Towards precision cosmology
—— systematics removal with Stage III data

Ji Yao （姚骥） Shanghai Astronomical Observatory

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

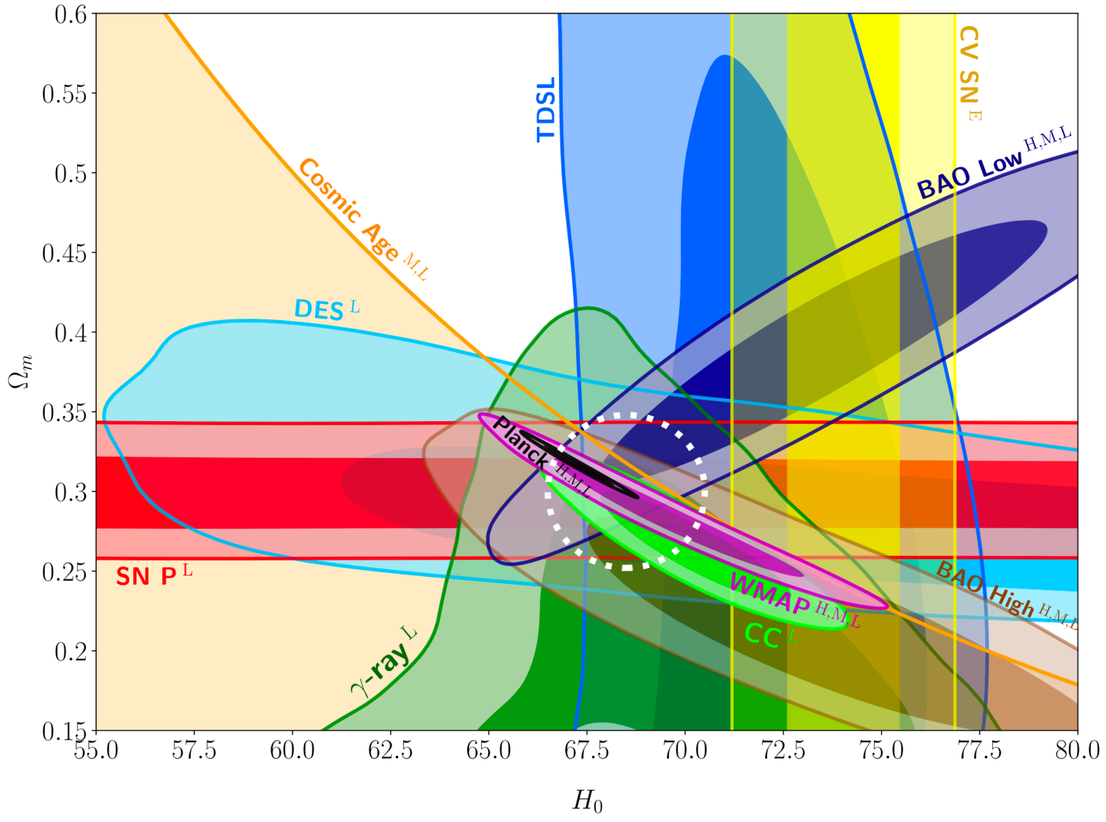
Outline

- Background: weak lensing cosmolog
- Systematics
  - Intrinsic alignment
  - Shear bias
  - Redshift bias
- Forecast for CSST
  - Above and baryonic feedback

- Related data
  - KiDS-1000
  - DECaLS DR9
  - DESI 1% (part of EDR)

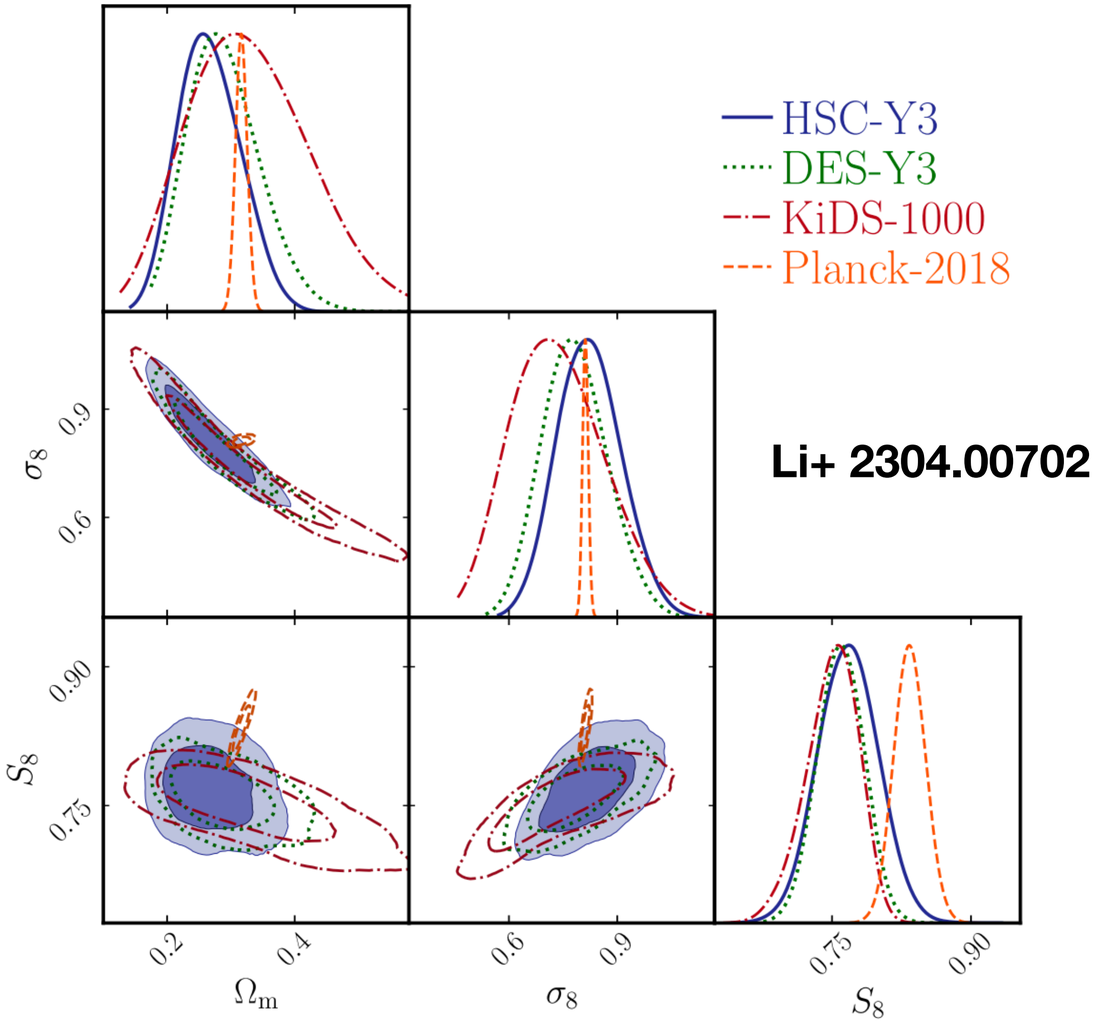
Modern observational cosmology —— 2 tensions

Expansion history



Lin+ 1910.02978

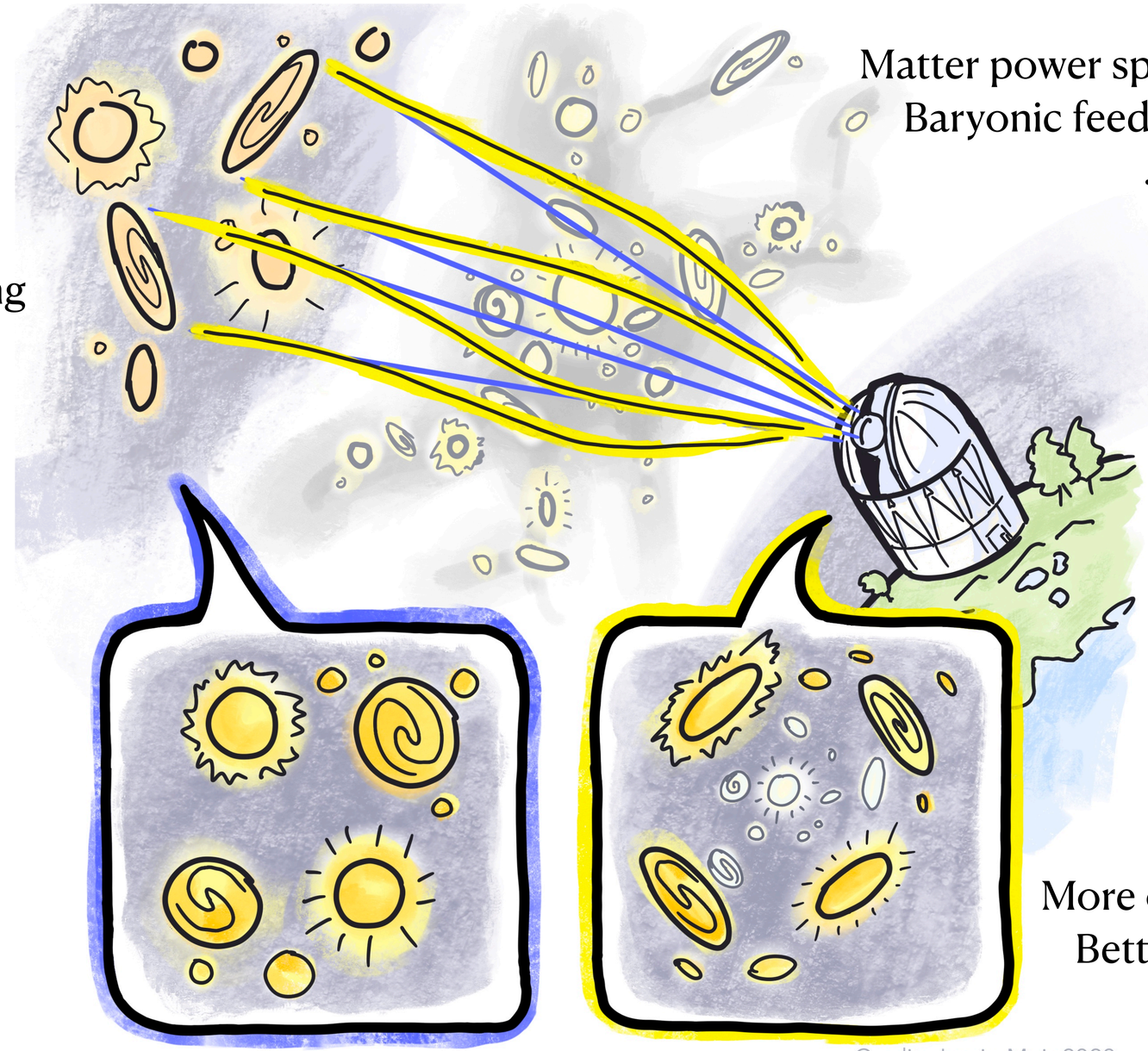
Large-scale structure



Li+ 2304.00702

What can go wrong in weak lensing cosmology?

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



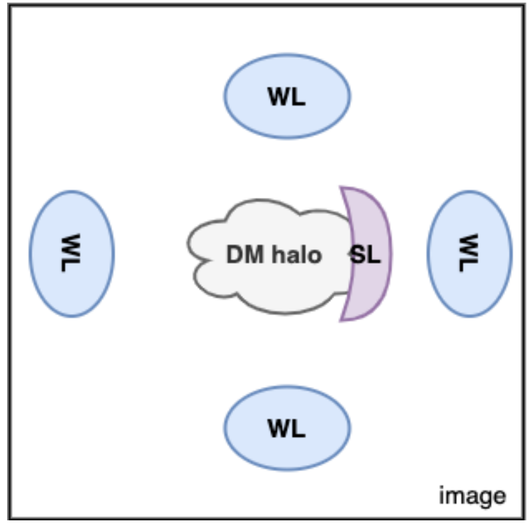
Matter power spectrum modeling
Baryonic feedback modeling
...

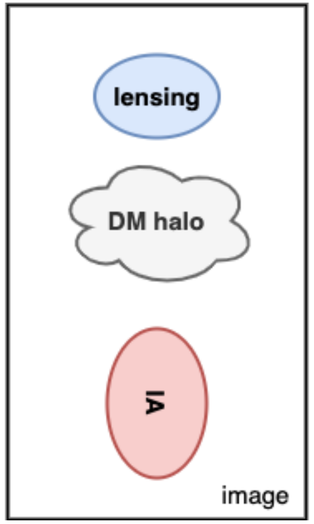
PSF modeling/deconvolution
Detecter effects
...
Covariances
Priors
...

