HIGH ORDER DITHERING: EXTENDING JWST SMALL GRID DITHERING STRATEGIES ON ROMAN CGI

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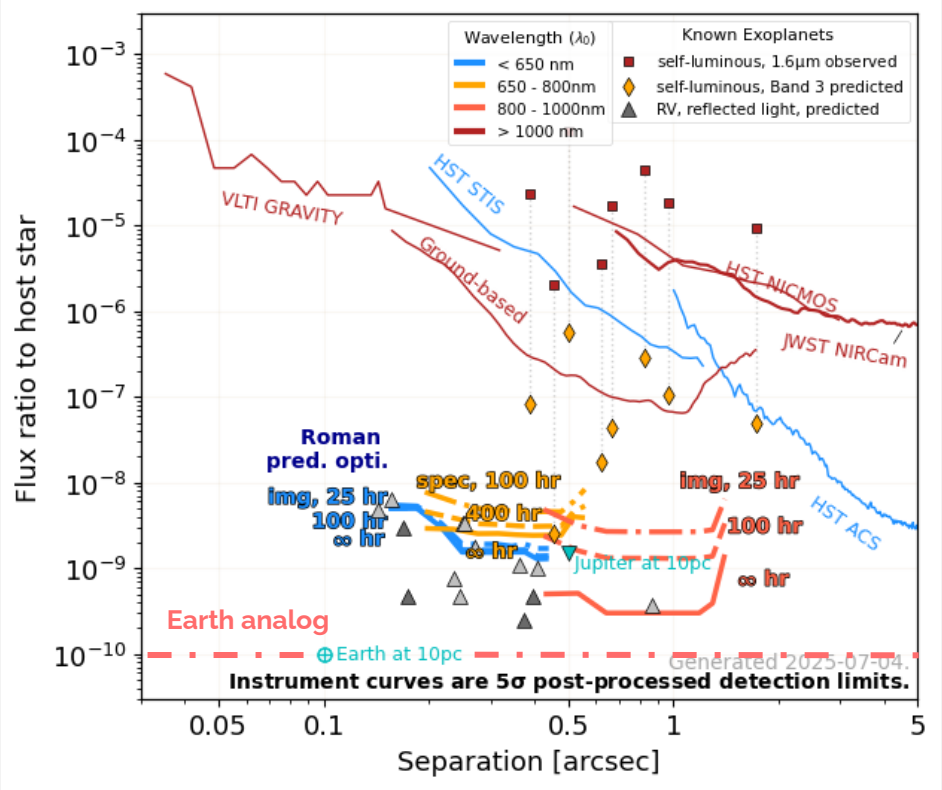
PREDICTED PERFORMANCE OF ROMAN AND CURRENT CAPABILITY



github.com/nasavbailey/DI-flux-ratio-plot

→ Performance: **10^{-8} → reach up to 10^{-9} after post-processing**

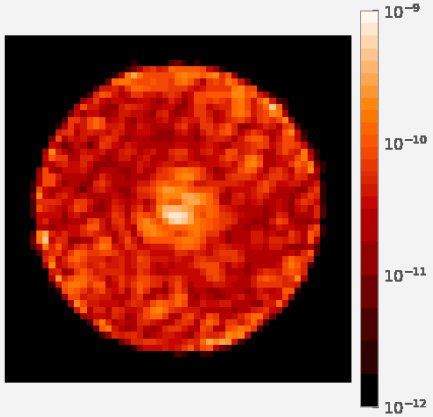
→ Expected yield: detection of cold giants, with handful candidates

→ Roman CGI is equipped with DMs, enabling active wavefront control

Roman is an ideal platform to **develop** and **mature techniques** needed for **HWO**

WHY POST-PROCESSING BECOMES LIMITED:
LIMITED OVERLAP BETWEEN REFERENCE AND SCIENCE SPECKLE REALISATIONS

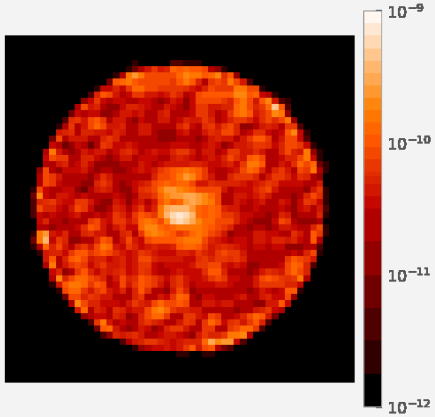
Reference (t)



