

HLIS



roman-hlis-cosmology.caltech.edu



github.com/Roman-HLIS-Cosmology-PIT



Weak Gravitational Lensing Cosmology with the Roman Space Telescope High Latitude Imaging Survey

Presenter: Kaili Cao (The Ohio State University → University of Michigan)

University of Michigan Cosmology Group Seminar, April 17, 2026

Astronomy is a peaceful field... and I'm joining
Michigan Institute for Data and AI in Society.



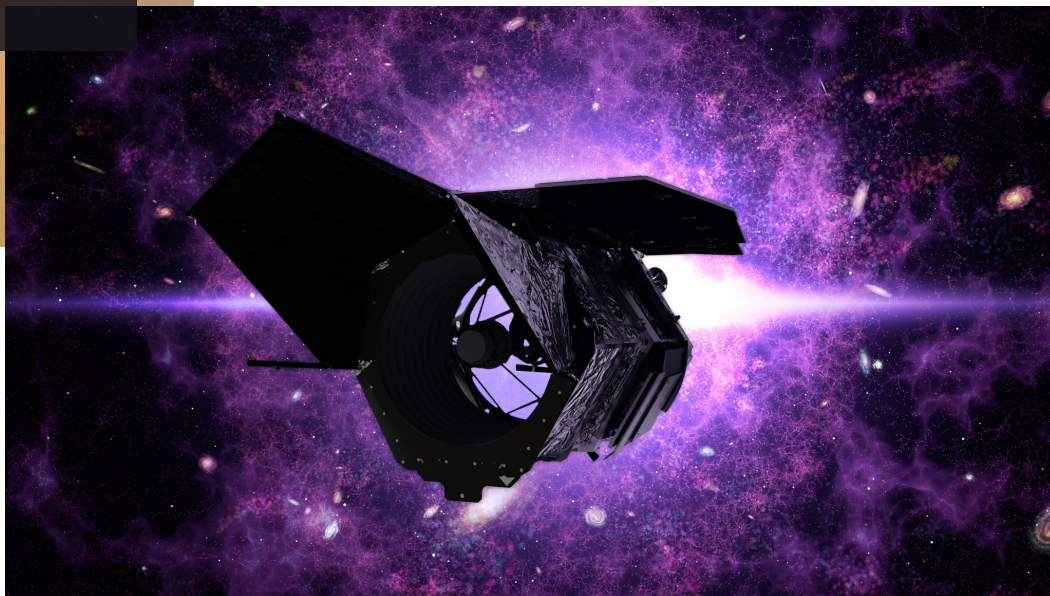
11:00 AM – 11:30 AM, Friday, April 17, 2026

Currently scheduled
for **September 7, 2026.**

Blurred image: a stock photo of a table of lunch dishes.

Ready for lunch?
Ready for **launch!**

Credits: ↑ Epicurean Traveler, → GSFC/SVS



HIGH-LATITUDE WIDE-AREA SURVEY



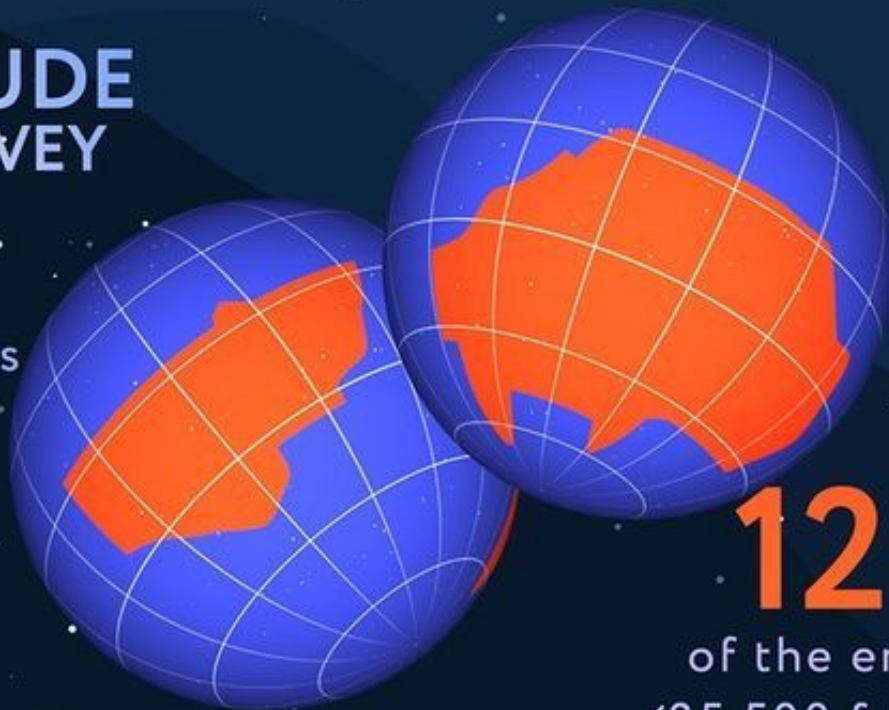
520 days over five years



Exposure times from
11 to 150 minutes



5,100 square degrees



12%

of the entire sky
(25,500 full moons)



Dark Energy



Dark Matter



Galaxies



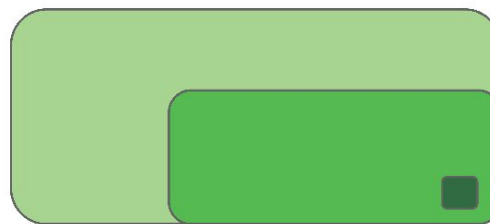
Solar System



Milky Way

*Credit: NASA's
Goddard Space
Flight Center*

HLWAS recommendations



In-Guide Survey Breakdown

Name	Area & Filters	Exposure times	Depth	Survey yields
★ Wide	2702 deg ² H	2x3x107 s (H)	26.2 (H)	$n_{\text{eff}} = 26.7 \text{ arcmin}^{-2}$ $N_{\text{shape}} = 260\text{M}$
★ Medium	2415 deg ² YJH + Grism	2x3x107 s (YJH) 4x2x190 s (Grism)	26.5 (Y) / 26.4 (JH) 1.5×10^{-16} (Grism)	$n_{\text{eff}} = 41.3 \text{ arcmin}^{-2}$ $N_{\text{shape}} = 360\text{M}$ $N_{\text{spec}} = 19.1\text{M}$ (total) 9.3M (z=1-2) 1.7M (z=2-3) $n_{\text{spec}} = 9.8 \times 10^{-4} h^3 \text{Mpc}^{-3}$
★ Deep	19.2 deg ² WZYJHFK + Grism	+5x3x295 s (WZYJHFK) +36x2x190 s (Grism)	27.7 (ZY) / 27.6 (J) / 27.5 (H) / 27.0 (F) / 25.9 (K) / 28.3 (W) 5.8×10^{-17} (Grism)	(for calibration)
★ Ultra Deep	5 deg ² YJH	+10x3x295 s (YJH)	28.2 (YJ) / 28.1 (H)	(for calibration)

