



STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

JWST Pipeline Development

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JSTUC Meeting
March 18, 2024



Introducing the JWST Pipeline (JP) Coordination Team

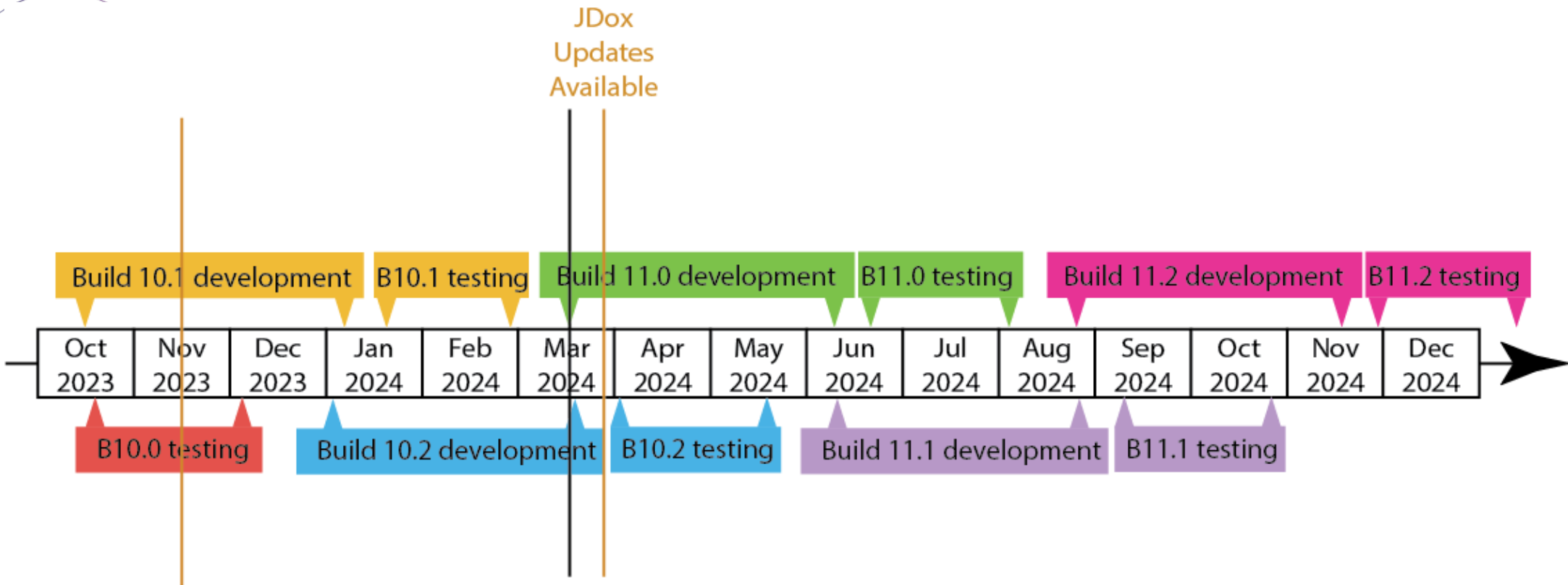
The JWST pipeline will never automate everything for everybody, but it should be capable of doing most things for most people.

In January 2024, STScI adopted a new framework for management and oversight of the JWST pipeline.

- JWST Pipeline (JP) Coordination Team has broad responsibility for all issues relating to the quality of the data products and documentation thereof being provided to the community.
- Set priorities, cross-division communication within STScI. Investigate, delegate, and track issues as necessary.
- Led by D. Law, with representatives from each instrument team.
- Common point of contact for questions and data-related issues.



