PDRs4All: Status of Our ERS Observations

ERS 1288 (PDRs4All) Community Telecons in Support of JWST Cycle 2 Proposals

Telecon #1 of 3

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1 December 2022

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The PDRs4All Team

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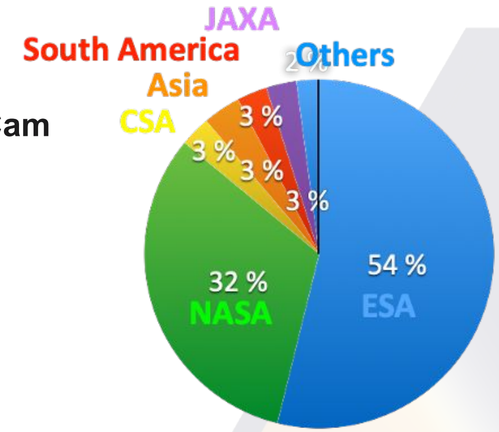
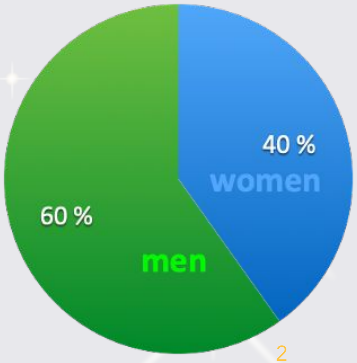
- **Extended Core Team** : Alain Abergel, Felipe Alarcón, Edwin A. Bergin, Jeronimo Bernard-Salas, Christiaan Boersma, Emeric Bron, Jan Cami, Amélie Canin, Ryan Chown,Sara Cuadrado, Emmanuel Dartois, Daniel Dicken, Meriem El-Yajouri, Asunción Fuente, Javier R. Goicoechea, Karl D. Gordon,Lina Issa, Christine Joblin, Olga Kannavou, Baria Khan, Ozan Lacinbala, David Languignon, Romane Le Gal, Alexandros Maragkoudakis, Raphael Meshaka, Yoko Okada, Takashi Onaka,Sofia Pasquini, Marc W. Pound, Massimo Robberto,Markus Röllig, Bethany Schefter,Thiébaut Schirmer, Ilane Schroetter, Ameek Sidhu,Thomas Simmer, Benoit Tabone, Alexander G. G. M. Tielens, Boris Trahin, Dries Van De Putte, Sílvia Vicente, Mark G. Wolfire, Marion Zannese
- **Collaborators** : 122 scientists, from 18 countries

- **Target : Orion Bar**
- **Duration of program : 40 hours**
- **Instruments : 15.5h NIRspec / 22.5h MIRI / 2.7h NIRCam**





Credits : NASA / ESA / CSA / PDRs4All team S. Fuenmayor


PDRs4All
The inner Orion Nebula seen with JWST
Towards Trapezium cluster
Young star with disk inside its cocoon
Cocoon
Disk
Orbit of Neptune
Young star inside globule
Orion Bar
Filament
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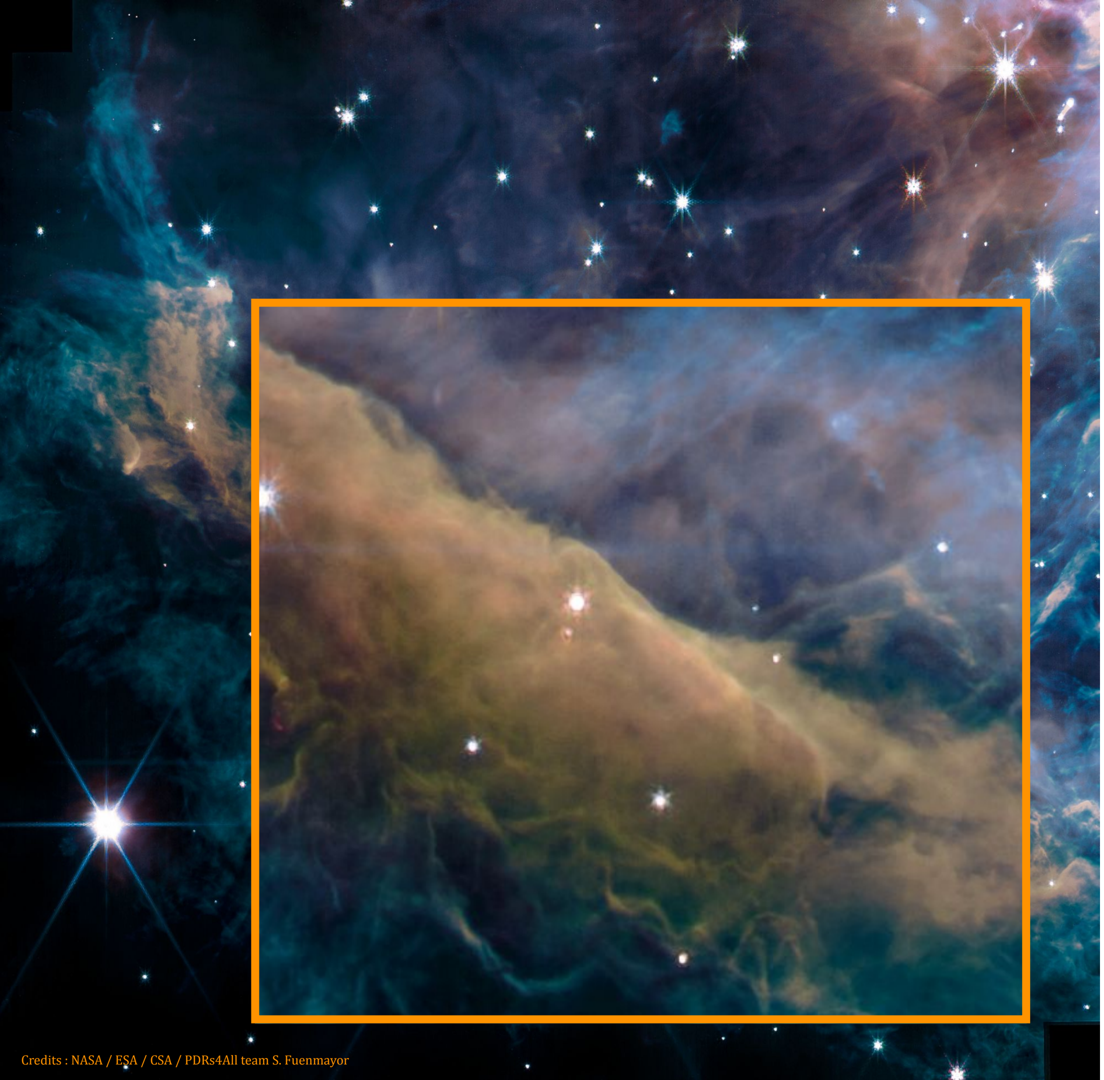