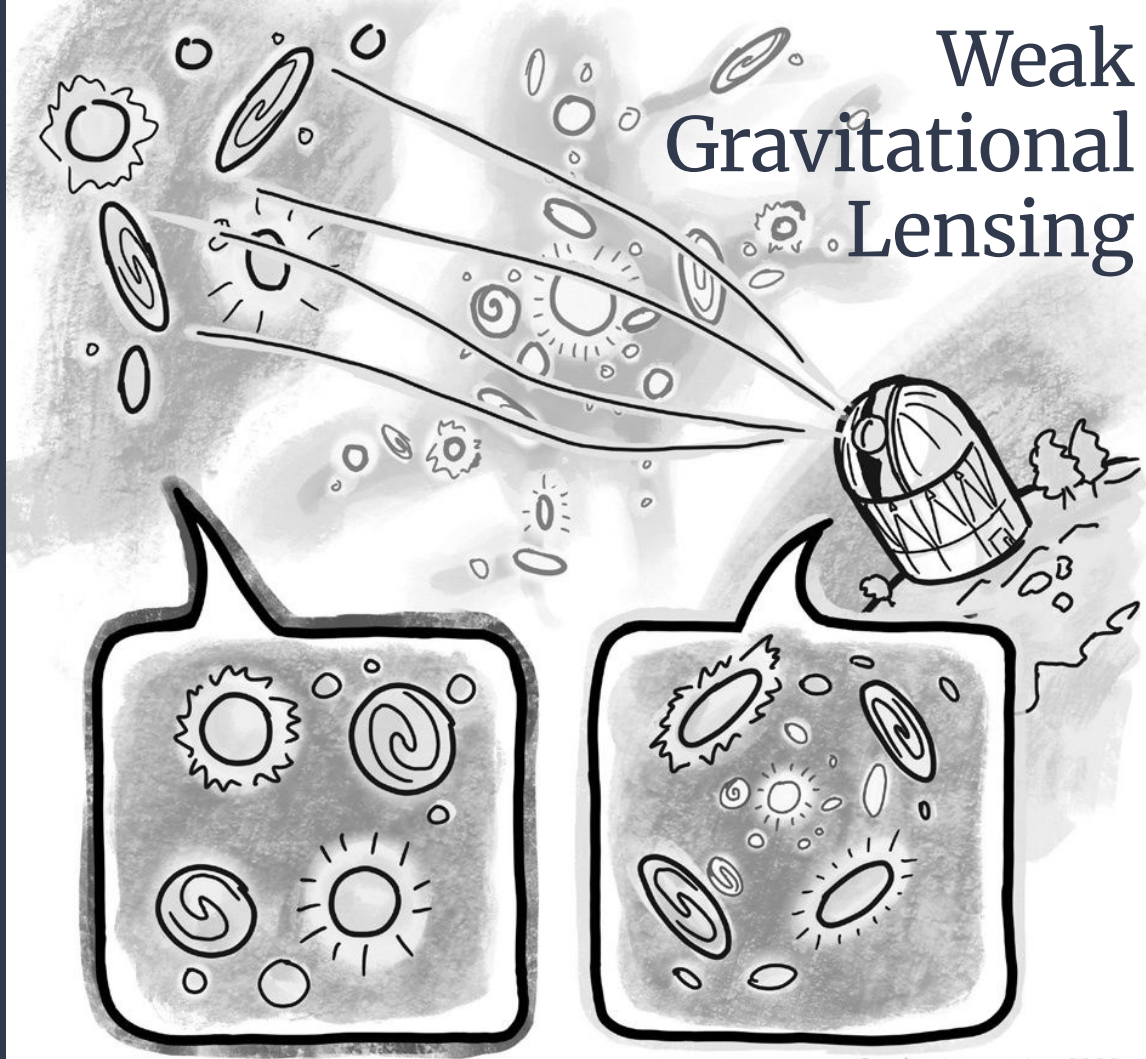
Survey yields:

> **600M** galaxies
with shape
measurements

> **19M** galaxies
with spectroscopic
redshifts

Our Project
Infrastructure
Team:
Maximizing
Cosmological
Science with the
Roman High
Latitude
Imaging Survey

Weak
Gravitational
Lensing

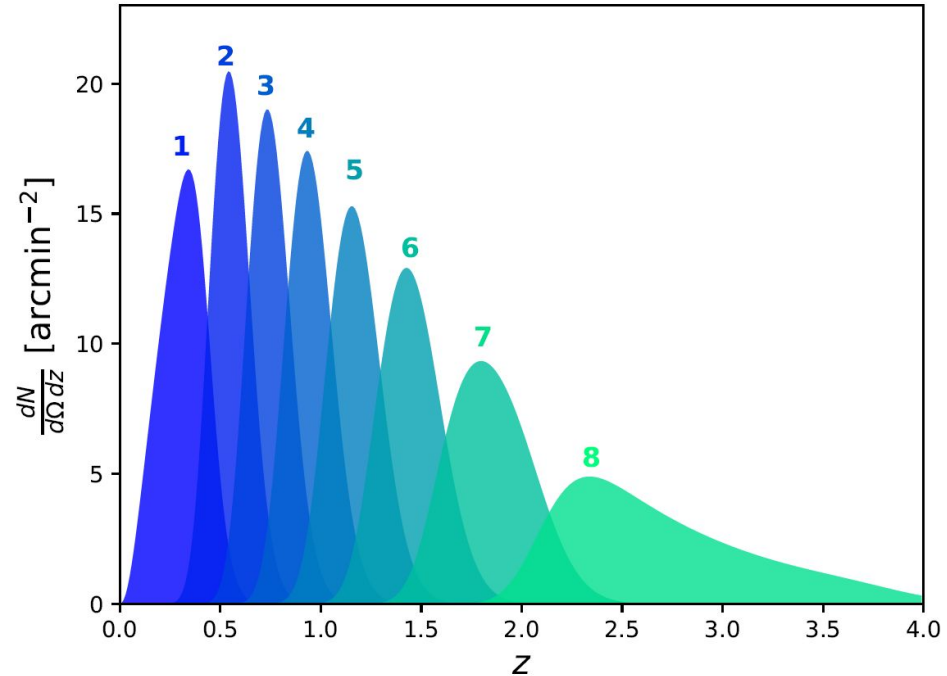


Weak Lensing Observables: 3×2pt (Three Two-Point Correlation Functions)

Cosmic shear: autocorrelation of galaxy **shapes**

Galaxy-galaxy lensing (GGL): cross-correlation of galaxy **shapes** and galaxy **positions**

