Towards precision cosmology —— systematics removal with Stage III data

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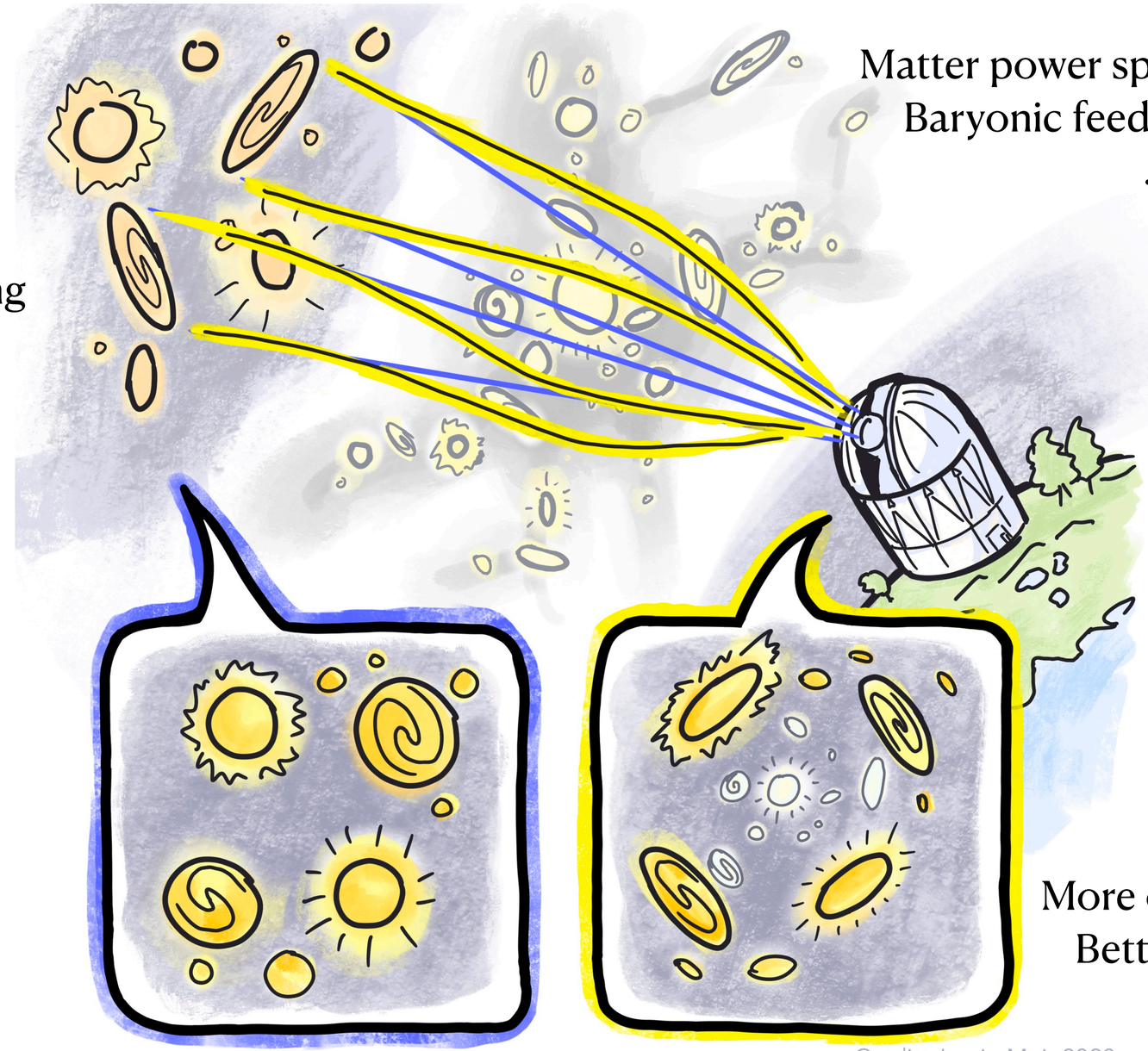
Collaborators: Huanyuan Shan, Pengjie Zhang, CSST, KiDS, DESI

What can go wrong in weak lensing cosmology?

Shear measurement
Redshift measurement
Intrinsic alignment modeling
Sample selection
...



Matter power spectrum modeling
Baryonic feedback modeling
...

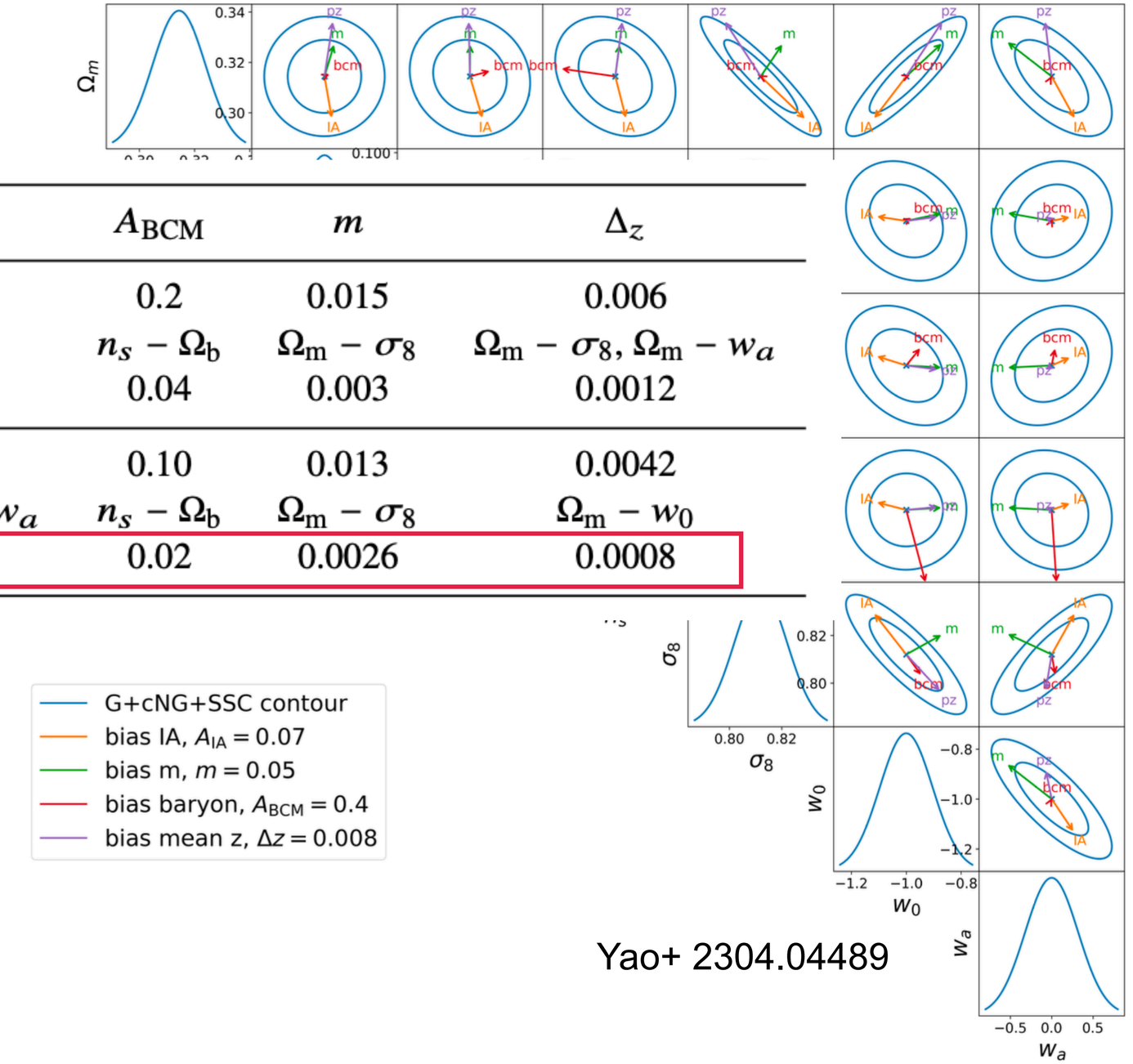
PSF modeling/deconvolution
Detecter effects
...
Covariances
Priors
...

We need:
More observations: cross-checking
Better methods for systematics

Credit: Jessie Muir 2020

Requirements for CSST systematic-control

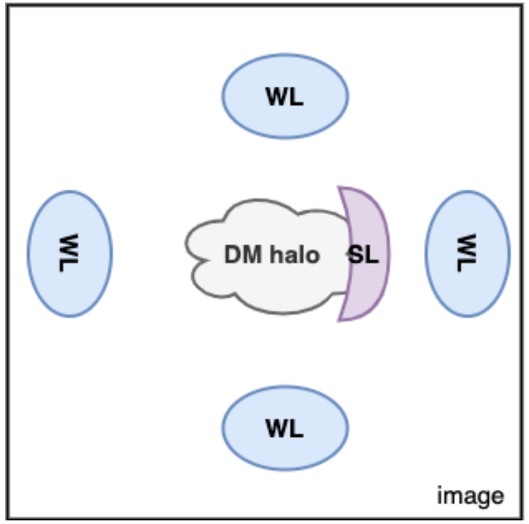
Case	$A_{\rm IA}$	$A_{\rm BCM}$	m	Δ_z
$\ell < 1000$, 68% contour	0.058	0.2	0.015	0.006
main constrain	$\Omega_{\rm m} - \sigma_8$	$n_s - \Omega_{\rm b}$	$\Omega_{\rm m} - \sigma_8$	$\Omega_{\rm m} - \sigma_8, \Omega_{\rm m} - w_a$
$\ell < 1000$, 95% prob	0.012	0.04	0.003	0.0012
$\ell < 3000$, 68% contour ($\sigma_{\rm 2D}$)	0.044	0.10	0.013	0.0042
main constrain	$\Omega_{\rm m} - \sigma_8 - w_0 - w_a$	$n_s - \Omega_{\rm b}$	$\Omega_{\rm m} - \sigma_8$	$\Omega_{\rm m} - w_0$
$\ell < 3000$, 95% prob ($\Delta_{\rm req}$)	0.009	0.02	0.0026	0.0008

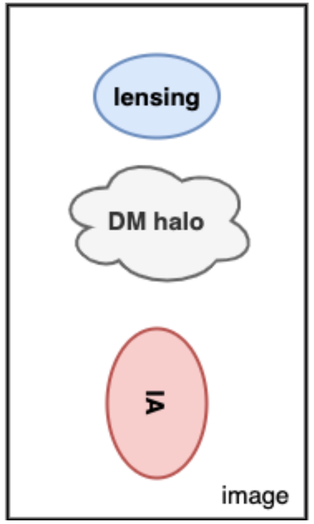


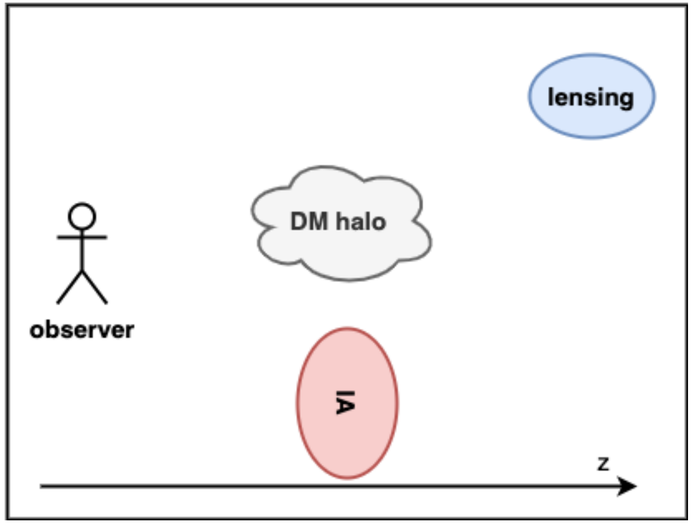
We want 1% - 0.1% level residual systematics!