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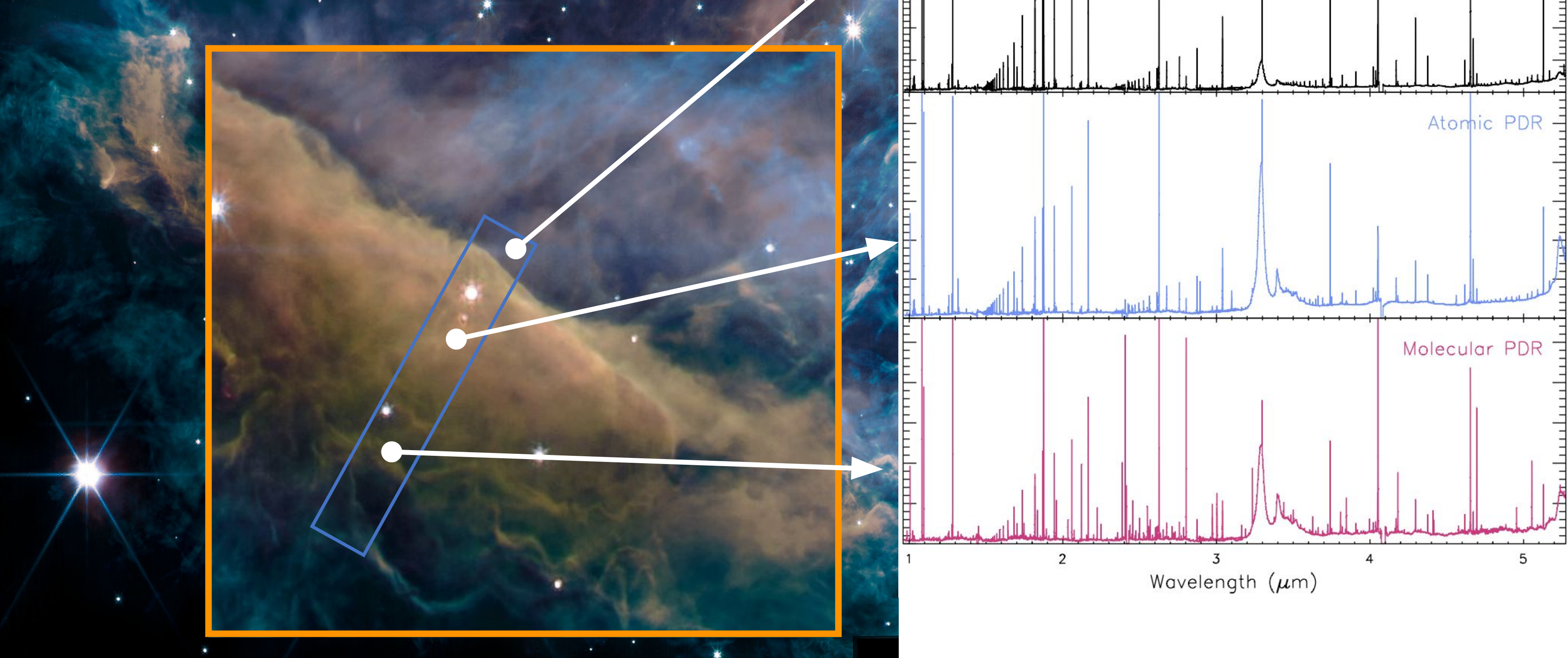
3 papers in prep :

- Peeters et al. : Orion bar spectroscopy
- Habart et al. : Orion Bar imaging
- Berné et al. : Protoplanetary disk imaging & spectroscopy



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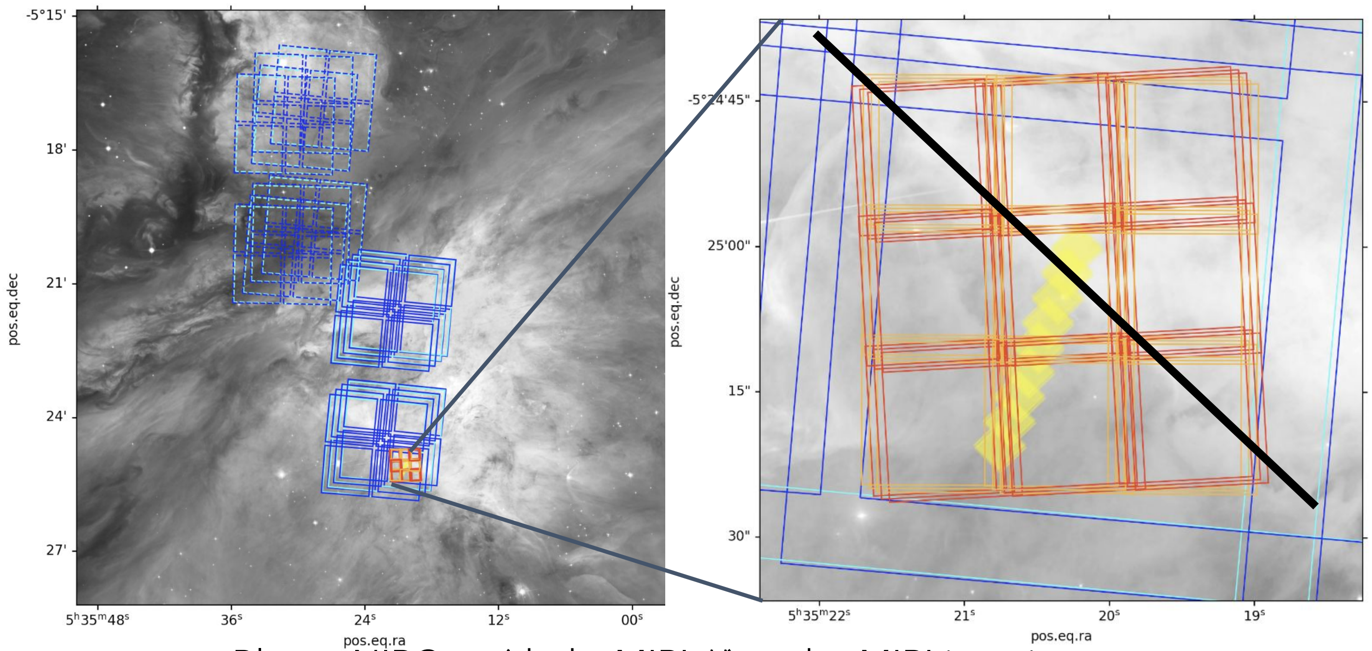
Outline

