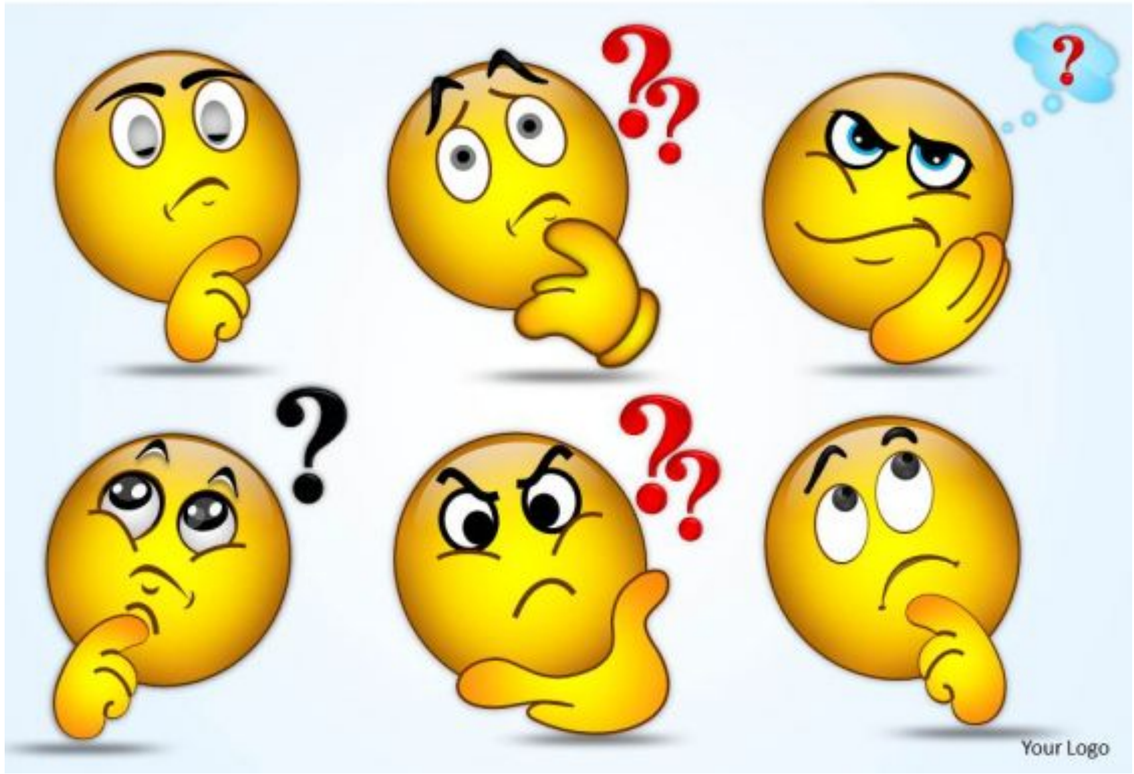
Spectra on the detector have different length: PRISM