Temporal wavefront drift

(e.g. thermal deformation, slew and roll)

Science (t+Δt)

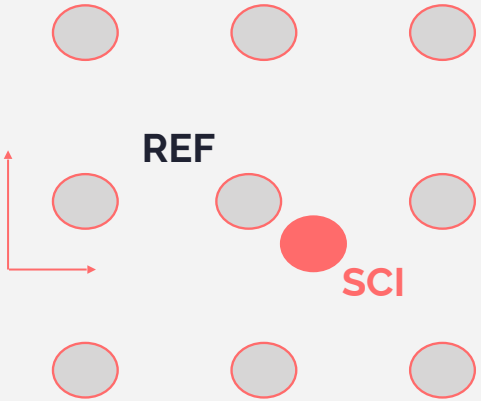


🌊 Speckle evolves between science and reference

🙈 Reference does not sample wavefront drift in science

SMALL GRID DITHERING: IMPROVED SAMPLING OF SPECKLE VARIATIONS

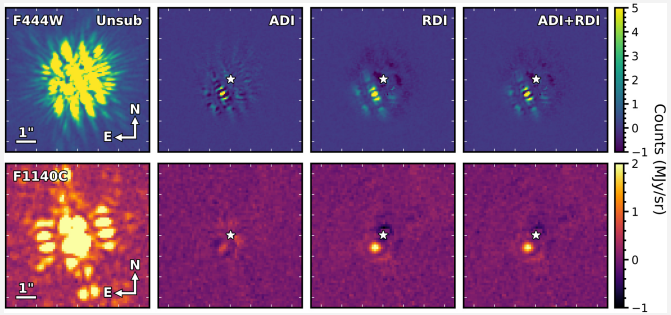
JWST mitigates **limited sampling of speckle variations** using **Small-Grid Dithering** (Soummer+14, Lajoie+16).



↔️ Acquire reference PSFs at **controlled offset positions** behind the coronagraph

📚 Build a compact reference PSF library sampling **speckle variations**

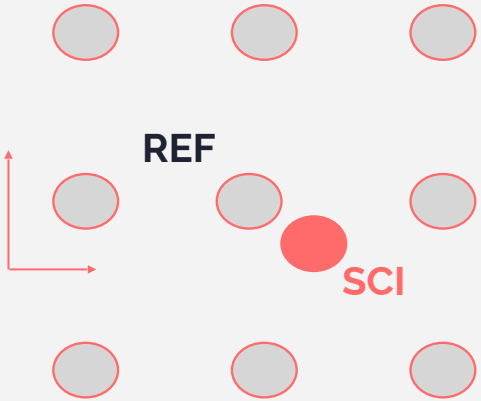
🧠 Better sampling of **speckle variations** improves overlap with the science speckle subspace



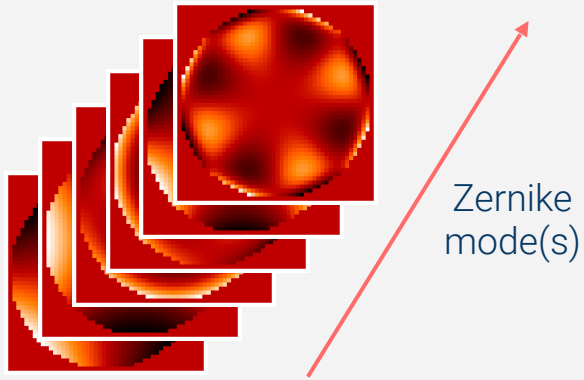
Carter et al. +23

EXTENDING SMALL GRID DITHERING TO HIGH ORDER DITHERING

Small Grid Dithering



High-Order Dithering



Dither pattern on the DM

→Replace tip-tilt with controlled Zernike dithers

→ Use DM to inject complex modes

→ Applied only during reference acquisition

Richer PSF Diversity —> Richer Model Subspace

THE ESCAPE PROJECT: TEAM AND SCOPE

Goal: Develop modern post processing methods tailored to active space telescopes and enable the direct imaging of cold giant exoplanets

Lisa Altinier

on the job market!