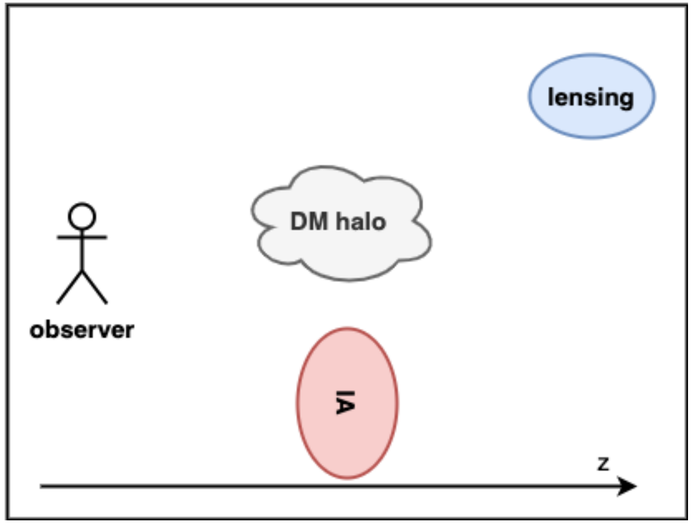
We need:
More observations: cross-checking
Better methods for systematics

Credit: Jessie Muir 2020

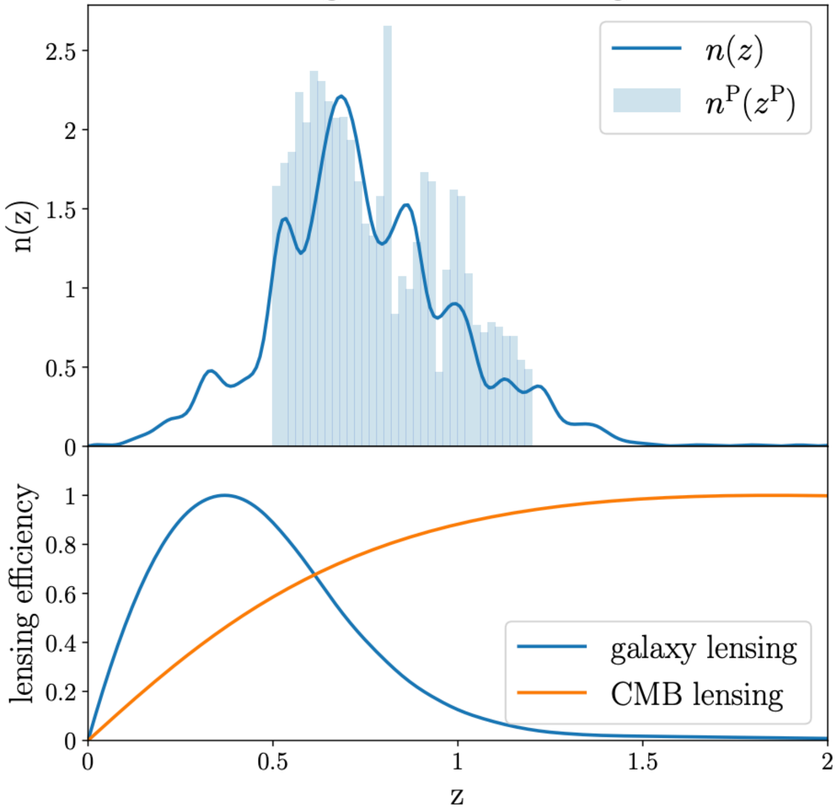
Lensing v.s. IA: different z-dependency



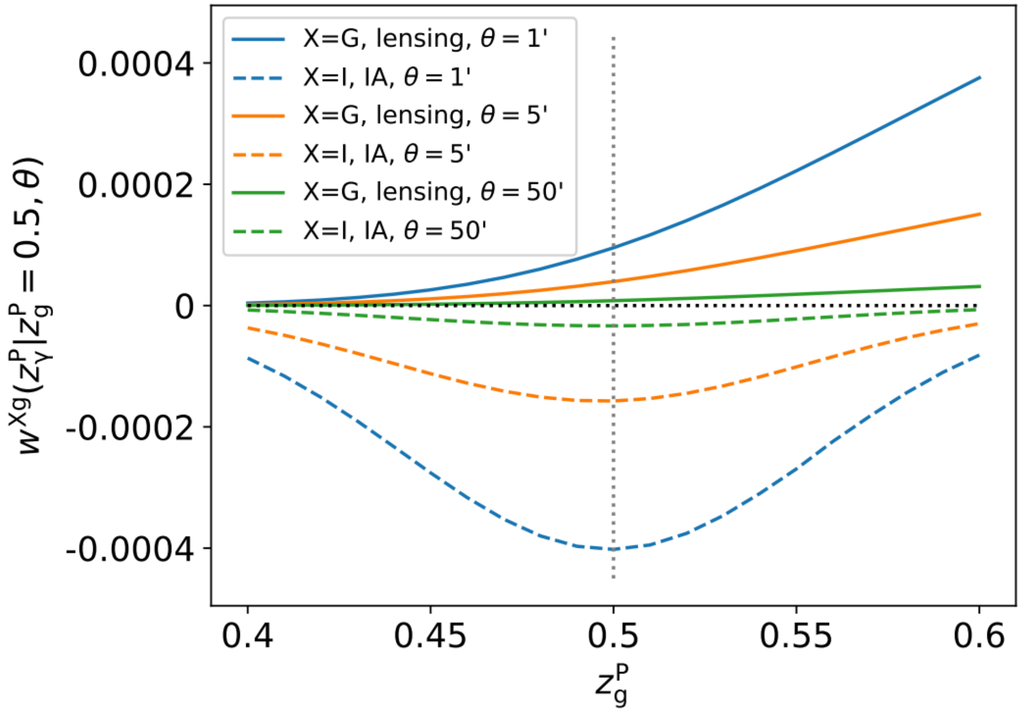




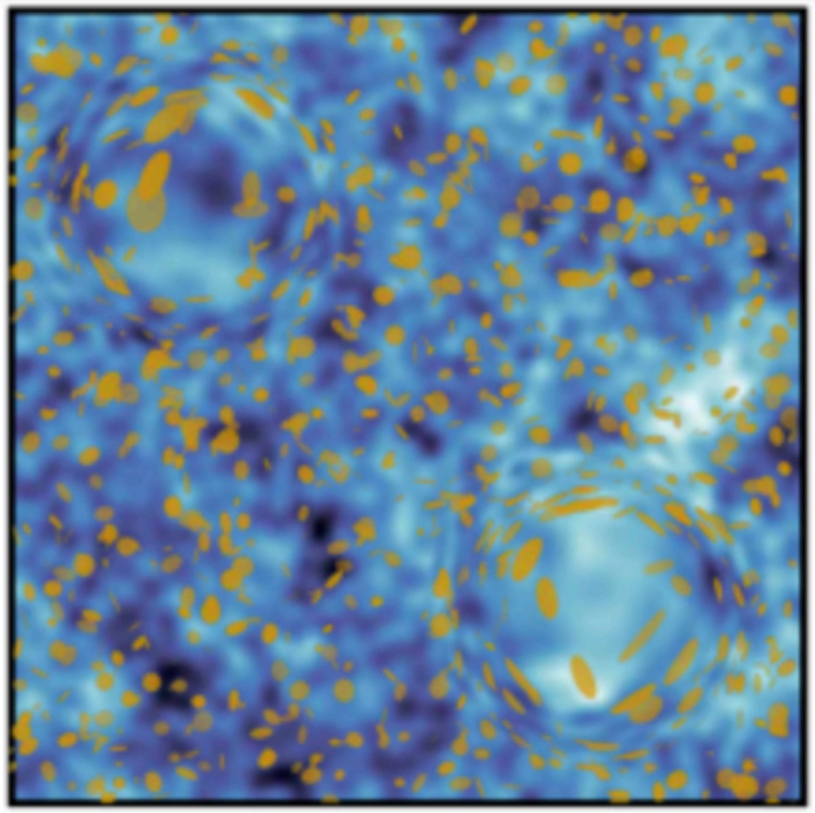
choose KiDS high-z data as light source



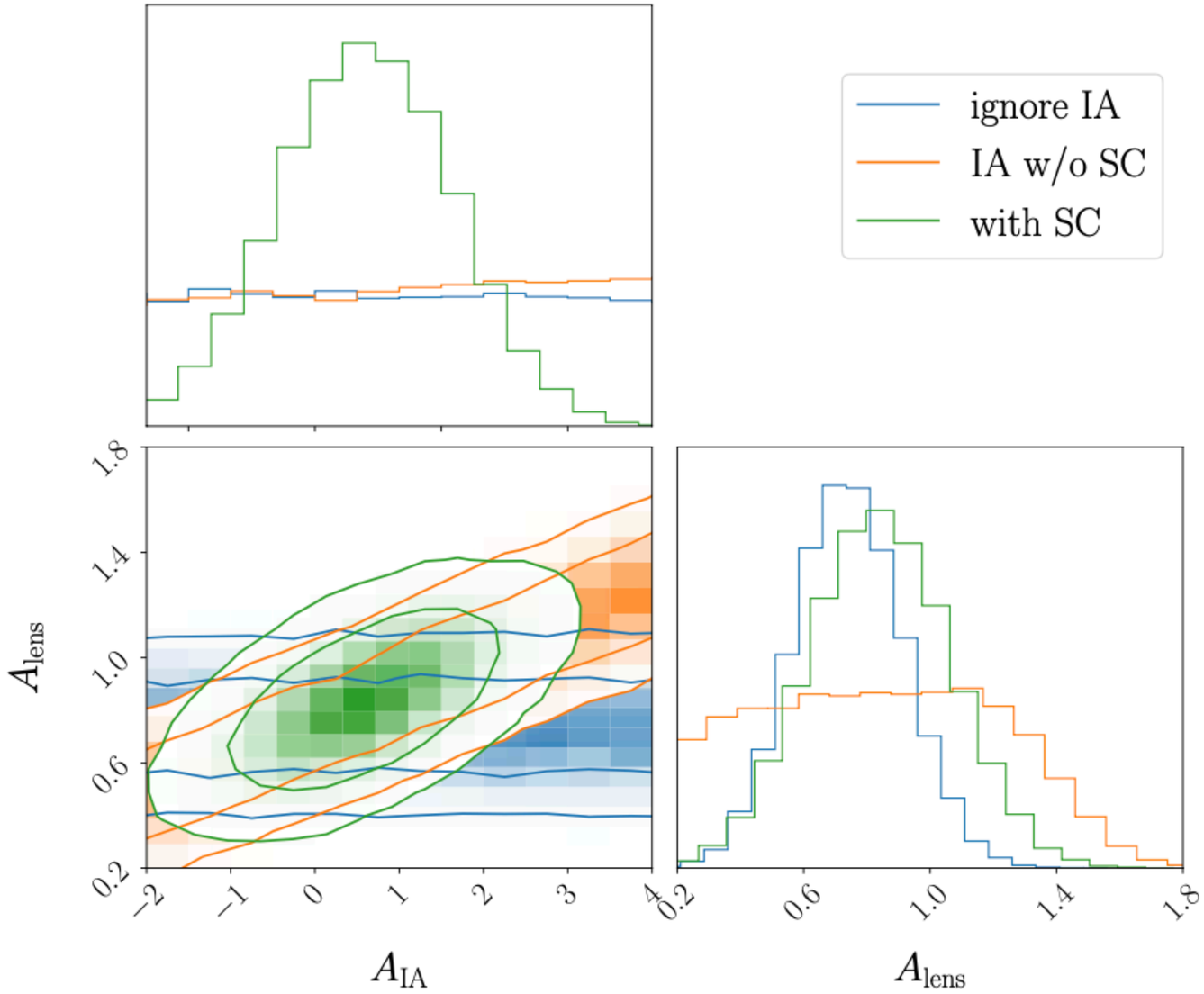
Fix lens-matter



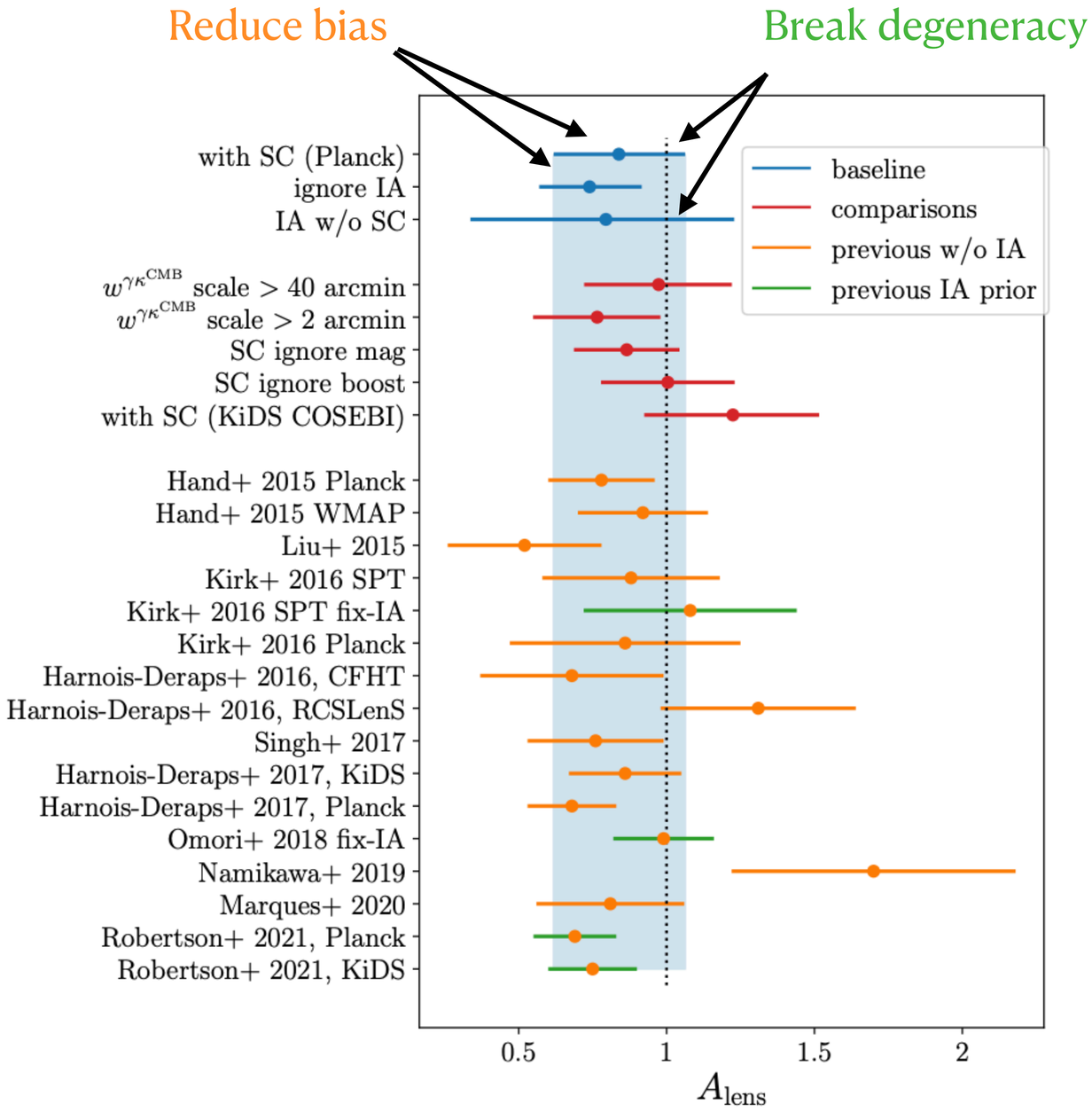
Benefits of using IA self-calibration in CMB lensing