Galaxy clustering: autocorrelation of galaxy **positions**



Credit: Haley Bowden

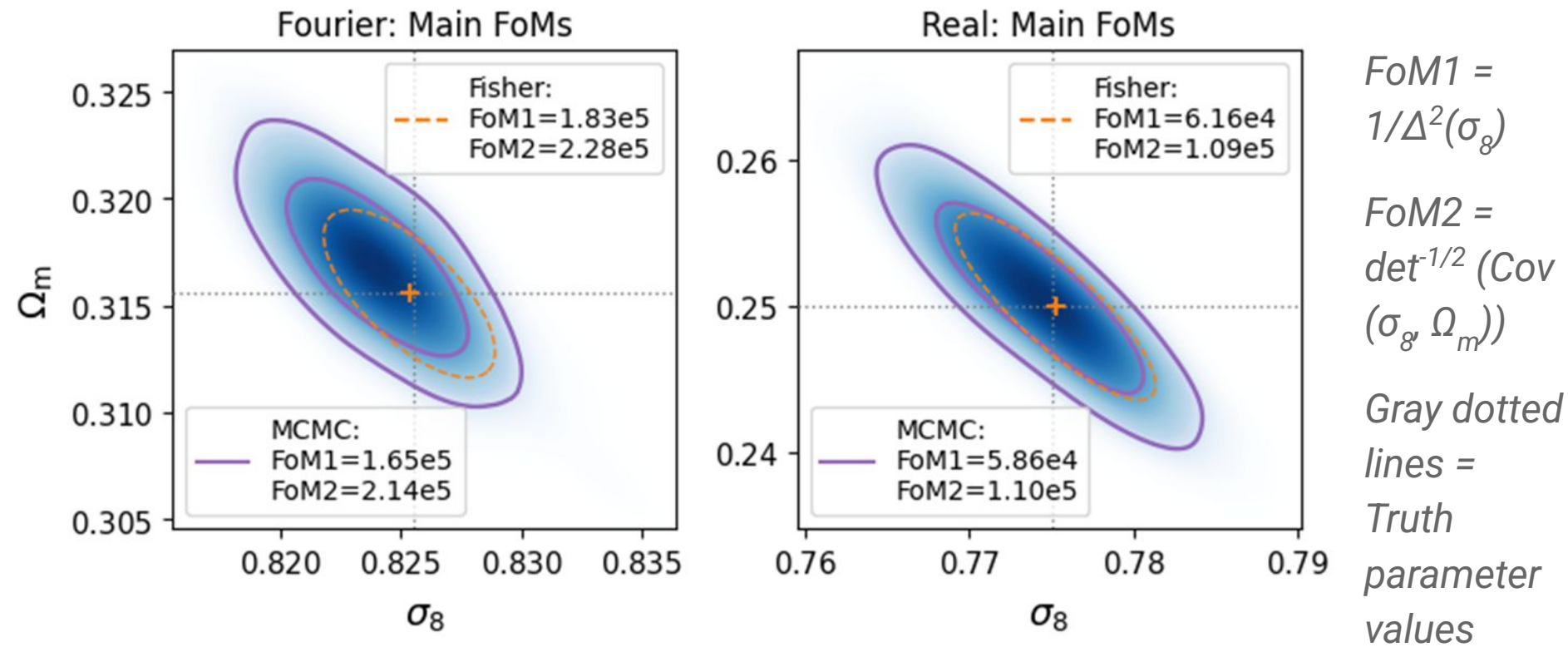
What if the **Maker of the Universe** came to tell us the correct cosmological model and parameters?

We would say:

- a) We already know, but thanks!
- b) Thank you for taking our jobs...
- c) That does not sound very likely.
- d) You answer here: _____

Fisher Forecasts for Constraining Power

(Below: Figure 6 in K. Cao et al. 2026, submitted)



Cosmological Parameter Inference Pipeline (CPIP)

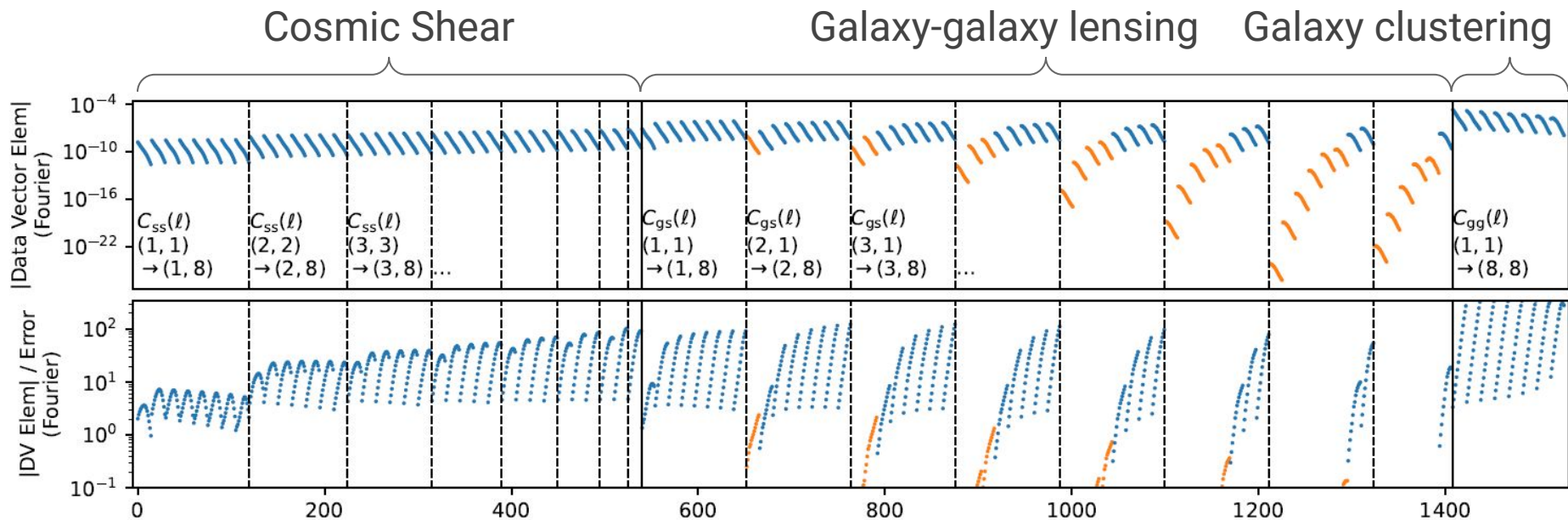


COCOA

COBAYA-COSMOLIKE JOINT ARCHITECTURE

Roman HLIS CPIP Data Challenge 1 (DC1)

