STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

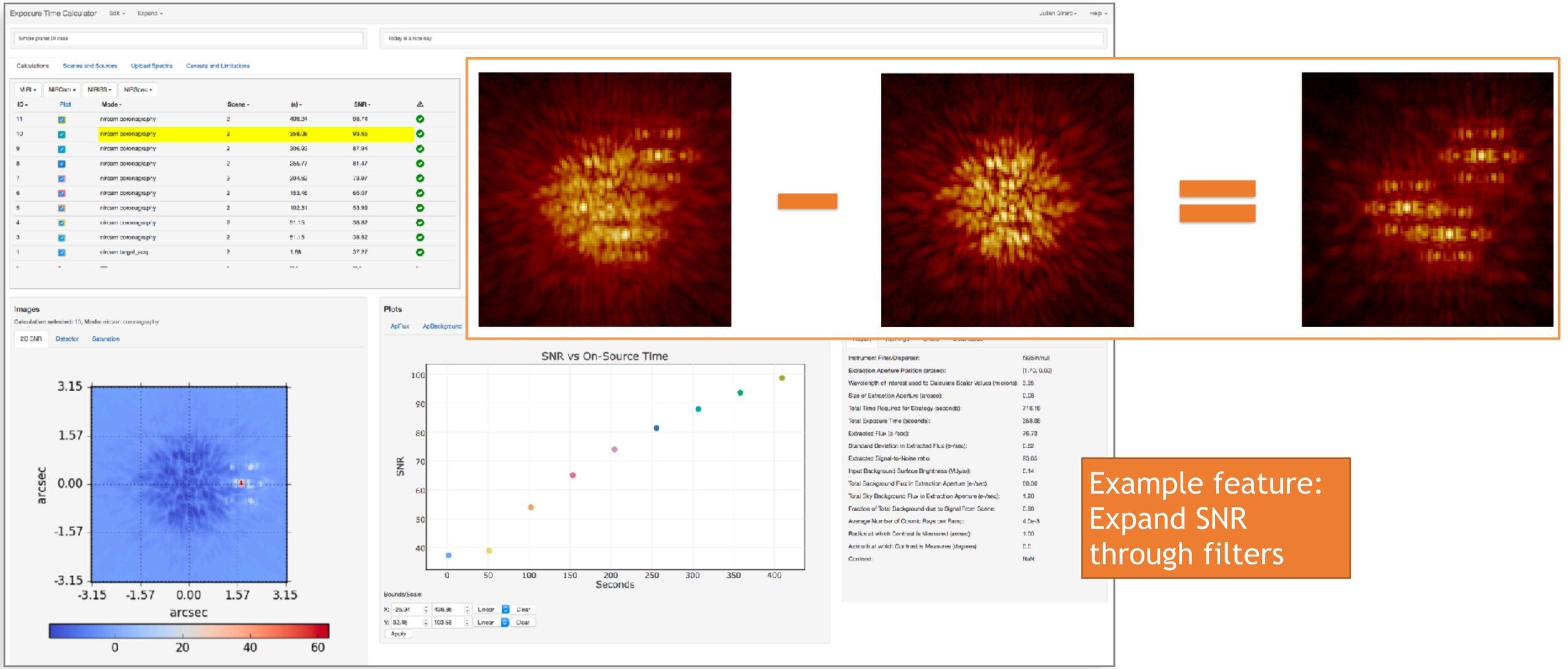
HIGH CONTRAST IMAGING (HCI) WITH JWST

ETC Limitations & high(er) fidelity calculations: **PanCAKE demo**

Julien Girard & Bryony Nickson

Master Class - Level 2 - Nov 19th & 20th 2019 - STScI

ETC for Coronagraphy: PSF subtraction from a reference star



Example feature:
Expand SNR
through filters

jwst.etc.stsci.edu

ETC for Coronagraphy: Limitations for High Contrast Imaging

Pre-computed PSF library from WebbPSF with a discrete number of angular separations (sparse spatial sampling)

- ➜ Calculations can be inaccurate in the speckle limited regime (close to the coronagraphs, typically at separations < 1")

ETC does not account for spectral mismatch (only photometrically) of the PSF reference star

ETC supposes a perfect centering (target acquisition) of all stars

- ➜ Calculations can be optimistic

PSF calculations "on the fly" are time consuming: can be done in command line with Pandeia engine or with PanCAKE (not yet fully supported)

- ✦ Custom small grid dithers and positioning
- ✦ Custom spectral sampling
- ✦ Custom field of view