CMB LENSING
X
GALAXY SHEAR

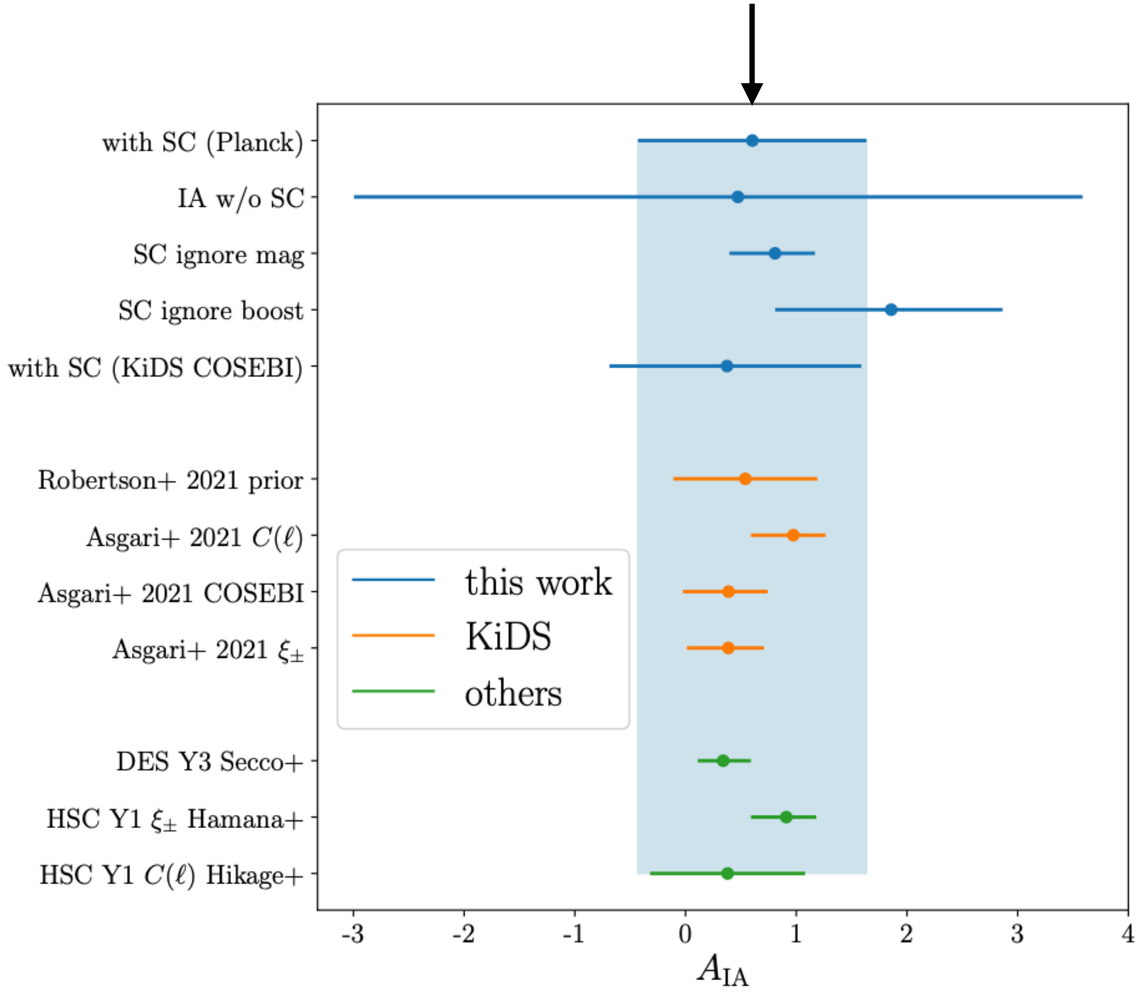


Comparisons

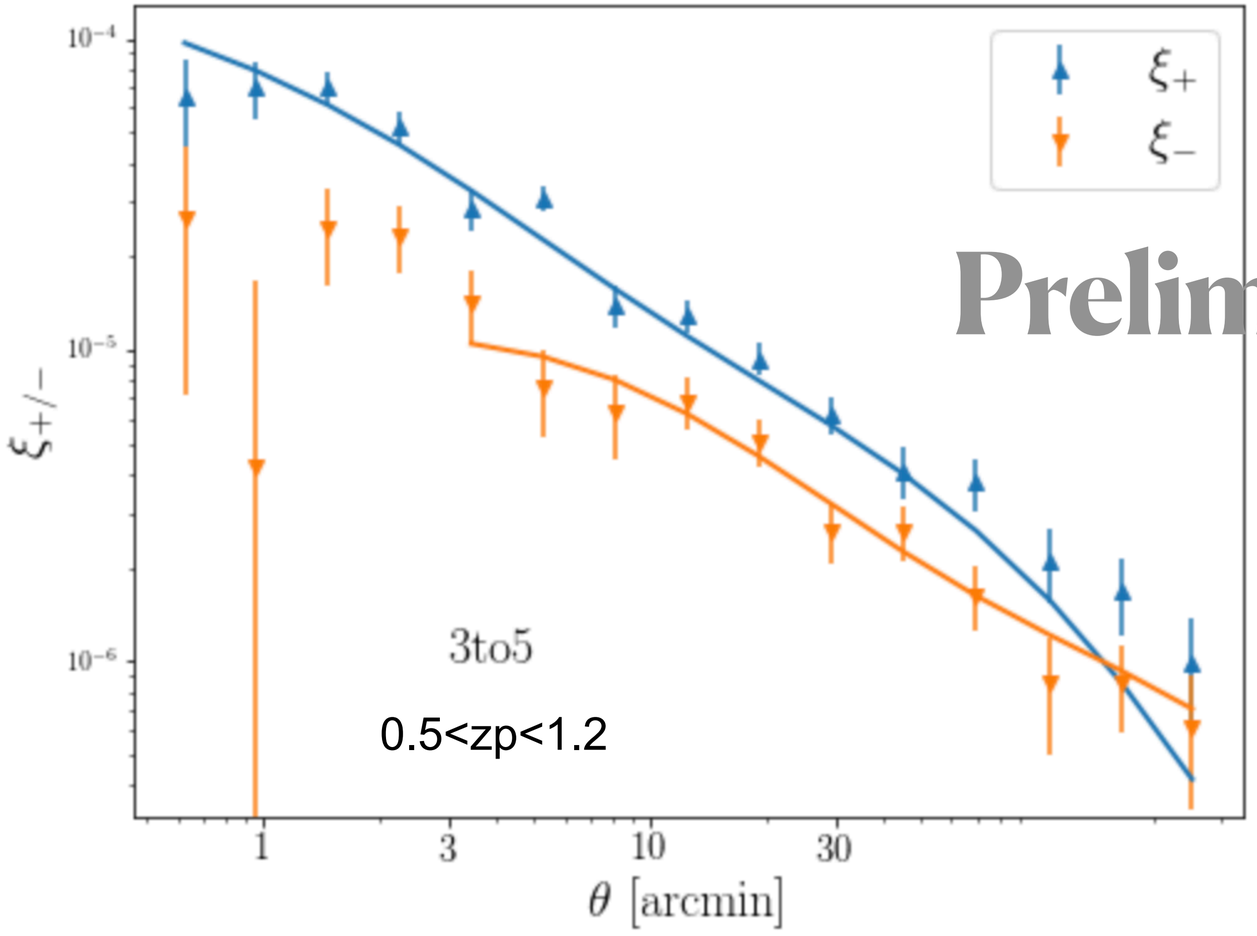


Yao+ 2301.13437

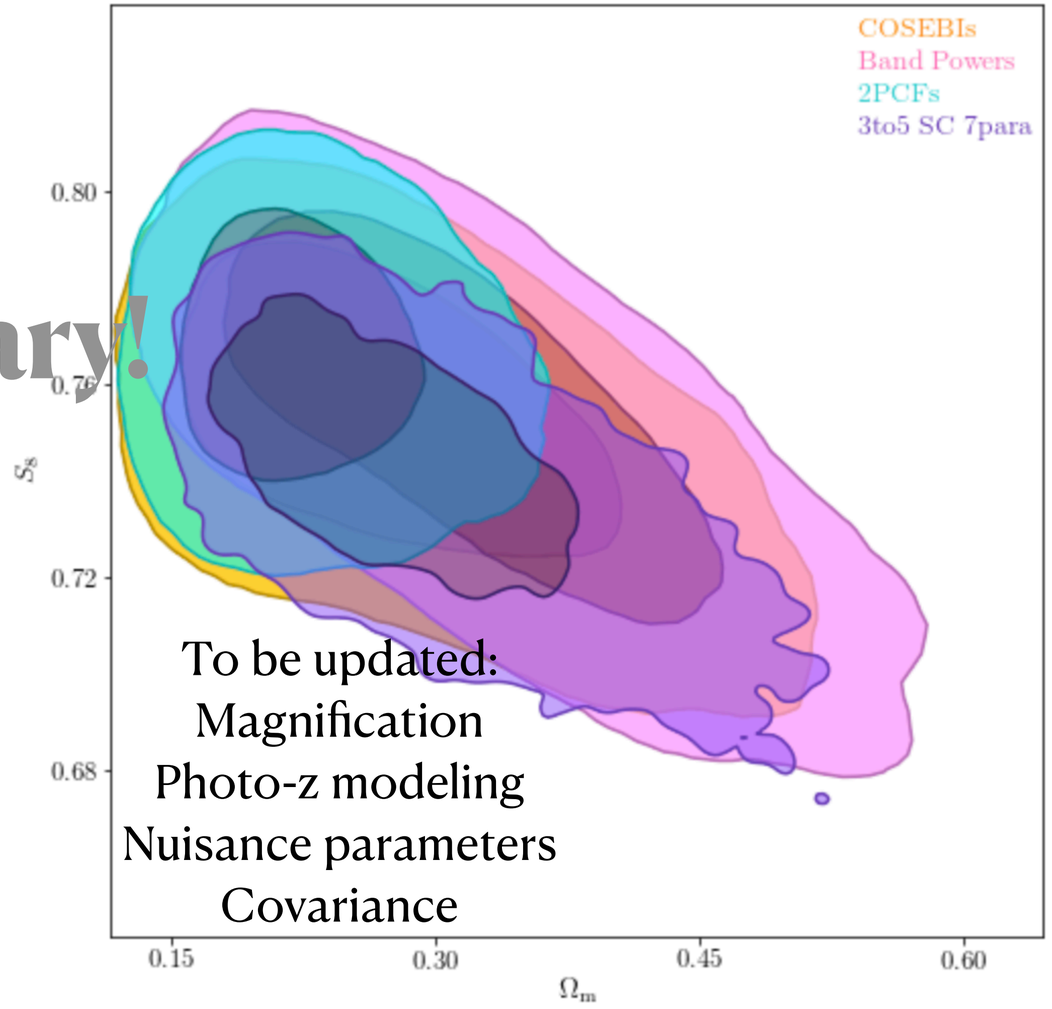
Independent measurement: more info



Apply SC to cosmic shear —— no need for tomography



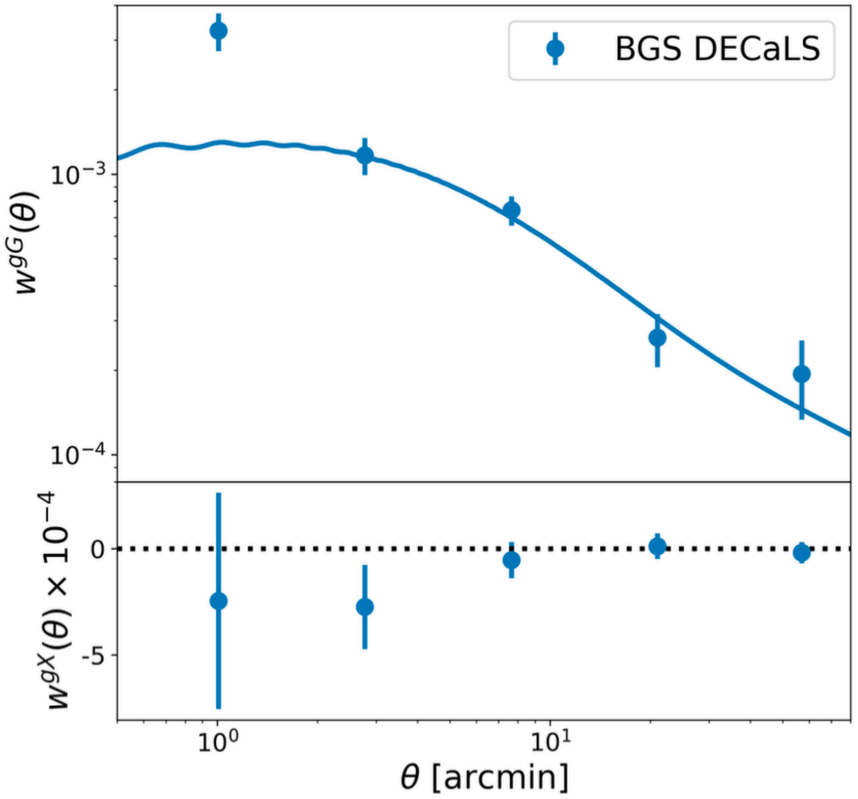
Preliminary!



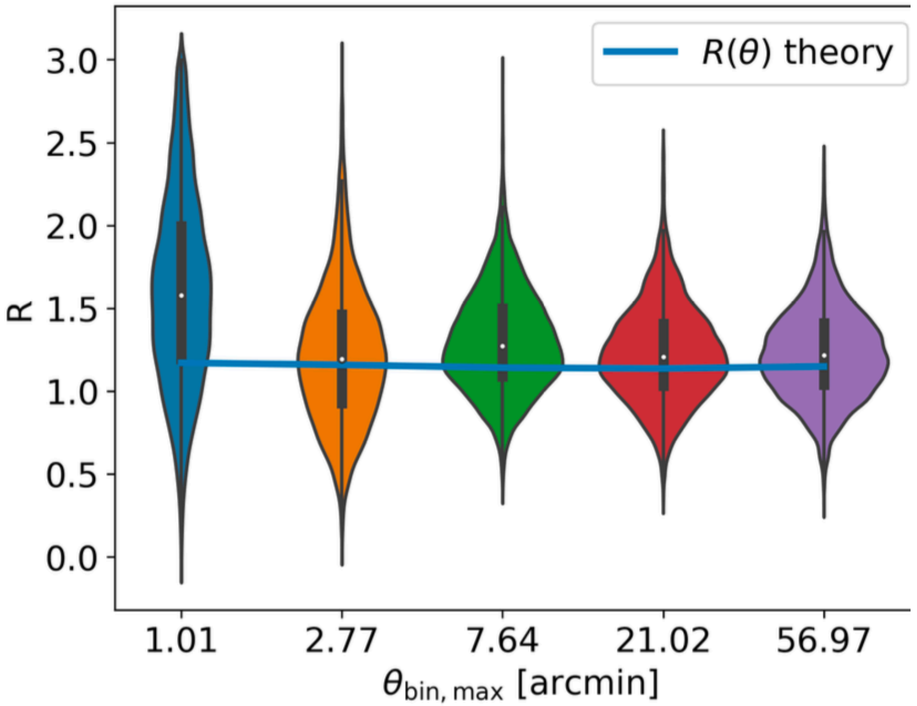
To be updated:
Magnification
Photo-z modeling
Nuisance parameters
Covariance

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

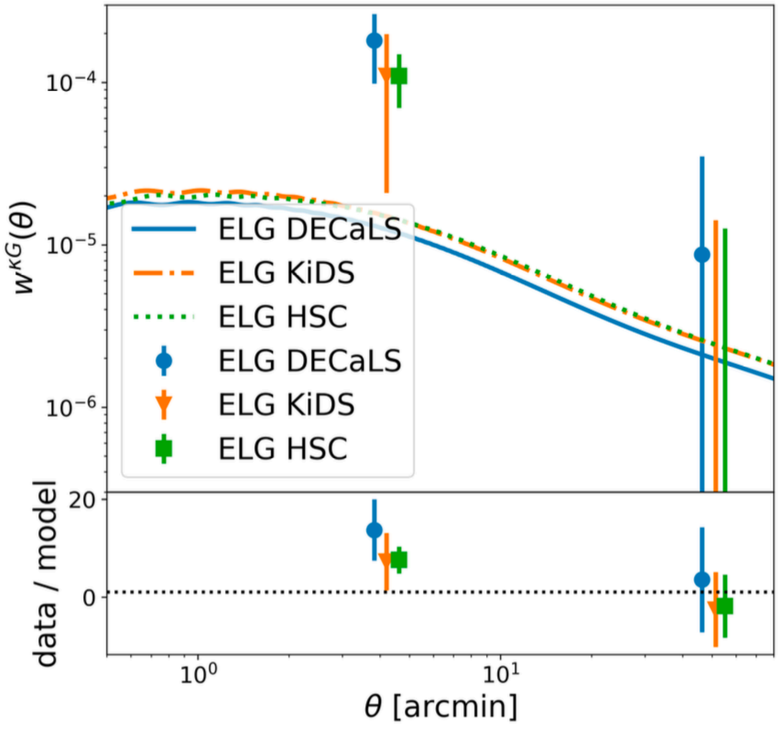
g-g lensing



Shear ratio



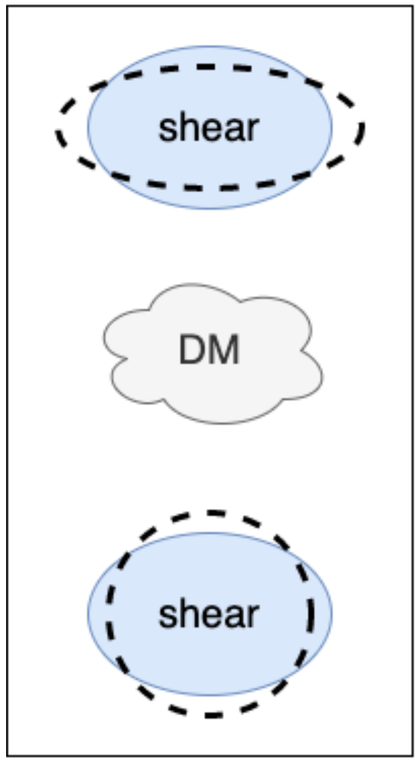
Magnification

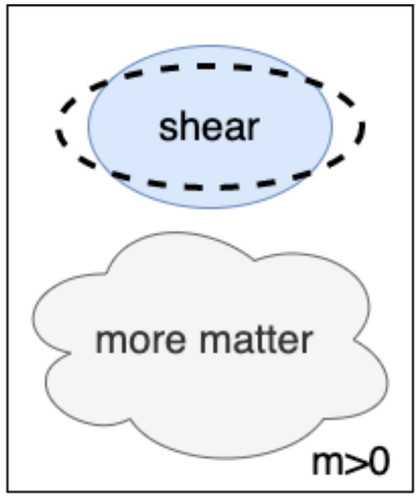


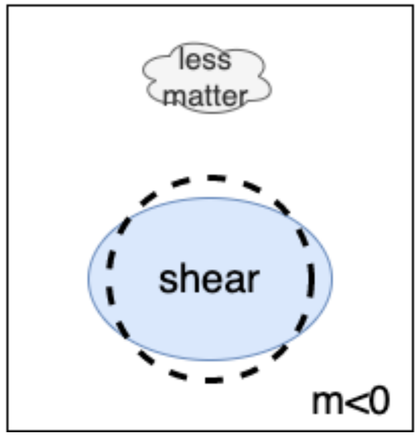
The large overlap is the best advantage for DECaLS before Stage IV!