Simulation focuses on HO-Dithering

Élodie Choquet

PI

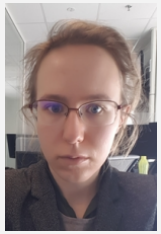
Alexis Lau

Experimental validations

Nico Godoy

JWST data reduction + analysis

Sophie Noiret



Software development (corgisim, corgidrp)

Mascot

VERIFYING HIGH-ORDER DITHERING: EXPERIMENT AND SIMULATION

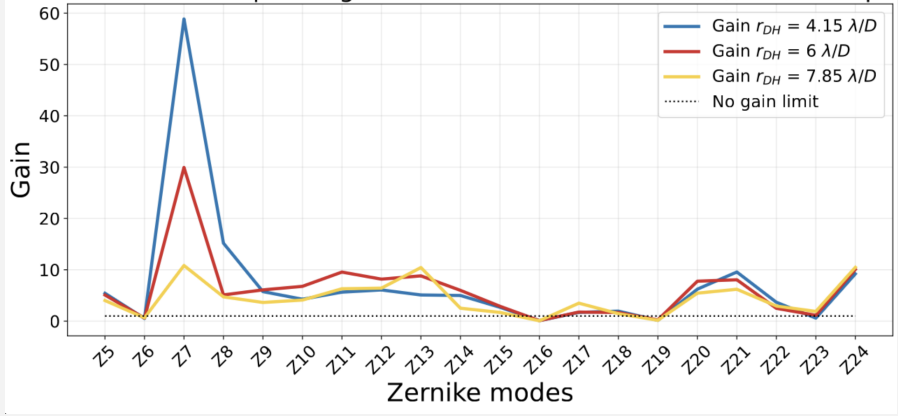
Simulation Validation on CAPyBARA

A&A: Altinier et al., (in prep)

End-to-End prototyping of observing sequence

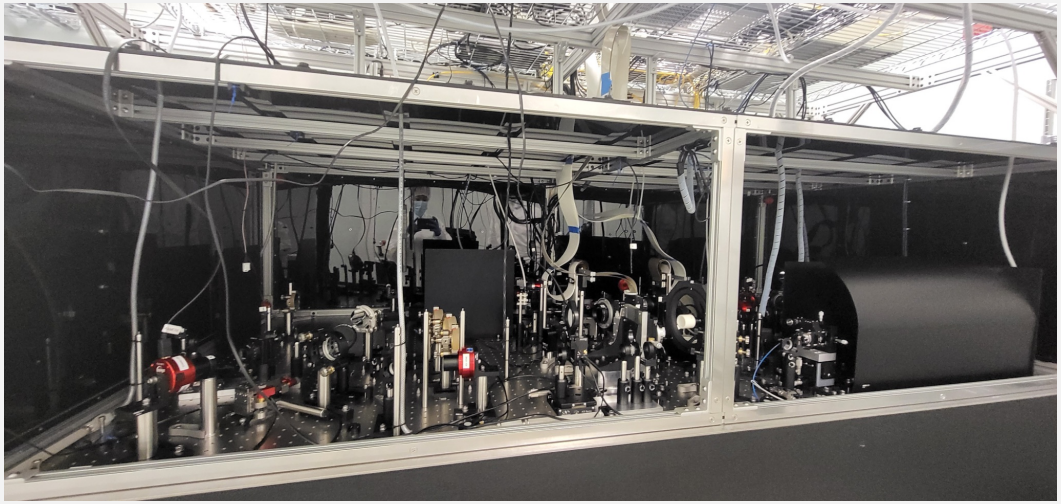
Lisa Altinier

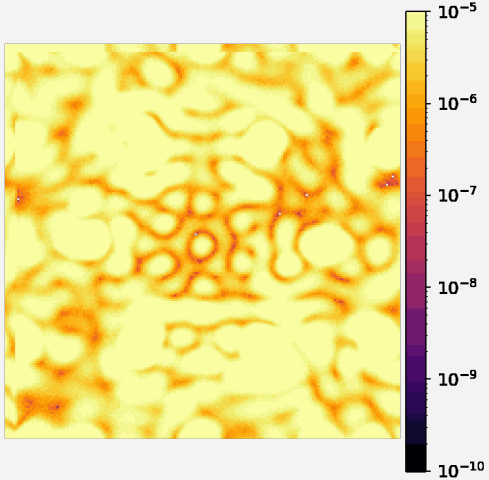
CAPyBARA



Software - Altinier et al., +24, JOSS: Lau, Altinier et al., (in prep)