https://github.com/spacetelescope/pandeia-coronagraphy

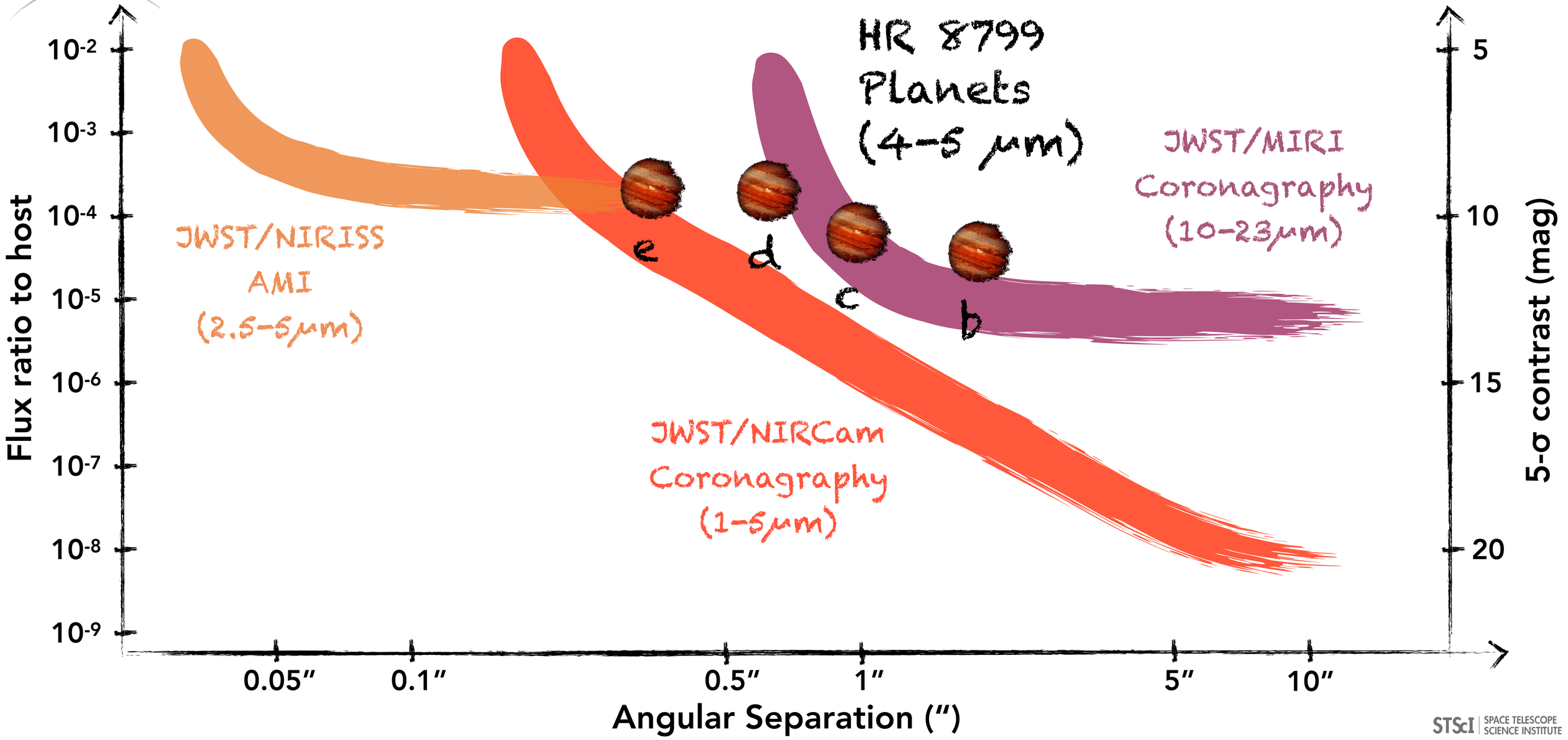
The ETC PSF subtraction strategies assume the same detector readout parameters for all stars in a workbook

- ➜ If one wants to use a brighter reference star, several ETC workbooks are needed

The ETC cannot inject ring like features or disks

Can be done with pyNRC (not supported by STScI) https://pynrc.readthedocs.io

NIR to MIR Coronagraphy & Aperture Masking: Ground & Space



Why do we recommend two rolls plus a PSF calibrator?

Factors degrading PSF calibration and subtraction

Wavefront drifts of the observatory

PSF star color differences

Self-subtraction biases (esp. for disks)

Imperfect target acquisitions

Line-of-sight jitter and dynamic wavefront error

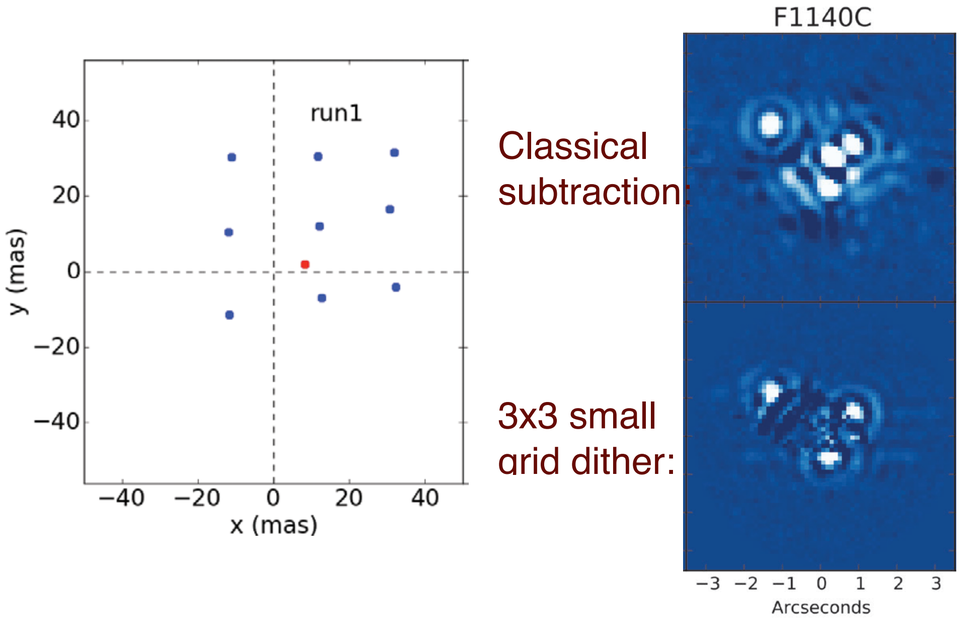
Optional:
Perform sub pixel dithers of the PSF star to build mini PSF reference library, then synthesize an optimal PSF that matches the target
position precisely. “Small Grid Dithers”.

>10x contrast improvement for MIRI,
3-5x improvement for NIRCam.

Cost: 5-9x longer PSF star exposure times.