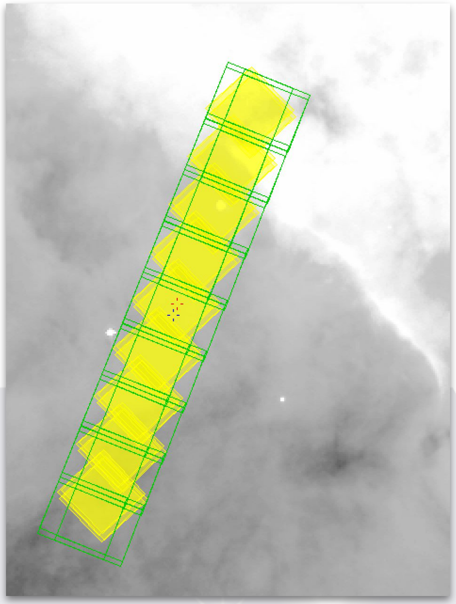
Our goal is to help you prepare for JWST Cycle 2

1. Summary of our observations and data reduction
2. Describe some of the issues we've encountered and fixes
3. Provide recommendations for dealing with these problems if you find them in your data

JWST Fields of View



Blue = NIRCam (dash=MIRI //); red = MIRI imaging; yellow = NIRSpec
Background = HST 1.3 um (Robberto et al. 2020)
Figure from Habart et al. 2022 (in prep.)



Green: Future MRS observations (early 2023)

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Observation Checklist

- ✓ <u>NIRCam:</u> 14 filters. 14 cover the Orion Bar, 8 cover parallel observation FoV (M43/NGC 1982)
- ✓ <u>MIRI Imager:</u> 4 filters, all on the Orion Bar
- ✓ <u>NIRSpec:</u> 9 pointings along a line ~perpendicular to the OB, each in 3 grating/filter combinations (spectral range 0.95-5.27 um, R~2700)
- ❑ <u>MIRI MRS:</u> to be executed early 2023. 9 pointings overlapping with NIRSpec FoV, covering 5-27 microns

Observation Details: Imaging

- NIRCam:
    - *Filters*: F140M, F162M, F164N, F182M, F187N, F210M, F212N, F277W, F323N, F335M, F405N, F470N, F480M
    - *Mosaic*: 1x1
    - *Dithering*: 4 positions (INTRAMODULE pattern), FULL array
    - *Parameters*: 2 groups/integrations, 2 integrations, RAPID readout mode
    - M43 observations with F182M, F187N, F210M, F212N, F300M, F335M, F405N, F410M from MIRIM parallel observations

- MIRIm:
    - *Filters:* F770W, F1130W, F1500W, F2550W
    - *Mosaic:* 3x3, SUB128 array
    - *Dithering*: 3 positions (3-POINT-MIRI-F770W-WITH-NIRCAM pattern)
    - *Parameters*: 5 groups/integration, 115 integrations, FASTR1 readout mode
    - Background observations (only for F1500W and F2550W -FGS lost during F770W and F1130W observations)

Observation Details: Spectroscopy

- NIRSpec:
  - *Gratings/Filters:* G140H/F100LP, G235H/F170LP, G395H/F290LP
  - *Dithering*: 4 positions
  - *Mosaic*: 9x1
  - *Parameters*: 5 groups/integration, 1 integration, NSRAPID readout mode

- MRS:
  - *Gratings*: SHORT, MEDIUM, LONG (5-28 microns)
  - *Dithering*: 4 positions (EXTENDED SOURCE pattern)
  - *Mosaic*: 9x1
  - *Parameters*: 47 groups/integration, 1 integration, FASTR1 readout mode
  - MIRIM parallel observations using F770W, F1130W and F1500W

