

Weak lensing with Roman: from galaxy shapes to shear measurement

Axel Guinot

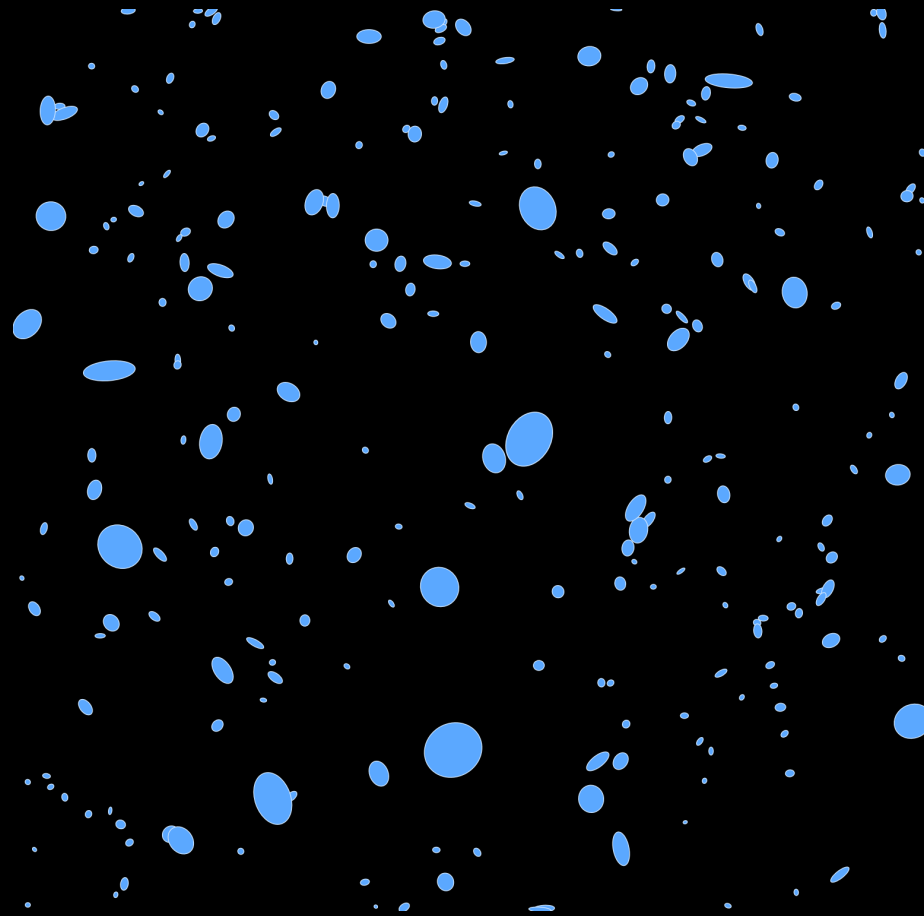
On behalf of the HLIS PIT



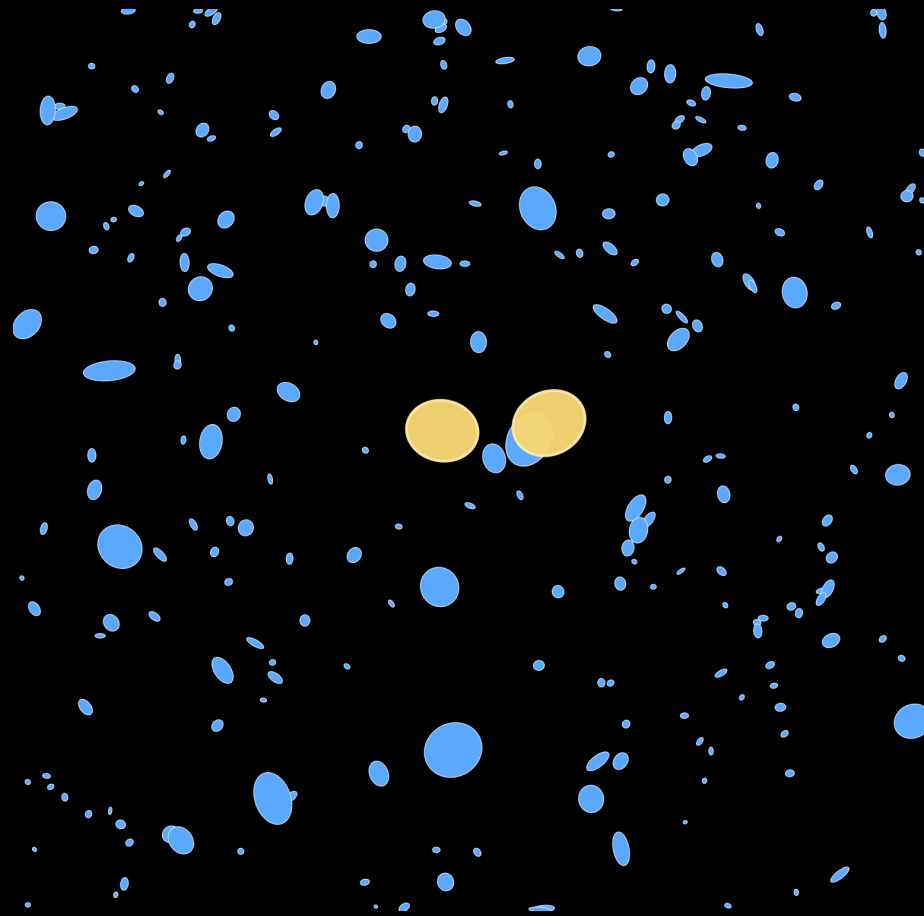
aguinot@andrew.cmu.edu

**Carnegie
Mellon
University**

Gravitational Lensing introduction

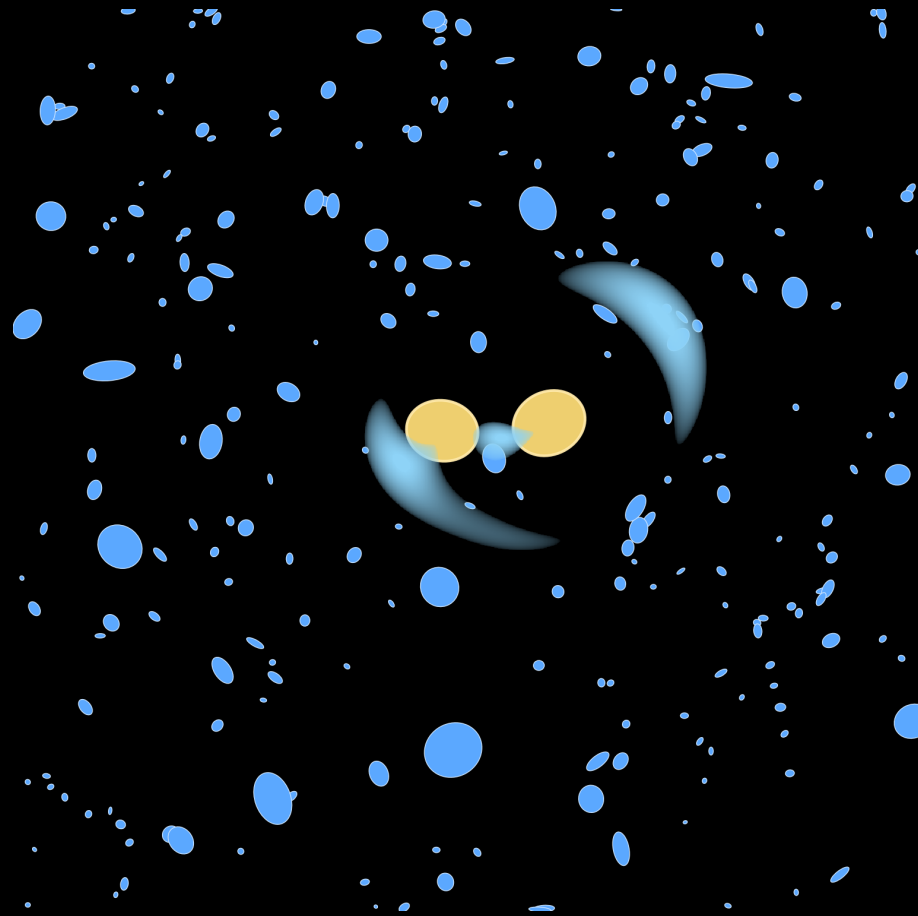


Gravitational Lensing introduction



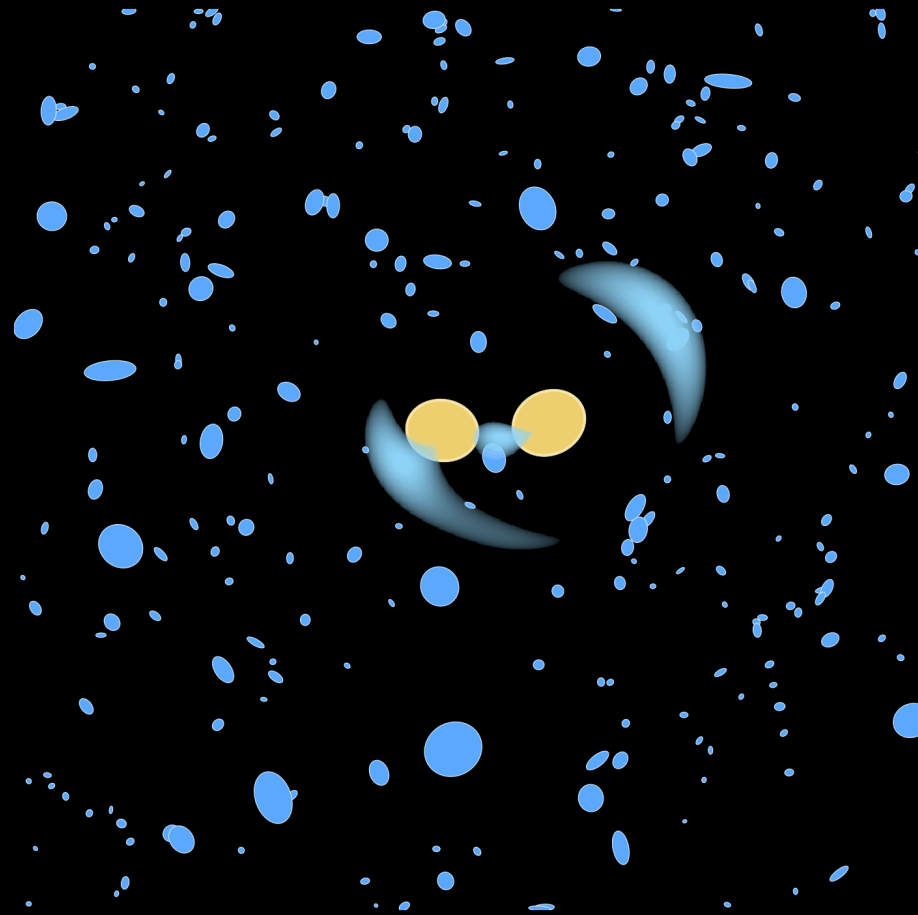
Gravitational Lensing introduction

Strong Lensing

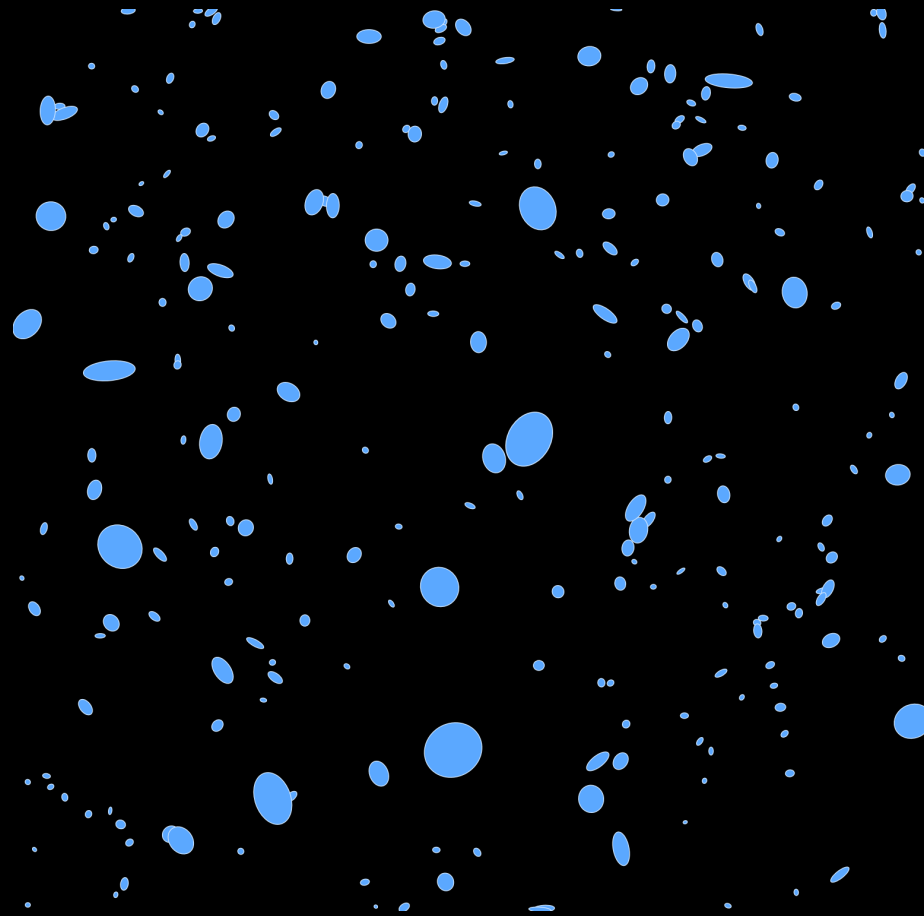


Gravitational Lensing introduction

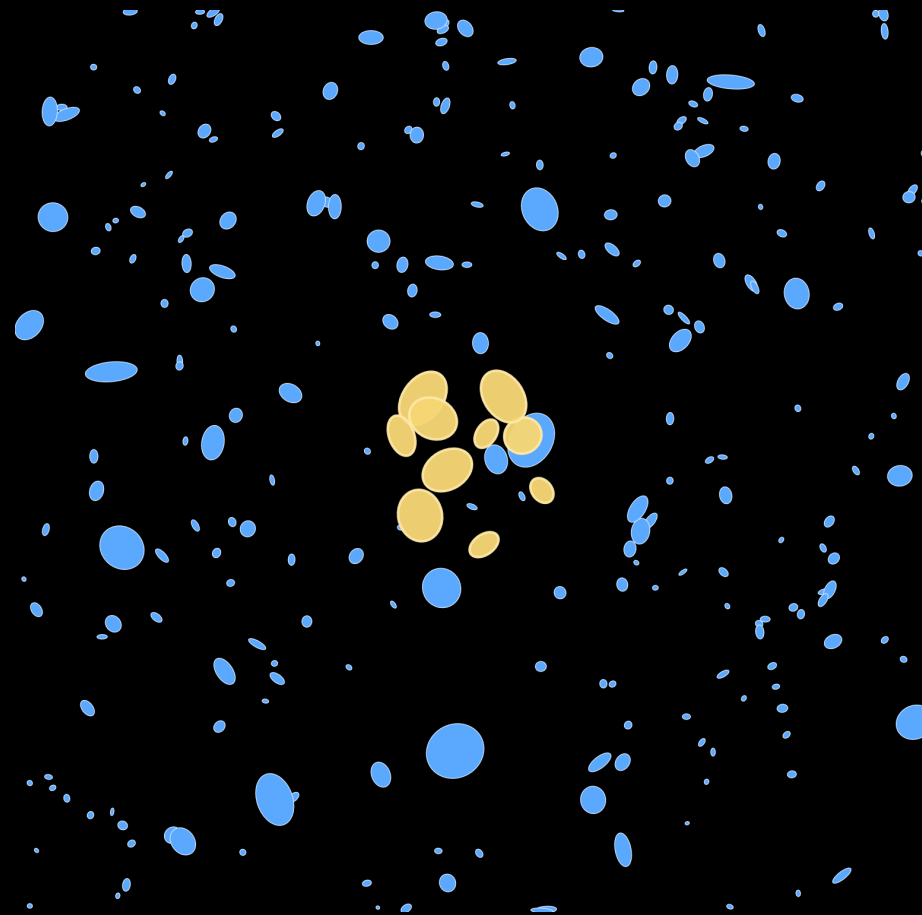
Strong Lensing



Gravitational Lensing introduction



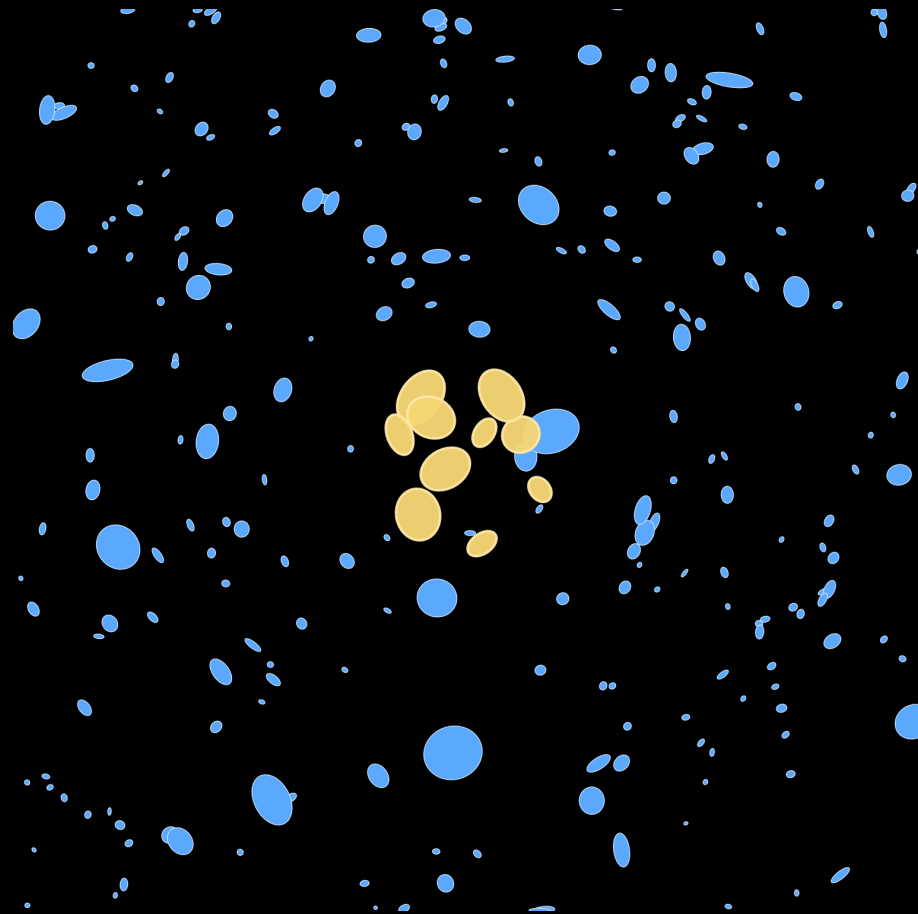
Gravitational Lensing introduction



Gravitational Lensing introduction

Weak Lensing

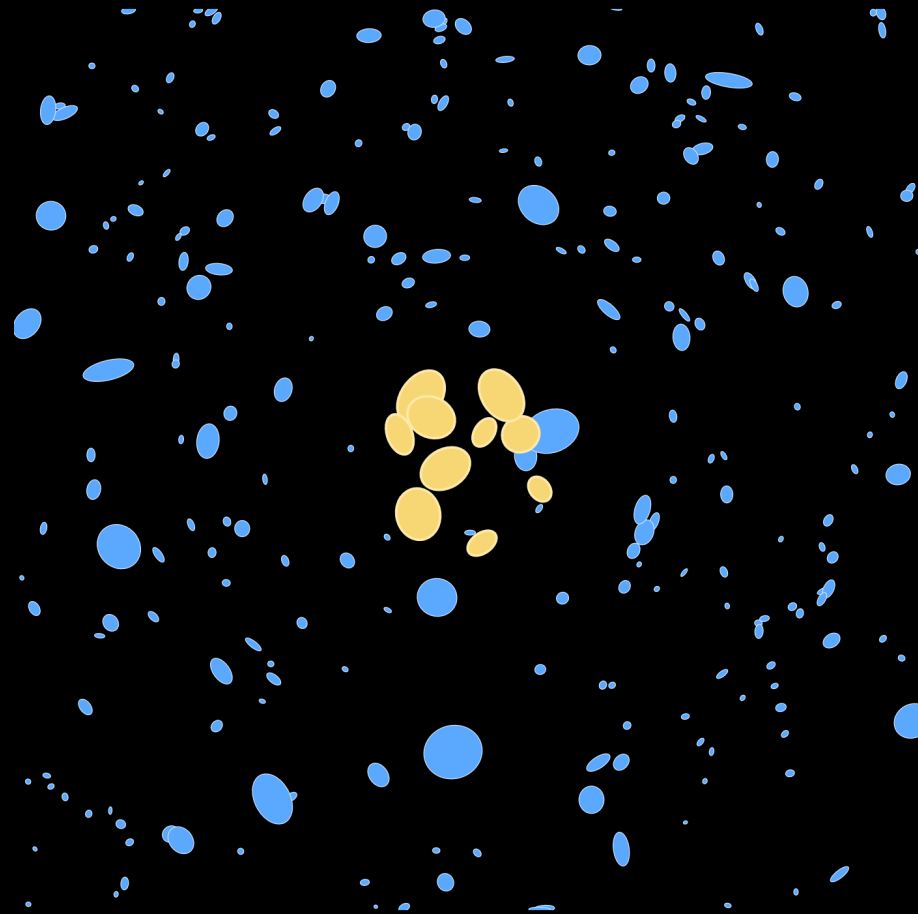
**Illustrated with
cluster lensing**



Gravitational Lensing introduction

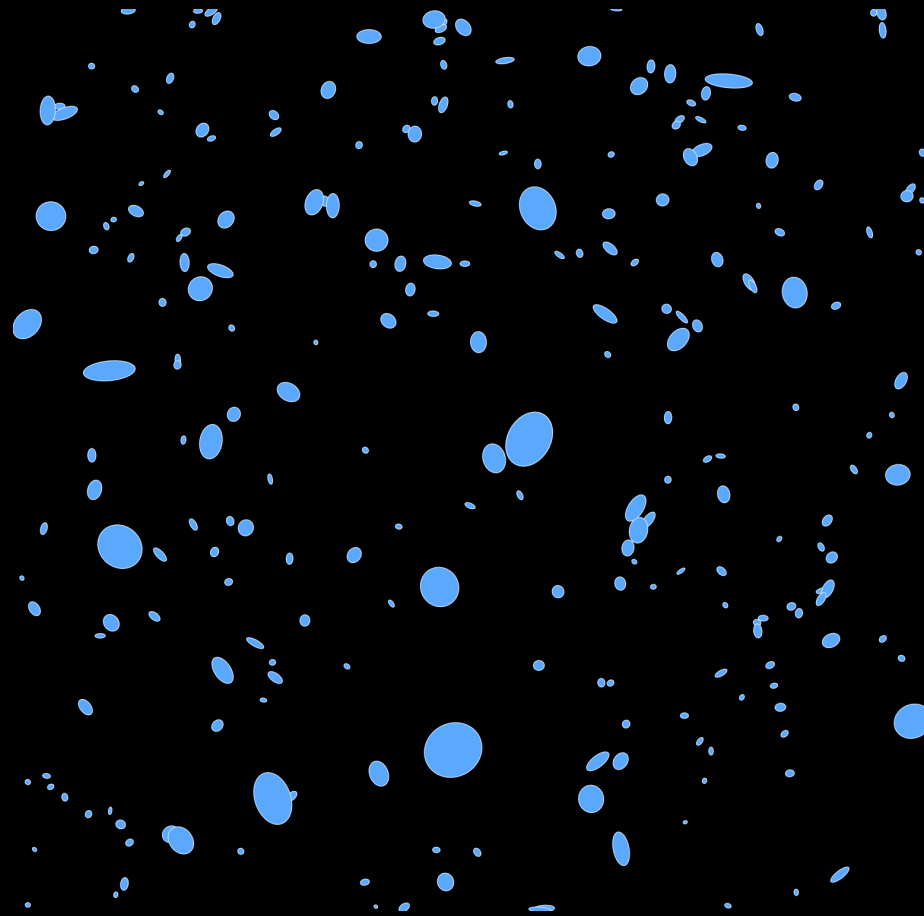