JWST Pipeline Development Timeline



- New pipeline builds are released quarterly
- 3 months development, 6 weeks testing
- Note that dates for Build 11.x are tentative

The latest development pipeline is always available from <https://github.com/spacetelescope/jwst>



Improving JWST Data Products Workshop

<https://outerspace.stsci.edu/display/JEA/Improving+JWST+Data+Products+Workshop>

- Held at STScI November 14—17 2023
- Workshop was well-attended by science users from around the world; ~ 80 participants crossing many different science areas.
- Presentations and topical breakout sessions focusing on community experts providing suggestions for new algorithms and areas of improvement
- Key areas of discussion included:
 - WCS of data products
 - Error estimates and sources of noise
 - Bad pixels, cosmic rays, and outlier flagging
 - 1/f noise
 - Pipeline runtime and memory usage
 - PSF-based spectral extraction
 - Other topics (WFSS, TSO, coronagraphy)



Feedback provided by the recent User Survey

November/December 2023 user survey provided additional feedback from 400+ individual responses.

Top five areas identified:

- 1) Bad pixels/cosmic rays/outlier detection
- 2) Correction for $1/f$ noise
- 3) Runtime (detector1 pipeline stage in particular)
- 4) Need better JDOX documentation of the pipeline data, known issues, and options for reprocessing for each instrument mode.
- 5) WCS alignment

Additional areas: Background subtraction, flux calibration, RAM usage, **ERR estimates**, NIRSpec calibration, undersampling, reproducing MAST results, automatic vs offline corrections, etc.



Jan/Feb 2024: JDox Data Overhaul

- In the last two months, we've completely overhauled the Data pages on JDox. Will be published mid-late March with JWST Observer announcement.
- Fundamental restructure and rewrite with an eye to consistency and streamlining, establishing a page tree common across instruments, and eliminating redundant pages. Content to be added to over time.
- Roughly 80 pages new or rewritten, about 50 deprecated for removal
- High-level organization:
 - Getting Started with JWST Data (Start here)
 - Accessing JWST Data (How to get data, data formats)
 - JWST Science Calibration Pipeline (Pipeline overview, how to run it, what's new, what will be coming soon, etc)
 - JWST Calibration Status (Astrometric, photometric, wavecal accuracy; pages for each of the instrument modes)
 - Known Issues with JWST Data (Artifacts, pipeline issues, D2P tables, notes for rerunning, etc for each of the instrument modes)
 - JWST Post-Pipeline Data Analysis (Jdazviz tools, analysis notebooks, etc)



Jan/Feb 2024: JDOX Data Overhaul

- › JWST Astronomers Proposal Tool Overview
- JWST APT Observation Templates
- › JWST ETC to APT Interface Support Inform
- › JWST Other Tools
- Proposal Planning Video Tutorials
- Getting Started with JWST Data
 - › Accessing JWST Data
 - › JWST Science Calibration Pipeline
 - › JWST Calibration Status
 - ▼ Known Issues with JWST Data
 - Known Issues with JWST Data - High-Le
 - Shower and Snowball Artifacts
 - ▼ MIRI Known Issues
 - MIRI Coronagraphy Known Issues
 - MIRI Imaging Known Issues
 - MIRI LRS Known Issues
 - **MIRI MRS Known Issues**
 - MIRI Time-Series Observations Known
 - › NIRCam Known Issues
 - › NIRISS Known Issues
 - › NIRSpec Known Issues
 - › JWST Post-Pipeline Data Analysis

MIRI MRS Known Issues

Created by David Law, last modified on Mar 05, 2024 JDOX Review 1 Task Added in this space version

Known issues specific to [MIRI MRS](#) data processing in the [JWST Science Calibration Pipeline](#) are described below. This article is not intended as a how-to guide or as full documentation of individual pipeline steps, but rather to give a scientist-level overview of issues that users should be aware of for their science.

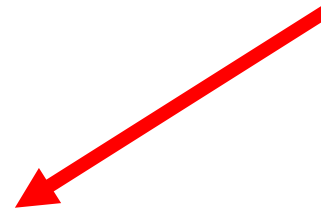
We describe specific artifacts in the [Artifacts](#) section below, provide some guidance on using the pipeline data products in the [Pipeline Notes](#) section, and summarize some common issues and workarounds in the [Summary](#) section.

See also [MIRI MRS Calibration Status](#) for an overview of the current astrometric, wavelength, and flux calibration of MIRI MRS data products.

