



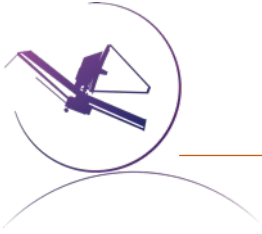
STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

Science Quality of Pipeline Data Products for Near Infrared Imager and Slitless Spectrograph (**NIRISS**)

Stephanie LaMassa (NIRISS Branch Manager on behalf of the AMAZING NIRISS Team)

Jan 11, 2025



*NIRISS enables ground-breaking science with
four complementary observing modes*



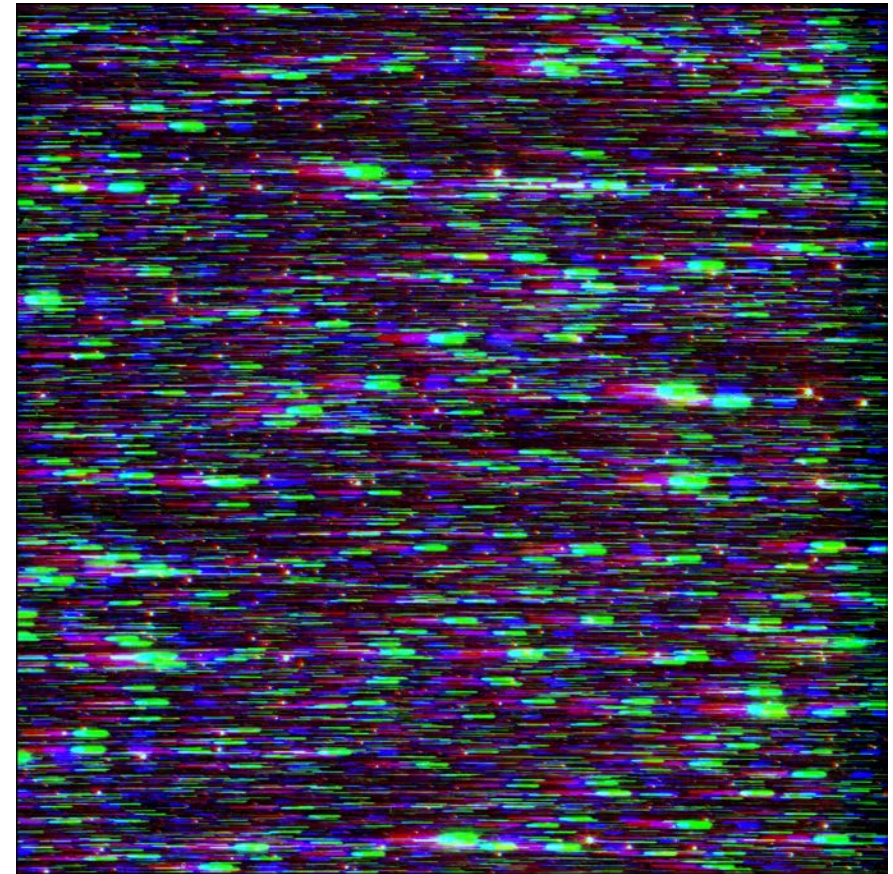
Wide Field Slitless Spectroscopy (WFSS): 0.8 – 2.2 μm , R ~150

Direct image



Data from APT 1085 (CAR NIS-010)

GR150C



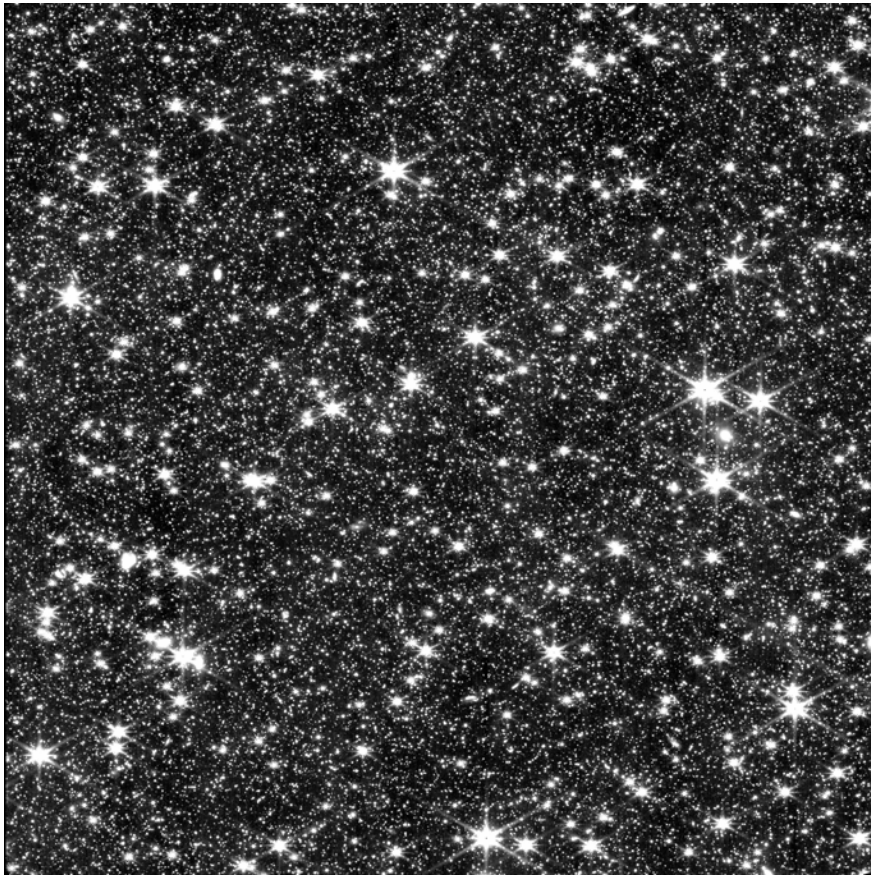
F090W F150W F200W

Credit: Swara Ravindranath

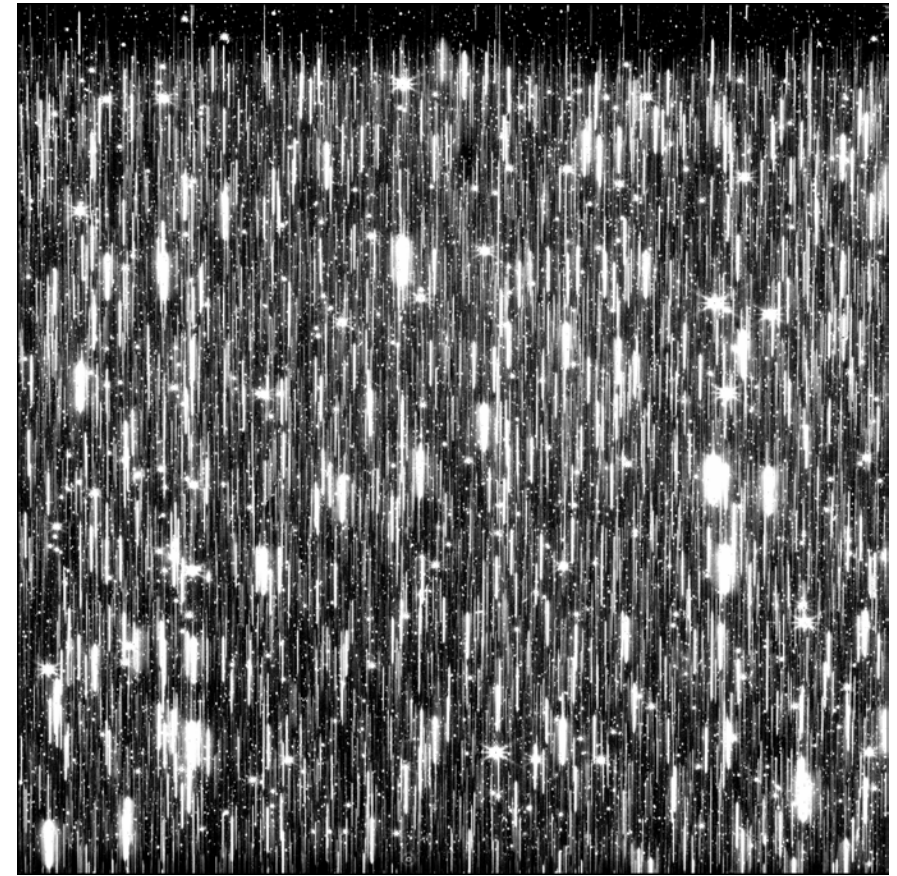


Wide Field Slitless Spectroscopy (WFSS): 0.8 – 2.2 μm , R \sim 150

Direct image (F200W)



F200W + GR150C GR150R



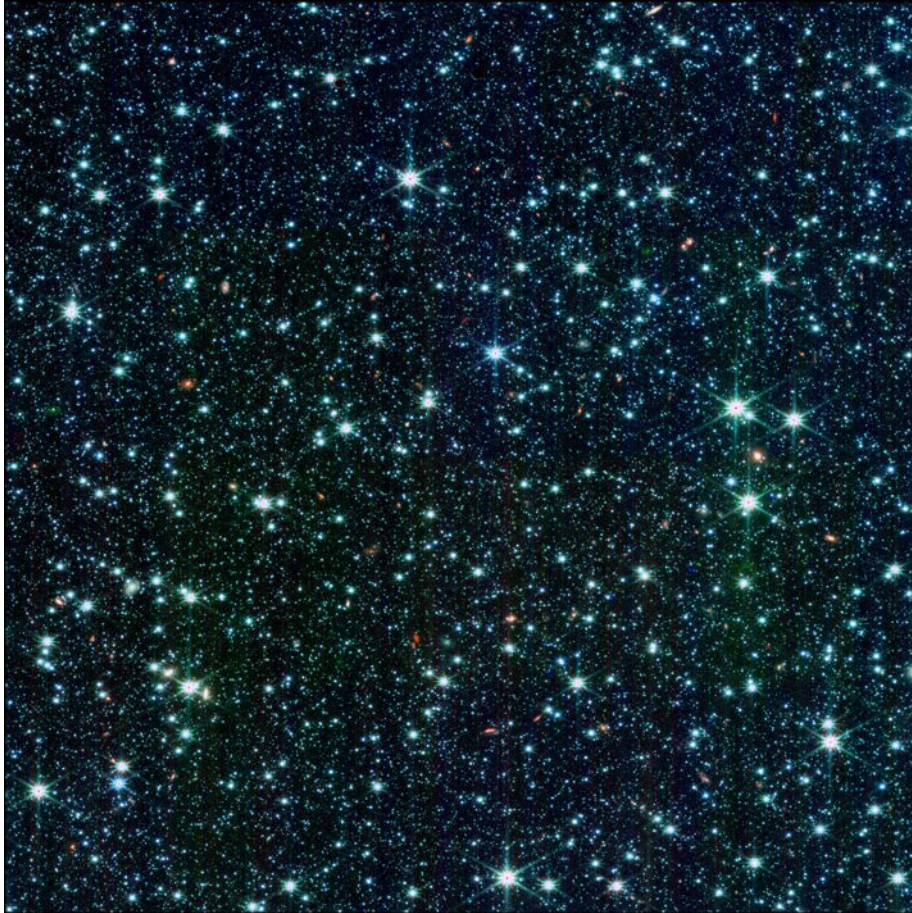
Data from APT 1085 (CAR NIS-010)

Credit: Swara Ravindranath



Imaging: 0.9 – 4.8 μm

Red galaxies in a sea of stars



F115W F150W F356W

Data from APT 1085 (NIS-010)

Stars and more stars...



