NIRCam Grism:
Basics & Reduction Demo

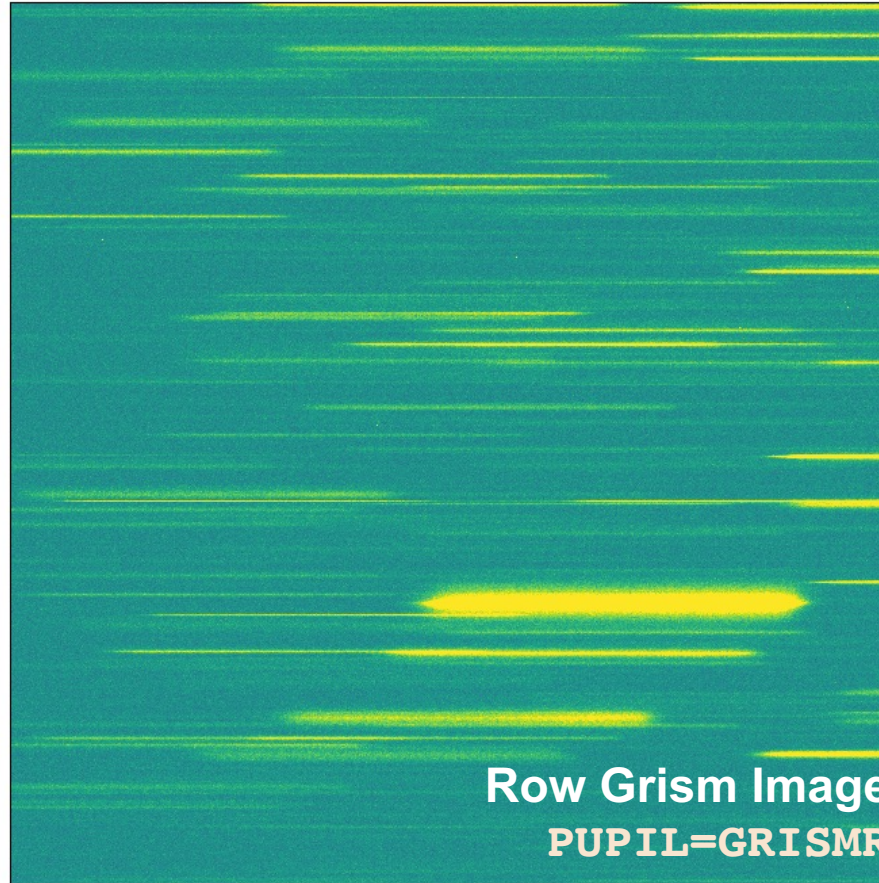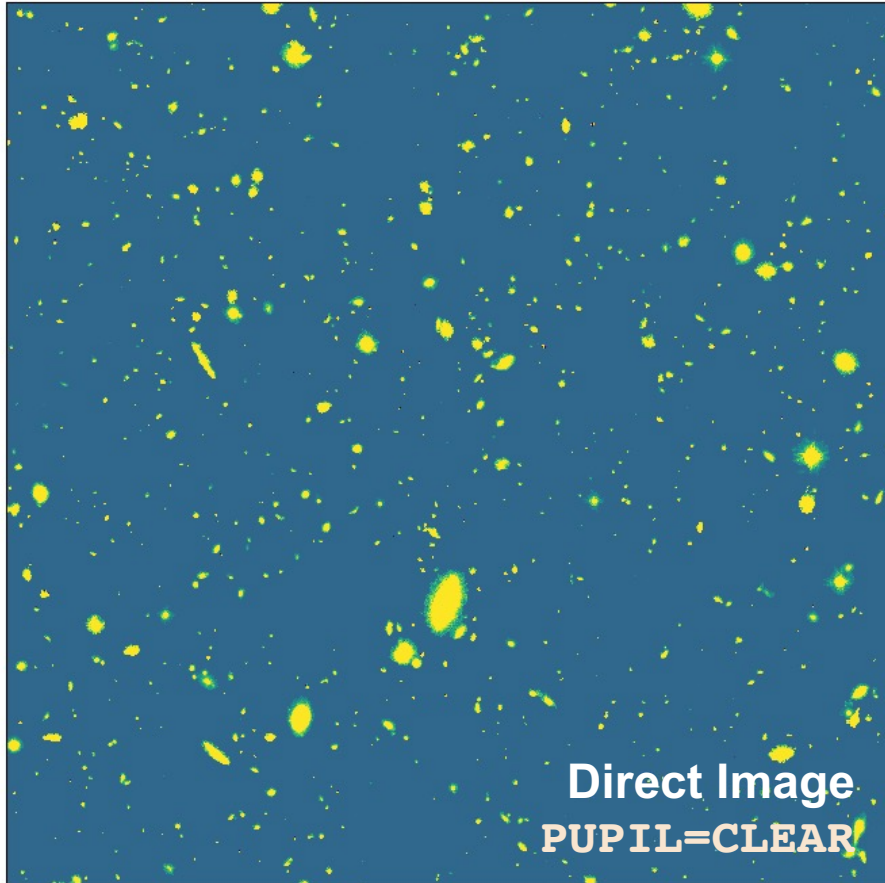**Fengwu Sun**

Steward Observatory, University of Arizona

NIRCam Optical Design

1	Pick-off Mirror assembly
2	Coronagraph
3	First Fold Mirror
4	Collimator lens group
5	Dichroic Beamsplitter
6	Longwave Filter Wheel Assembly
7	Longwave Camera lens group
8	Longwave Focal Plane
9	Shortwave Filter Wheel Assembly
10	Shortwave Camera lens group
11	Shortwave Fold Mirror
12	Pupil Imaging Lens
13	Shortwave Focal Plane
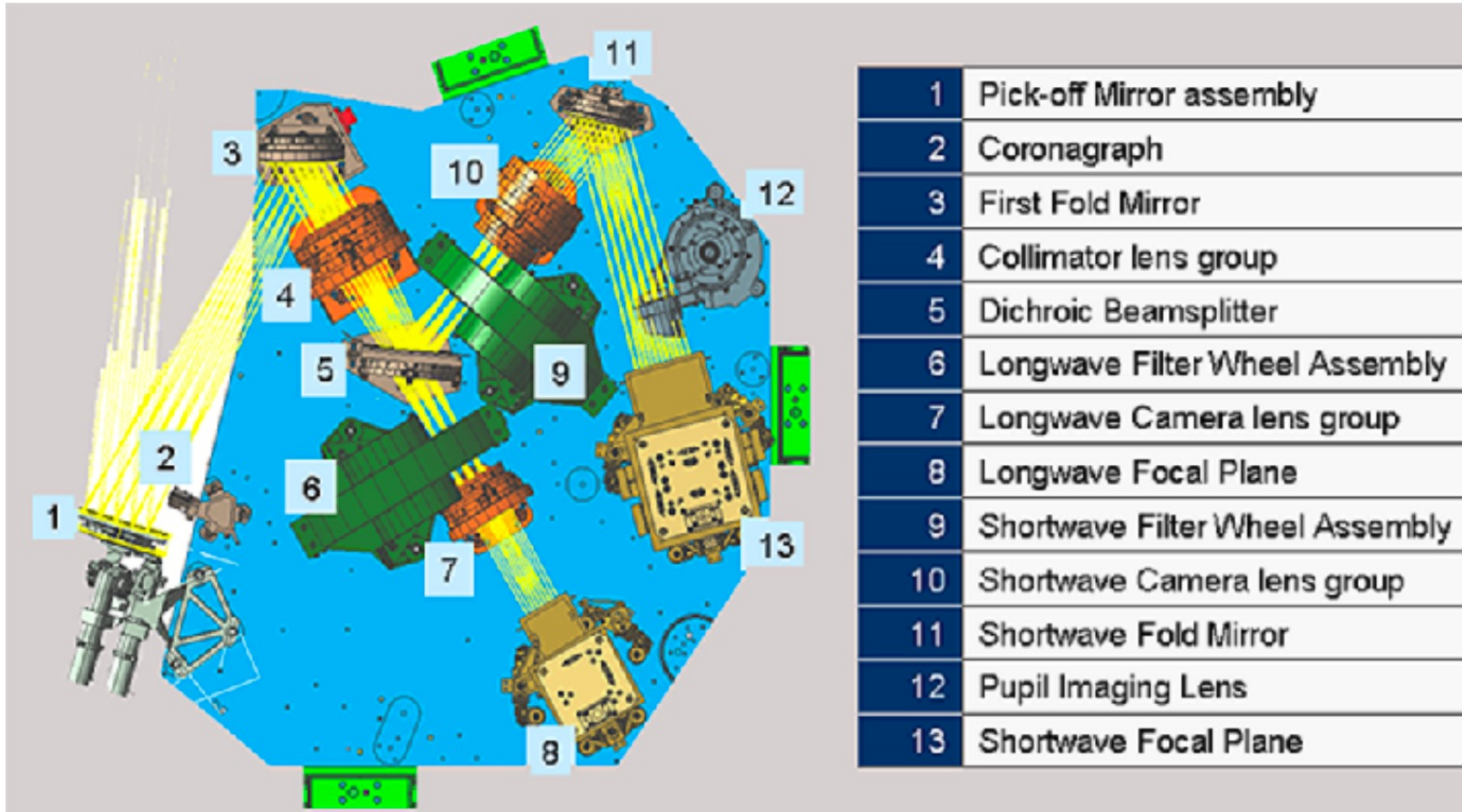
Technical Goal: 2 modules x 2 x 2 arcmin^2, Nyquist sampling at 2 & 4µm