EXPERIMENTAL VALIDATION ON HICAT



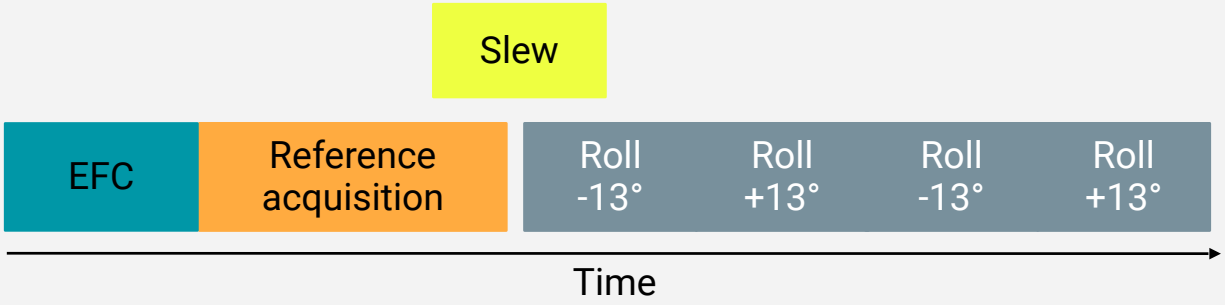


→ system-level HCI testbed

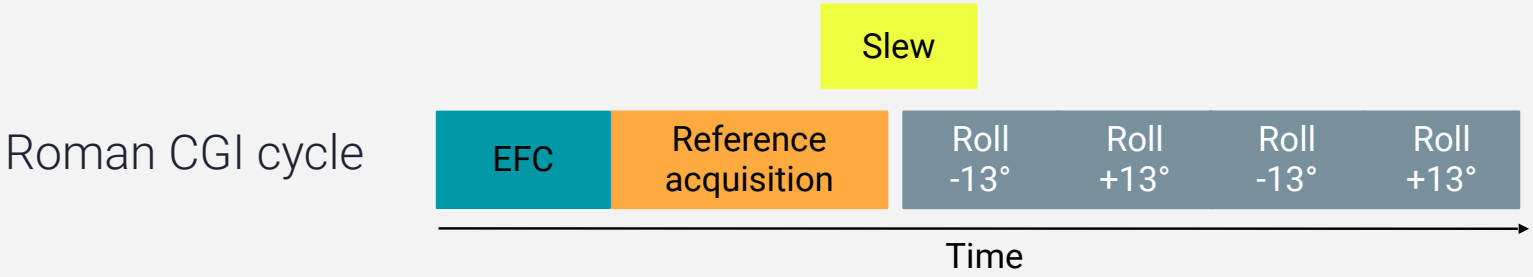
→ ~10^{-8} contrast level (~Roman)

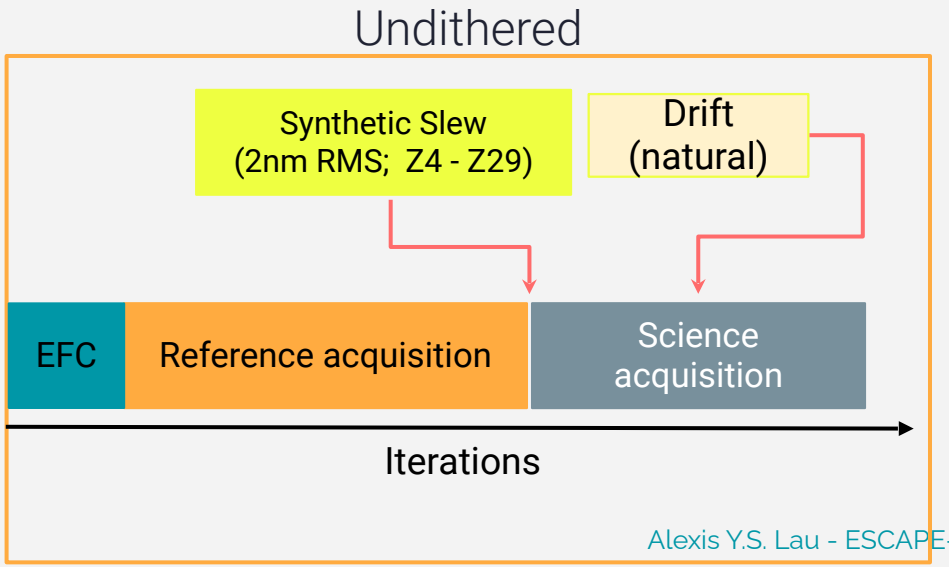
(Soummer et al., +24)