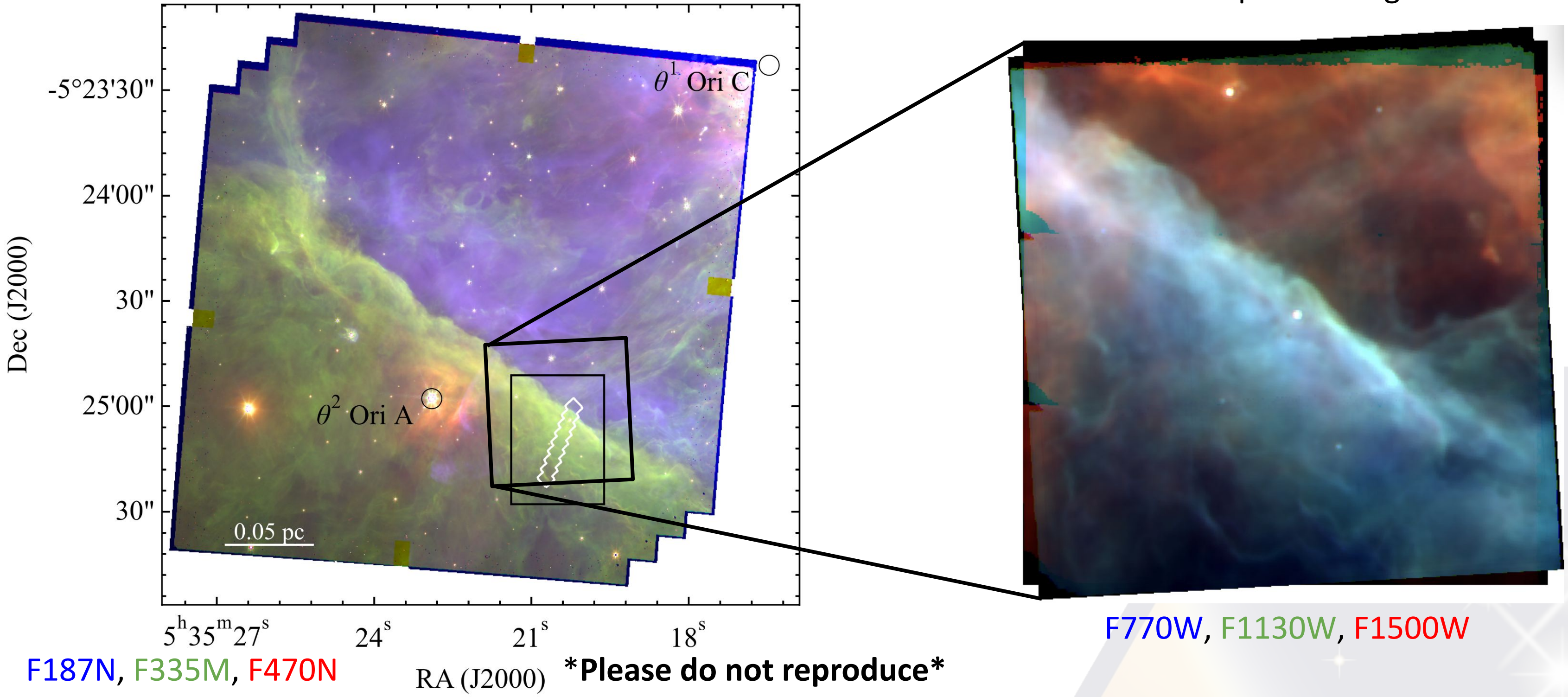
Data Reduction

- Ran the pipeline as CRDS contexts and JWST pipeline evolve
  - Latest: CRDS 1017 (17/11/2022), pipeline development version 1.8.3+
- Significant improvements since arrival of data
- More progress to be made as in-flight reference files become available

NIRCam and MIRI Imager Data

NIRCam composite image

MIRIM composite image



F187N, F335M, F470N

F770W, F1130W, F1500W

Please do not reproduce

Figure from Peeters et al. 2022 (in prep.), Habart et al. (2022)

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NIRSpec Data

- Beautiful spectra, lots of lines, lots of modelling underway
- Spectra extracted from apertures

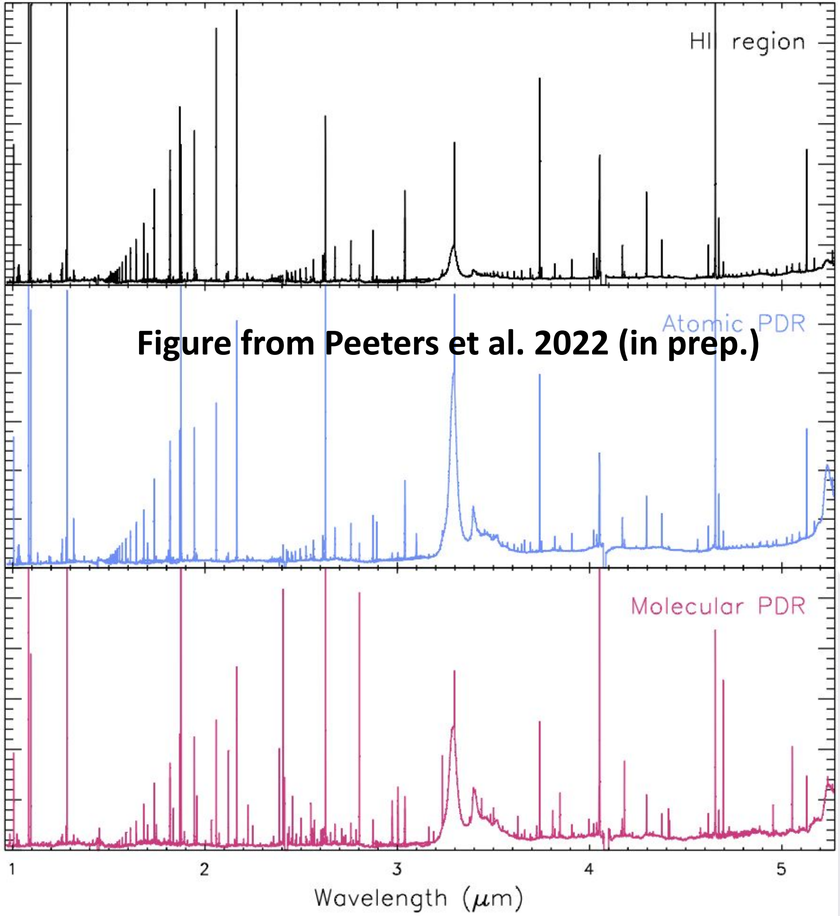

Figure from Peeters et al. 2022 (in prep.)

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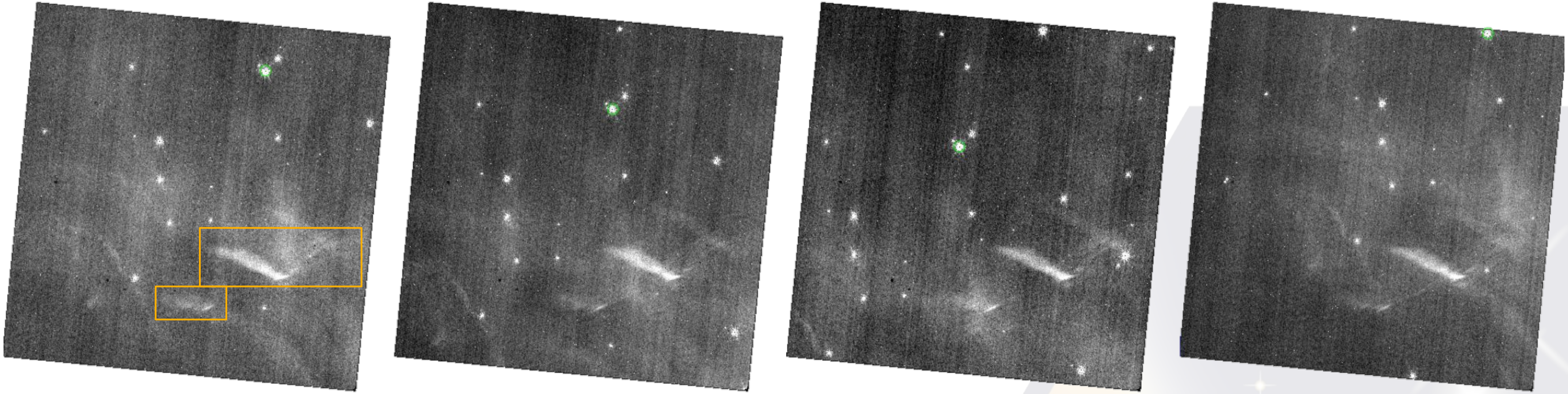
Overview of Lessons Learned

