STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

The Mid-Infrared Instrument (MIRI) Performance

Alberto Noriega-Crespo on behalf of the MIRI Team

Feb 28, 2023

Outline

- MIRI Team (USA)
- Snapshot of MIRI
- Imager Performance & Calibration Status
- Low Resolution Spectrometer (LRS) Performance & Calibration Status
- Medium Resolution Spectrometer (MRS) Performance & Calibration Status

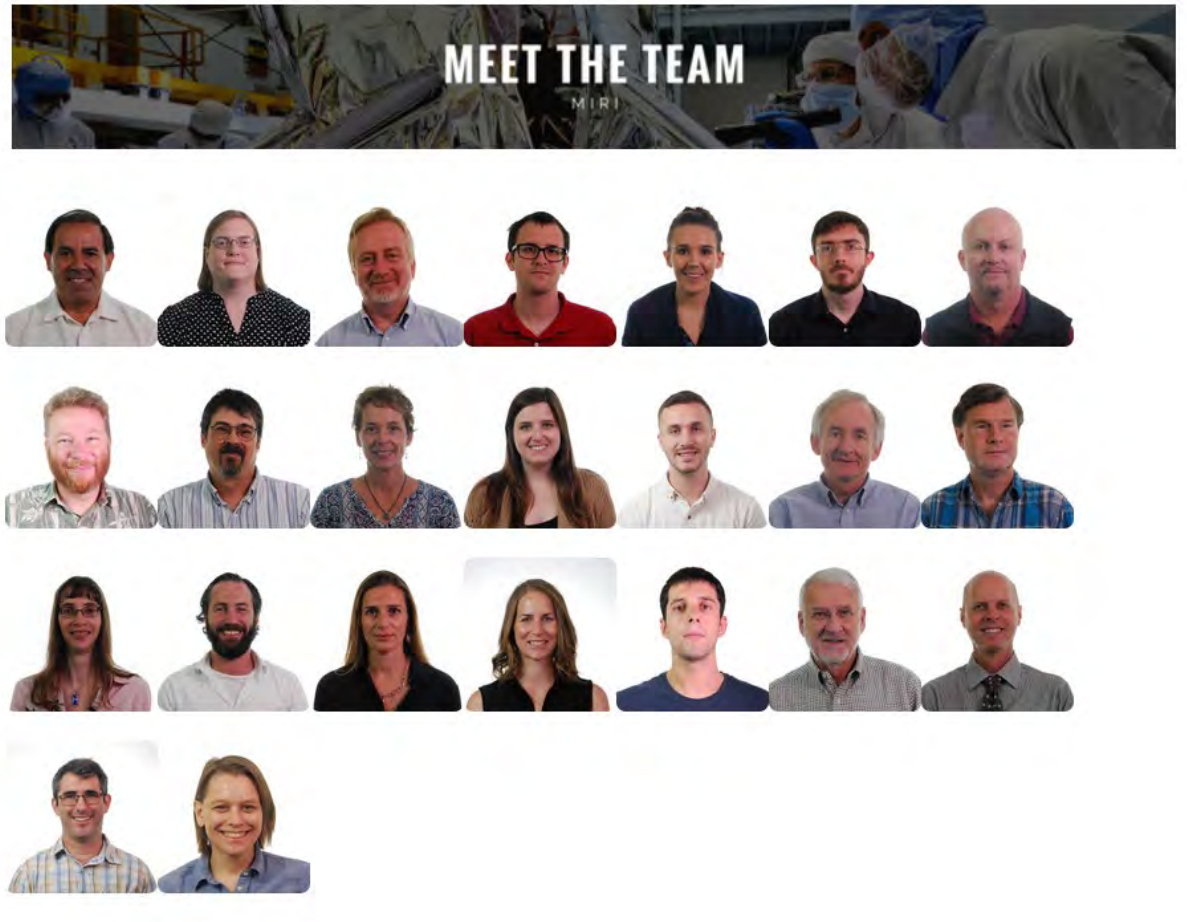
  Dichronic and Grating Wheel Assembly (DGA-A) Anomaly [AR-2173; open]
- Coronagraph Performance & Calibration

  Coronagraph Glowsticks Anomaly [AR-1192; open]