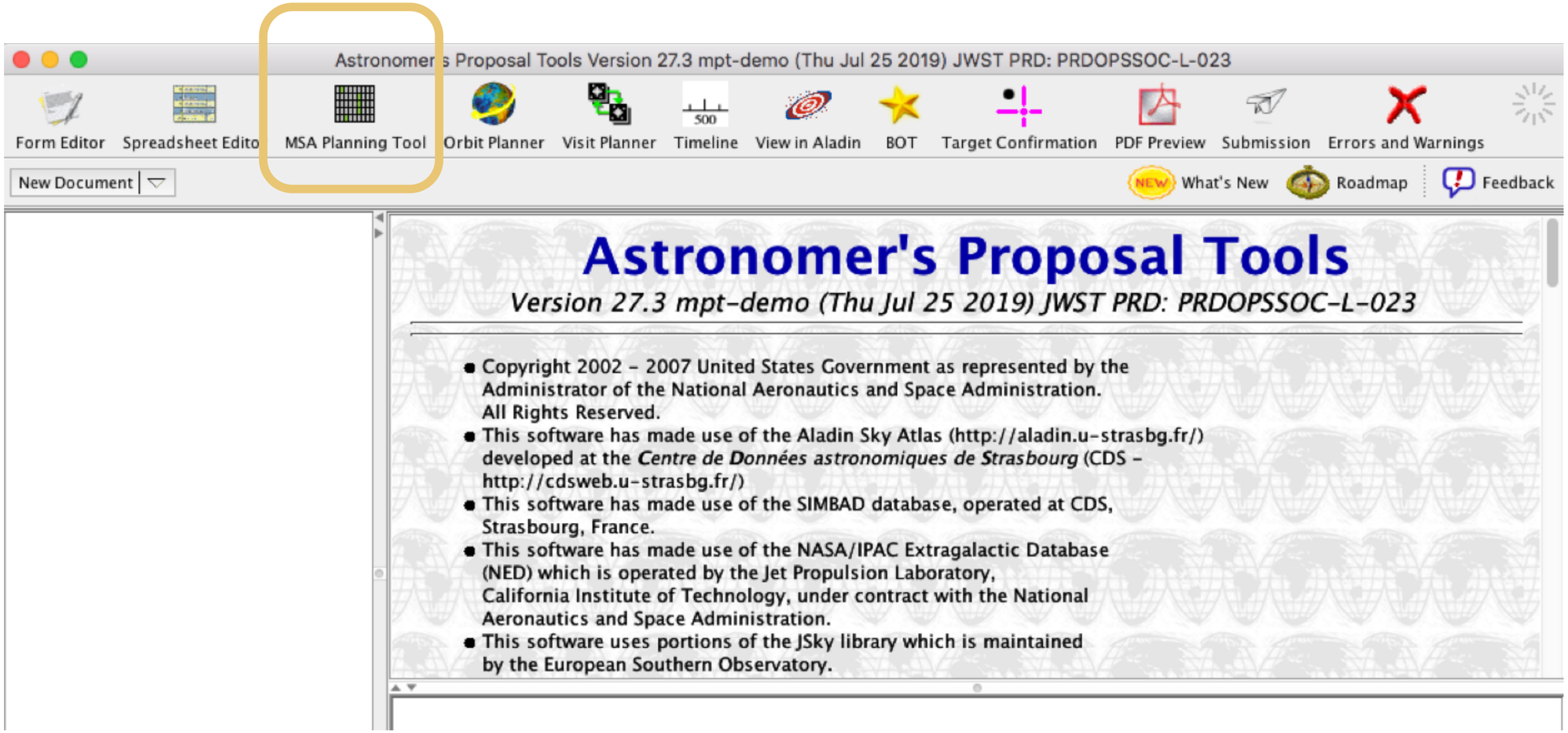
Spectra on the detector have different length: G395H



All this seem rather complicated…



The answer: MSA Planning Tool (MPT)



Multiplexing levels (optimal planning – real MSA)

