Kavli JWST data reduction workshop: NIRCam

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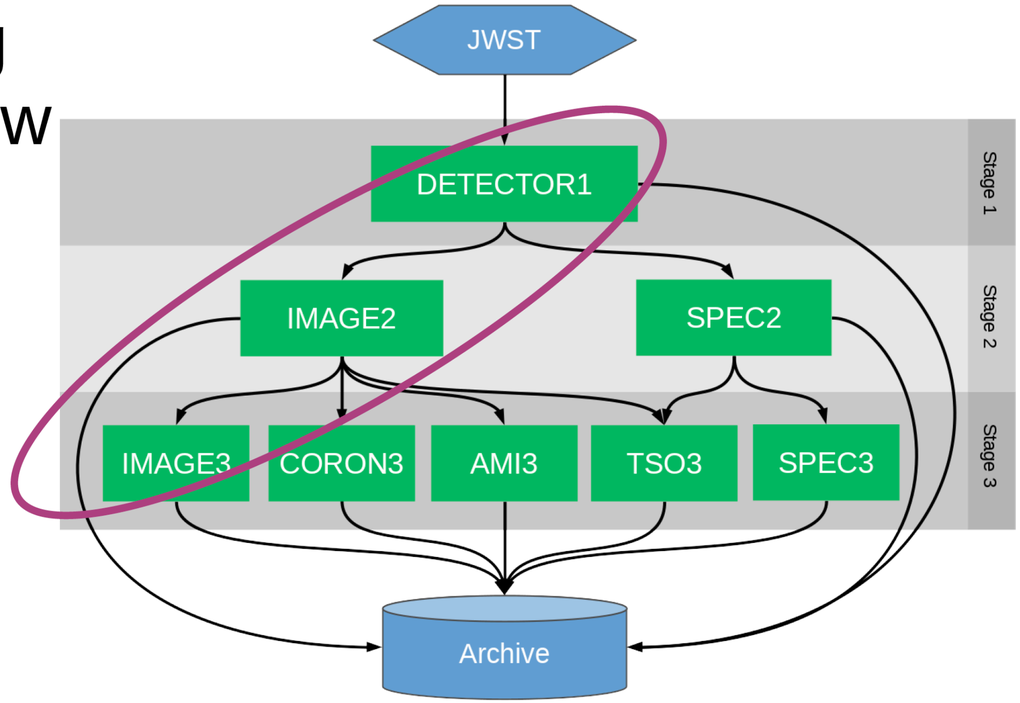
Objectives

1. Everyone has the JWST STScI pipeline installed.
   ➜ Who hasn't?
   ➜ Who has reduced JWST previously?
2. Everyone has reduced (parts of) the NIRCam SMACS ERO programme.
   (a) demonstrate how to run the JWST Calibration Pipeline on two of the raw images
   (b) scale this up to run it on all images
3. Others?

Imaging Overview



Resources

JWST Help Desk:
https://stsci.service-now.com/jwst

MAST website:
https://archive.stsci.edu

JDox for data products:
https://jwst-docs.stsci.edu/understanding-data-files

JWST data products in Read-the-Docs:
https://jwst-pipeline.readthedocs.io/en/latest/jwst/data_products/index.html

JWST Pipeline Products JWebbinar:
https://www.stsci.edu/jwst/science-execution/jwebbinars

Data in MAST

Standard science data files include:

- uncalibrated raw data, identified by the suffix `uncal`
- countrate data produced by applying the Stage 1 (detector-level) corrections in order to compute count rates from the original accumulating signal ramps, identified by the suffix `rate` or `rateints`
- calibrated single exposures, identified by the suffix `cal` or `calints`
- resampled and/or combined exposures, identified by the suffixes `i2d` or `s2d`
- extracted spectroscopic 1D data, identified by the suffixes `x1d` or `c1d`