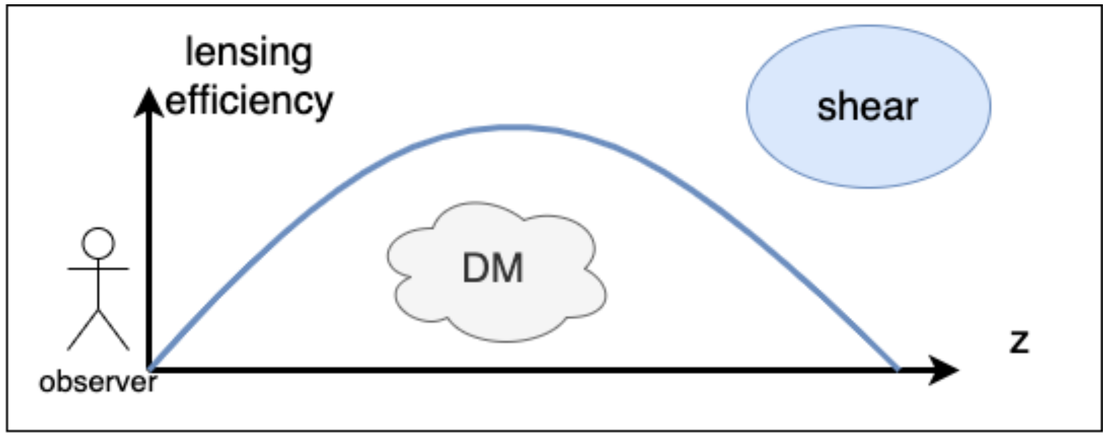
Yao+ 2301.13434

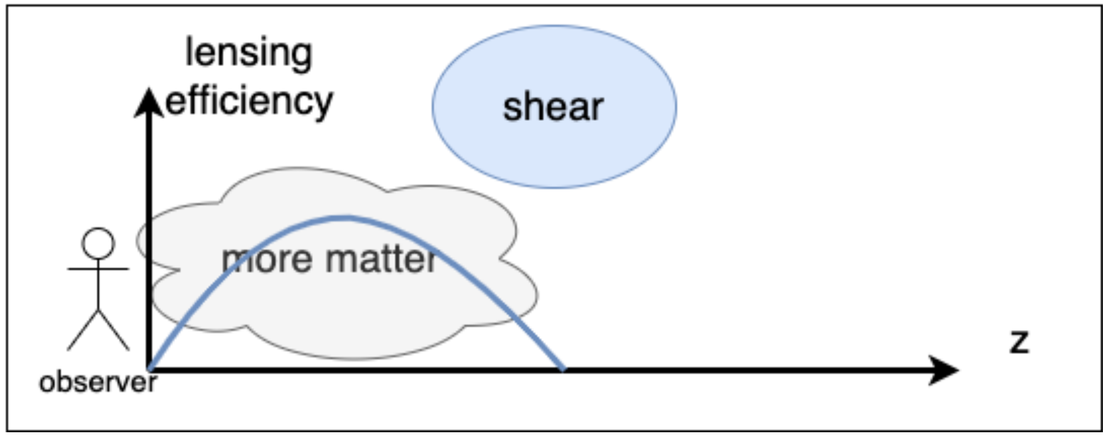
How shear bias and z bias work











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

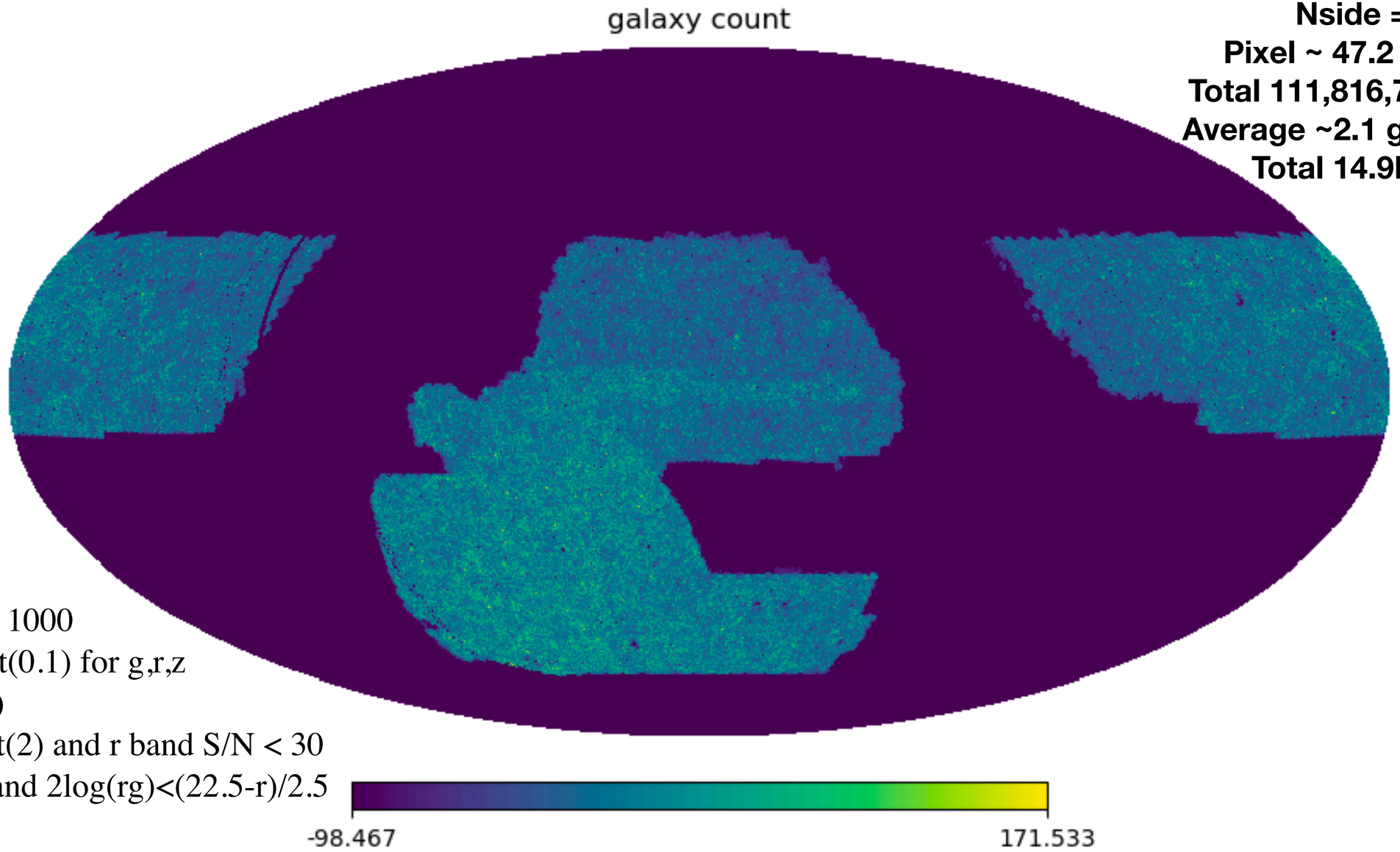
rg / psf_rg > sqrt(0.1) for g,r,z

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

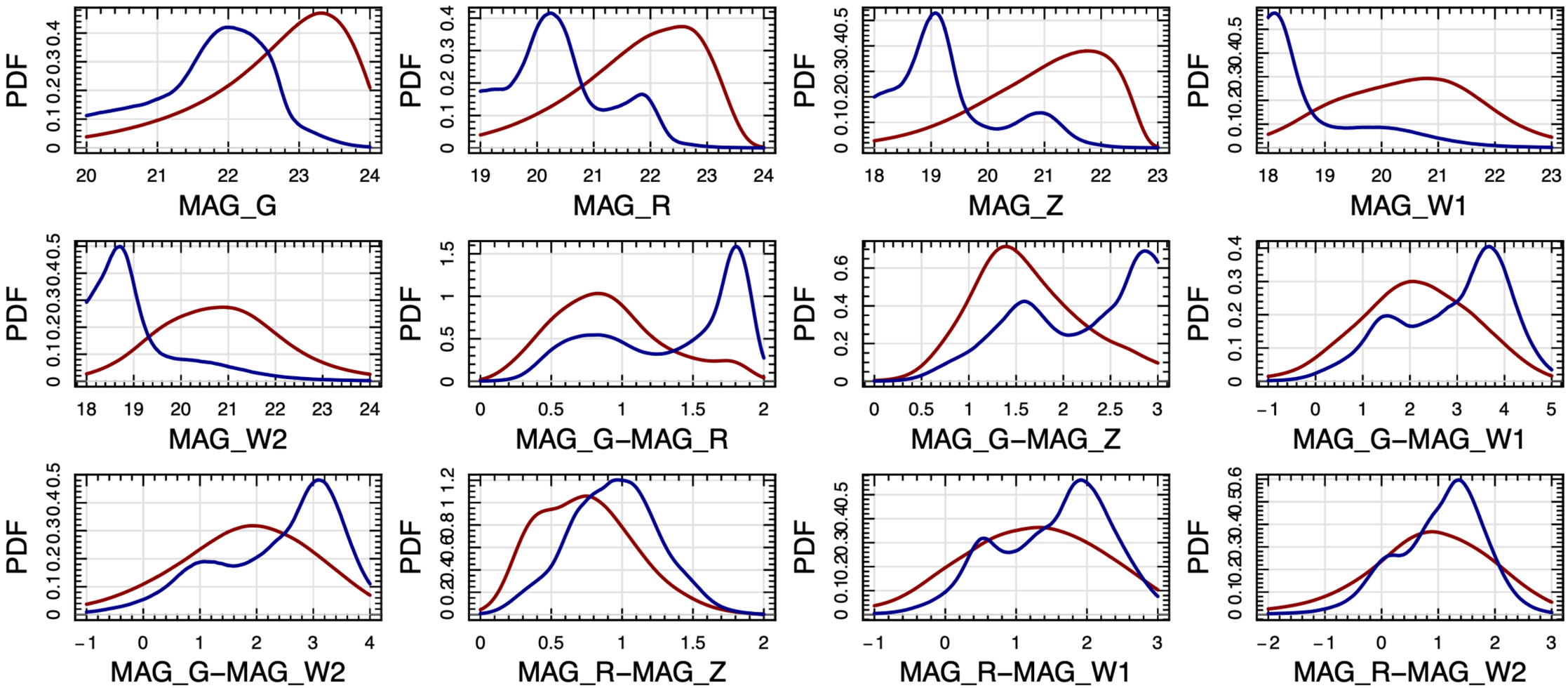
Pixel ~ 47.2 arcmin^2

Total 111,816,750 galaxies

Average ~2.1 gal/arcmin^2

Total 14.9k deg^2

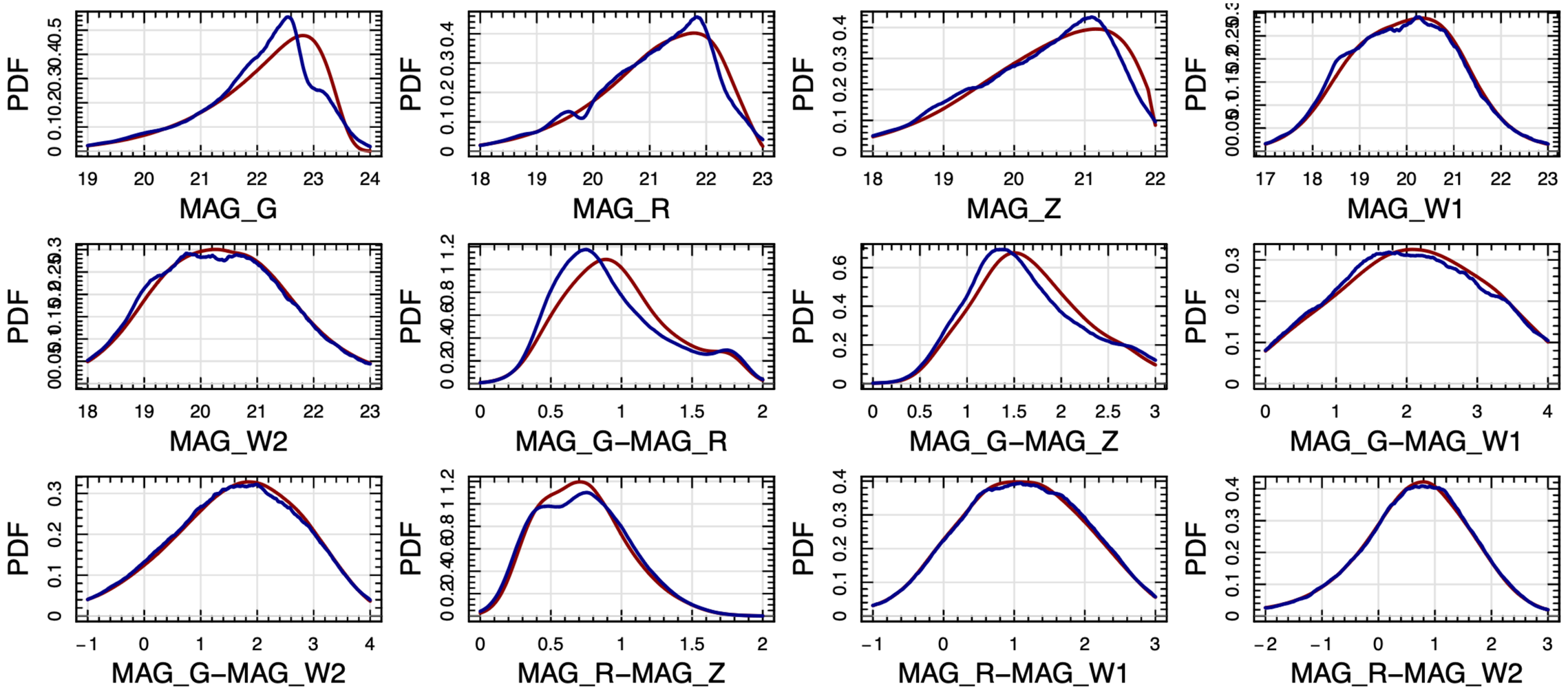
spec-z sample & photo-z sample



Red: distribution of photometric galaxies

