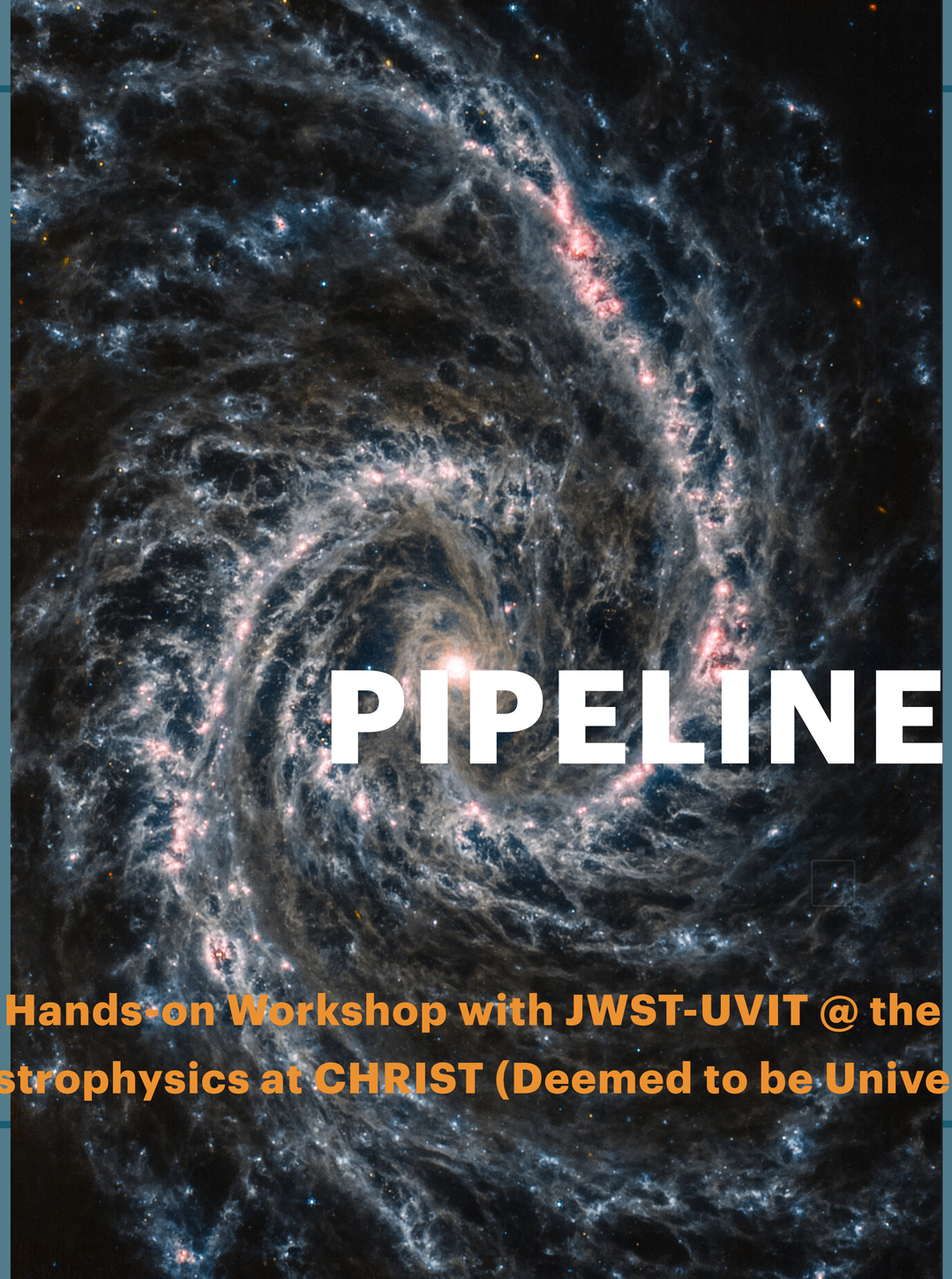


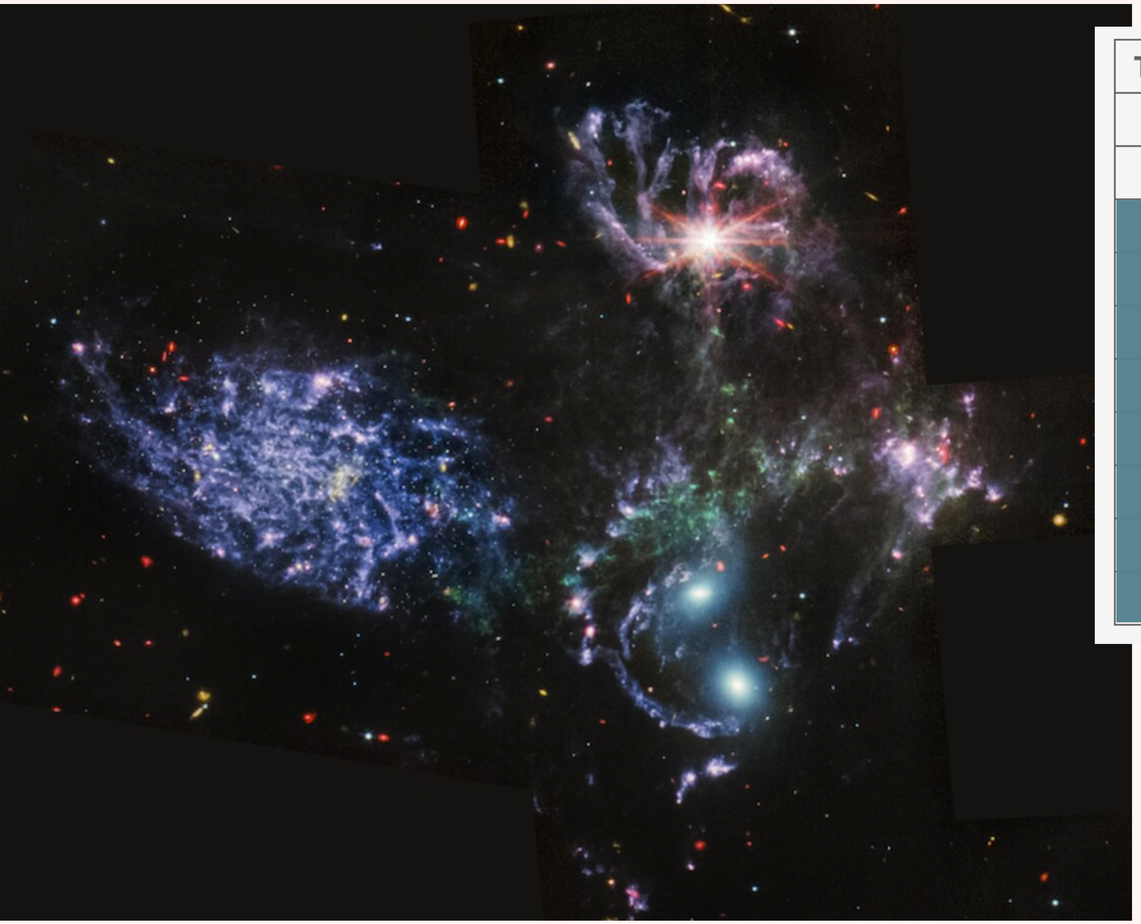
presented by Stacey Alberts (STScI)

PIPELINE REDUCTION FOR JWST IMAGING

A Hands-on Workshop with JWST-UVIT @ the Center for Excellence in Astronomy and Astrophysics at CHRIST (Deemed to be University), Bangalore, India

MIRI Imaging Demo

https://jwst-pipeline.readthedocs.io/en/stable/jwst/data_products/file_naming.html



Target: Stephan's Quintet		
Proposal ID	02732	Program number
OBSERVTN	002	Observation number
Filters	F770W;F1000W;F1500W	
SUBARRAY	FULL	Subarray used
NINTS	1/1/2	Number of integrations in exposure/filter
NGROUPS	60/60/30	Number of groups in integration/filter
DURATION	149.464/805.258 [s], depending on filters	Total duration of one exposure
READPATT	FASTR1	Readout Pattern
PATTTYPE	Cycling LARGE	Dither pattern type
NUMDTHPT	8	Total number of points in dither pattern