Observational Data: ERO SMACS data

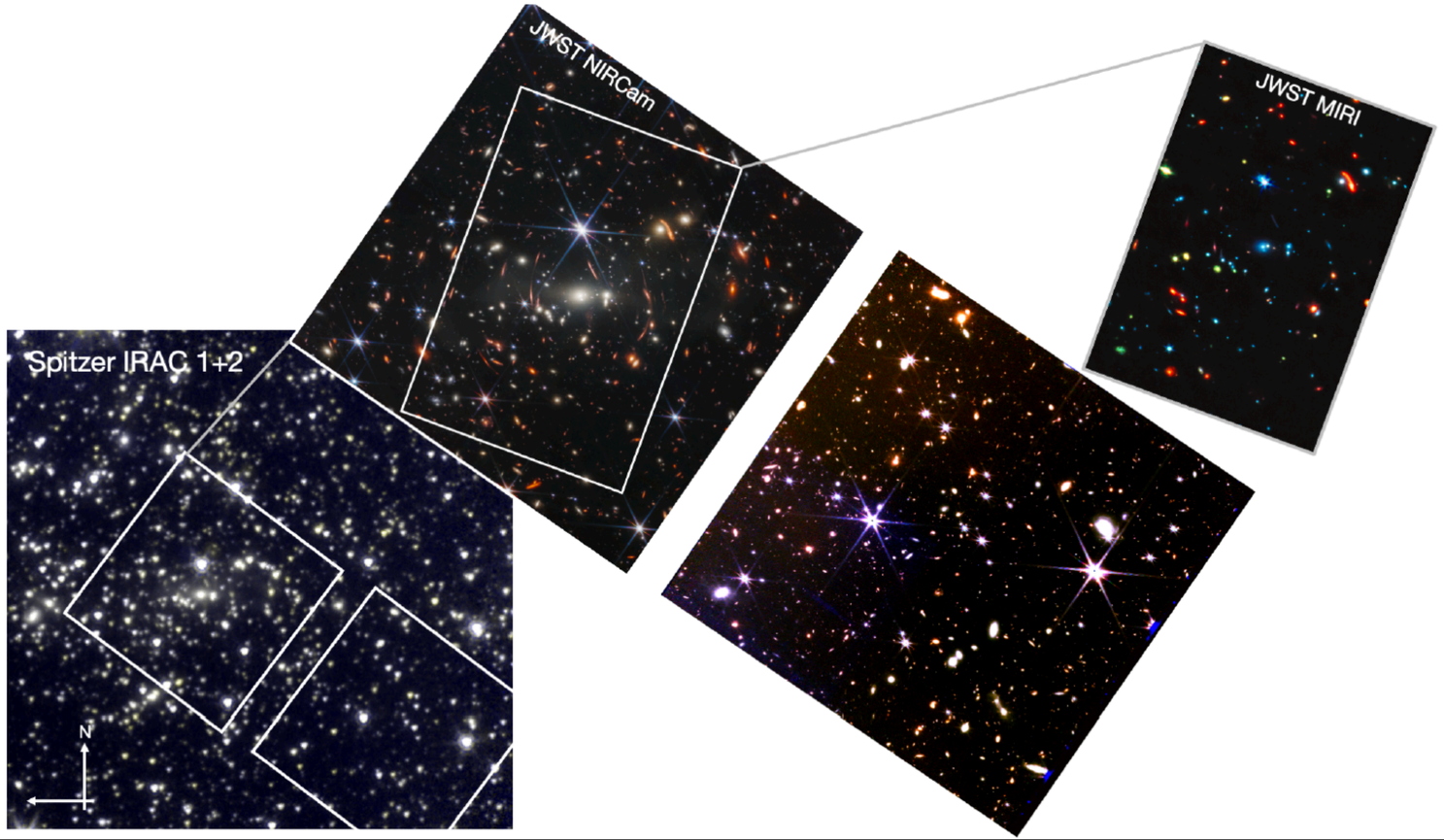
Based on JWST Early Release Observations (Pontoppidan et al. 2022)

Target:
SMACS J0723.3-7327 — massive galaxy cluster (z=0.388)

Filters:
SWC: F090W, F150W, F200W
LWC: F277W, F356W, F444W

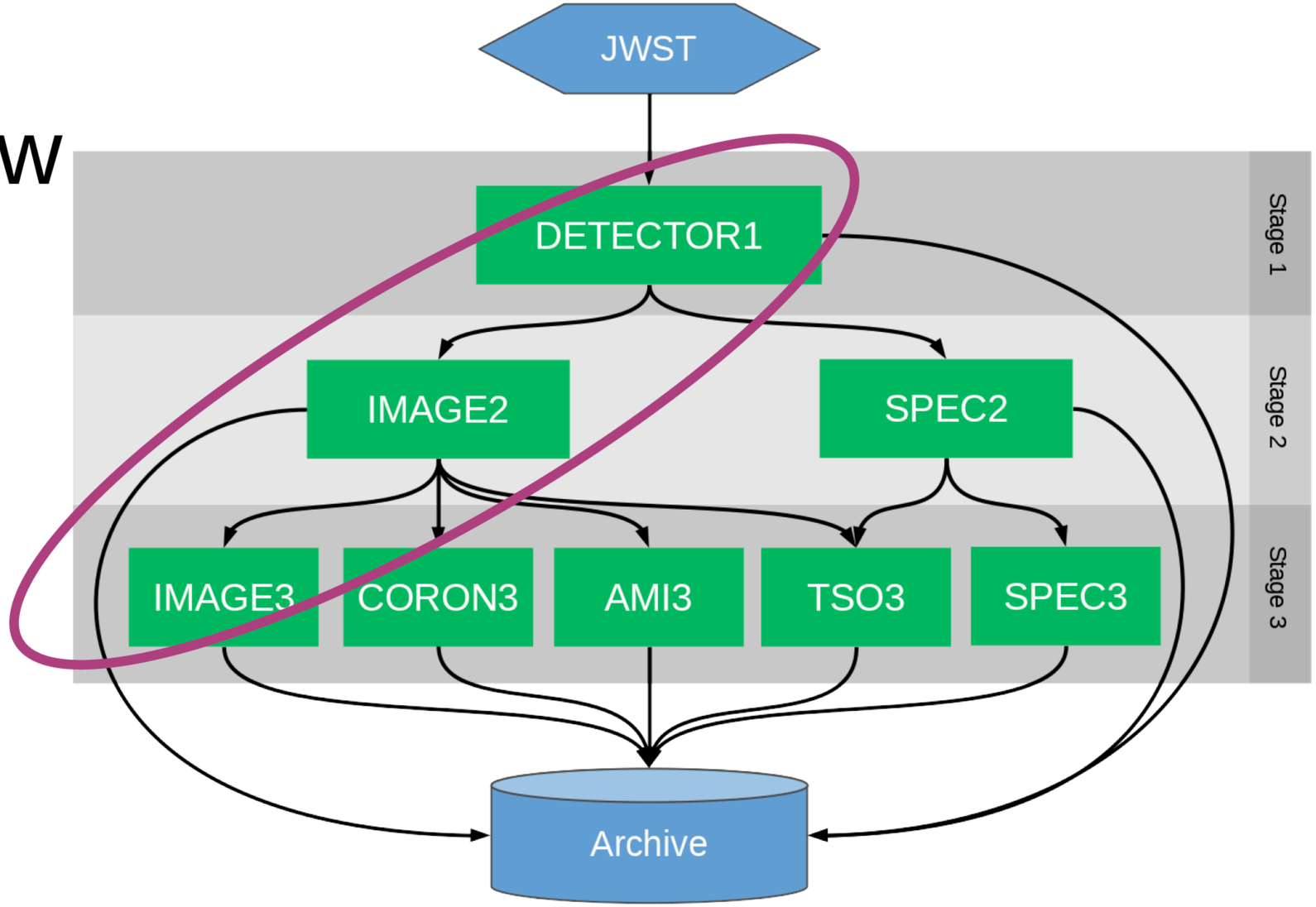
Readout:
MEDIUM8

Dithers:
9 point dither in each filter



JWST Calibration Pipeline

Imaging Overview



Resources

Algorithm details

– DETECTOR1:

https://jwst-docs.stsci.edu/stages-of-processing/calwebb_detector1

– IMAGE2:

https://jwst-docs.stsci.edu/stages-of-processing/calwebb_image2

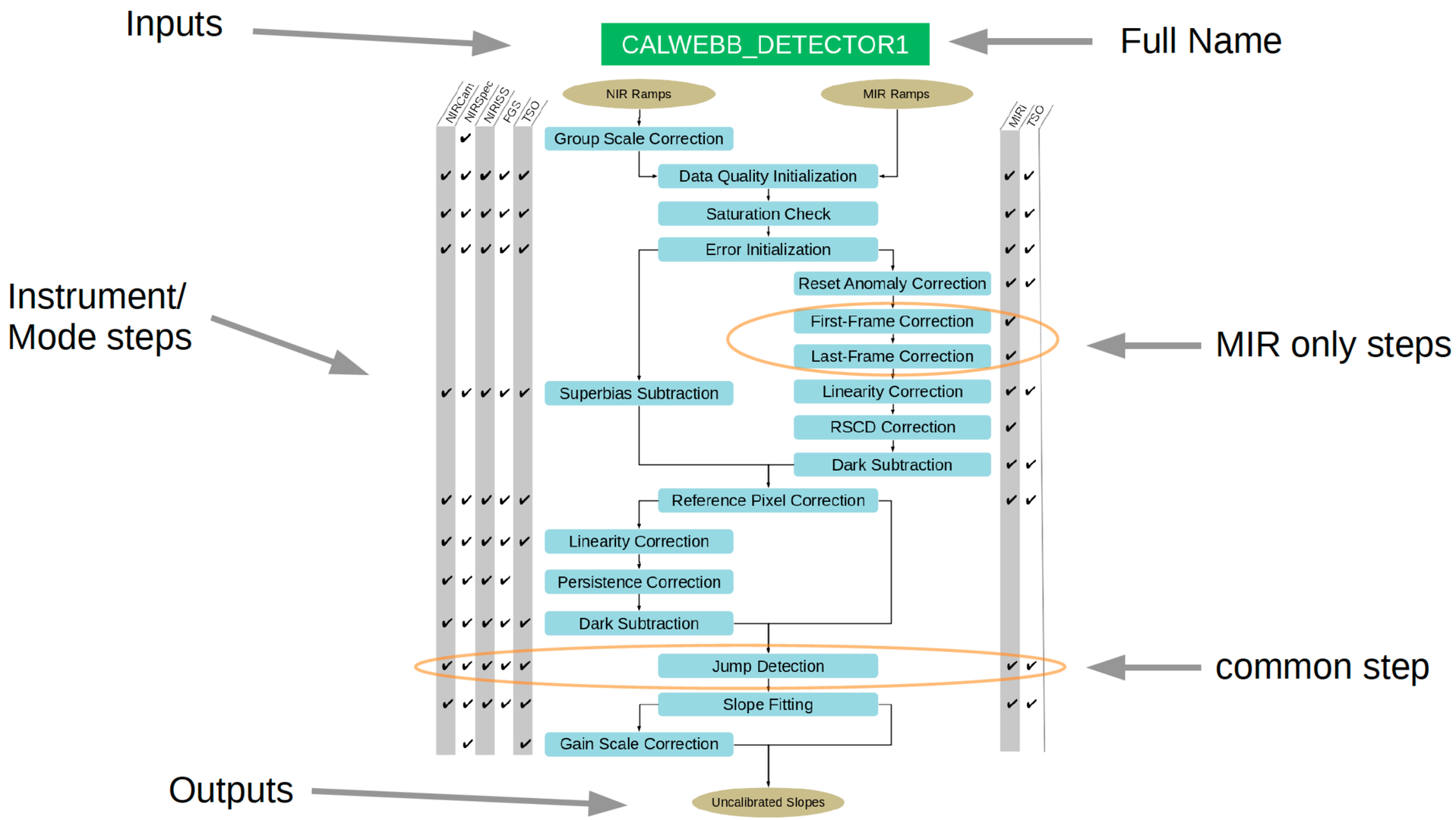
– IMAGE3:

https://jwst-docs.stsci.edu/stages-of-processing/calwebb_image3

Code focused documentation

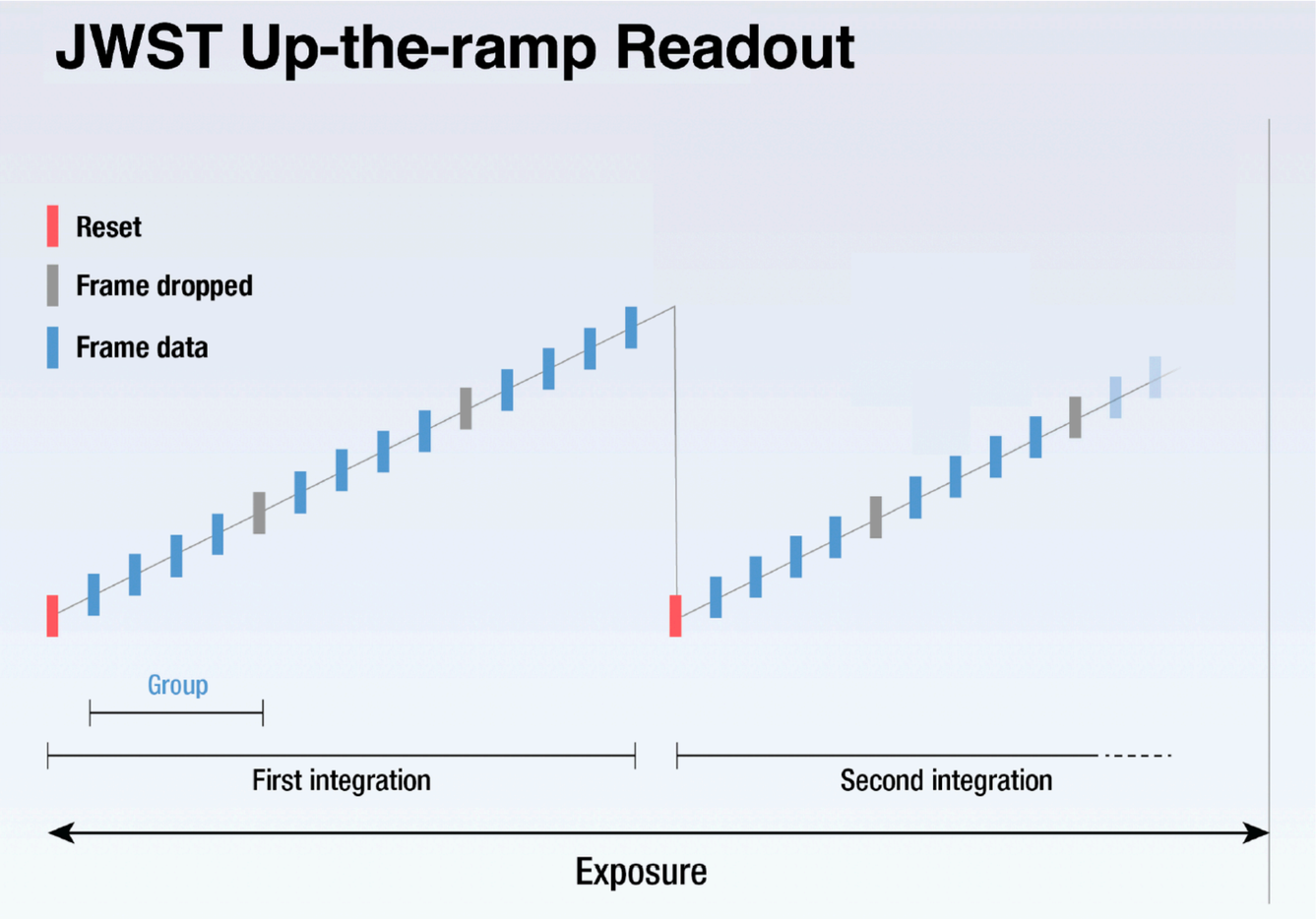
– https://jwst-pipeline.readthedocs.io/en/latest/index.html

JWST Calibration Pipeline



JWST Calibration Pipeline

JWST Measurement = Ramp → Slope

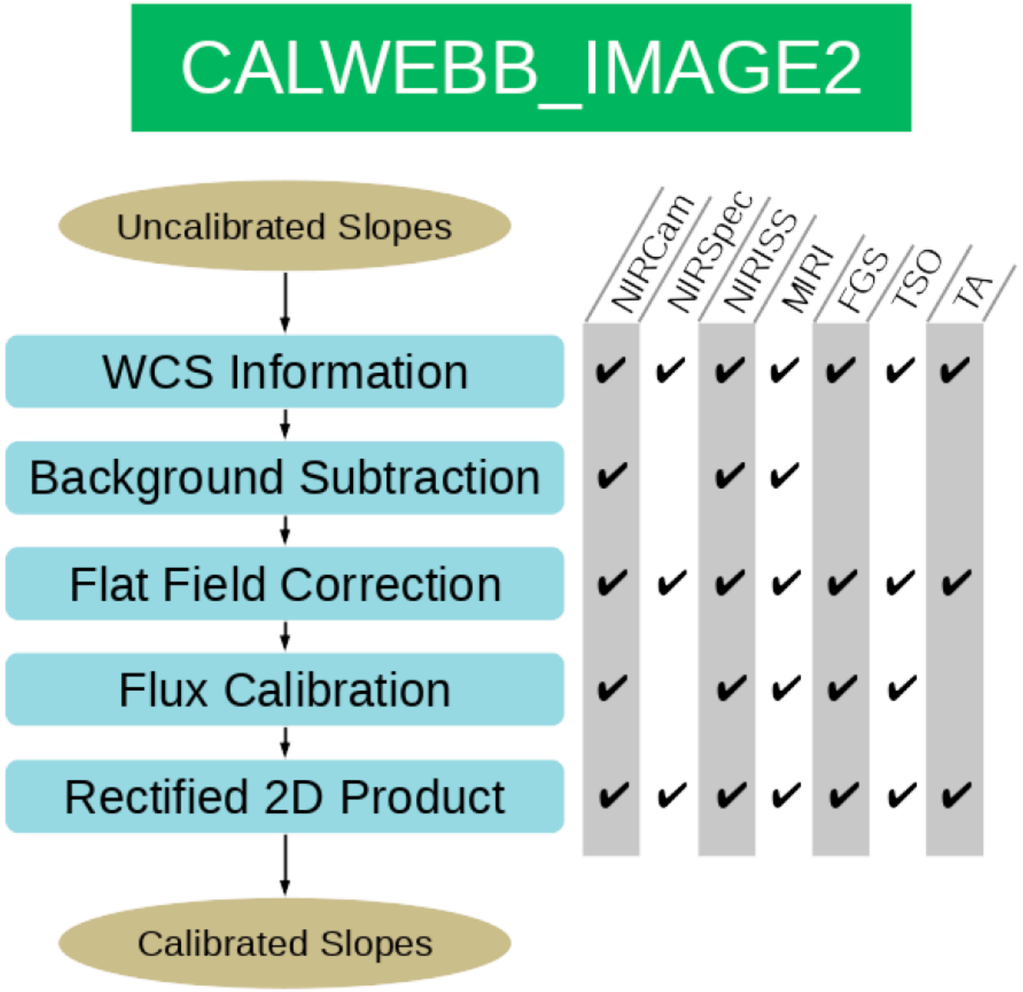


JWST Calibration Pipeline: Detector 1

Many instrumental level effects corrected or accounted for:

1. Saturation: Saturation above some Signal (DN) Value: Groups flagged and not used in slope fit
2. Reference Pixel Correction: Subtract an average of “reference” pixels (Reference pixels are non-photon seeing pixels that track variations in the electronic baselines)
3. Linearity Correction: Linearize the ramps based on appropriate reference file
4. Detect Jumps: Cosmic rays inject step functions to ramps; Jumps flagged and not used in slope fit
5. Calculate Slope: Weighted linear fit; Uncertainty on slope from read and photon noise

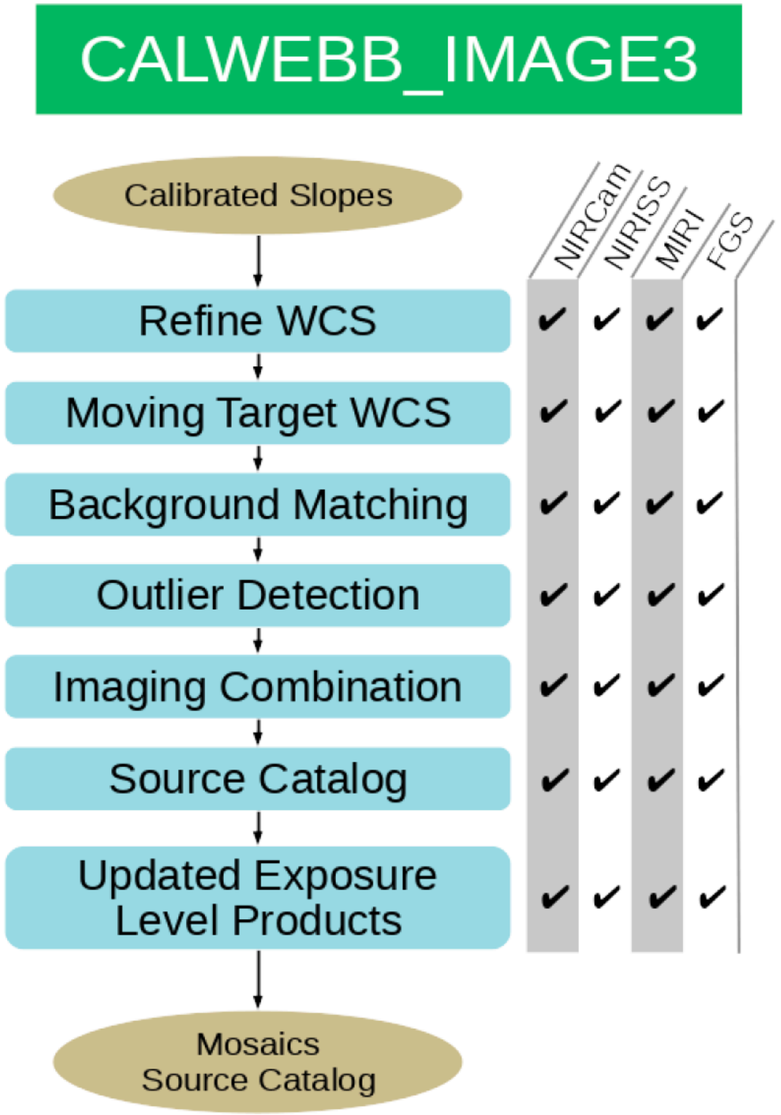
JWST Calibration Pipeline: CALWEBB_IMAGE2



JWST Calibration Pipeline: CALWEBB_IMAGE2

1. GWCS Information: Add Generalized Word Coordinate System (GWGS) information to the data
2. Background Subtraction: Subtract any dedicated background images taken in the same filter
3. Flat Field Correction: Correct for variations in responsivity, illumination, and varying pixel sizes; Divide by the appropriate flat field given as a reference file
4. Flux Calibration: Multiply image by the appropriate calibration factor; Calibrated units are MJy/sr

JWST Calibration Pipeline: CALWEBB_IMAGE3



JWST Calibration Pipeline: CALWEBB_IMAGE3

1. Refine GWCS: Use the location of point sources (e.g., Gaia and other astrometric catalogs)
2. Background Matching: Equalize the background using overlapping regions between images
3. Outlier Detect: Detect outliers using overlapping regions; Outliers found when n-sigma from the average; Outliers flagged and not used
4. Imaging Combination: Combine images into a single coadded mosaic (“drizzle”); Uncertainty mosaics created
5. Source Catalog: Using standard aperture photometry algorithms

JWST Calibration Pipeline

1. Stage 1 — Detector-level corrections and ramp fitting, outputs an uncalibrated slope image in units of DN/sec
2. Imaging striping (1/f noise)
3. Stage 2 — instrumental corrections and calibrations to the slope images, outputs a calibrated, unrectified image in units of MJy/sr
4. Sky Subtraction
5. Stage 3 — combining one or more calibrated images into a final mosaic, outputs a mosaic in units of MJy/sr and photometry catalog