Blue: distribution of spectroscopic galaxies without SOM weight

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

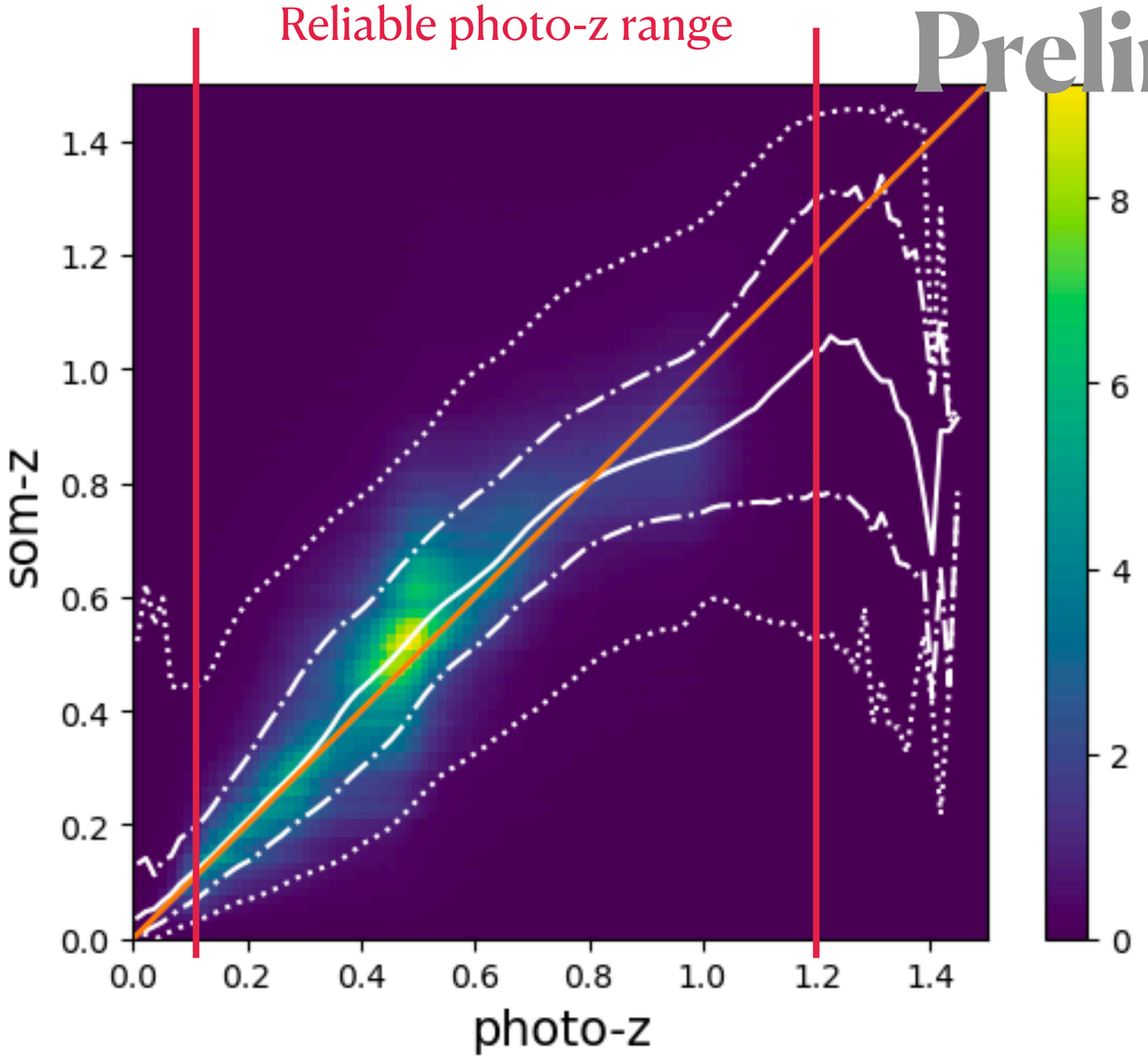


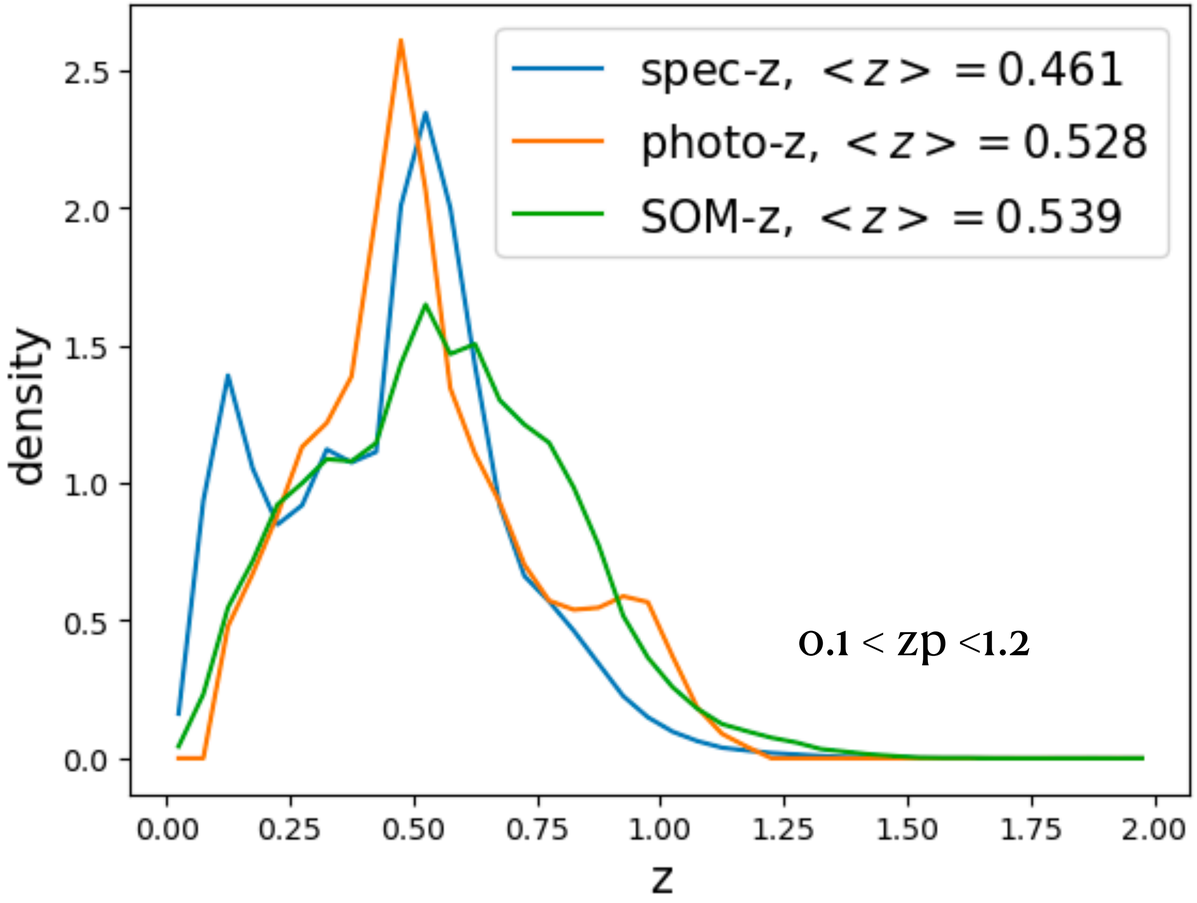
Red: distribution of photometric galaxies

Blue: distribution of spectroscopic galaxies with SOM weight

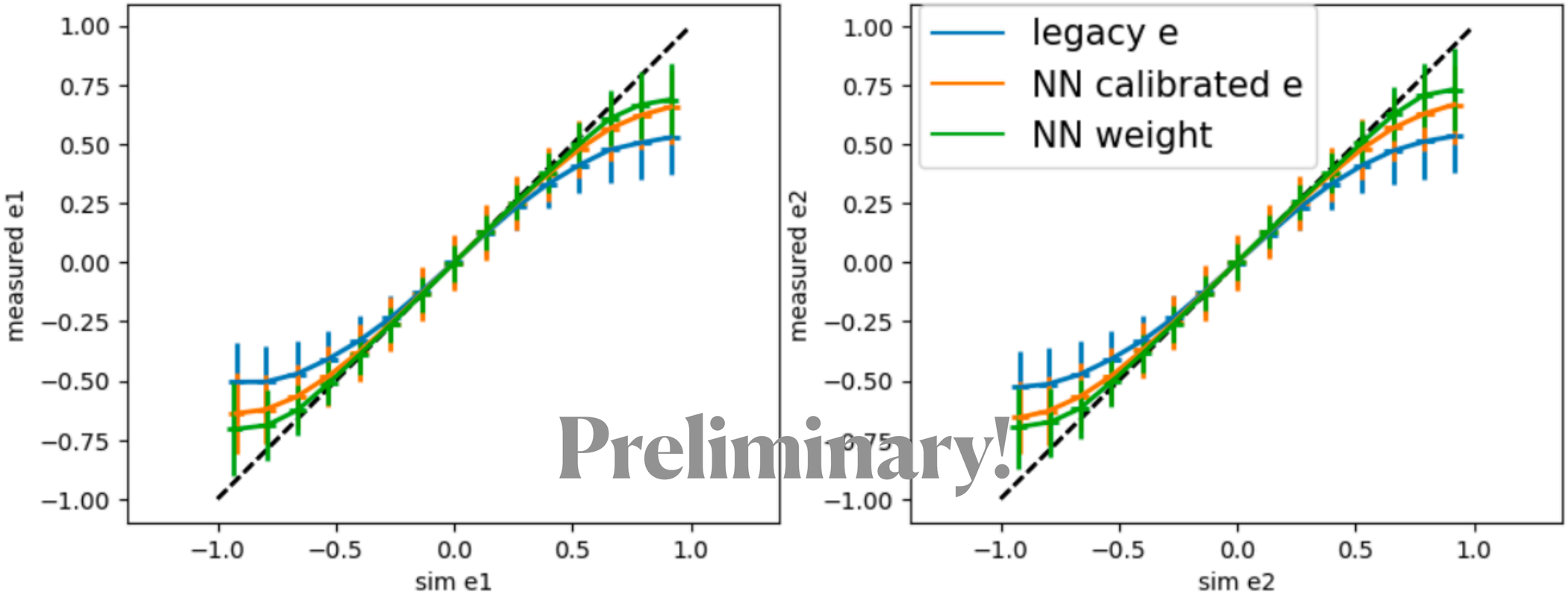
DR9 redshift properties

Preliminary!





A neural network based shear calibration



Preliminary!

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

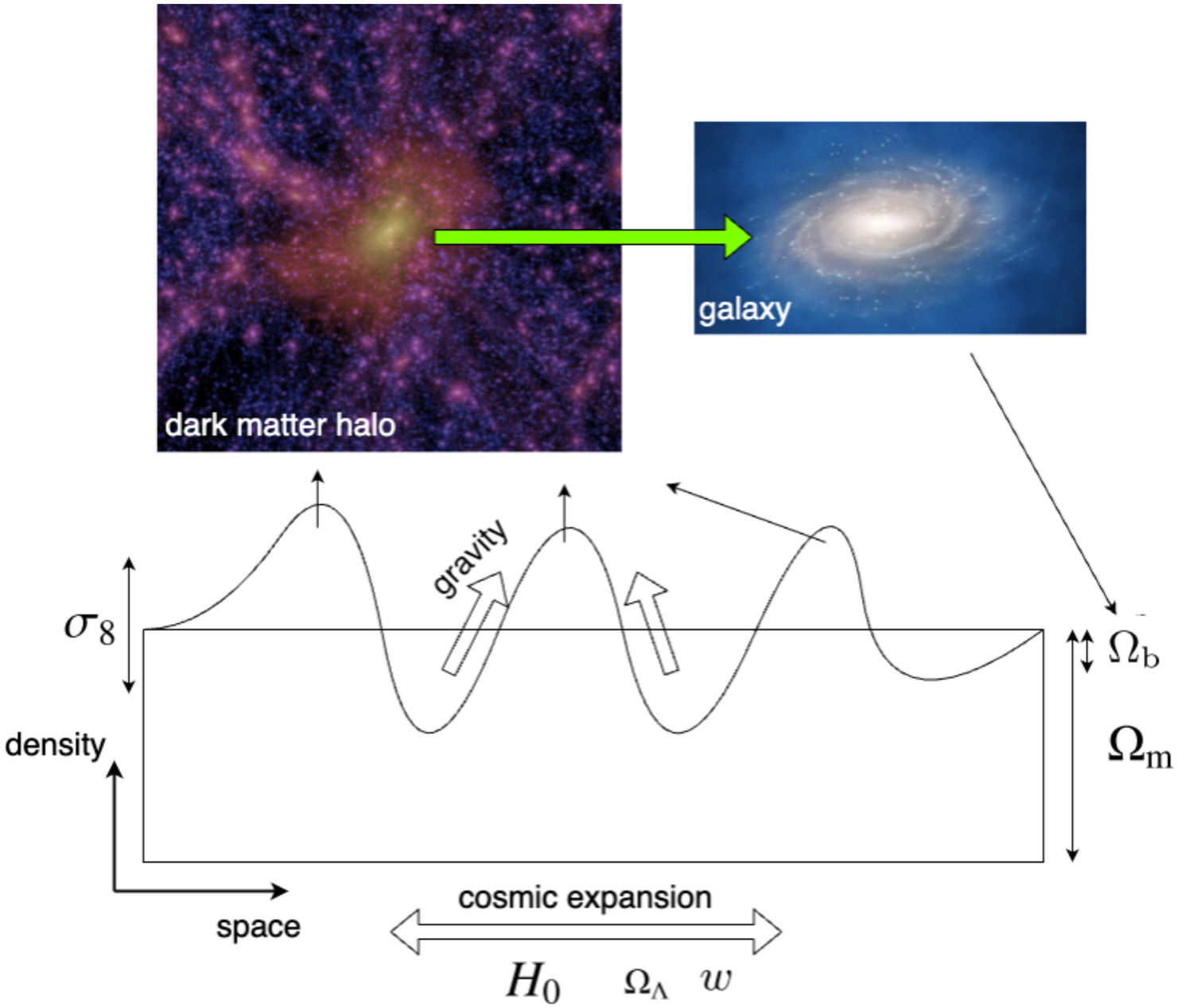
We want 1% - 0.1% level residual systematics!