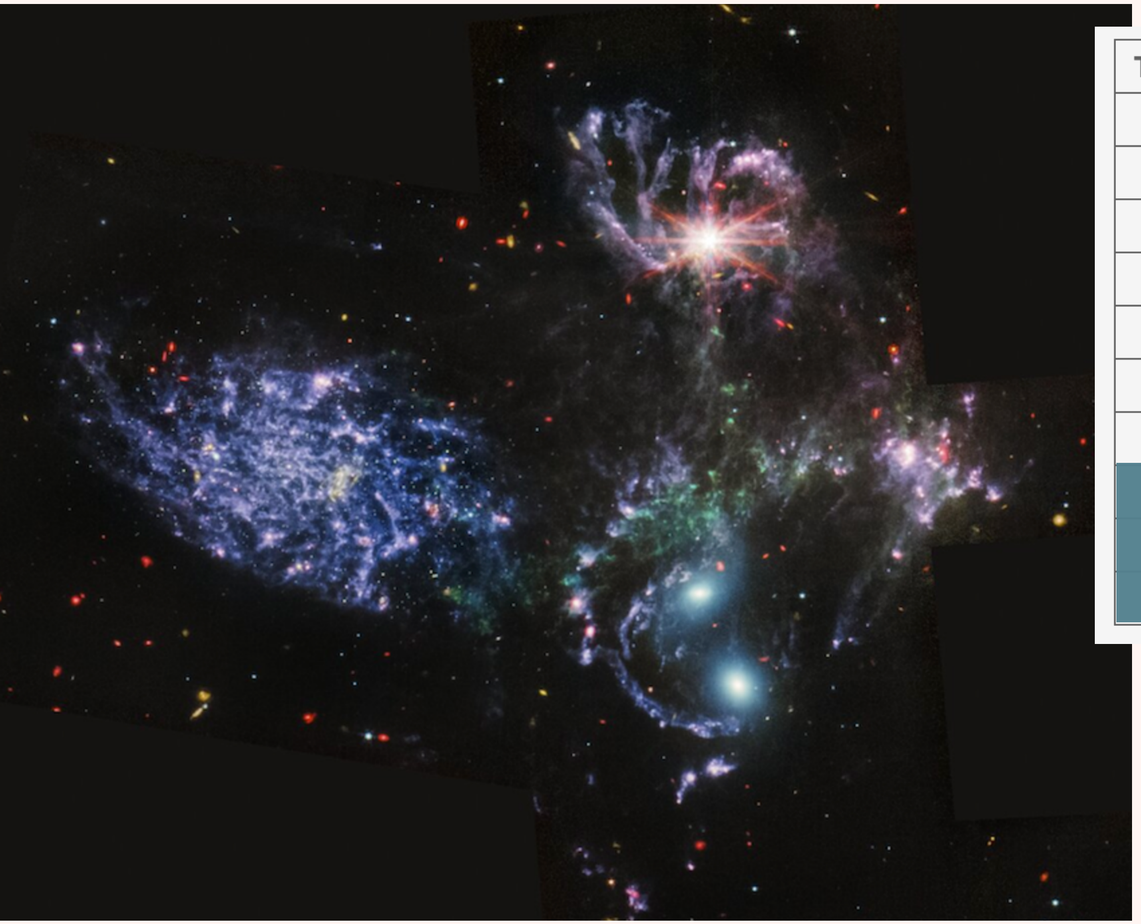
Product Type

jw02732002001_02101_00001_mirimage_uncal.fits

Program # ObsVisit (From APT) Dither #

MIRI Imaging Demo

https://jwst-pipeline.readthedocs.io/en/stable/jwst/data_products/file_naming.html



Target: Stephan's Quintet		
Proposal ID	02732	Program number
OBSERVTN	002	Observation number
Filters	F770W, F1000W, F1500W	
SUBARRAY	FULL	Subarray used
NINTS	1/1/2	Number of integrations in exposure/filter
NGROUPS	60/60/80	Number of groups in integration/filter
DURATION	149.464/805.258 [s], depending on filters	Total duration of one exposure
READPATT	FASTR1	Readout Pattern
PATTTYPE	Cycling LARGE	Dither pattern type
NUMDTHPT	8	Total number of points in dither pattern

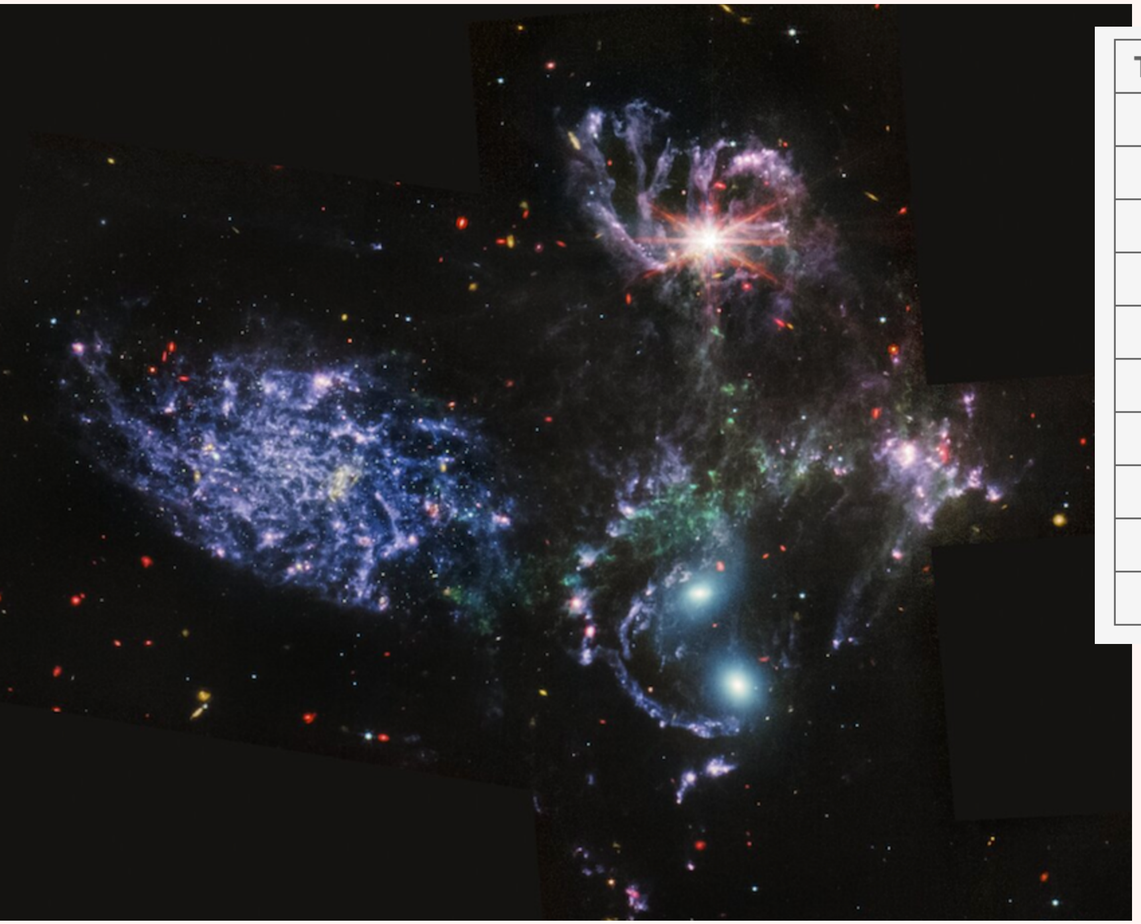
Product Type

jw02732002001_02101_00001_mirimage_uncal.fits

Program # ObsVisit (From APT) Dither #

MIRI Imaging Demo

https://jwst-pipeline.readthedocs.io/en/stable/jwst/data_products/file_naming.html



Target: Stephan's Quintet		
Proposal ID	02732	Program number
OBSERVTN	002	Observation number
Filters	F770W, F1000W, F1500W	
SUBARRAY	FULL	Subarray used
NINTS	1/1/2	Number of integrations in exposure/filter
NGROUPS	60/60/80	Number of groups in integration/filter
DURATION	149.464/805.258 [s], depending on filters	Total duration of one exposure
READPATT	FASTR1	Readout Pattern
PATTTYPE	Cycling LARGE	Dither pattern type
NUMDTHPT	8	Total number of points in dither pattern

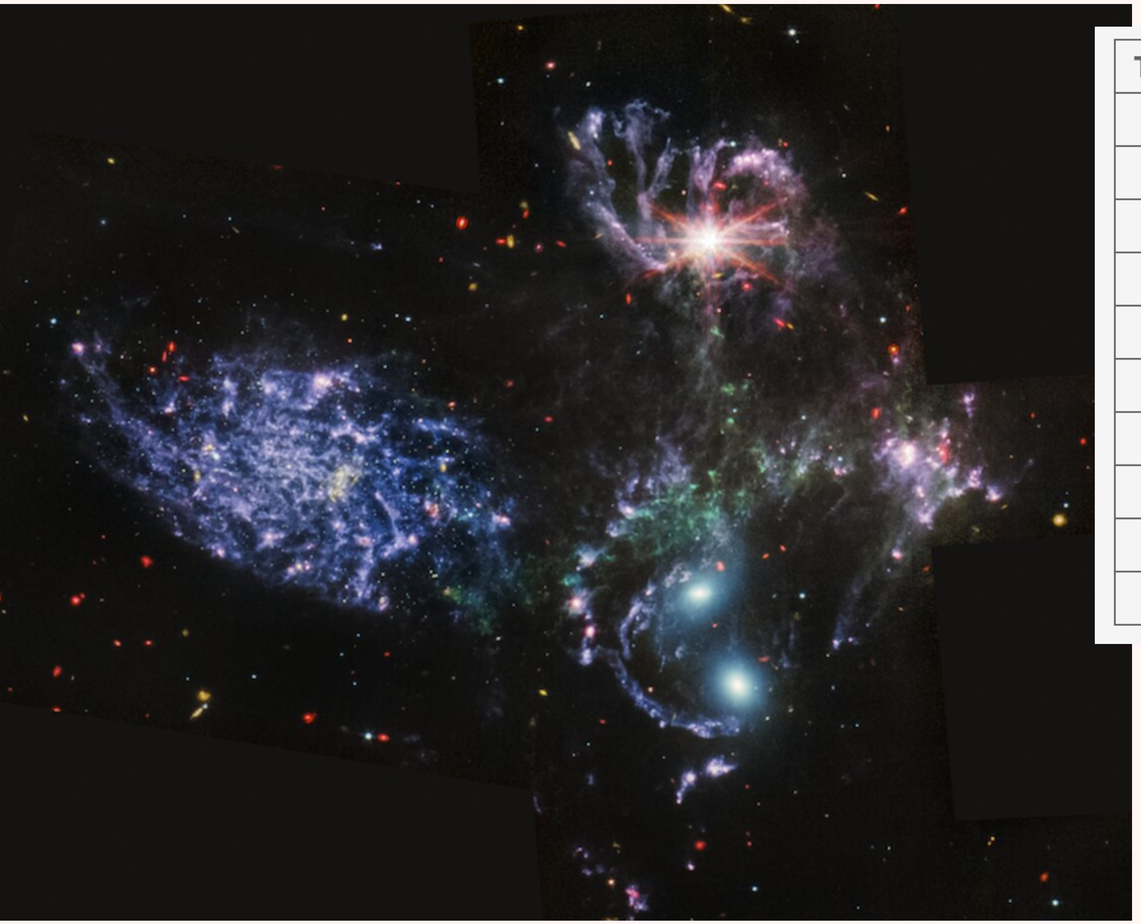
Product Type

jw02732002001_02101_00001_mirimage_uncal.fits

Program # ObsVisit (From APT) Dither #

MIRI Imaging Demo

https://jwst-pipeline.readthedocs.io/en/stable/jwst/data_products/file_naming.html



Target: Stephan's Quintet		
Proposal ID	02732	Program number
OBSERVTN	002	Observation number
Filters	F770W, F1000W, F1500W	
SUBARRAY	FULL	Subarray used
NINTS	1/1/2	Number of integrations in exposure/filter
NGROUPS	60/60/80	Number of groups in integration/filter
DURATION	149.464/805.258 [s], depending on filters	Total duration of one exposure
READPATT	FASTR1	Readout Pattern
PATTTYPE	Cycling LARGE	Dither pattern type
NUMDTHPT	8	Total number of points in dither pattern

Product Type

jw02732002001_02101_00001_mirimage_uncal.fits

Program # ObsVisit (From APT) Dither #

READOUT MODES

MIRI: so easy!