Weak Lensing

**Illustrated with
cluster lensing**

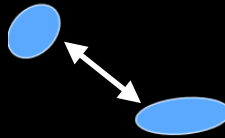
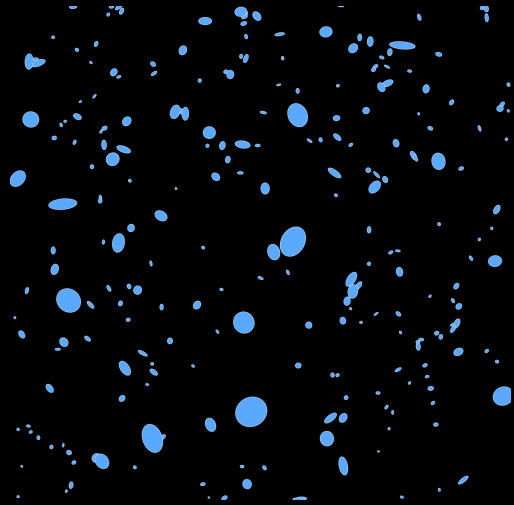


Mass mapping

Gravitational Lensing introduction

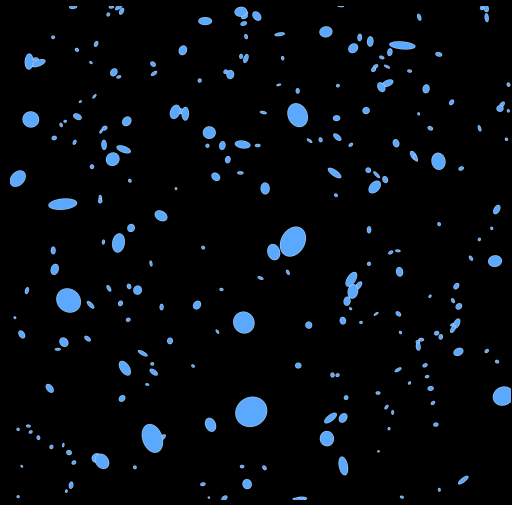


Gravitational Lensing introduction

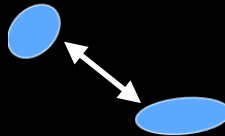


Cosmic shear

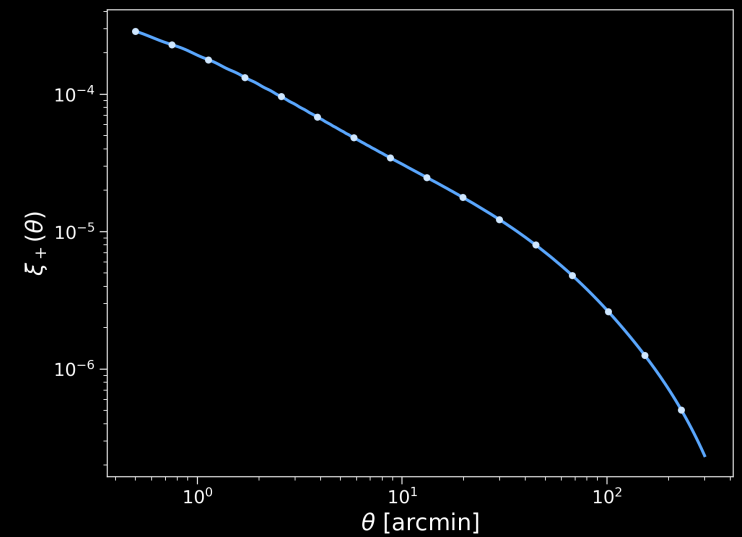
Gravitational Lensing introduction



Cosmic shear



2-points correlation functions



Measuring galaxy shapes

Cosmic shear relies on the measurement of [galaxy shapes](#)

Measuring galaxy shapes

Cosmic shear relies on the measurement of **galaxy shapes**

Problem

What is the shape of a galaxy?



Measuring galaxy shapes

Cosmic shear relies on the measurement of **galaxy shapes**

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Measuring galaxy shapes

Cosmic shear relies on the measurement of **galaxy shapes**

Problem