- NIRCam
  - Wisps
  - 1/f noise
  - WCS misalignment
  - SNR lower than expected in narrow filters (~10x lower for extended sources)
- NIRSpec
  - Outliers (very high/low flux), flux calibration, edges, WCS correction. All highly impacted by reference files. Many reference files still a combination of dummy and ground data.
  - Stitching cubes with different grating/filter combinations is best done outside of the pipeline
  - We detect lines as faint as ~10^{-9} W m^{-2} sr^{-1} with SNR of ~10
- MIRIm
  - SUB128 array edge effects
  - Saturation reached at F2250W at ~56000 DN/s (higher than expected)

NIRCam: Wisps

"Wisps" are a contamination of the scene due to stray light. Wisps are located on the same pixels of the detector regardless of the dithers but the location depends on the observations.

Wisps are particularly present on the detectors A3, B3 and B4.



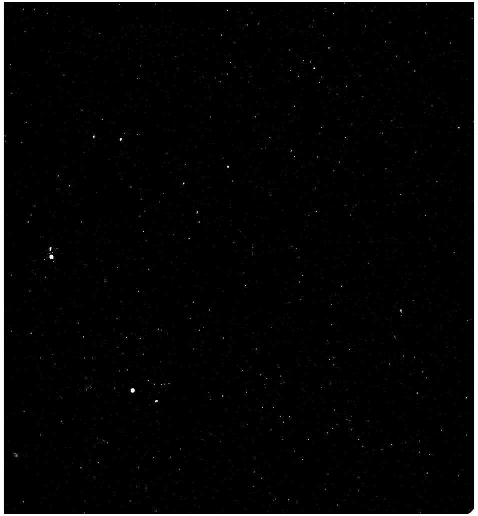
Wisp

Dithers of detector B4 aligned by pixel

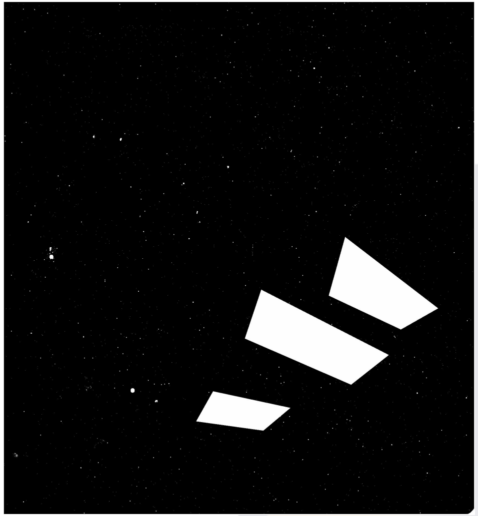
NIRCam Wisp Correction

Changed manually the DQ array on calibrated files after stage 2 and before stage 3 (DO_NOT_USE flag).

Before



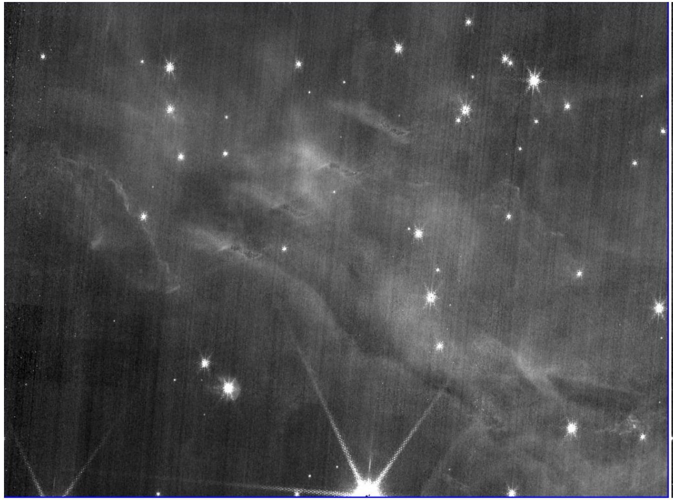
After



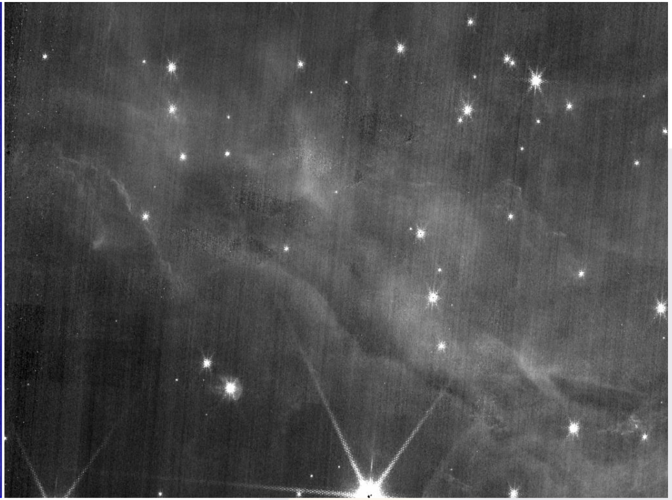
NIRCam Wisp Correction

After correction: wisps are gone, but more noise in these areas because data have been removed

Before



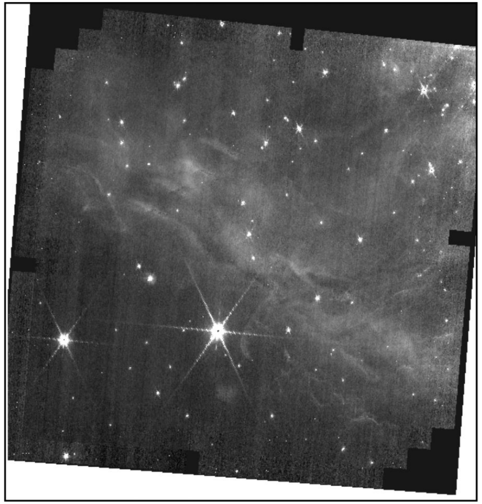
After



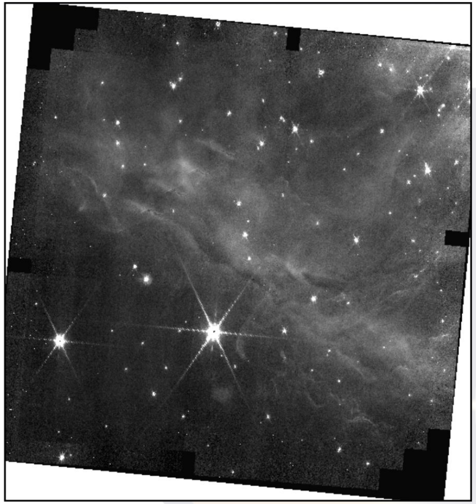
NIRCam 1/f noise Correction

1/f readout noise is not corrected in the pipeline
→ stripes present in the images