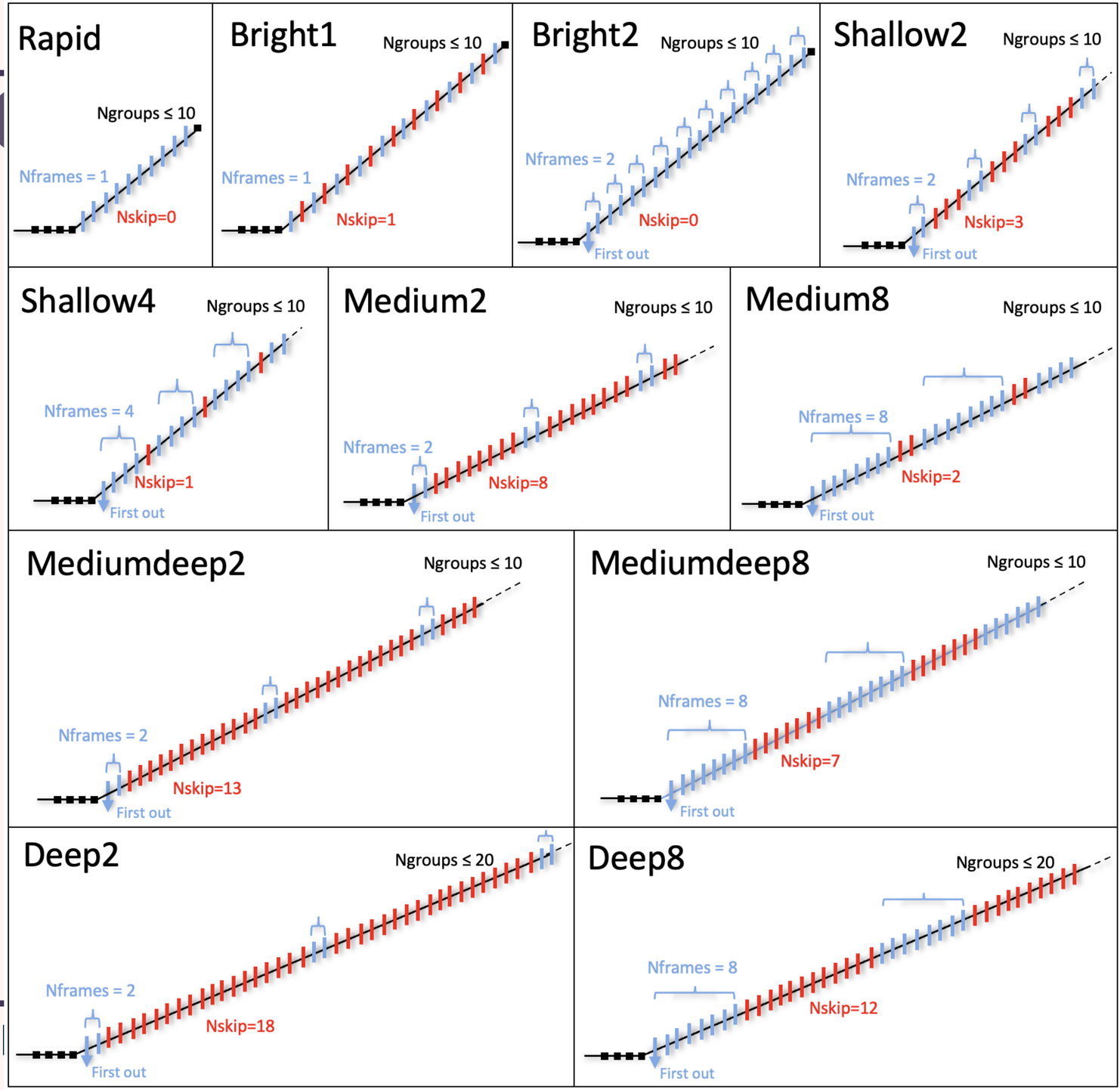
1. ***SLOWR1*** ($N_{samples}$ = 9, t_1 = 23.890 s)
2. ***FASTR1*** ($N_{samples}$ = 1, t_1 = 2.775 s)

USE FASTR1 UNLESS YOU HAVE DATA RATE ISSUES

READ

NIRCam: yikes!

- Averaging more groups lowers readout noise but increases cosmic ray problems
- Larger number of groups is better against cosmic rays
- Ultimately, need to test with ETC for best exposure setup (but watch saturation and data rates!)



But how do I even know where to start with readout modes and groups and integrations and dithers and… ?????

JDOX RECOMMENDED STRATEGIES AND BEST PRACTICES PAGES

MIRI Observing Strategies

MIRI-specific guidance for preparing observing programs using each of the 4 main observing modes, as well as time-series observations, are provided in this article.

See also: MIRI Example Science Programs, Methods and Roadmaps

Observers will have to make a series of choices concerning detector usage, dither options, and background observations among others. The following articles contain recommendations that are meant to help observers optimize their programs and obtain the best science output.

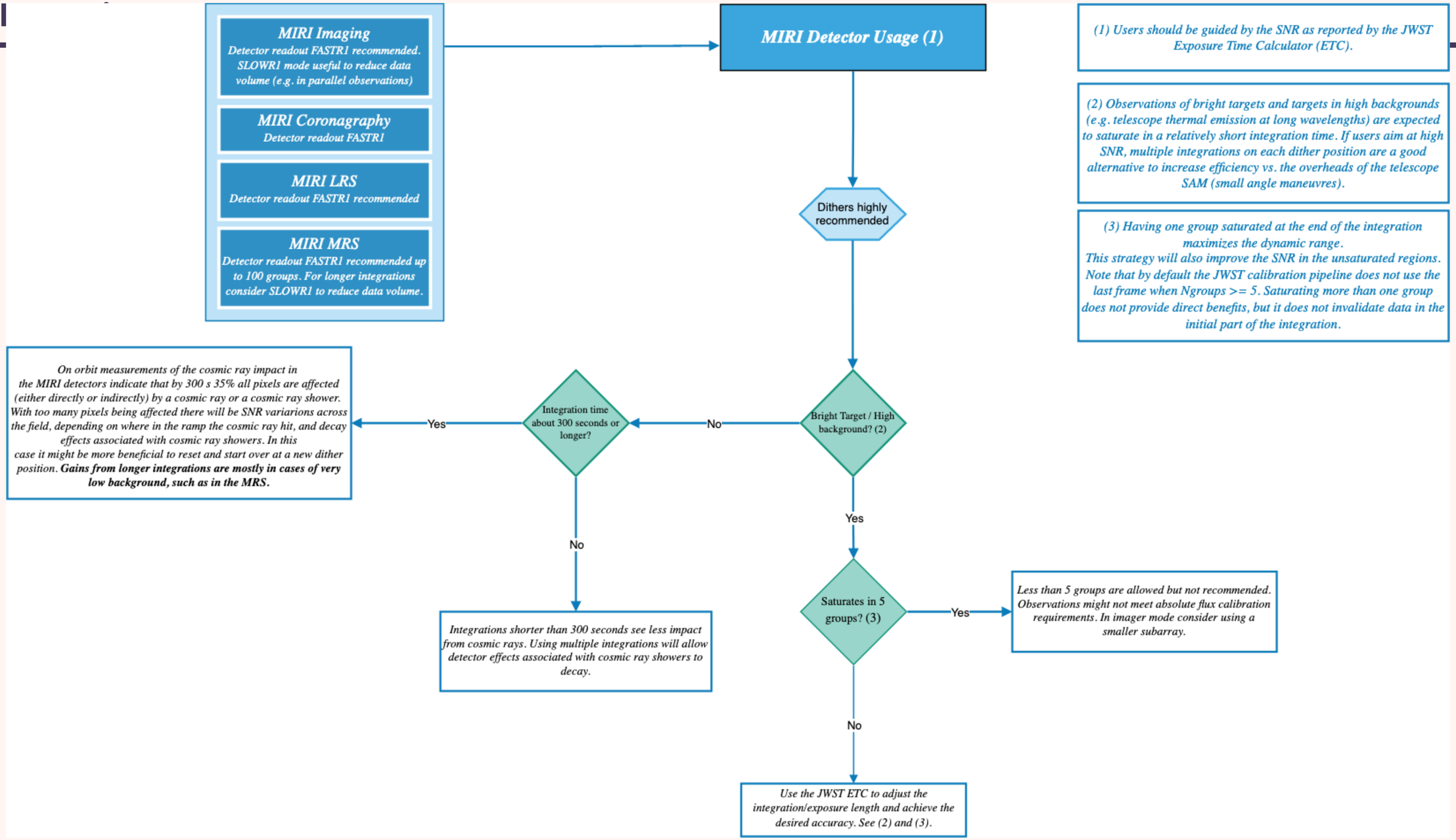
MIRI Observing Strategies

- MIRI Cross-Mode Recommended Strategies
- MIRI Imaging Recommended Strategies
- MIRI Coronagraphic Recommended Strategies
- MIRI LRS Recommended Strategies
- MIRI MRS Recommended Strategies
- MIRI TSO Recommended Strategies
- MIRI WFSS Recommended Strategies

MIRI Cross-Mode Recommended Strategies are not dependent on the observing mode, and cover aspects like:

- Detector usage and exposure set-up
- Background strategies
- Target acquisition