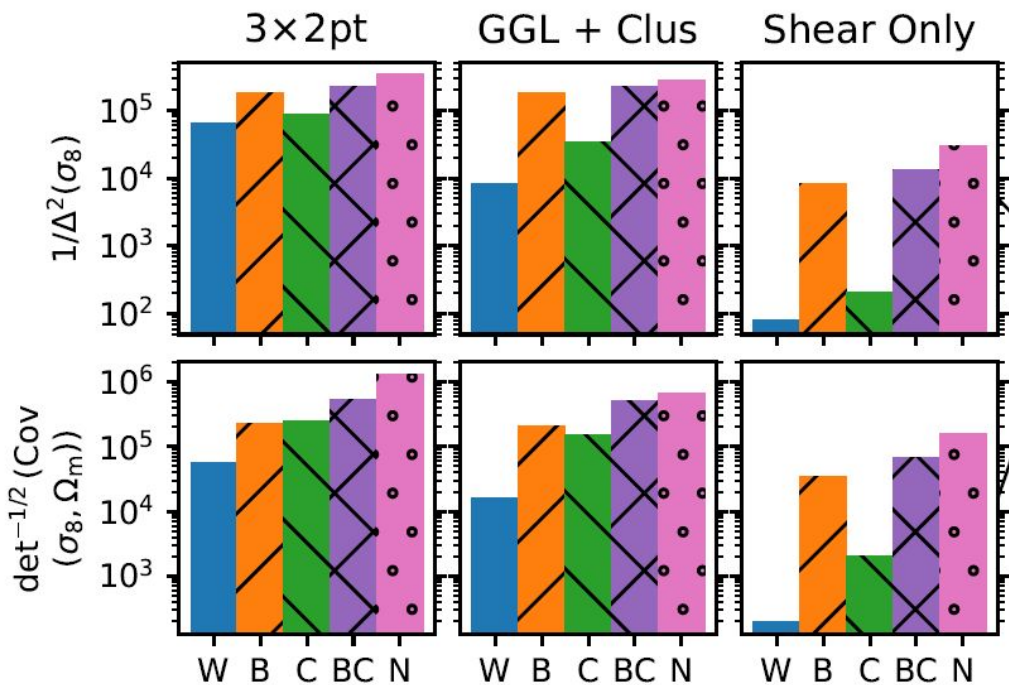
(Part of Figure 1 in K. Cao et al. 2026, submitted)



Blue: positive elements; orange: negative elements.

Constraining Power from Different Probes

(Part of Figure 7 in K. Cao et al. 2026, submitted)



W: infinitely wide priors on all (i.e., both cosmological and “nuisance”) parameters

B: benchmark priors on photo- z bias (Δz ; 0.002) and shear bias (m ; 0.005)

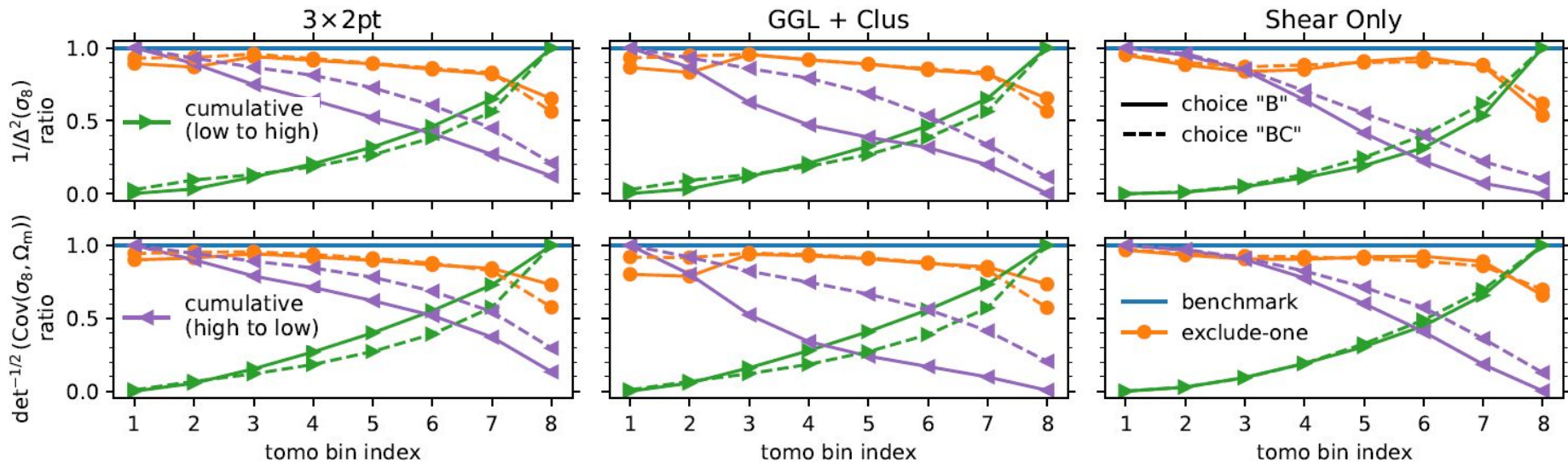
C: infinitely narrow priors on other studied cosmological parameters (n_s , Ω_b , and h_0)

BC: benchmark priors on Δz and m (B) + infinitely narrow priors on n_s , Ω_b , and h_0 (C)

N: infinitely narrow priors on all parameters other than σ_8 , Ω_m , and galaxy bias (b)

Contributions From Different Tomographic Bins (Part of Figure 8 in K. Cao et al. 2026, submitted)

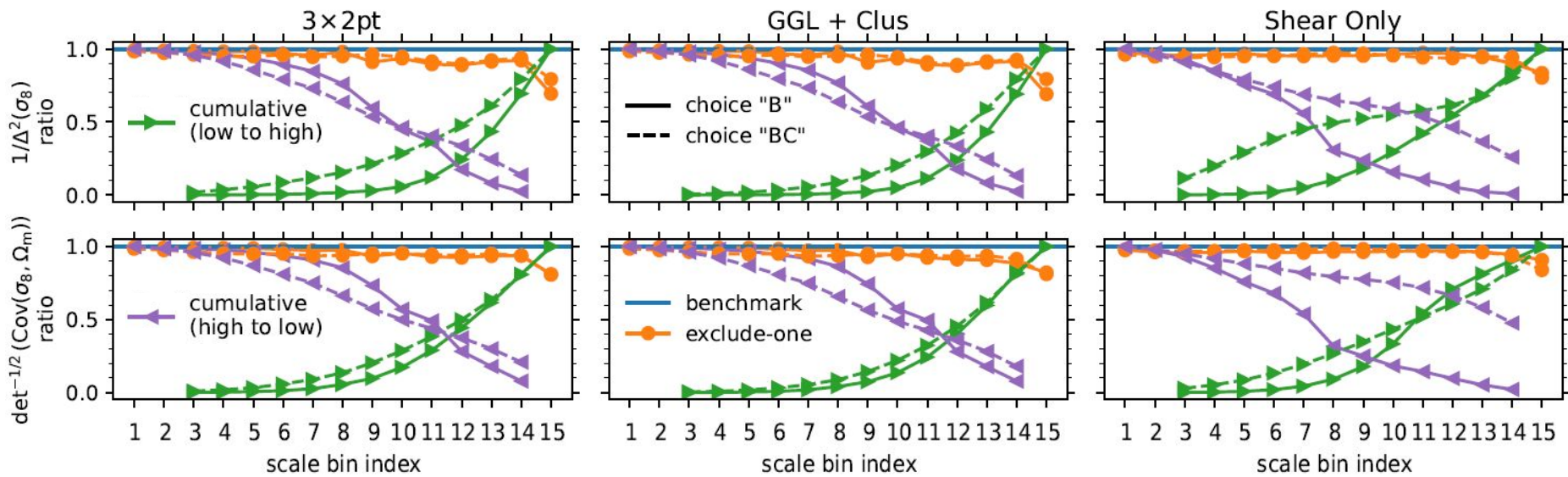
Solid curves: w/o external cosmology; dashed curves: w/ external cosmology.