NIRCam Features and Caveats

- https://jwst-docs.stsci.edu/jwst-near-infrared-camera/nircam-features-and-caveats
- Scattered light artifacts:
  - **Dragon's breath type I** artifacts are due to bright sources just off the edge (within 2") of the NIRCam field of view scattering light onto the NIRCam detectors.
  - **Dragon's breath type II** artifacts are caused by bright sources ~12" from the detectors in the field of view. They are only seen in short wavelength images.
  - **Claws** are artifacts created by an extremely bright star (K ~< 3 Vega mag) ~10° from the target observation in the +V3 direction.
  - **Wisps** are stationary features that always appear in the same locations, most prominently on the B4 detector, and sometimes detected on the A3 and B3 detectors. During data analysis, they may be subtracted by a template that has been developed and is available in the NIRCam Claws and Wisps article.
  - **Ginkgo Leaf** artifacts have been observed in long wavelength module A images due to a star out of the field to the left (+V2) and ~24.5" below the top edge (in V3) of the detector A5.
  - **Tadpoles** are artifacts in NIRCam WFSS data that may be mistaken for emission line galaxies. They are most prominent and ubiquitous in grism C module B data.
  - **Shells** are fainter WFSS artifacts that appear occasionally due to scattered light from very bright sources.

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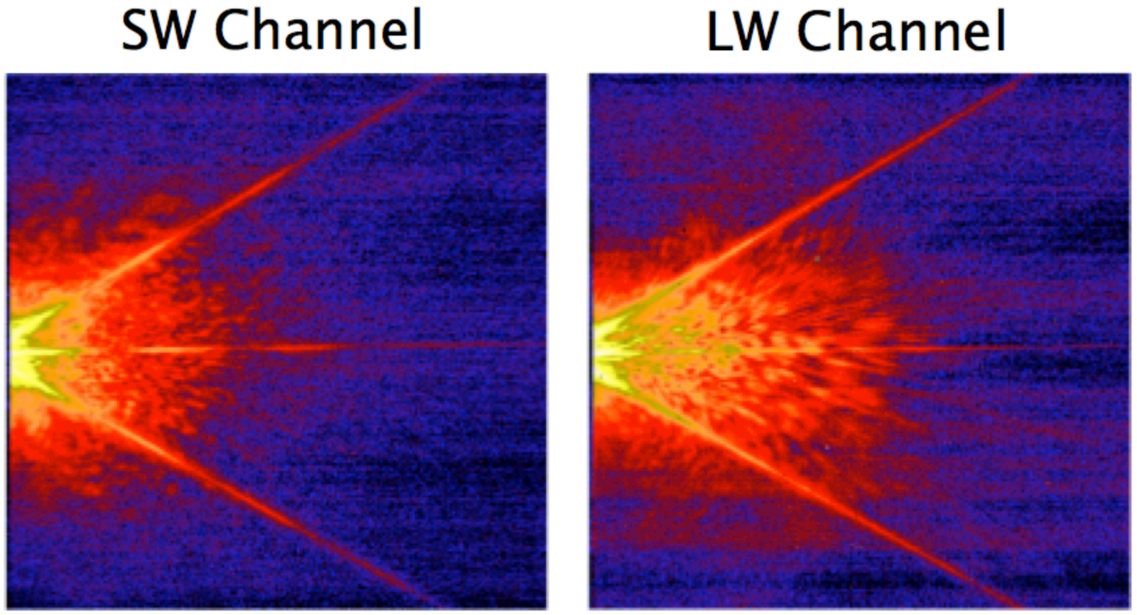