What is the shape of a galaxy?



Galaxy intrinsic shape

Galaxy sheared shape

Measuring galaxy ~~shapes~~ shear

Cosmic shear relies on the measurement of galaxy shapes

Solution

Measuring how galaxy shapes respond to shear



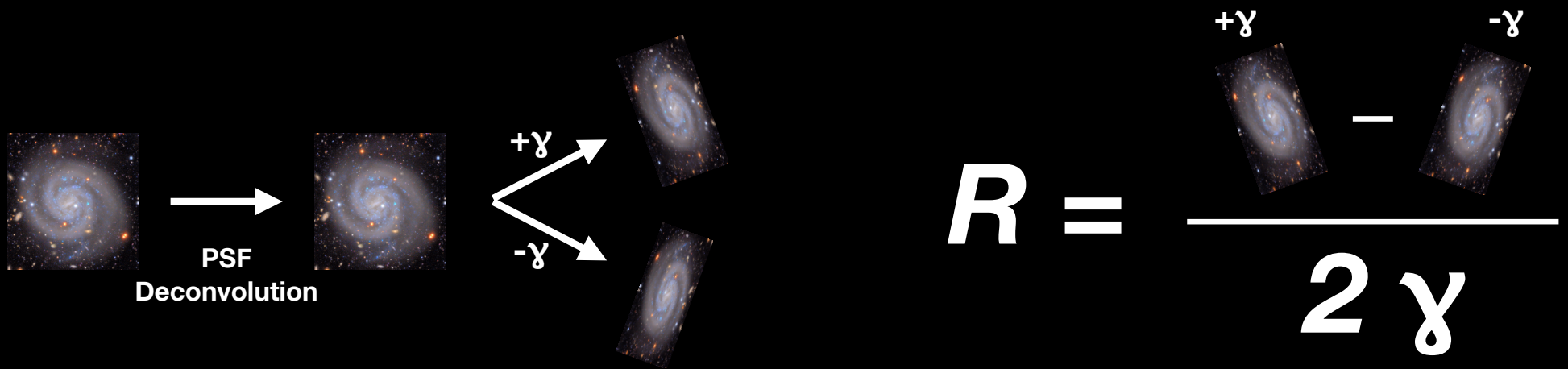
Galaxy intrinsic shape

Galaxy sheared shape

MetaCalibration

Measuring how galaxy shapes respond to shear $R = \frac{\partial e}{\partial \gamma} \rightarrow e_{\text{obs}} = R\gamma + c$

This method is called MetaCalibration ([Huff & Mandelbaum 2017](#), [Sheldon & Huff 2017](#))



MetaCalibration

MetaCalibration can account for:

- Model bias
- Noise bias
- Selection effects

MetaDetection

MetaCalibration can account for:

- Model bias
- Noise bias
- Selection effects

What if we have more than one galaxy?



MetaDetection

MetaCalibration can account for:

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What if we have more than one galaxy?