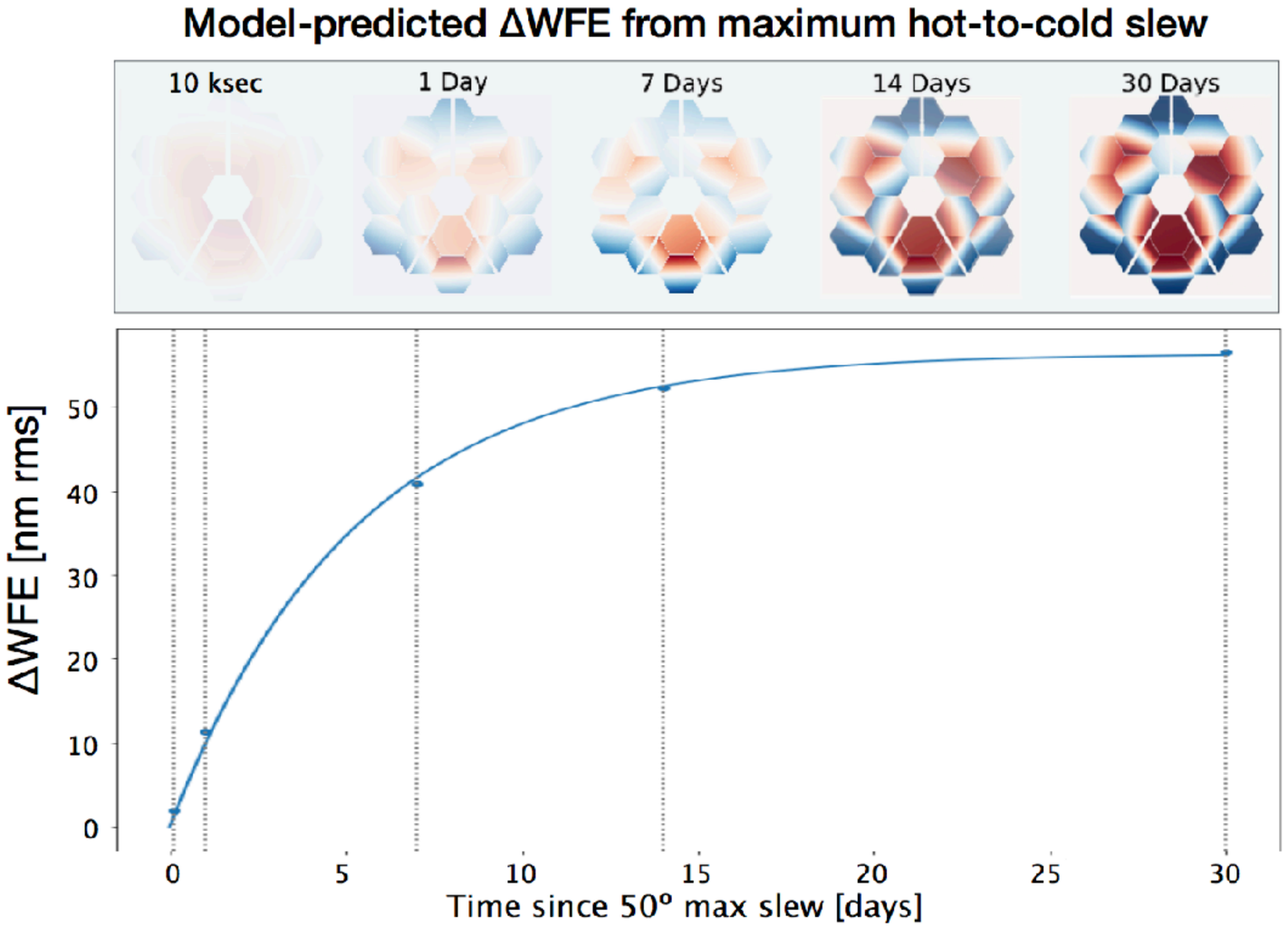
Target acq is required for all coronagraphy.
Expected precision is very good (~ few mas)
but residuals still matter.

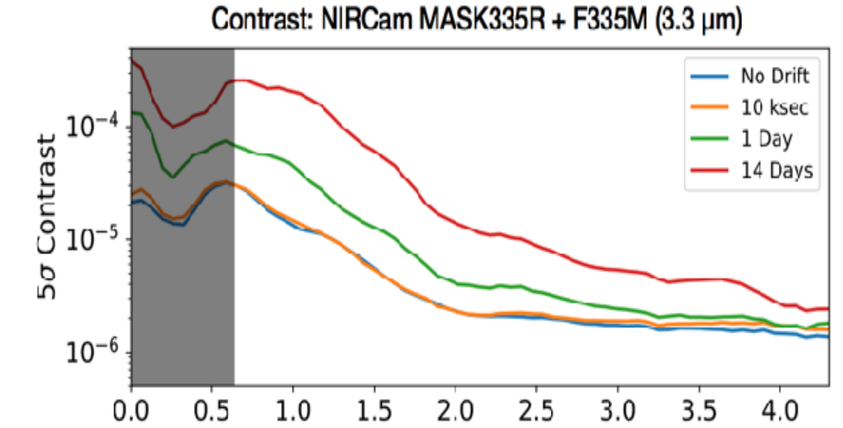
All coronagraphs are sensitive to misalignments;
MIRI FQPMs more sensitive than NIRCam Lyot corons.