On this page

- [Artifacts](#)
 - [Bad Pixels](#)
 - [Cosmic Ray Showers](#)
 - [Cruciform Artifact](#)
 - [Fringing](#)
 - [Resampling Noise](#)
 - [Spectral Leak](#)
 - [Time-dependent Count Rate Loss](#)
- [Pipeline Notes](#)
 - [WCS Accuracy](#)
 - [Background subtraction](#)
 - [Outlier detection](#)
 - [Cube building](#)
 - [Variance , Covariance, and DQ Arrays](#)
 - [Spectral extraction](#)
- [Summary of Common Issues and Workarounds](#)
- [References](#)

'D2P' tables; now with fix builds indicated





Major Changes in pipeline Build 10.0

Development finished in October 2023, OPS install December 2023

Software

- Update 1d spectral extraction for NIRSpec MOS/FS and MIRI LRS to address an issue with extractions at the wrong location **due to bad WCS**
- Improve exclusion of **intermittent bad pixels** in NIRSpec IRS2 reference pixel subtraction
- Fixed issue with duplicate product names for some NIRCам coronagraphic observations
- Update NIRSpec fixed slit source ID assignment
- Updates to NIRISS charge migration step

Reference files

- Updated photometric calibration for NIRCам imaging/coronagraphy, NIRISS imaging/SOSS, MIRI MRS
- Updated NIRISS linearity and saturation flagging of bad pixels
- New NIRSpec darks, biases, and **bad pixel masks**
- Updated NIRISS SOSS wavelength reference data to rest vacuum



Major Changes in pipeline Build 10.1

Development finished in December 2023, OPS install February 28 2023

Software

- Added [1/f noise correction](#) for NIRSpec (NSClean; off by default)
- Added EMI pattern noise removal for MIRI subarray data
- Correct 12 micron spectral leak for MIRI MRS (point sources)
- Model time-dependent flux evolution for MIRI Imager
- Improved NIRSpec pathloss correction for slitlets other than 1x1 or 1x3 shutters long
- [Cosmic ray shower/snowball correction](#) enabled by default for NIRSpec, NIRCcam, MIRI imaging

Reference files

- Update MIRI MRS [bad pixel masks](#), wavelength solutions
- Update MIRI LRS slit wavelength/photometric calibration
- Update NIRCcam imaging distortion and pixel area maps
- Update NIRSpec barshadow correction



What are we doing about outliers and bad pixels?

Impact is most noticeable on spectroscopic observations

In progress Tracking evolution of bad pixels; number is increasing over time

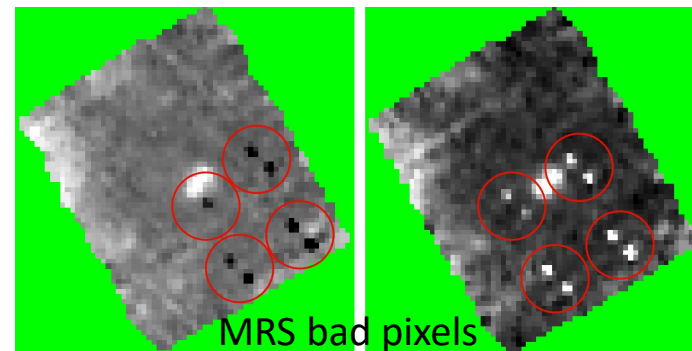
In progress B10.1 delivered new MIRI MRS bad pixel masks for every six months of observing, at three levels of depth. Assessing for other instrument modes.

In progress Looking into improvements to Detector1 jump flagging for cosmic rays, incorporating multi-integration data into the statistics.

Starting Considering adding a new optional step to produce a custom bad pixel mask for a given program (based on existing workaround notebook).

Starting Exploring algorithms to improve outlier detection for NIRSpec observing modes (originally based on MIRI MRS)

Easy Rearrange pixel replacement step so that users do not need to rerun spec2 to modify parameters or turn on/off.