Yao+ 2304.04489

Summary

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

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

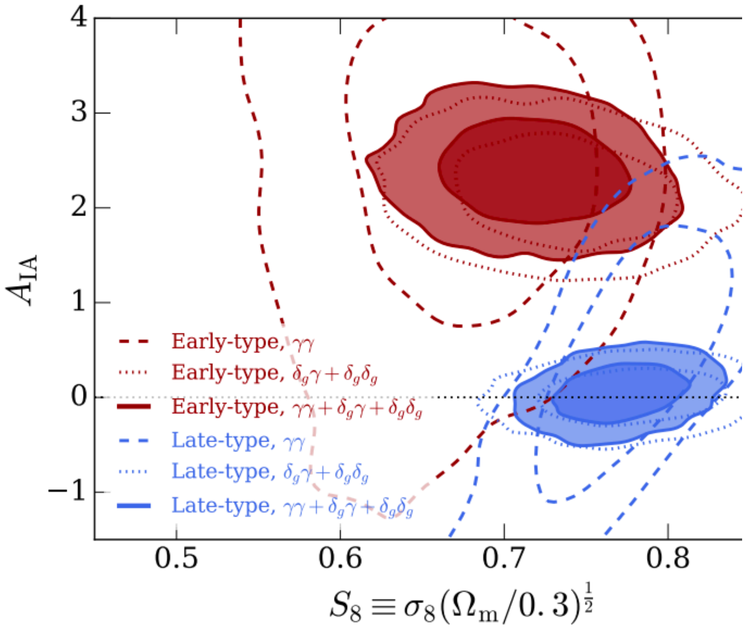


The intrinsic alignment (IA) complication

It is galaxy type-dependent

It could be redshift-dependent

We don't know a precise model



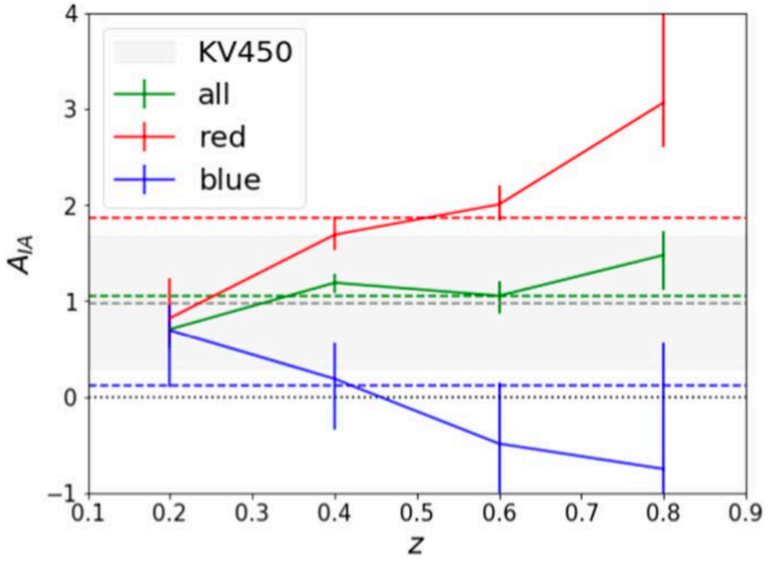
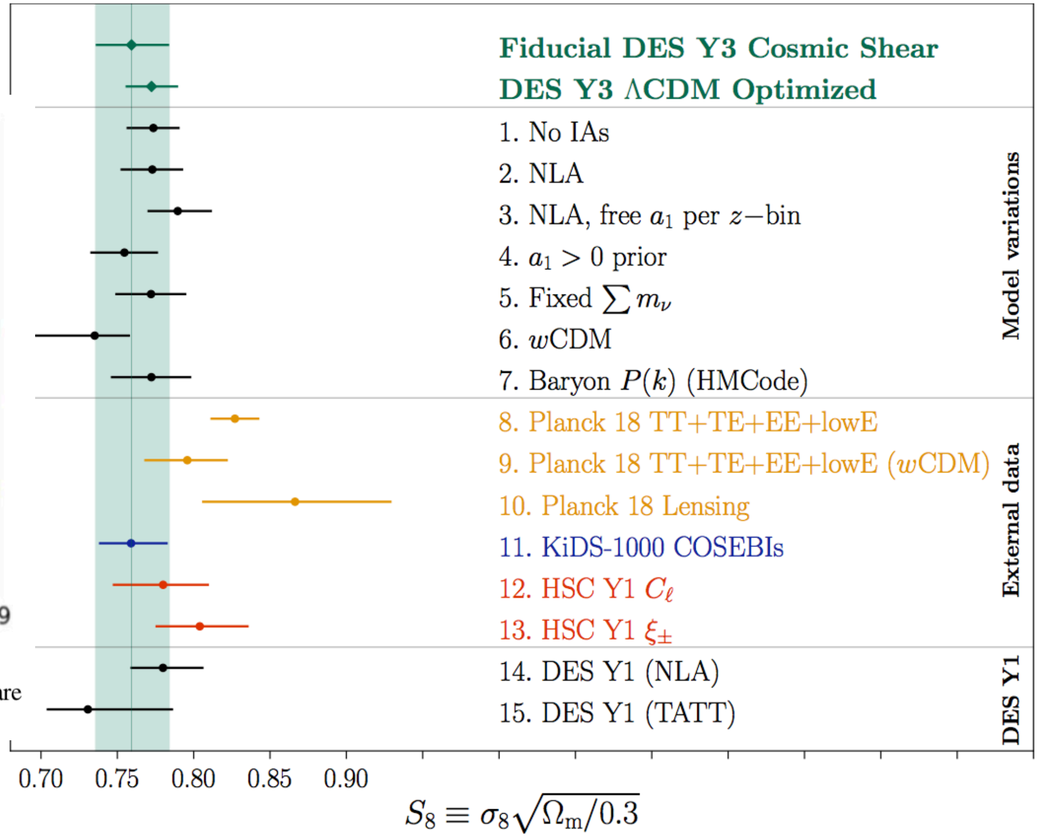


Figure 15. Color and redshift dependence of the best-fit $A_{\rm IA}$. Dashed lines are the best fit with the constant $A_{\rm IA}$ assumption.