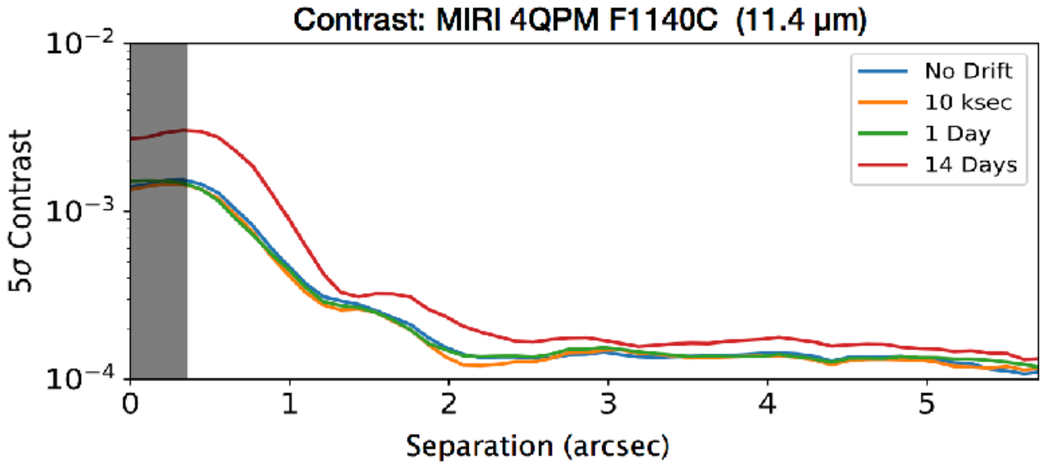


Simulated small grid dither PS subtraction
Lajoie et al. 2106

Towards the generation of realistic datasets : impact of slew



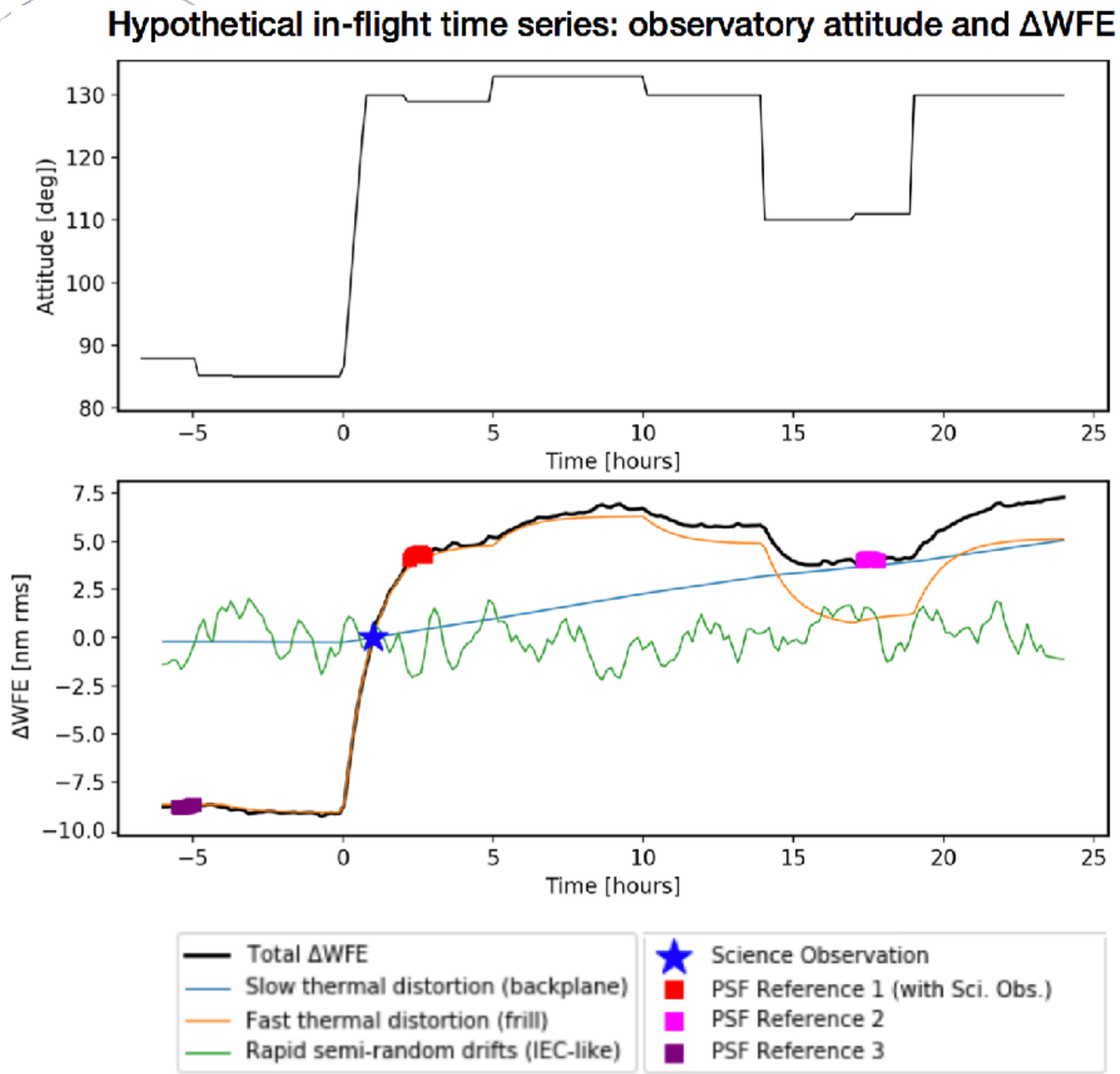


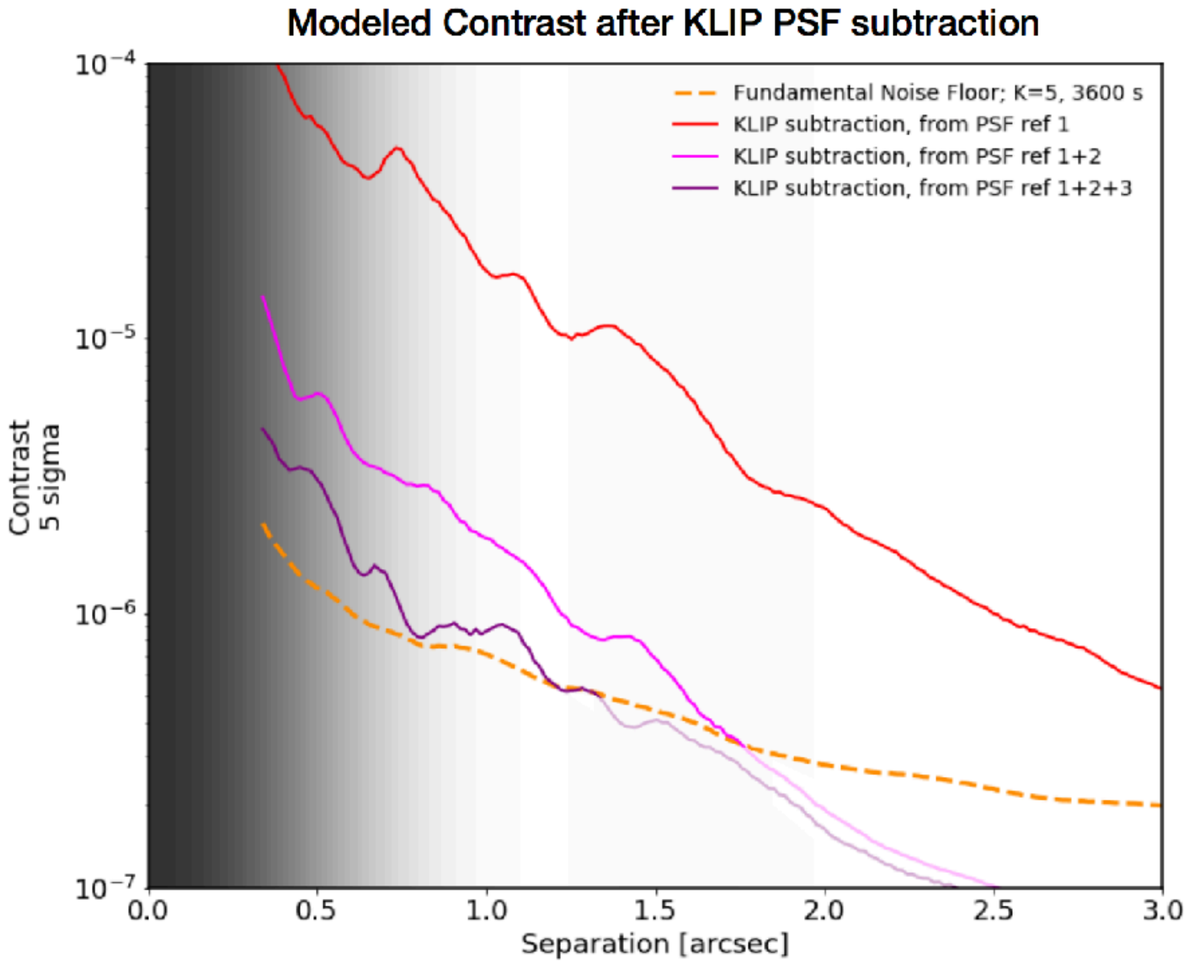


Perrin et al. SPIE 2018

Brooks et al. #AAS233