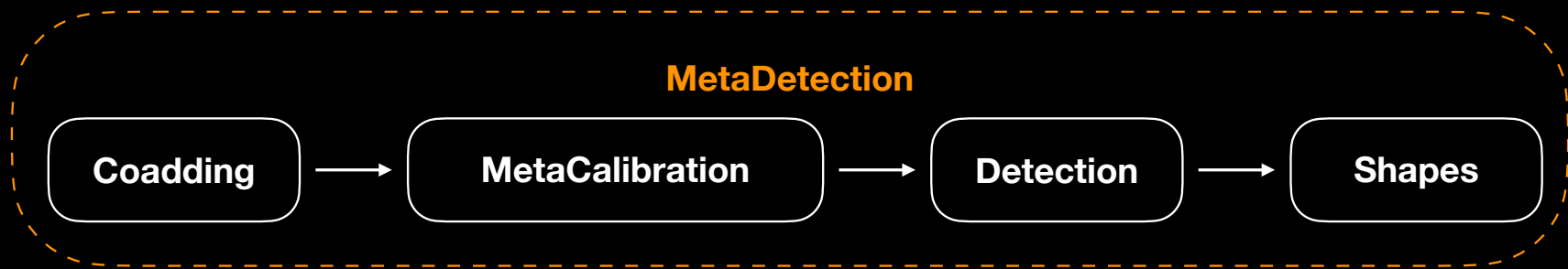


Now we have MetaDetection (Sheldon et al. 2020)

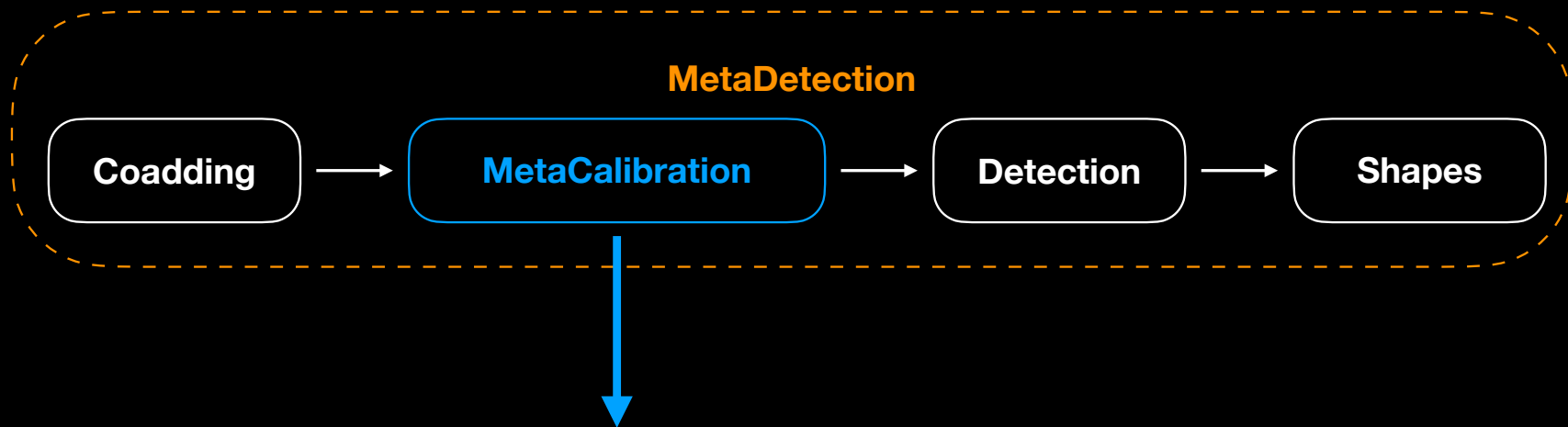
It can account for:

- Metacalibration biases
- Detection bias

MetaDetection on Roman



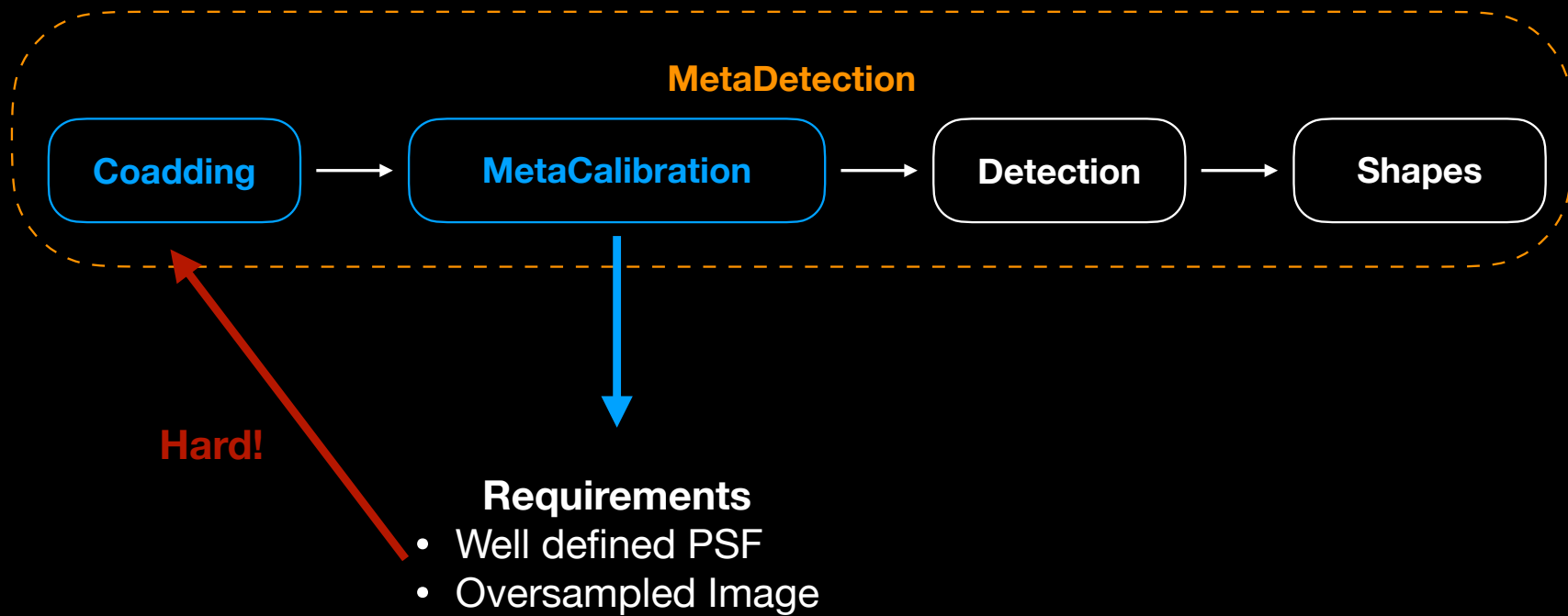
MetaDetection on Roman



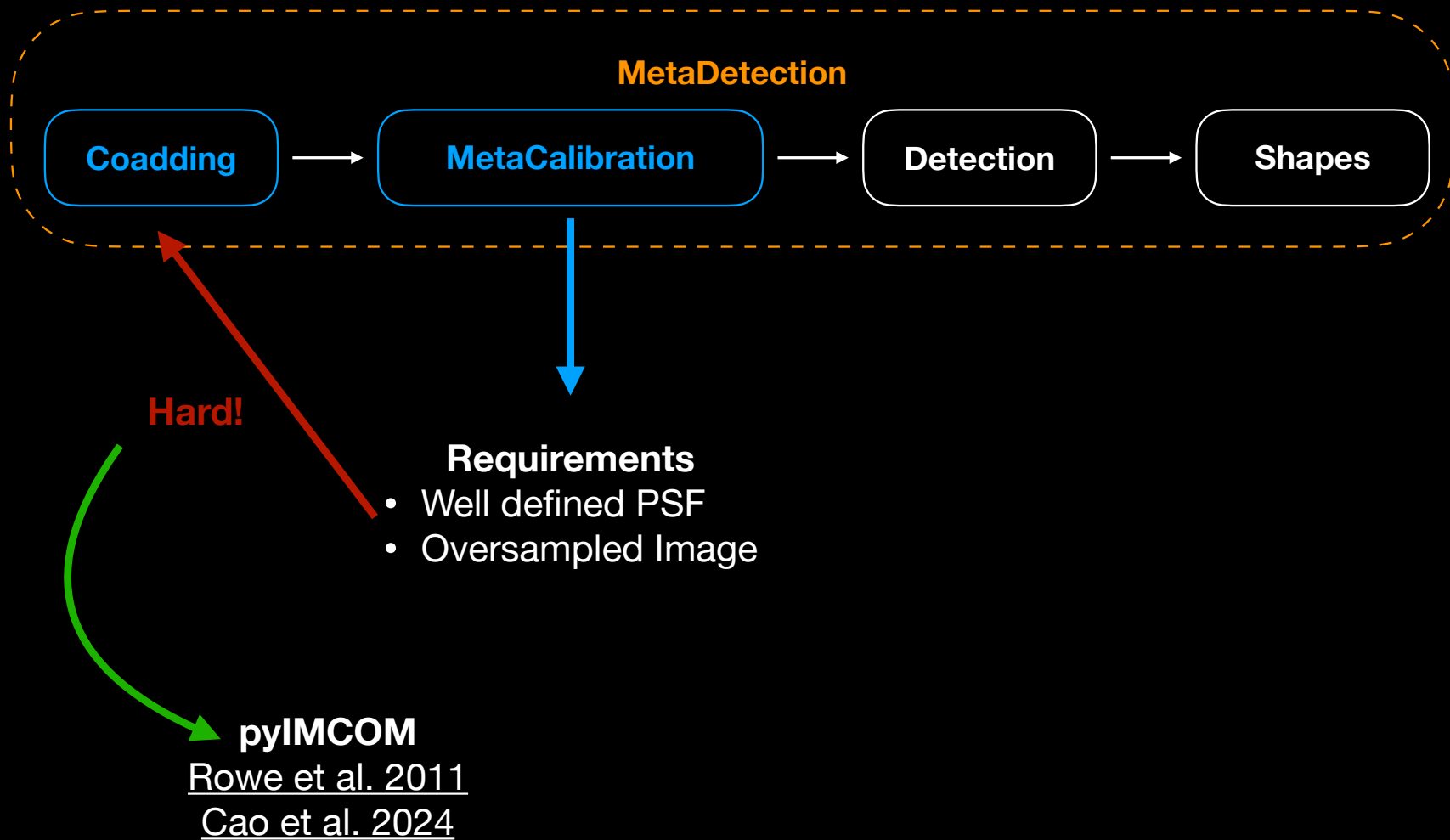
Requirements

- Well defined PSF
- Oversampled Image

MetaDetection on Roman



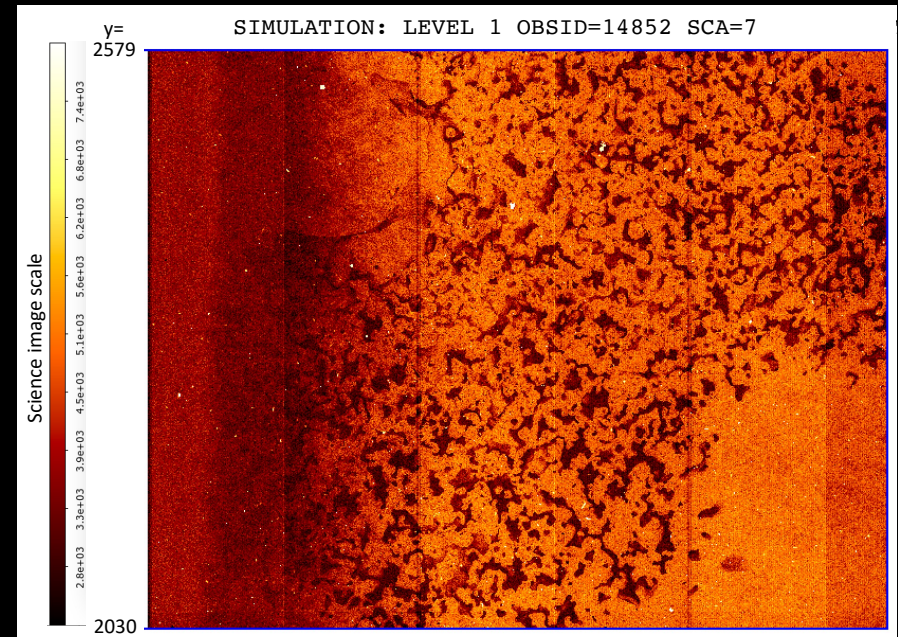
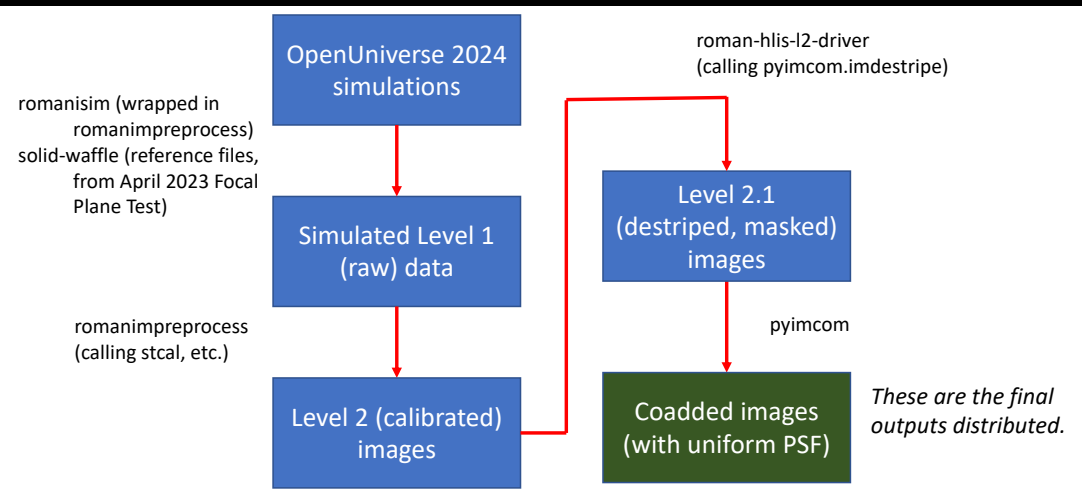
MetaDetection on Roman



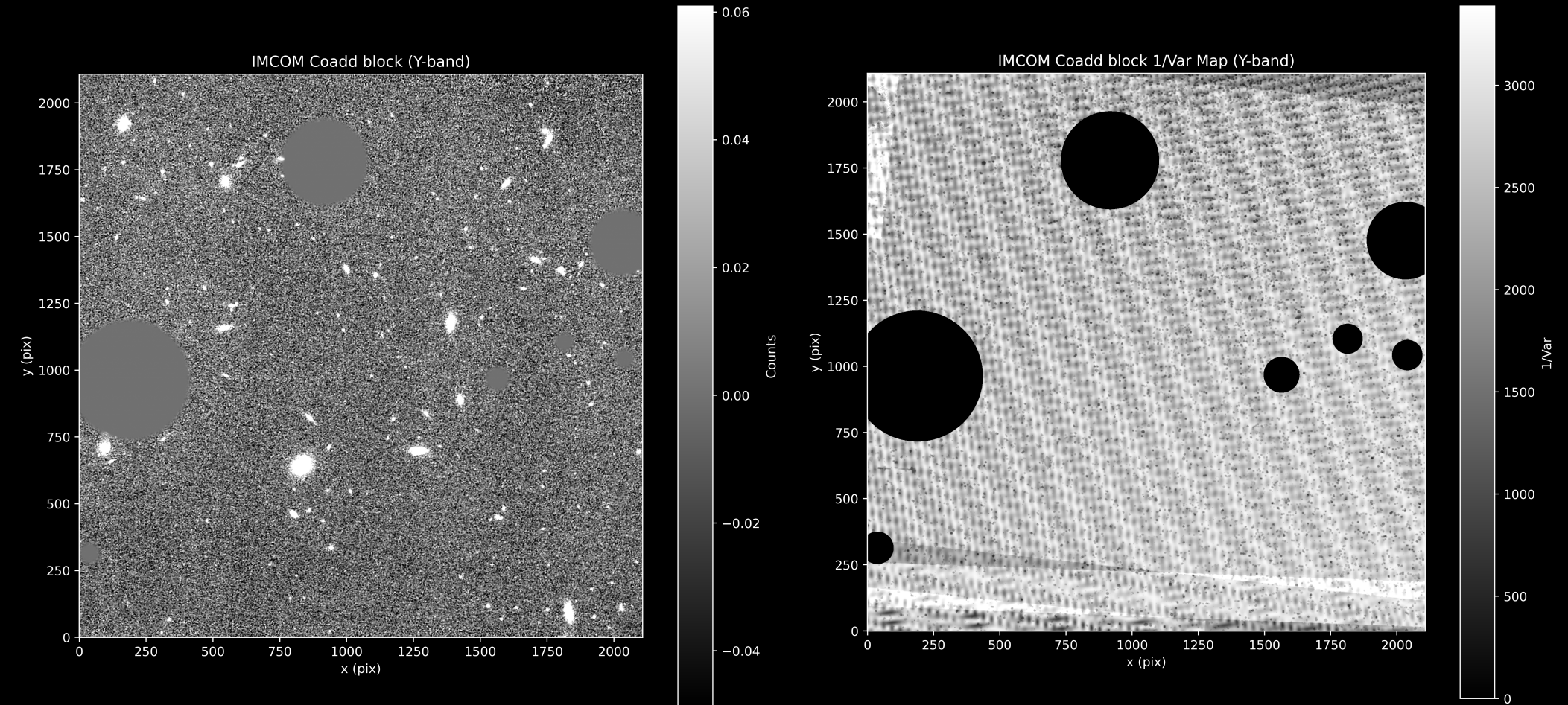
Realistic image simulations

Our test of MetaDetection on our latest run of image simulation.

- 4 IMCOM mosaics, total: 5 deg²
- Include several instrumental effects
 - Simulate L1 products and process to L2



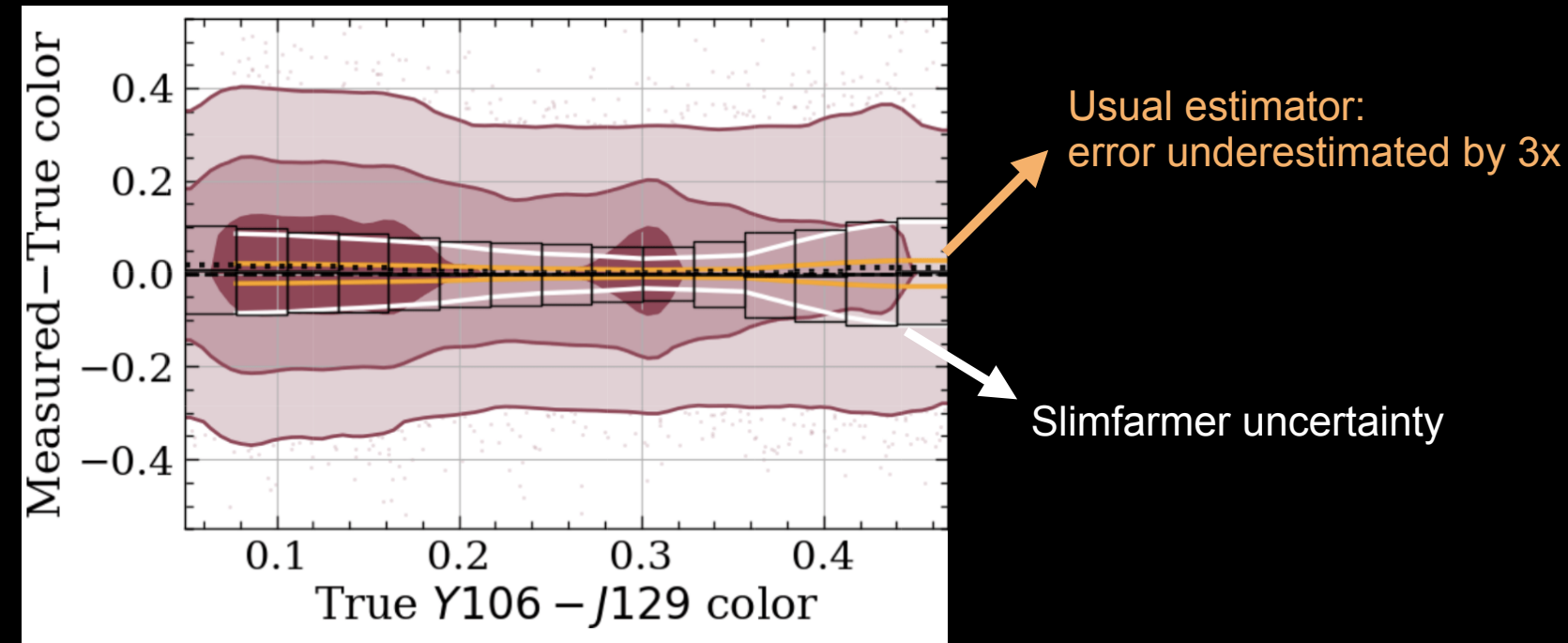
IMCOM coadds from simulation



The large holes are due bright star masks

IMCOM correlated noise: impact on photometry

- A photometry pipeline built from a cosmology perspective.
- End-to-end tested with Roman and Rubin image simulations.