⬡ Correct for the effect of a variable background, mask pixels containing sources and subtract the median value
⚠️ inspect the results for any unintended consequences



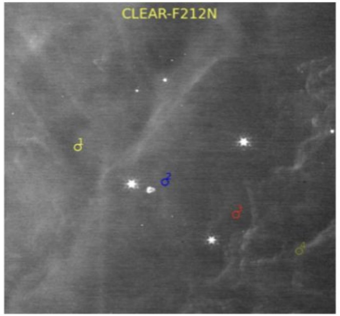
Before 1/f noise correction



After 1/f noise correction

NIRCam SNR

SNRs values ~10x lower than expected from ETC for extended sources



Pupil-Filter	Noise Sky	SNR 1	SNR 2	SNR 3	SNR 4
CLEAR-F140M	1.35	49	36	25	19
F162M-F150W2	1.12	65	58	36	27
F164N-F150W2	9.83	10	8	5	4
CLEAR-F182M	1.04	227	138	96	75
CLEAR-F187N	9.28	187	94	71	54
CLEAR-F210M	1.18	96	74	47	38
CLEAR-F212N	8.41	9	9	6	7
CLEAR-F277W	0.29	350	365	211	182
CLEAR-F300M	0.34	277	332	176	131
F323N-F322W2	2.98	60	152	93	75
CLEAR-F335M	0.57	382	1119	678	508
F405N-F444W	3.71	326	209	131	98
F470N-F444W	3.30	56	109	60	54
CLEAR-F480M	0.73	257	499	258	198

NIRCam SNRs

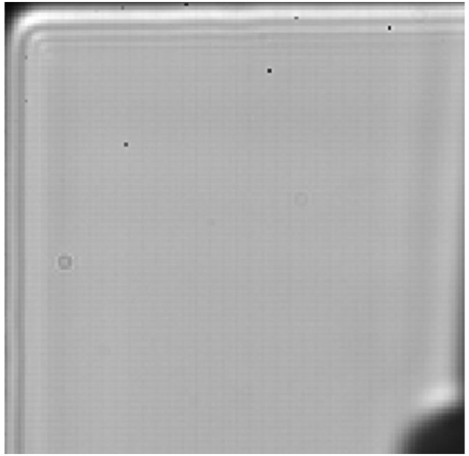
Pupil-Filter	SNR 1	SNR 2	SNR 3
CLEAR-F140M	622	504	579
F162M-F150W2	712	654	598
F164N-F150W2	140	127	109
CLEAR-F182M	1662	1341	1214
CLEAR-F187N	1306	881	765
CLEAR-F210M	940	819	633
CLEAR-F212N	148	144	107
CLEAR-F277W	1320	1417	1071
CLEAR-F300M	786	1007	627
F323N-F322W2	712	654	598
CLEAR-F335M	1392	2091	1760
F405N-F444W	4	845	593
F470N-F444W	259	448	270
CLEAR-F480M	942	1331	946

ETC sith NIRSpec SNRs

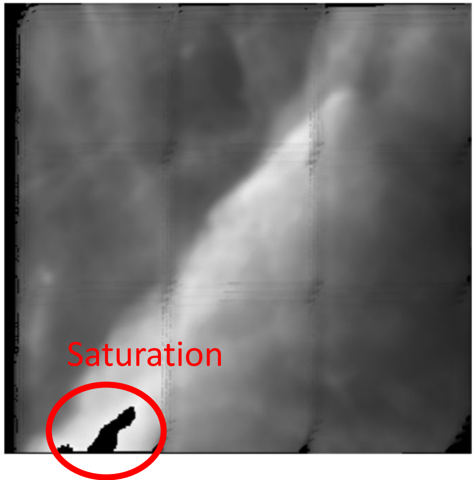
MIRIm: Lessons Learned

MIRIm SUB128 flat field present edge brightening (straylight features), especially at large wavelength (F1500W and F2550W).
⚠ No satisfactory correction at the moment

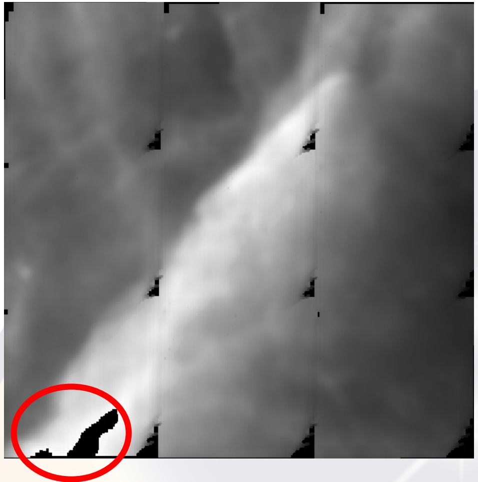
1st method:
⬡ Flag affected columns/rows as DO_NOT_USE (if sufficient overlap between tiles)
⚠ trade off between having pixels for the overlap and removing the pixels with a worse quality
2nd method:
⬡ Determine new flat field from overlap tiles (in progress)



SUB128 flat field



F2550W image with original flat field



F2550W image with “flagged” flat fields

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NIRSpec: Lessons Learned

- WCS offsets: off by about 2 arcsec
- Spikes/blobs: very high/low fluxes at narrow wavelength regions in the spectra
- Edge effects: lower flux along two edges of each pointing due to missing path-loss correction
- Flux calibration: pixel area reference file update helped, but work is ongoing
- SNR: we detect many lines down to ~ 10^{-9} W m^{-2} sr^{-1} with SNR of 10