Towards the generation of realistic datasets : impact of slew





Perrin et al. SPIE 2018

Brooks et al. #AAS233

ETC extensions: PanCAKE (STScI) & pyNRC (NIRCam IDT)

github.com/spacetelescope/pandeia-coronagraphy

PanCAKE

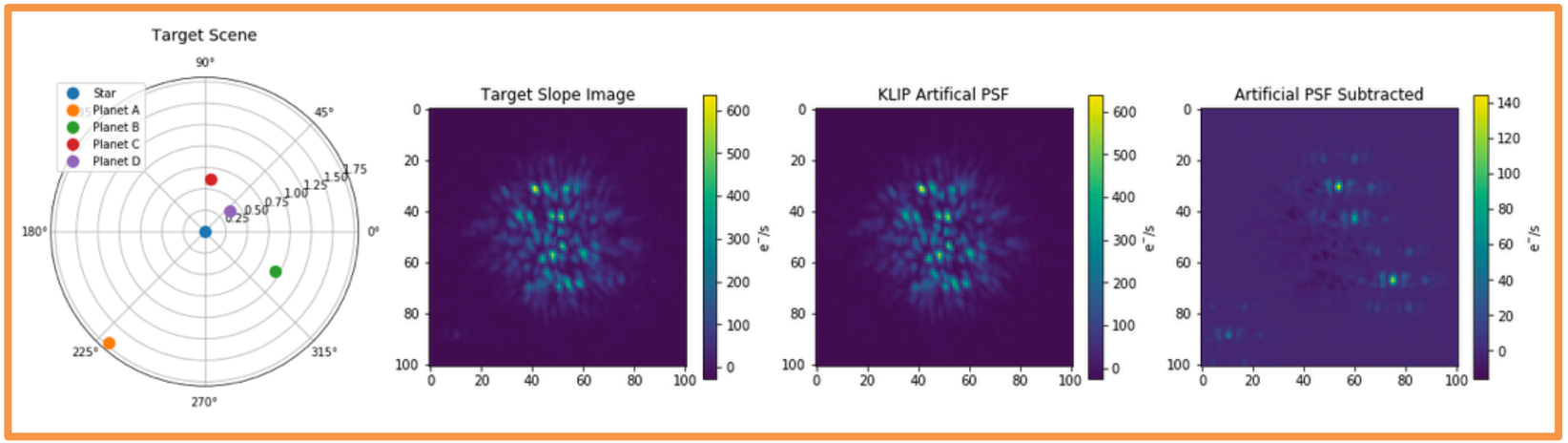
Can call WebbPSF “on the fly”