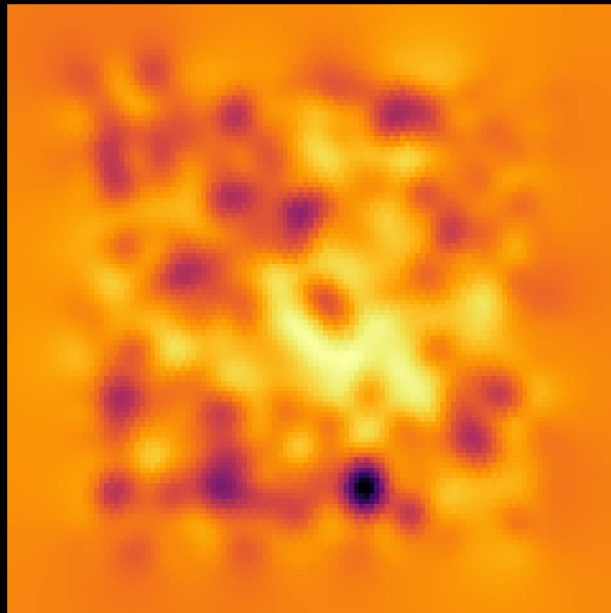


Paper at: 2607.09849
Chun-Hao et al.

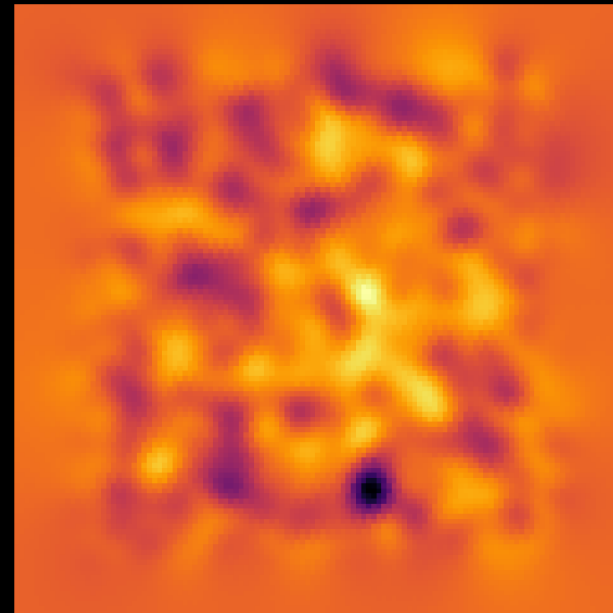


Results from Metadetection

Expected



Measured



Area: 4.7deg2

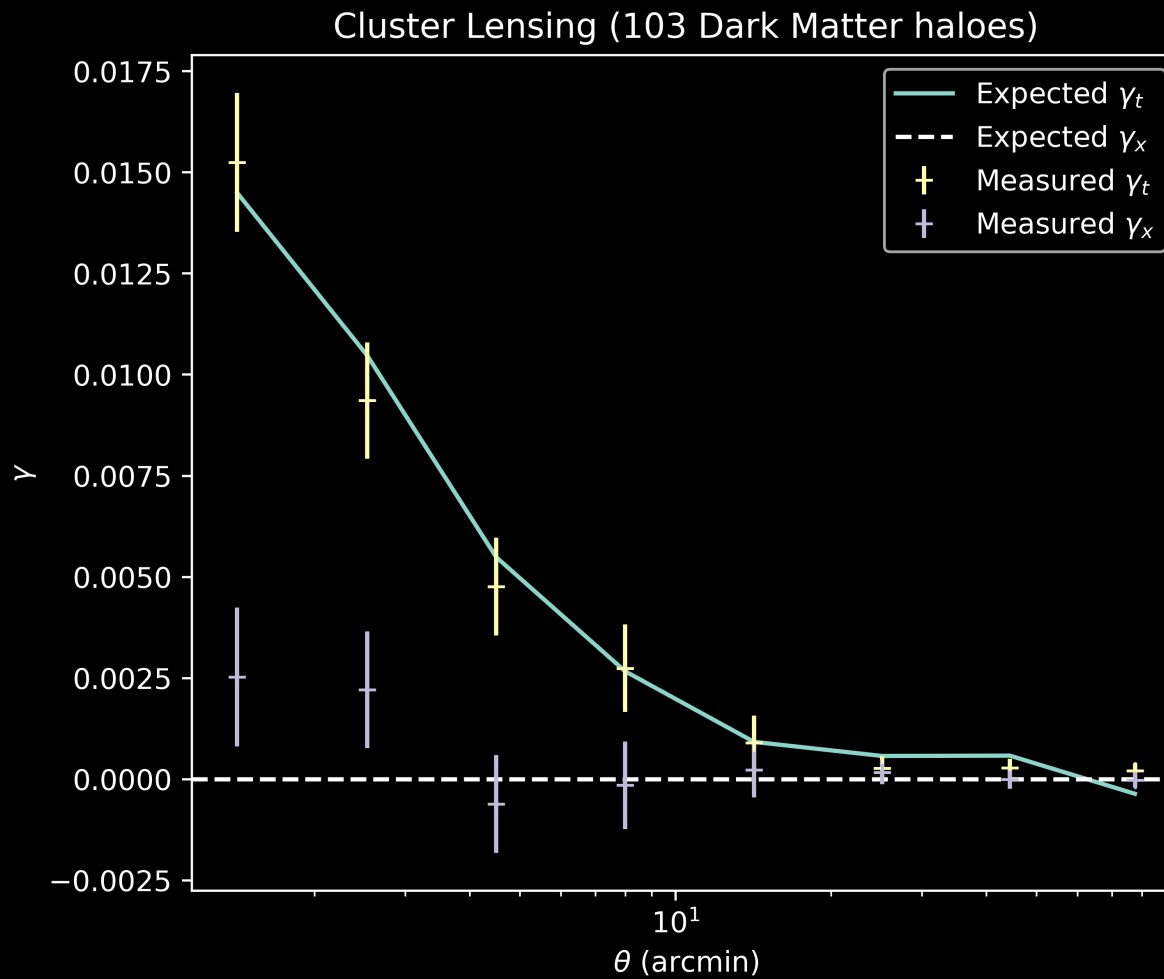
Shape Measurement:

- Matched to truth: 97.4%
- Galaxy Density: 41.555 gal.arcmin⁻²
- Shape Noise: 0.252
- Additive bias: $c_1 = 5.09 \times 10^{-3} \mid c_2 = 1.46 \times 10^{-3}$

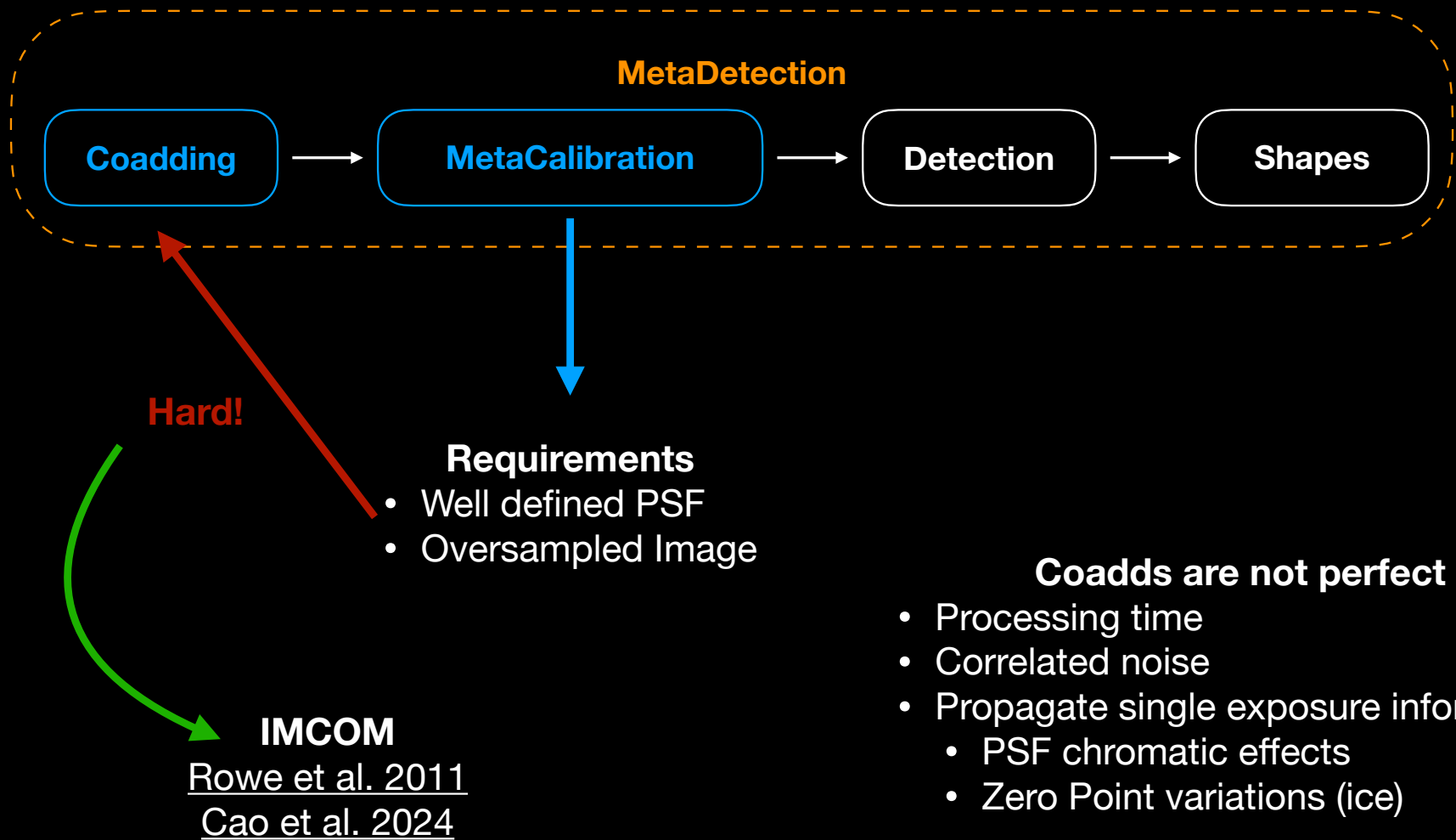


Reconstructed mass maps

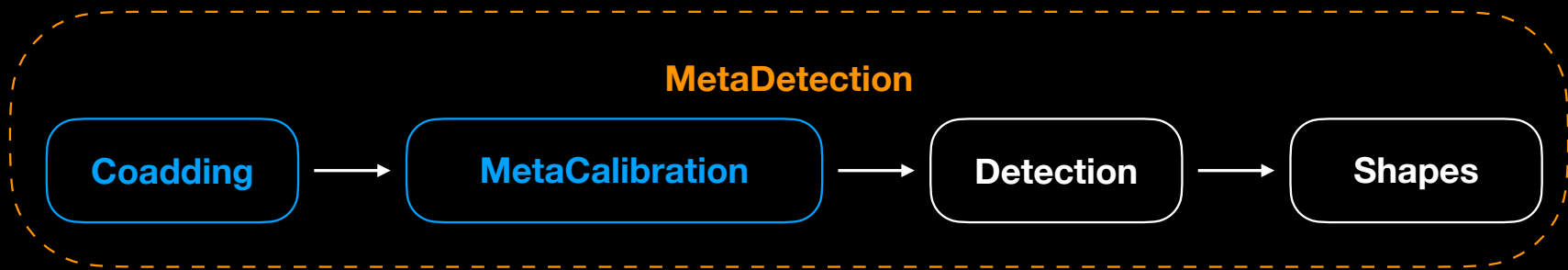
Results from Metadetection: Cluster Lensing