PRISM: With catalog source densities greater than ~600 sources/arcmin^2

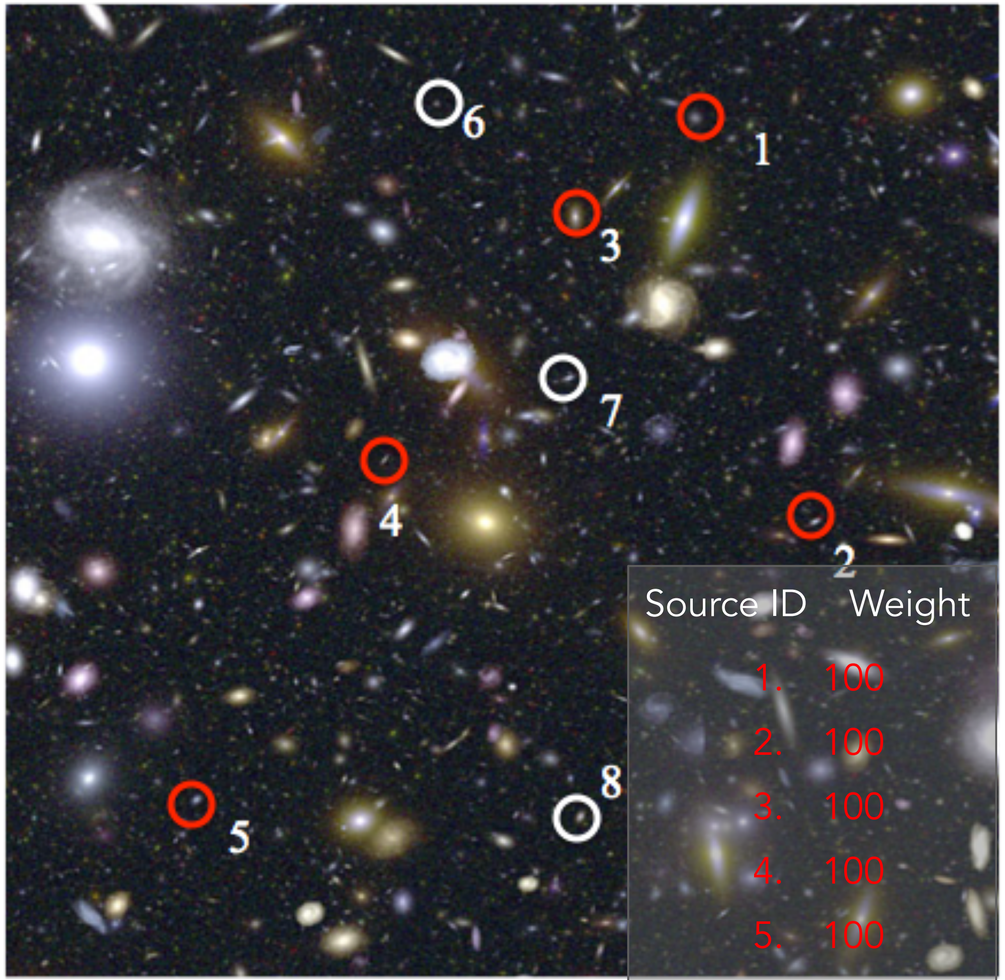
➔ typically ~180 to 200 sources can be observed simultaneously.