- custom PSF grids/dithers, FoV, spectral sampling, more precise extractions

Several coronagraphic specific functions

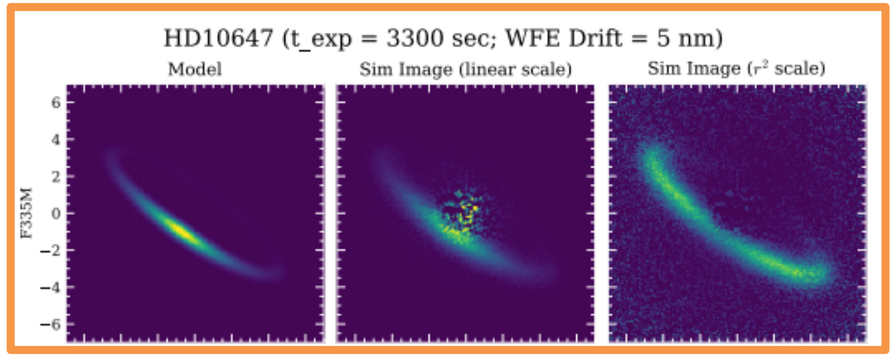
- Contrast curves

Currently improving the scene compatibility with ETC UI and outputs



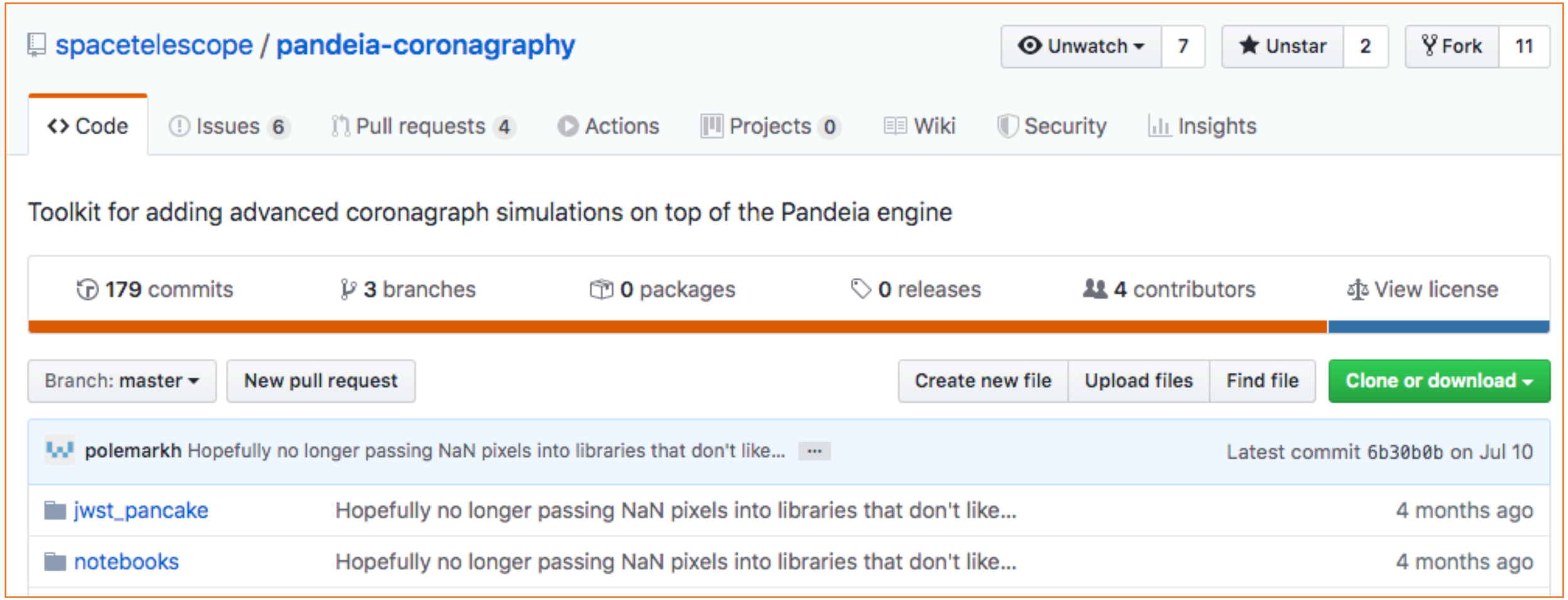
Van Gorkom, York, Perrin, Girard

Check also (disks)! pyNRC



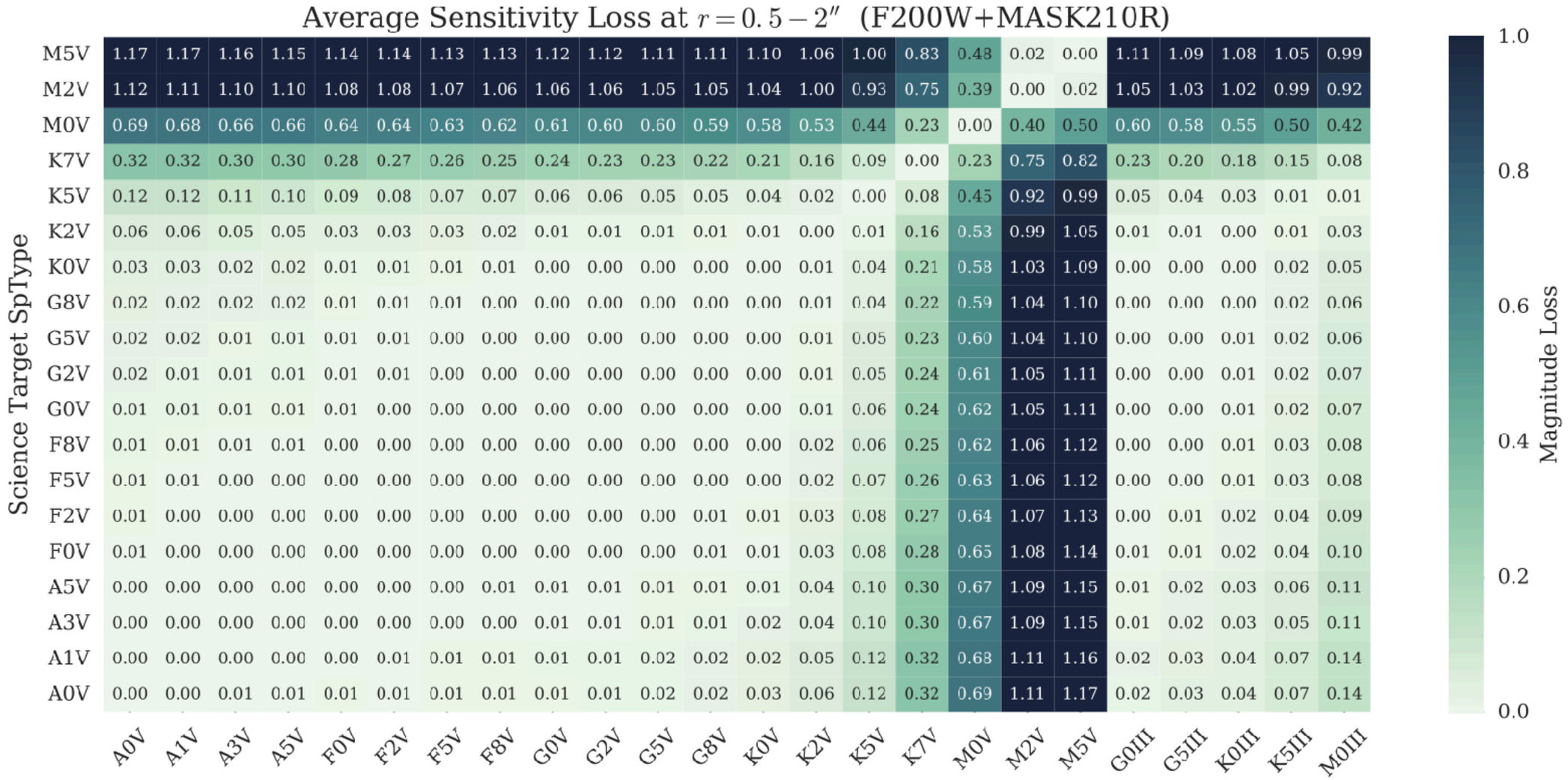
Leisenring

PanCAKE (formely Pandeia-Coronagraphy)



https://github.com/spacetelescope/pandeia-coronagraphy

Selecting a PSF Reference Star (avoid spectral mismatch)