* Summary

MIRI Team

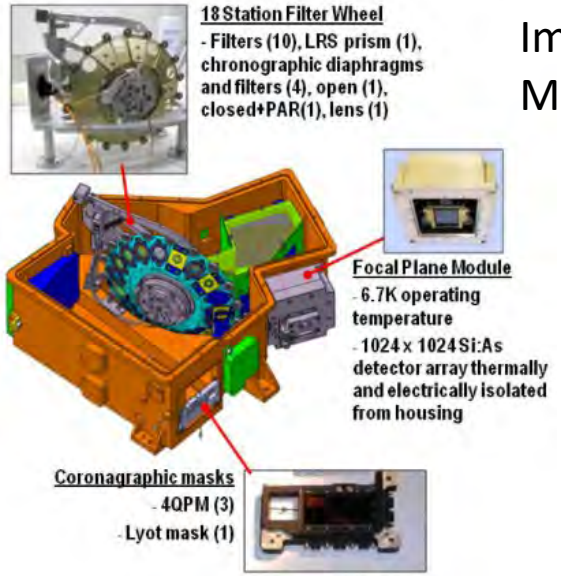
- Jonathan Aguilar (*Coronagraph Lead*)
- Stacey Bright (*Imager; Helpdesk Lead*)
- Misty Cracraft (*DMSWG Lead; Pipeline Testing*)
- Michael Engesser (JWQL, Detectors)
- Ori Fox (*Detectors; JDAT Project Scientist*)
- Karl Gordon (*JWST Absolute Calibration Lead*)
- Dean Hines (*Coronagraph, JDOX Lead*)
- Bryan Holler (*ETCWG Lead; Solar System IS*)
- Sarah Kendrew (*LRS Lead; ESA*)
- Kirsten Larson (*MRS;ESA/AURA*)
- David Law (*MRS Lead*)
- Mattia Libralato (*Imager Lead; ESA/AURA*)
- Jane Morrison (*UofA, Detectors*)
- Katherine Murray (*LRS; JDOX*)
- Bryony Nickson (*Coronagraph/MRS*)
- Alberto Noriega-Crespo (*Operations Lead AURA*)
- Brian O'Sullivan (*Operations Lead; ESA*)
- Michael Regan (*(MESA) Detectors; Pipeline*)
- Beth Sargent (*MRS; JWebbinar Coordinator Lead*)
- Gregory Sloan (*LRS; JWST Calibration Lead*)



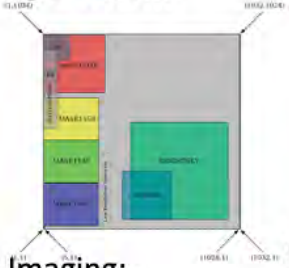
FOT support: Patrick Falini, Chris Long & Thomas Wheeler
OSS support: Michael Robinson
Imager Support: Nicholas Flagey (Telescope)

MIRI Instrument

Imager Module



- Imaging:
  9 Filters covering 5 - 28um
  4 Subarrays



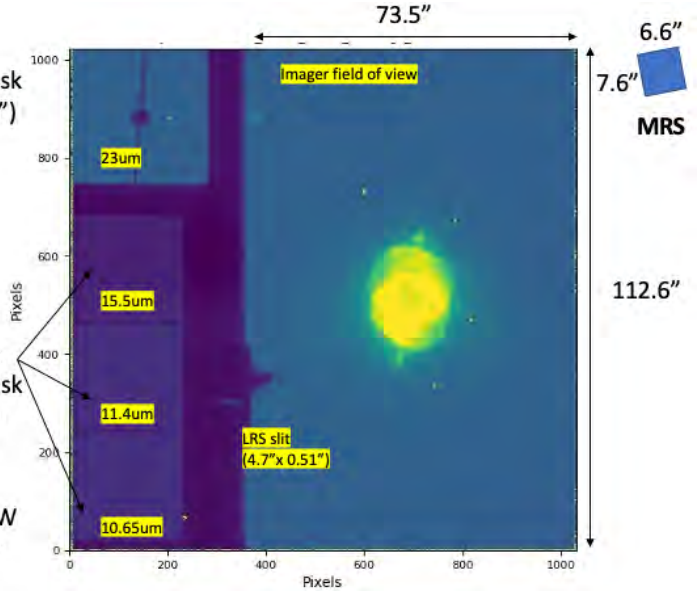
- Coronagraphic Imaging:
  Lyot & 3QPMs

- Low Resolution
  Slit Spectroscopy: 5 – 12 (14)um
  And Slitless Spectroscopy (TSO)

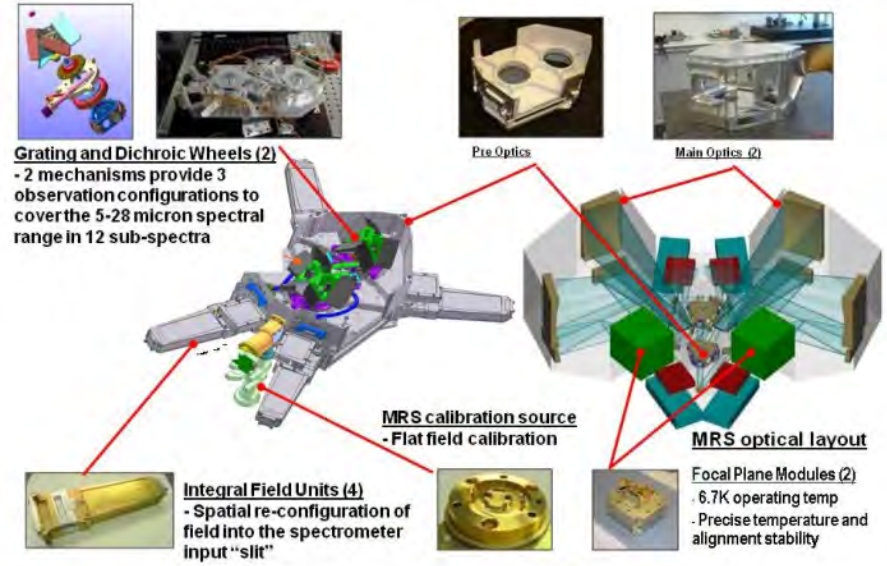
Lyot Mask (30”x30”)

Four-Quadrant Phase Mask (24”x24”)