Thanks to the high sensitivity of Roman Wide Field Instrument (WFI)!

Contributions From Different Angular Scales (Part of Figure 9 in K. Cao et al. 2026, submitted)

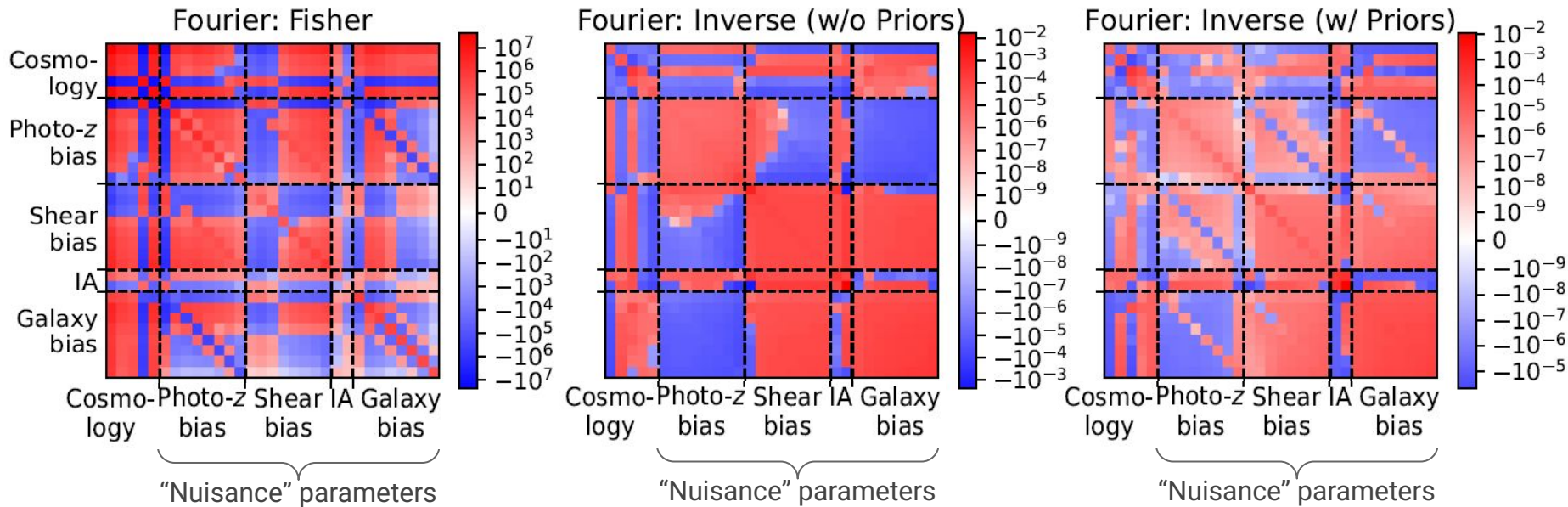
Solid curves: w/o external cosmology; dashed curves: w/ external cosmology.



Good news for people working on effective field theory!

Fisher Forecasts for Constraining Power

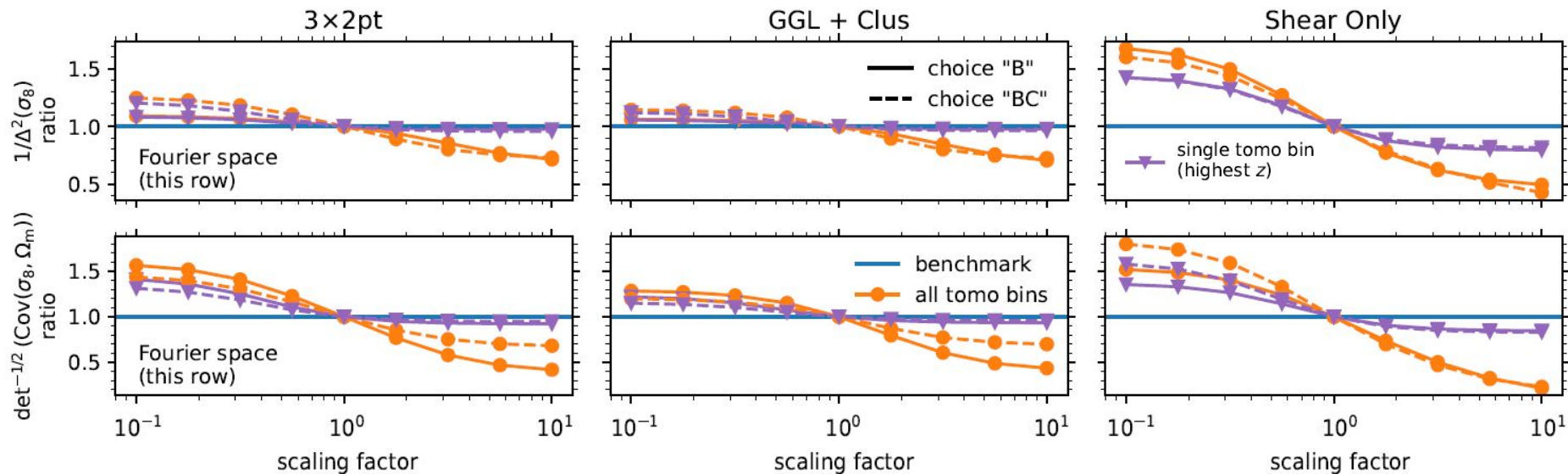
(Part of Figure 18 in K. Cao et al. 2026, submitted)



The ordering of cosmological parameters in this figure is: σ_8 , n_s , h_0 , Ω_b , and Ω_m .