EXPERIMENTAL SEQUENCE ON HICAT TESTBED



EXPERIMENTAL SEQUENCE ON HICAT TESTBED





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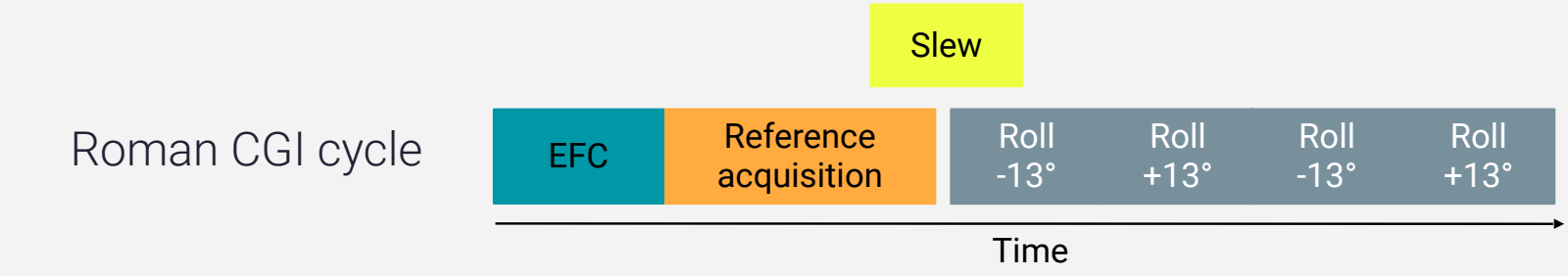
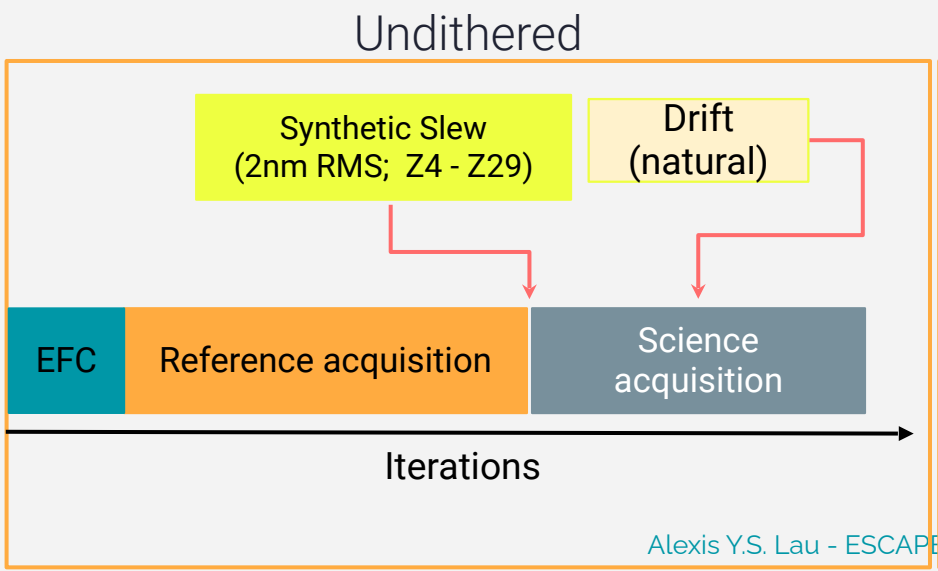
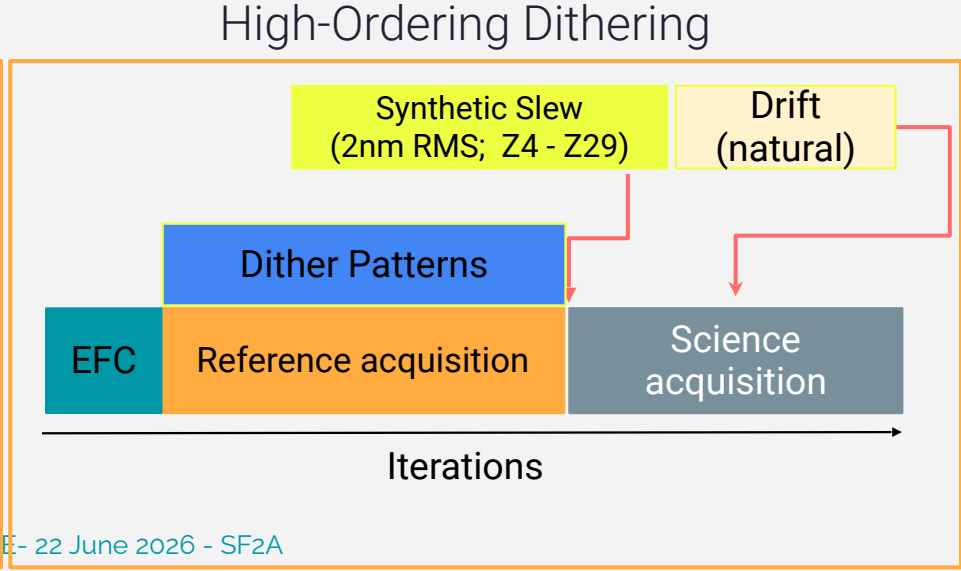
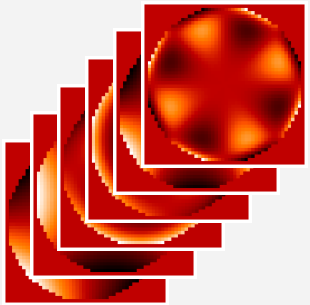




