STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

JWST NIRSpec MOS: Lessons Learned on Proposal Planning (so far)

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Key Players on the MOS Proposal Planning front end at STScI

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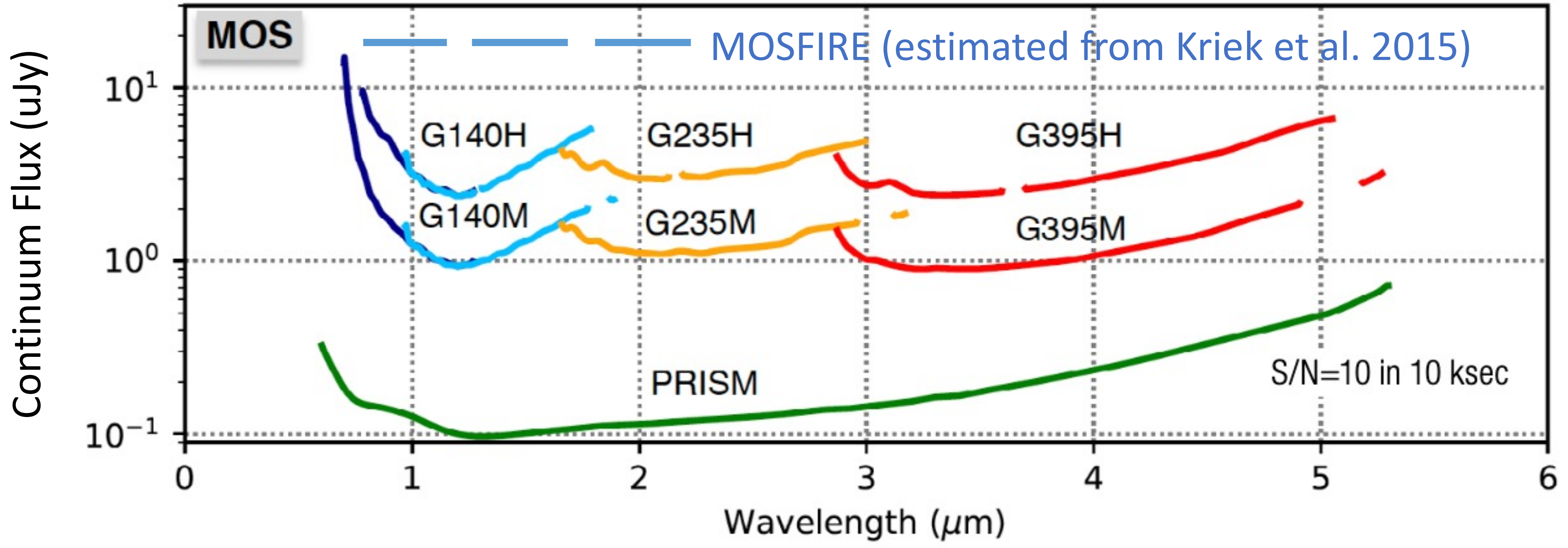
Stephan Birkmann