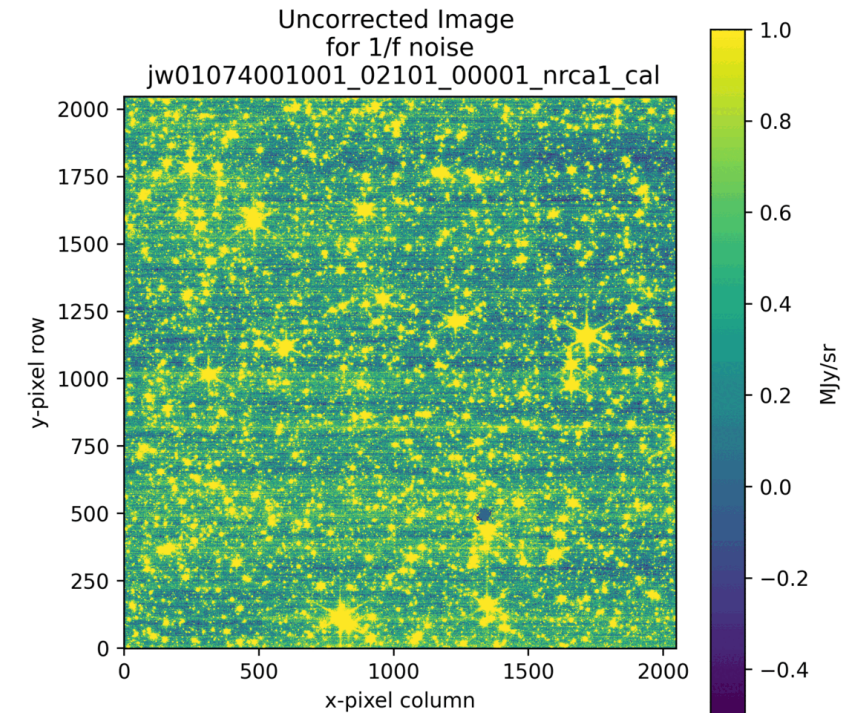




What are we doing about $1/f$ noise?

SIDECAR ASICs produce $1/f$ noise in all NIR data, visible as striping (particularly in shallow exposures)

- Done** Build 10.1 added $1/f$ noise correction for NIRSpec, using the NSClean algorithm. Off by default, as performance can be scene-dependent.
- Starting** Currently studying multiple different algorithms for use with NIRCам data, along with ways of generalizing corrections beyond specific science cases.
- Starting** Goal is to converge on a generic implementation strategy for all three NIR instruments, possibly with different flags for various science cases.





What are we doing about pipeline runtime?

Some of the most time-consuming steps already have an option to use parallel processing, but can still take hours or longer to run.

In progress November calibration workshop discussed code (T. Brandt, now at STScI) that can run $\sim 10x$ faster than existing detector1 (jump/ramp fitting) code. However, this does not handle edge cases, CR showers, etc. Currently exploring a fusion of the two codes that does not compromise performance in edge cases.

Starting Exploring revision of NIRSpec distortion model framework that might improve runtime for NIRSpec IFU data.

Starting Exploring benefits of combining sky matching with outlier detection for imaging mosaics

Starting Exploring segmentation of large mosaics, and possibilities for runtime improvements in 1d spectral extraction code.



What are we doing about **estimated uncertainties**?

All JWST pipeline products have associated uncertainties, but those uncertainties are not currently reliable. Investigation is ongoing into why these are not reliable- typically multiple reasons.

In progress Build 10.2 will introduce Poisson noise on the subtracted dark, which can be important for very deep spectroscopic observations.

Starting Working on updating reference files to ensure consistent handling of NaN-values in error propagation and add reasonable estimates of flatfield errors.

Ready Considering how to add treatment of covariance for IFU 1-d spectral extraction. This can be a large effect, algorithm recently outlined by Law + 2023 (AJ, 166, 45)



Work underway in pipeline Build 10.2

Development to finish in March 2024, OPS install May 2024

Software

- Include dark current contributions to Poisson noise
- New source finding options for tweakreg image alignment (DAOStarFinder, IRAFStarFinder, SourceFinder)
- Improve NIRCAM WFSS photometric calibration by accounting for spectral dispersion
- Mask persistence after snowballs/showers
- NIRISS AMI data format and algorithm updates (OIFITS)
- Begin improvements to NIRSpec IRS2 reference pixel correction

Reference files

- New NIRSpec subarray darks
- NIRISS WFSS spectral trace updates
- MOS Sflat and Fflat updates