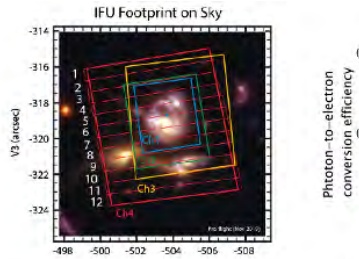
F560W Filter

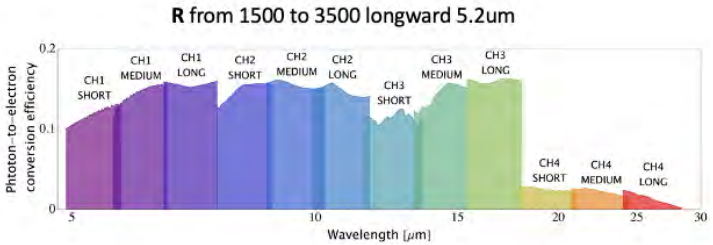


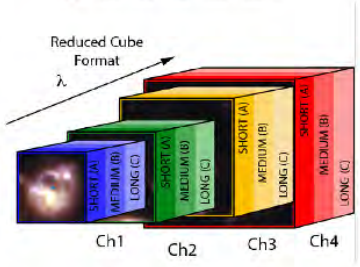
Medium Resolution Spectrometer (MRS)

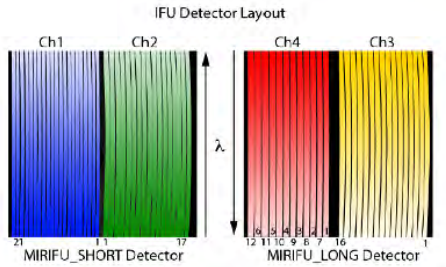


T=6.4K









SPACE TELESCOPE SCIENCE INSTITUTE
STScI SPACE TELESCOPE SCIENCE INSTITUTE

Imager Status

Where we are:

- Imager Performance is outstanding
- Pipeline Products are ready for Science

Calibration:

* Repeatability is ~0.5% (1-sigma)

  - based on 4 observations of same star over 200 days

  - more observations are being scheduled

- Variations between full and subarrays are between 1% and 4% (Scatter is less than 2%)

Where we are heading:

- Clearer strategies/guidelines to implement observations (e.g. dedicated background for 25um observations).
- Improve the basic calibration datasets, e.g. Flats, using all useful available data.
- Improve the background subtraction at longer wavelengths.
- Trend the Background as function of time (mostly at longer wavelengths)
- Improve the flux calibration (adding the new data).
- Continue the support of the astronomical community

MIRI Image

NGC1433
Physics of High Angular Resolution in Nearby Galaxies (PHANGS)

7.7, 10, 11.3 & 21um

ESA Webb release
16 Feb 2023

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

MRS Status

Where we are

- MRS performance is great (albeit MRS Anomaly AR-2173)
- Pipeline products are fine, yet improvements can be made.

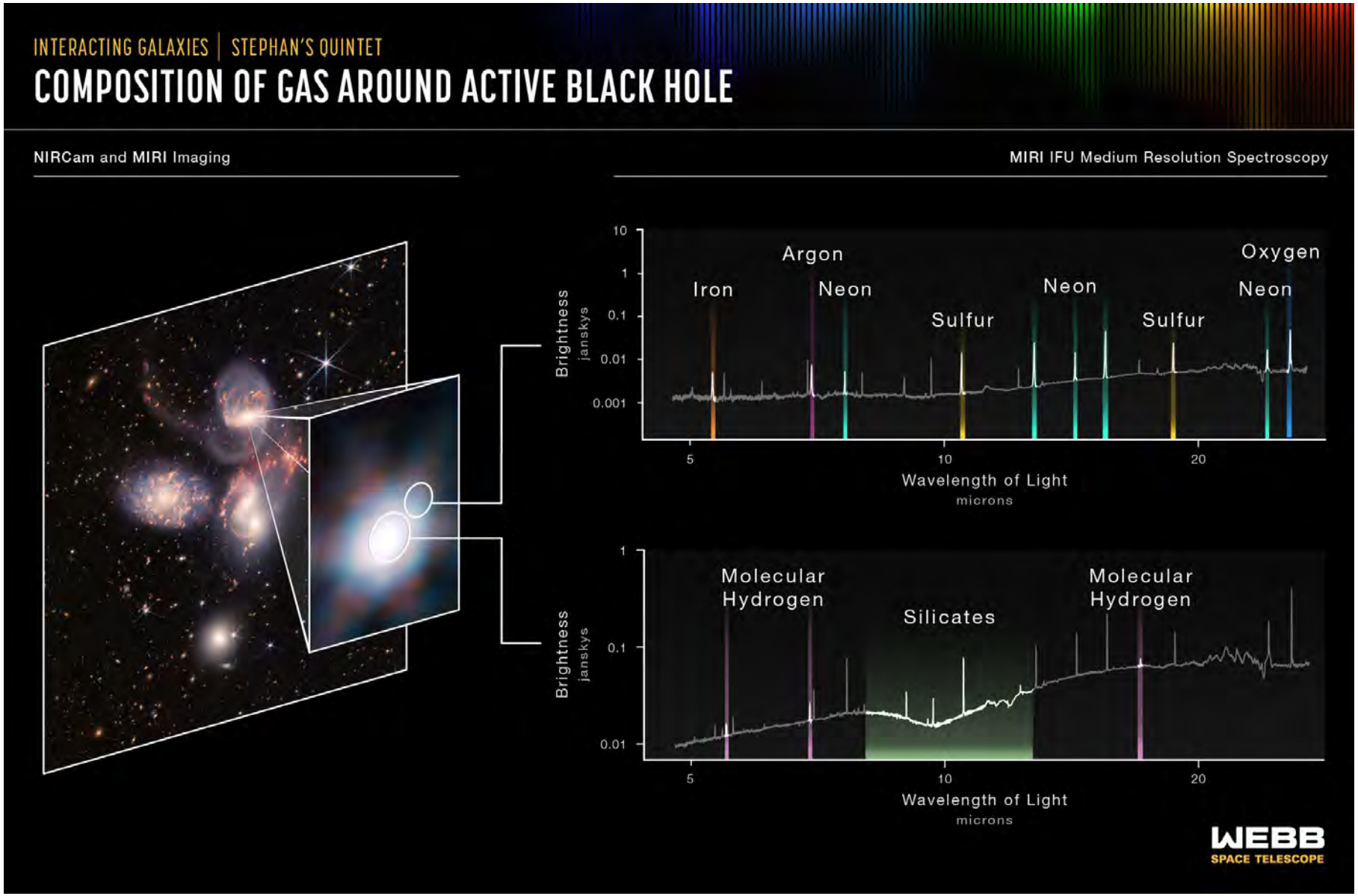
Calibration:

- Astrometric: 0.1 arcsec (relative); 0.3 arcsec (absolute) [Requirement < 0.5 arcsec]
- Wavelength: from few hundreds km/s (Commissioning) to few tens km/s.
- Spectrophotometric: Still based on Commissioning, good to 10% at most wavelengths. Not fully constrained above 20um; not optimal yet at 10-12um (fringe calibration).
- Pipeline provides error information for all the products.
- Covariance is significant for data cubes.

Where we are heading

- On going efforts to improve the Astrometric Calibration (e.g. based on more observations).
- Wavelength calibration efforts to achieve few km/s.
- Accuracy of the Pipeline errors under study; known issues at faint surface brightness.
- Improving the techniques to detect and flag Cosmic Ray showers (to be removed by the pipeline).
- Improvements in the Cross artifact (bright regions can cause artifacts in neighboring parts of the detector) based on modeling of the spectral dimension to improve the spatial dimension.
- MRS is spatially undersampled, is recommended to use 4-pt dithers during observations.

MRS in the News



MRS Dichronic and Grating Wheel Assembly (DGA) Anomaly

Where we were/are:

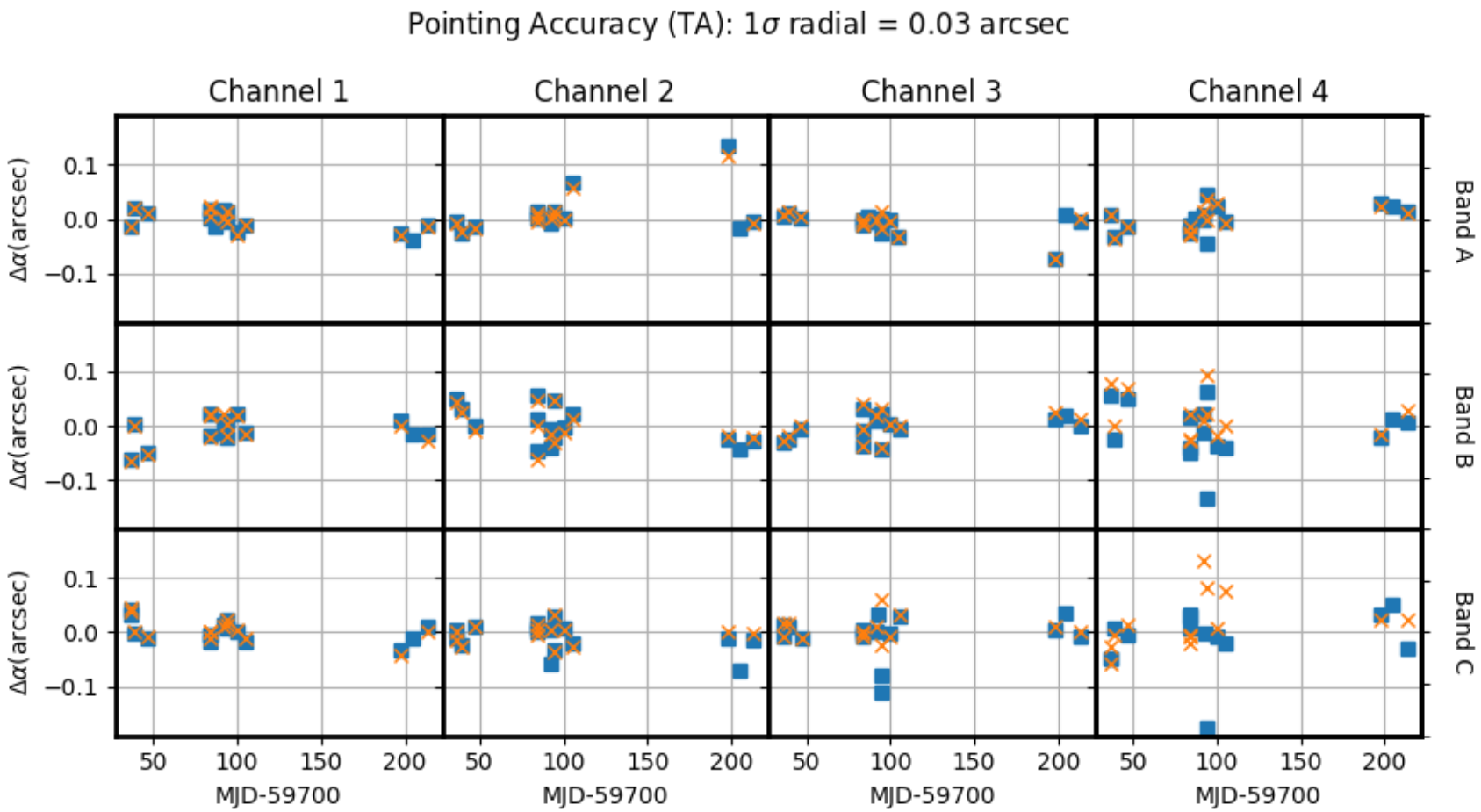
- An increase in friction in the DGA-A led to an anomaly during Commissioning (AR-2173)
- The Anomaly Board developed a 3 phase plan to proceed (cautiously and protecting the hardware) to bring back MRS to Science/Normal Operation (e.g. we have met 29 times; nearly 200 technical presentations & documents).
- We are currently in the last phase, Phase 3, that consists in scheduling Cycle I programs within some well defined wheel rotation boundaries.
- Phase 3 has been successfully implemented manually by Operations & Planning and Scheduling teams.