Emily Wislowski

Elena Sabbi

Plus a fantastic team of ground-system engineers and software developers

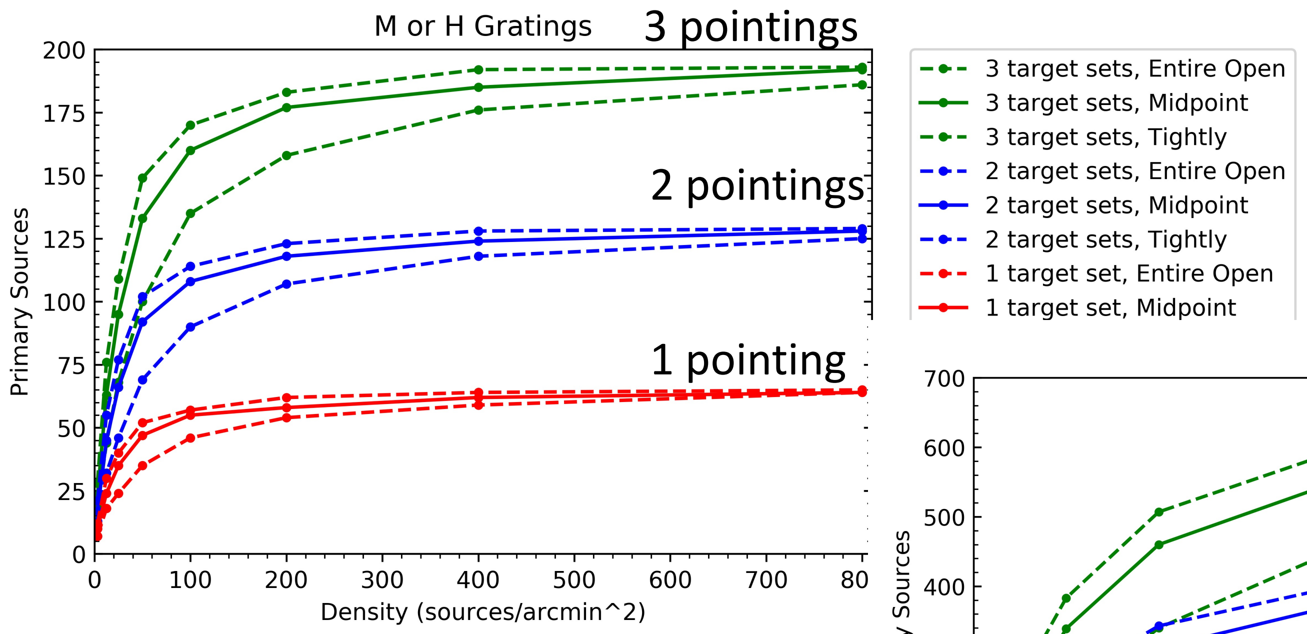
NIRSpec: The first slit-based MOS in space has unprecedented sensitivity



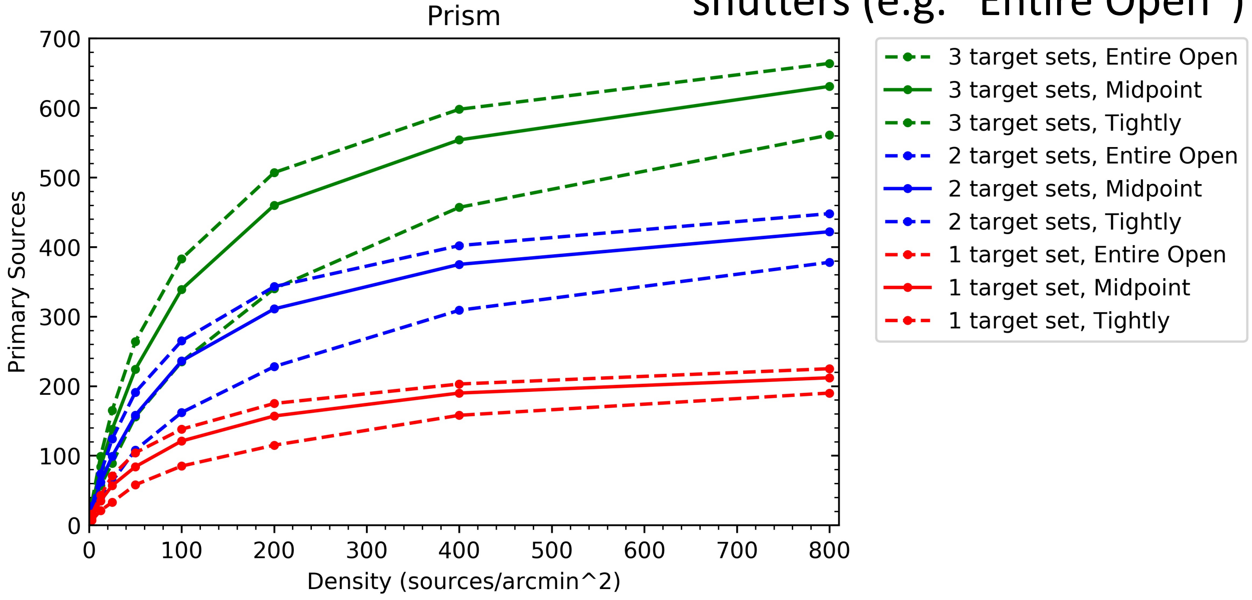
NIRSpec:
SNR = 10
point source
continuum sensitivity
10ks

Detector noise limited (or close to it), so SNR scales *better* than sqrt(exptime).