Gratings: With catalog source densities greater than ~200 sources/arcmin^2

➔ typically ~65 to 70 sources.

Which are the observational parameters that influence the multiplexing levels & drive the planning of a MOS observation?

Main input to the MPT: catalog of sources

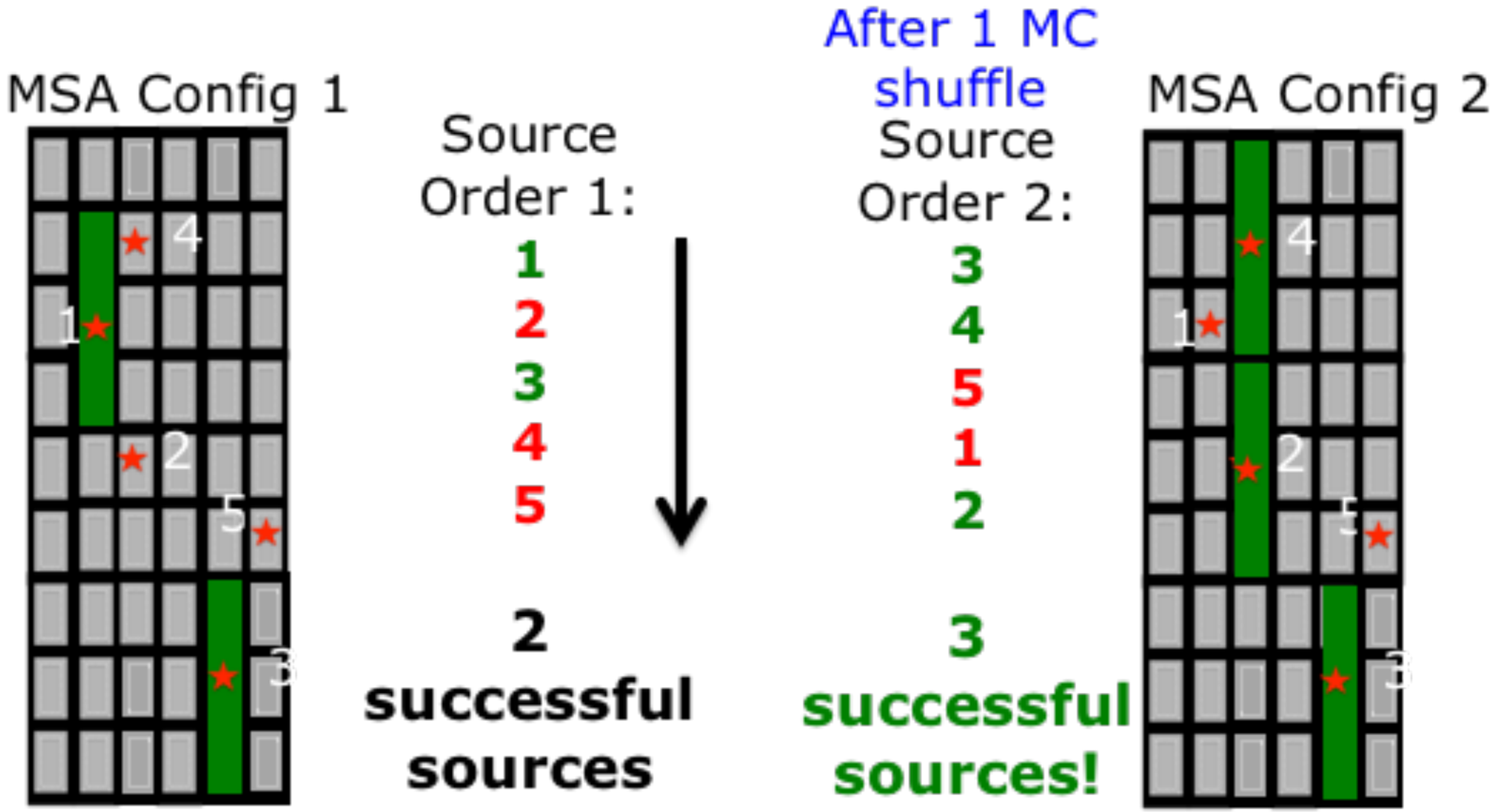


Source ID	Weight
1.	100
2.	100
3.	100
4.	100
5.	100
6.	1
7.	1

- Target weights can be added in catalog: relative weights. Integer values. W(100) = 100 x W(1).
- Order your input catalog by target weight before ingest.
- Create a **Primary candidate set**, and an optional **Filler candidate set**
- Fillers help to **optimize the MSA configuration**.
- The **best pointing** is determined from the (weighted) Primaries, i.e. the weights of the primaries are used during planning.

Key parameter of MPT algorithm: Monte Carlo reshuffle

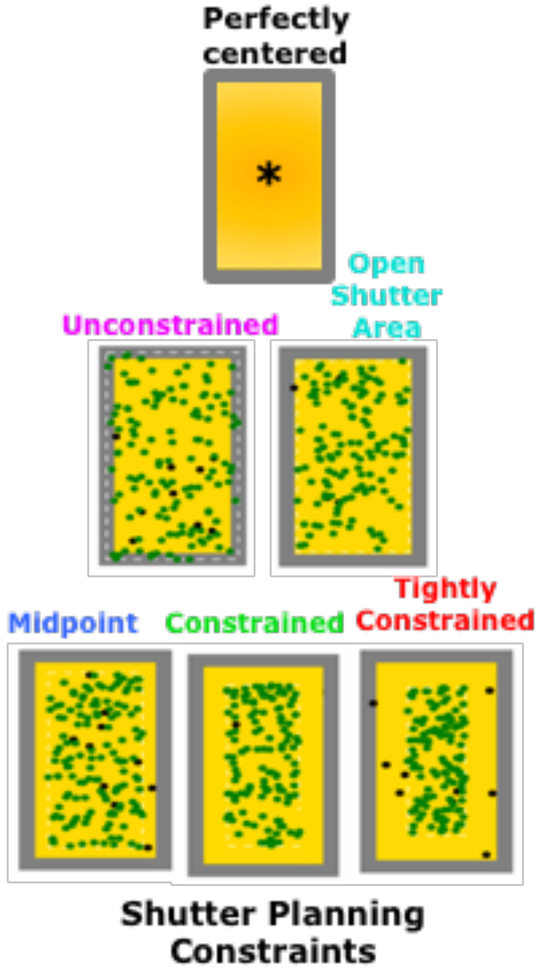
User can **choose whether to re-order the Primary candidate list** at each pointing.
This can increase the number of targets observed at that pointing.



Catalogue Key parameter: astrometric accuracy

- MOS mode observations can be planned using astrometry with accuracies from 5-50mas.
- High precision spectral calibration needs relative positional accuracy of 15 milli-arcsec or less, which most likely requires space-based observations.
- Images obtained using JWST, HST/ACS and WFC3 within the past ten years should have this level of accuracy.
- In some cases, the planning of the NIRSpec spectroscopy will require NIRCam observations, a process that is called NIRCam pre-imaging.
  If needed, users can request NIRCam pre-imaging in their MOS proposal