High impact tasks for Build 11.0

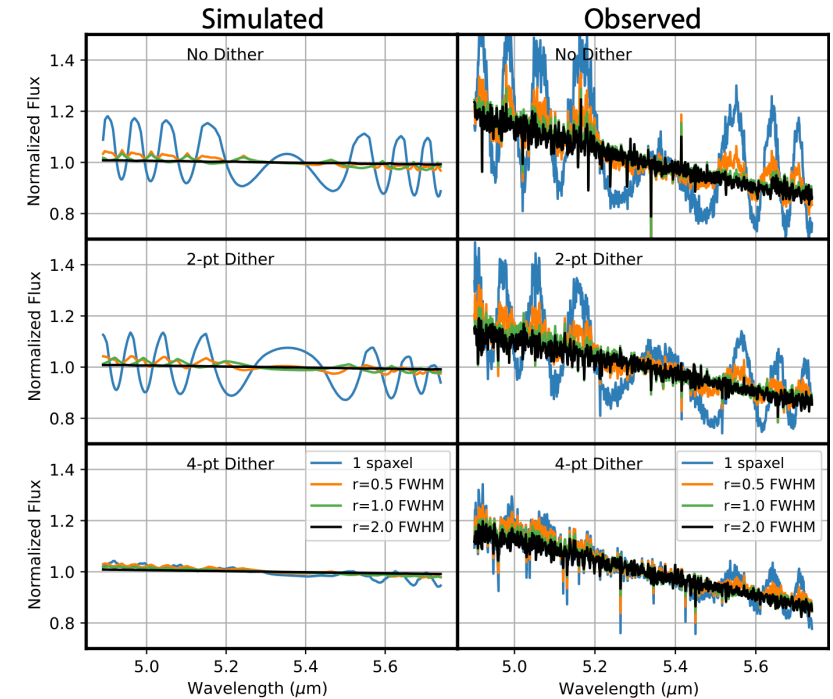
Development starts March 2024, OPS install ~ August 2024

- Progress on **Bad Pixels**, **1/f noise**, **runtime**, and **uncertainties**
- Potential change to archive cadence; 'data release' style reprocessing every quarter with fixed code + reference files. Looking for feedback.
- Improve **WCS SIP coefficient accuracy** for imaging mosaics
- NIRCam imaging distortion updates (contamination correction, intermediate products, background subtraction)
- NIRCam WFSS improvements (contamination correction, intermediate products, background subtraction)



Long term development issues

- PSF-based spectral extraction
 - Extract point source spectra directly from original data without resampling (MUCH better)
 - Algorithms under study, but can vary significantly by mode
- IFU undersampling issues (MIRI + NIRSpec)
 - Resampling introduces variable-periodicity wiggles in rectified data cubes on single-spaxel scales
 - Fundamental consequence of hardware design, requires forward modeling
- Improving the astrometry provided by spacecraft/FGS



IFU undersampling (Law+23)



Upcoming work by most-affected instrument mode

Mode	Percent [‡]	JDox	Bad pixels	1/f	Runtime	WCS	ERR
NIRCam imaging	21.0%	X		X	X	X	X
NIRSpec IFU	15.9%	X	X	X	X		X
MIRI MRS	15.3%	X	X				X
MIRI Imaging	11.6%	X				X	X
NIRSpec MOS	6.6%	X	X	X	X		X
MIRI LRS	6.2%	X					X
NIRSpec FS	5.4%	X	X	X			X
NIRSpec BOTS	5.1%	X	X	X	X		X
NIRCam Coron	2.3%	X		X			X
NIRISS Imaging	2.1%	X		X		X	X
NIRISS SOSS	1.6%	X		X			X

[‡]: Percent of total programs (Cycles 1+2)



Summary

- Solving one science case is easy; solving the general case is hard.
- Pipeline should make as many automated, general corrections as possible
- Add optional offline options for case-specific improvements
- Focus on getting to 90% of the solution rapidly, rather than 100% more slowly
- JDox data page overhaul complete, will continue to be filled out

- Near-term development focus on bad pixels/outliers, 1/f noise, runtime, and uncertainties.