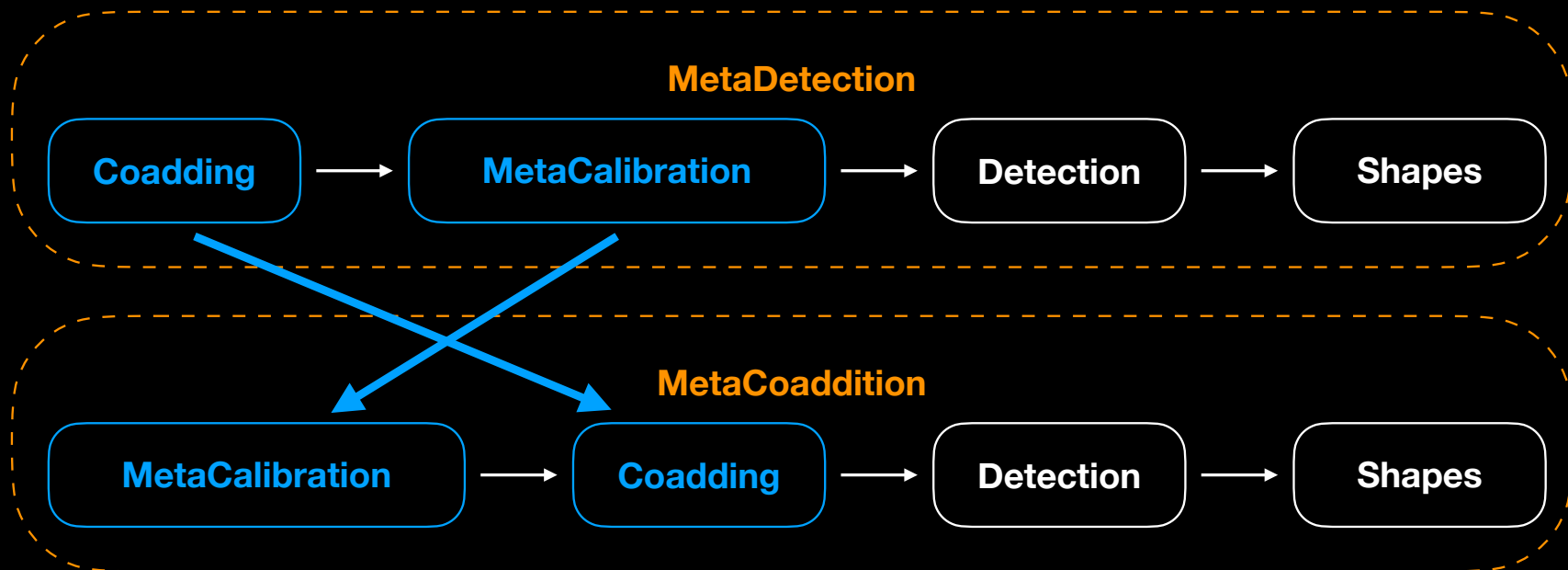
From MetaDetection to MetaCoaddition



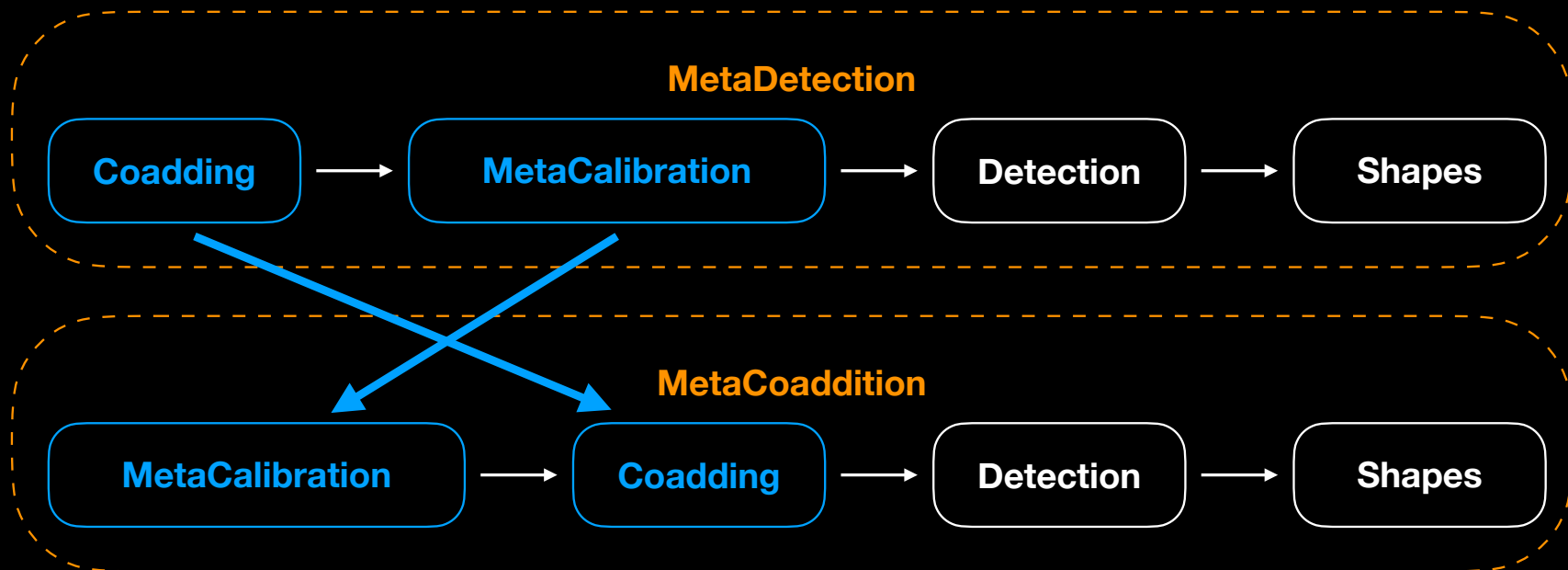
From MetaDetection to MetaCoaddition



From MetaDetection to MetaCoaddition



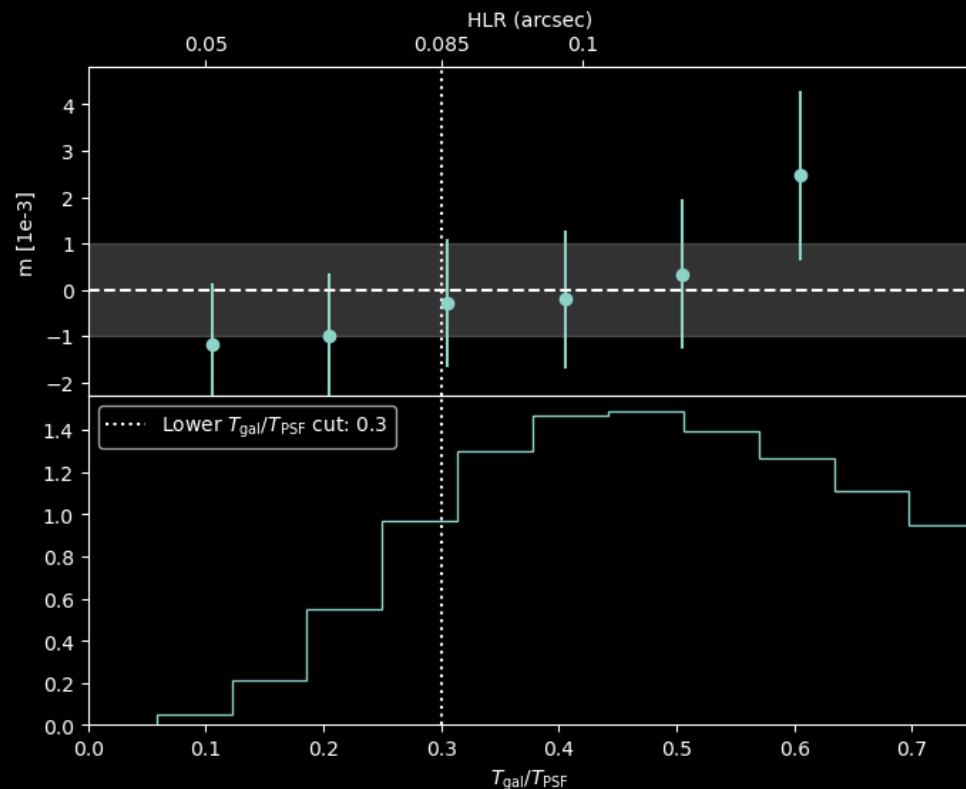
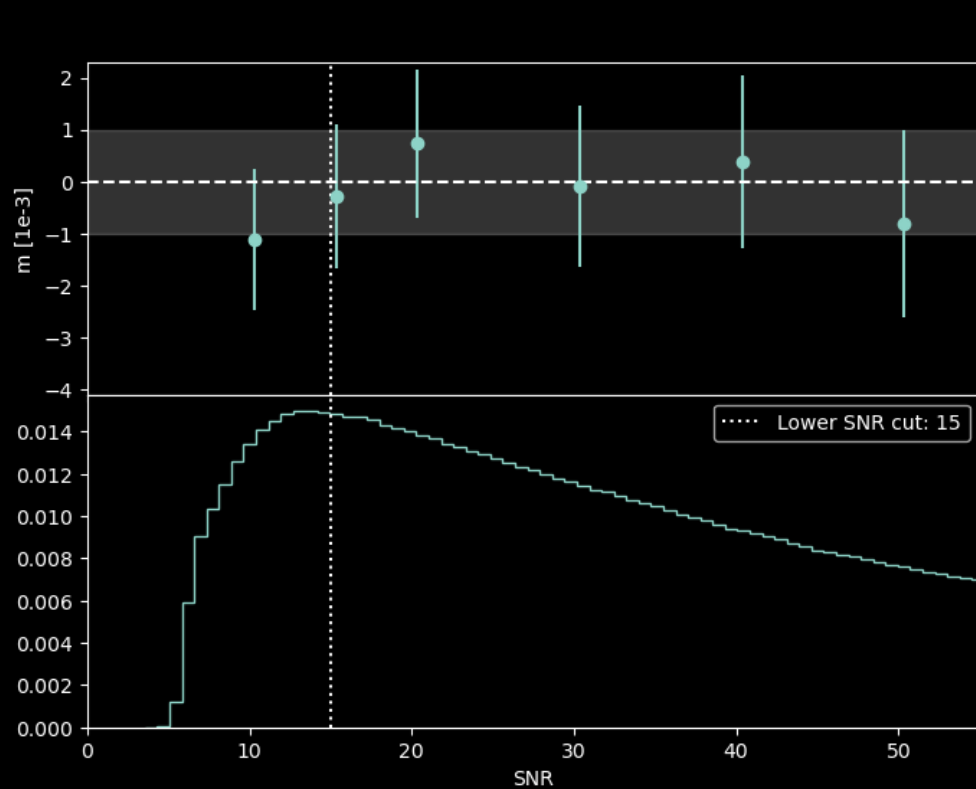
From MetaDetection to MetaCoaddition