JWST/NIRSpec Multiplexing efficiency



Source Centering Constraints:
You can observe more targets if they
Are allowed to be in the corners of the
shutters (e.g. ”Entire Open”)

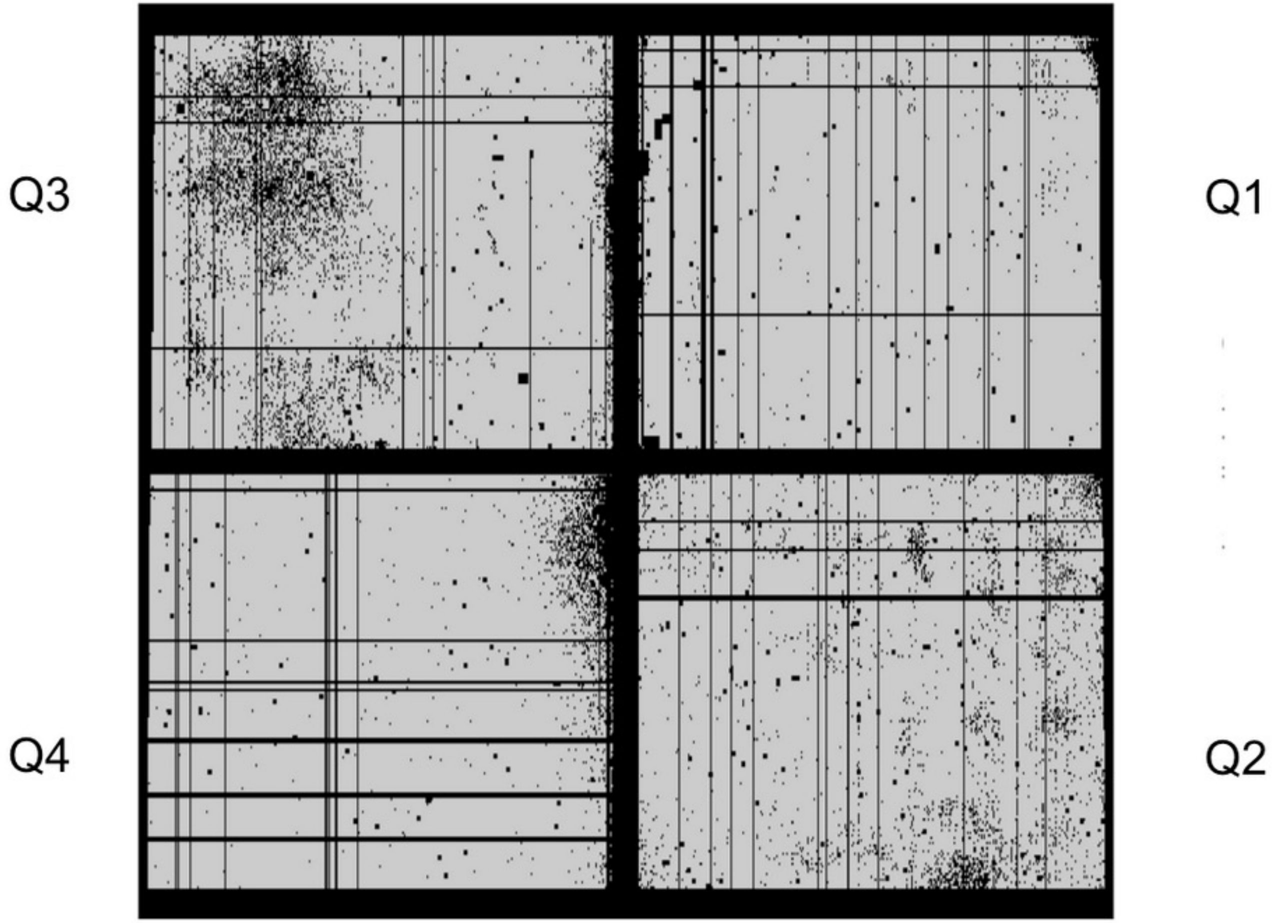


Multiplexing Efficiency : ~40-60 targets per pointing in M/H; ~150 in prism (FOV 3.6’ x 3.4’).
Depends on density of targets and source centering constraint.