Yao+ 2304.04489

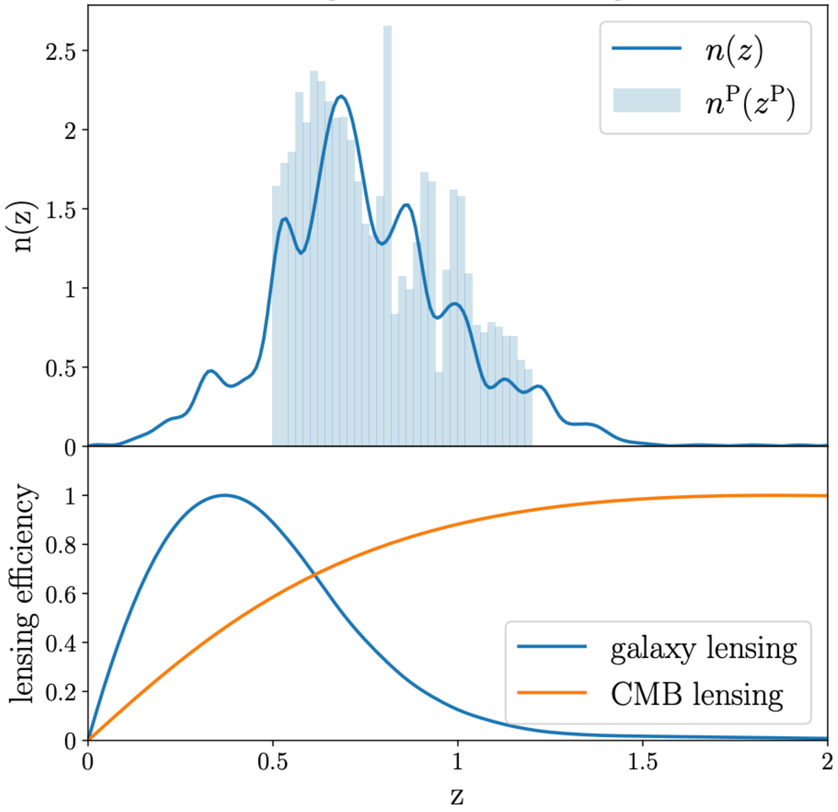
Lensing v.s. IA: different z-dependency





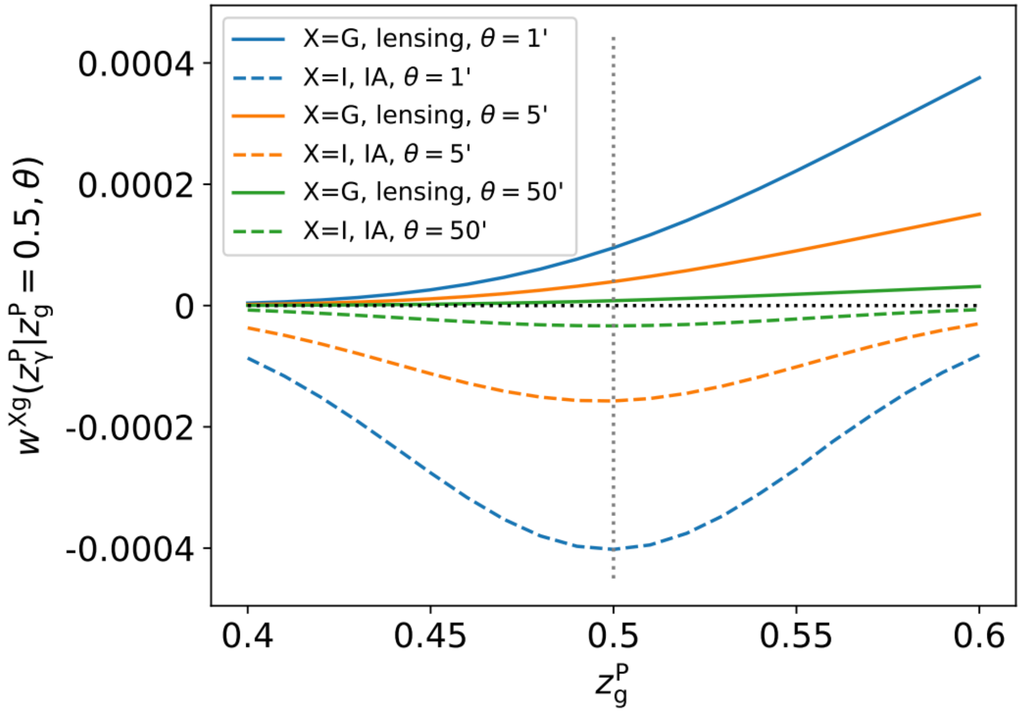


choose KiDS high-z data as light source

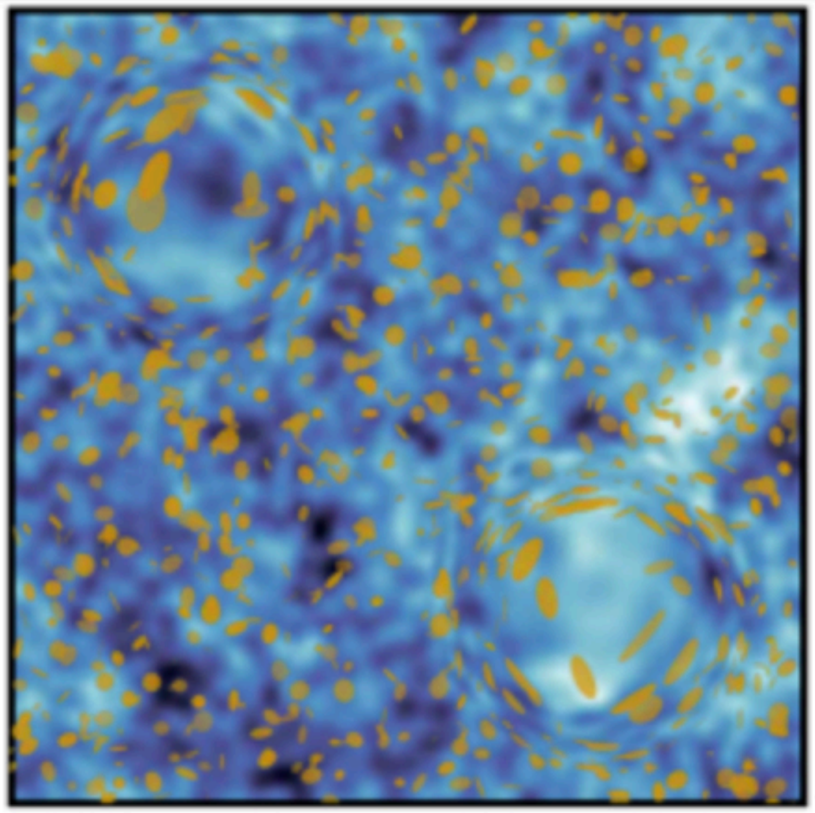


Zhang 0811.0613

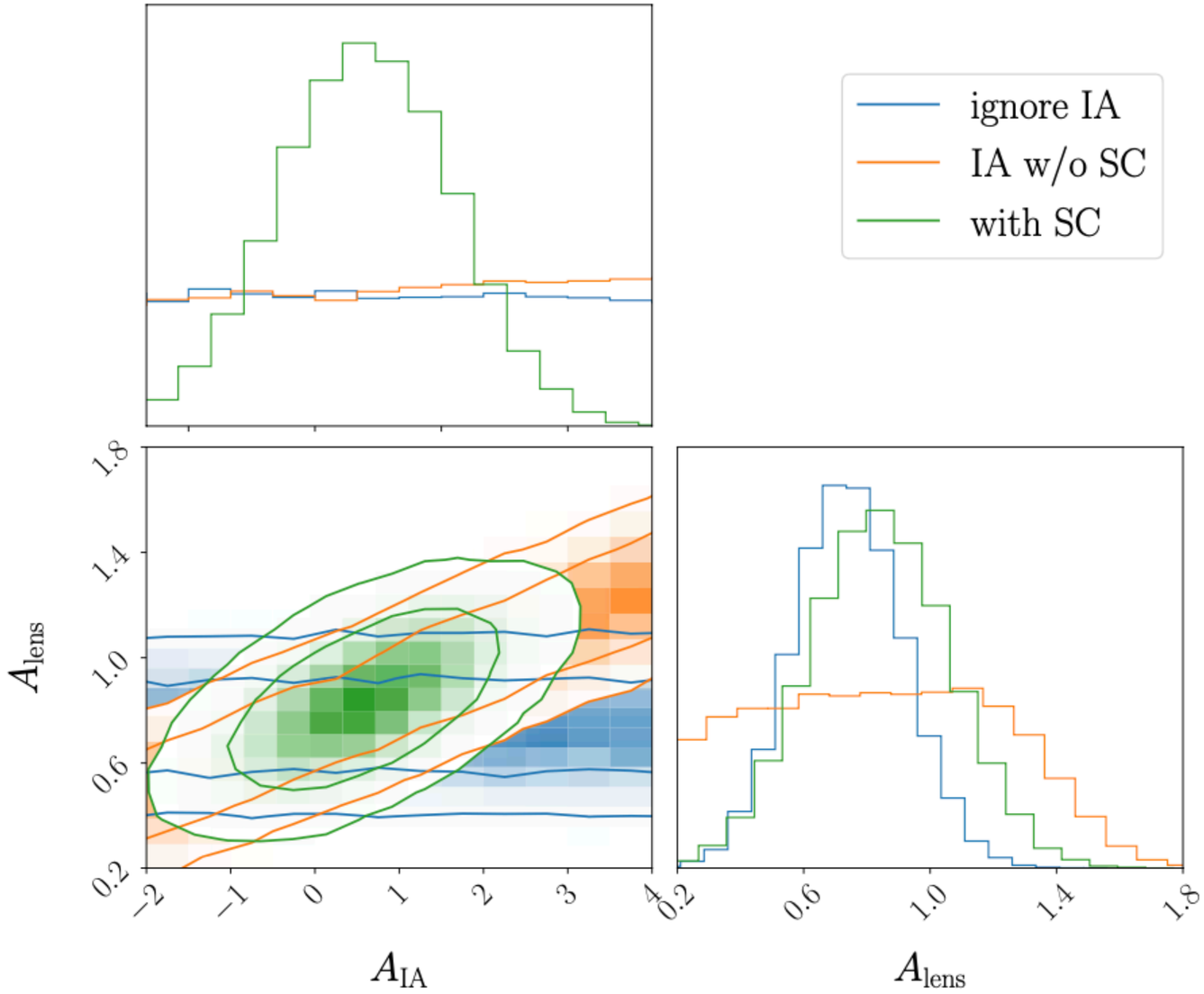
Fix lens-matter



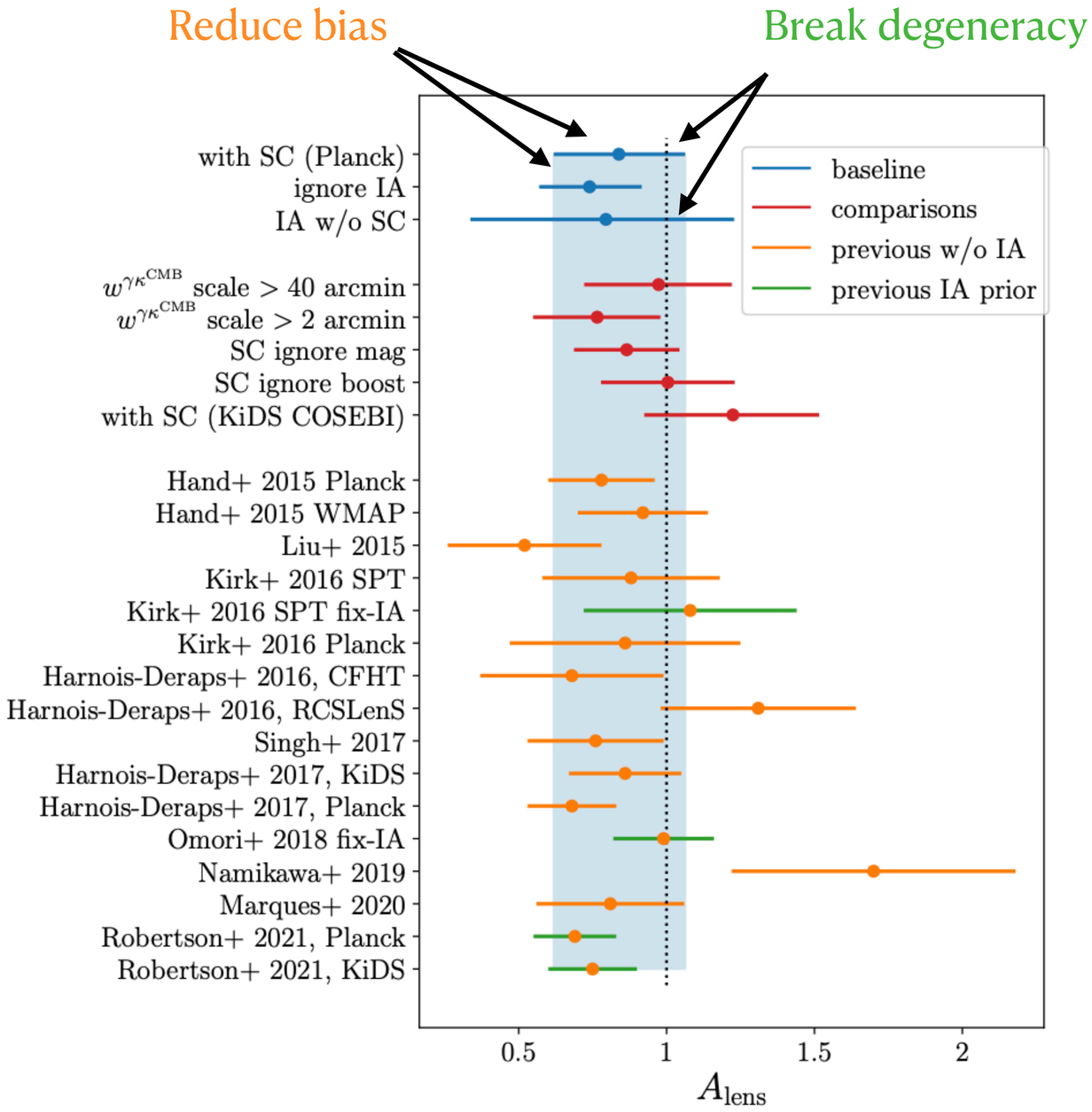
Benefits of using IA self-calibration in CMB lensing