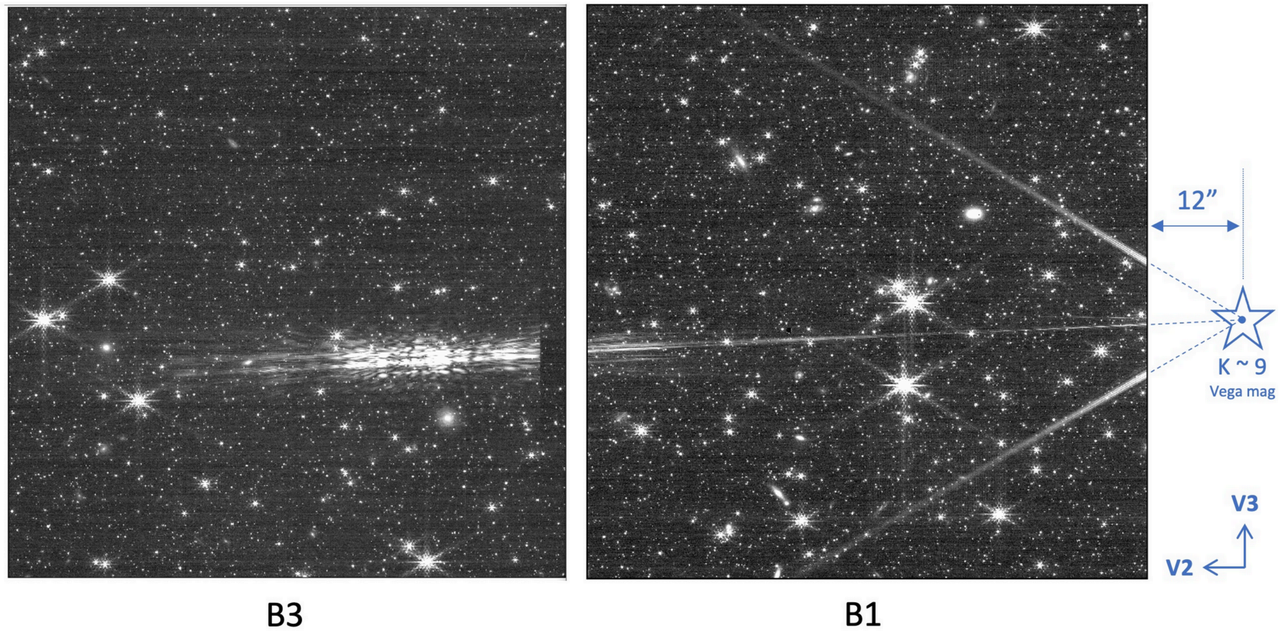

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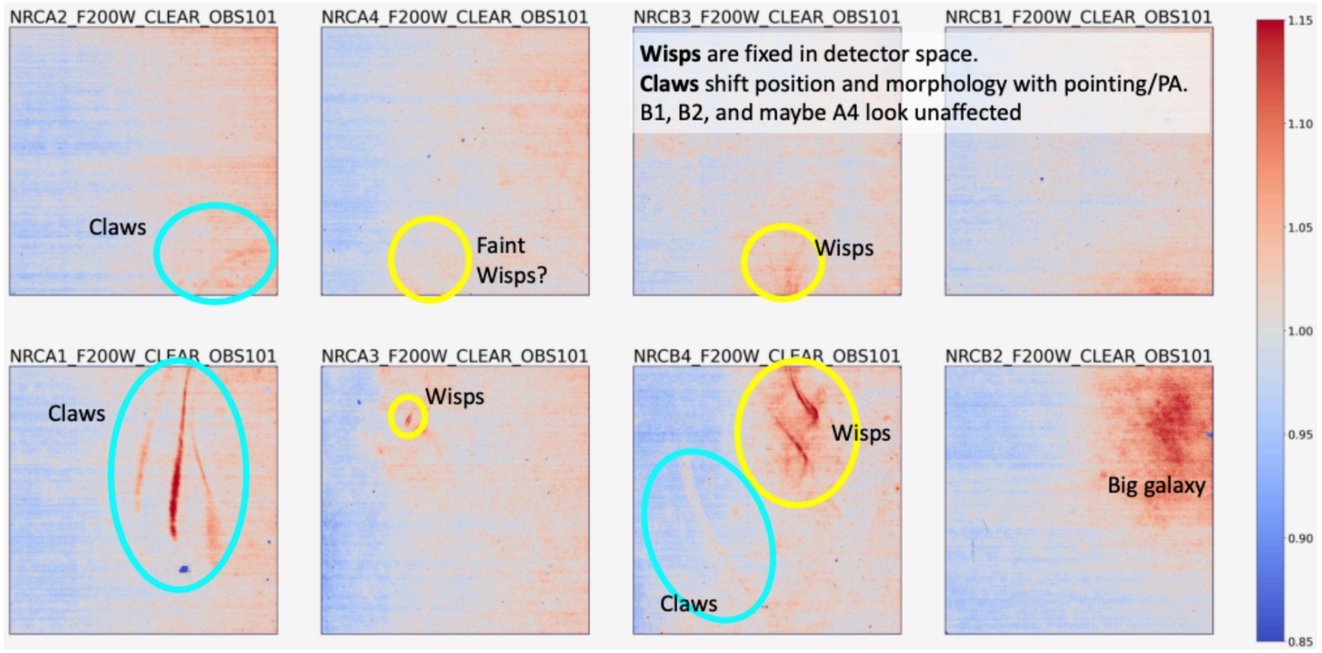

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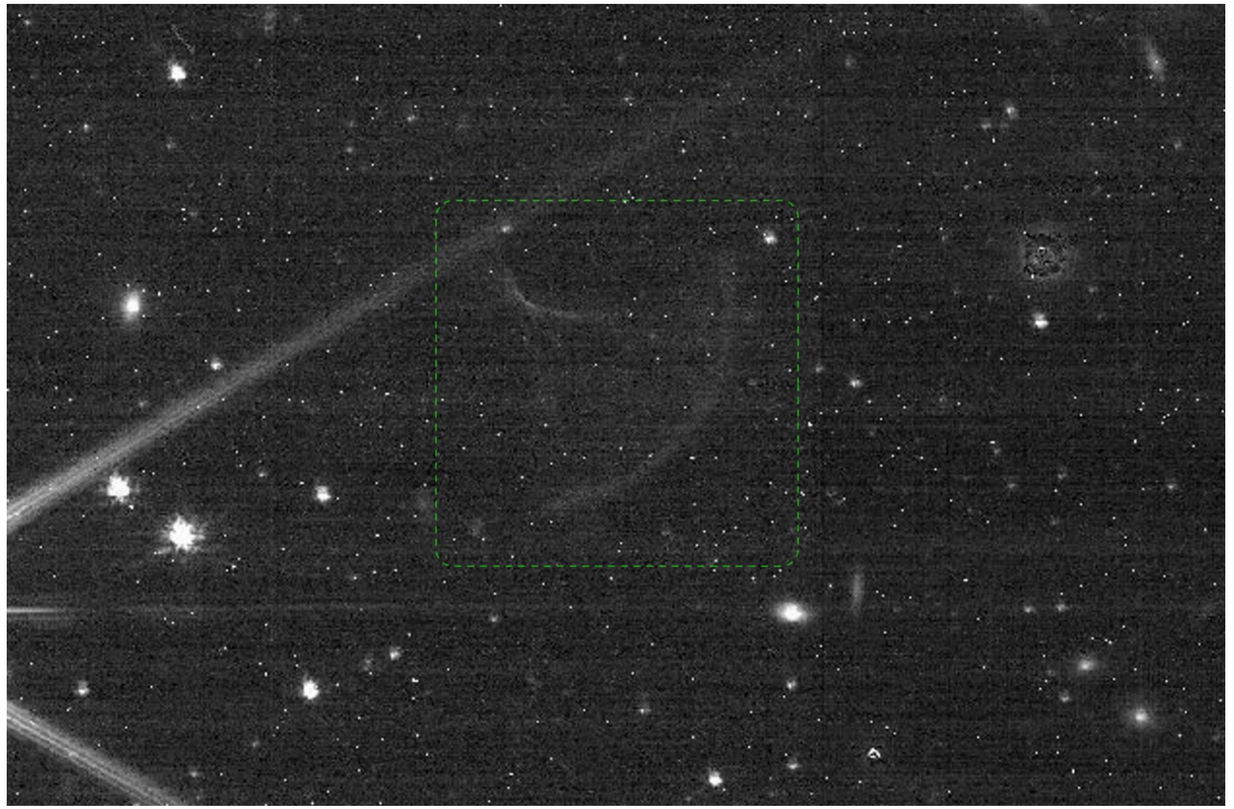