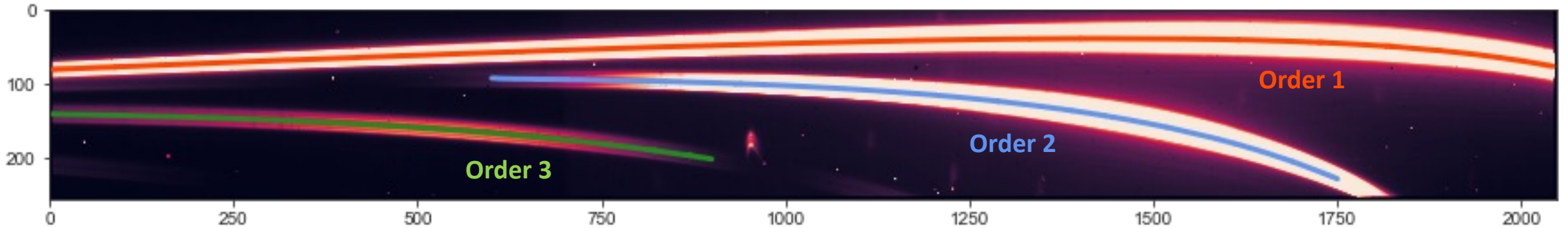
F090W F150W F277W

Credit: Swara Ravindranath



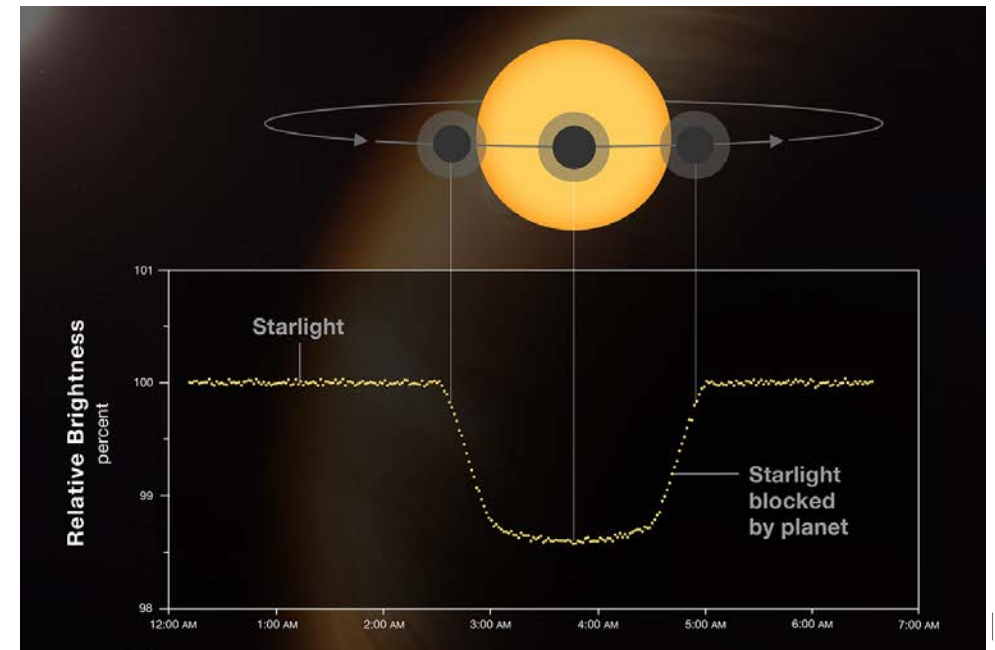
Single Object Slitless Spectroscopy (SOSS): 0.6 – 2.8 μm , $R \sim 700$

SOSS is Time Series Observation (TSO) mode for NIRISS – optimized to characterize atmospheres of transiting exoplanets



Data from APT 1541 (CAR NIS-034)

Credit: Néstor Espinoza

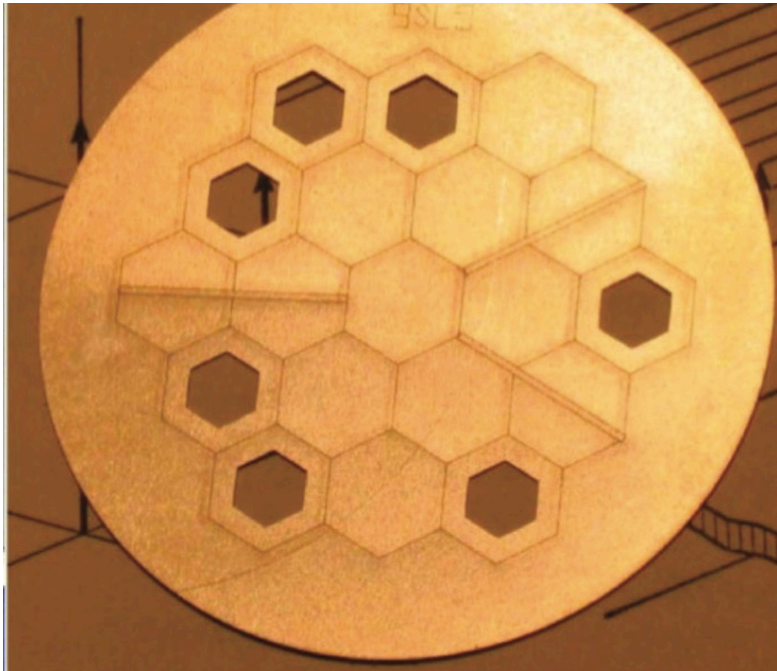


Credit: NASA, ESA, CSA, STScI

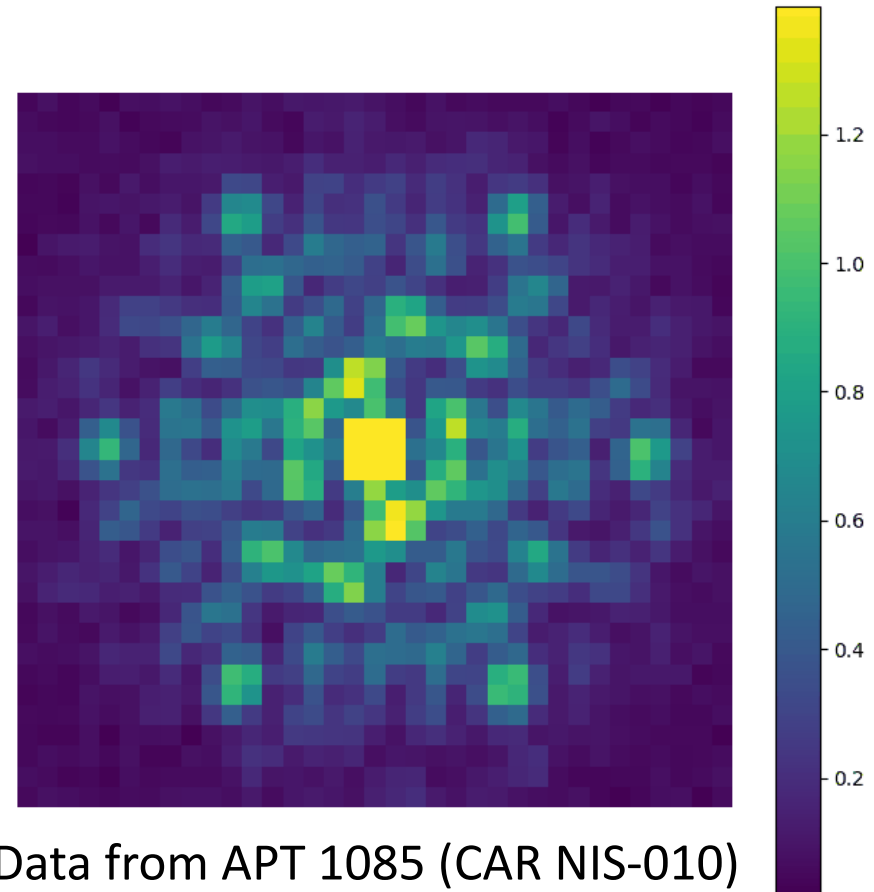


Aperture Masking Interferometry (AMI): 2.8, 3.8, 4.3, 4.8 μm

AMI is High Contrast Imaging (HCI) mode for NIRISS – resolve separations of $\sim 70\text{-}400$ mas for contrast ratios of $\sim 10^{-4}$



Non-Redundant Mask (NRM)



Data from APT 1085 (CAR NIS-010)