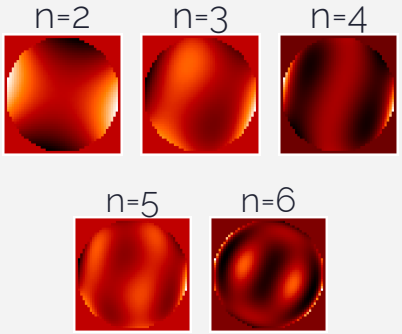


HIGH-ORDER DITHERING: STUDY DESIGN AND PARAMETER SPACE

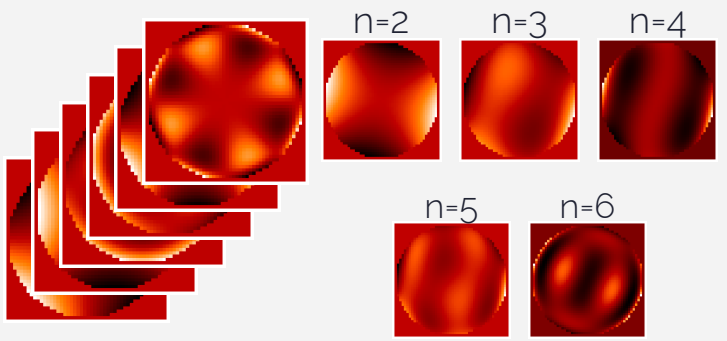
Grouped single mode (radial degree)



Linear combinations (compact)