Rieke et al. (2023)

NIRCam Grism Spectroscopy:

Direct Image
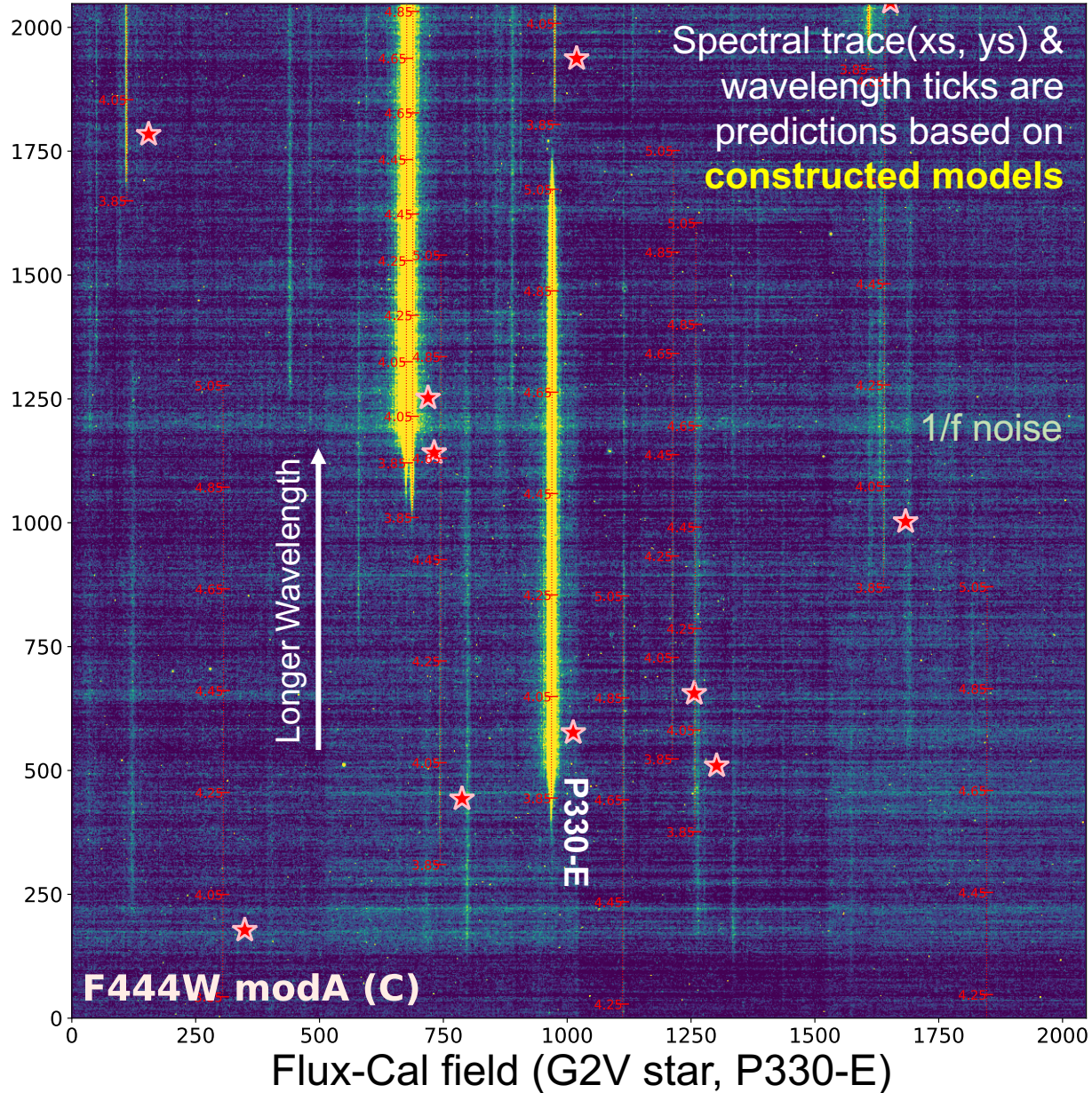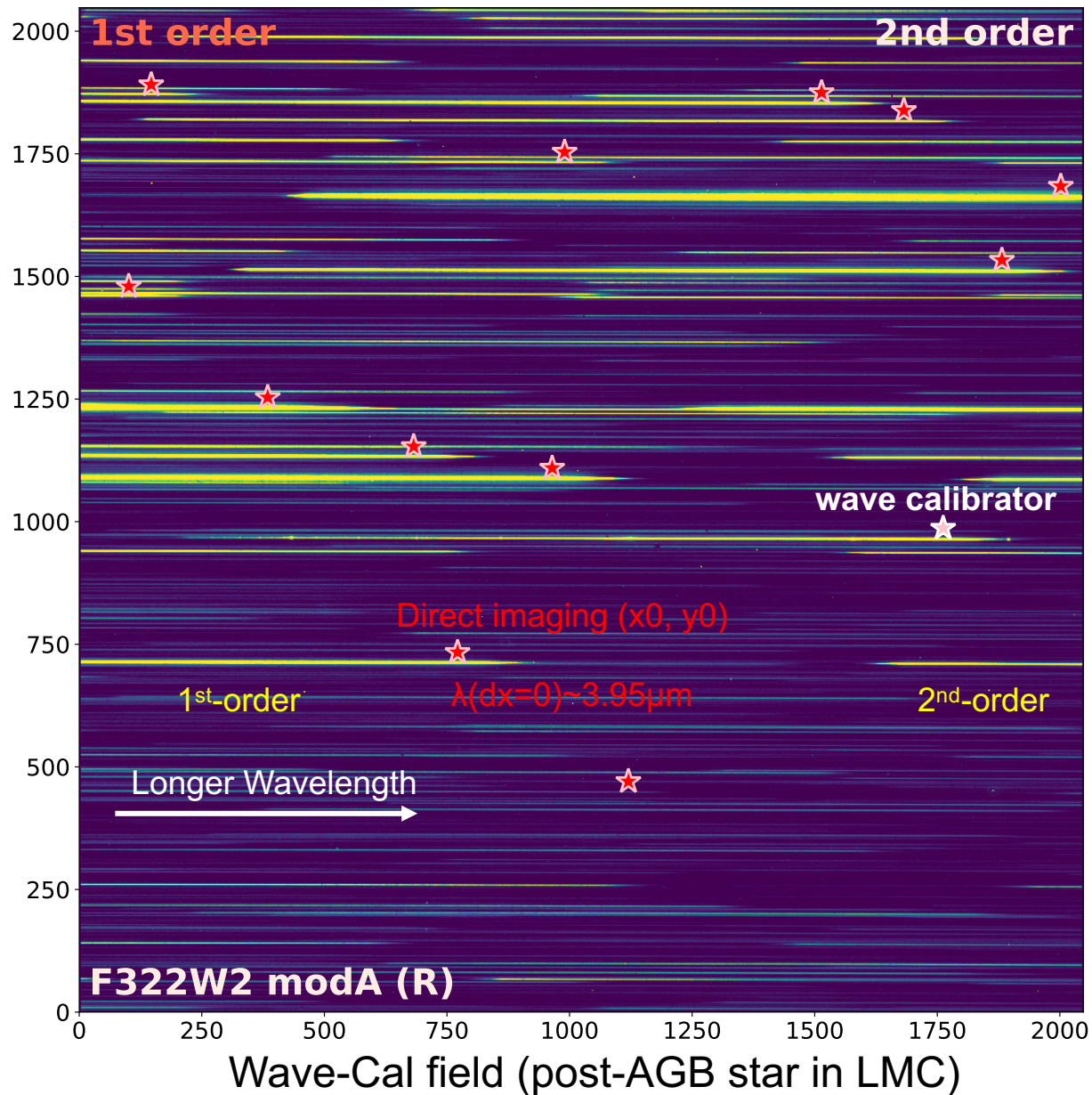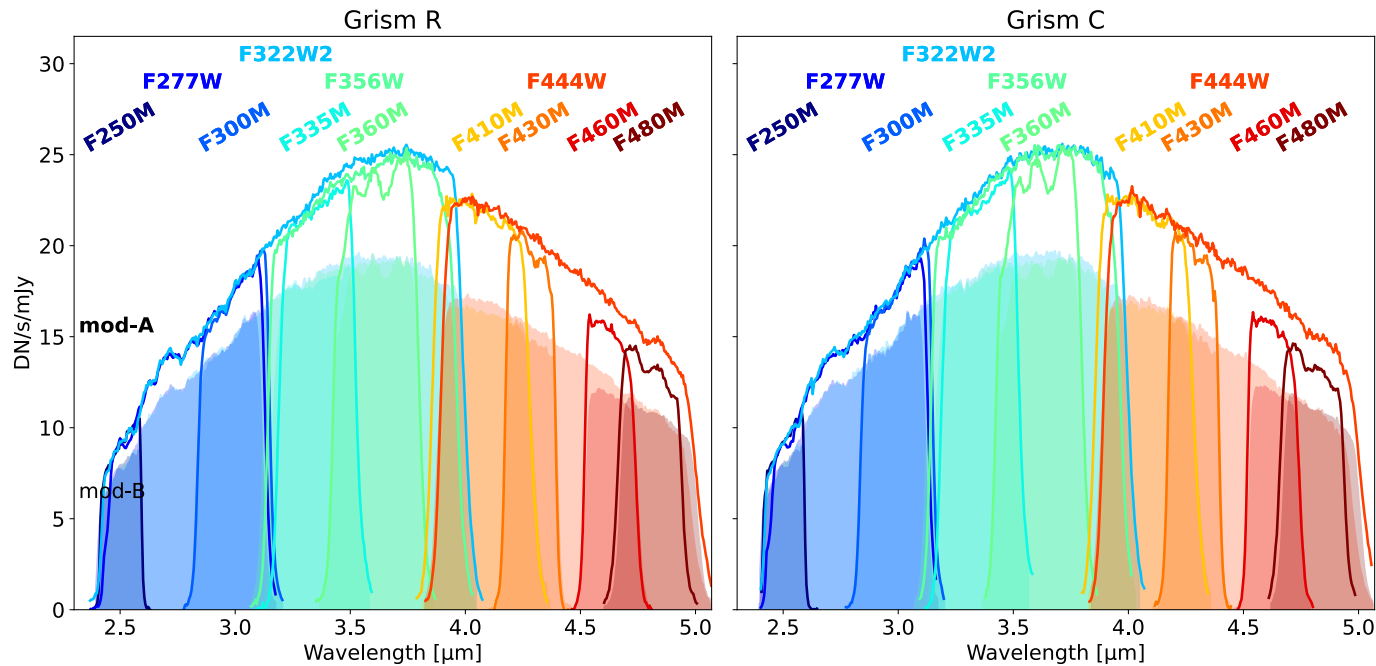PUPIL=CLEAR