CMB LENSING
X
GALAXY SHEAR

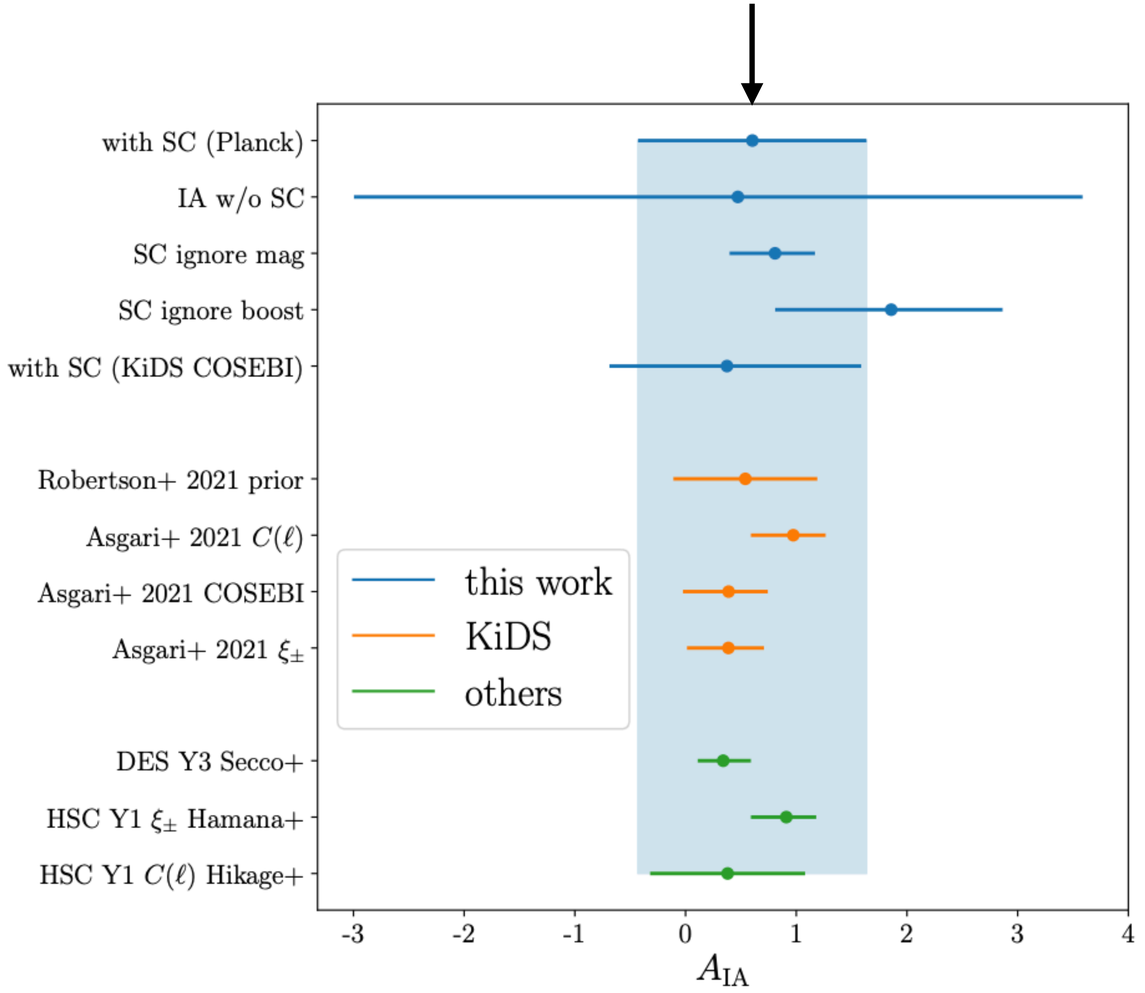


Comparisons

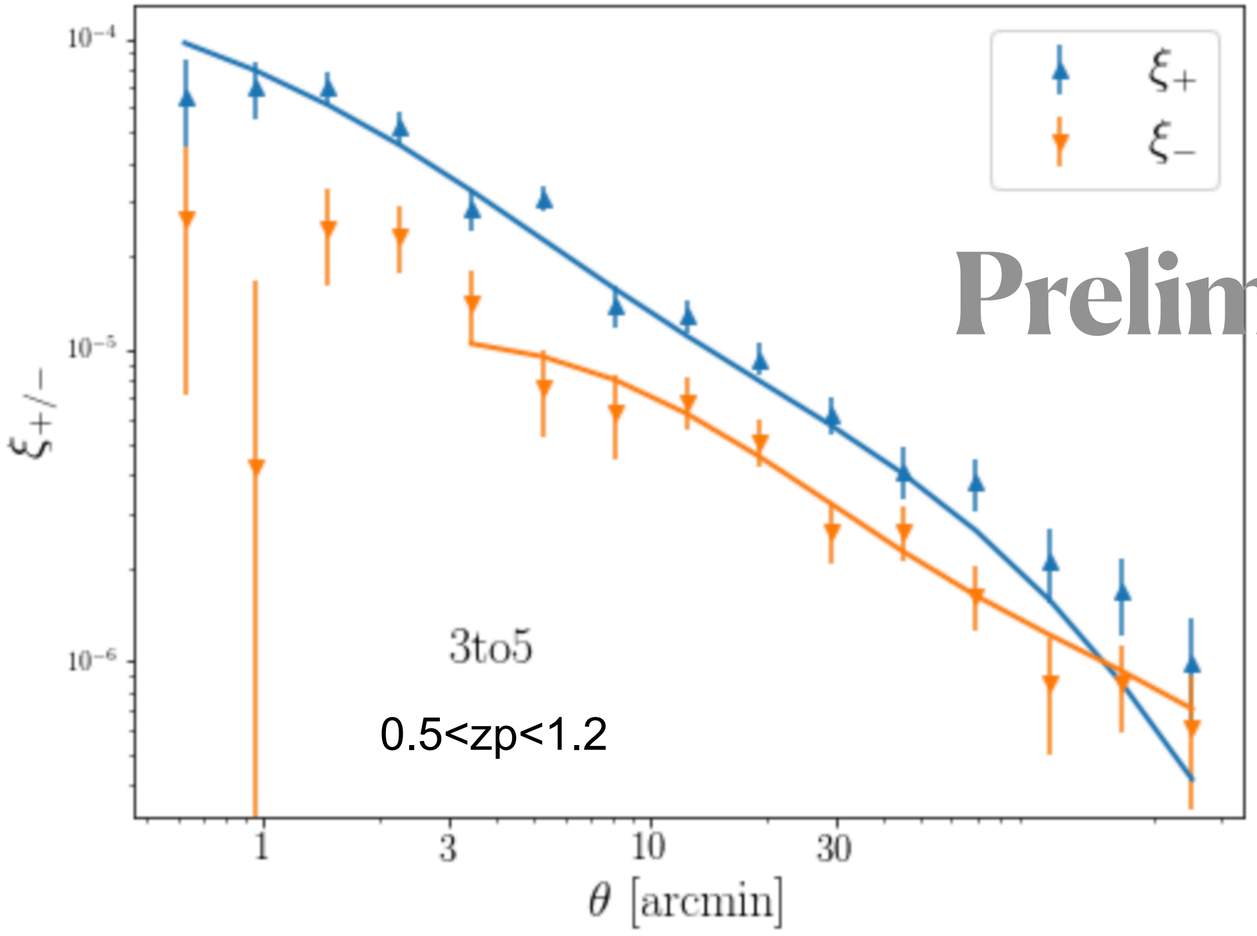


Yao+ 2301.13437

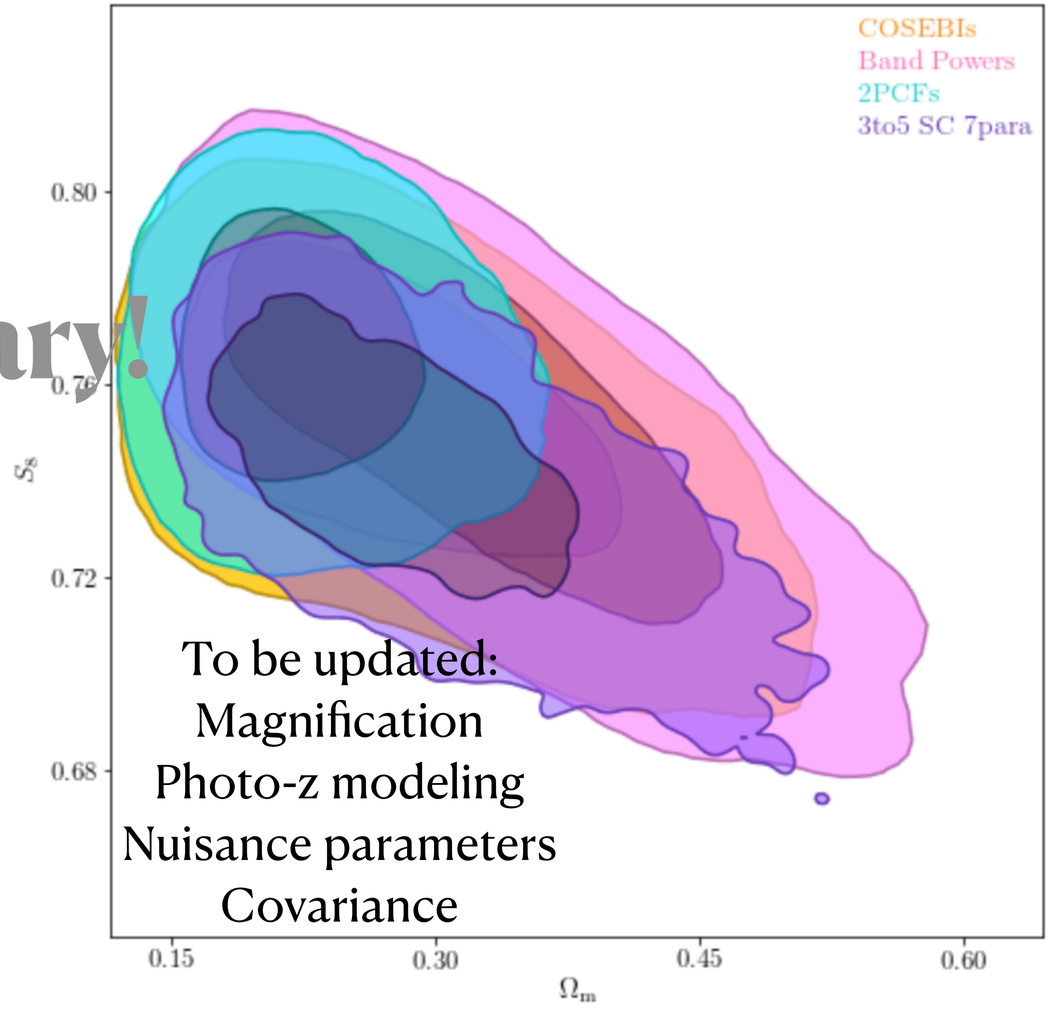
Independent measurement: more info



Apply SC to cosmic shear —— no need for tomography



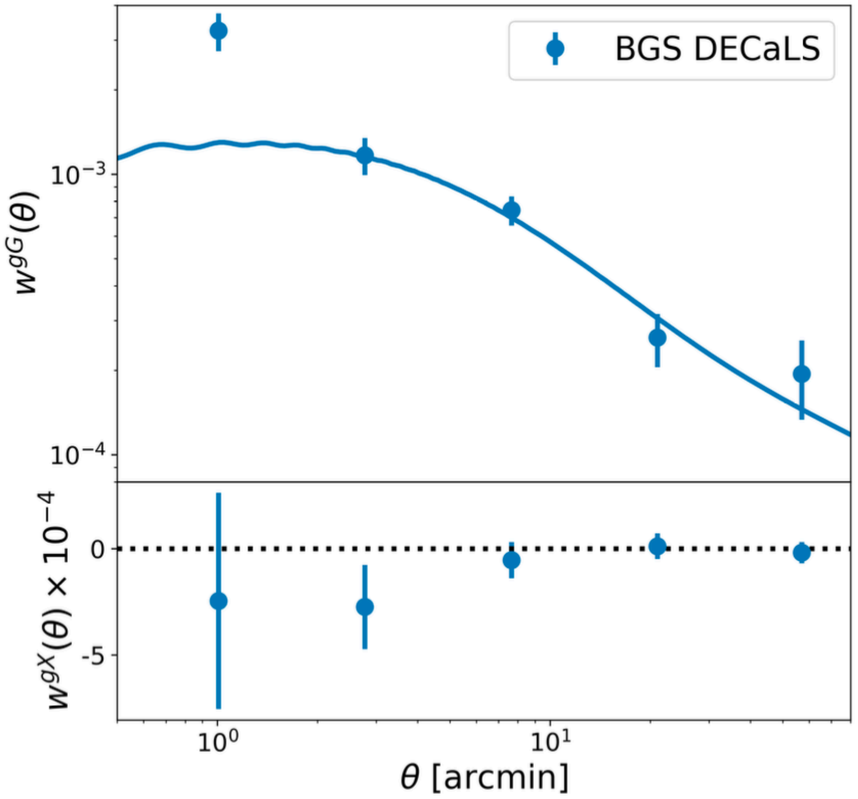
Preliminary!



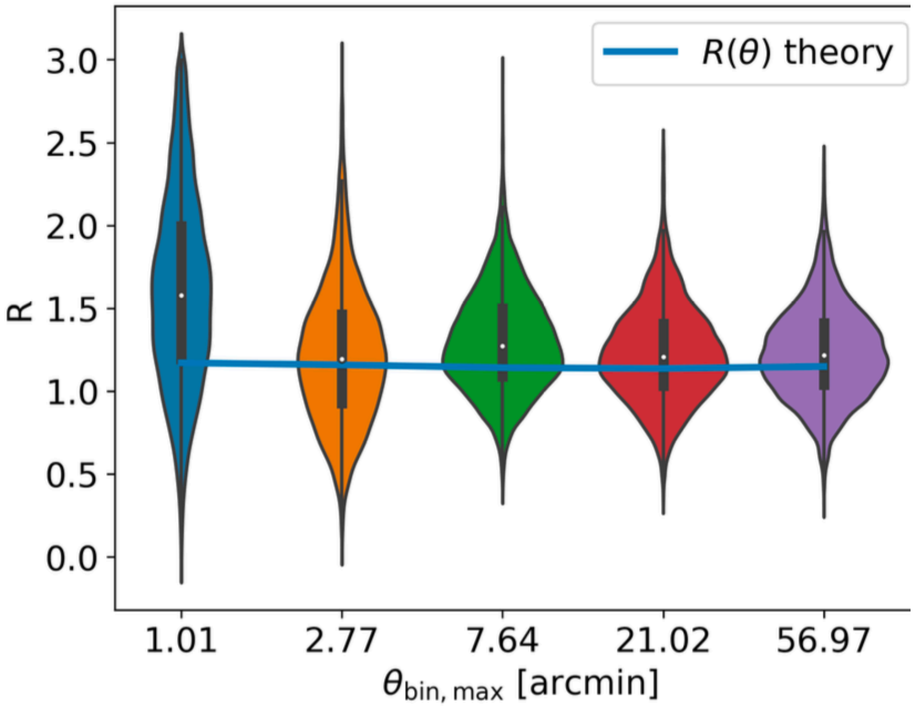
To be updated:
Magnification
Photo-z modeling
Nuisance parameters
Covariance

DECaLS x DESI (DnD) —— using only 1% data

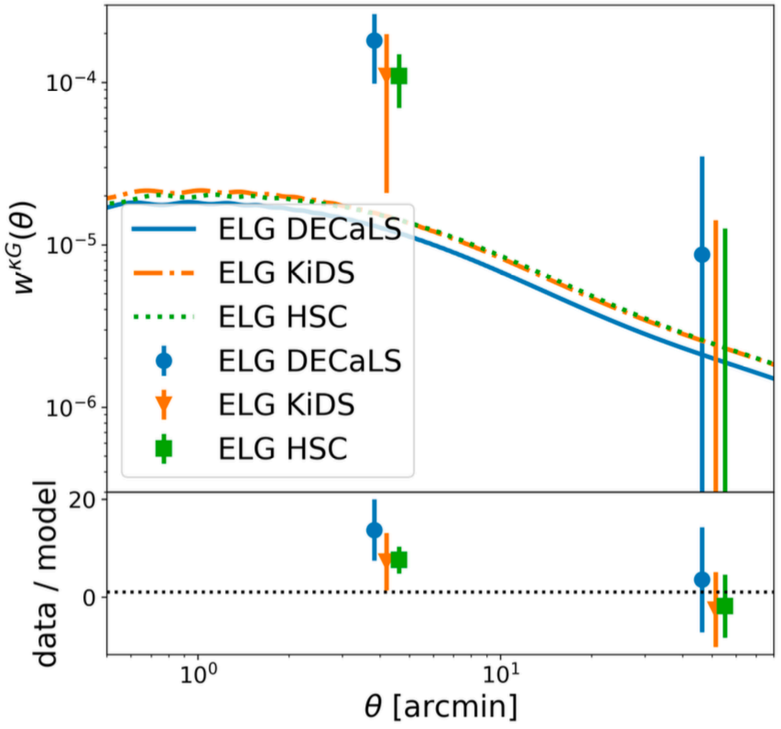
g-g lensing



Shear ratio



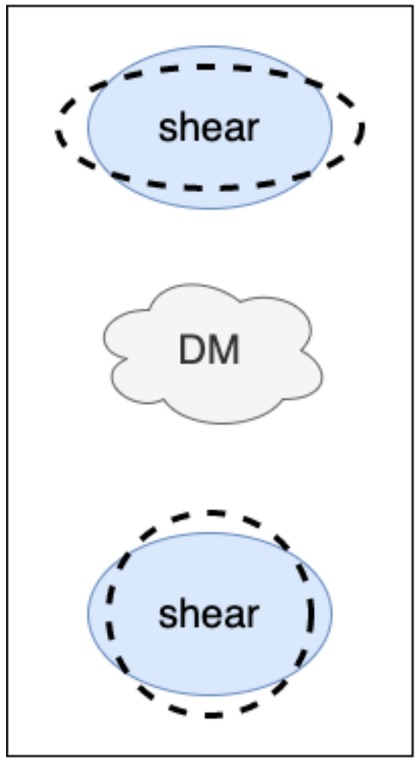
Magnification

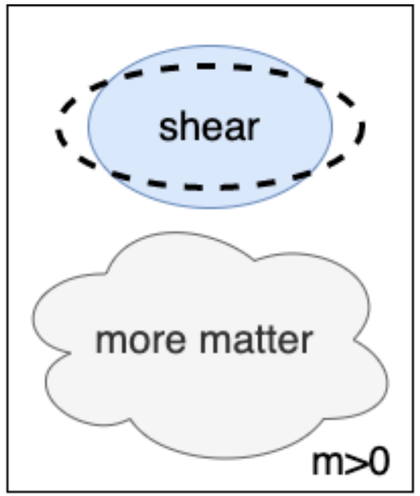


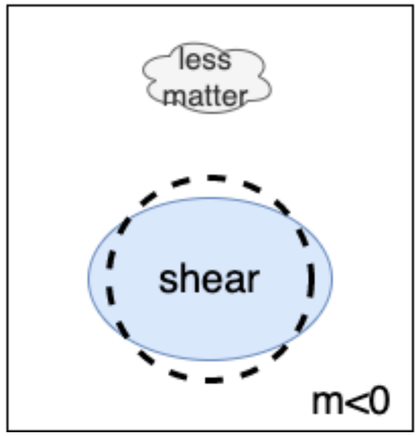
The large overlap is the best advantage for DECaLS before Stage IV!