But, all of this comes at the cost of complexity

And, ATLAS may share some of these complexities

NIRSpec's Microshutter Assembly (MSA)



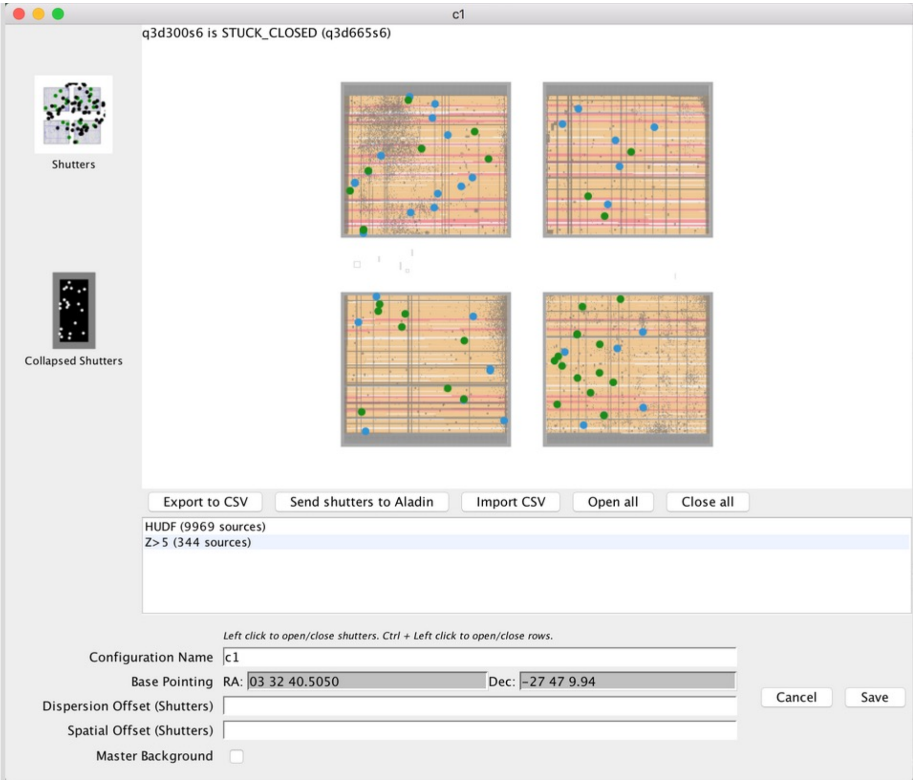
- ~250,000 microshutters
- 0.20" x 0.46" open area (0.27" x 0.53" center-to-center)
- 10-15% failed closed
- Shorted rows and columns
- ~18 failed open
- 3.6' x 3.4' FOV

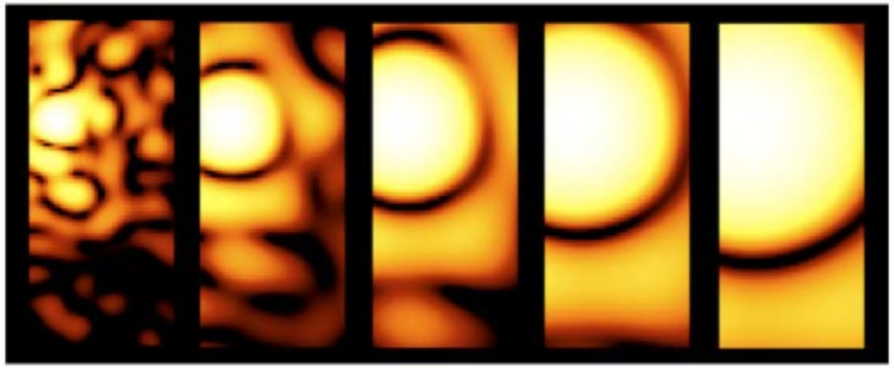
- MSA operability is dynamic: it has changed between different ground-testing campaigns; will be monitored on-sky

- We have to work around these characteristics when configuring the MSA on targets.