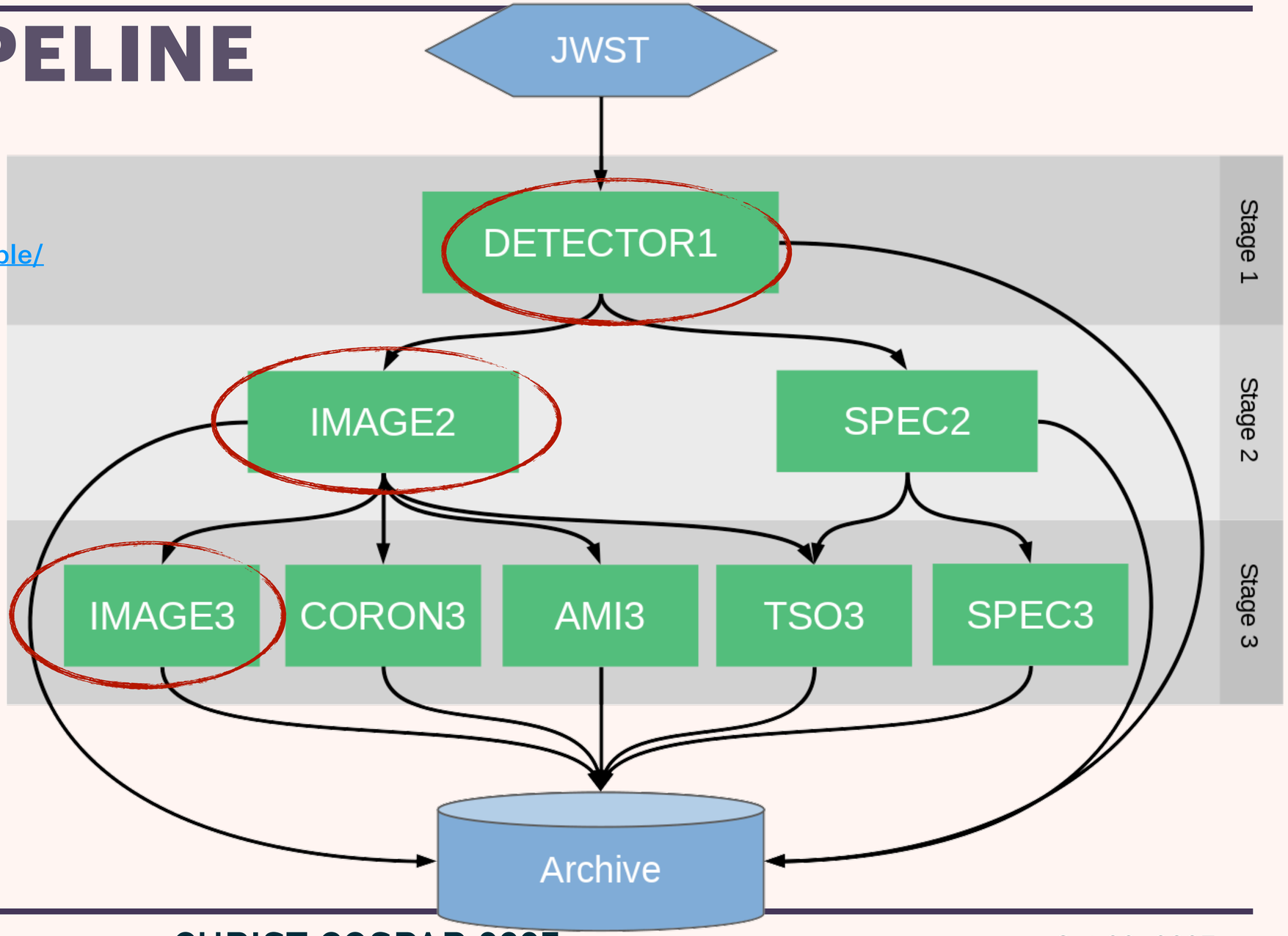
https://jwst-docs.stsci.edu/jwst-mid-infrared-instrument/miri-observing-strategies/miri-cross-mode-recommended-strategies#gsc.tab=0


MIRI Imaging
Detector readout FASTR1 recommended. SLOWR1 mode useful to reduce data volume (e.g. in parallel observations)
MIRI Coronagraphy
Detector readout FASTR1
MIRI LRS
Detector readout FASTR1 recommended
MIRI MRS
Detector readout FASTR1 recommended up to 100 groups. For longer integrations consider SLOWR1 to reduce data volume.
MIRI Detector Usage (1)
(1) Users should be guided by the SNR as reported by the JWST Exposure Time Calculator (ETC).
(2) Observations of bright targets and targets in high backgrounds (e.g. telescope thermal emission at long wavelengths) are expected to saturate in a relatively short integration time. If users aim at high SNR, multiple integrations on each dither position are a good alternative to increase efficiency vs. the overheads of the telescope SAM (small angle maneuvres).
(3) Having one group saturated at the end of the integration maximizes the dynamic range.
This strategy will also improve the SNR in the unsaturated regions. Note that by default the JWST calibration pipeline does not use the last frame when Ngroups >= 5. Saturating more than one group does not provide direct benefits, but it does not invalidate data in the initial part of the integration.
Dithers highly recommended
Bright Target / High background? (2)
No
Integration time about 300 seconds or longer?
Yes
On orbit measurements of the cosmic ray impact in the MIRI detectors indicate that by 300 s 35% all pixels are affected (either directly or indirectly) by a cosmic ray or a cosmic ray shower. With too many pixels being affected there will be SNR variarions across the field, depending on where in the ramp the cosmic ray hit, and decay effects associated with cosmic ray showers. In this case it might be more beneficial to reset and start over at a new dither position. Gains from longer integrations are mostly in cases of very low background, such as in the MRS.
No
Integrations shorter than 300 seconds see less impact from cosmic rays. Using multiple integrations will allow detector effects associated with cosmic ray showers to decay.
Yes
Saturates in 5 groups? (3)
Yes
Less than 5 groups are allowed but not recommended. Observations might not meet absolute flux calibration requirements. In imager mode consider using a smaller subarray.
No
Use the JWST ETC to adjust the integration/exposure length and achieve the desired accuracy. See (2) and (3).

THE JWST PIPELINE

PIPELINE READTHEDOCS

https://jwst-pipeline.readthedocs.io/en/stable/



THE JWST PIPELINE

https://jwst-crds.stsci.edu/

All the reference files and defaults are set by the context (pmap)

Build Contexts

Cal Ver	Context
1.20.0	jwst_1462.pmap
1.19.1	jwst_1413.pmap
1.19.0	jwst_1410.pmap
1.18.1	jwst_1364.pmap
1.18.0	jwst_1364.pmap

- Calibration References Data System (CRDS)
  - export CRDS_PATH=$HOME/crds_cache
  - export CRDS_SERVER_URL=https://jwst-crds.stsci.edu

On Mac/Linux, put in something like the .bashrc file

DIRECTORY STRUCTURE

Parent directory: mir_im_demo
(JWPipeNB-MIRI-imaging-COSPAR_Workshop.ipynb in parent directory)

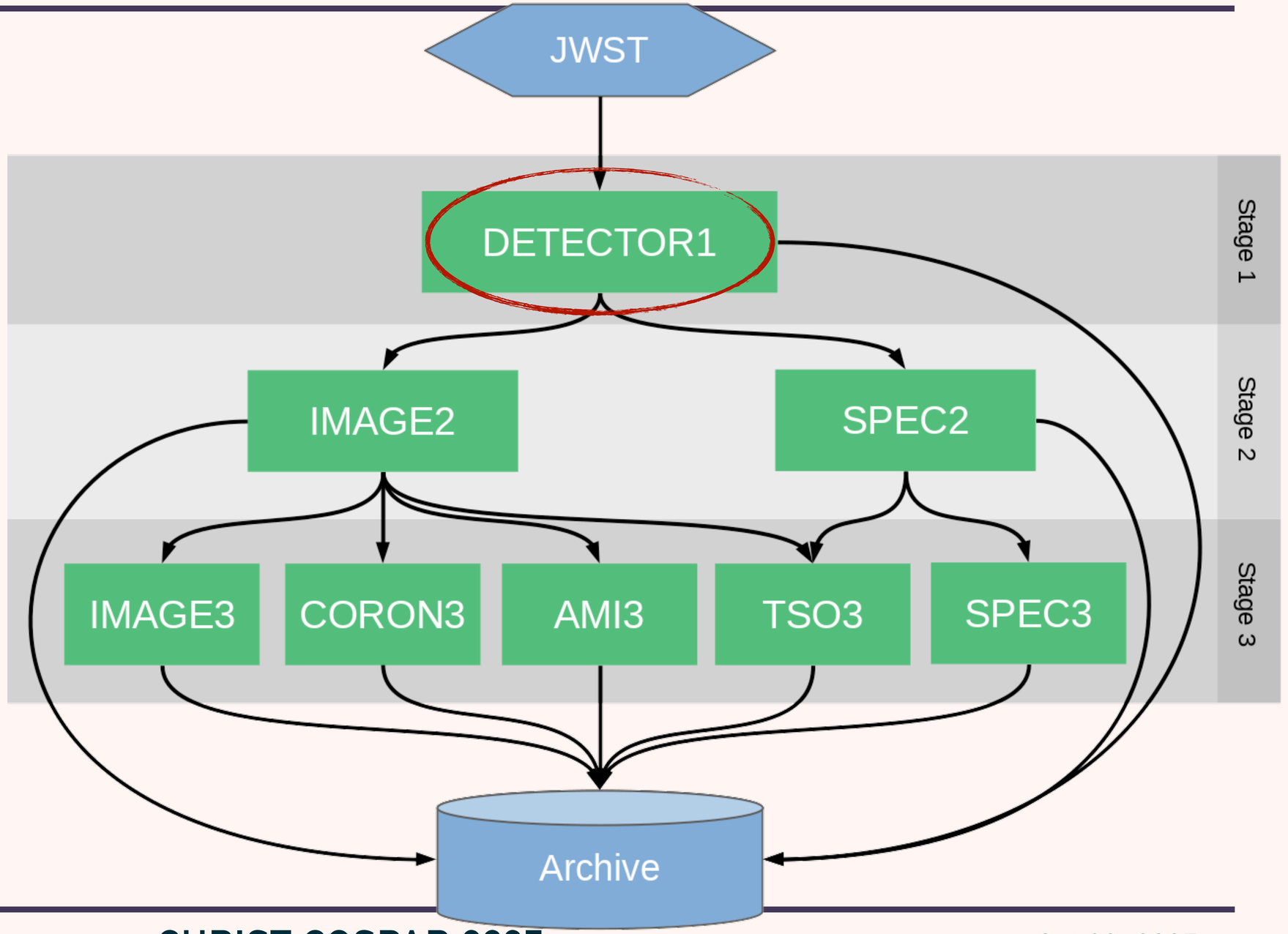
CRDS directory: mir_im_demo/crds_cache

Data directory: mir_im_demo/mir_im_demo_data

```
uncal_dir = os.path.join(sci_dir, 'uncal')  # Uncalibrated pipeline inputs should be here
det1_dir = os.path.join(sci_dir, 'stage1')  # calwebb_detector1 pipeline outputs will go here
image2_dir = os.path.join(sci_dir, 'stage2')  # calwebb_image2 pipeline outputs will go here
image3_dir = os.path.join(sci_dir, 'stage3')  # calwebb_image3 pipeline outputs will go here
```