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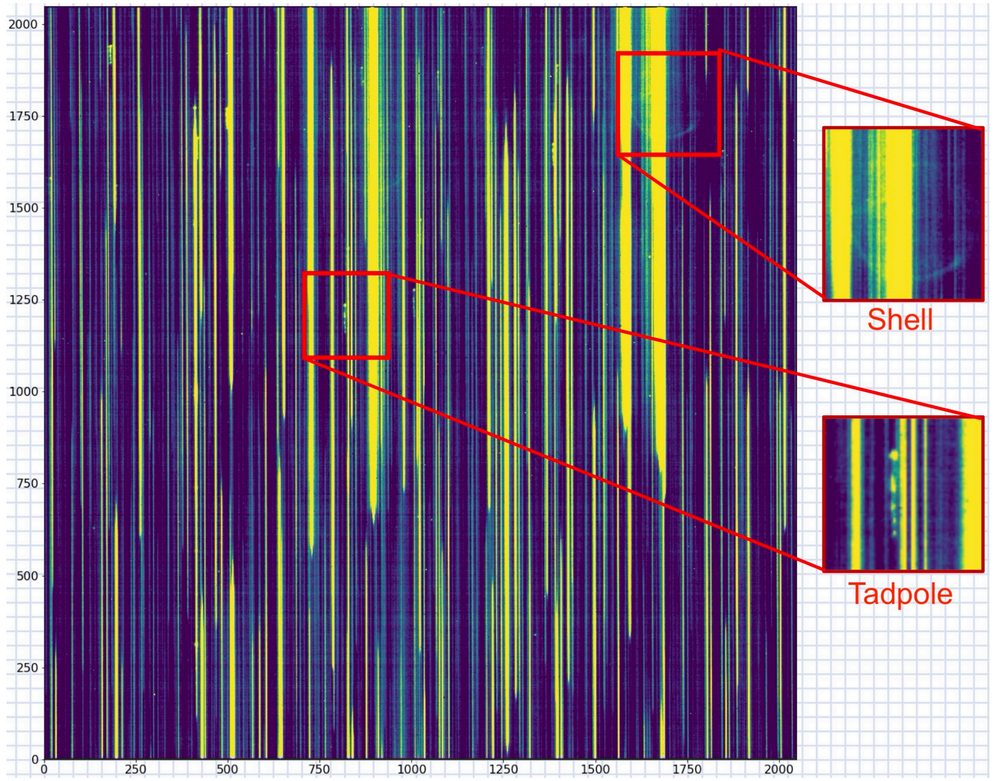

NIRCam Features and Caveats

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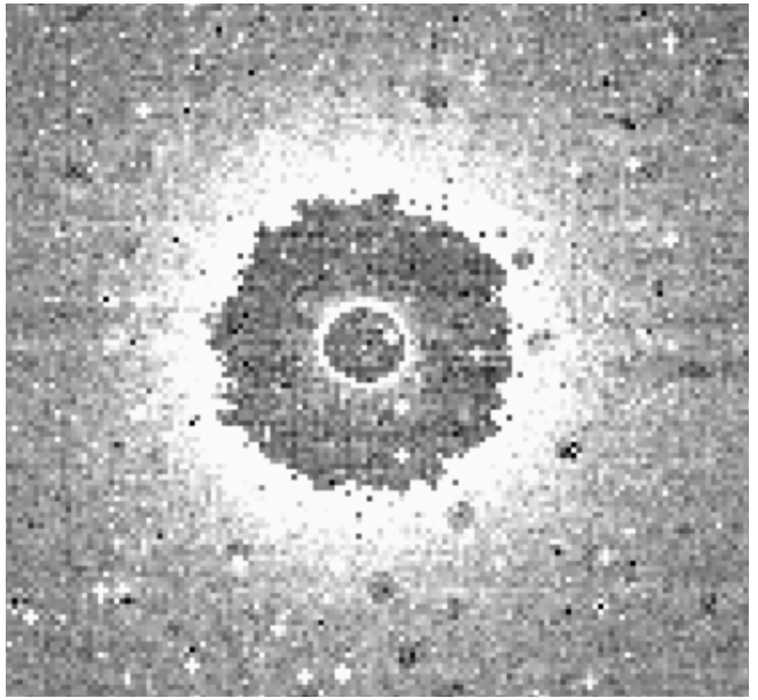
- Scattered light artifacts
- **Snowballs:** Extreme cosmic ray impacts introduce large artifacts in near-IR detectors named snowballs that are not currently corrected by the pipeline. Most snowballs appear round. Some are elongated. Some have long tails or streaks. None of these features are properly flagged as cosmic rays by the current pipeline.



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- Snowballs
- **Persistence:** Bright sources produce faint residual images that persist in subsequent integrations. This persistence declines exponentially in the detector pixels subjected to illumination.