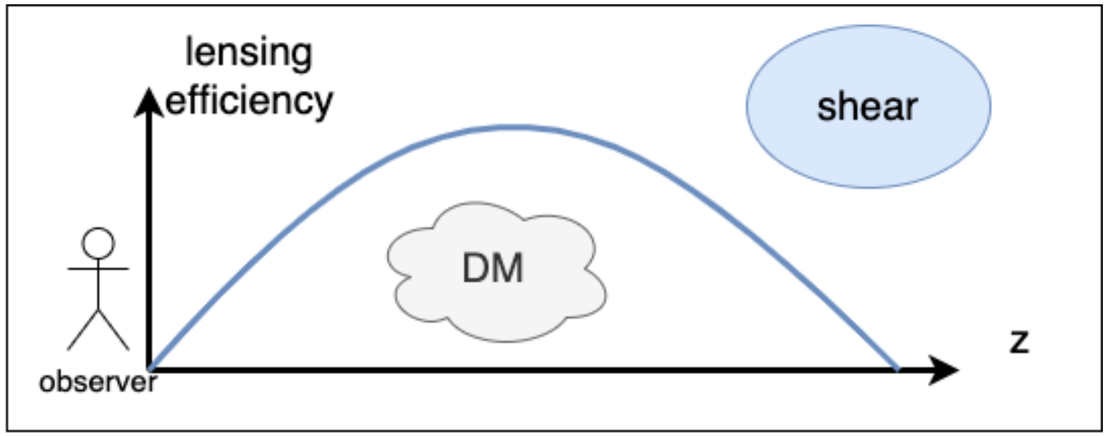
Yao+ 2301.13434

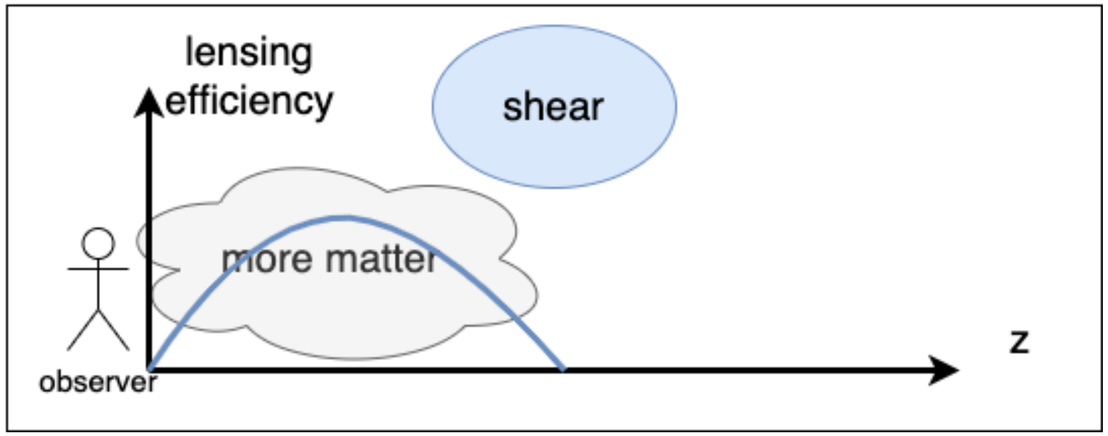
How shear bias and z bias work











Shear measurements from DECaLS DR9

DR8:

z < 21

DR9:

15 < g < 25

15 < r < 23

15 < z < 22

-1.5 < g-r < 3

-1.5 < r-z < 3

10 < g,r,z S/N < 1000

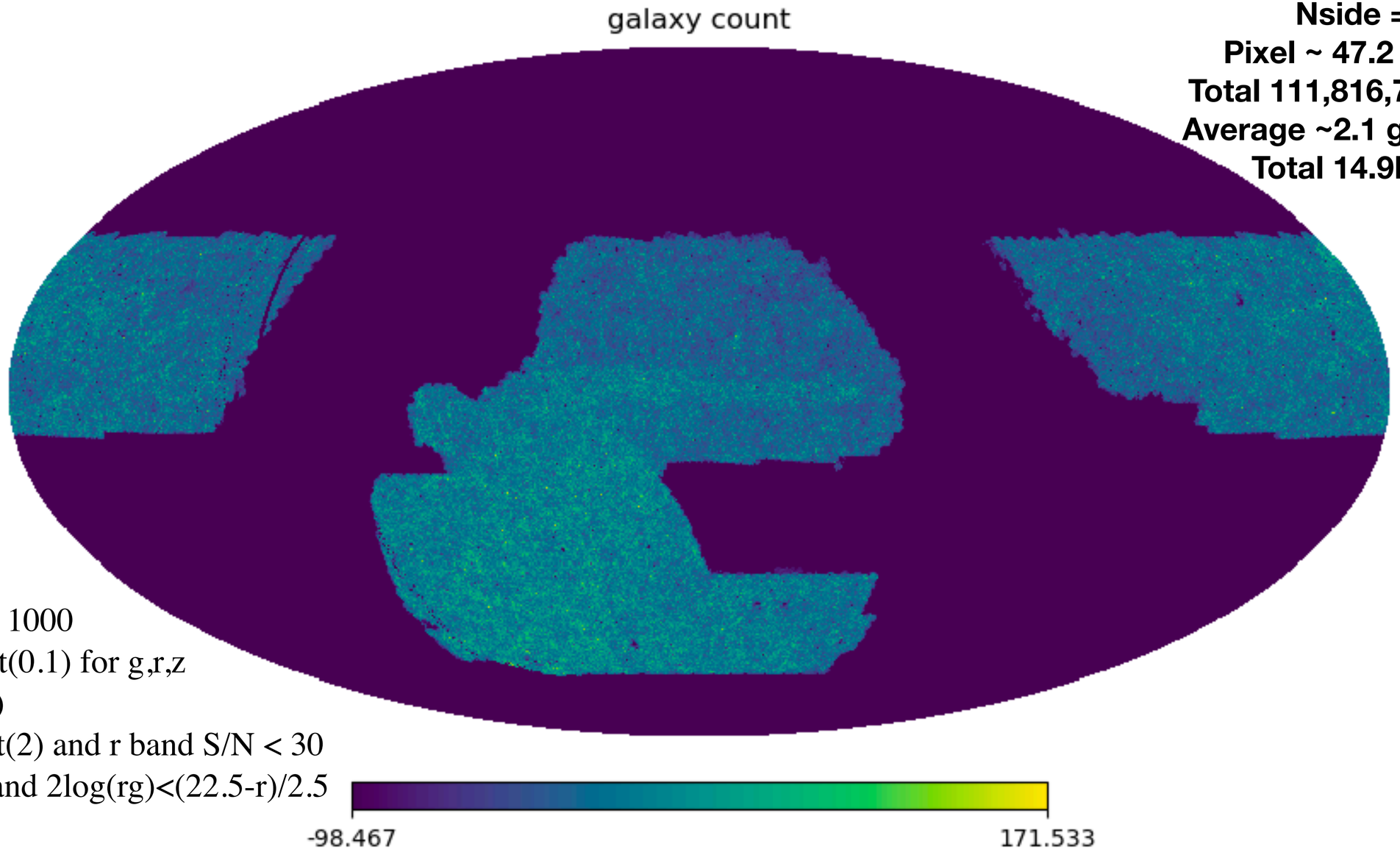
rg / psf_rg > sqrt(0.1) for g,r,z

0 < rg < sqrt(10)