STAGE 1

- Detector-level corrections and ramp fitting
- Input **uncal** files
- Output **rate** (individual exposures) and **rateints** (individual integrations in extensions) files

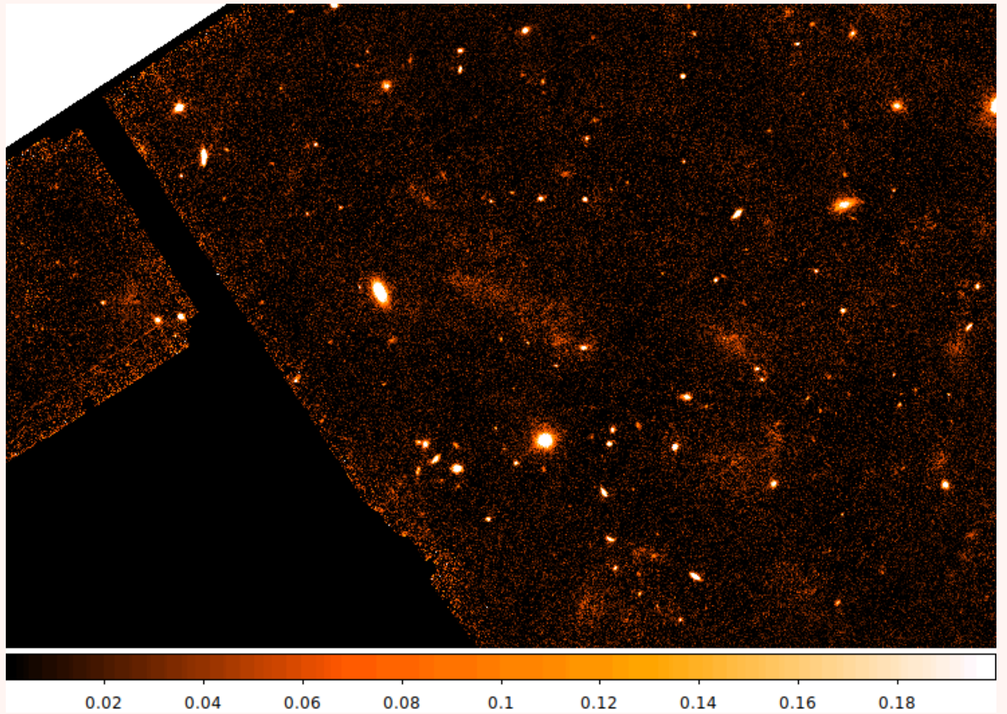


MIRI Imaging Demo

MIRI		
Step	**Non-TSO**	**TSO**
~~group_scale~~	✓	✓
dq_init	✓	✓
emicorr	✓	✓
saturation	✓	✓
~~ipc~~		
firstframe	✓	
lastframe	✓	
reset	✓	✓
linearity	✓	✓
rscd	✓	
dark_current	✓	✓
refpix		
jump	✓	✓
~~clean_flicker_noise~~	✓	✓
ramp_fitting	✓	✓
~~gain_scale~~	✓	✓

```
# Boilerplate dictionary setup
det1dict = {}
det1dict['group_scale'], det1dict['dq_init'], det1dict['emicorr'] = {}, {}, {}
det1dict['saturation'], det1dict['firstframe'], det1dict['lastframe'] = {}, {}, {}
det1dict['reset'], det1dict['linearity'], det1dict['rscd'] = {}, {}, {}
det1dict['dark_current'], det1dict['refpix'], det1dict['jump'] = {}, {}, {}
det1dict['ramp_fit'], det1dict['gain_scale'] = {}, {}
```

Contains the correction for cosmic ray showers (Only up to F1500W)



Gif Credit: Pablo Perez Gonzalez

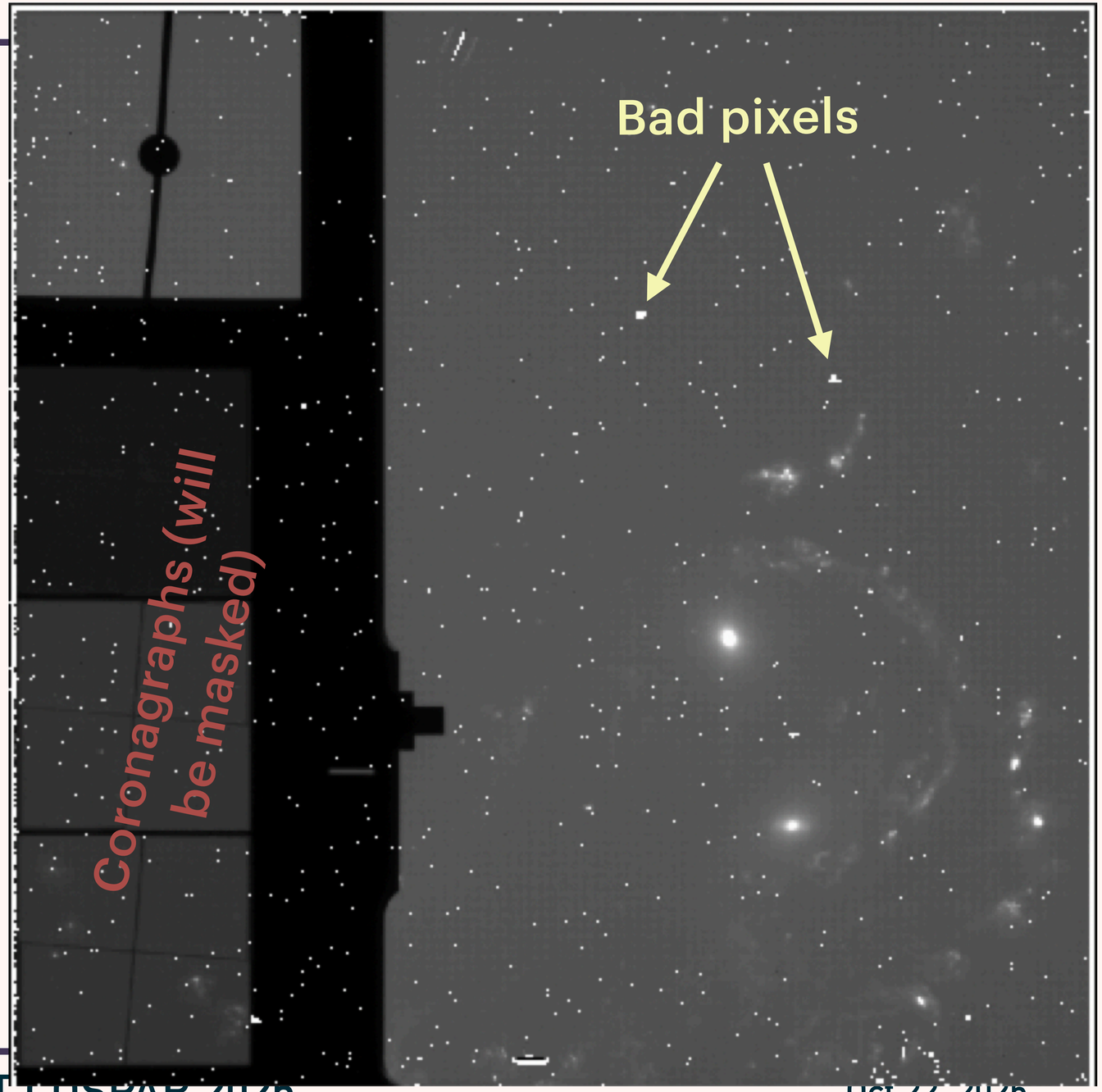
STAGE 1 - RATE FILES

Cell 38

```
{'charge_migration': 'SKIPPED',
 'clean_flicker_noise': 'SKIPPED',
 'dark_sub': 'COMPLETE',
 'dq_init': 'COMPLETE',
 'emicorr': 'COMPLETE',
 'firstframe': 'COMPLETE',
 'gain_scale': 'SKIPPED',
 'group_scale': 'SKIPPED',
 'ipc': 'SKIPPED',
 'jump': 'COMPLETE',
 'lastframe': 'COMPLETE',
 'linearity': 'COMPLETE',
 'ramp_fit': 'COMPLETE',
 'refpix': 'SKIPPED',
 'reset': 'COMPLETE',
 'rscd': 'COMPLETE',
 'saturation': 'COMPLETE'}

{'crds': {'context_used': 'jwst_1413.pmap', 'sw_version': '13.0.6'},
 'dark': {'name': 'crds://jwst_miri_dark_0113.fits'},
 'emicorr': {'name': 'crds://jwst_miri_emicorr_0003.asdf'},
 'gain': {'name': 'crds://jwst_miri_gain_0034.fits'},
 'linearity': {'name': 'crds://jwst_miri_linearity_0032.fits'},
 'mask': {'name': 'crds://jwst_miri_mask_0036.fits'},
 'readnoise': {'name': 'crds://jwst_miri_readnoise_0085.fits'},
 'reset': {'name': 'crds://jwst_miri_reset_0077.fits'},
 'rscd': {'name': 'crds://jwst_miri_rscd_0017.fits'},
 'saturation': {'name': 'crds://jwst_miri_saturation_0034.fits'},
 'superbias': {'name': 'N/A'}}
```