Row Grism Image
PUPIL=GRISMR

- FoV:
  2x2 arcmin^2 $\times$ 2 modules
- Wavelength Range:
  2.4-5.0 μm
- Resolution ~ **1600**
- Dispersion ~1 nm/pix
- Row/Column Direction:
  Grism R/C
- No 0th order!
- No 2nd order at >3μm
- Simultaneous SW (0.6-2.4μm) direct imaging

More Info on JDox:

https://jwst-docs.stsci.edu/jwst-near-infrared-camera/nircam-observing-modes/nircam-wide-field-slitless-spectroscopy

Examples of grism images obtained during commissioning:

1st order ... **2nd order**

Spectral trace(xs, ys) & wavelength ticks are predictions based on **constructed models**

wave calibrator

Direct imaging (x0, y0)

$\lambda(dx=0) \sim 3.95\mu m$

1st-order ... 2nd-order

Longer Wavelength

F322W2 modA (R)

Wave-Cal field (post-AGB star in LMC)

1/f noise

Longer Wavelength

P330-E

F444W modA (C)

Flux-Cal field (G2V star, P330-E)

Grism R

Grism C

Flux Calibration:

- Cycle-1 calibration with A / G / White-dwarf;

- **1-2% absolute uncertainty;**

- Throughput are **20-40%** higher than pre-launch prediction.

Wavelength Calibration:

- Commissioning calibration with post-AGB star in LMC;

- **1nm absolute uncertainty (△v~75 km/s);**

- might be limited by astrometry, source size, distortion, etc.

STAR

IRAS 05248-7007   F322W2=15.46

(4423.3, 3972.4)   (81.08647, -70.08378)

N(R)=24 f_{F322W2}=2.384 mJy

[Al V] 2.905

He II (7-6) 3.092

PAH 3.3

Pfund lines   Humphreys lines

N(C)=24
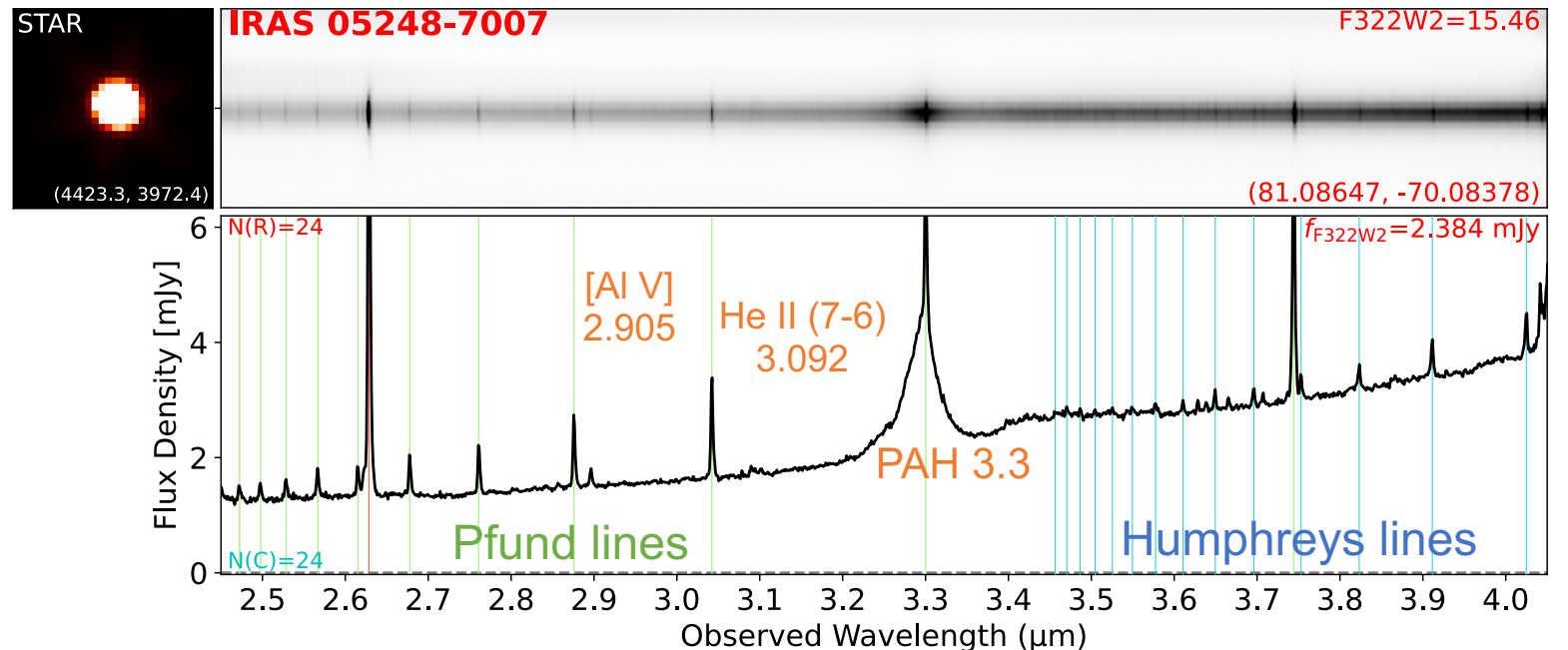
Spectral Tracing: Predict spectral pixel (x_s, y_s) with an RMS accuracy of ~0.1 pixel (6mas)

F322W2 modA grismR

Spectra (x_s, y_s) Sources ($x0$, $y0$)

Curvature exaggerated by 50 times

Y [pixel]

X [pixel]

Perpendicular-Direction dy_s [pixel]