Credit: Anand Sivaramakrishnan, Deepashri Thatte, Rachel Cooper

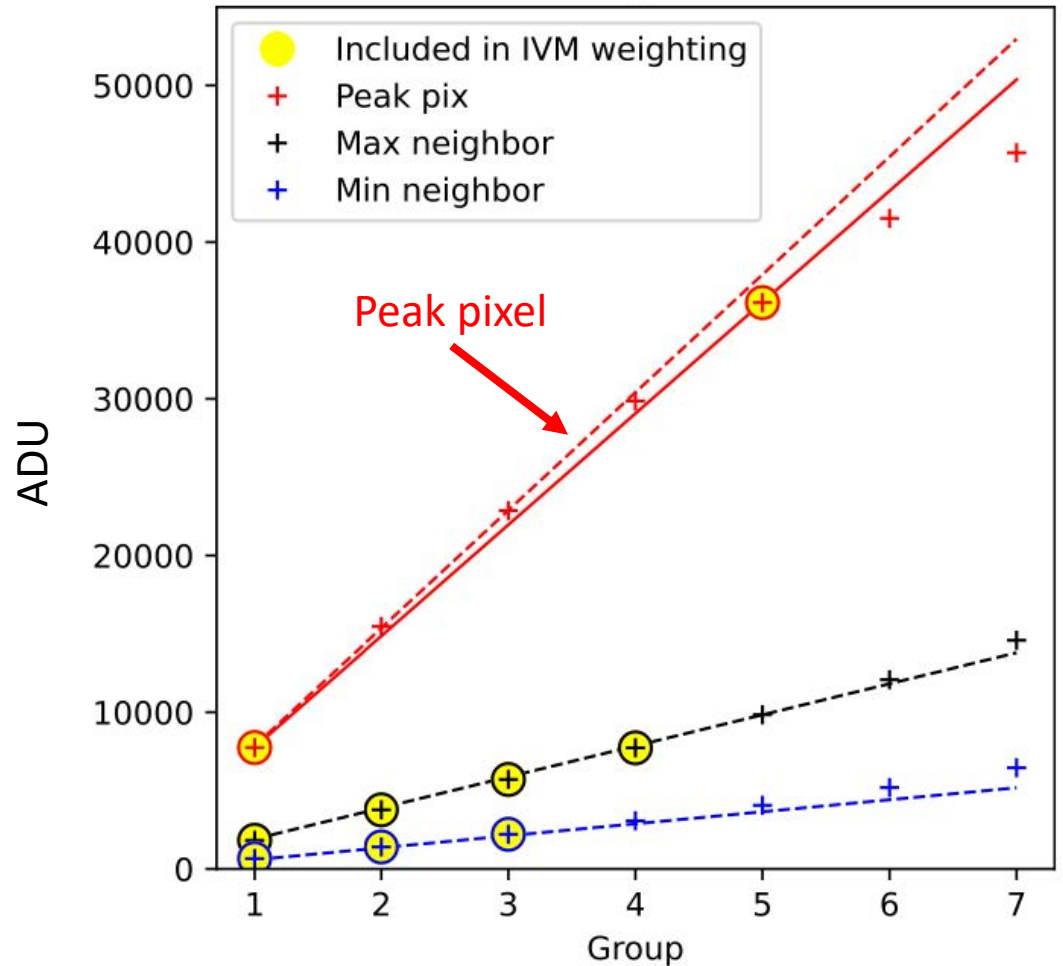


DETECTOR1 updates and work-in-progress

Mitigating impact of “brighter-fatter” effect with *charge_migration* step: pipeline build 10.0 released Dec 2023



F090W image, dither 2

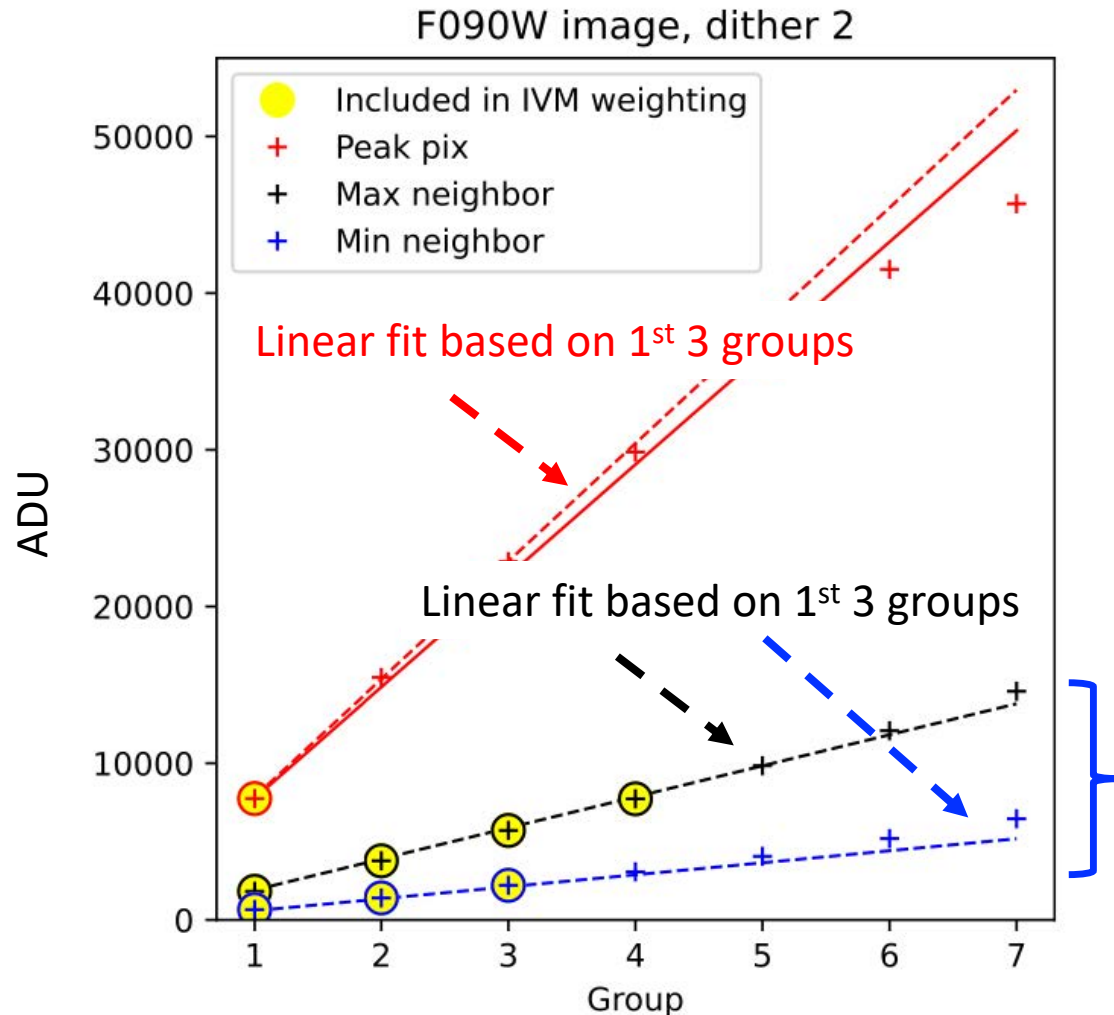


- At certain signal limit (~25,000 ADU) in point sources, charge spills from peak pixel to neighboring pixels

Neighboring pixels

[Goudfrooij et al. 2024 \(PASP\)](#)

Mitigating impact of “brighter-fatter” effect with *charge_migration* step: pipeline build 10.0 released Dec 2023



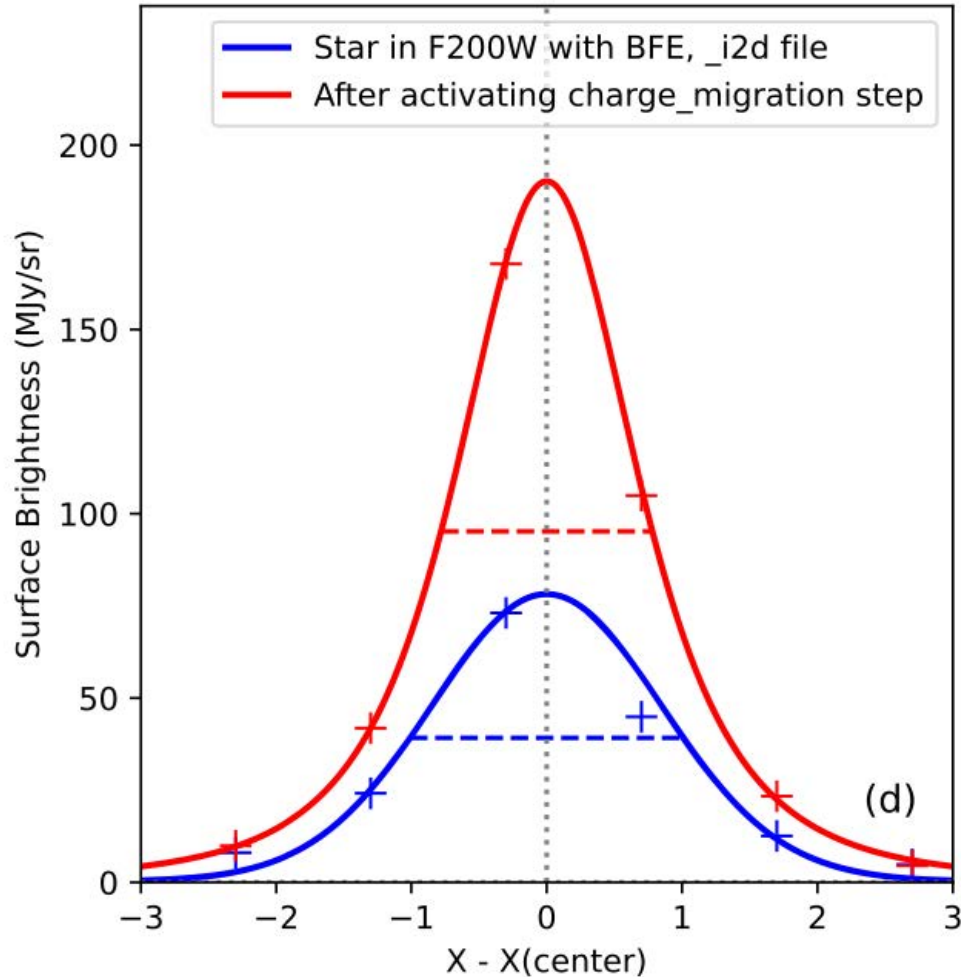
- At certain signal limit (~25,000 ADU) in point sources, charge spills from peak pixel to neighboring pixels
- Peak pixel: signal levels below extrapolation of linear slope

Neighboring pixels receive charge (signal levels above extrapolation of linear slope)

[Goudfrooij et al. 2024 \(PASP\)](#)



Mitigating impact of “brighter-fatter” effect with *charge_migration* step: pipeline build 10.0 released Dec 2023



- At certain signal limit ($\sim 25,000$ ADU) in point sources, charge spills from peak pixel to neighboring pixels
- *charge_migration* step mitigates effect when measuring source flux by:
 - Flagging pixels with charge above signal limit & neighboring pixels
 - Excluding groups above signal limit from measuring ramp slope, but accounting for those groups in noise calculation during resampling