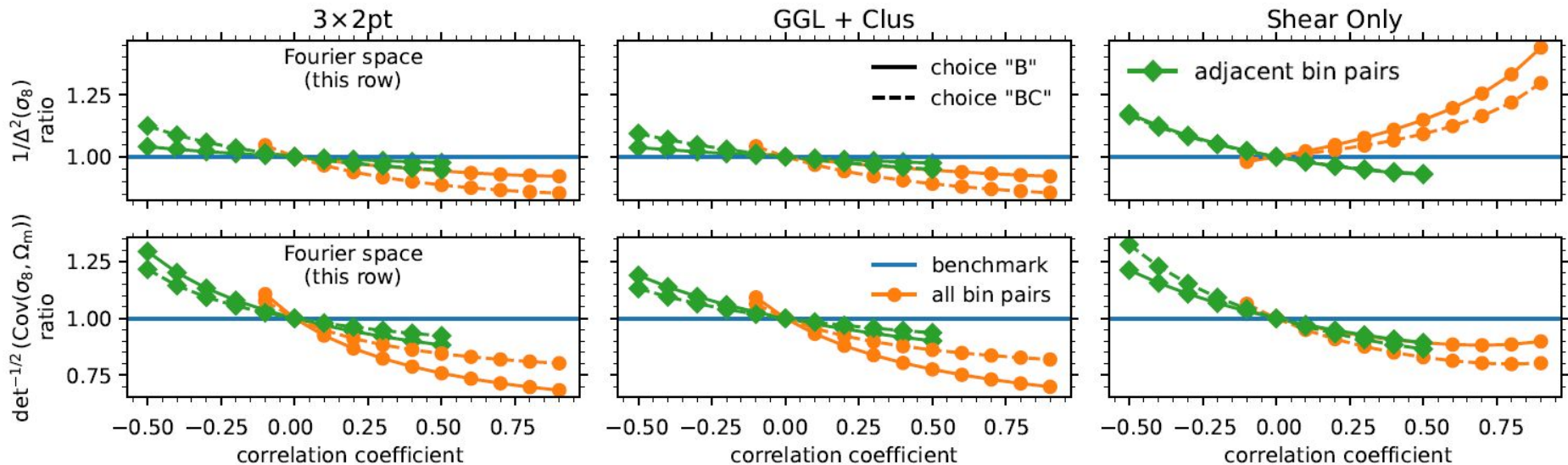
Impact of Rescaled Priors on Shear Biases (Part of Figure 13 in K. Cao et al. 2026, submitted)

Solid curves: w/o external cosmology; dashed curves: w/ external cosmology.



Impact of Correlated Priors on Shear Biases (Part of Figure 14 in K. Cao et al. 2026, submitted)

Solid curves: w/o external cosmology; dashed curves: w/ external cosmology.



Forecasts for Roman Weak Lensing: Takeaways

The Nancy Grace Roman Space Telescope is poised to provide unprecedented weak gravitational lensing data with its **High Latitude Imaging Survey (HLIS)**.

Weak lensing observables include **three two-point correlation functions (3×2pt)**: cosmic shear, galaxy-galaxy lensing, and galaxy clustering.

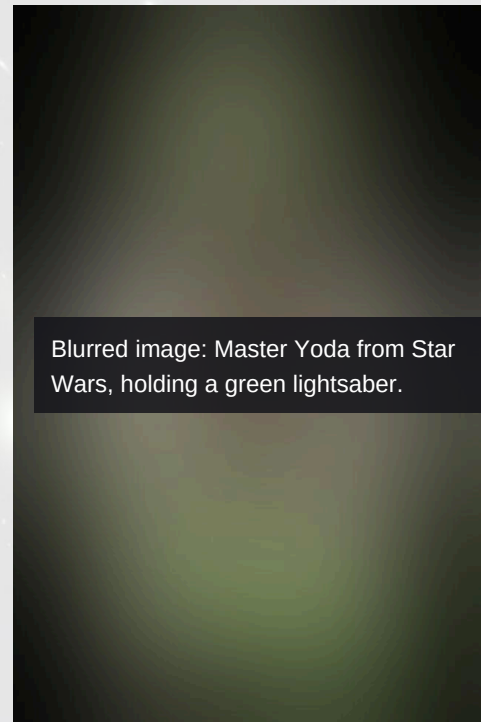
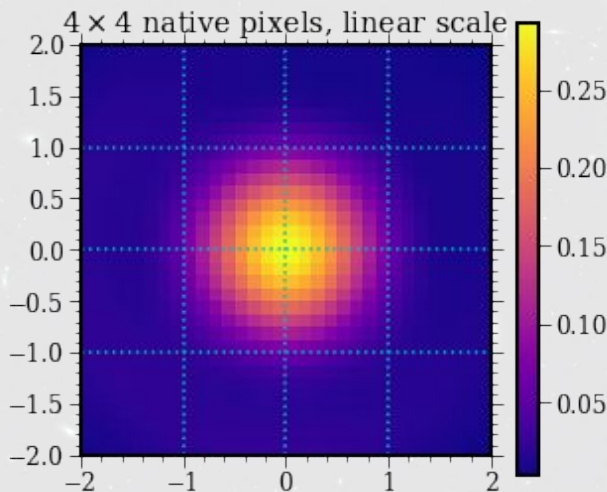
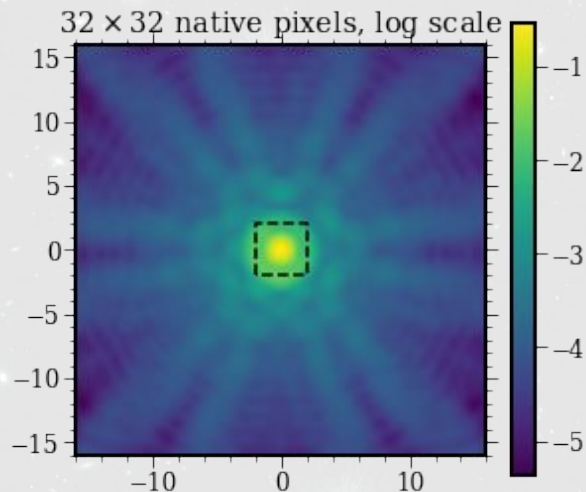
Control over **systematics** is crucial for realizing Roman HLIS's full potential.

To overcome the difficulty of undersampling, images will be coadded using **IMCOM**. A more efficient algorithm, **Effortless**, is under development.

Presenter: Kaili Cao (The Ohio State University; email: cao.1191@osu.edu).

Why do we coadd images? – “Oversample, we must!”