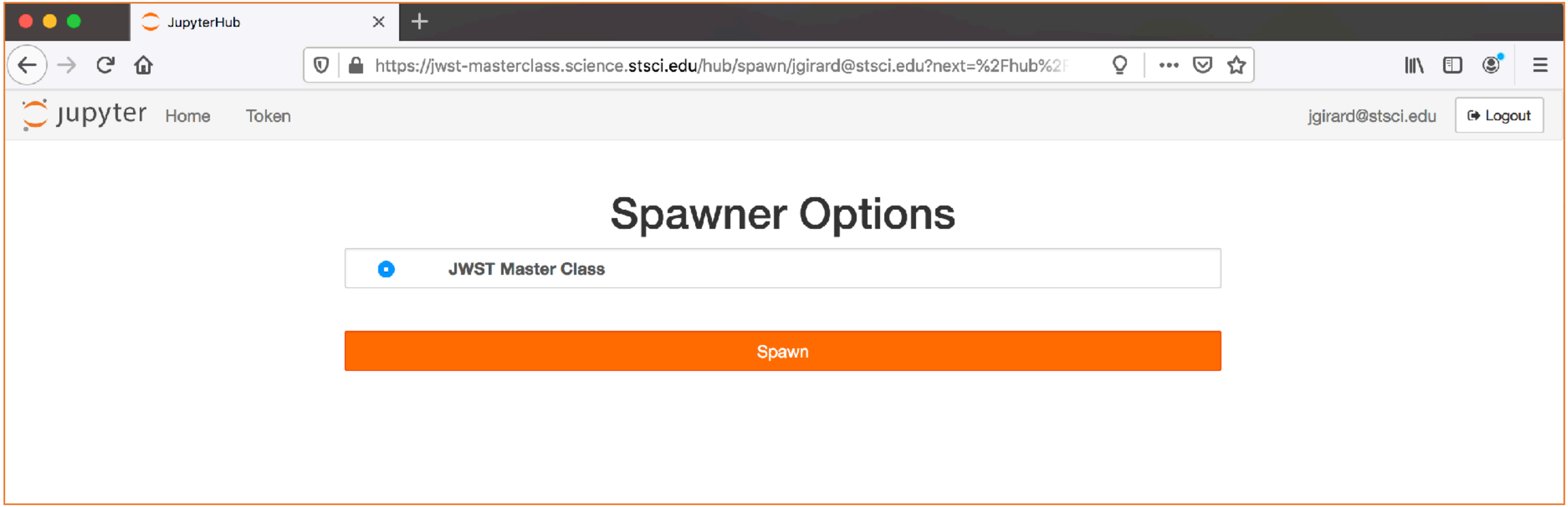


Credit: Jarron Leisenring (pyNRC)