Before: Apparent flux losses as high as $>50\%$

Now: Photometry measurements stay within 1%

[Goudfrooij et al. 2024 \(PASP\)](#)



**New bad pixel mask, full frame dark, full frame superbias calibration
reference files: pipeline build 11.2 to be released Mar 2025**

**Created linked set of calibration reference files,
covering same time periods, for full frame
darks, superbias, and bad pixel mask reference
files:**

- 7 epochs covering ~3-4 months
- Applies to start of science operations to present

Future plan:

- Deliver new linked set of reference files for every quarterly pipeline build

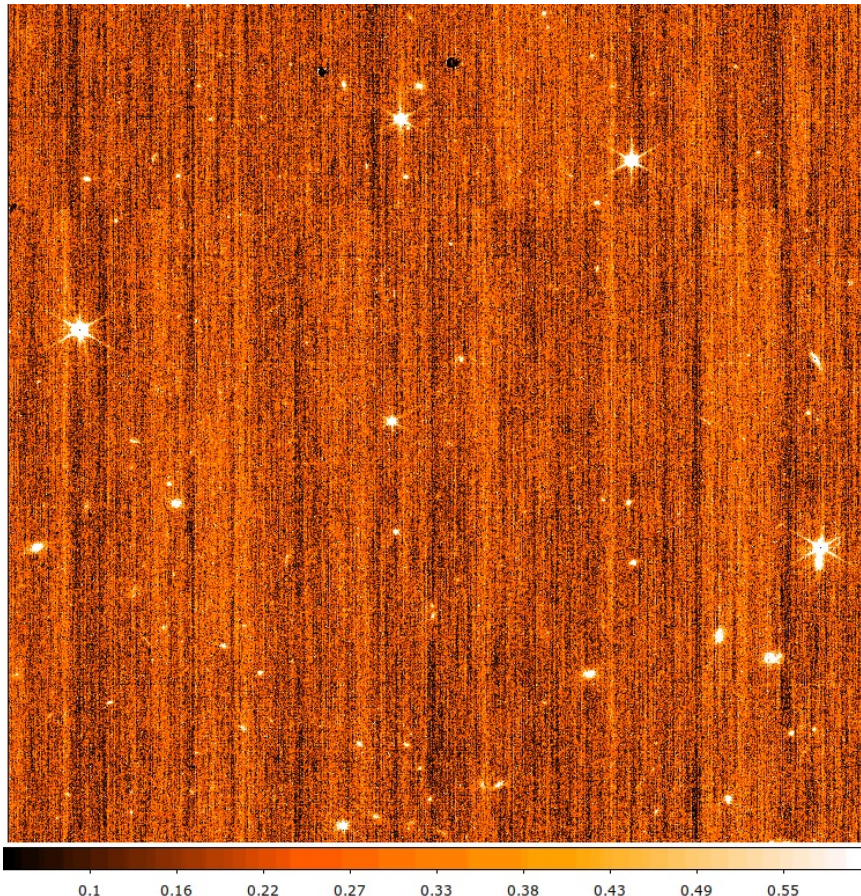
Credit: Joe Filippazzo, Rachel Cooper



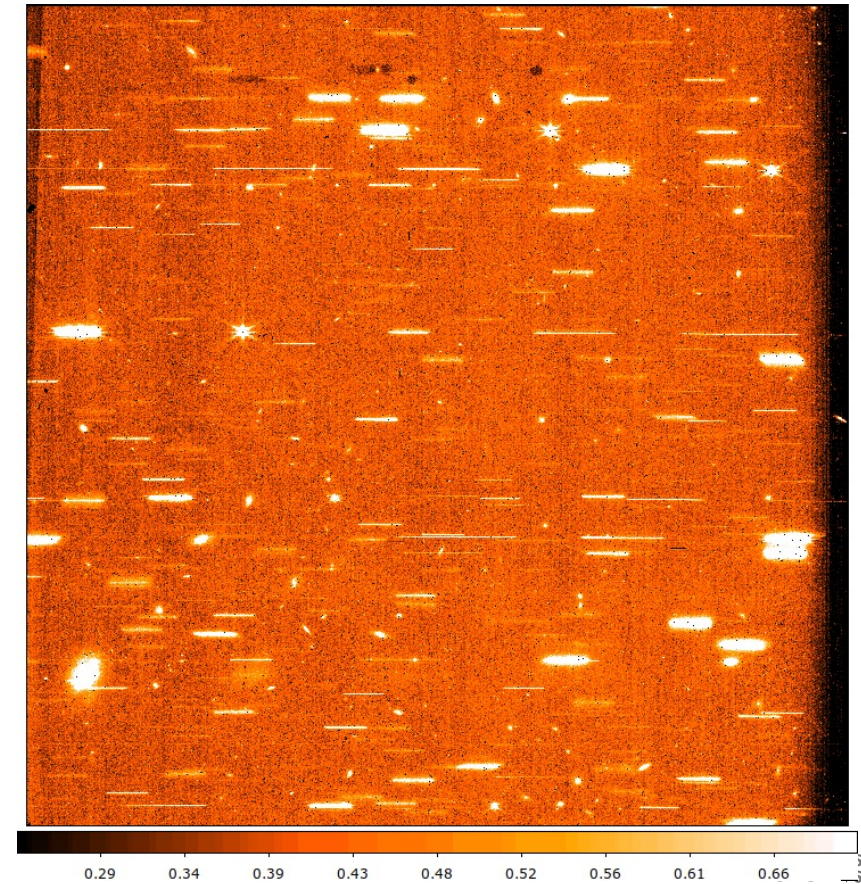
Correcting 1/f noise with stand alone codes: see [NIRISS 1/f Noise Removal JDOx article](#) for details

- *clean_flicker_noise* step in pipeline affects flat fielding of NIRISS data (fix in-progress)
- [Codes available on github](#) to correct 1/f noise in imaging & WFSS observations, where recommended defaults depend on scene ([see JDOx](#))

Imaging – sparse field



WFSS – GR150C grism





AMI updates

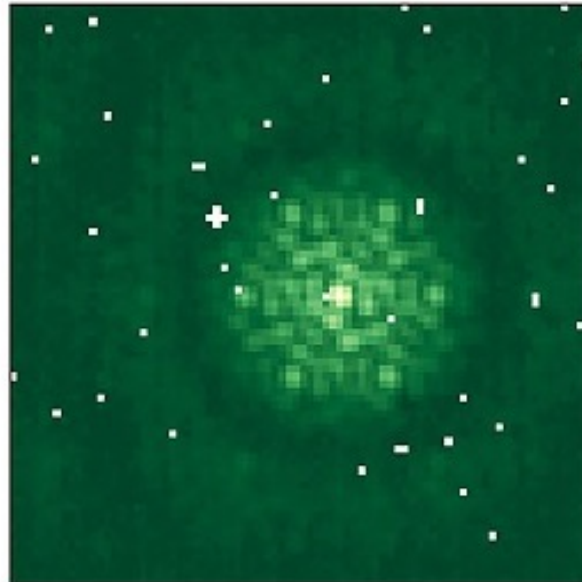


Major overhaul to AMI3 stage of the pipeline: pipeline build 10.2 released Jul 2024

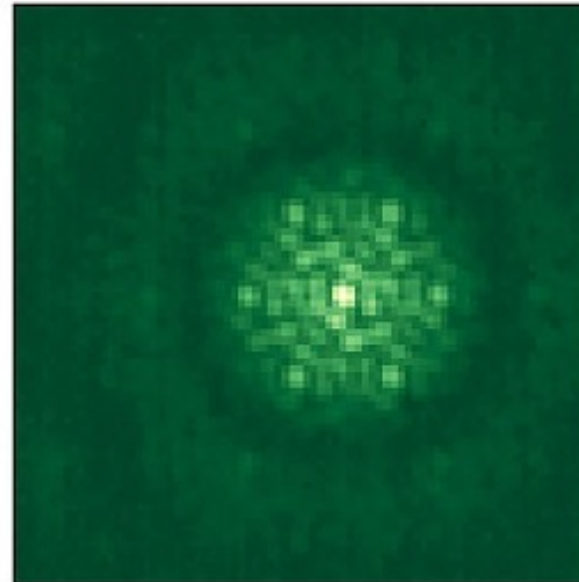
Major updates:

- **Bad pixel correction:** automated Fourier-based correction (see below, [Kammerer+ 2019](#))
- **Algorithm update:** integrated latest version of ImPlaneIA ([Greenbaum+ 2018](#)) that had continued development through 2022
- **Output files:** conforms to OIFITS (optical interferometry fits) v2 standard
- **Updated reference files:** filter throughputs and non-redundant mask (NRM)