Where we are heading:

- Automatically capture telemetry information to determine the friction under normal MRS observations
- Simultaneously tracking/trending the DGA-A (B) friction and analyzing the science data for any subtle effects (in at least 3 complementary ways; see an example in next slide).

TA Point Source Trending

David Law



Typical along-slice pointing accuracy for TA point-source observations taken to date. One-sigma radial is ~ 0.03 arcsec with TA (0.45 arcsec without TA). Orange crosses and blue square represent dither positions 1 and 2; comparison is against the median measured alpha position in the expected peak slice.

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

LRS Status

Where we are:

* LRS is in good shape

* TSO performance is fantastic

* No significant operational issues

* Calibration files are of good quality and pipeline is functional well (albeit both

* Target Acquisition is accurate & reliable.

Calibration:

* Photometric: Accuracy in ~5.5-8um range less than 4%, otherwise ~10%

* Wavelength: separate reference files for Slit & Slitless operation.

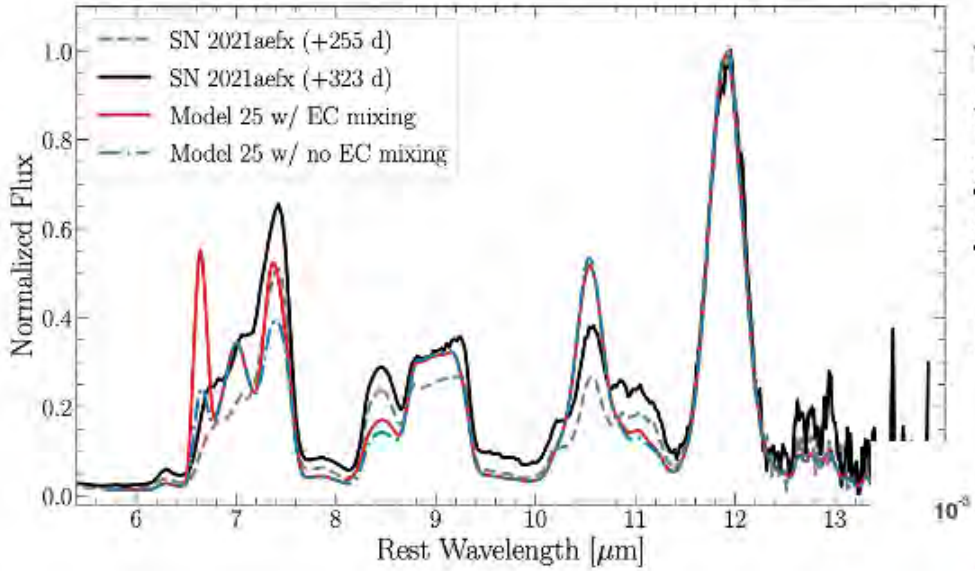
Slitless accuracy at 0.01 – 0.02 um

Slit accuracy at 0.02-0.05 um

Where we are heading:

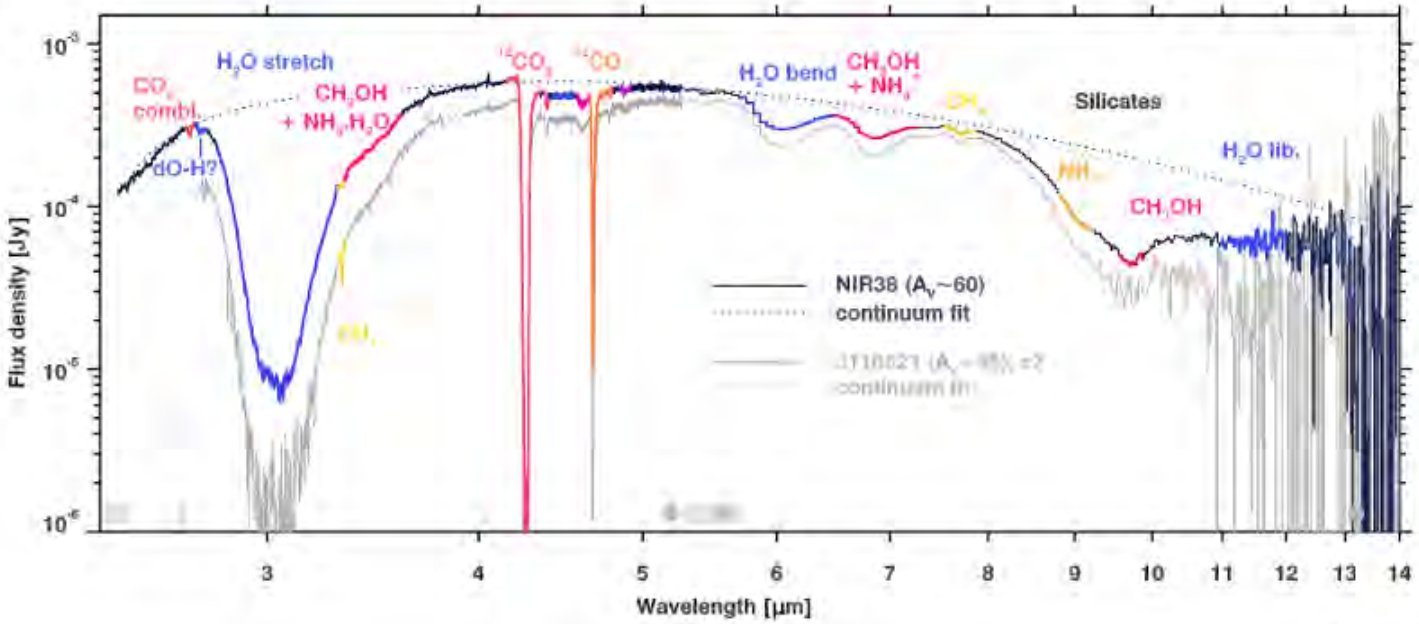
- Improving calibration and pipeline spectral extraction
- Photometric calibration beyond 8um under investigation
- Flat Field improvements
- Complete Aperture Correction Analysis (combining data WebbPSF)
- Complete Path Loss Analysis
- Push the optimization of the detector calibration for optimal TSO performance (high level of community involvement)

LRS Highlights



Type Ia supernova SN 2021aefx: combined data from 2 programs taking spectra at 2 different epochs with LRS, from DerKacy et al 2023. The +255d spectrum is described in more detail in Kwok et al 2022.

Lines from heavy elements such as Co, Ni



NIRSpec, NIRCam + LRS spectrum of cloud ice absorption features. Published in McClure et al 2023 as part of the IceAge ERS program led by Melissa McClure.

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

Coronagraph Status

Where we were/are:

- No changes in the Calibration Status since the delivery. The effort has been focus on support the Cycle I observing programs and further characterization of the Glowstick issue (“Anomalous Illumination in the 4QPM Transition” AR-1192).
- Reference positions and Coronagraph Apertures were updated during Commissioning.
- Take data for an ongoing target acquisition monitoring program. Currently, the prime target can be placed behind the mask with an accuracy better than ***10milli-arcseconds***.

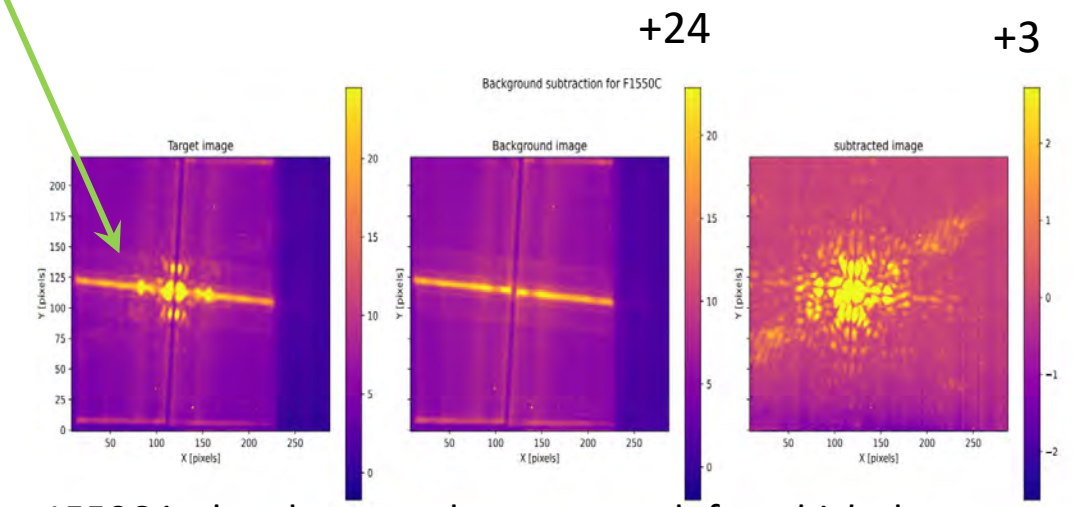
* Due to the “Glowsticks” light contamination there are a couple restrictions on the coronagraph operations:

(a) target acquisition can only be performed with the neutral density filter using the upper right quadrant of the Coronagraphic subarrays.

(b) all observations must be paired with a separate background observation to remove the ‘glowsticks’ effect.