What is the advantage of doing that:

- No need to run IMCOM
- Split the analysis: detection (& photometry) on coadds / measurement on single exposures
- Handling of chromatic effects more straightforward
- Direct access to single exposures effect such as zero point variations
- Processing time is significantly faster

MetaCoaddition: Preliminary results



Selection cuts:

- SNR > 15
- $T_{\text{gal}}/T_{\text{PSF}} > 0.3$

$$m = -0.25 \pm 1.55 (\times 10^{-3})$$

Conclusion

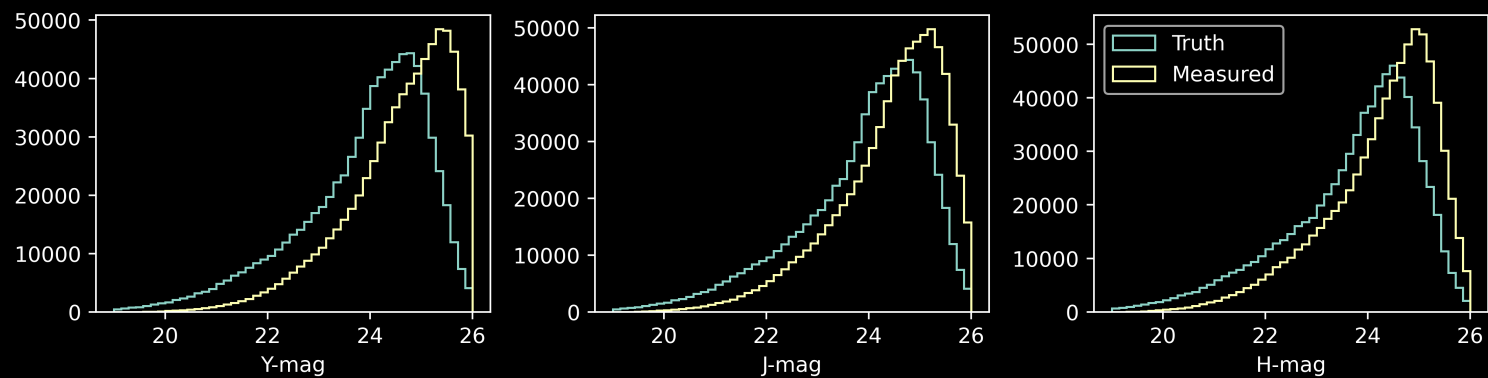
- Thanks to the HLIS PIT for the incredible efforts in developing the pipeline!
- Preliminary tests on realistic simulation of our pipeline IMCOM + MetaDetection
 - We made good progress to simulate and calibrate Level 1 exposures to Level 2
 - To know more about cosmic ray see Anthony Harbo Torres Poster! #10
- Results from simulations are very encouraging
 - We can recover cluster lensing signal
 - Cosmic shear is also very well recovered
- We are developing new methods
 - Metacoaddition
 - We can keep the multiplicative bias within Roman requirement
 $m = |-0.25| < 1 \quad (\times 10^{-3})$
 - Effortless: see Kaili Cao Poster! #3 (& #2)

A deep space photograph showing a vast field of stars against a black background. A prominent, colorful nebula with red and blue filaments is visible on the left side of the frame. The text "Thank you !" is overlaid on the right side of the image.

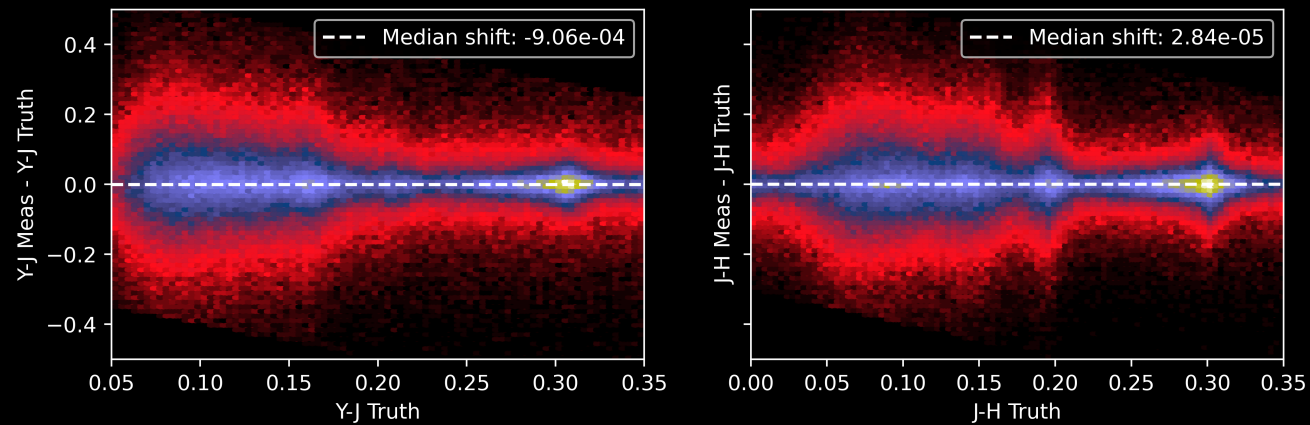
Thank you !

Results from Metadetection: Flux recovery

Magnitude Distribution with GAaP-like (PGauss)

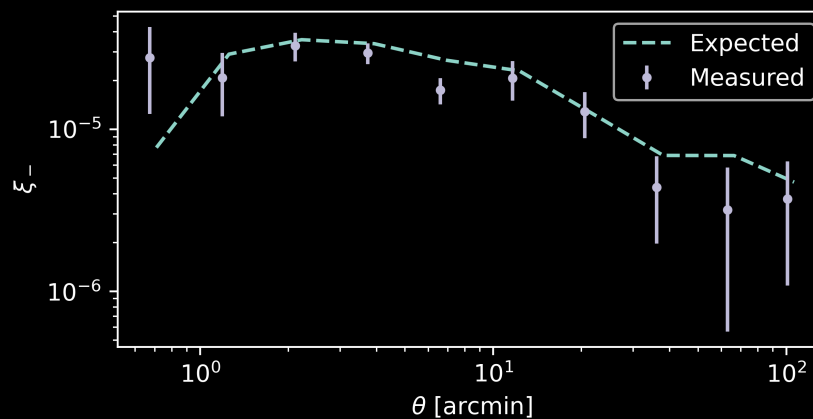
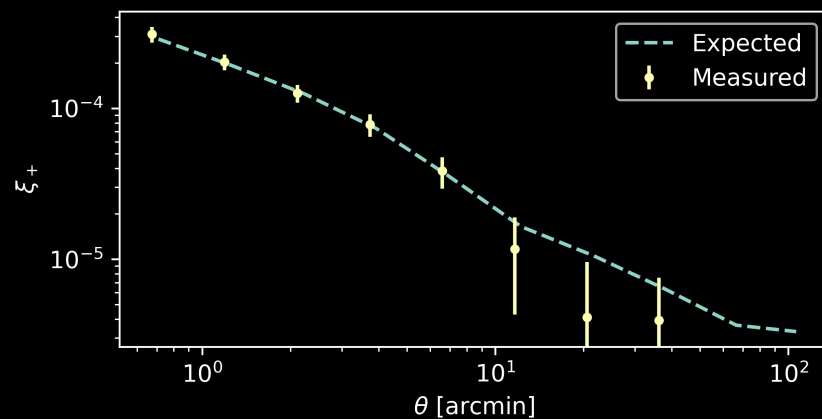


Error in color distribution with GAaP-like (PGauss)

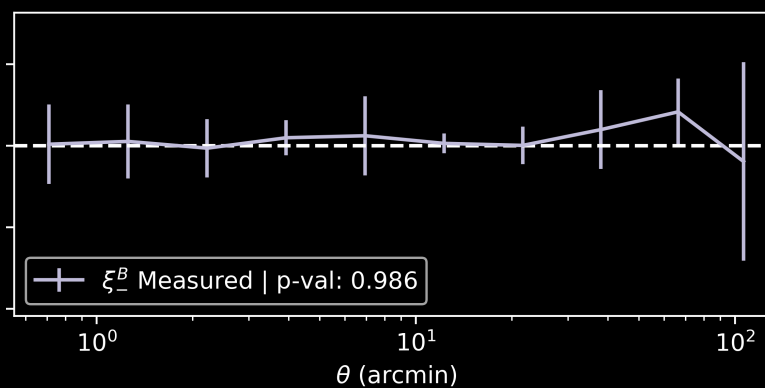
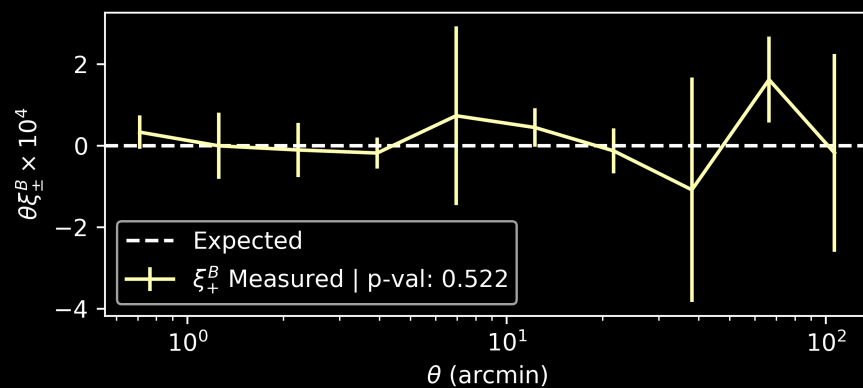


Results from Metadetection: Cosmic Shear

shear-shear Correlation function



B-modes
p-value (total): 0.811



MetaCoadd tests: Simulation setup

Simulation based on the OpenUniverse DiffSky catalog

- Galaxy light profile
 - Bulge + disk + knots
- PSF
 - Roman PSF (WebbPSF Cycle 9)
- Chromaticity
 - Galaxies: fixed SED (average from DiffSky)
 - PSF: stellar SED
- Roman WCS
- 3 bands: YJH (medium tier)
- 1 epoch per band (save computing time)
 - 6 x exposure time
- Expected Roman noise level
- Objects are placed on a 4x4 grid