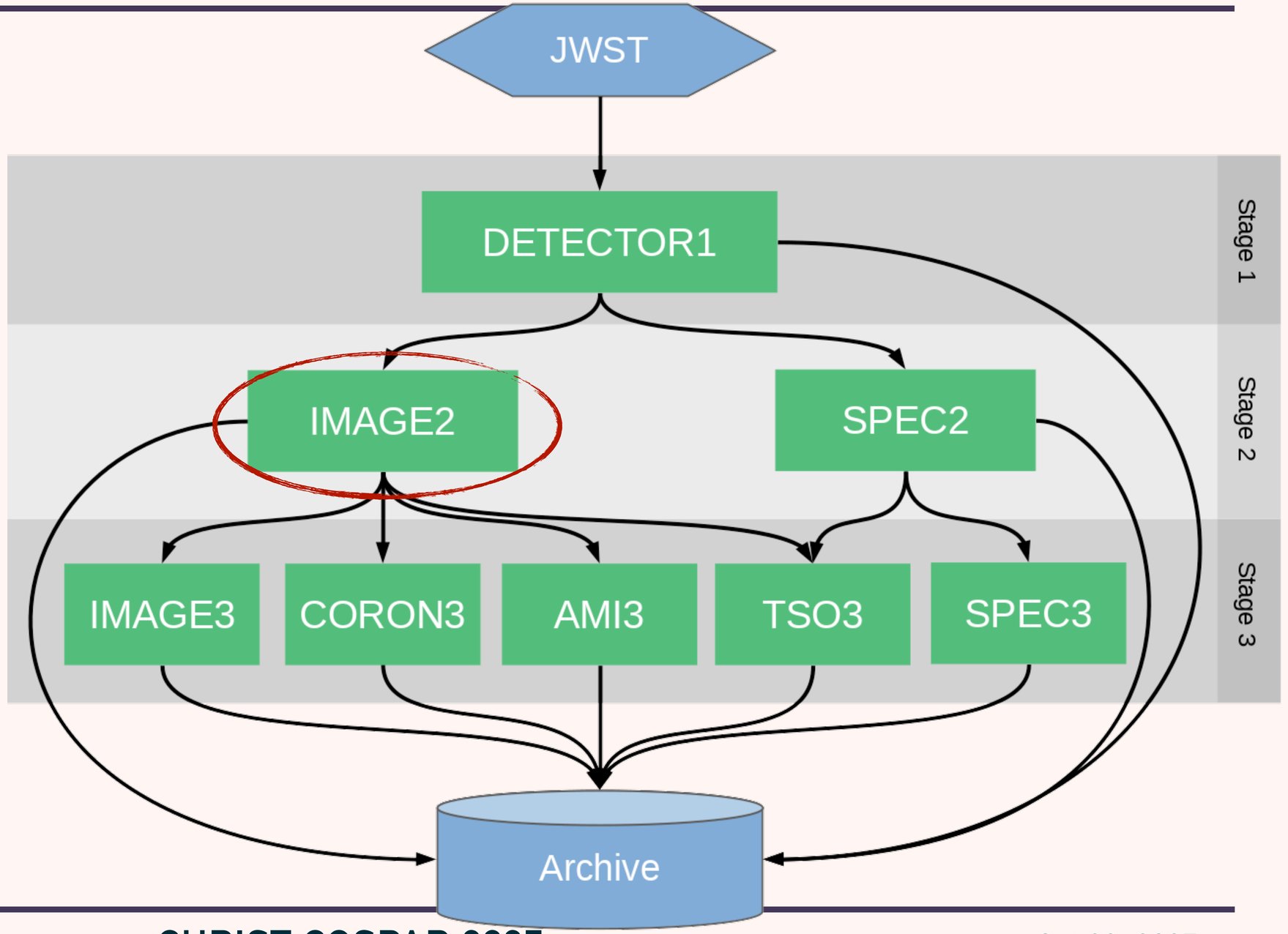
```
        CRDS parameters

CRDS_VER= '13.0.6  '           / Version of CRDS file selection software used
CRDS_CTX= 'jwst_1413.pmap'     / CRDS context (.pmap) used to select ref files

        Dark reference file information

R_DARK  = 'crds://jwst_miri_dark_0113.fits' / Dark reference file name

        MIRI EMI reference file information

R_MIREMI= 'crds://jwst_miri_emicorr_0003.asdf' / MIRI EMI correction reference f

        Gain reference file information

R_GAIN  = 'crds://jwst_miri_gain_0034.fits' / Gain reference file name

        Linearity reference file information

R_LINEAR= 'crds://jwst_miri_linearity_0032.fits' / Linearity reference file name

        Mask reference file information

R_MASK  = 'crds://jwst_miri_mask_0036.fits' / Mask reference file name

        Read noise reference file information

R_READNO= 'crds://jwst_miri_readnoise_0085.fits' / Read noise reference file nam

        Reset reference file information

R_RESET = 'crds://jwst_miri_reset_0077.fits' / Reset reference file name

        RSCD reference file information

R_RSCD  = 'crds://jwst_miri_rscd_0017.fits' / RSCD reference file name

        Saturation reference file information

R_SATURA= 'crds://jwst_miri_saturation_0034.fits' / Saturation reference file na

        Superbias reference file information

R_SUPERB= 'N/A     '           / Superbias reference file name

        Calibration step information

S_CHGMIG= 'SKIPPED '           / Charge Migration
S_CLNFNS= 'SKIPPED '           / Clean Flicker Noise
S_DARK  = 'COMPLETE'           / Dark Subtraction
S_DQINIT= 'COMPLETE'           / Data Quality Initialization
S_MIREMI= 'COMPLETE'           / MIRI EMI Correction
S_FRSTFR= 'COMPLETE'           / First Frame Correction
S_GANSCL= 'SKIPPED '           / Gain Scale Correction
S_GRPSCL= 'SKIPPED '           / Group Scale Correction
S_IPC   = 'SKIPPED '           / Interpixel Capacitance Correction
S_JUMP  = 'COMPLETE'           / Jump Detection
S_LASTFR= 'COMPLETE'           / Last Frame Correction
S_LINEAR= 'COMPLETE'           / Linearity Correction
S_RAMP  = 'COMPLETE'           / Ramp Fitting
S_REFPIX= 'SKIPPED '           / Reference Pixel Correction
S_RESET = 'COMPLETE'           / Reset Anomaly Correction
S_RSCD  = 'COMPLETE'           / RSCD Correction
S_SATURA= 'COMPLETE'           / Saturation Checking
END
```

STAGE 1 - RATE FILES



STAGE 2

- Applies instrument calibration
- Input rate or rateint files
- Output cal and i2d files of individual exposures



STAGE 2

Step	Non-TSO	TSO
background	✓	
assign_wcs	✓	✓
flat_field	✓	✓
photom	✓	✓
resample [1]	✓	

Only automatic for dedicated backgrounds you linked in APT
(see intro presentation)

photometric calibration
(Changing slowly at long MIRI wavelengths)

Resamples individual exposures only
(Produces i2d files with distortion correction)

STAGE 2

Step	Non-TSO	TSO
background	✓	
assign_wcs	✓	✓
flat_field	✓	✓
photom	✓	✓
resample [1]	✓	

Only automatic for dedicated backgrounds you linked in APT
(see intro presentation)

photometric calibration
(Changing slowly at long MIRI wavelengths)

Resamples individual exposures only
(Produces i2d files with distortion correction)

STAGE 2

Step	Non-TSO	TSO
background	✓	
assign_wcs	✓	✓
flat_field	✓	✓
photom	✓	✓
resample [1]	✓	

How does the pipeline know??

Only automatic for dedicated backgrounds you linked in APT
(see intro presentation)

photometric calibration
(Changing slowly at long MIRI wavelengths)

Resamples individual exposures only
(Produces i2d files with distortion correction)