Dispersion-Direction dx_s [pixel]
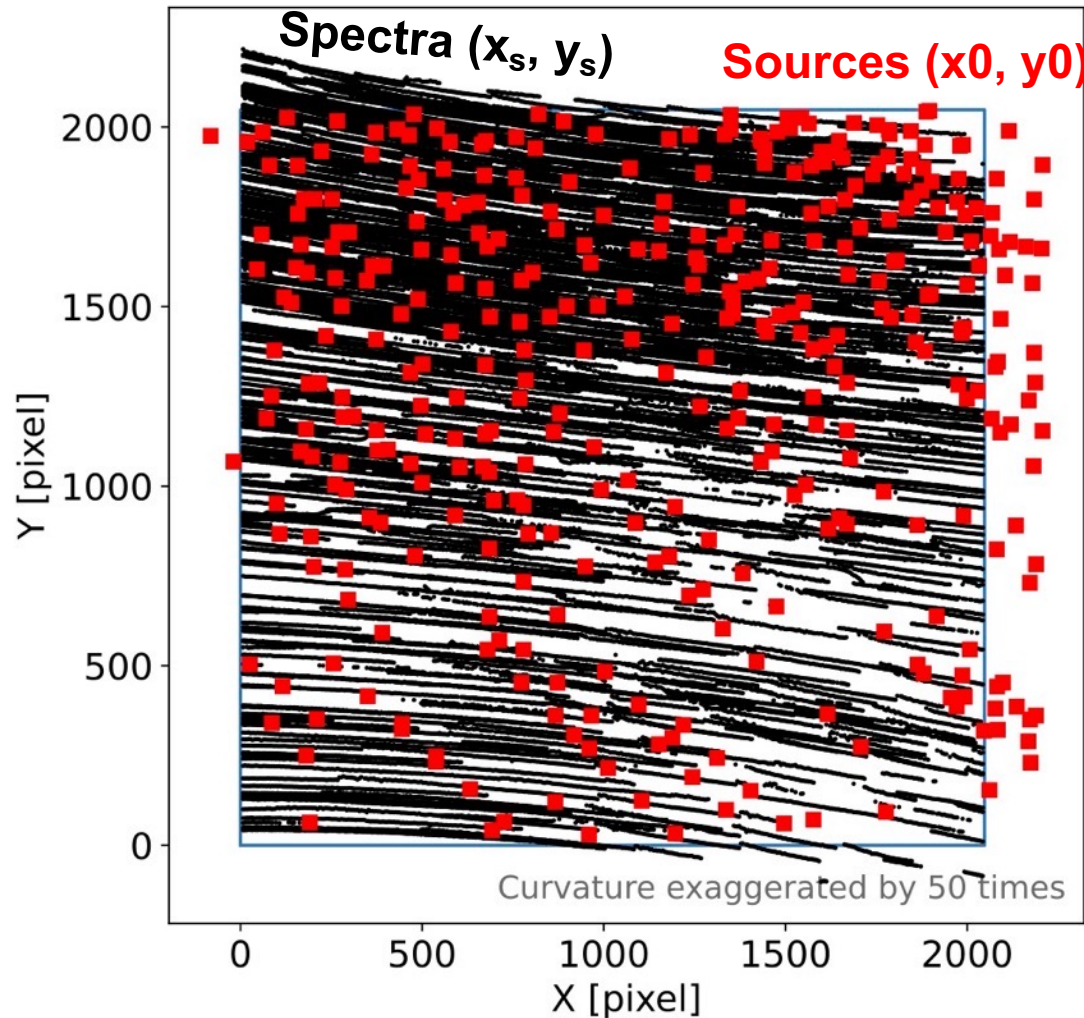
Spectra are curved (exaggerated)
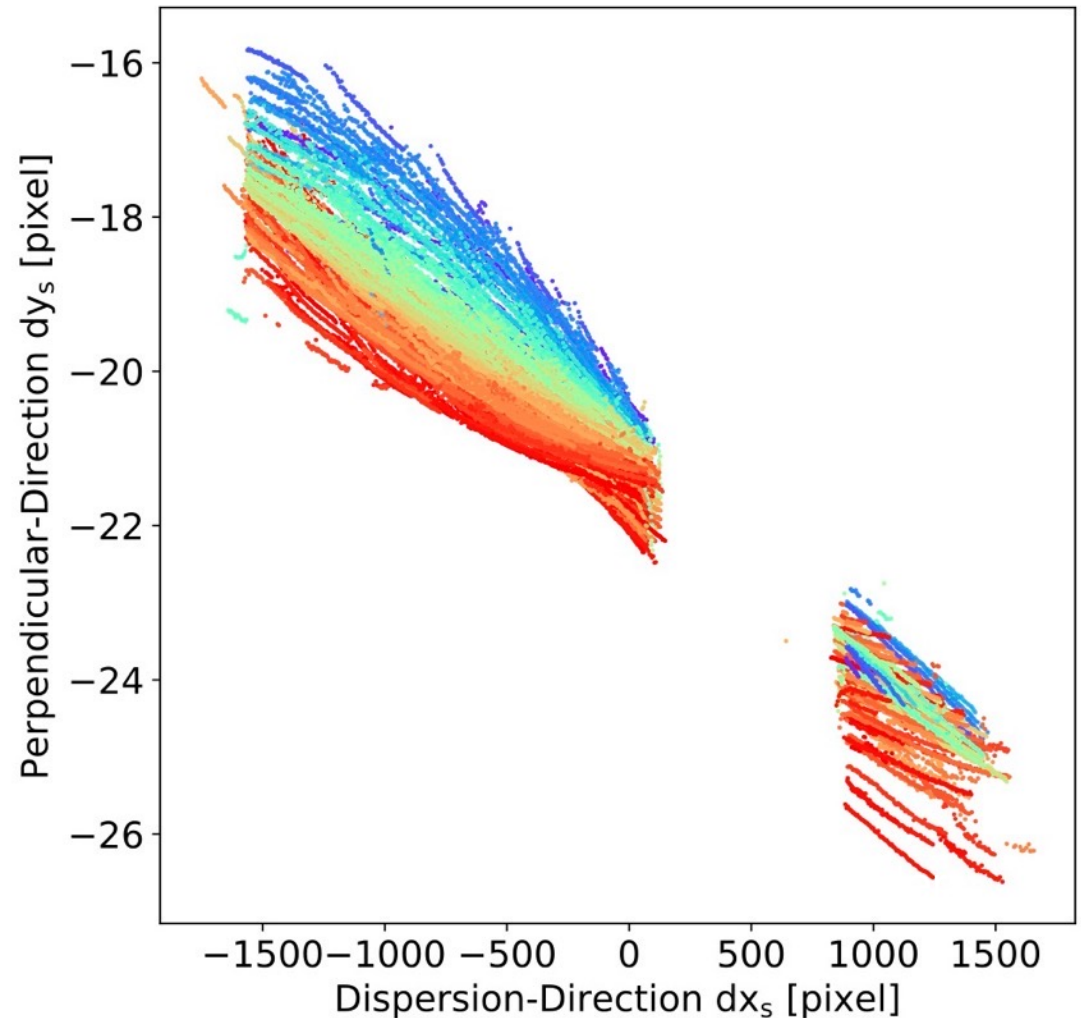
$dy_s = (y_s - y0)$ is a function of dx_s, $x0$, $y0$

Spectral Tracing: Curvature of traces, visualized by dy_s at $dx_s=0$ (undeflected wavelength)