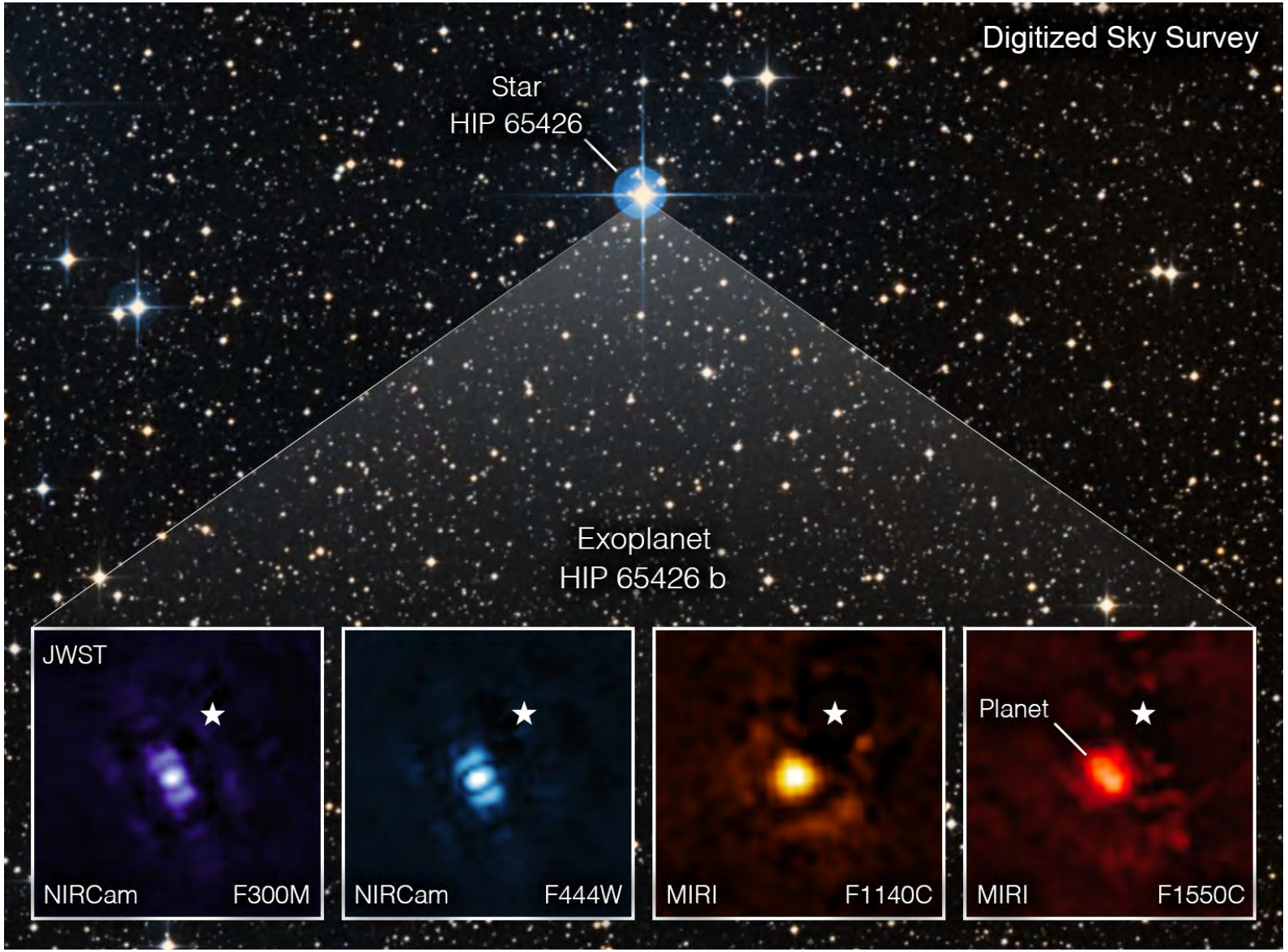
Where we are heading:

- About one third (4 out 11) of the Cycle I Coronagraph programs have been scheduled and successfully executed (only 4 unique targets out 25, so a way to go).
- Finishing the Commissioning of the remaining Quadrants and Coronagraph Filters as needed.
- Explore other background subtraction strategies to reduce overhead



1550C is the phase mask coronagraph for which the glow stick straylight feature is brightest