Before Bad Pixel Correction



After Bad Pixel Correction

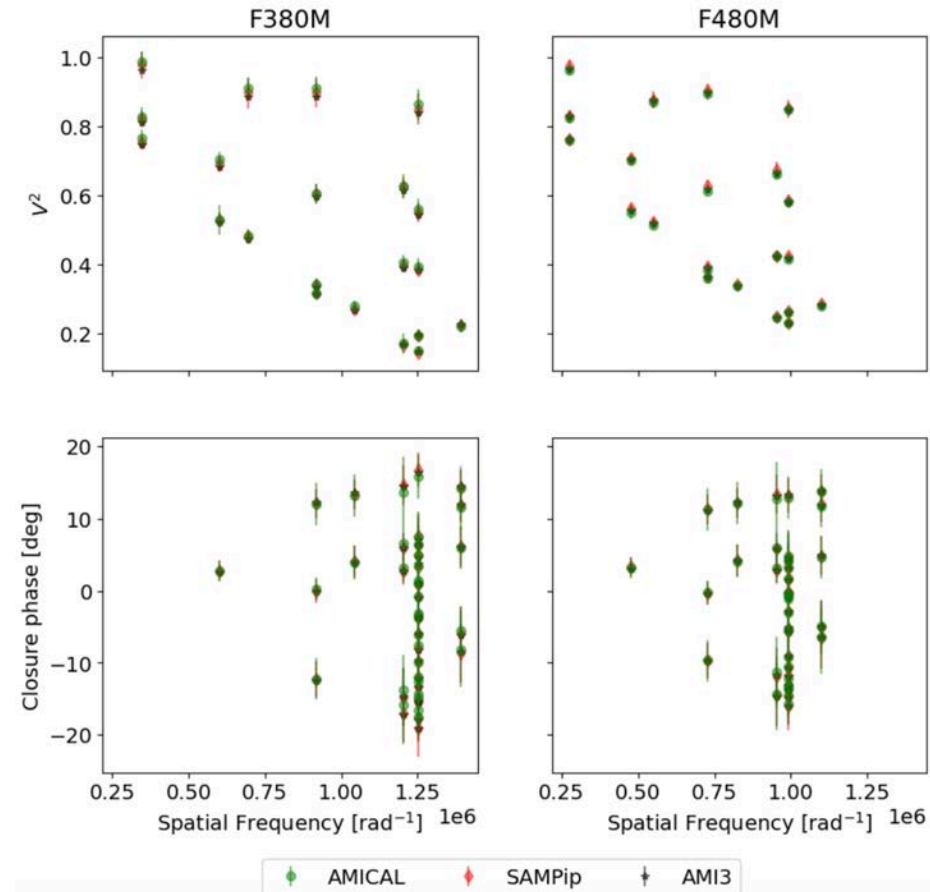
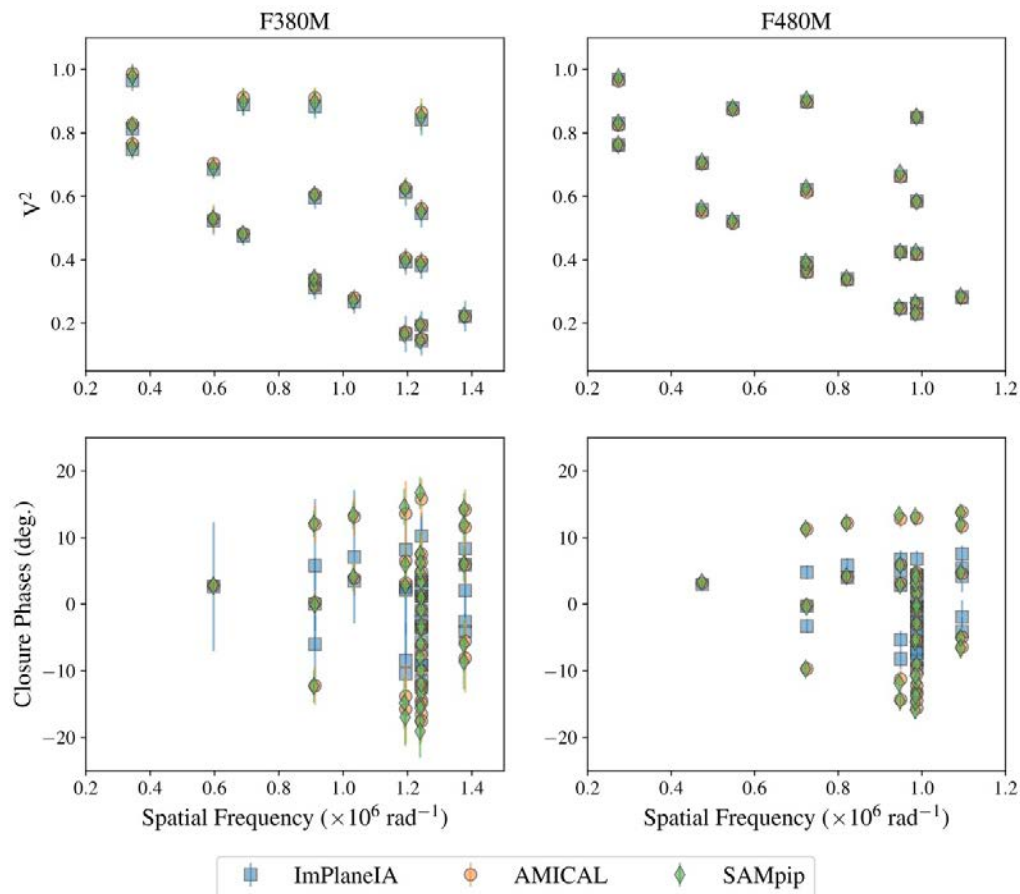




Improved handling of errors in AMI3 stage of the pipeline: pipeline build 11.2 to be released Mar 2025

Before: ImplaneIA larger error bars & slightly offset CPs compared with SAMpip (Sanchez-Bermudez+2022) & AMICAL (Soullain & Roberts 2023)

After: AMI3 fully consistent with publicly available state-of-the-art codes





Imaging updates and work-in-progress

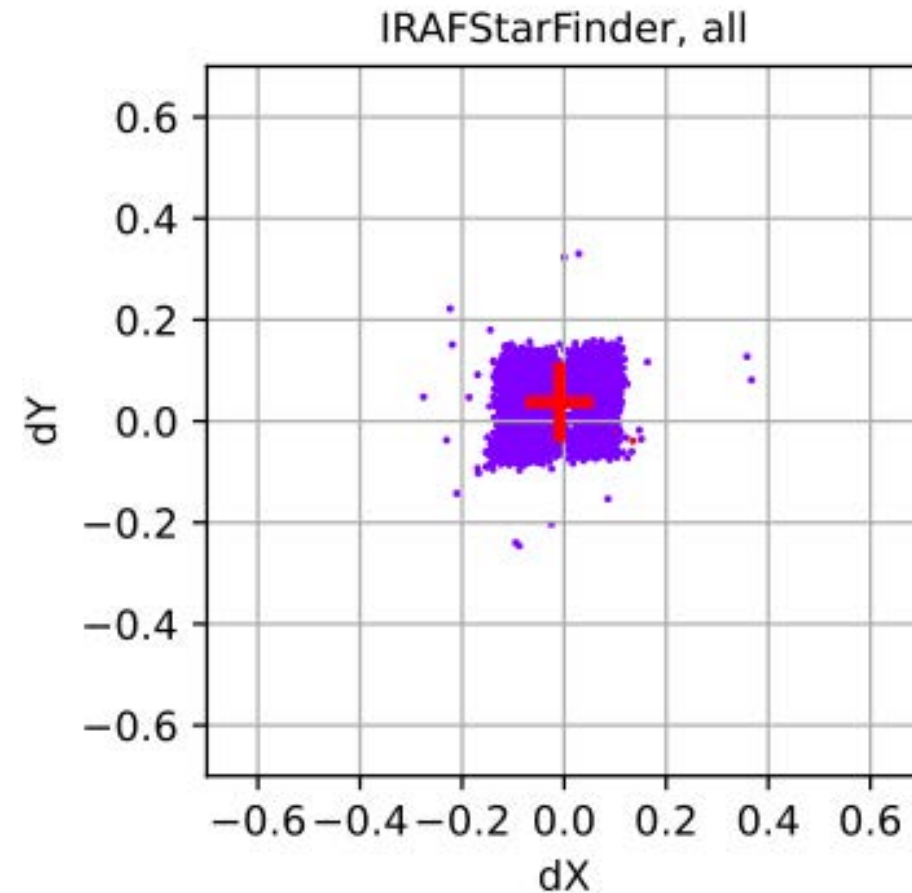
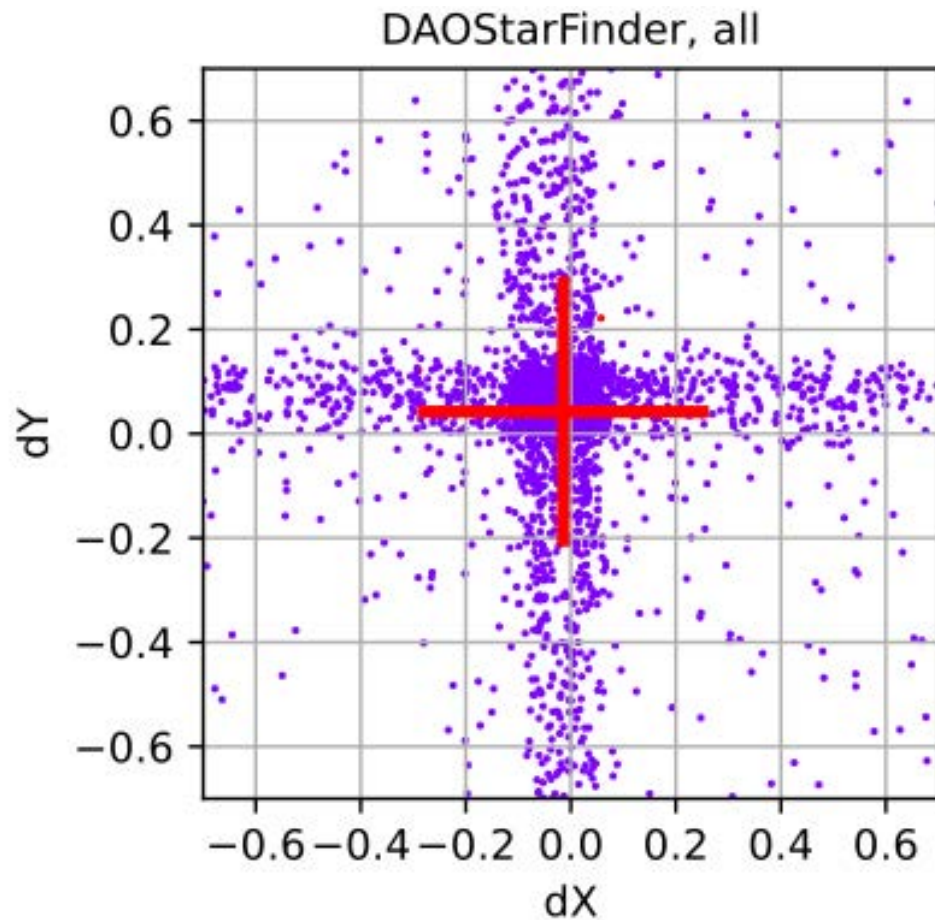


Updated default source finding algorithm in tweakreg to IRAFStarFinder: pipeline build 10.2 released Jul 2024

Previous default

F090W filter

Current default





Imaging Calibration Work-in-Progress

Update imaging flat fields

Provide template PSFs for saturated stars

- Allow profile fitting photometry using PSF wings of saturated stars (following heritage from Spitzer)