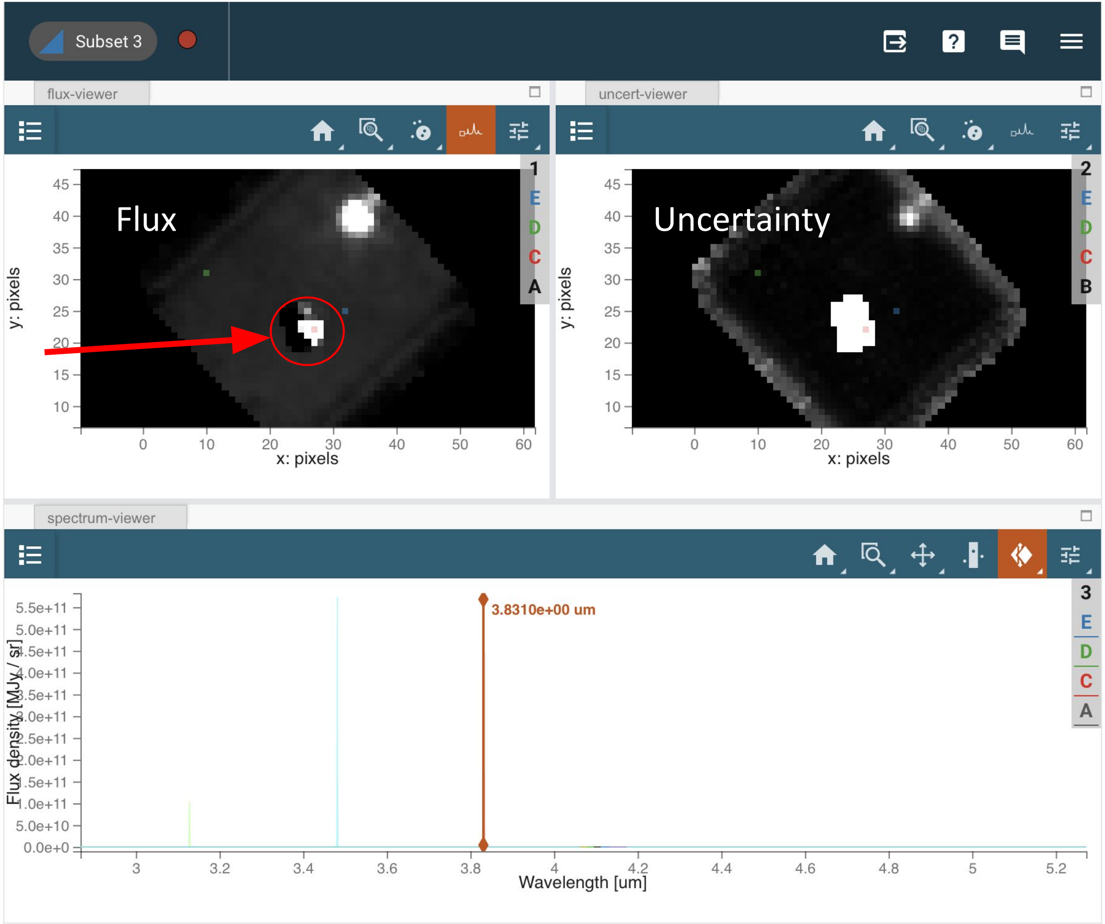
NIRSpec Outliers

Status

- Still present. Originate from reference files in Spec3. HelpDesk has been contacted. In our data, outliers are found in spatial clusters in the same parts of the FOV and same wavelengths in each pointing.

Recommendation

- No universal workaround yet. Just be on the lookout for these features.



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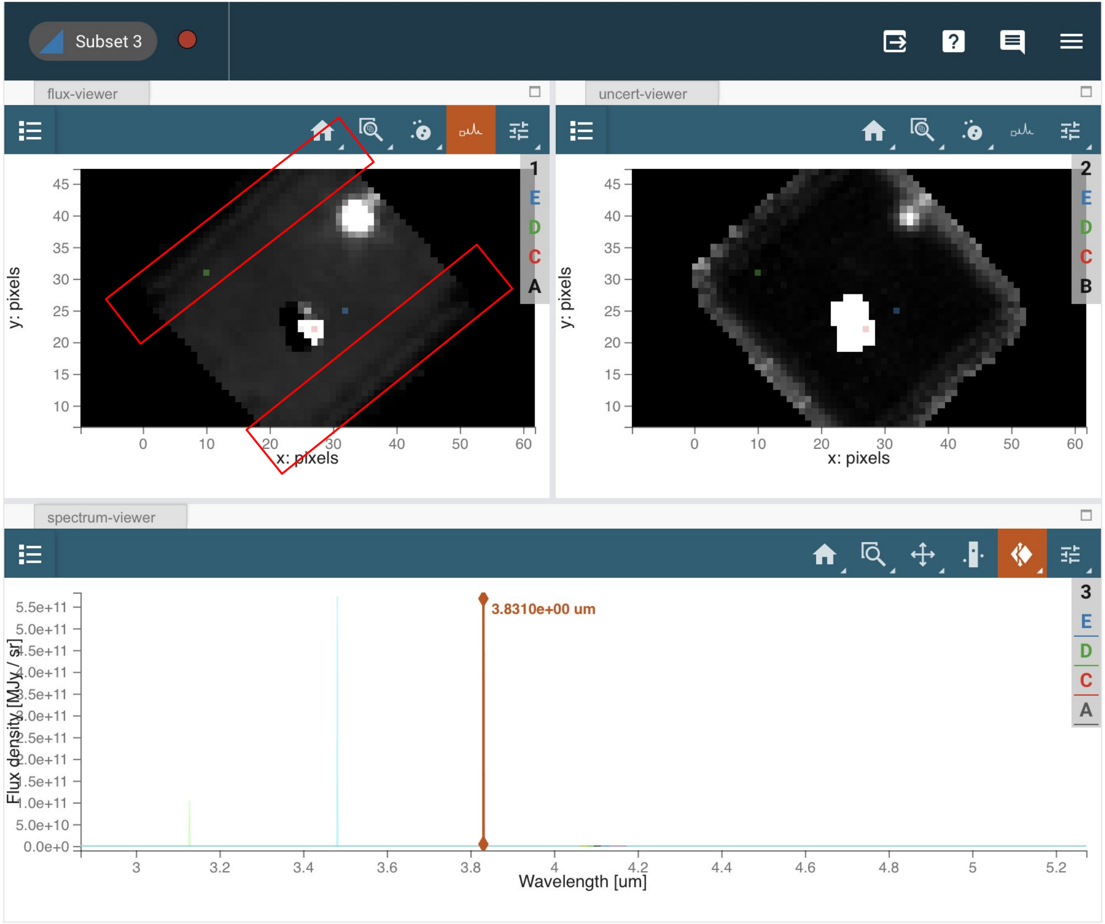
NIRSpec Edge Effects