remove rg > sqrt(2) and r band S/N < 30

remove lel>0.8 and 2log(rg)<(22.5-r)/2.5

0.1 < zp < 1.2



Nside = 512

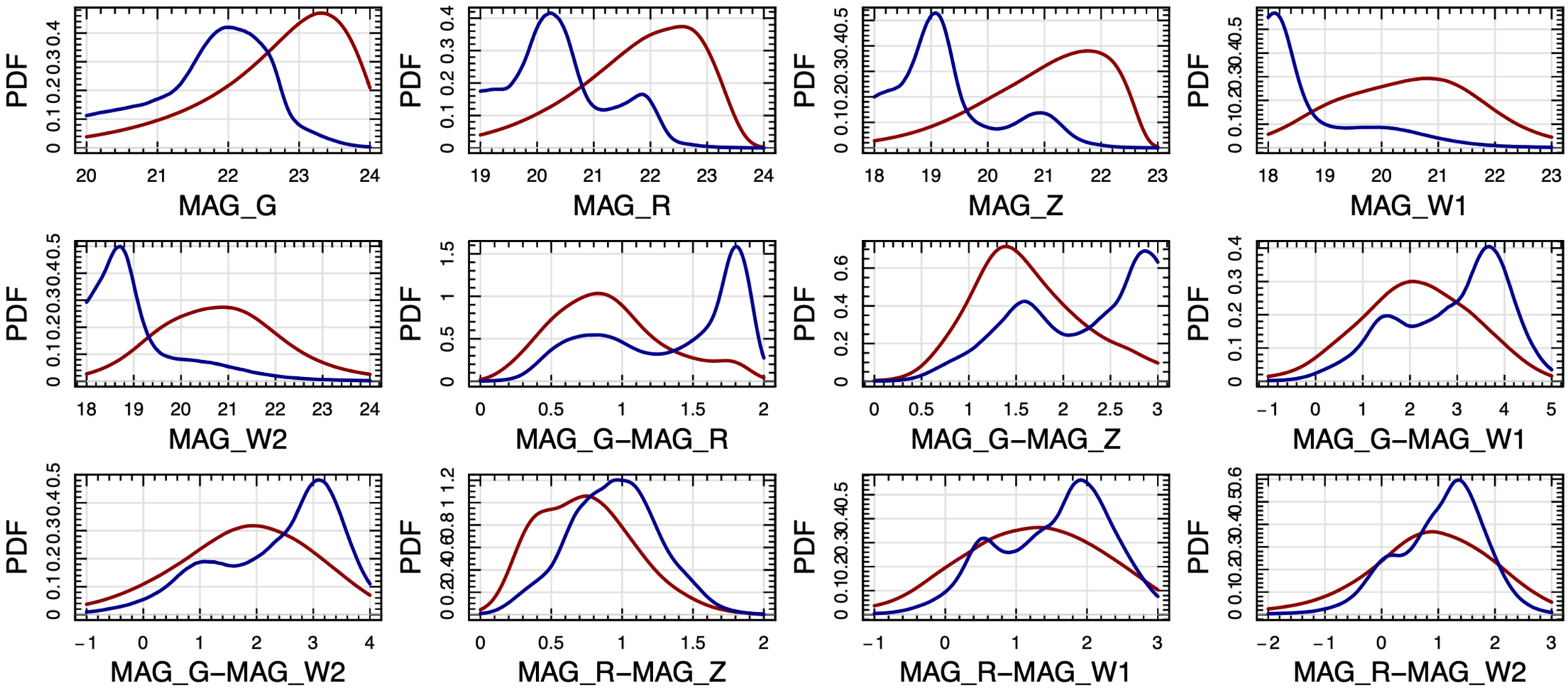
Pixel ~ 47.2 arcmin^2

Total 111,816,750 galaxies

Average ~2.1 gal/arcmin^2

Total 14.9k deg^2

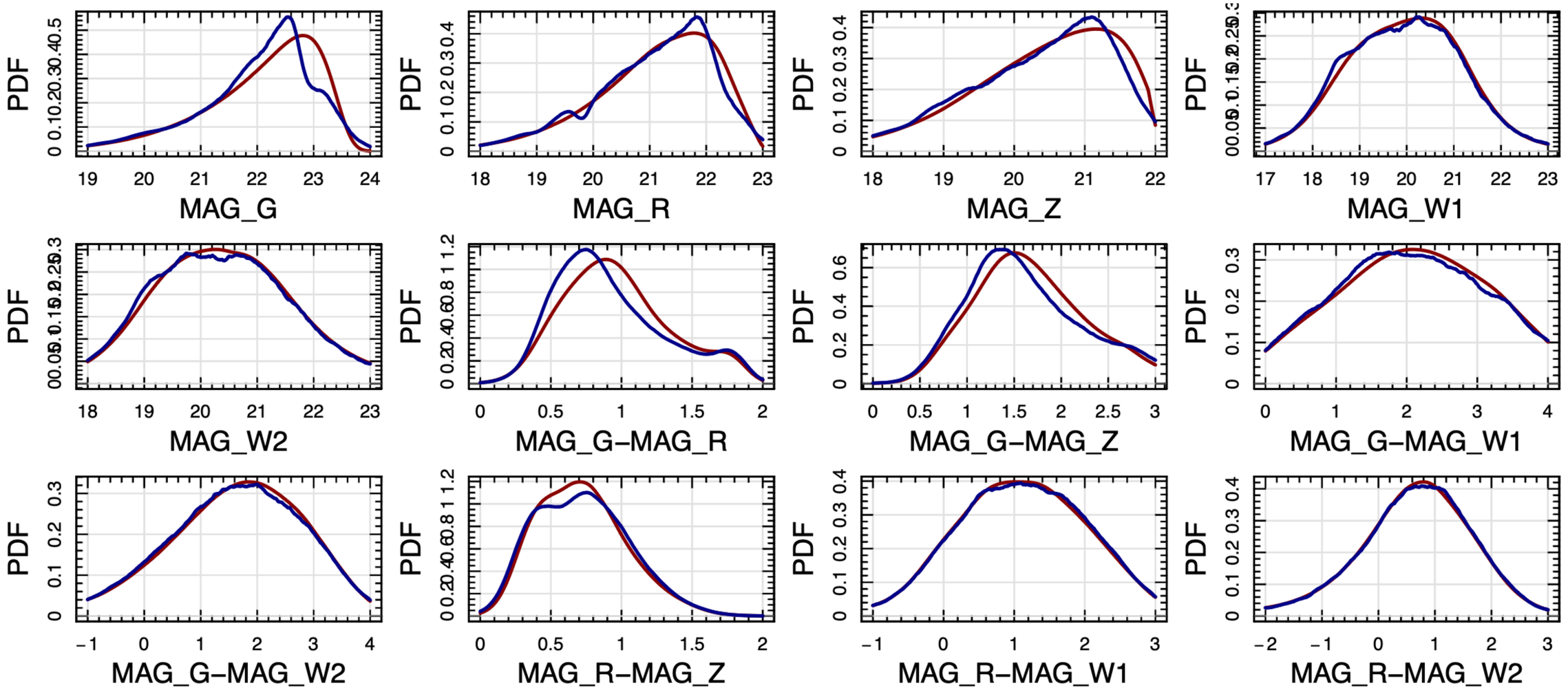
spec-z sample & photo-z sample



Red: distribution of photometric galaxies

Blue: distribution of spectroscopic galaxies without SOM weight

spec-z sample (SOM weight) & photo-z sample

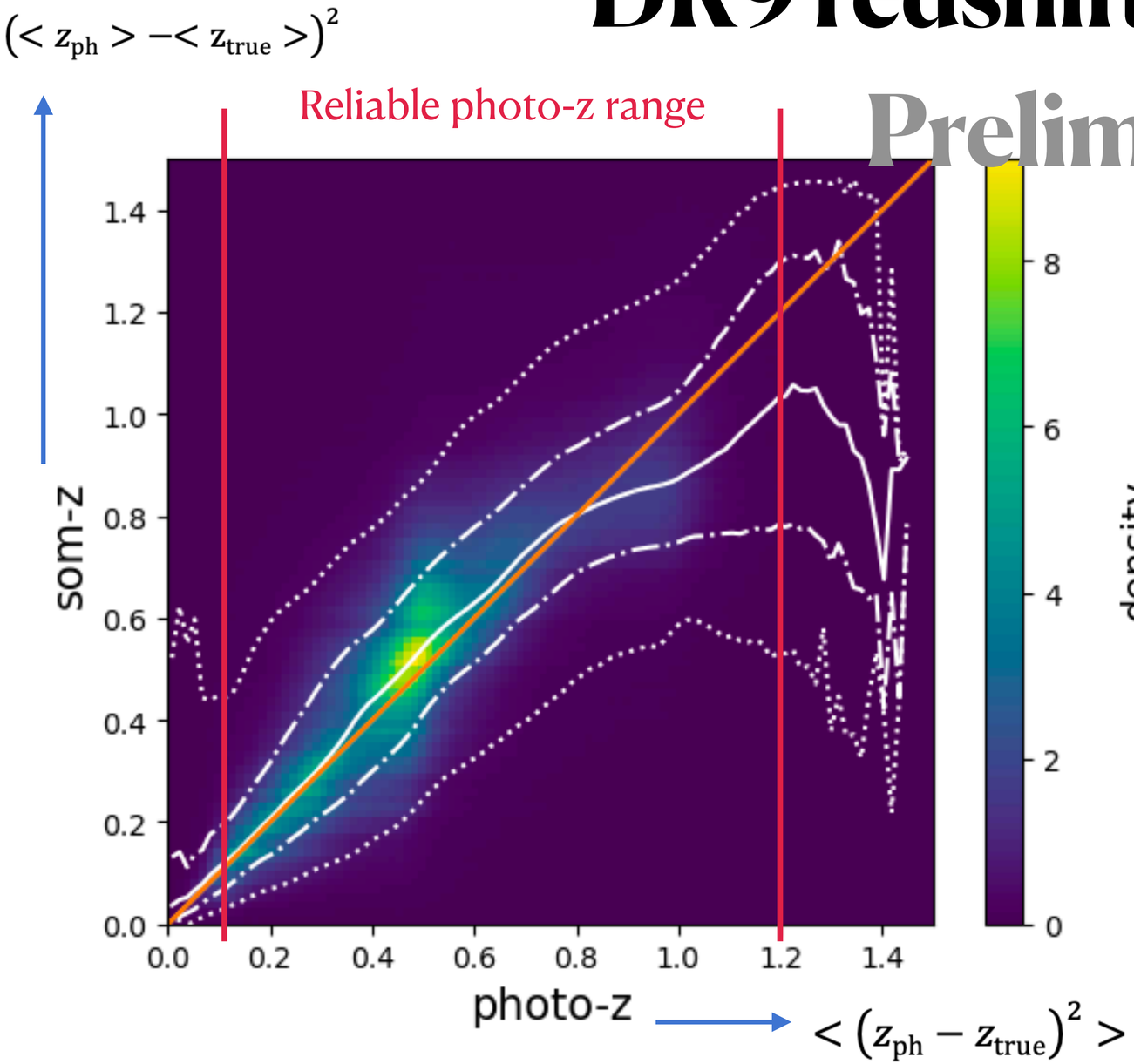


Red: distribution of photometric galaxies

Blue: distribution of spectroscopic galaxies with SOM weight

DR9 redshift properties

Preliminary!



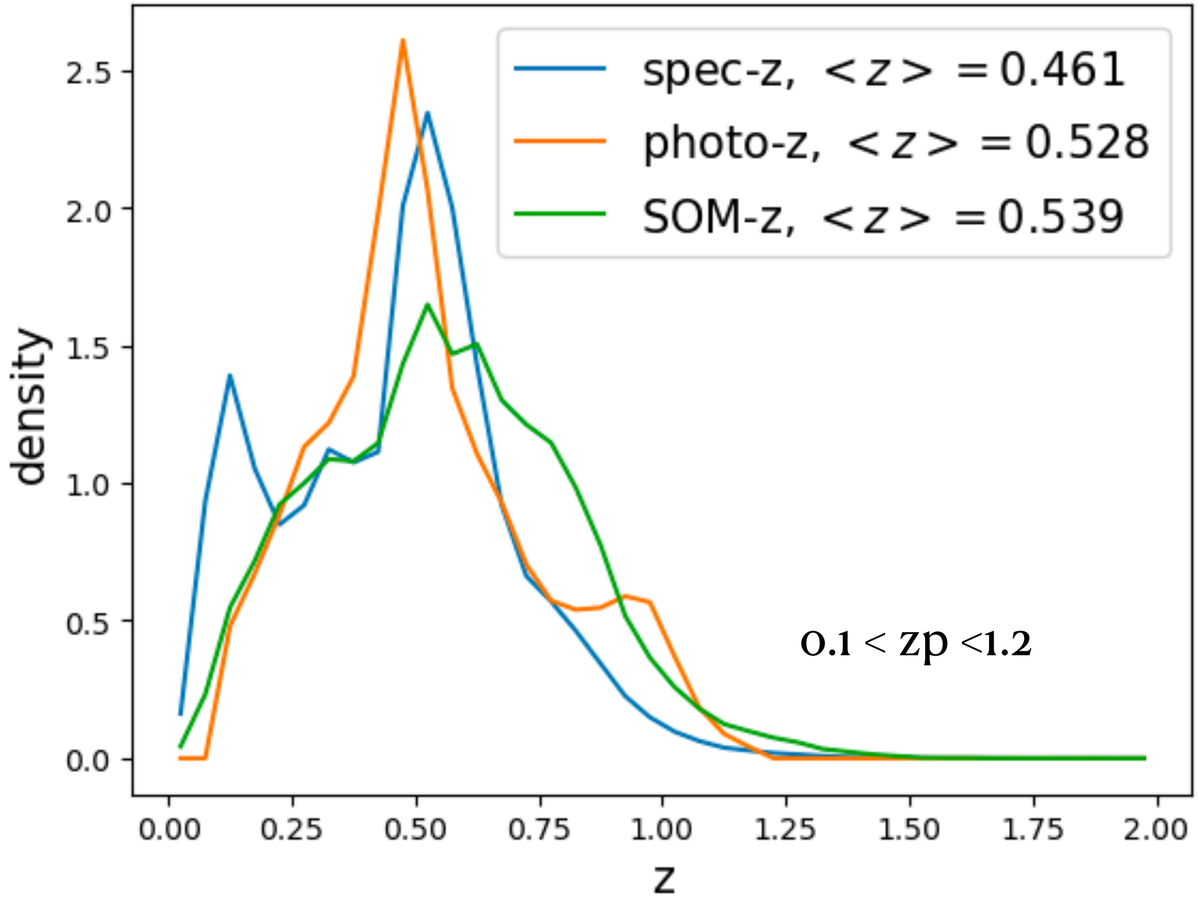


Image simulation with Obiwan

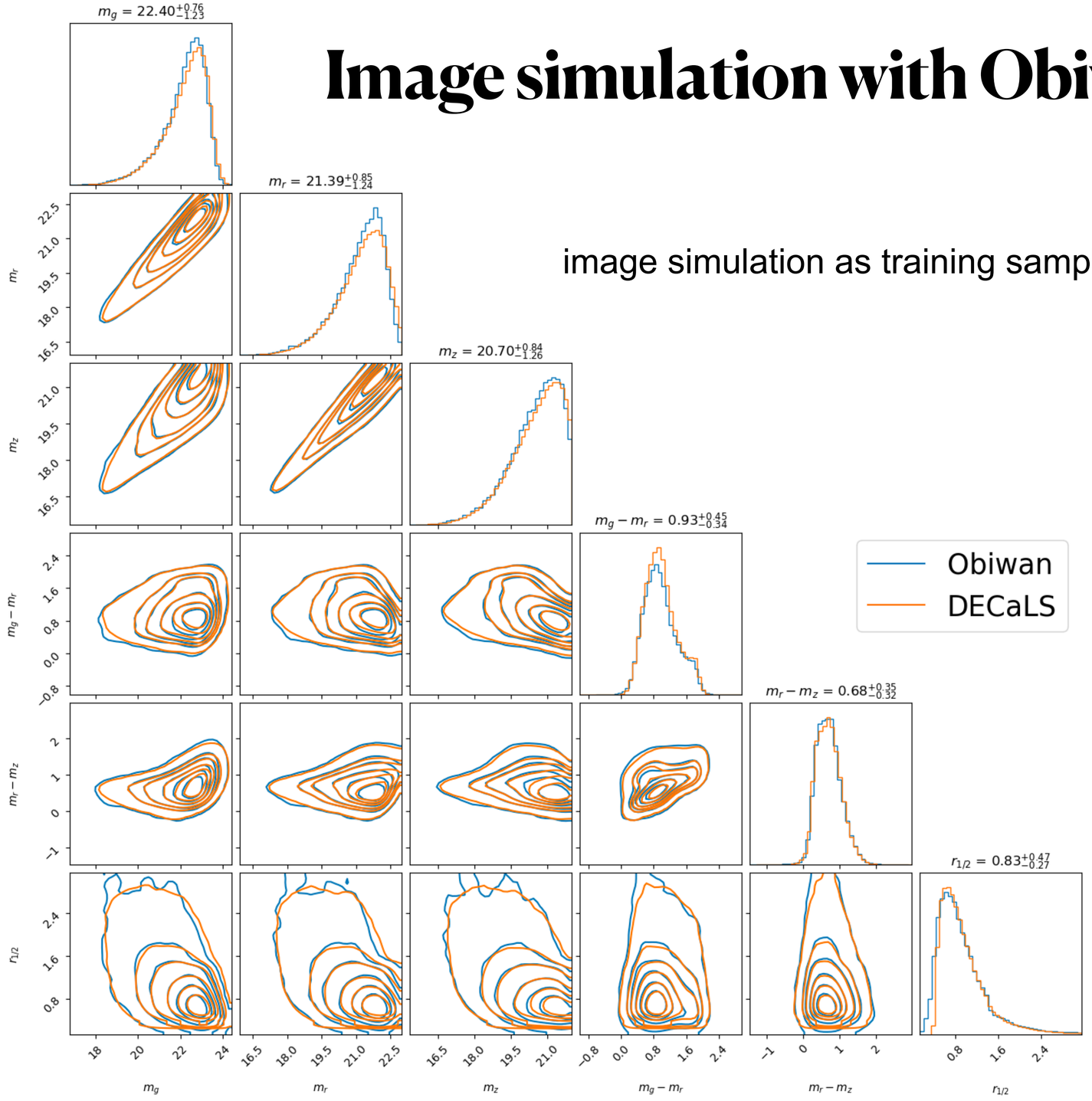
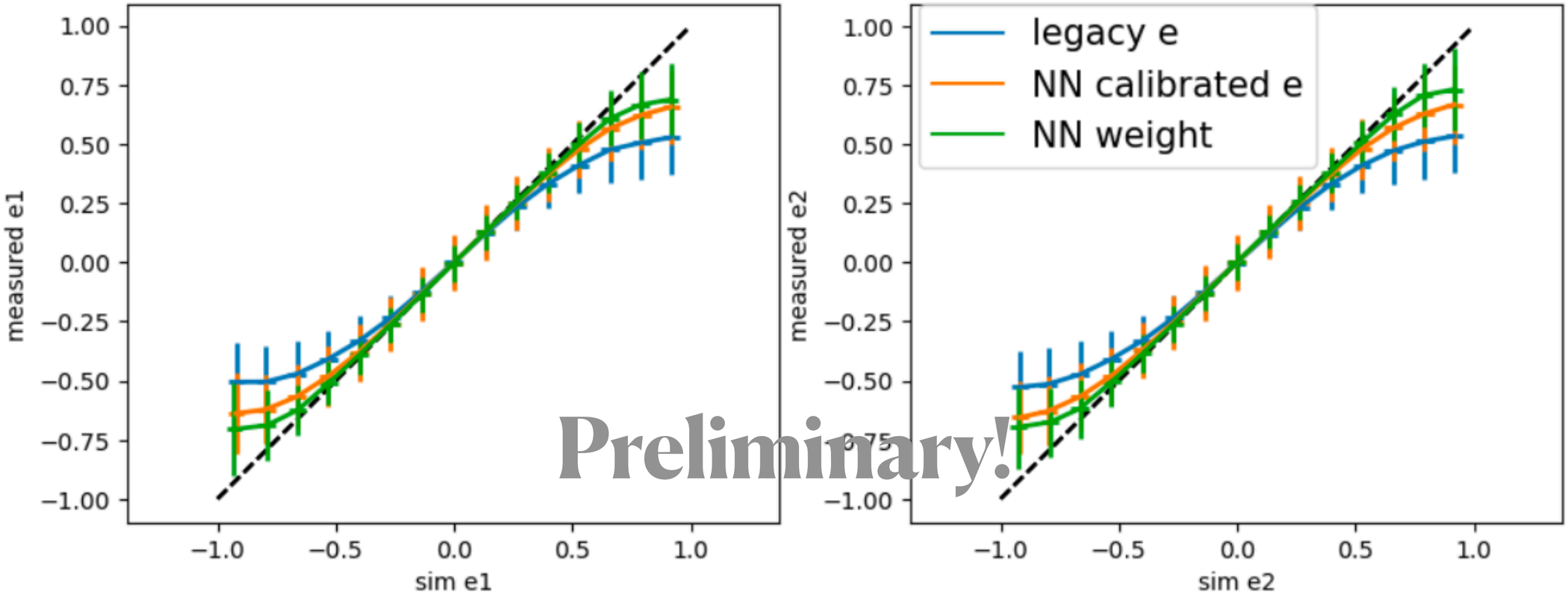


image simulation as training sample: 0.55 M galaxies

Obiwan:
Hui Kong
Huanyuan Shan
Eric Jullo
Marie-Claude Cousinou

A neural network based shear calibration

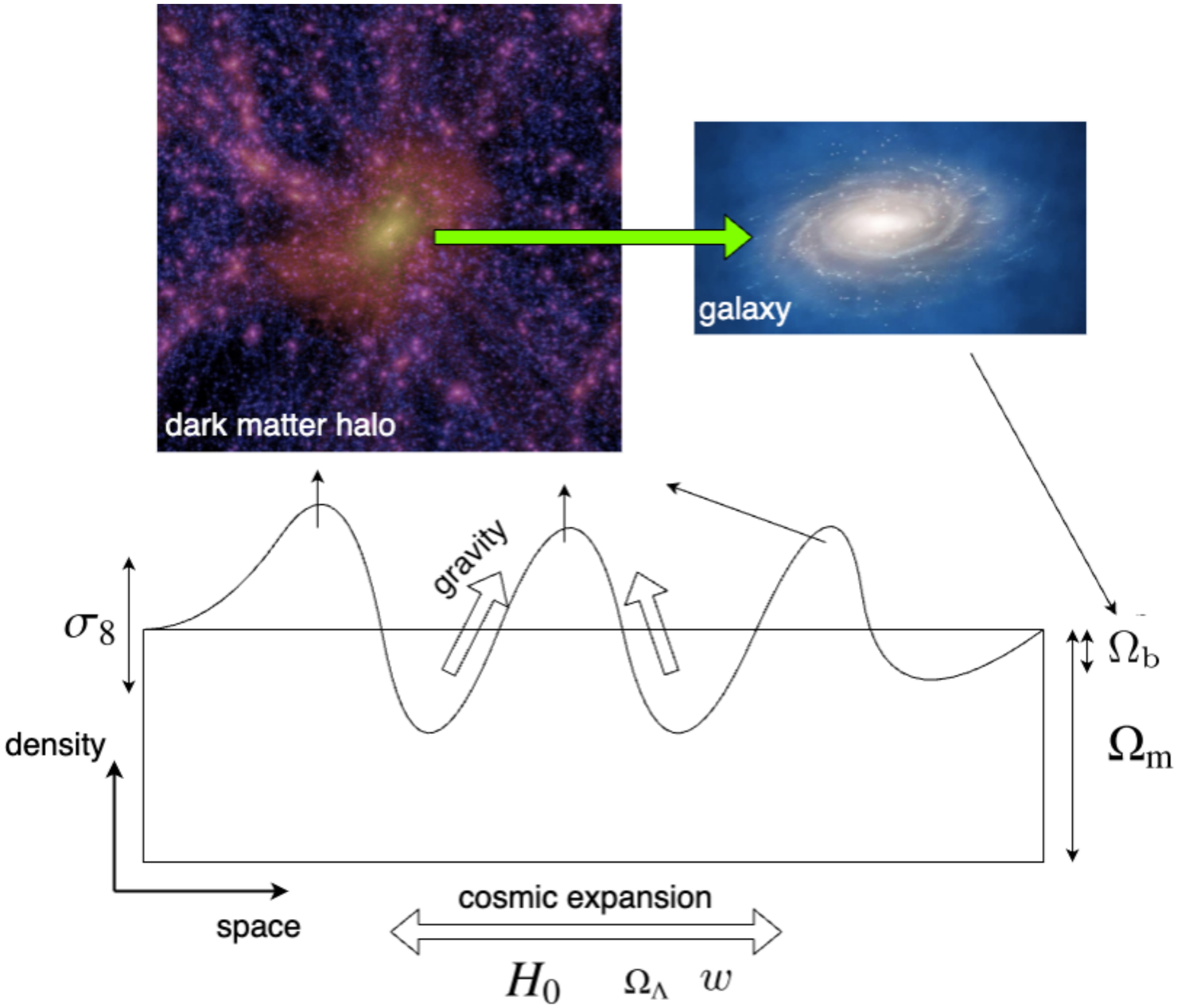


Preliminary!