Optimize stage 3 products

- Improve source catalog

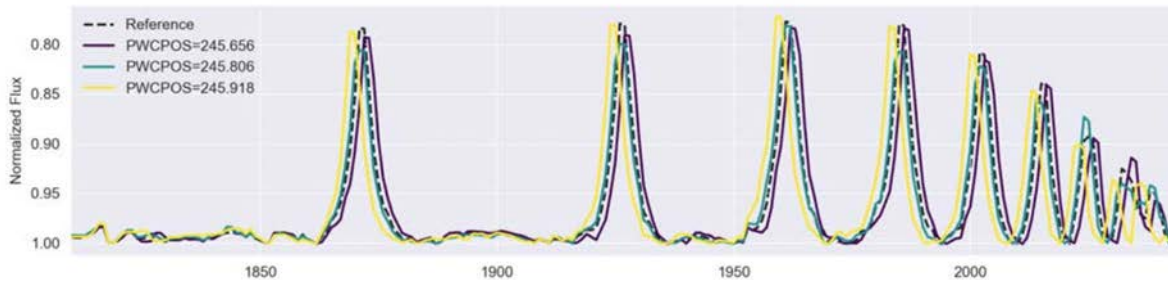


SOSS updates and work-in-progress

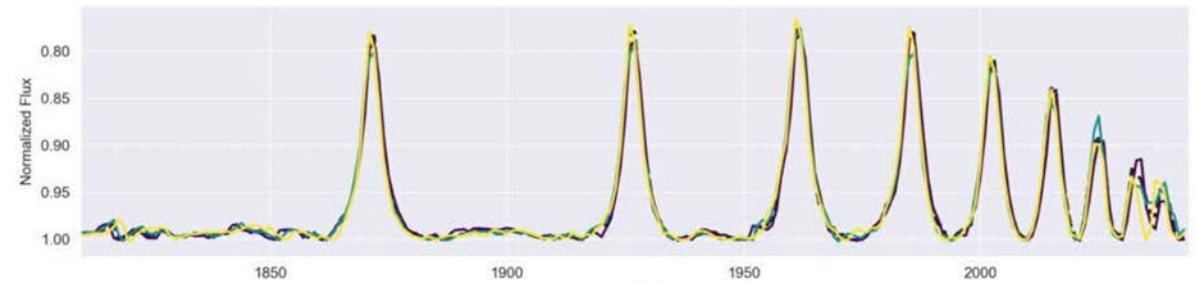


Improved wavelength solution: pipeline build 11.1 released Sep 2024

Before: wavelength shifts between observations up to several pixels



After: wavelength accuracy < 0.5 pixel

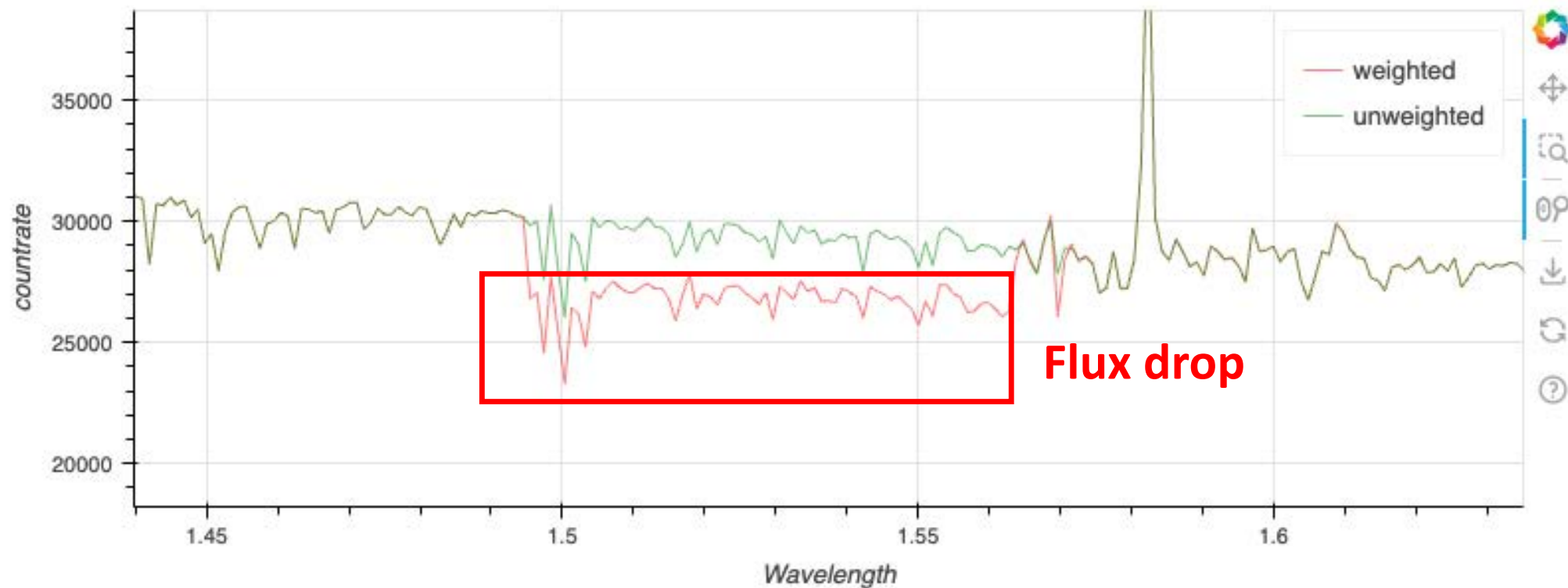


- Based on PASTASOSS package ([Baines et al. 2023a](#), [Baines et al. 2023b](#)) released in 2023

Credit: Tyler Baines, Joe Filippazzo, Néstor Espinoza



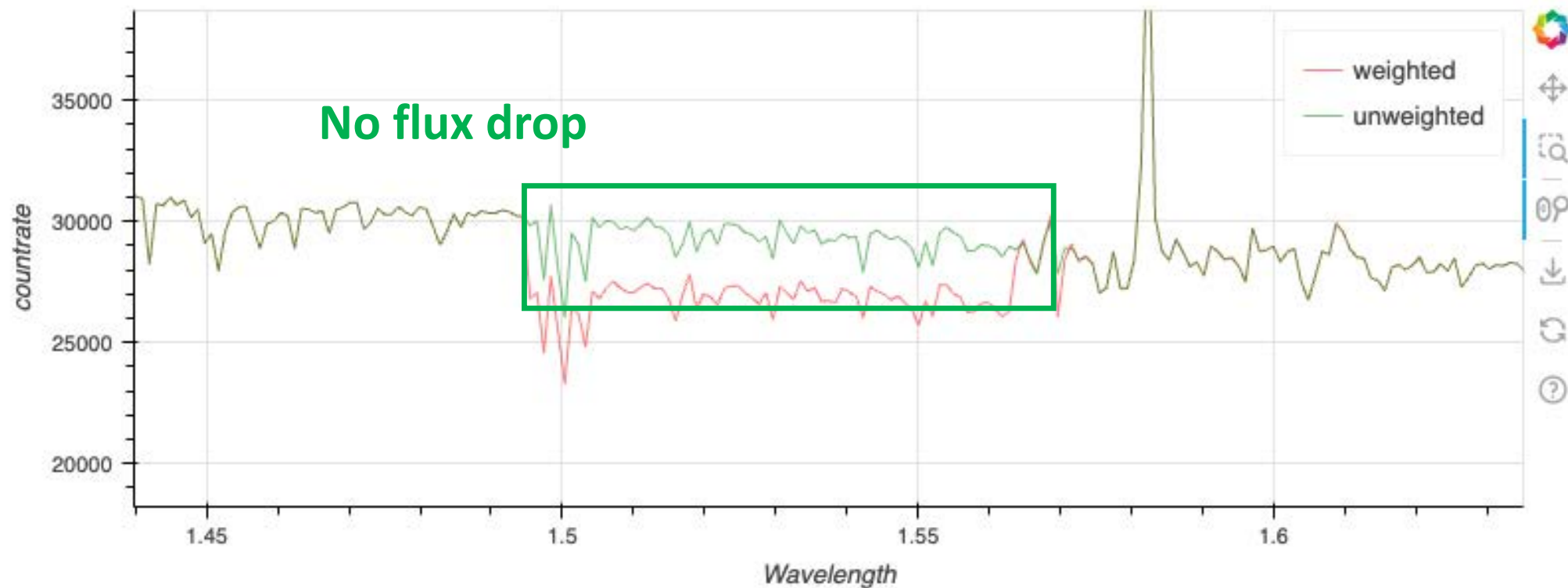
Fixed SUBSTRIP96 flux drop in order 1 spectrum: pipeline build 11.2 to be released Mar 2025



Credit: Joe Filippazzo



Fixed SUBSTRIP96 flux drop in order 1 spectrum: pipeline build 11.2 to be released Mar 2025