F444W modA grismR (N=188)
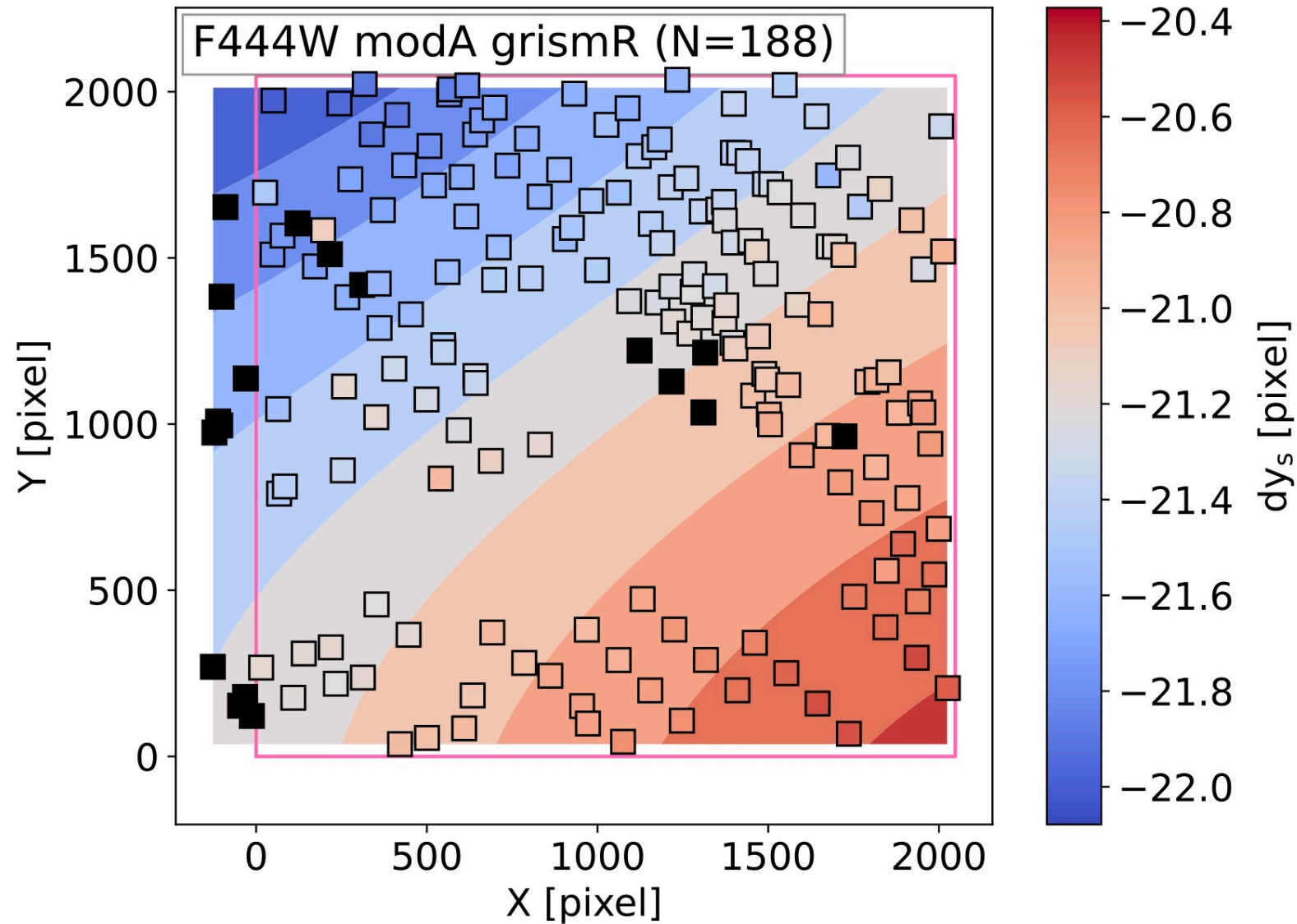
Spectral Tracing: small residuals of spectral tracing (0.05-0.10 pixel, 3-6 mas).
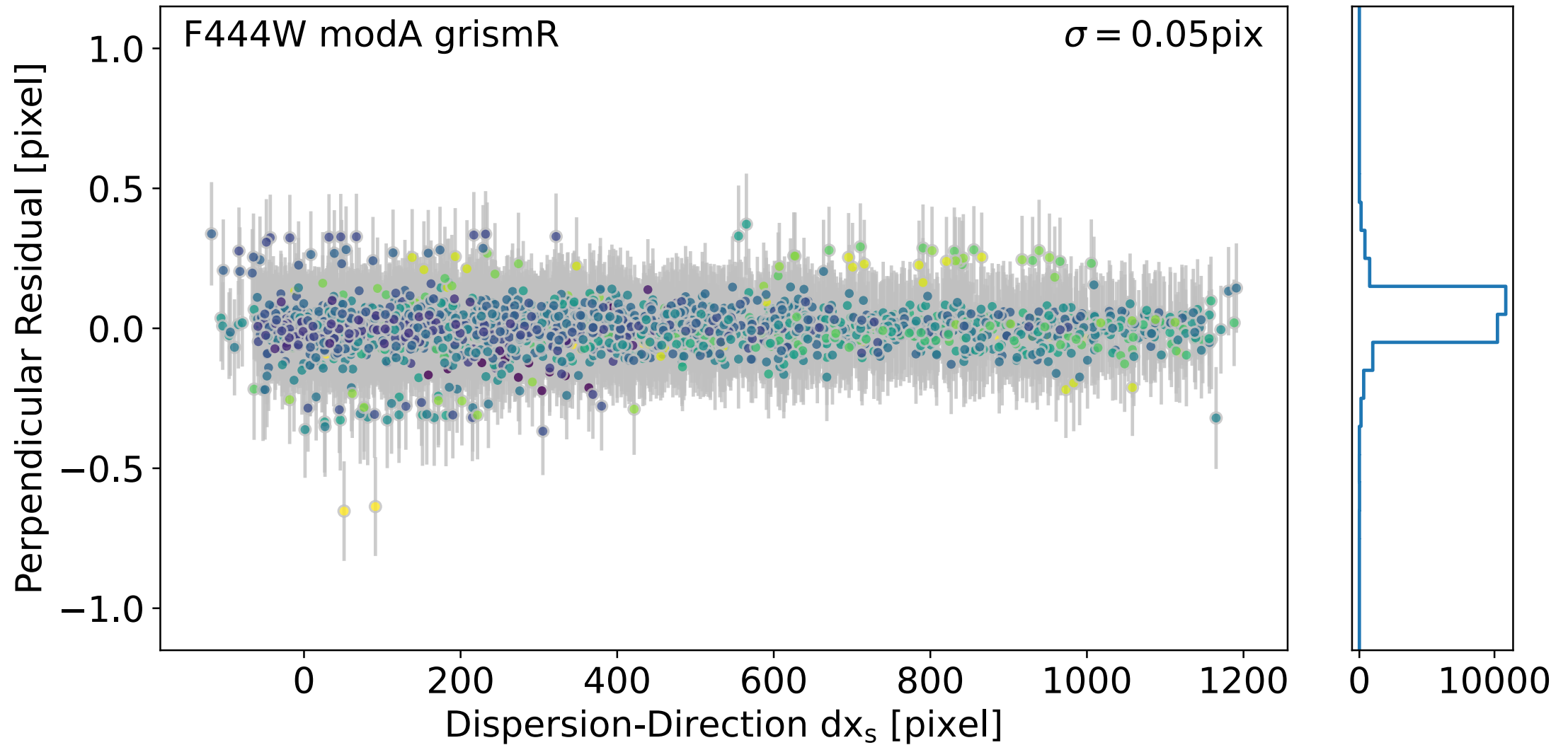
Codes & Demos with FRESCO (GO-1895; PI: Oesch) are publicly available:
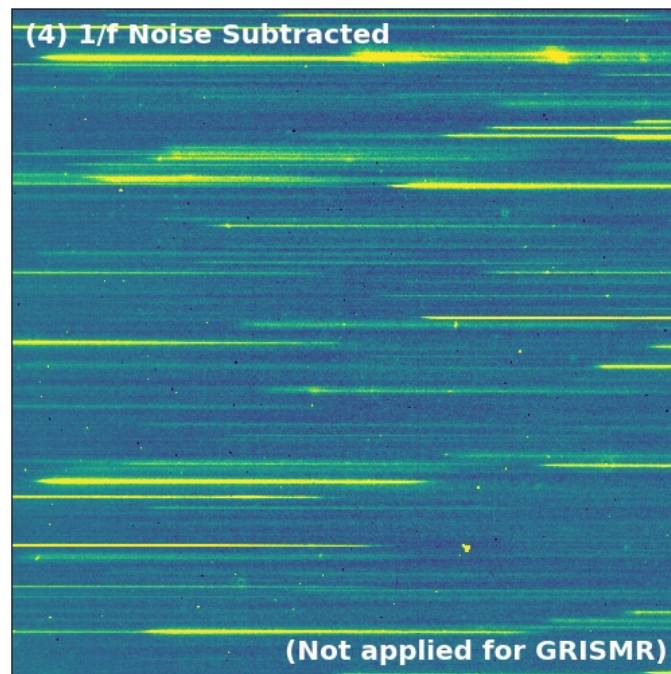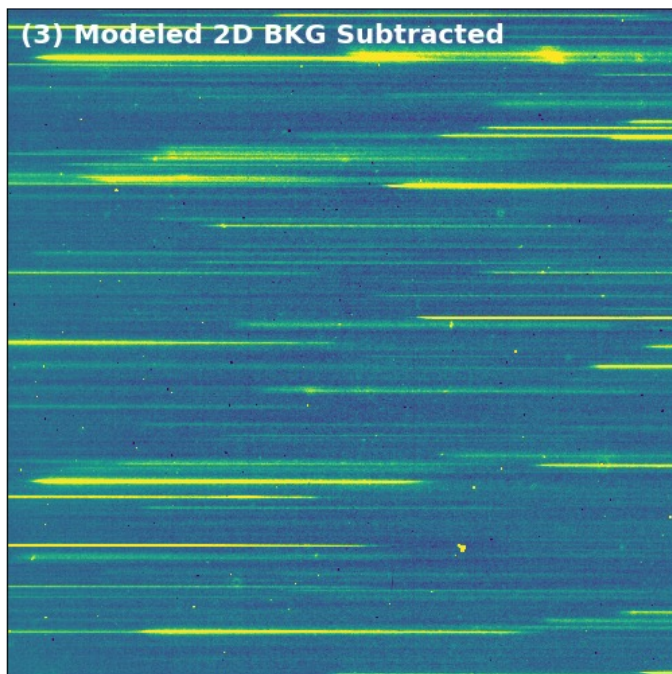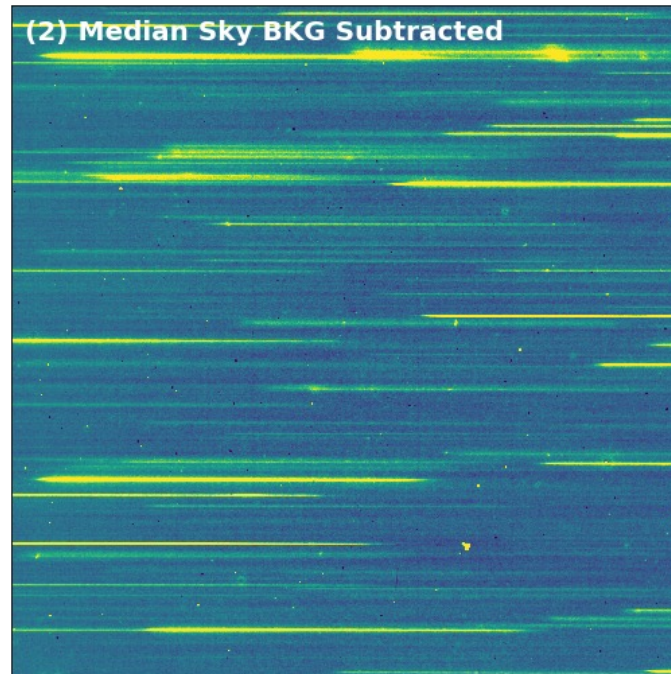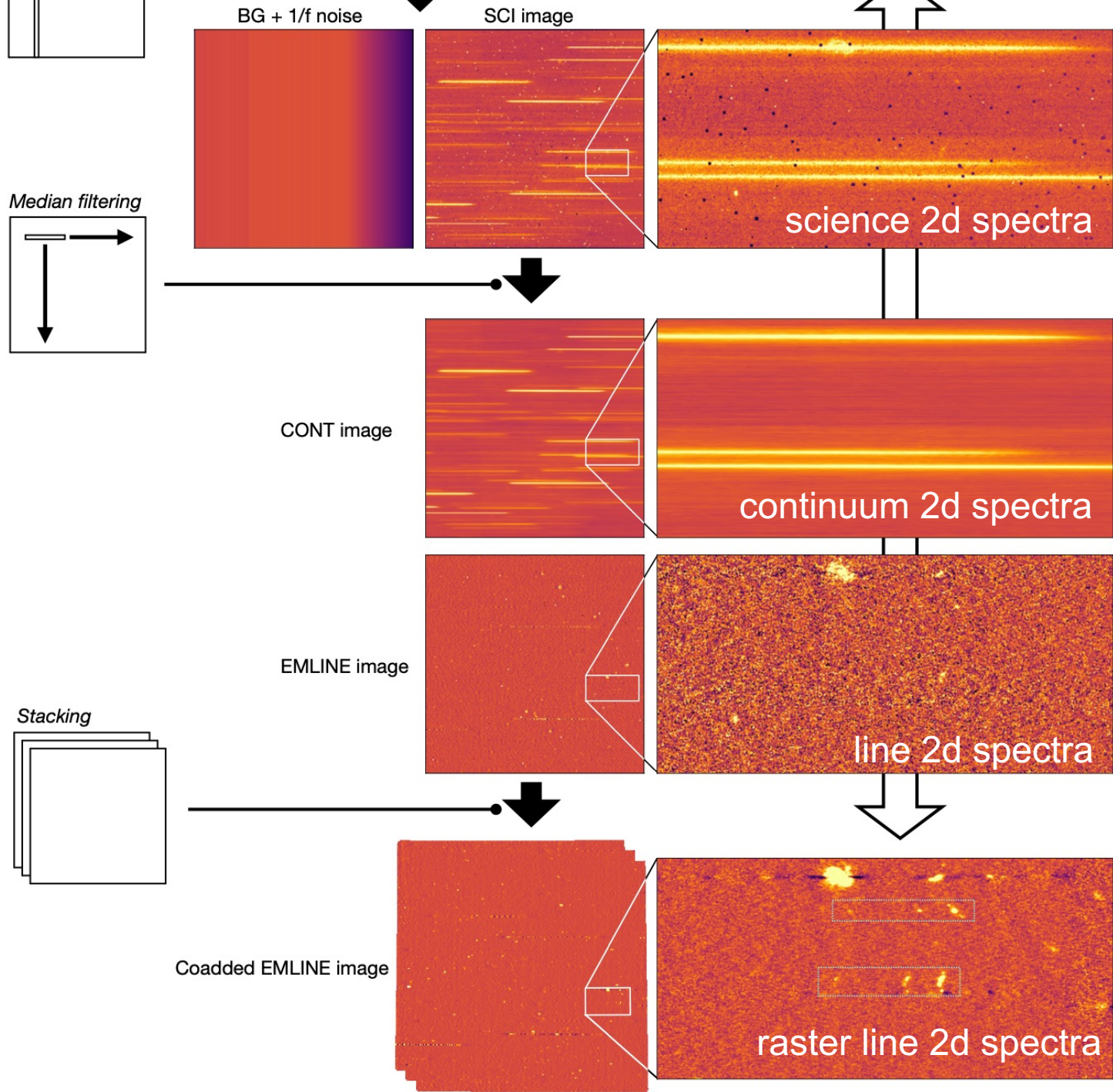## https://github.com/fengwusun/nircam_grism