Status

- Low flux (by a factor ~2) along two parallel edges of each pointing

Recommendation

- We apply a mask on the outer ~6 pixels from the edge of each pointing until the reference files are updated to fix this



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NIRSpec Flux Calibration

Status

- Relative calibration factor ~0.8 +/- 0.2

Recommendation

- Use the latest version of the pipeline (>=1.8.3) and CRDS >= 1017 (delivered 17/11/2022)
- Assume ~20% uncertainty on relative calibration of NIRSpec to NIRCam

NIRSpec Stitching

- Easiest to work with “stitched” cubes (all three grating/filter cubes combined)
- Pipeline will stitch cubes automatically, even create a mosaic (requires ~ 128 GB RAM)
- We stitch and coadd all cubes into a single spectral mosaic (9 pointings, 3 grating/filter combinations each), and deal with edge effects, etc. on our own
- First create stitched cubes for each pointing, then coadd them where they overlap spatially

Imaging/IFU Cross-calibration

- This is one of the Science Enabling Products (SEPs) – Chown et al. 2022 (in prep.)
- We calibrate NIRSpec data off of NIRCam (~2% absolute cal. uncertainty)
- Relative calibration factor = NIRCam flux density / NIRSpec flux density
- Initial reduction from MAST led to calibration factors of $\sim 10^{-9}$. Reference file and pipeline fixes have brought rel. cal. to ~0.8 +/- 0.2 (Chown et al. 2022, in prep.)
- Sensitive to outliers, snowballs, wisps, WCS offsets, extended vs. point sources, etc.
- Still some work to be done (pipeline + CRDS)

Imaging/IFU Cross-calibration

Line/continuum contributions to NIRCam images (some highlights):

- F335M mainly traces the 3.3 um aromatic IR band (AIB; 50-80% contribution)
- F210M traces 2.12 um H_2 but also strong HI, He, lines
- F212N continuum fraction is higher than F210M
- F405N is a good tracer of Brα

Stay tuned for Chown et al. 2022 (in prep); Habart et al. 2022 (in prep)

NIRSpec SNR

- Integration time = 11664 sec
- See APT file for more information
- We detect lines as faint as 10^{-9} W m^{-2} sr^{-1}, with SNR of ~10

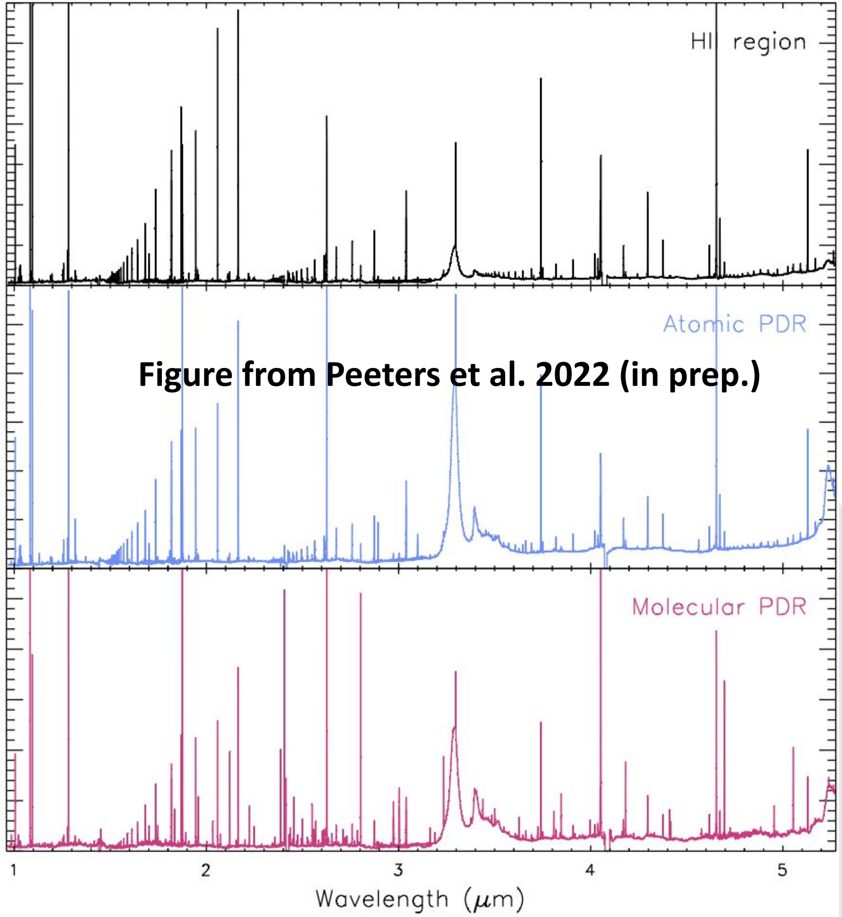

Figure from Peeters et al. 2022 (in prep.)

Summary of Recommendations

Use the last version of the JWST pipeline and calibration reference files (https://jwst-crds.stsci.edu/)

NIRCam

- Mask out wisps in stage 2 DQ arrays, then run stage 3
- Align _cal files (stage 2 products) with Gaia DR3
- Correct for 1/f readout noise on _cal files
- Optimize pipeline parameters for better results (e.g cosmic ray detection threshold)

MIRIm

- Mask top rows/left columns of SUB128 array flat field
- Detect sources in the shorter wavelength and apply offset with Gaia DR3 to the longer wavelengths
- Optimize pipeline steps parameters for better results (e.g skip outlier detection/jump/rscd/first frame...)

NIRSpec

- Use pipeline >= 1.8.3 and latest CRDS >= 1017
- Beware of outliers, blobs, edge effects, calibration offsets (of order ~1 with ~20% uncertainty)
- Perform stitching/coadding outside of the pipeline for now
- WCS offsets relative to NIRCam ~2 arcsec