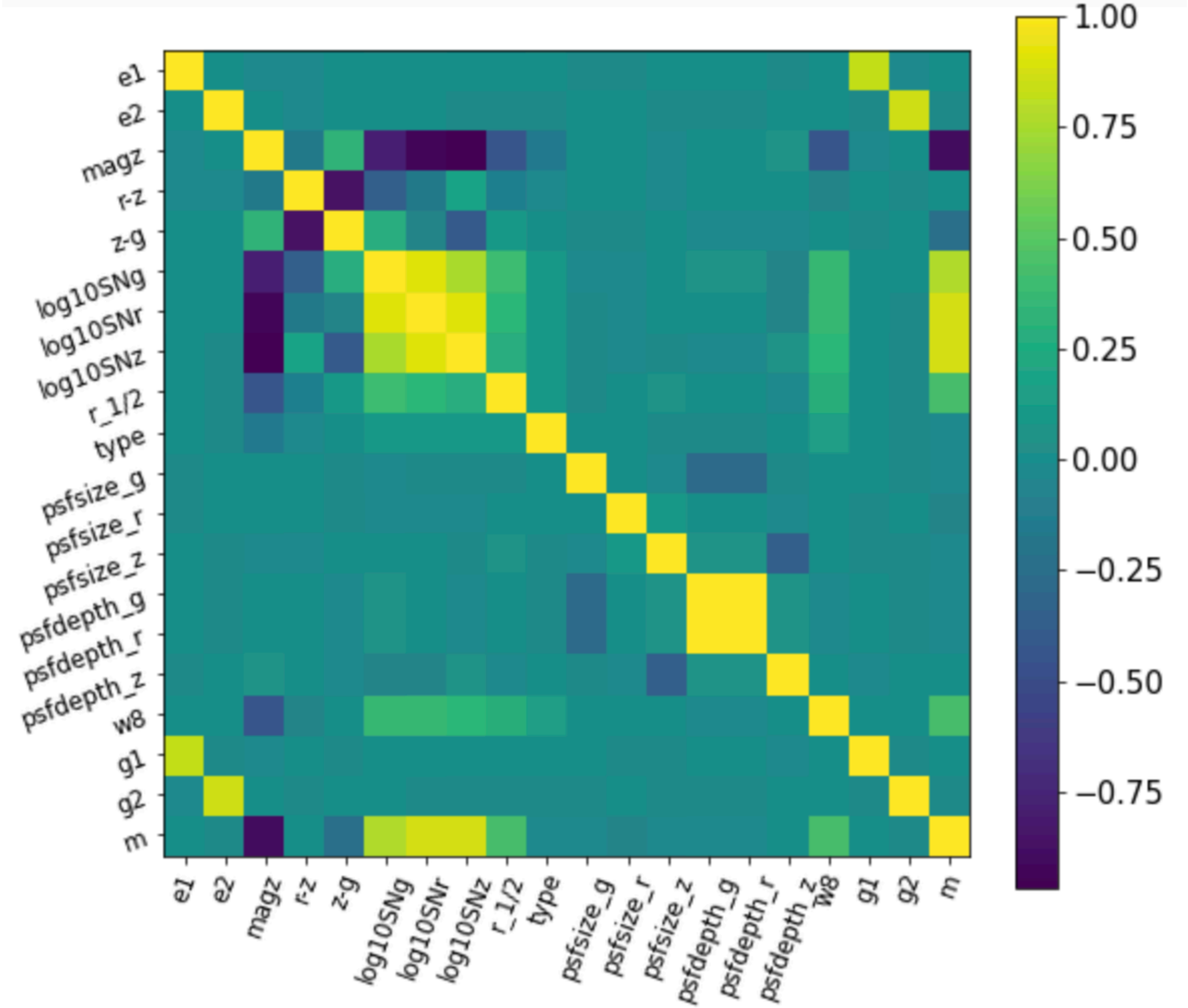


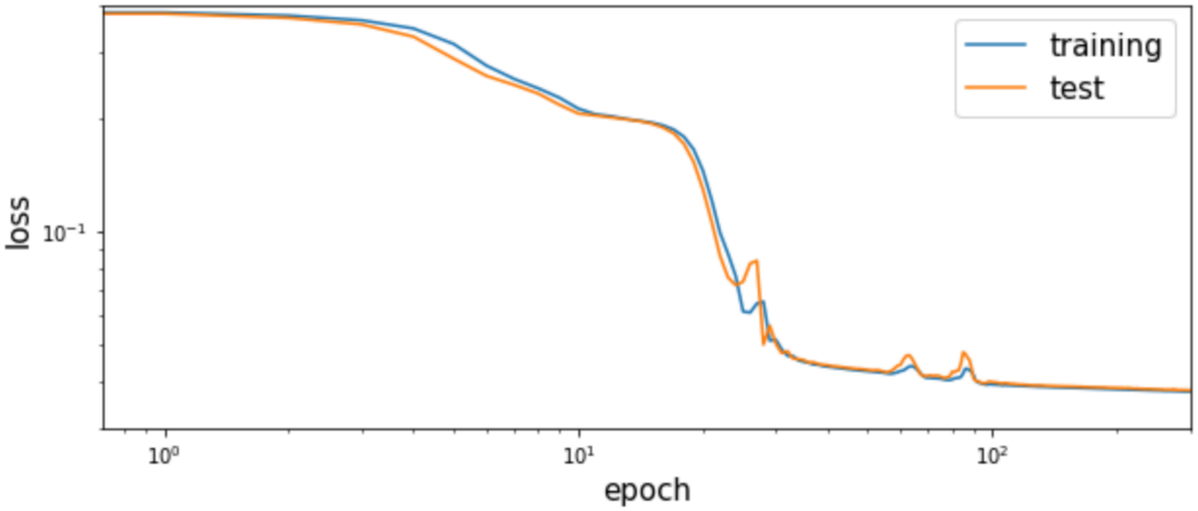
Samuroff+, 1811.06989

Yao+ 2002.09826

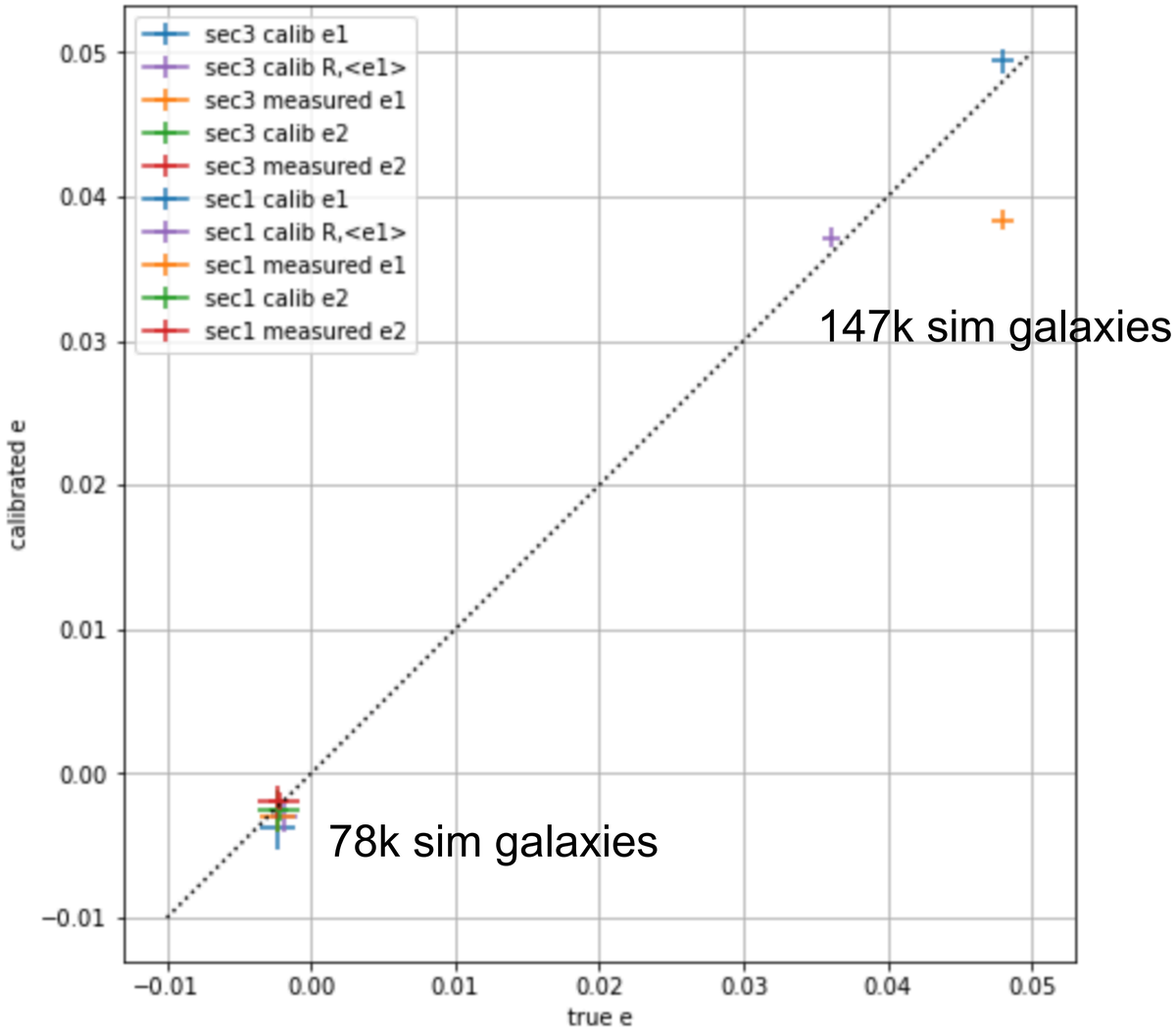
DES Y3 Secco+

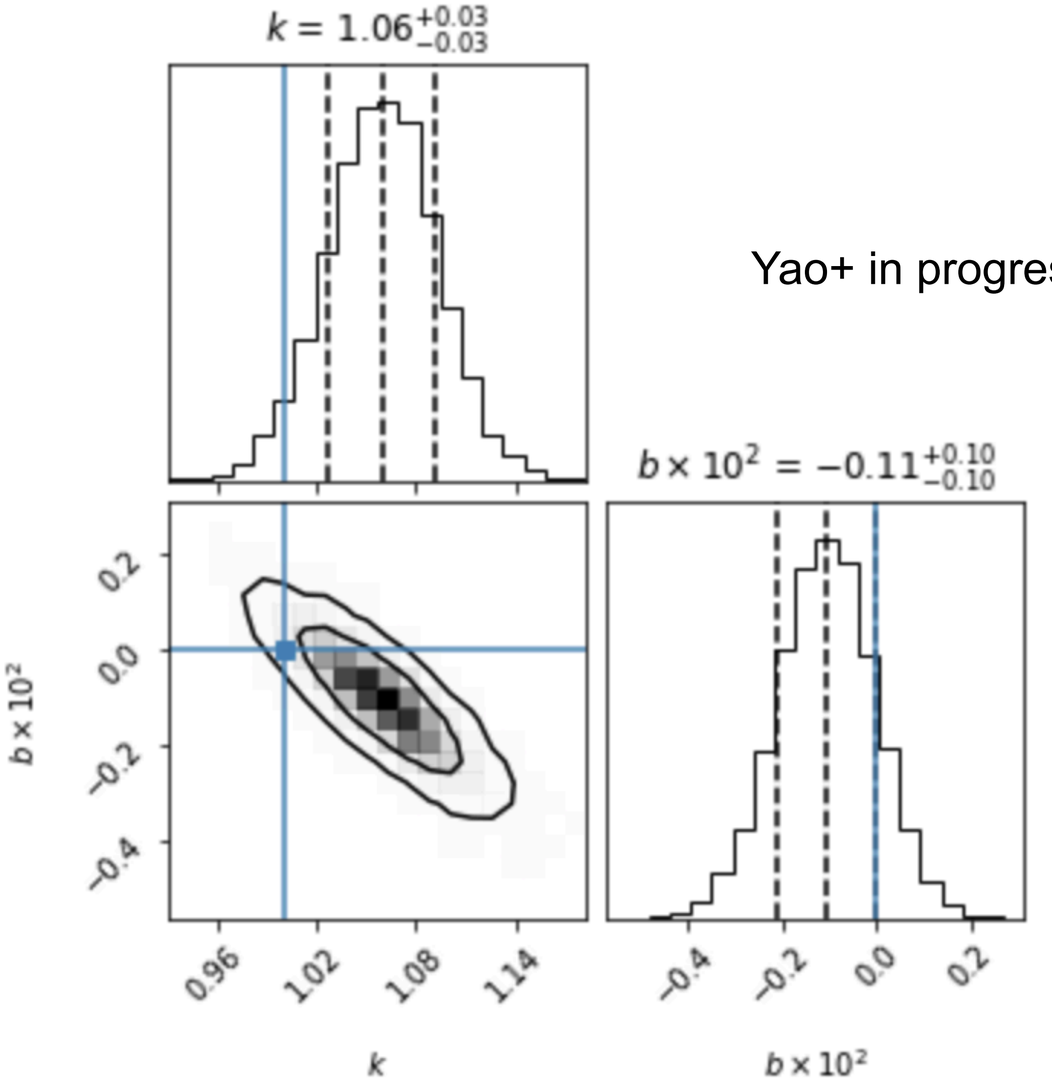
3-step shear calibraiton: (1) neural network shape