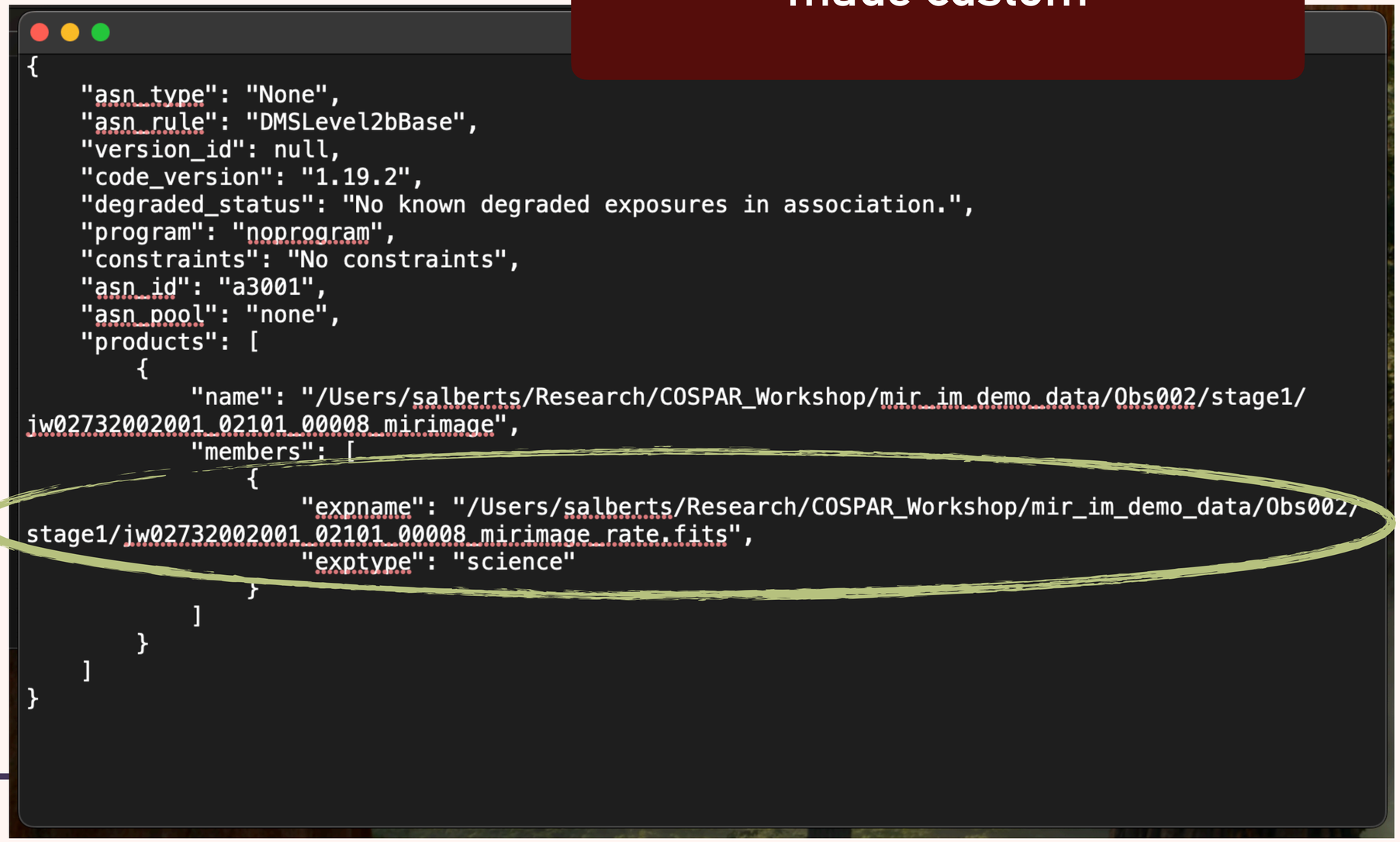
ASSOCIATION FILES

Formatted json files that tell the pipeline to associate files

Can be retrieved from MAST or made custom

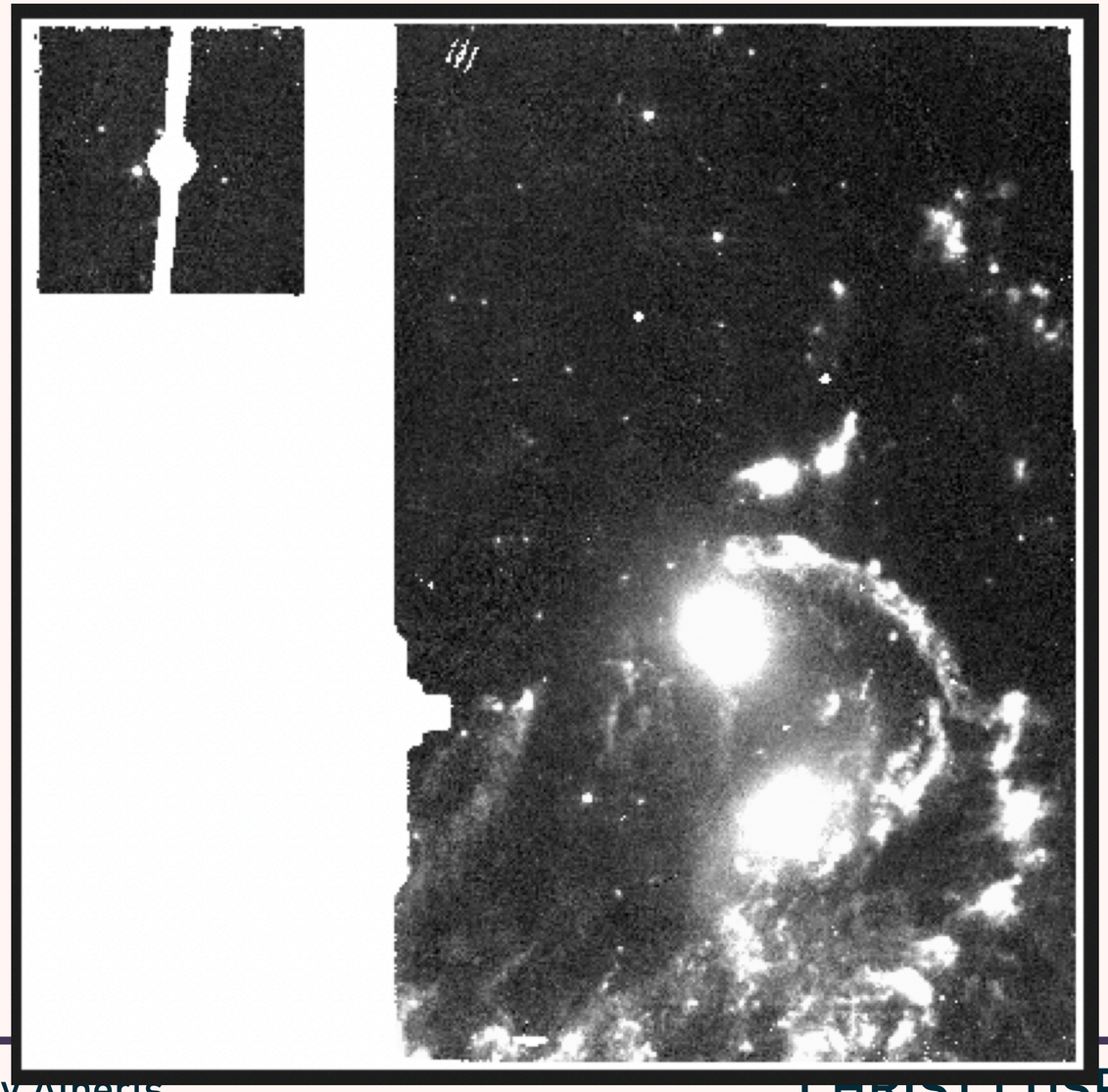
Associate science and background exposures

Associate science exposures for a mosaic (Stage 3)



```
{
    "asn_type": "None",
    "asn_rule": "DMSLevel2bBase",
    "version_id": null,
    "code_version": "1.19.2",
    "degraded_status": "No known degraded exposures in association.",
    "program": "noprogram",
    "constraints": "No constraints",
    "asn_id": "a3001",
    "asn_pool": "none",
    "products": [
        {
            "name": "/Users/salberts/Research/COSPAR_Workshop/mir_im_demo_data/Obs002/stage1/
jw02732002001_02101_00008_mirimage",
            "members": [
                {
                    "expname": "/Users/salberts/Research/COSPAR_Workshop/mir_im_demo_data/Obs002/
stage1/jw02732002001_02101_00008_mirimage_rate.fits",
                    "exptype": "science"
                }
            ]
        }
    ]
}
```