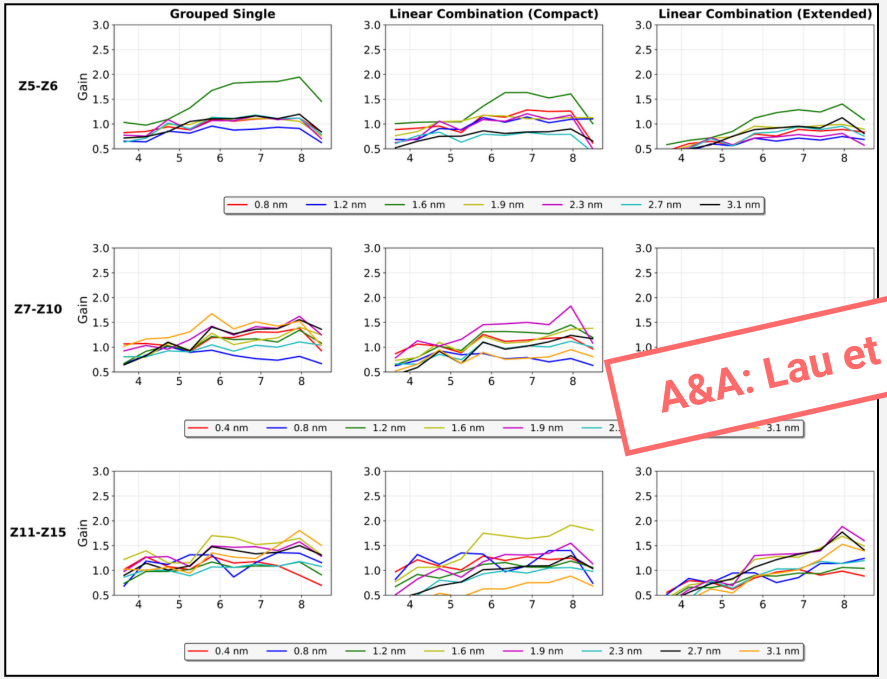


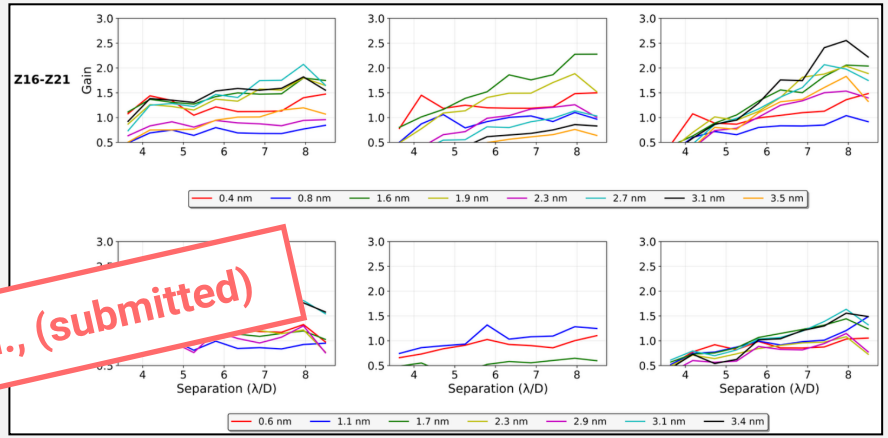
Linear combinations (extended)



Radial degree n = 2–6
multiple amplitudes explored (.4 nm - 3.5 nm)
Identical setup for observing sequence and post-processing setup for all cases