Summary

- Forecast errors for stage IV (CSST)
- Independent measurement of IA with self-calibration (KiDS)
- Machine learning based shear/redshift calibration (DECaLS)

LCDM Cosmology - Large-scale structure - DM halo - Galaxy

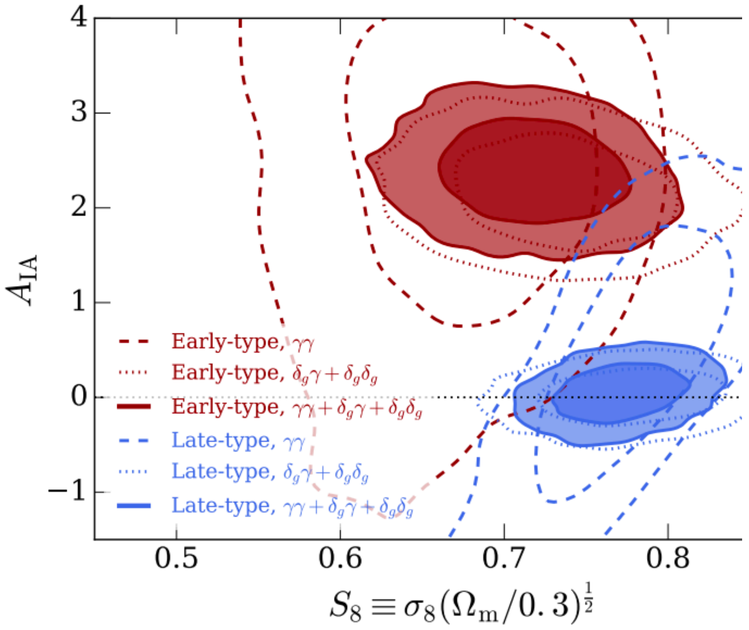


The intrinsic alignment (IA) complication

It is galaxy type-dependent

It could be redshift-dependent

We don't know a precise model



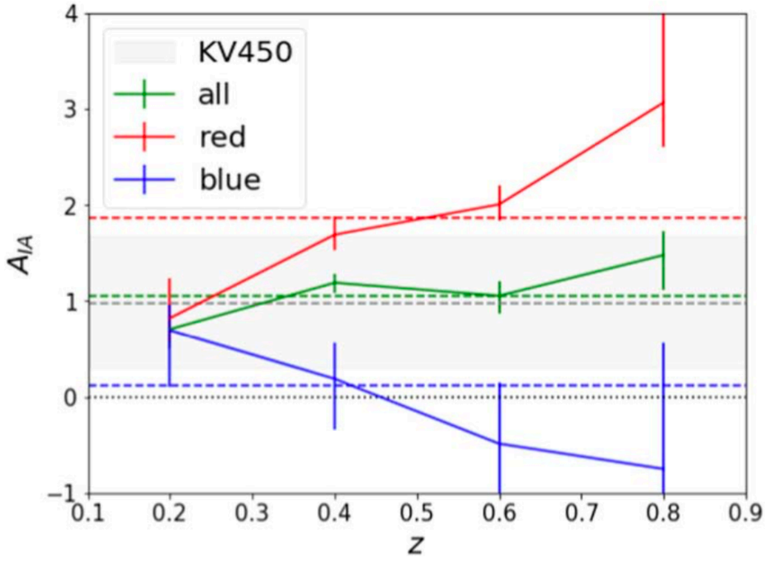
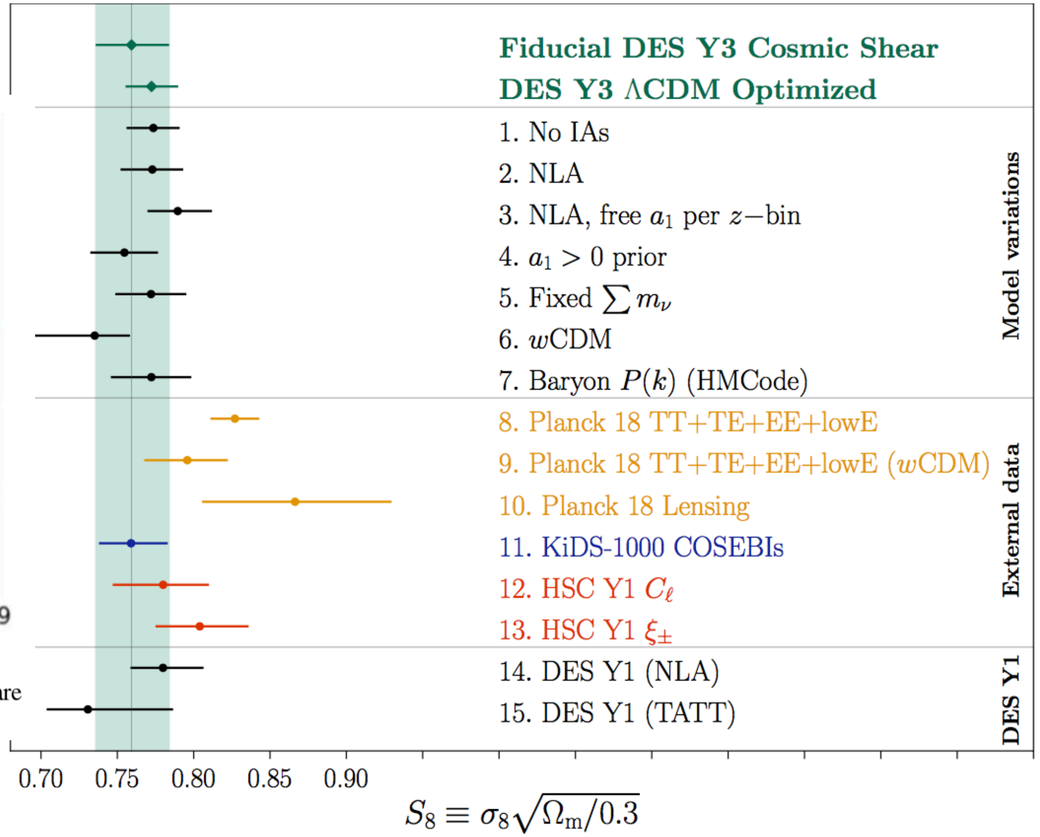


Figure 15. Color and redshift dependence of the best-fit $A_{\rm IA}$. Dashed lines are the best fit with the constant $A_{\rm IA}$ assumption.