MIRI Coronagraph exoplanet HP65426b

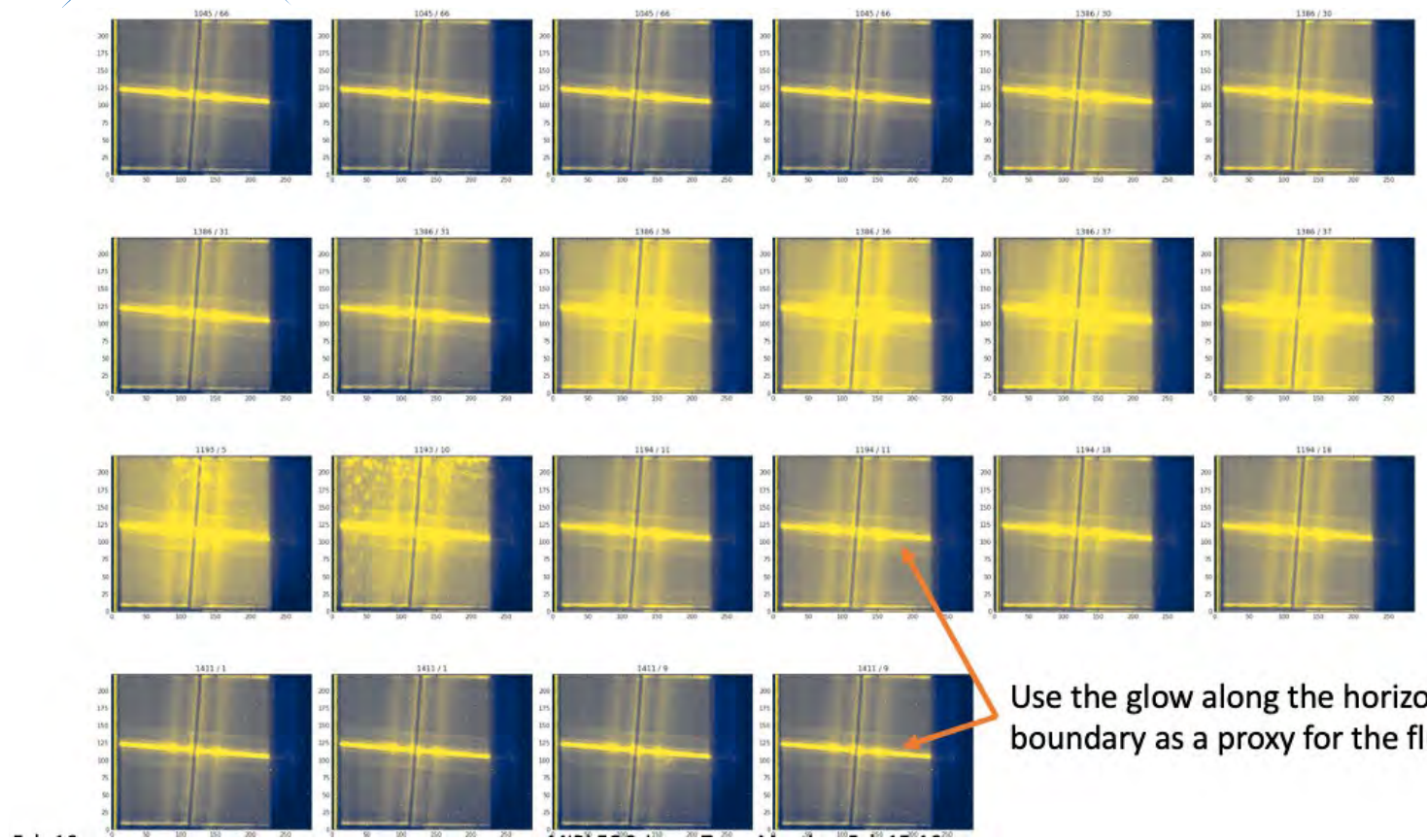


Summary

- The performance of MIRI is outstanding and is continuously producing data that is being used for “cutting edge” astrophysics.
- We have identified several places for improvement in our pipeline and science products (e.g. updating reference files using more data, optimization of spectral extraction, better wavelength and photometric calibration, etc).
- We have addressed both MRS and Coronagraph Anomalies; there are plans in places to monitor (MRS DGA-A friction) and reduce (Coronagraph “glowsticks”) their impact.
- TSO LRS observations have benefited from the community efforts . This is helping us to further look into the detector properties to reach further detection limits.
- We are actively working on updating the documentation to advice on the best observing practices.
- Last, but not least, we are collaborating with the European MIRI experts and continue to benefit from their deep knowledge of the instrument.

BACKUP SLIDES

Glowstick illumination across the Subarray

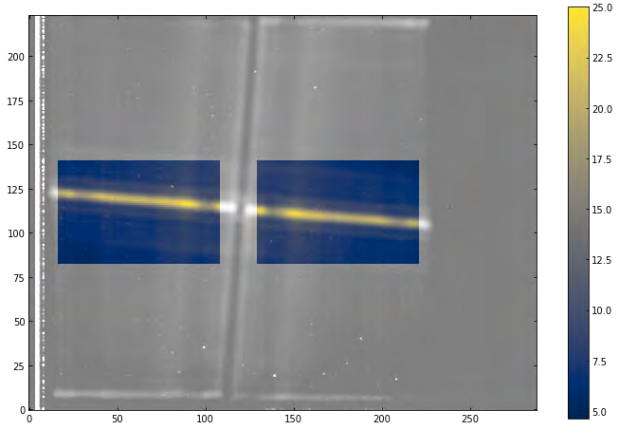


Use the glow along the horizontal quadrant boundary as a proxy for the flux

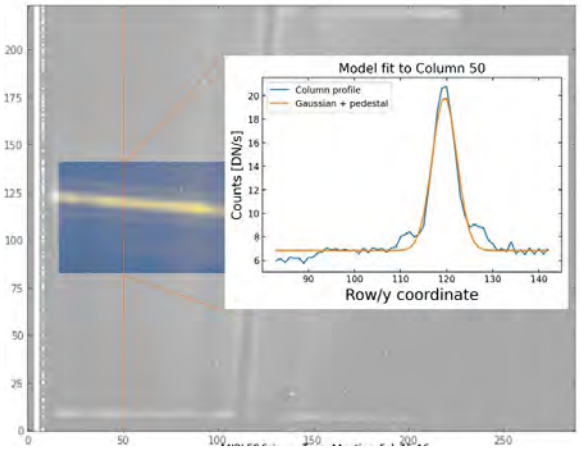
All 22 4QPM 1550 Backgrounds

Jonathan Aguilar

GOAL: How the amplitude changes over time across the subarray



Mask innermost region



Fit a Gaussian + pedestal to each column