Key Planning Parameters: Shutter Margin



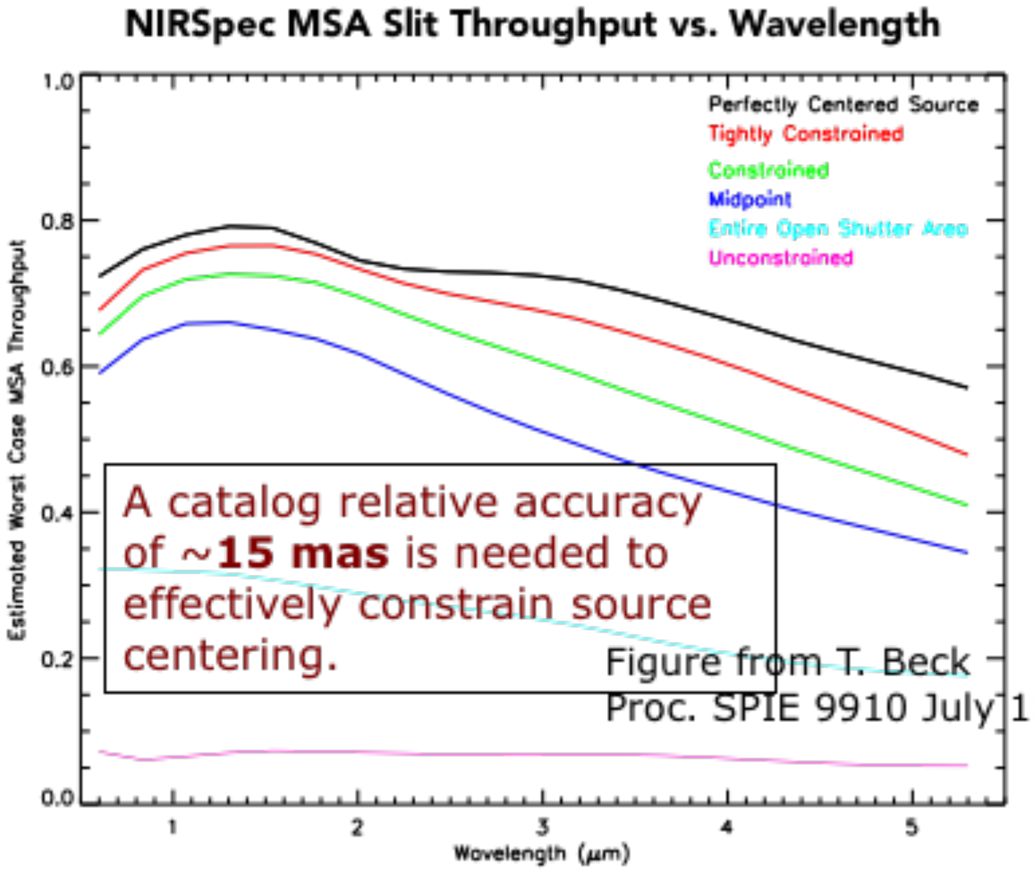


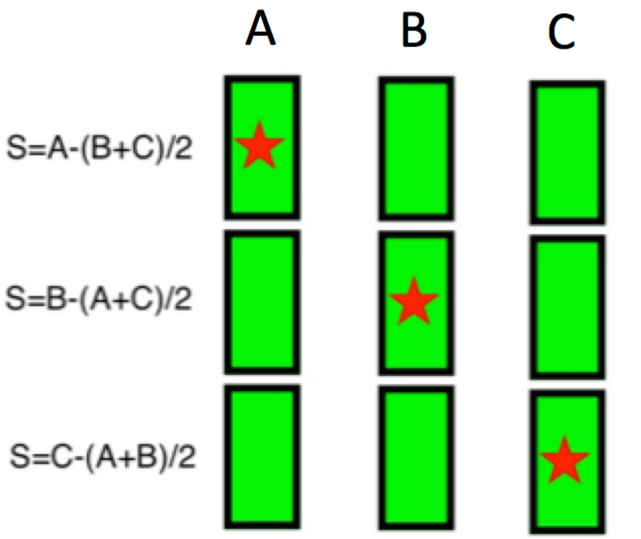
Figure from T. Beck
Proc. SPIE 9910 July 15 2016

Key Planning Parameters: Slitlet size

- By commanding open micro shutters, it is possible to create longer slits (in the cross-dispersion direction only) which are referred to as "slitlets".
- There are four selectable **Slitlets** 1, 2, 3, or 5.
- The spectrum from a slitlet will be segmented, with bar shadows between the individual shutters