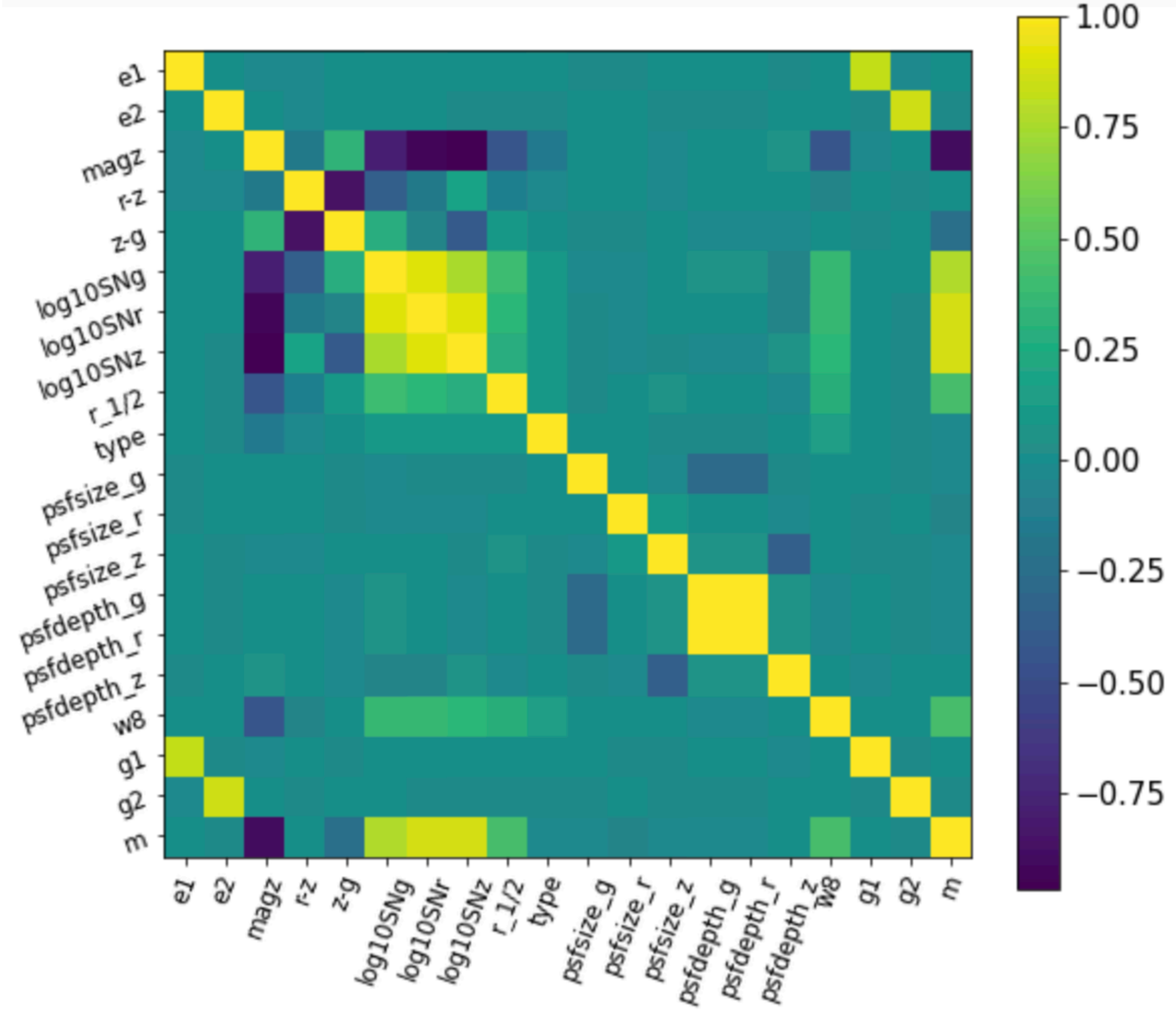


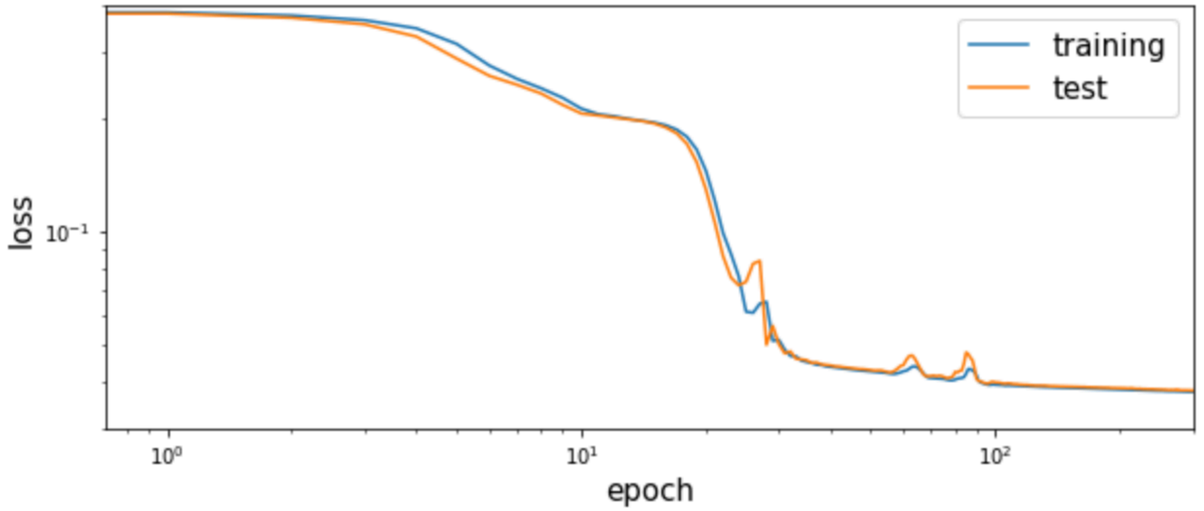
Samuroff+, 1811.06989

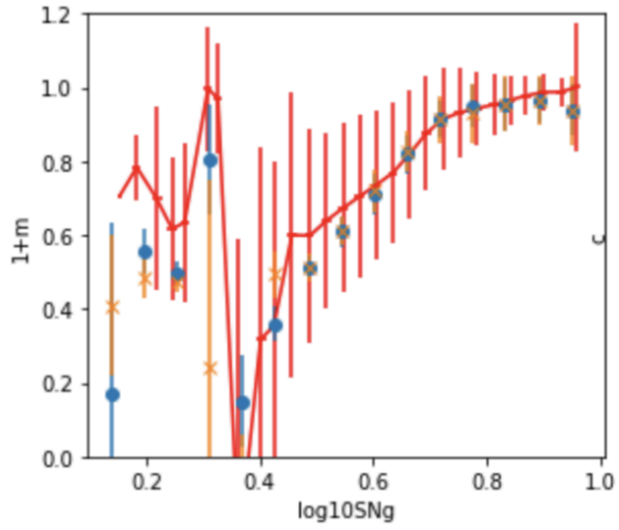
Yao+ 2002.09826

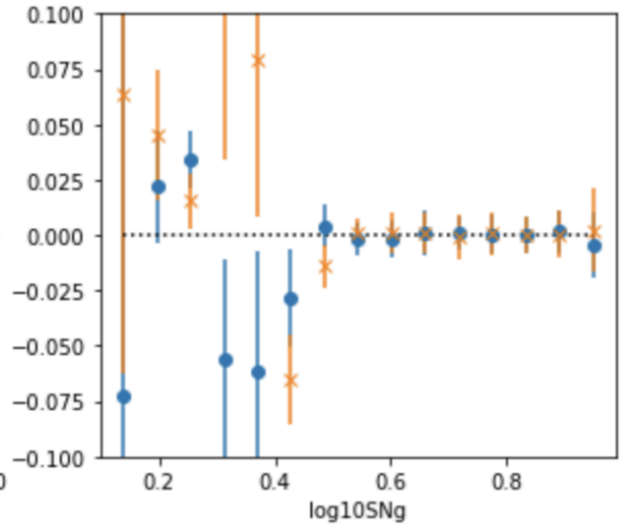
DES Y3 Secco+

3-step shear calibraiton: (1) neural network shape

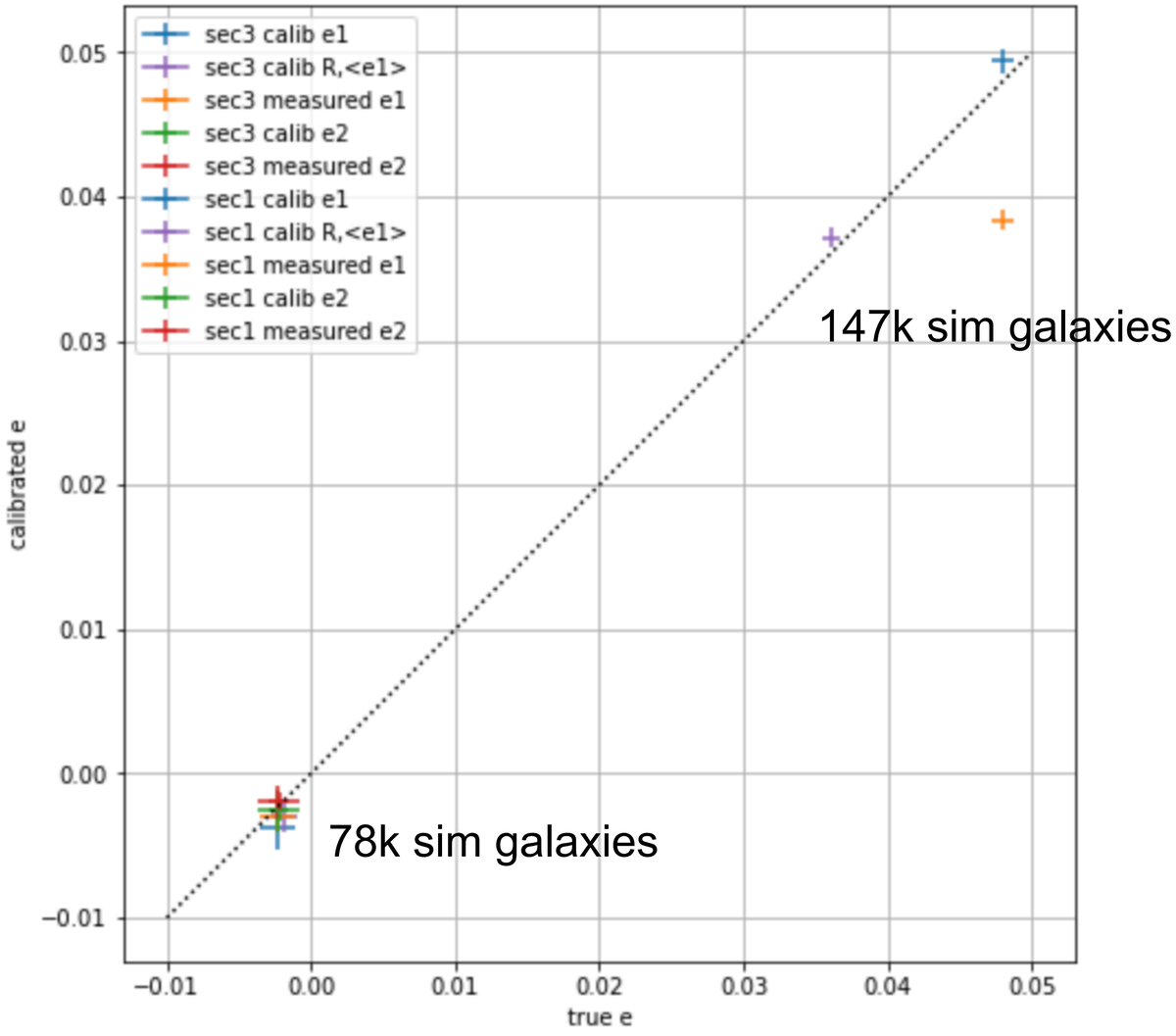


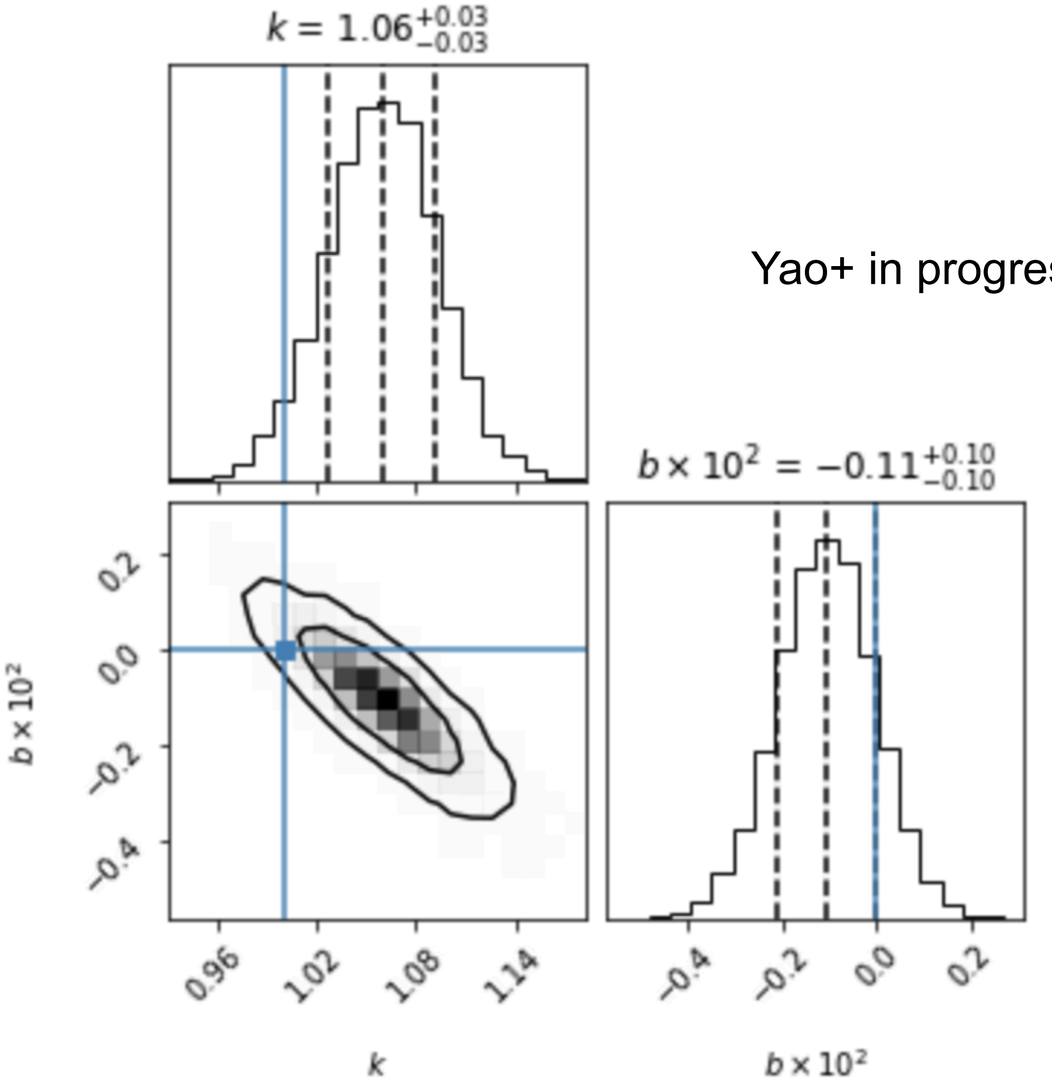






3-step shear calibration: (3) sample shear calibration

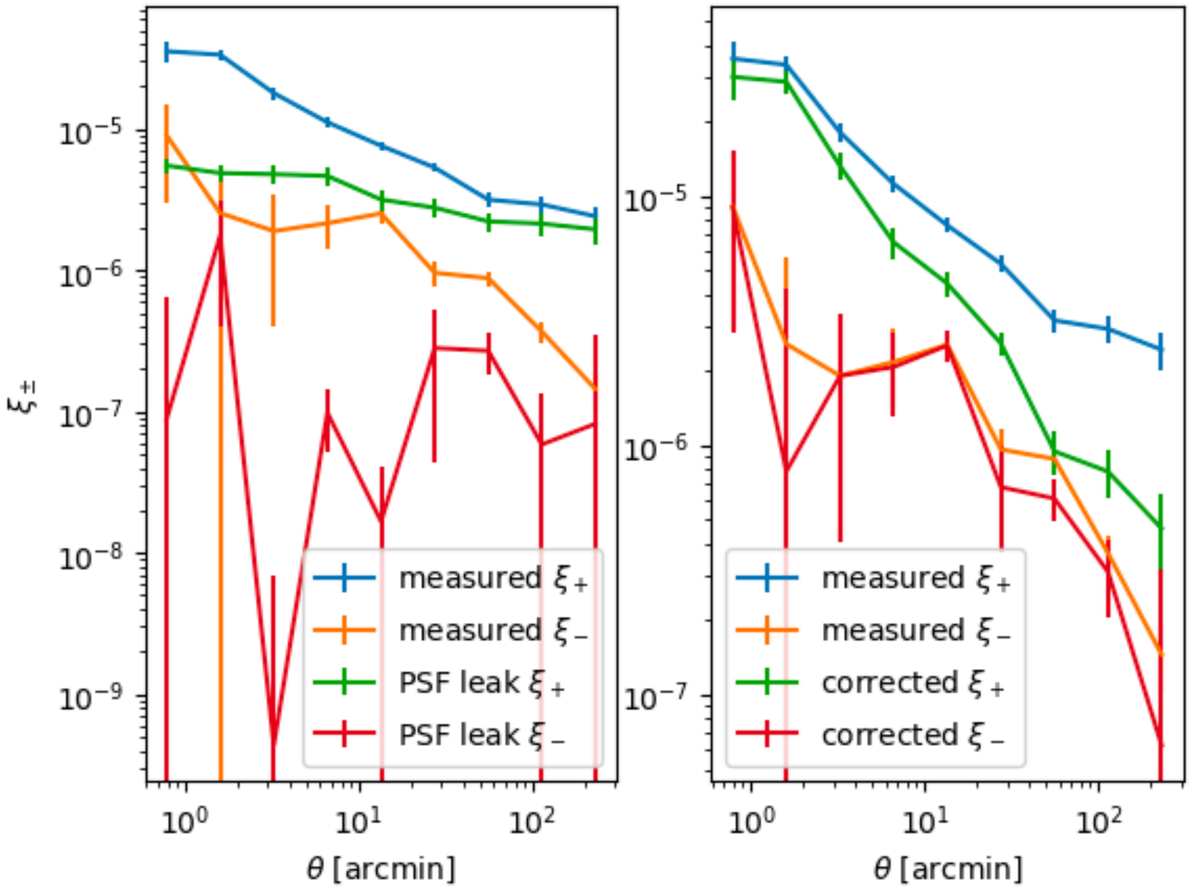


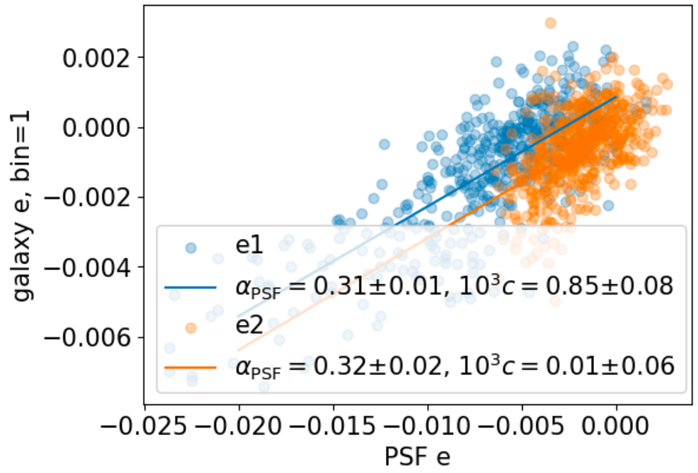


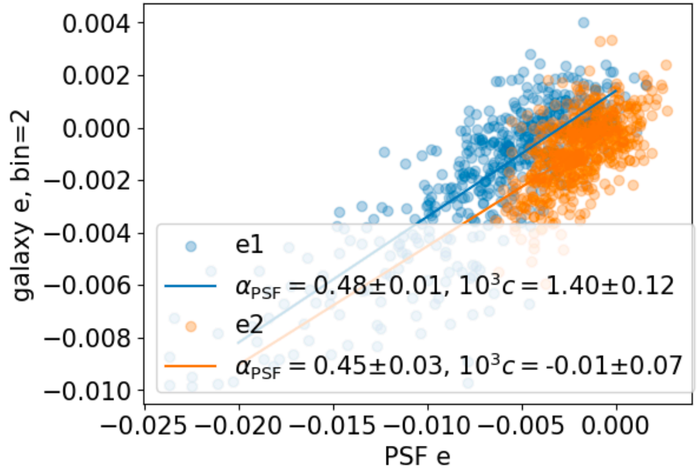
Yao+ in progress

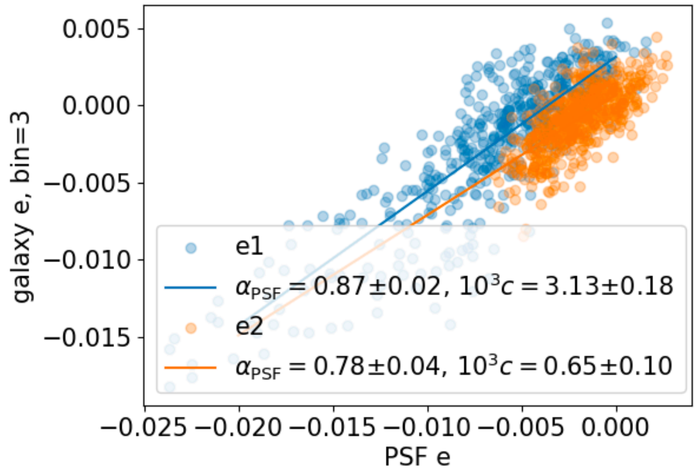
PSF problem

$$\epsilon^{\rm obs} = (1+m)(\epsilon^{\rm int} + \gamma) + \alpha\epsilon^{\rm PSF} + \beta\delta\epsilon^{\rm PSF} + c$$