More critical at shorter wavelengths (NIRCam), not critical for MIRI

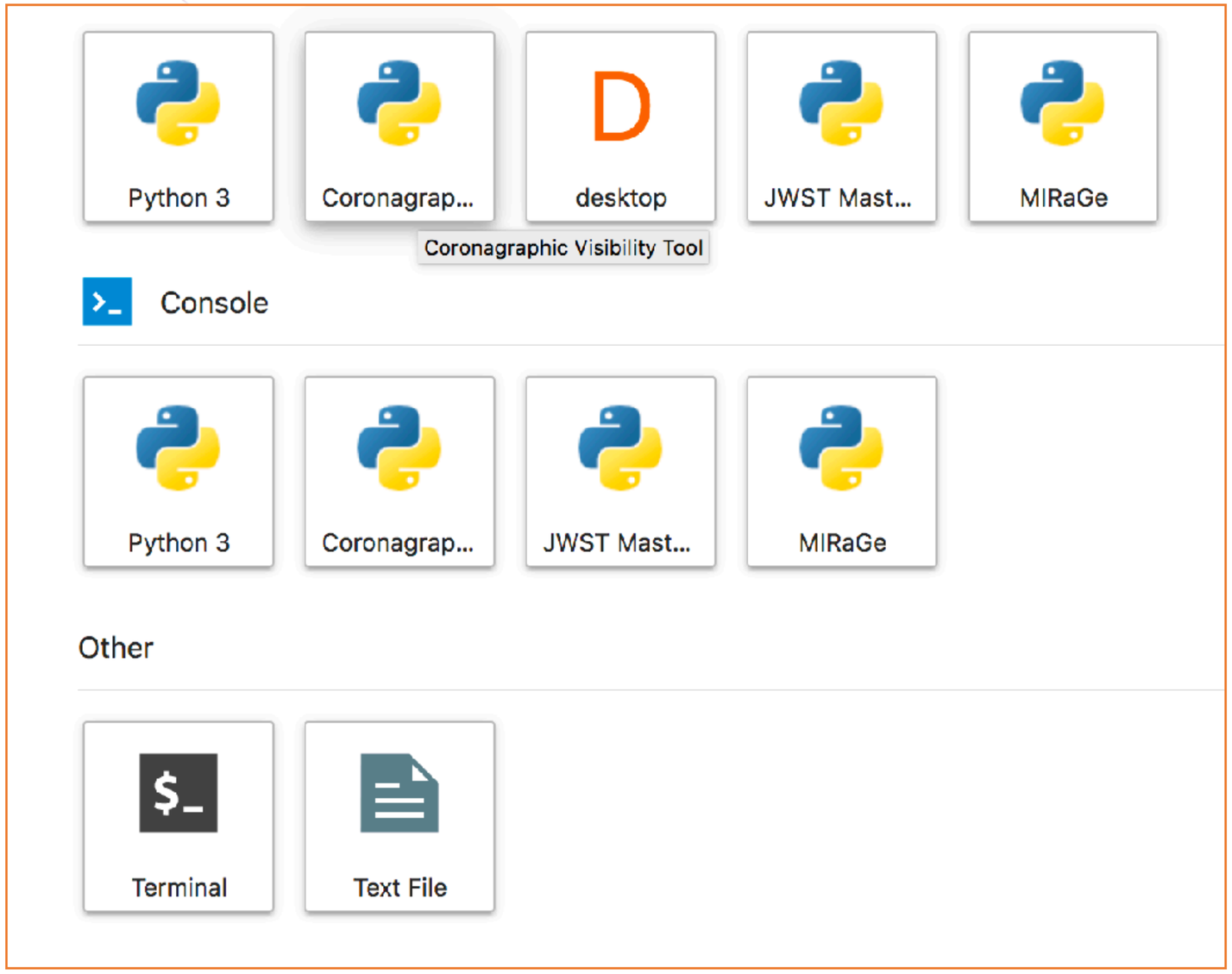
Jupyter Hub Server for the Master Class

https://jwst-masterclass.science.stsci.edu



May take a few minutes to load

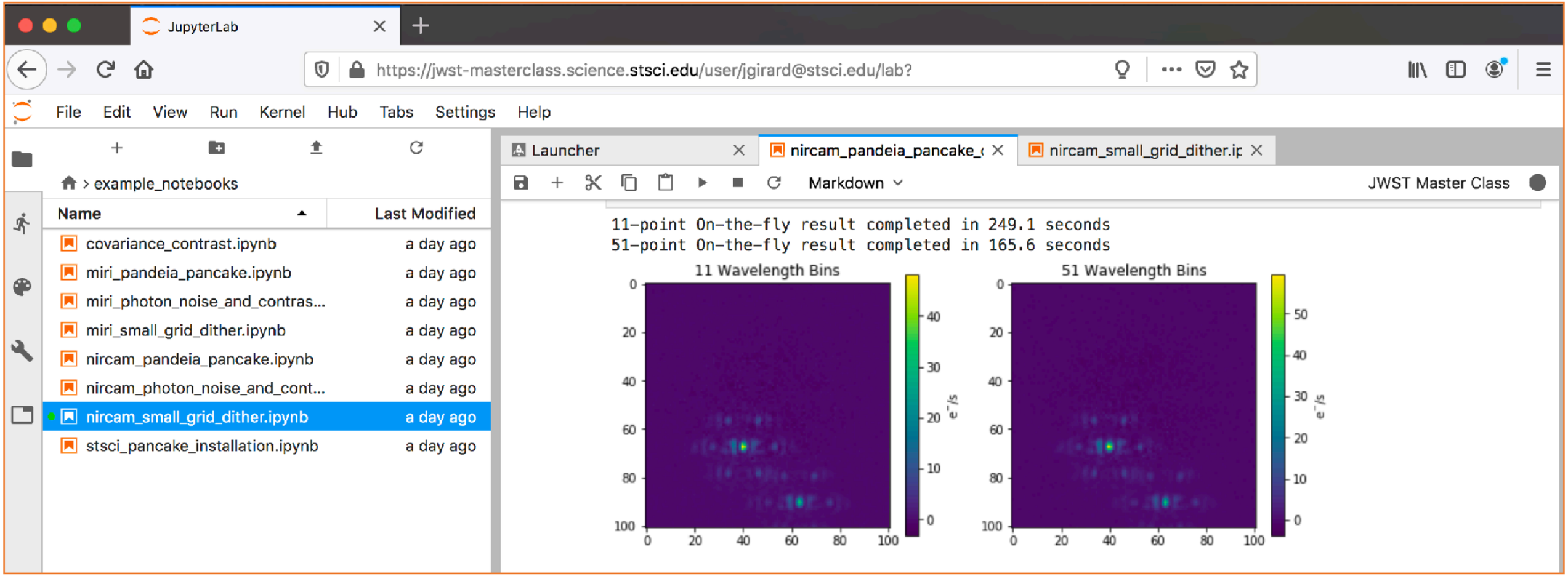
Jupyter Hub: Launcher



https://jwst-masterclass.science.stsci.edu

Jupyter Hub: “on-the-fly” calculations with PanCAKE

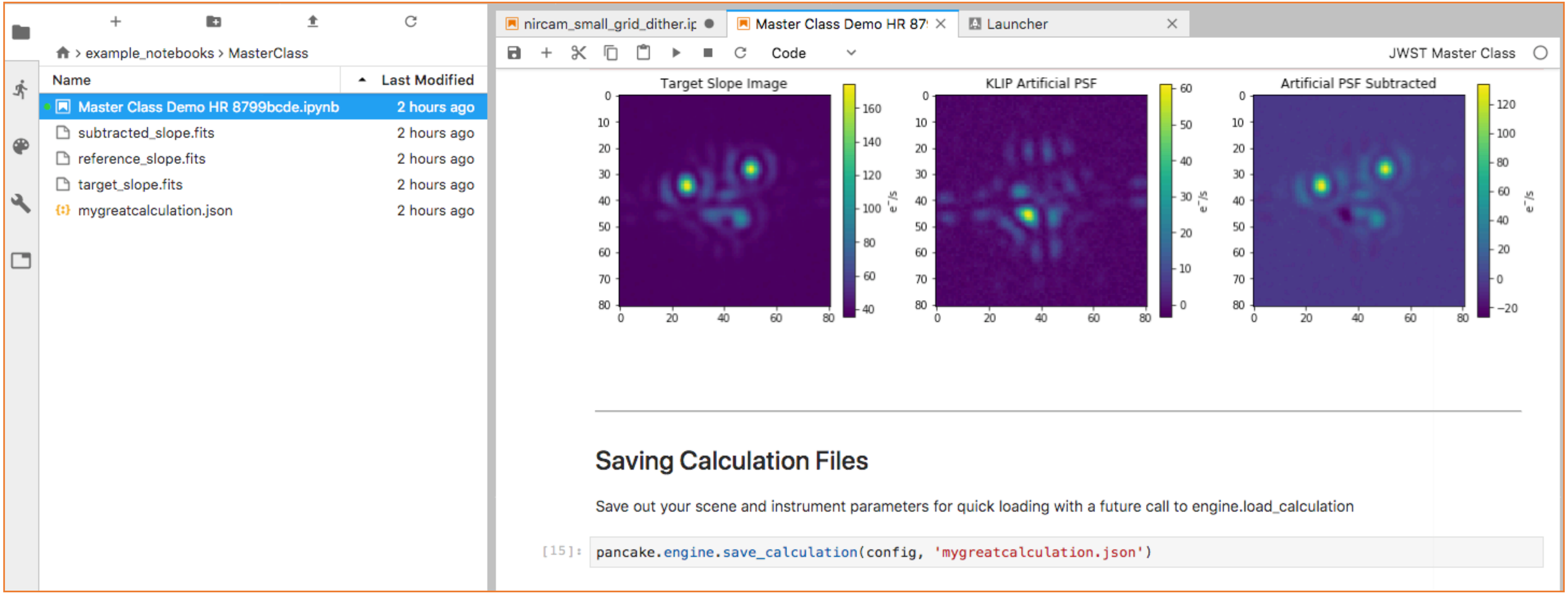
Pandeia/WebbPSF & Small Grid dithers (SGD)



https://jwst-masterclass.science.stsci.edu

Jupyter Hub: JWST Master Class PanCAKE notebook

NIRCam and MIRI Coronagraphy of HR 8799 bcde



https://jwst-masterclass.science.stsci.edu