Key Planning Parameters: Nodding & Dithers

Nodding



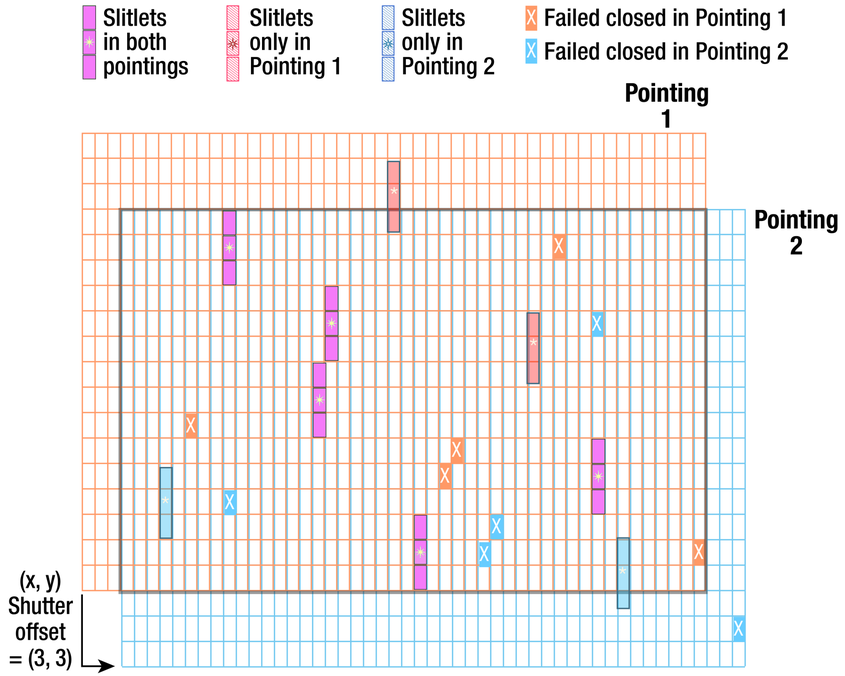
The telescope is repositioned slightly between exposures

➔ Background subtraction

➔ No MSA re-configuration

➔ Same targets at same 'depth'

Dither



Telescope repointing, translate a MSA configuration to a new location in FoV

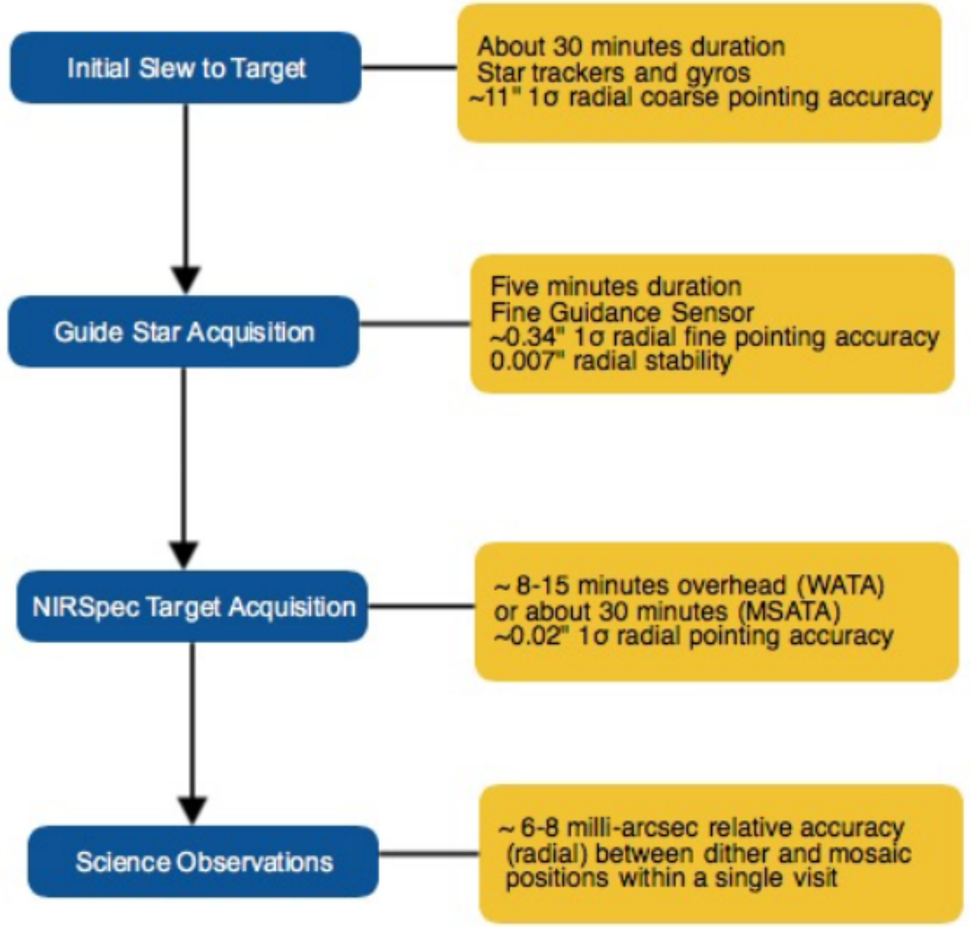
➔Cover the,wavelength gap

➔ Different MSA configuration

➔ Different (overlapping) target sets, different 'depth' for non-overlapping sources