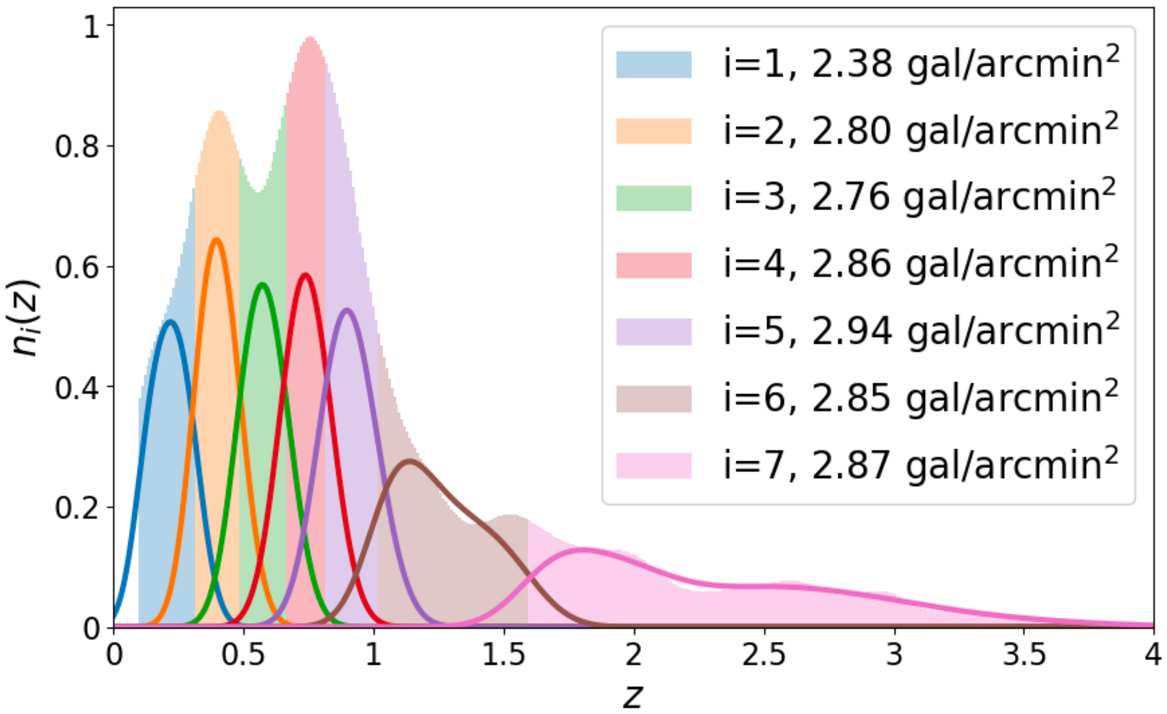




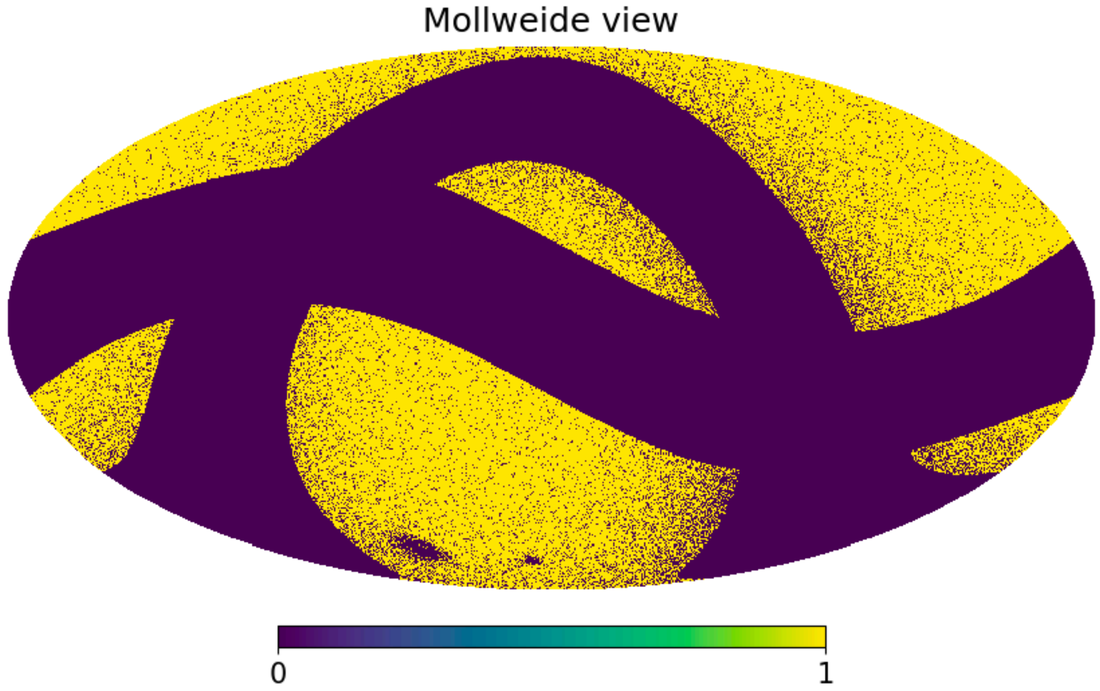




CSST forecast



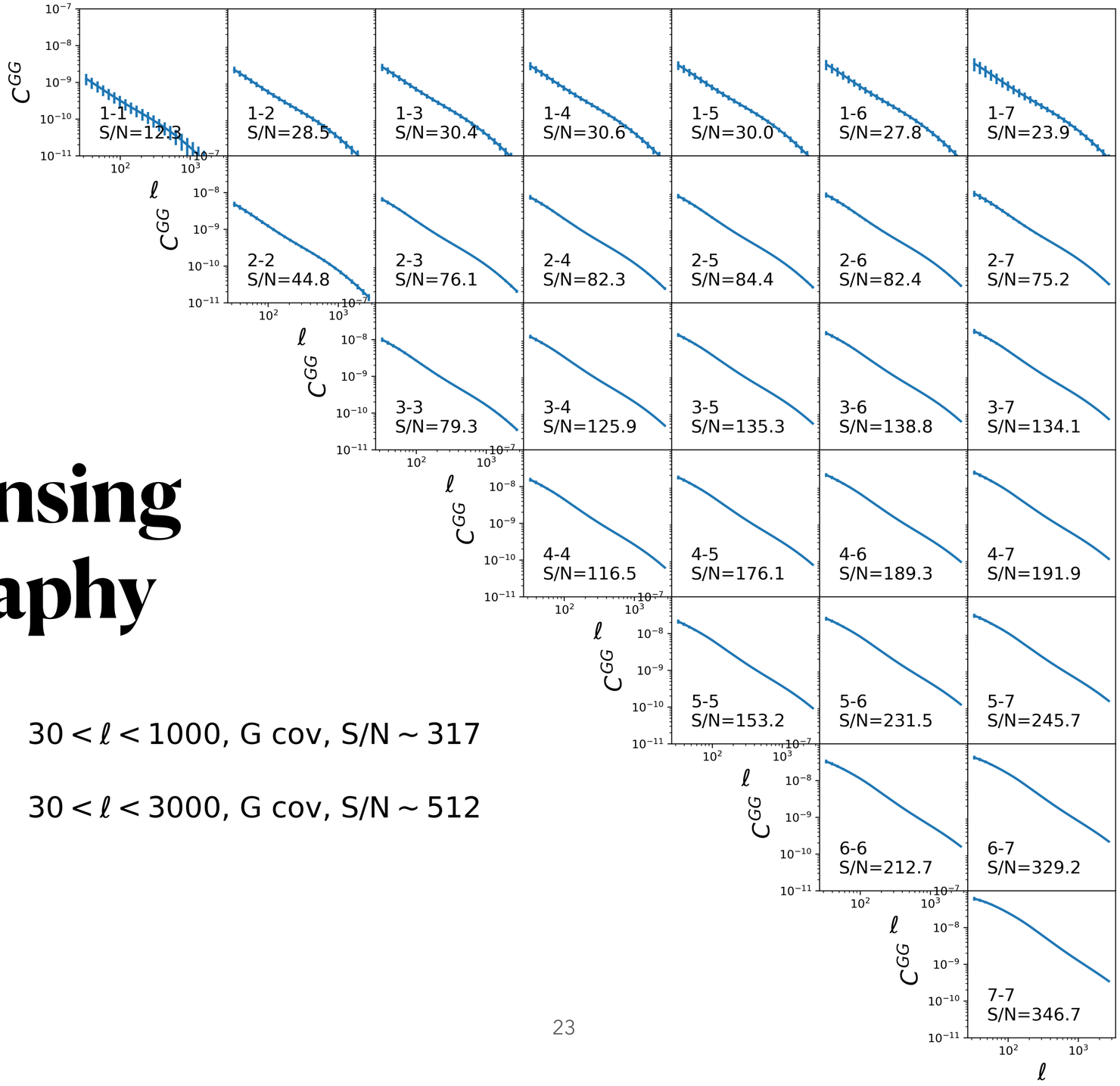
Galaxy number density 20 gal/arcmin^2



Remove bright galaxies/stars
Area 17500 deg^2 => ~15000 deg^2

Notice: both numbers can further decrease considering good shear/photo-z measurements, realistic blending, and masking!

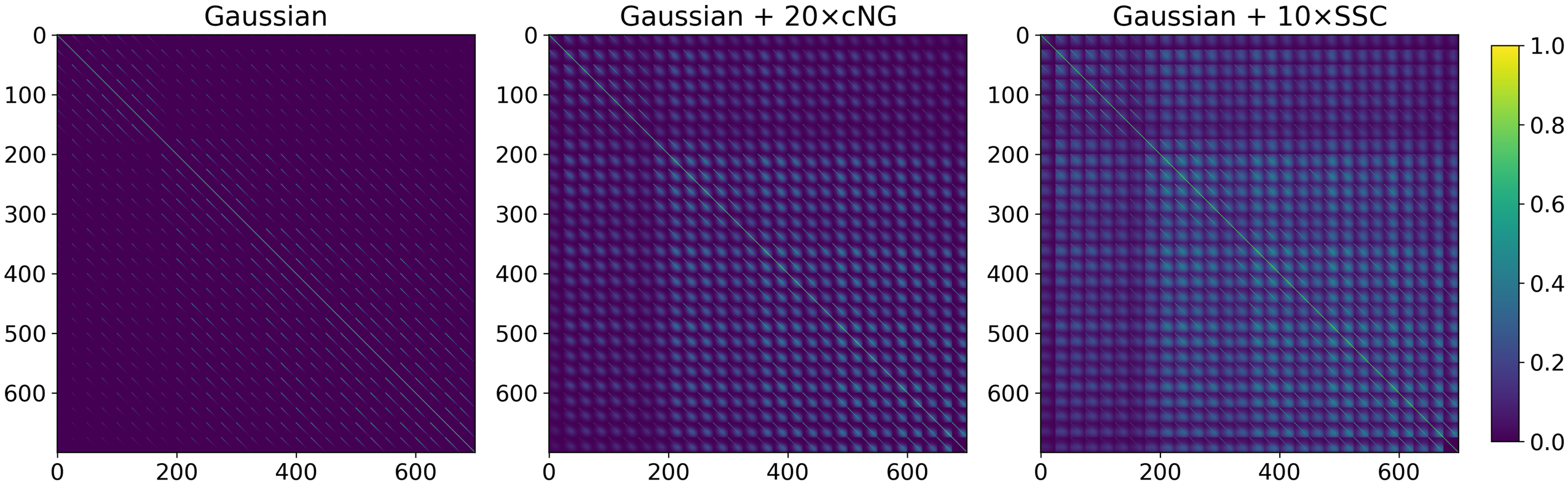
CSST lensing tomography



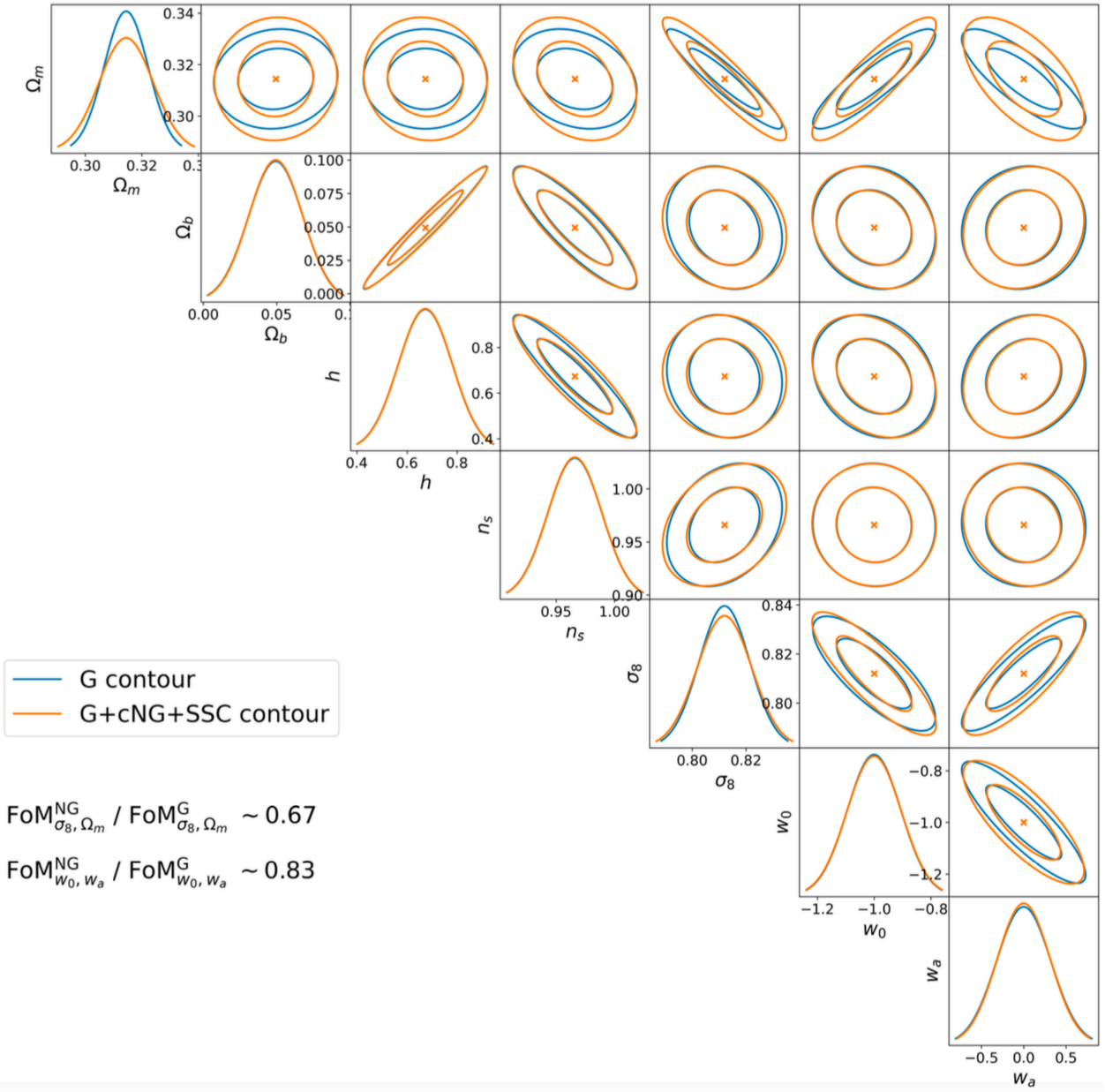
$30 < \ell < 1000$, G cov, S/N ~ 317

$30 < \ell < 3000$, G cov, S/N ~ 512

The non-Gaussian Covariances



Forecast for CSST



$\mathrm{FoM}^{\mathrm{NG}}_{\sigma_8,\Omega_m}$ / $\mathrm{FoM}^{\mathrm{G}}_{\sigma_8,\Omega_m}$ ~ 0.67

$\mathrm{FoM}^{\mathrm{NG}}_{w_0,w_a}$ / $\mathrm{FoM}^{\mathrm{G}}_{w_0,w_a}$ ~ 0.83