Flow chart of JWST/NIRCam grism data analysis

Example from ERS-1309 (Ice Age)

jw01309024002_02101_00009_nrcblong_rate (F322W2 - B - GRISMC)

(1) Flat-Fielded

(2) Median Sky BKG Subtracted

(3) Modeled 2D BKG Subtracted

(4) 1/f Noise Subtracted

Example from
GO-1895 (FRESCO)

jw01895001004_02101_00003_nrcalong_rate (F444W - A - GRISMR)

(1) Flat-Fielded

(2) Median Sky BKG Subtracted

(3) Modeled 2D BKG Subtracted

(4) 1/f Noise Subtracted

(Not applied for GRISMR)

BG + 1/f noise

SCI image

science 2d spectra

Median filtering

CONT image

continuum 2d spectra

EMLINE image

line 2d spectra

Stacking

Coadded EMLINE image

raster line 2d spectra
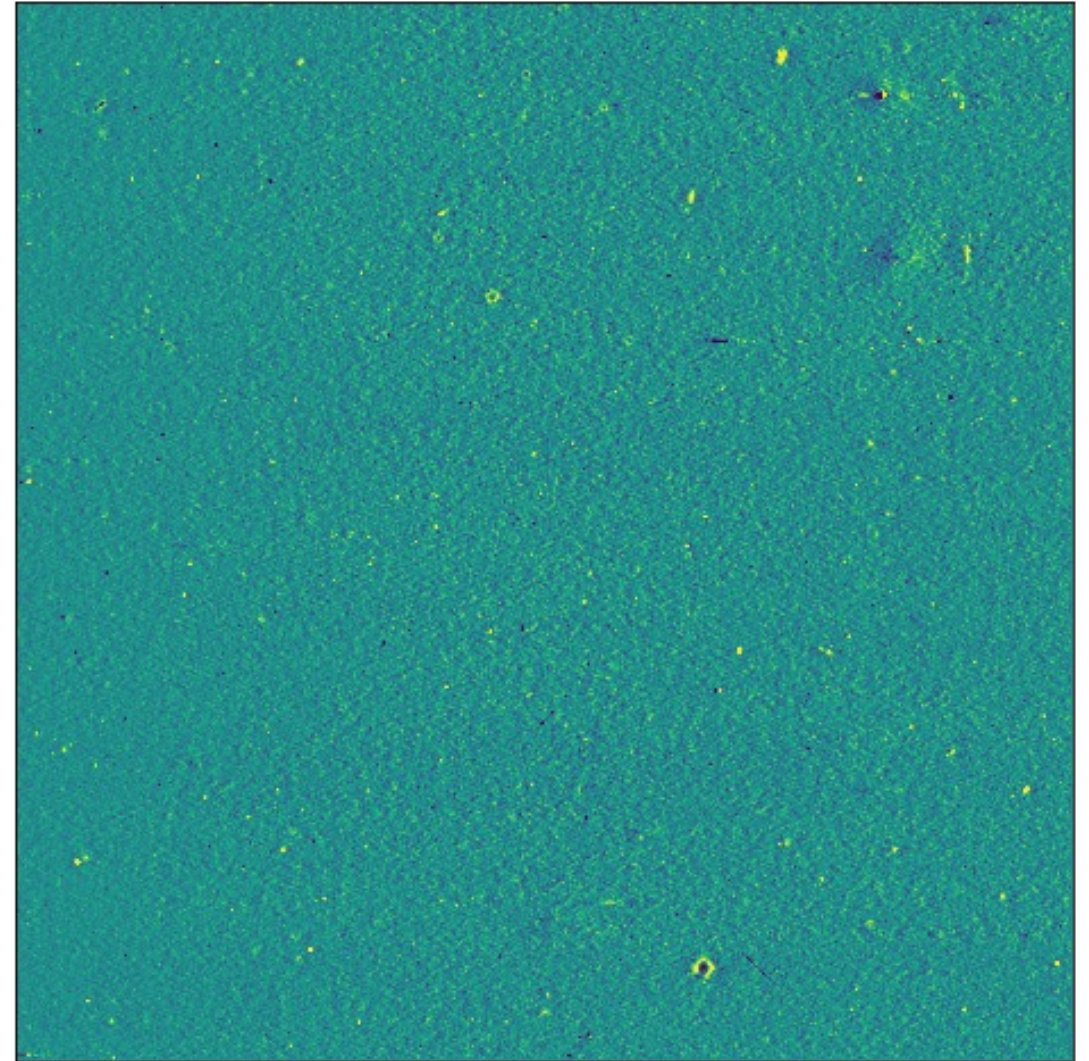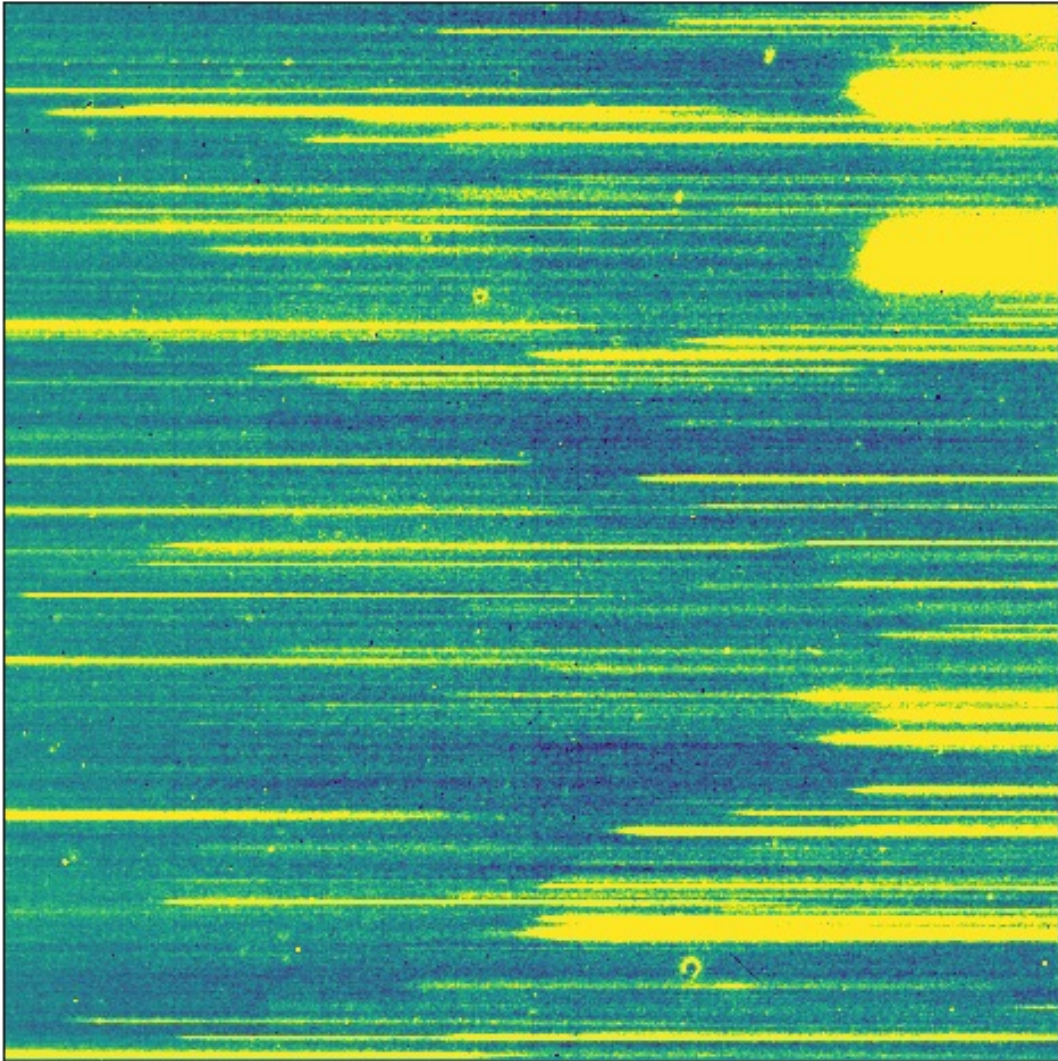
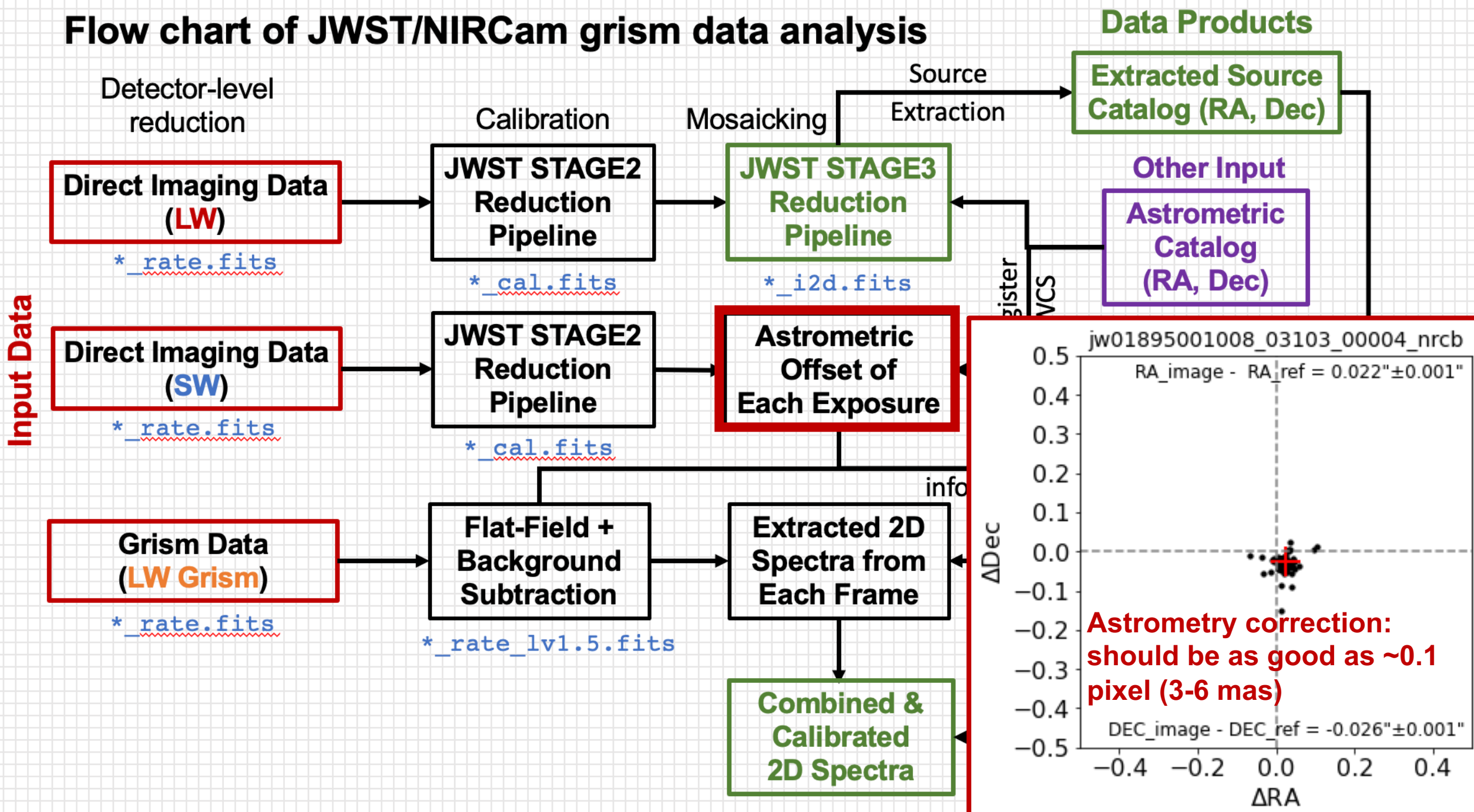**Median Filtering** technique presented by Kashino et al. (2023)
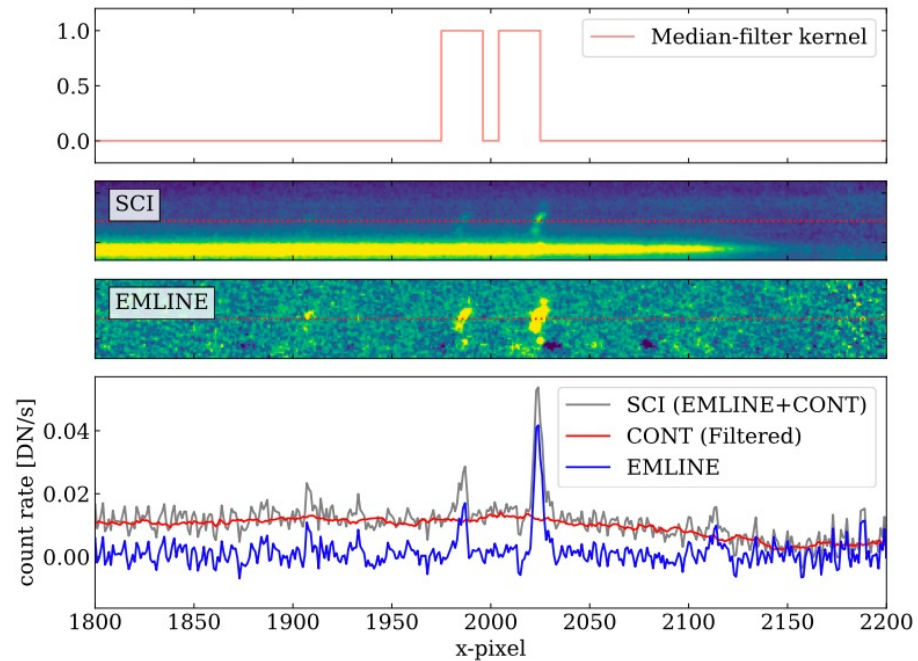
My advice:
DO NOT coadd EMLINE images