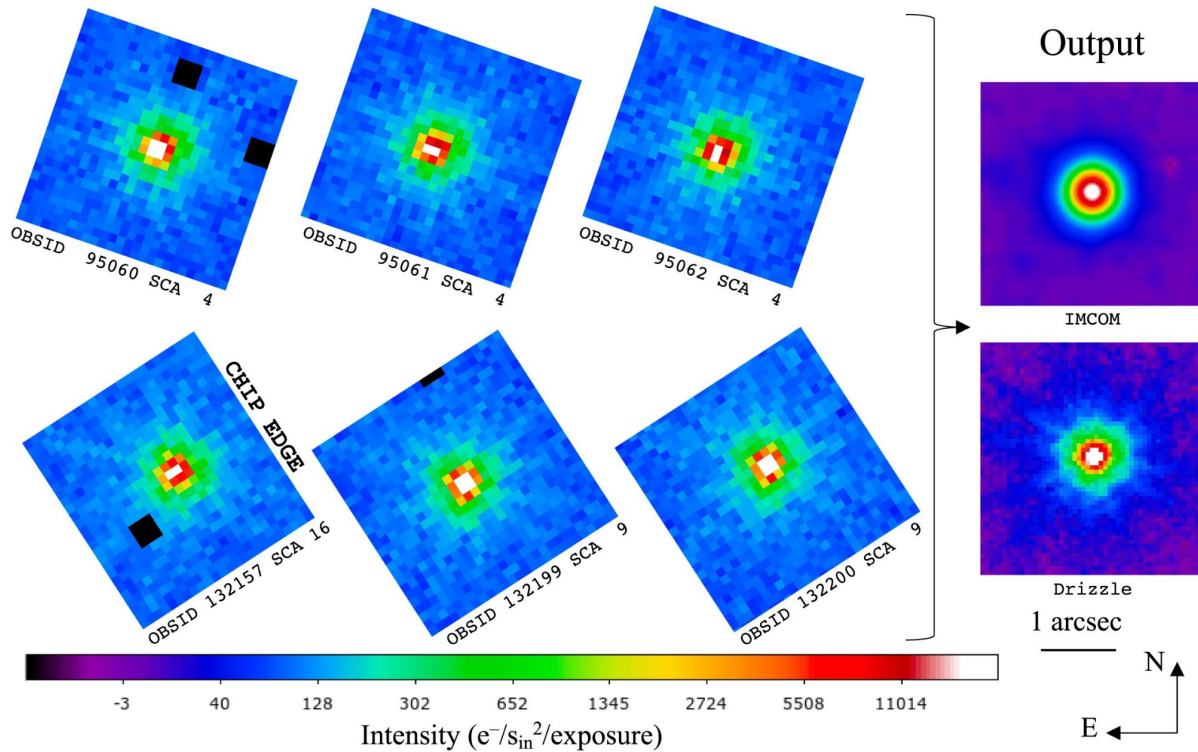
- Roman point spread functions (PSFs)
 - = Airy disk ($\sim \lambda/D$) + linear obscuration + diffraction spikes + detector effects
 - An example in **Y106** band shown below



Blurred image: Master Yoda from Star Wars, holding a green lightsaber.

Image credits: Lucasfilm Ltd., Janson_G

IMCOM (B. Rowe et al. 2011): Image Coaddition with Control over Output Point Spread Function



←: 3 dithers × 2 passes
(typical for Medium and
Wide Tiers of HLWAS)

↗: IMCOM (IMage
COMbination) – **optimal**
image coaddition

↘: Drizzle – **efficient**
image coaddition

*Credit: Figure 9 from
C. Hirata et al. 2024*

One day

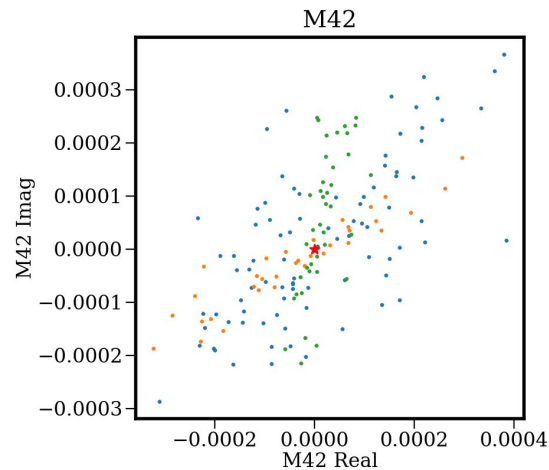
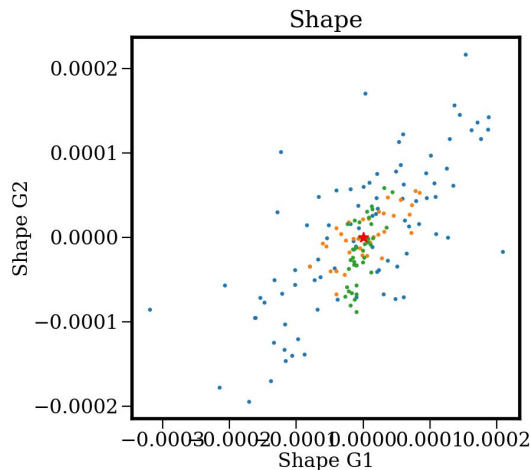
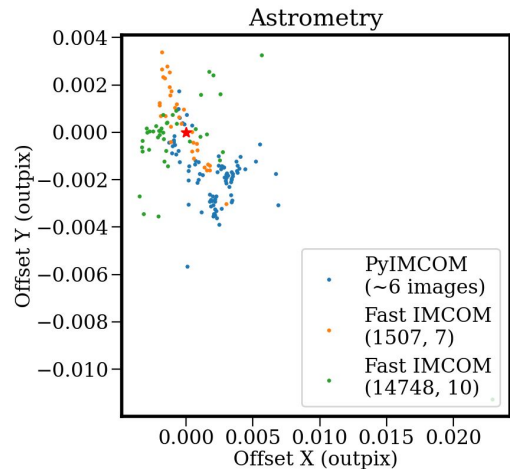
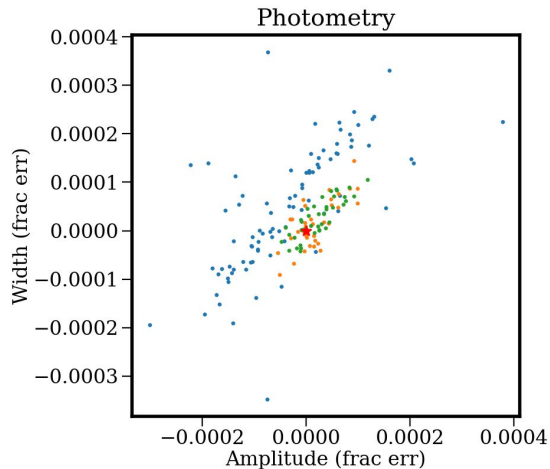
Time to reconstruct a Roman WFI image $[(7.5 \text{ arcmin})^2]$
with a single CPU core using IMCOM.

One day →
Half an hour

Time to reconstruct a Roman WFI image $[(7.5 \text{ arcmin})^2]$
with a single CPU core using IMCOM → Effortless.