STAGE 2 - CAL AND I2D FILES

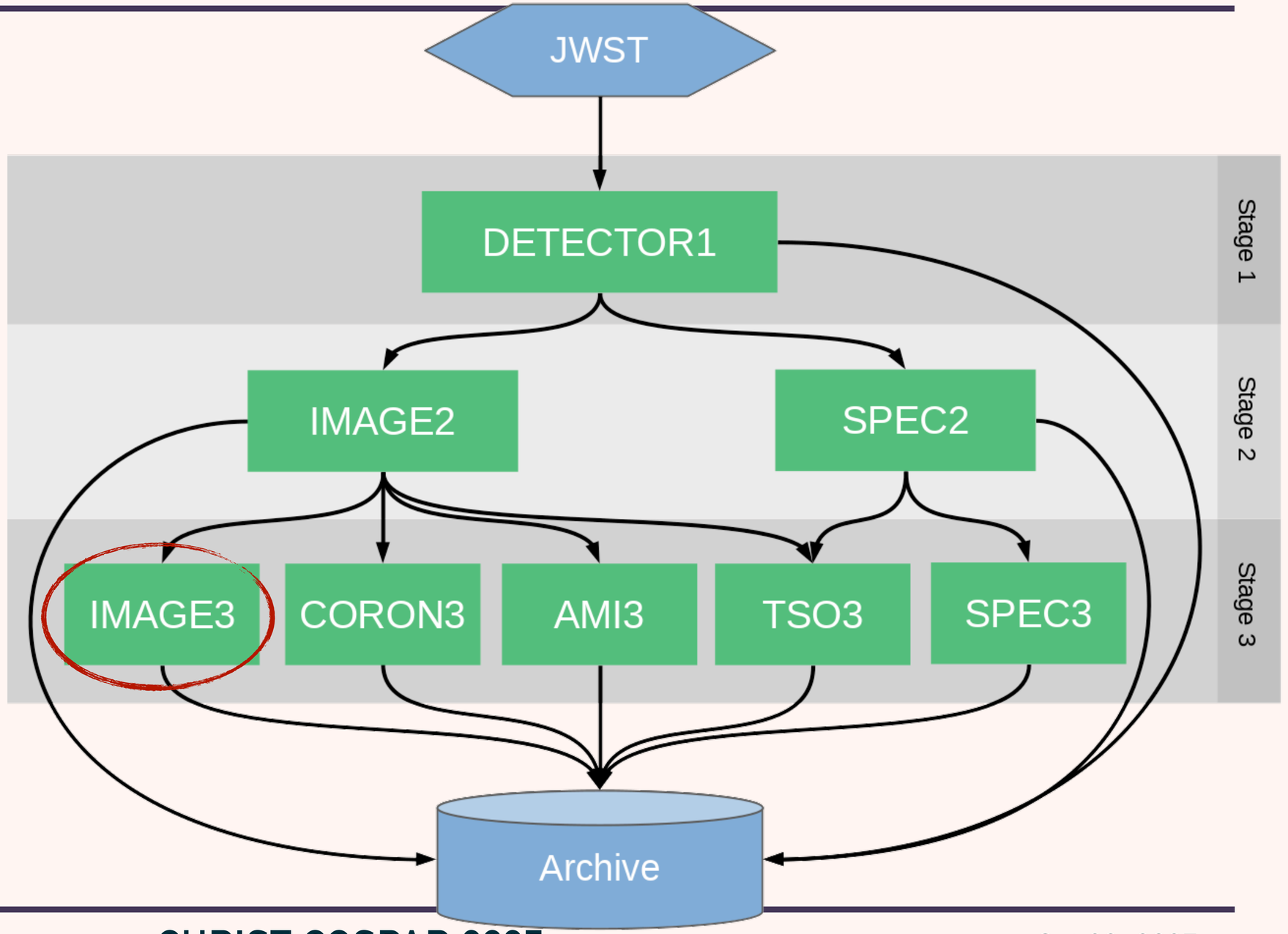


“cal” files are fed into stage 3.
Stage 2 “i2d” files are just for quick looks

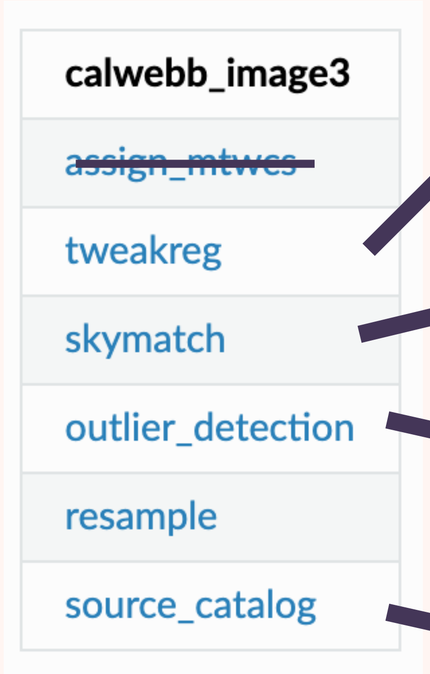
```
{'assign_wcs': 'COMPLETE',
 'charge_migration': 'SKIPPED',
 'clean_flicker_noise': 'SKIPPED',
 'dark_sub': 'COMPLETE',
 'dq_init': 'COMPLETE',
 'emicorr': 'COMPLETE',
 'firstframe': 'COMPLETE',
 'flat_field': 'COMPLETE',
 'gain_scale': 'SKIPPED',
 'group_scale': 'SKIPPED',
 'ipc': 'SKIPPED',
 'jump': 'COMPLETE',
 'lastframe': 'COMPLETE',
 'linearity': 'COMPLETE',
 'photom': 'COMPLETE',
 'ramp_fit': 'COMPLETE',
 'refpix': 'SKIPPED',
 'reset': 'COMPLETE',
 'rscd': 'COMPLETE',
 'saturation': 'COMPLETE'}
```

STAGE 3

- Combine calibrated exposures into dithered image or mosaic
- Input association files (listing cal files)
- Output i2d files



STAGE 3



Astrometry correction: to GAIA catalog or to custom catalog

GAIA catalog often doesn't have many matches to MIR
Recommend: custom astrometry catalog

skymatch: algorithm to match background levels

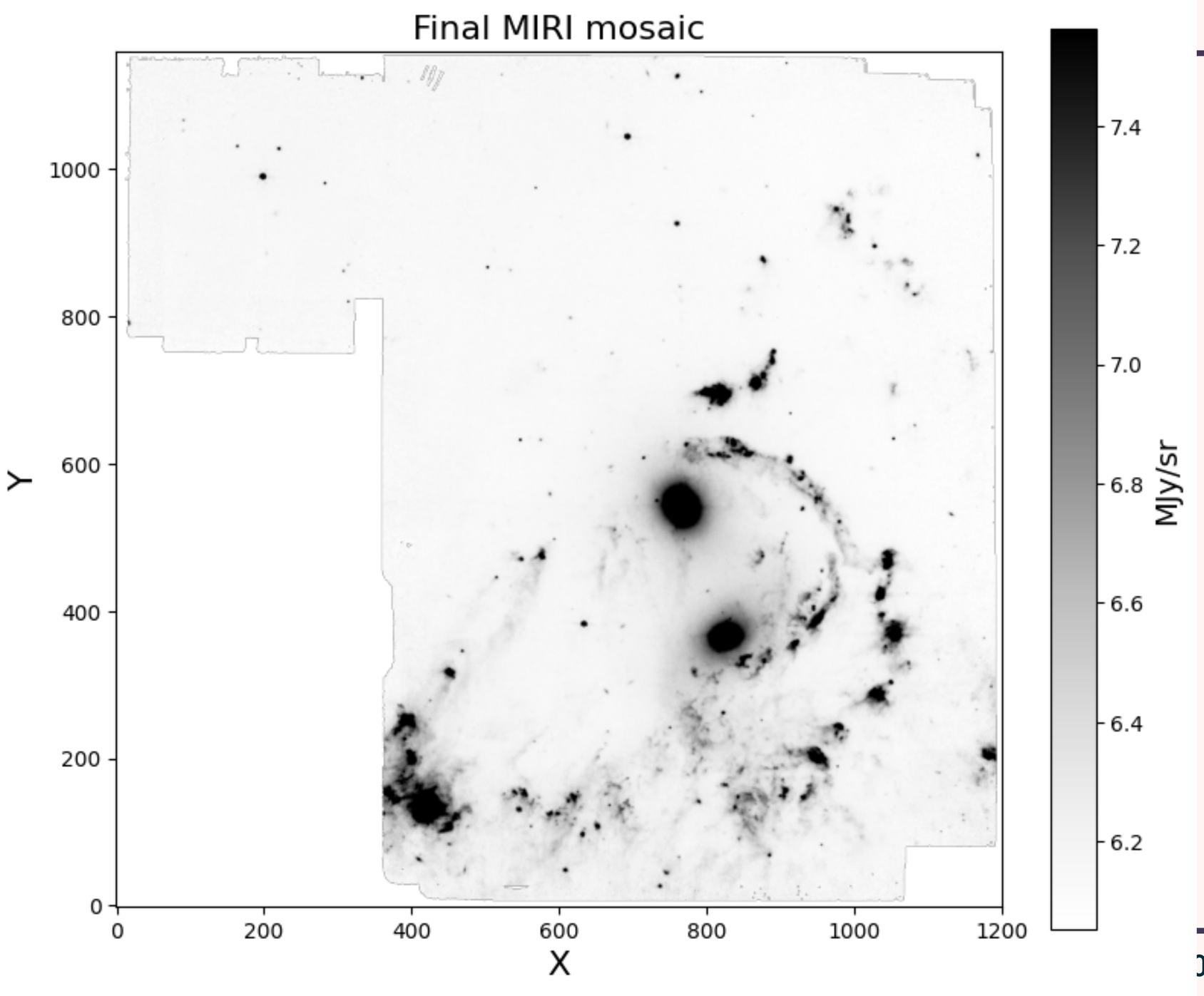
Doesn't always work very well…
Recommendation: skip, do during background subtraction if appropriate

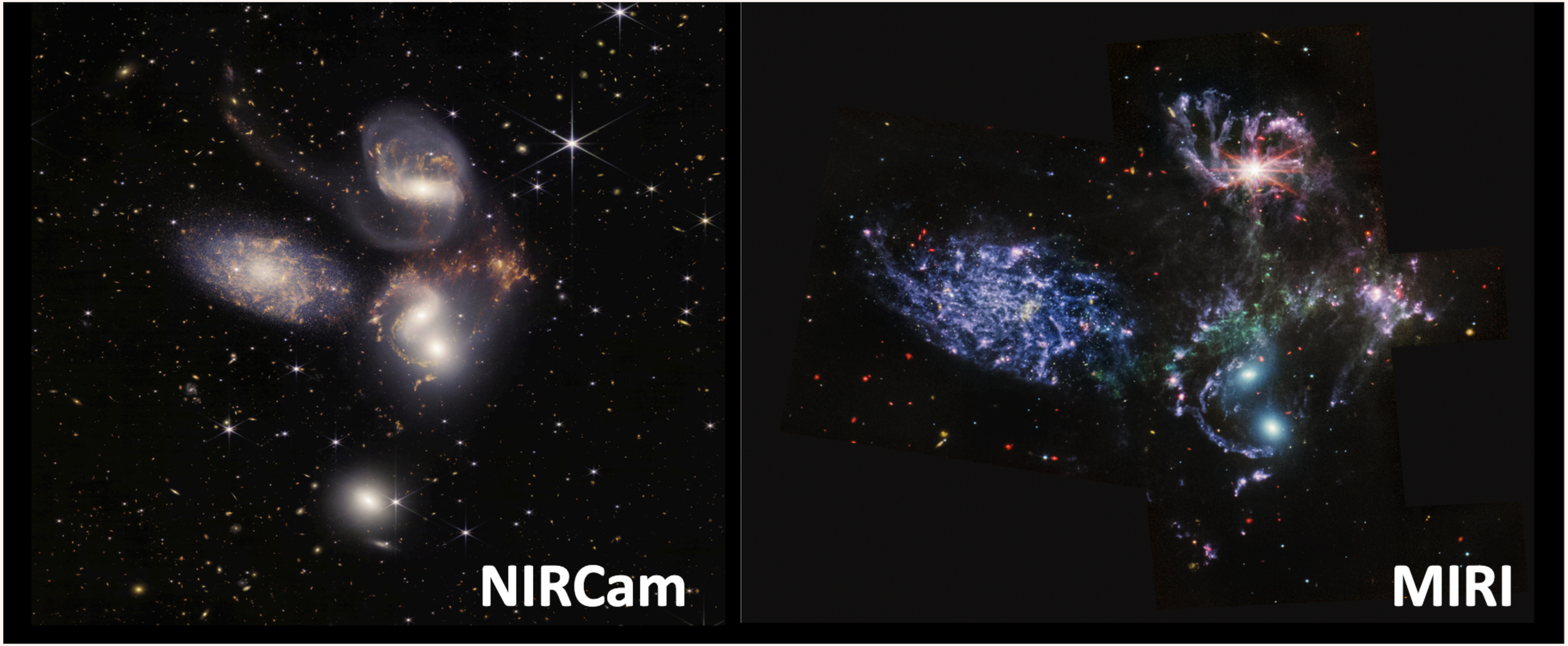
Final outlier detection

Creates source catalog

Doesn't always work very well…
Recommendation: skip, use program like photutils

TA DA!


Final MIRI mosaic
Y
X
0
200
400
600
800
1000
1200
MJy/sr
7.4
7.2
7.0
6.8
6.6
6.4
6.2


NIRCam
MIRI