tracing function is dependent on (x0, y0), co-adding could introduce astrometric error.
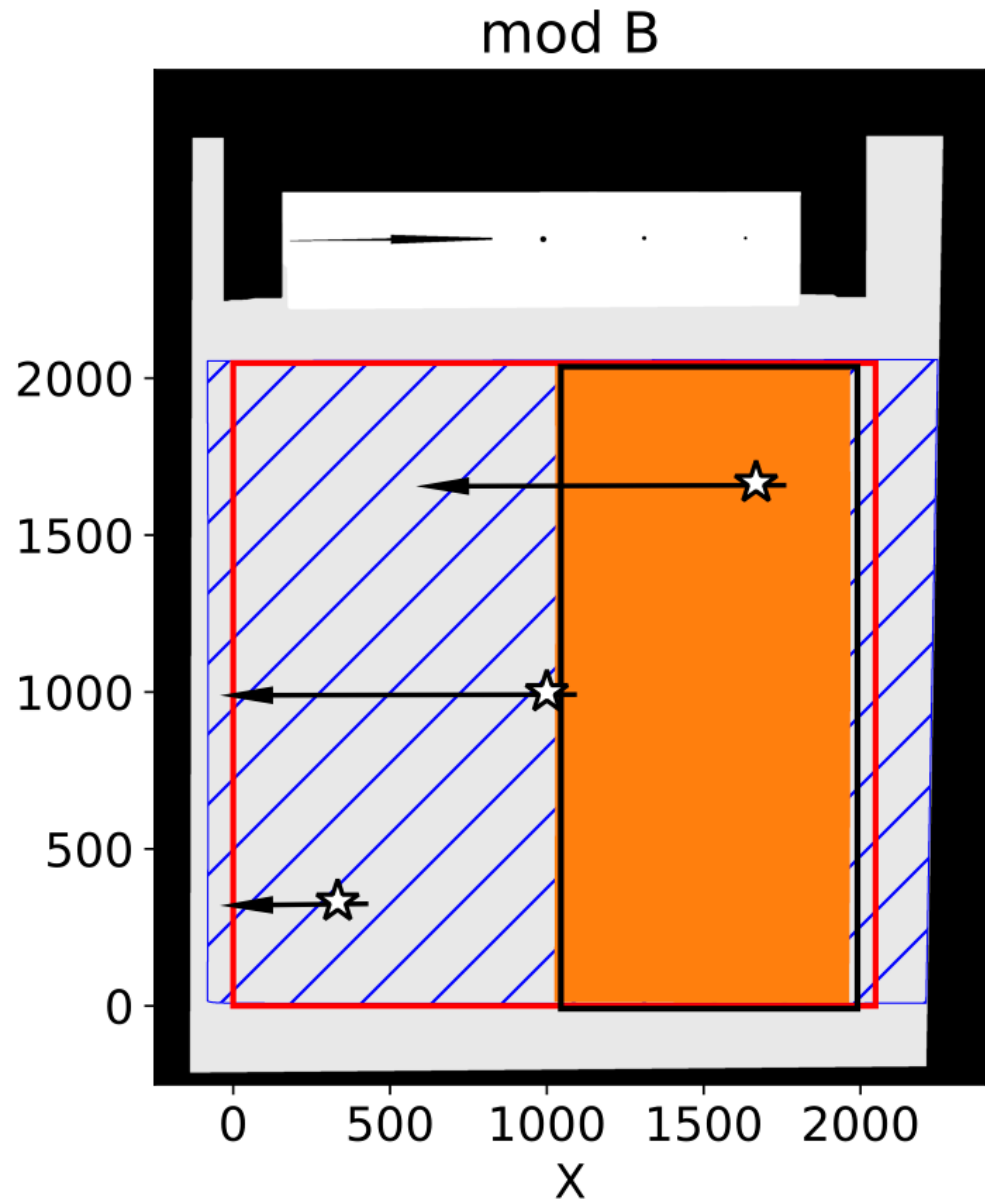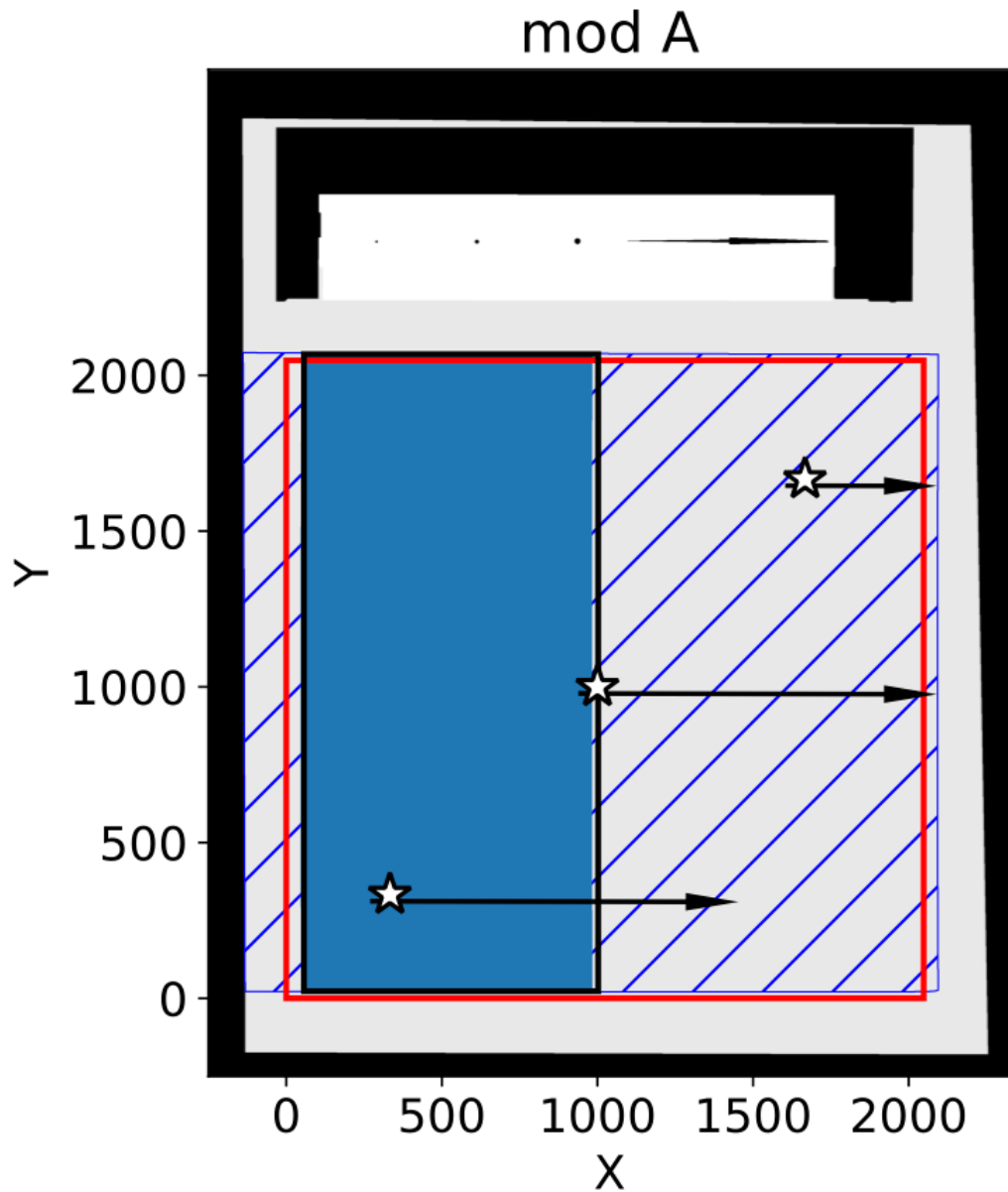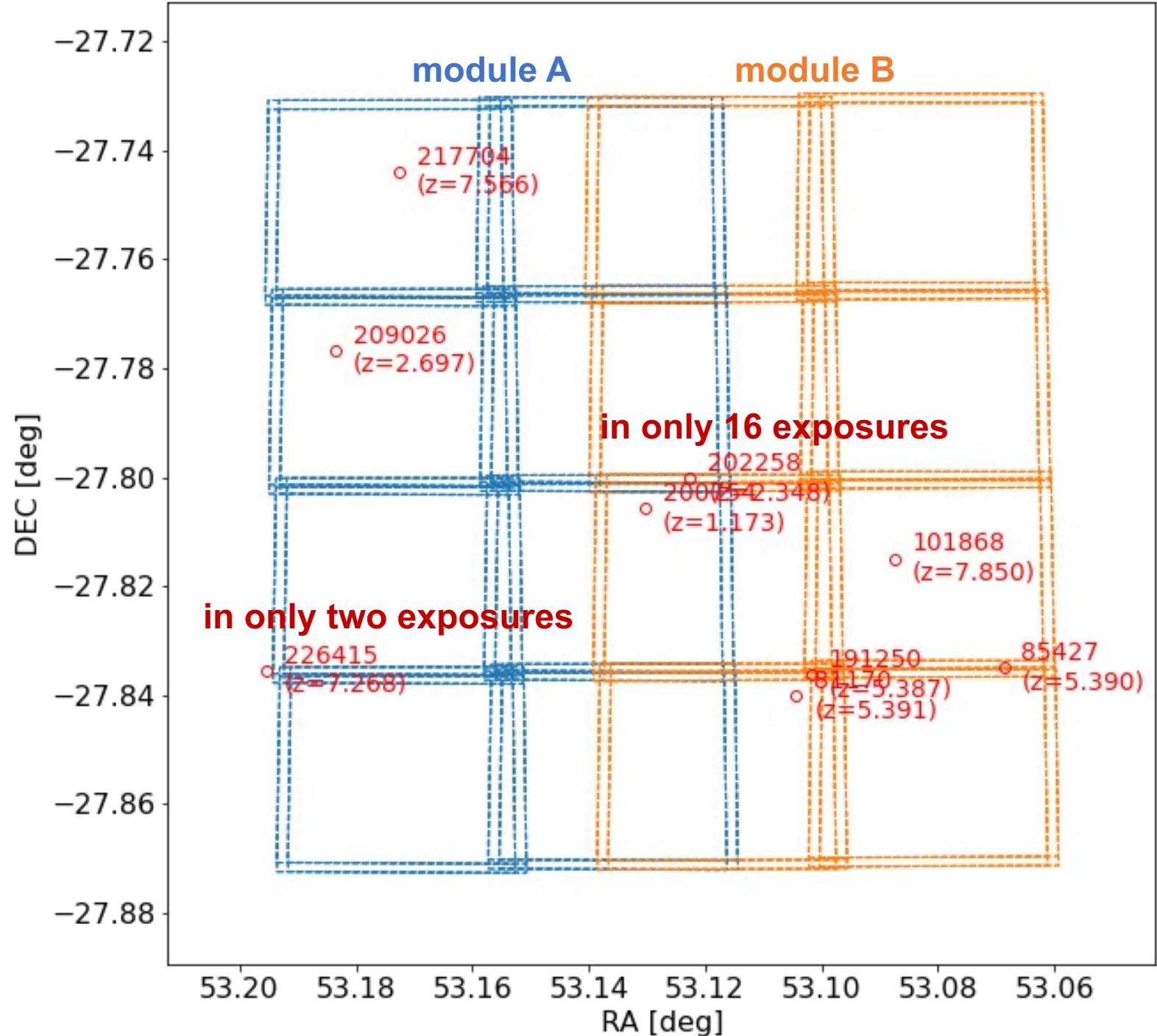
Example from GO-1895 (FRESCO)

Flow chart of JWST/NIRCam grism data analysis

Not all galaxies enter the pick-off mirror can yield grism spectra on the detector!
(F444W grism R for example)

GOODS-S FRESCO Example

Example GOODS-S FRESCO Grism Spectra