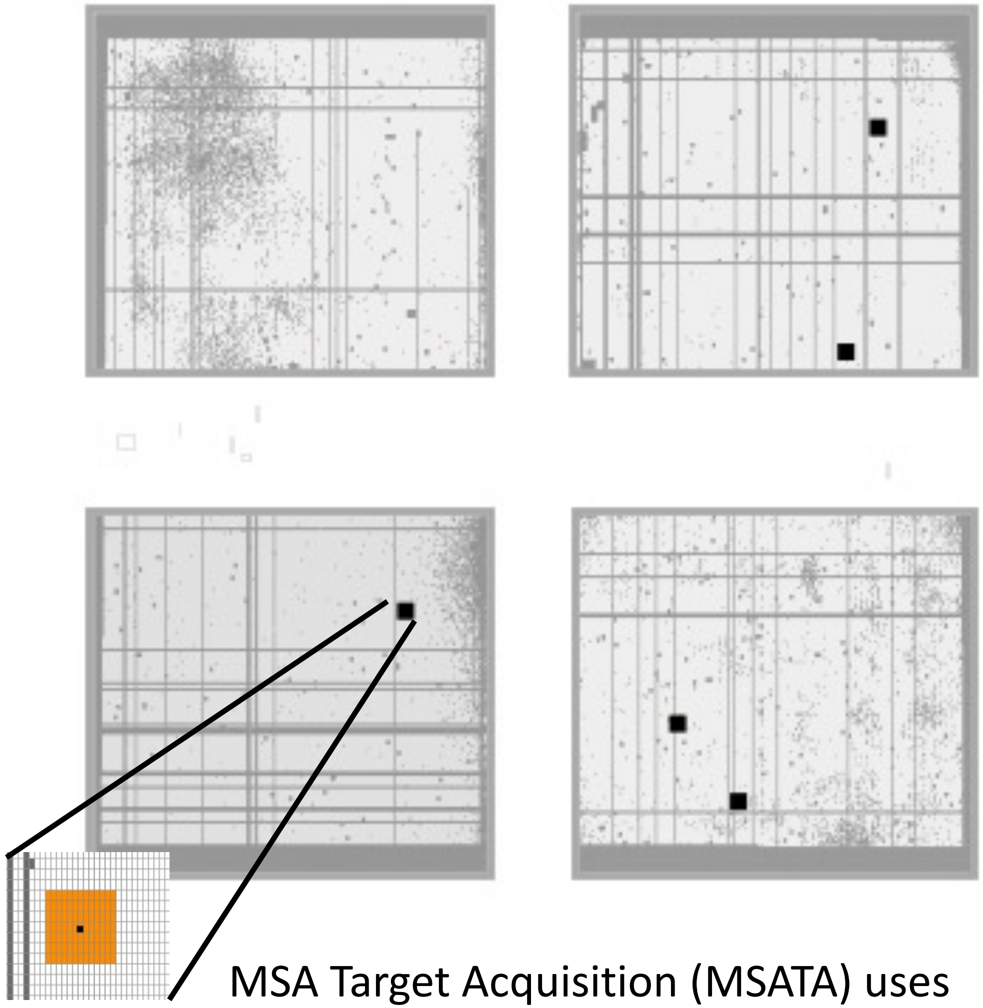
To create MSA configurations, we created the MSA Planning Tool (MPT)

- Plans around failed shutters
- Allows for in-slit nodding and larger dithers (with a reconfig)
- Specify parameters (e.g. weights, primary targets, fillers, source centering constraints) to optimize the target selection
- Can interactively open/close shutters
- All within APT!
    - Milli-arcsec precision on the sky to MSA plane coordinate transformations