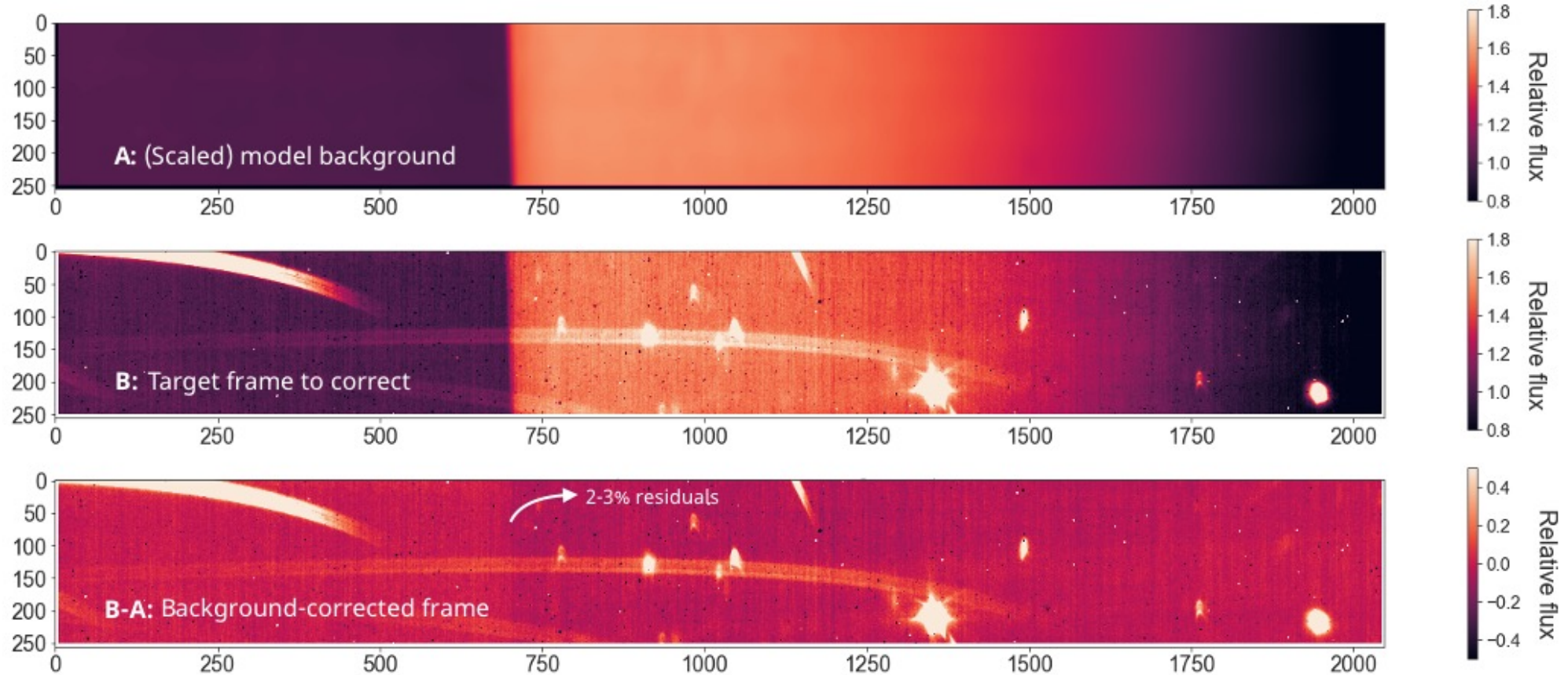


Credit: Joe Filippazzo



⚠️ Characterizing and subtracting background ⚠️

Background changes sharply at column ~ 700 (order 1). Depends on sky position & time of year



Credit: Tyler Baines, Aarynn Carter, Néstor Espinoza



🚧 Characterizing and subtracting background 🚧

Current status: manual background subtraction

- Provide template from commissioning data on JDox (**precision at 2-3% level**)
- Observers can take dedicated background observations, following JDox guidelines

Short term solution (Spring 2025)

- Provide library of background templates from different sky locations
- Publish Jupyter notebook demonstrating how to use template, library, and dedicated background observations to manually subtract background
- Publish Technical Report quantifying precision for different methods

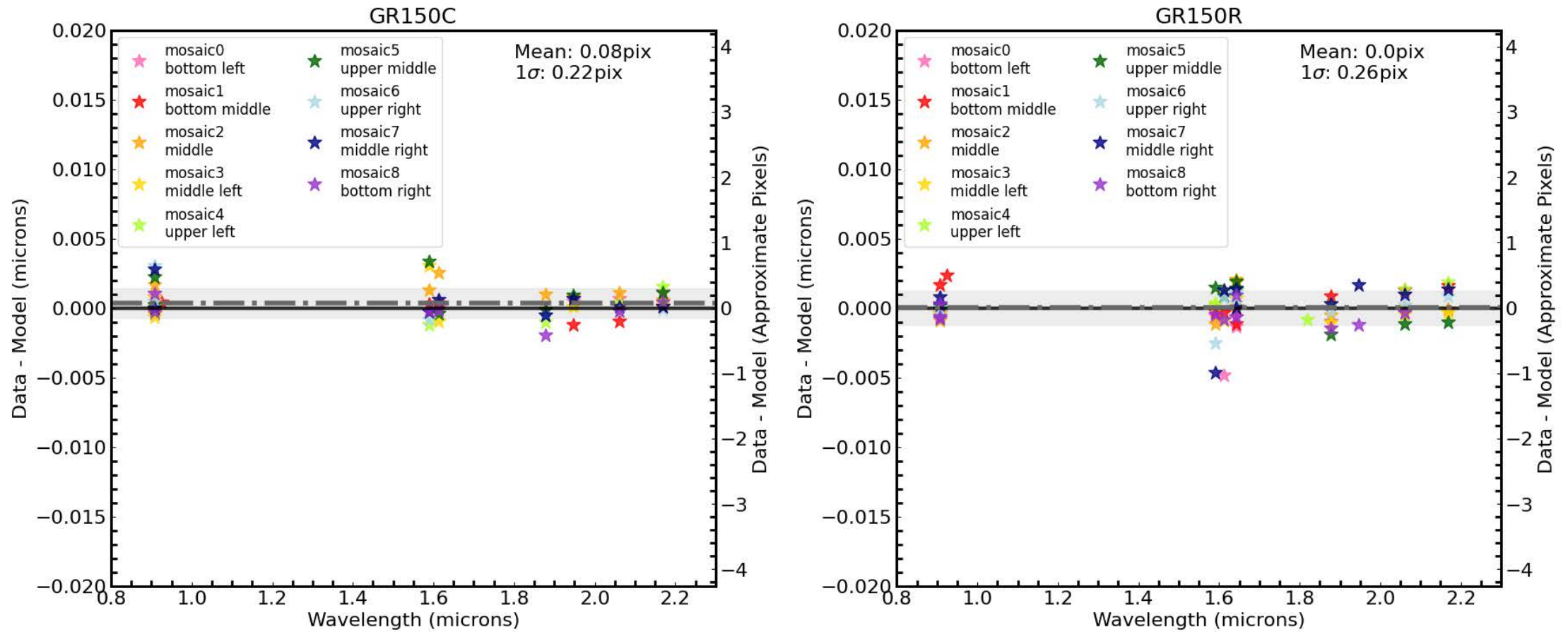
Long term solution (Fall 2025 – build 11.4 - tentative)

- Update JWST pipeline to support SOSS background subtraction using template library



WFSS updates and work-in-progress

Wavelength calibration accuracy of 10-12 Å (0.22 - 0.26 pixels)

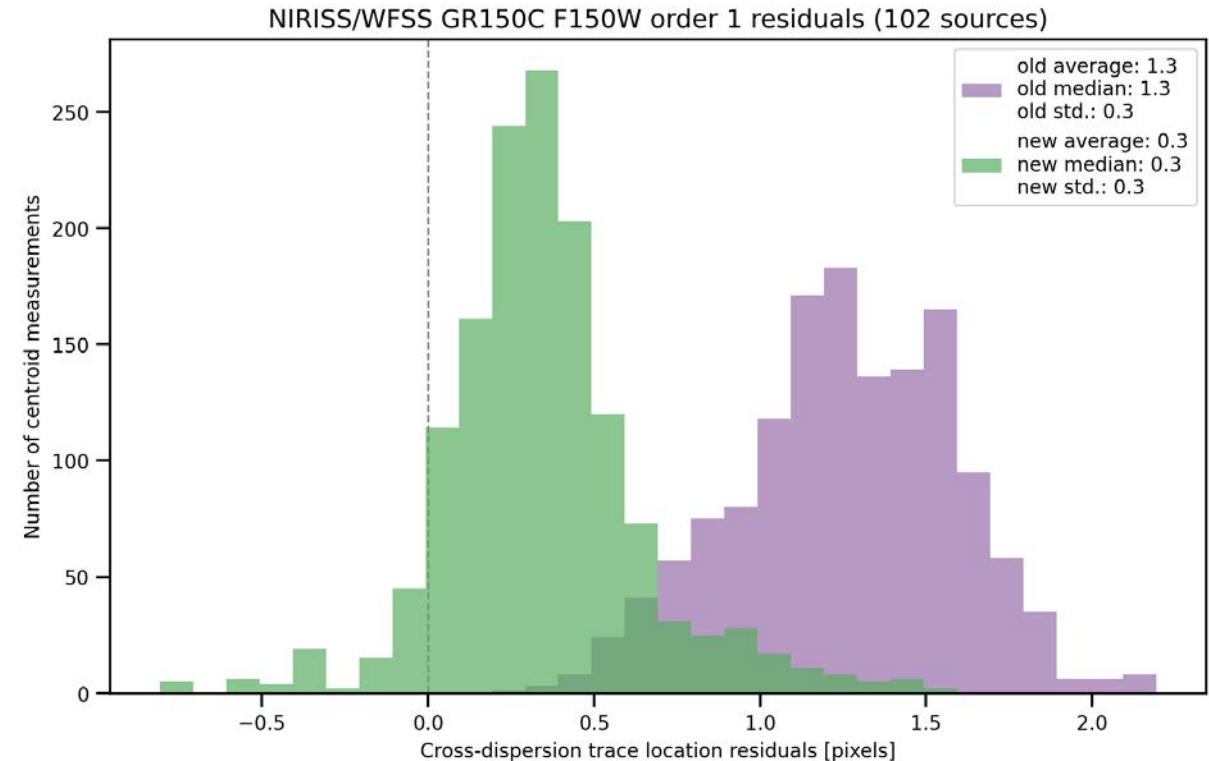
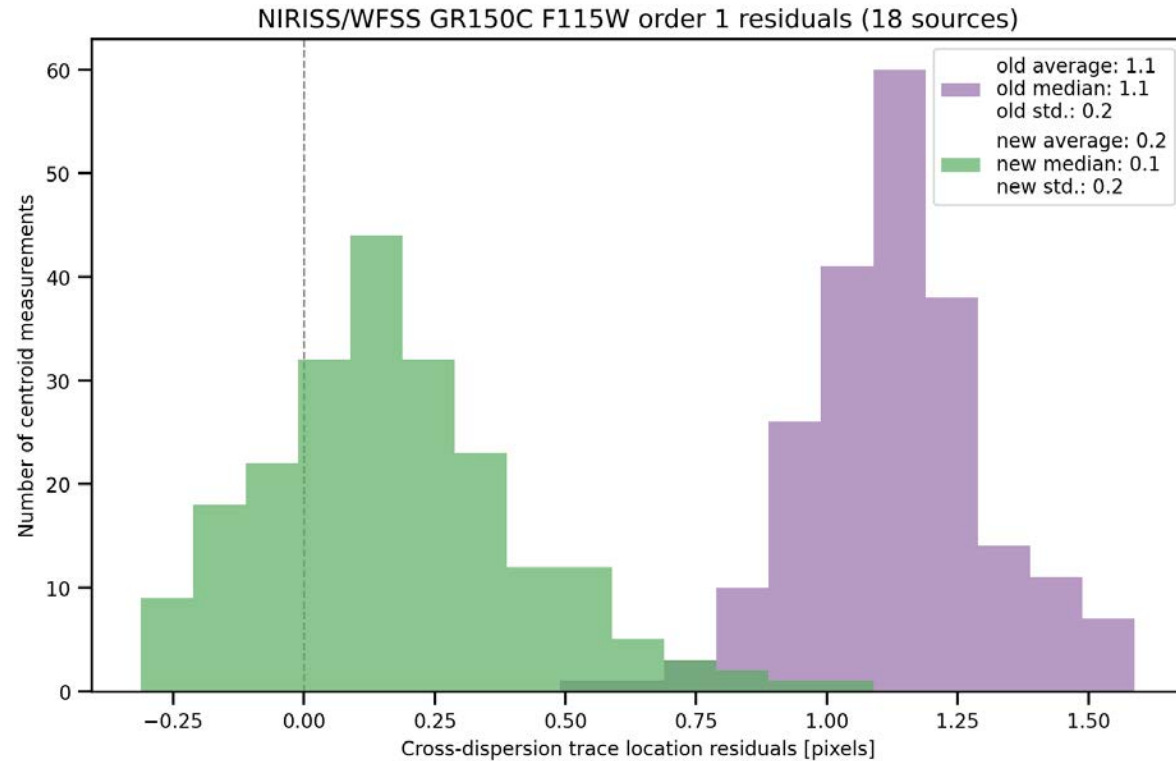