Effortless (Cao 2026*) features:

- $\sim 50\times$ faster
- Comparable or better results (for noiseless point sources) using individual images
- Better design
- White box



The output pixel scale is currently ~ 46.3 mas. ²⁷

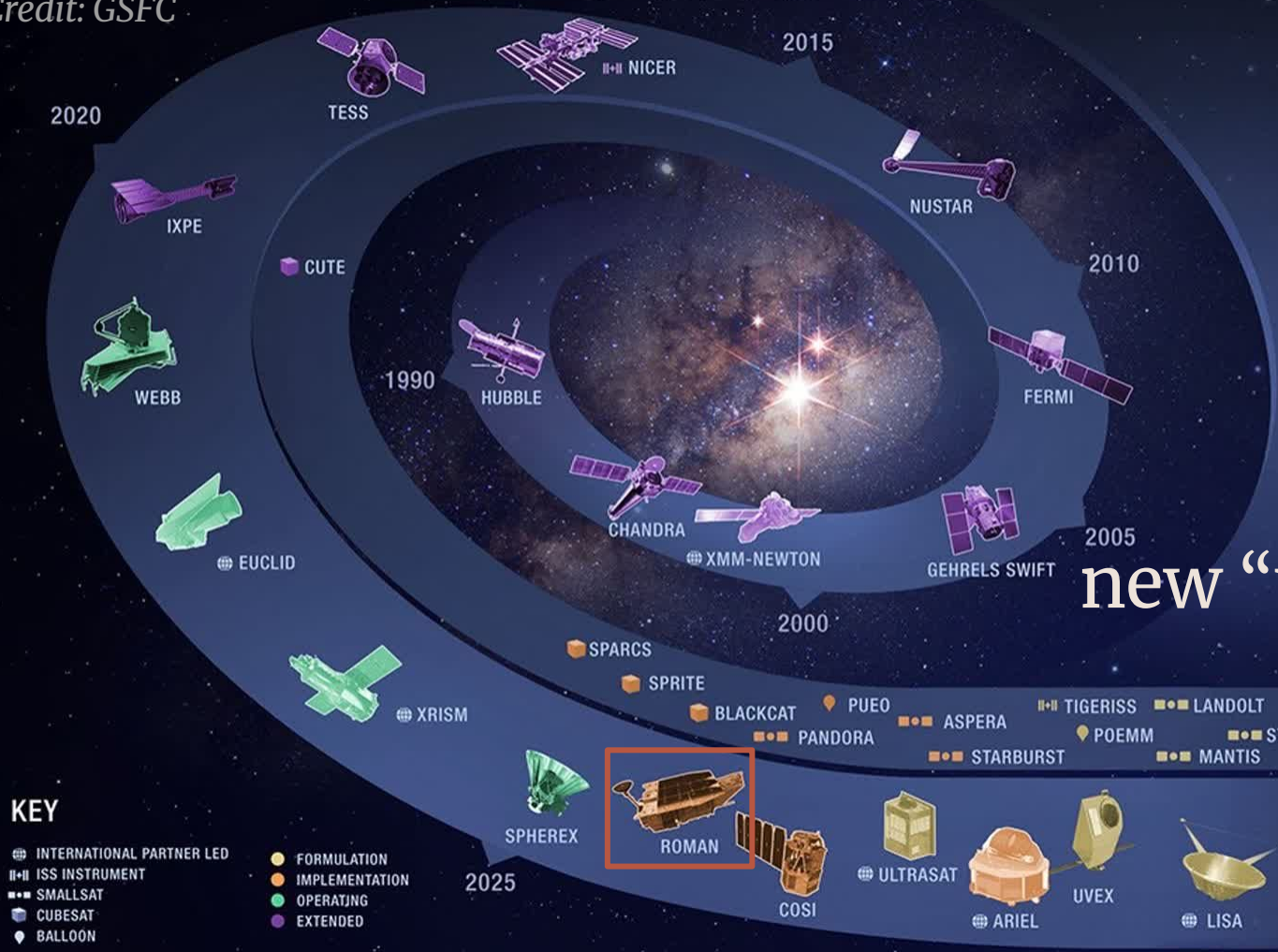
Credit: GSFC

National Aeronautics and
Space Administration



ASTROPHYSICS FLEET

New “eyes,”
new “visual cortex.”



PIONEERS & CUBESATS

TRADITIONAL MISSIONS

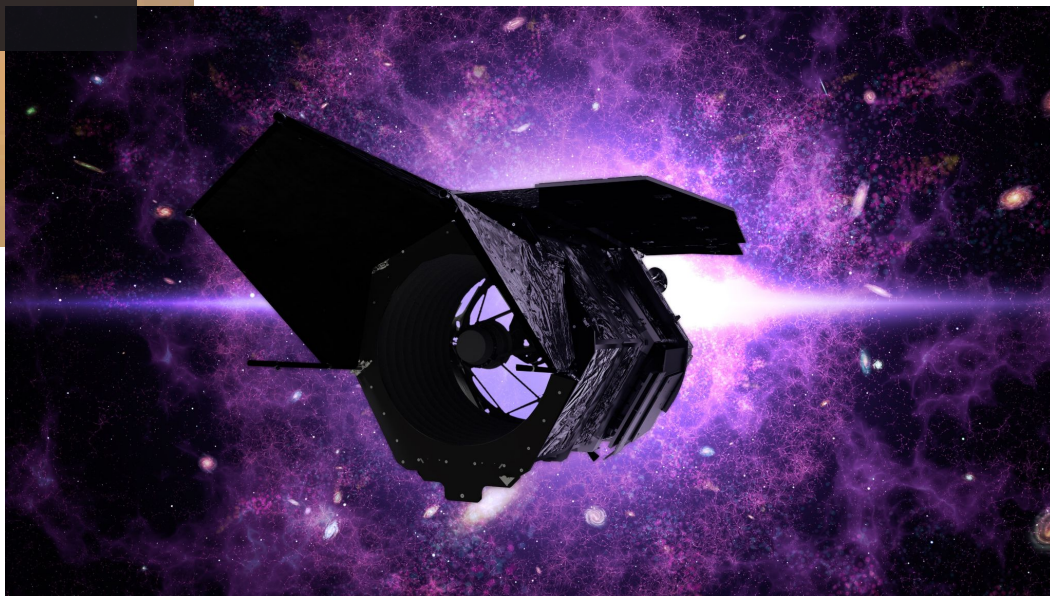
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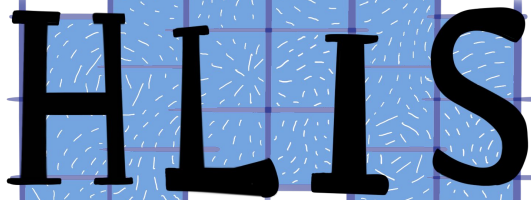
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