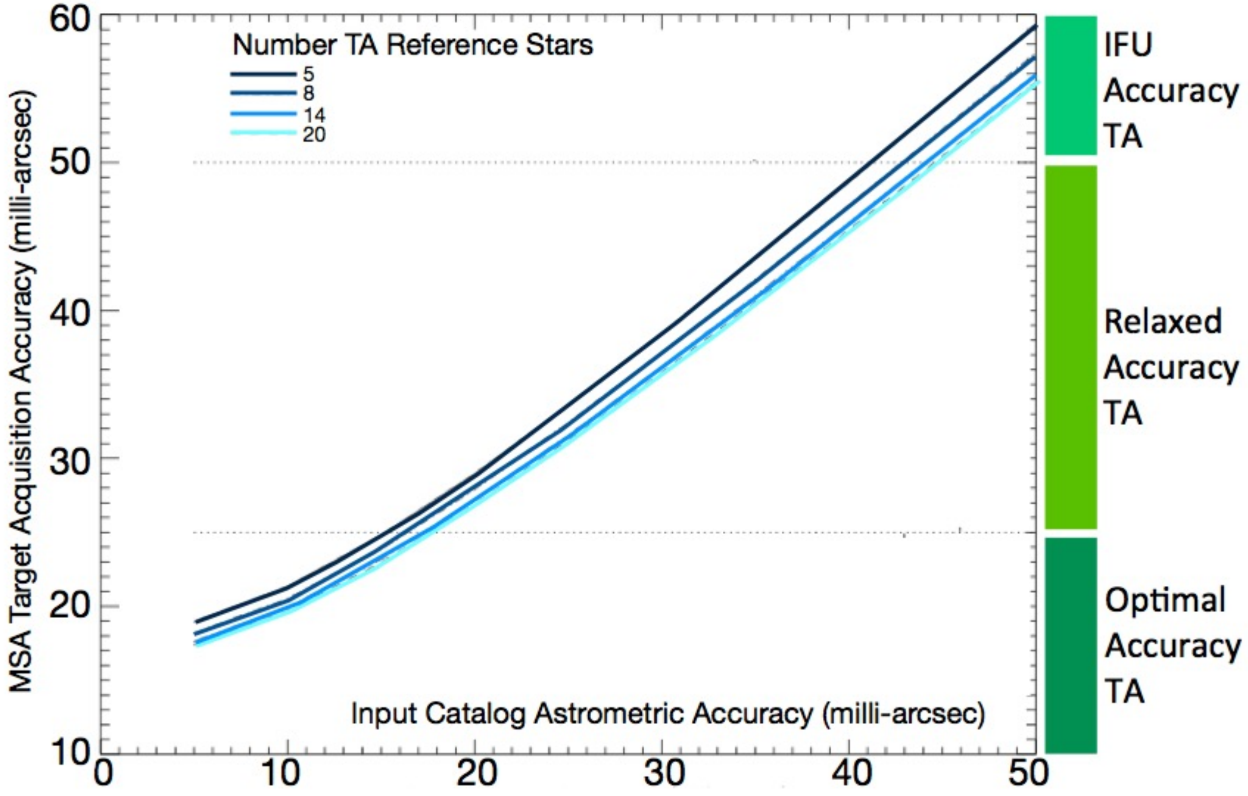




MSA shutters are 0.2” wide– target acquisition is key



MSA Target Acquisition (MSATA) uses reference stars imaged through 3” boxes of open shutters on the MSA



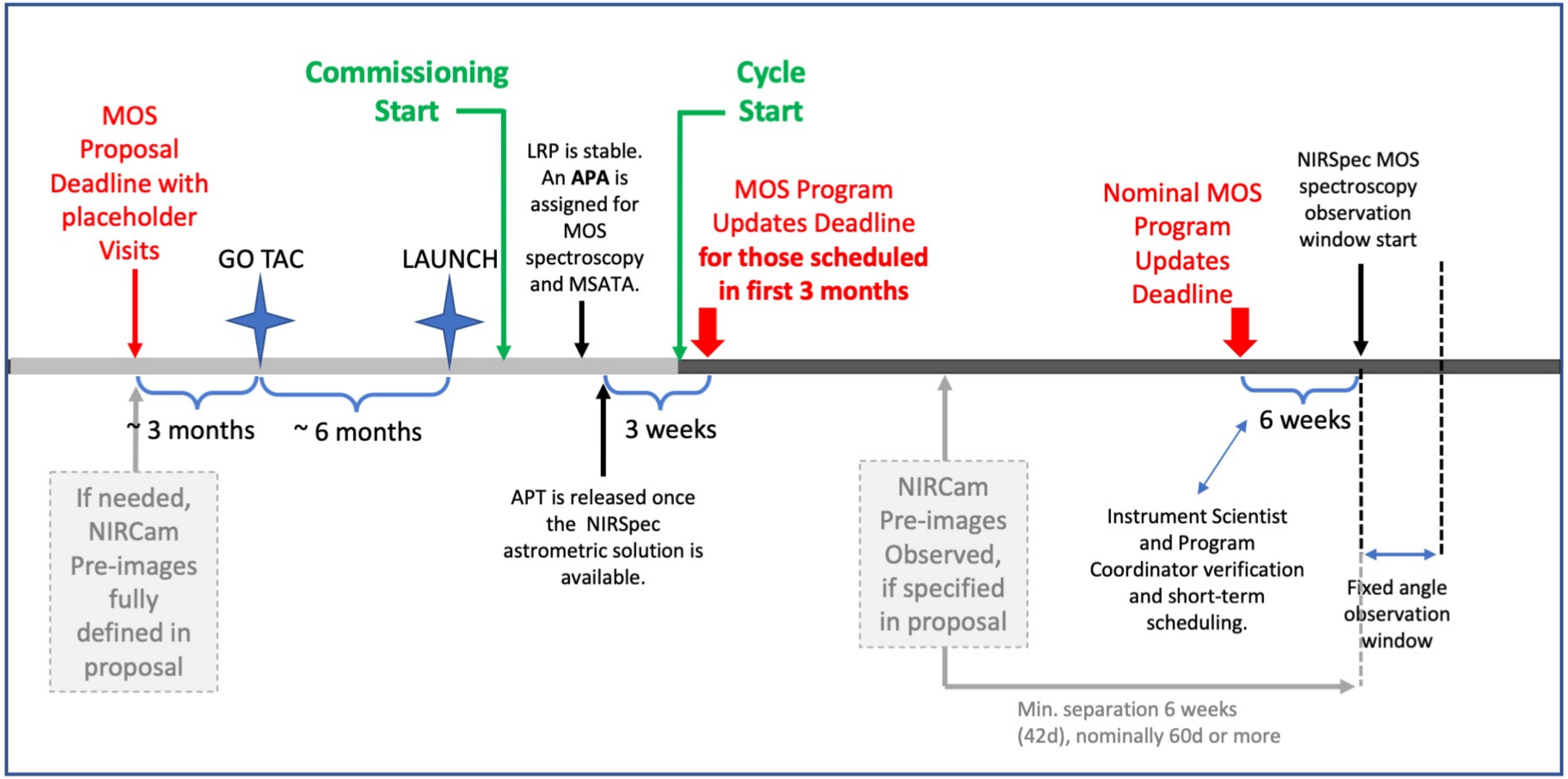
Reference Star Requirements:

- 5-8 stars; 18-25 mag (AB) in NIRSpec TA imaging bands
- Milli-arcsec precision → recent HST or NIRcam imaging
- Proper motion could be an issue in older HST imaging
- Compact galaxies are probably ok; objects must be isolated

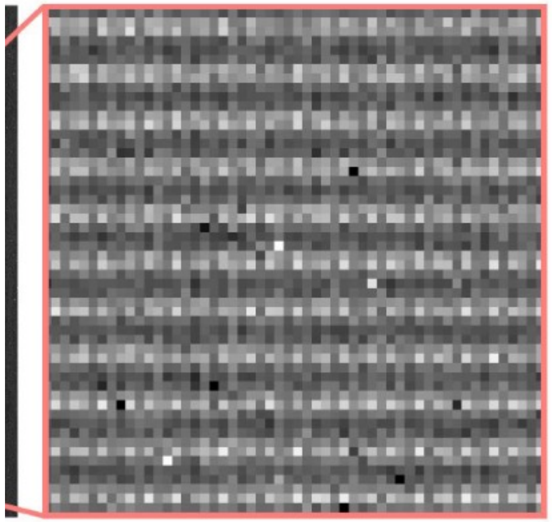
Schedule Efficiency Necessitates that STScI Assigns Position Angles

MOS Uses a Two Phase Process– the exception to single stream

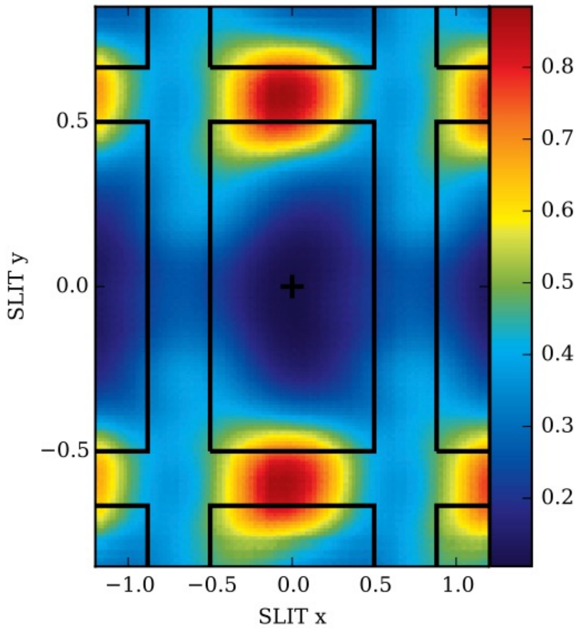
NIRSpec MOS Timeline



The MSA is not fully opaque ("MSA Leakage")