Accounts for change in wavelength solution as function of detector position

Credit: Rachel Plesha



Current trace accuracy $\sim 0.2 - 0.5$ pixels (F200W, F115W, F150W)



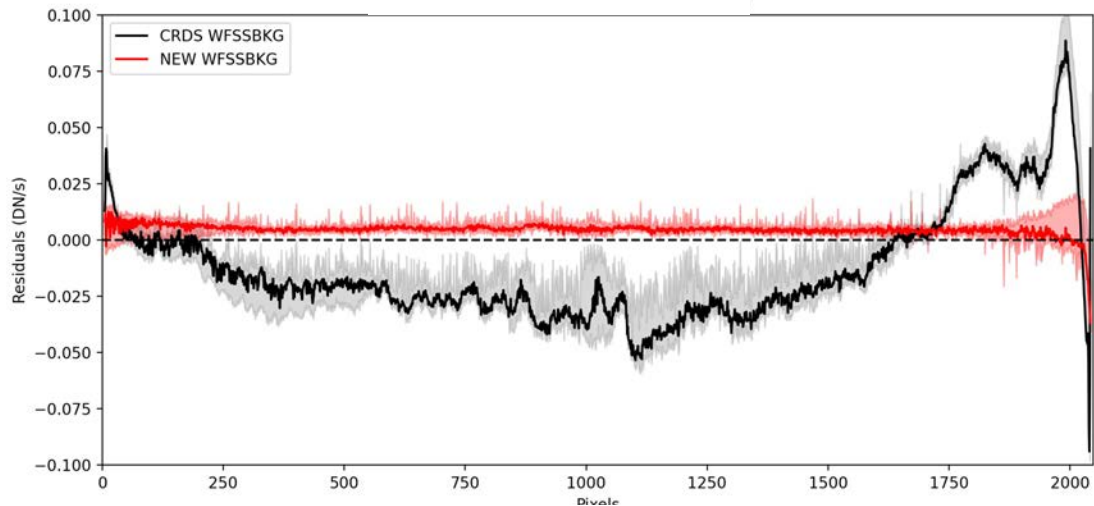
Residuals: difference between pipeline predicted trace location and measured trace centroids for same sources.

Credit: Jo Taylor

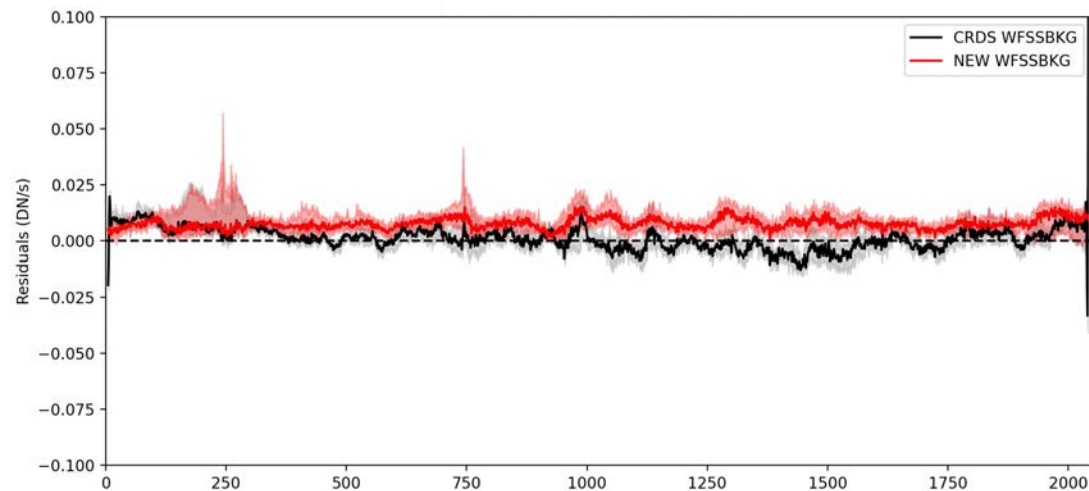


New background files: pipeline build 11.2 to be released Mar 2025

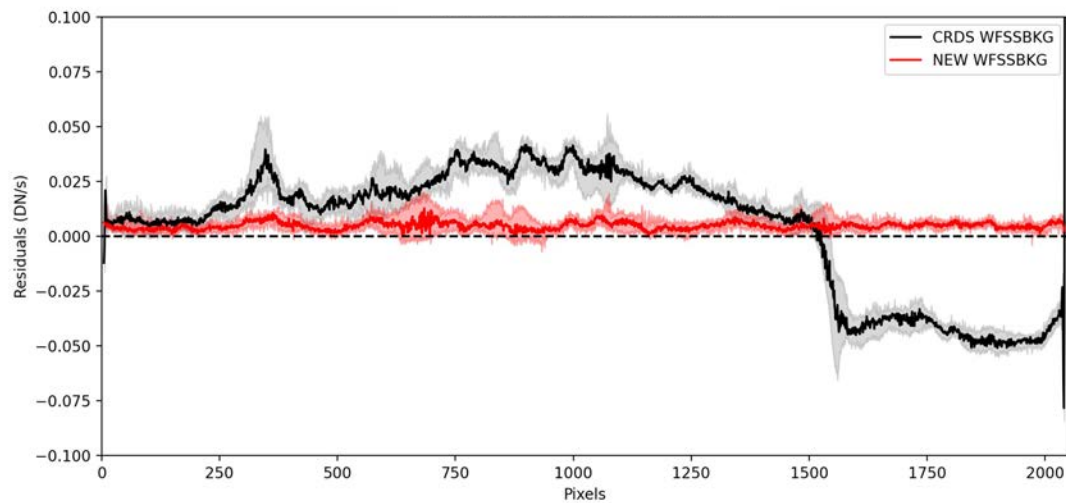
F090W GR150C X



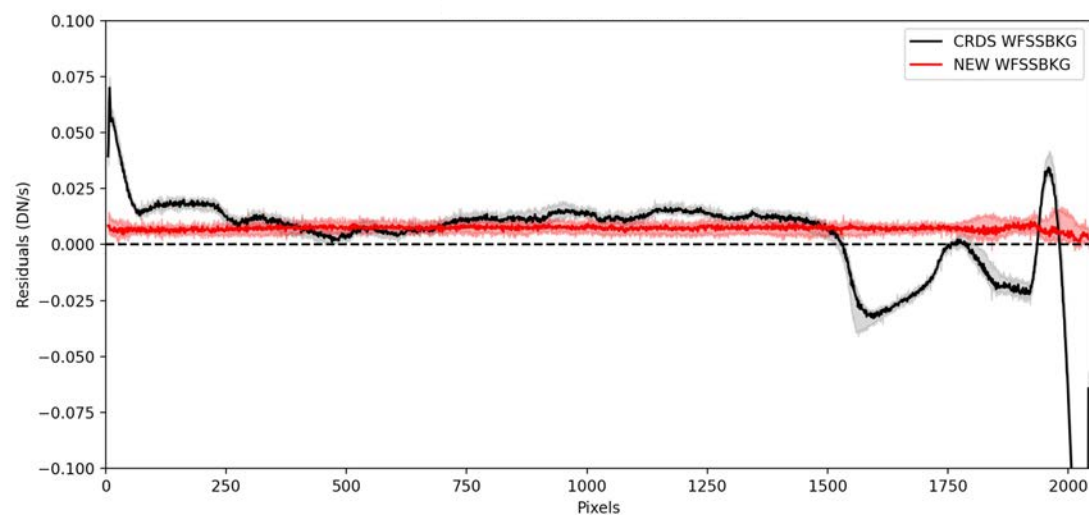
F090W GR150R X



F090W GR150C Y



F090W GR150R Y





WFSS Calibration & Pipeline Work-in-Progress

Improve calibration accuracy

- Trace residuals centered at 0 and $\sigma < 0.1$ pixels
- After trace calibration complete: update wavelength calibration → update photometric calibration

WFSS pipeline improvements: collaboration between NIRCam and NIRISS

- Improve contamination modeling and background subtraction
- Serve intermediate data products helpful for off-line tools



Summary of NIRISS Pipeline Data Products

Detector Calibration

- ✓ Enabled charge migration mitigation by default
- ⚠ Improving 1/f noise removal algorithm in pipeline
- ⚠ Testing alternate ramp fitting algorithms to improve TSO precision (SOSS)

WFSS

- ✓ Completed preliminary trace and wavelength calibration for 3 most-used filters
- ⚠ Improving accuracy of trace, wavelength, and photometric calibration
- ⚠ Supporting major revisions of WFSS pipeline to improve contamination modeling

AMI

- ✓ Final data products are state-of-the-art. No future enhancements planned at this time.

Imaging

- ✓ Data products through stage 2 are good!
- ⚠ Improving flat fields, PSF photometry for saturated stars, level 3 products

SOSS

- ✓ Improved wavelength accuracy
- ✓ Completed investigation into position- and time-dependent background levels
- ⚠ Providing updated background templates & supporting background subtraction in pipeline
- ⚠ Improving SOSS spatial profile characterization

Credit: Tyler Baines, Aarynn Carter, Rachel Cooper, Néstor Espinoza, Joe Filippazzo, Paul Goudfrooij, André Martel, Gaël Noirot, Rachel Plesha, Anand Sivaramakrishnan, Tony Sohn, Jo Tayler, Deepashri Thatte, Kevin Volk