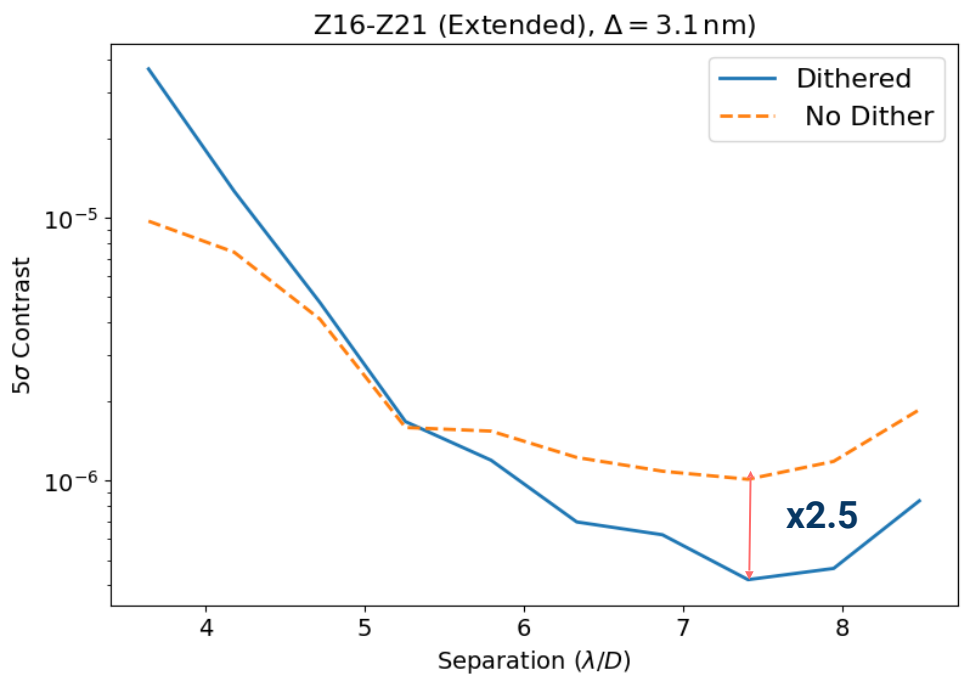
HIGH-ORDER DITHERING: STUDY DESIGN AND PARAMETER SPACE





A&A: Lau et al., (submitted)

HIGH-ORDER DITHERING: CONTRAST IMPROVEMENT RELATIVE TO NO DITHER



Radial group: Z16 - Z21

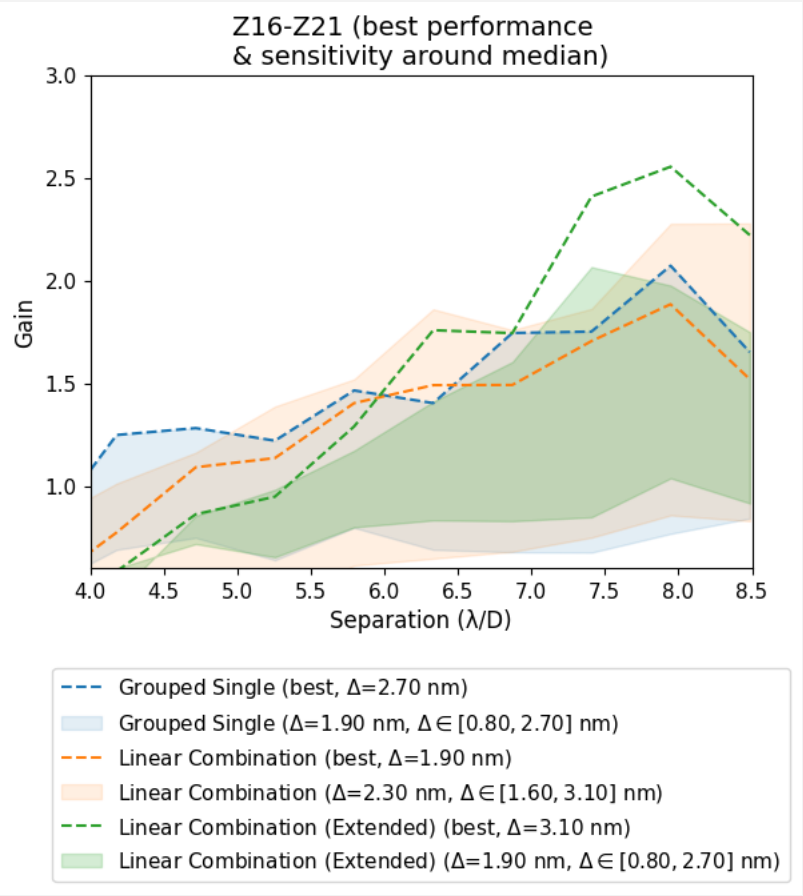
Strategy: Linear combinations (Extended)

Dither amplitude: 3.1 nm

Up to x2.5 contrast limit gain beyond 5 λ/D

HiCAT baseline contrast ~1e-8, higher level due to injected slew and drift to mimic the realistic observing sequence

HIGH-ORDER DITHERING: GAIN AND AMPLITUDE SENSITIVITY



Dashed line: Best performing amplitude for each method

Shaded region: local sensitivity to the amplitude choice

→ Correct modes alone are not sufficient; amplitude tuning is required

CONCLUSION AND PERSPECTIVES

Conclusion

High-order dithering can better capturing speckle variations -> improved performance

An optimal gain of ~2.5x ⇒ **Δmag = 1** detection limit

The approach remains operationally simple when the number of dithers is limited, making it compatible to Roman CGI

The dithering amplitude is a key control parameter, together with the choice of dithering modes; tuning and identification are therefore required, **likely informed by commissioning data.**

Perspectives

Use Roman Observing Scenario 11 and simulations to inform both modal content and amplitude selection.

Looking into other basis for dithers