Target Acquisition

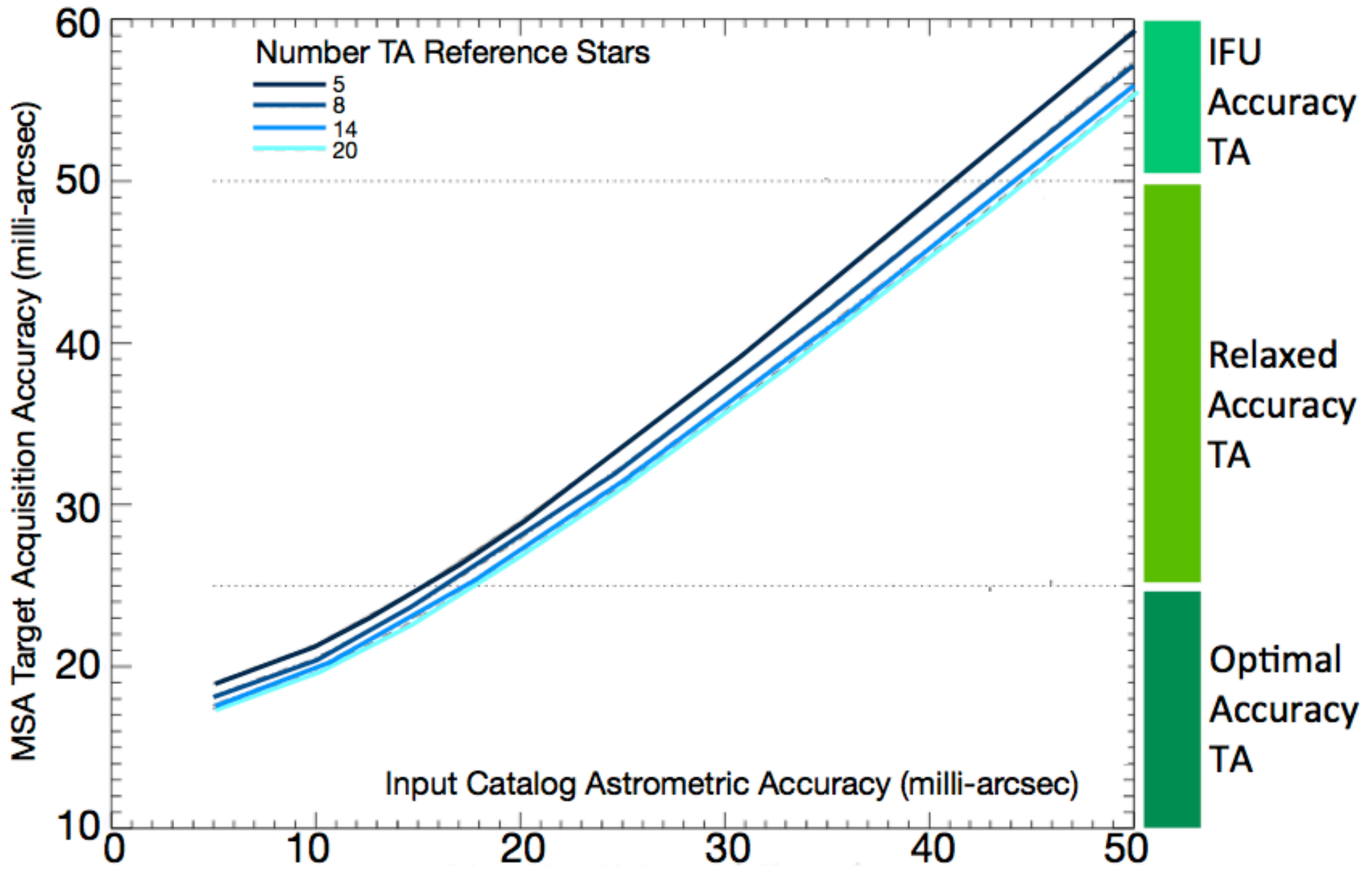
MSATA the common target acquisition method for the NIRSpec MOS science mode.