An image through the closed MSA



Pixels shifted and coadded relative to shutter center

Dispersed leakage signal piles up like background from slitless spectroscopy

Problem for IFU and MOS

Predicted 1-11% increase in background

Varies spatially on small and large scales

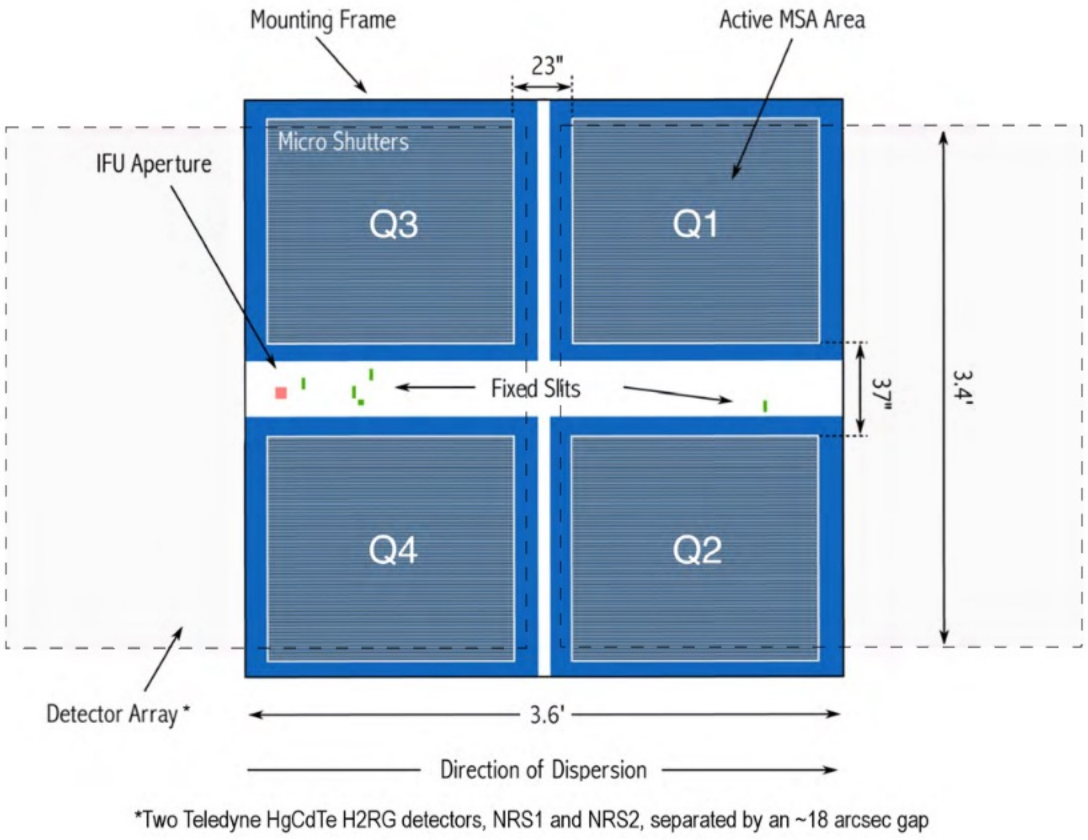
MSA-closed leakage calibrations (leak-cals) possible. Best practices not yet known (but estimated).

Calibrations: Not your typical MOS

We do not take flats and wavecals for every MSA configuration

- Instrument model-based calibration: a parametric model of the instrument geometry, calibrated on sky with lamps. Provides information trace, extract, rectify each spectrum. WCS for each pixel.
- Flat fields are divided into multiple components.
  - The D-flat handles pixel-to-pixel variations
  - The S-flat is taken from 20 MSA long slit flats, spaced in the dispersion direction. This flat is interpolated to construct the flat field of a given slit.
  - F-flat: field dependent throughput of the OTE and FORE optics.
- Wavelength calibrations use the instrument model
  - Critical : The grating wheel sensor adjusts for shifts from a GW movement.
- MSA Operability Monitoring

Next up: There's always more we can do with the instrument



- Slitlet stepping mode, mini-IFUs (two Cycle 1 programs)
- IFU + MOS mode for prism observations
- Adding "wavelengths of interest" to the optimization algorithm
- Smarter, faster optimization algorithms

Summary and Lesson Learned

- **JWST NIRSpec provides unprecedented sensitivity and great multiplexing.**
- Its all about astrometry. Ultra precise mas precision needed for both TA reference stars and science targets.
- Configuration-making software in APT broke new ground, working around MSA features, at milli-arcsec precision.
- Schedule efficiency requires that STScI assign the aperture position angle. NIRSpec MOS therefore deviates from JWST's single-stream approach.
- MSA contrast is not spatially uniform, and it has been difficult to make reliable recommendations on the need for "leak cals."   On sky experience will help.
- We are confident in the model-based calibration, but it is not the same thing as taking arcs and flats for every mask.

Figures in this talk were taken from JDox and the JWST pocket guide: https://jwst-docs.stsci.edu and https://www.stsci.edu/files/live/sites/www/files/home/jwst/instrumentation/_documents/jwst-pocket-guide.pdf.