MSATA procedure uses 5–20 reference stars over the entire MSA FoV

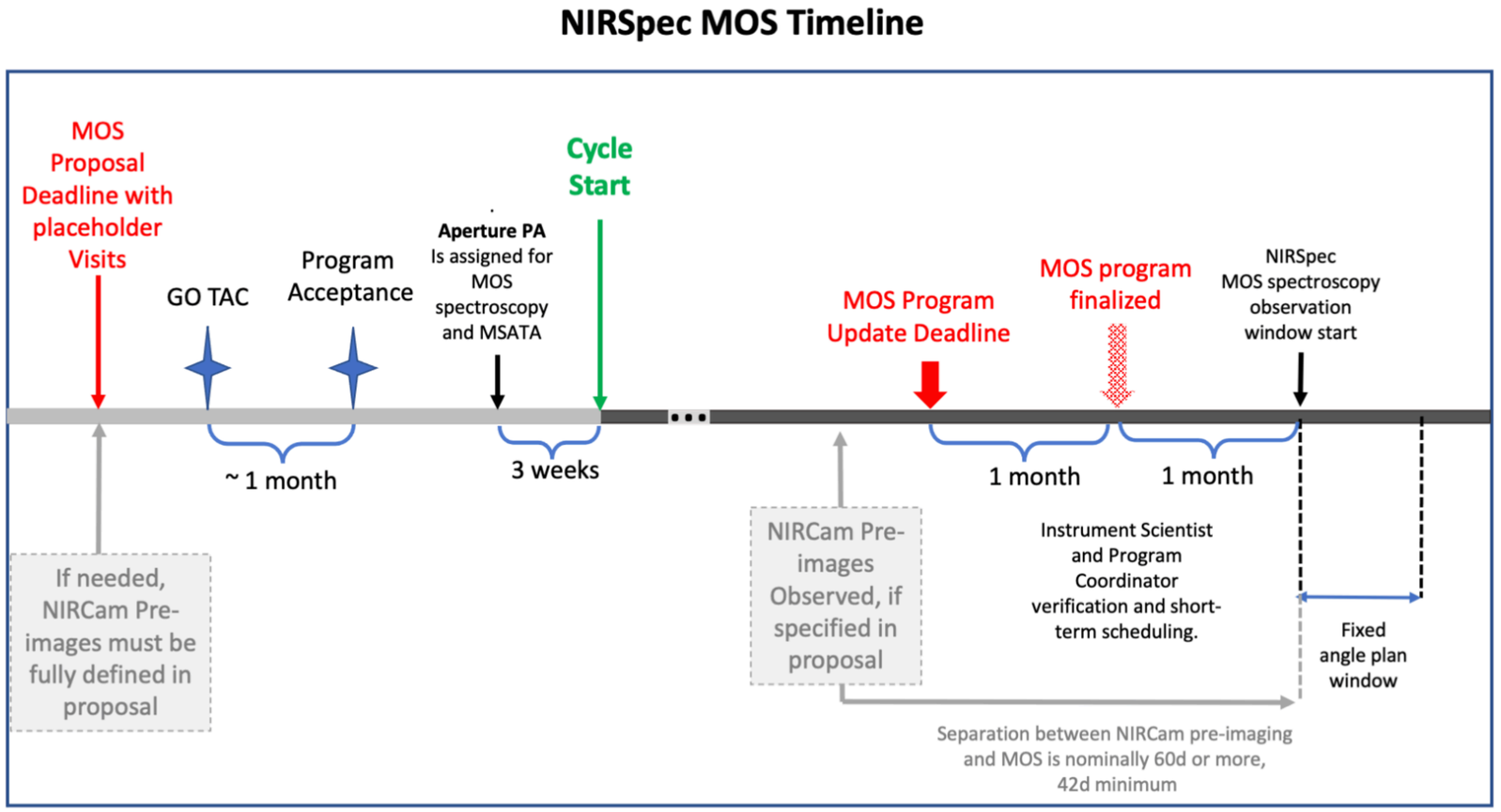
- determines their centroids on the detector
- compares them to the desired positions
- calculate a small-angle maneuver that adjusts the initial pointing and position angle.
- NIRCam Pre-imaging or use a software like EAzY to compute TA filter magnitudes.

MSATA accuracy vs Catalogue accuracy



Readout mode	S/N = 20			Saturation		
	F110W	***F140X***	***CLEAR***	***F110W***	***F140X***	***CLEAR***
NRSRAPID	22.0	23.0	23.8	19.5	20.6	21.3
NRSRAPIDD1			24.5			21.9
NRSRAPIDD2			24.9			22.2
NRS	24.1	25.1	25.7	21.0	22.1	22.8

MOS proposal timeline: with pre-imaging



Proposal Submission: Users must request the time needed (including overheads) to observe an expected number of targets to desired exposure depths. **Use the MPT** with simulated or existing catalogs to explore the effects of planning choices (dithers, slit length, etc.) on the **number of observable targets**, and the **number of MSA configurations needed** to obtain all dithered exposures..

Happy MOS proposal!!!

Documentation

JDOX: https://jwst-docs.stsci.edu/

- near-infrared-spectrograph/nirspec-observing-modes/nirspec-multi-object-spectroscopy
- NIRSpec APT Templates/NIRSpec Multi-Object Spectroscopy APT Template/NIRSpec MSA Planning Tool, MPT

➔ Hands-on