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

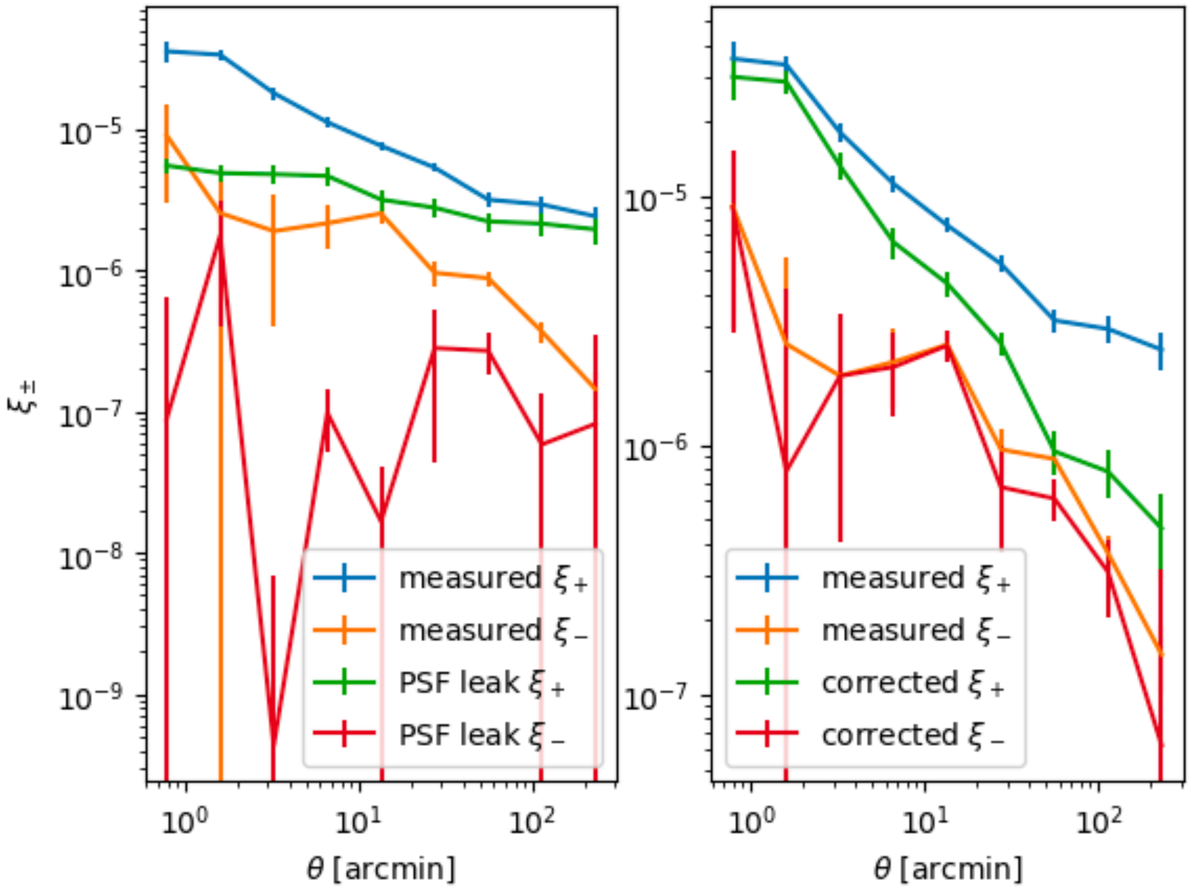


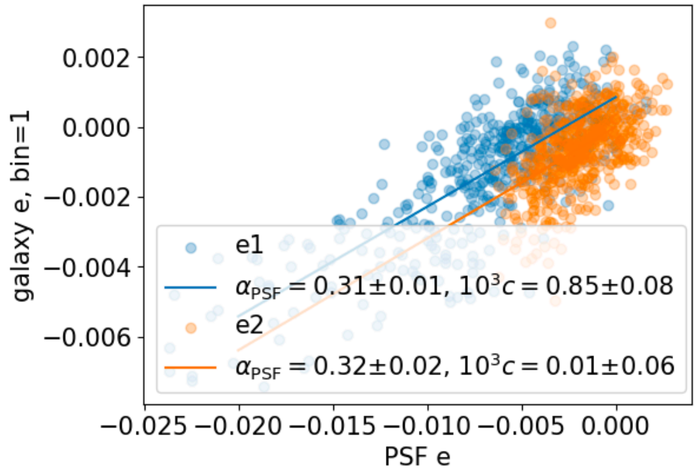


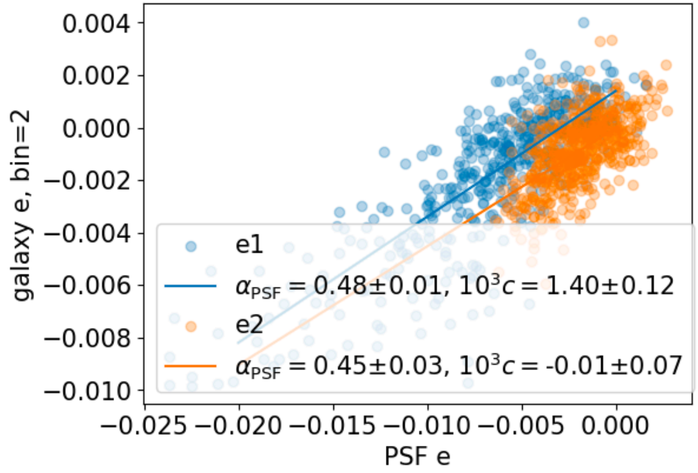
Yao+ in progress

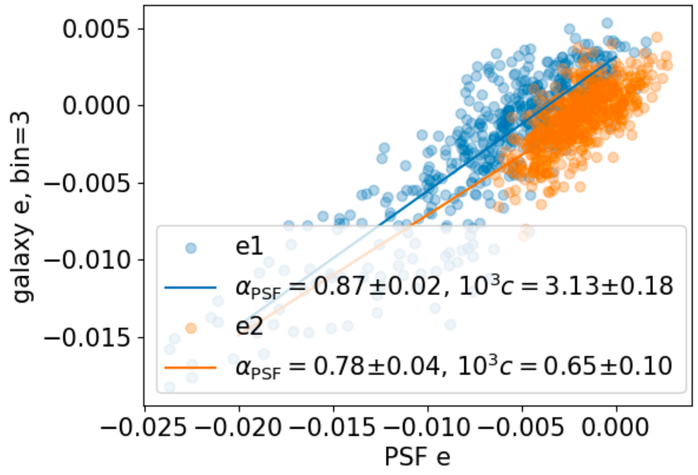
PSF problem

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

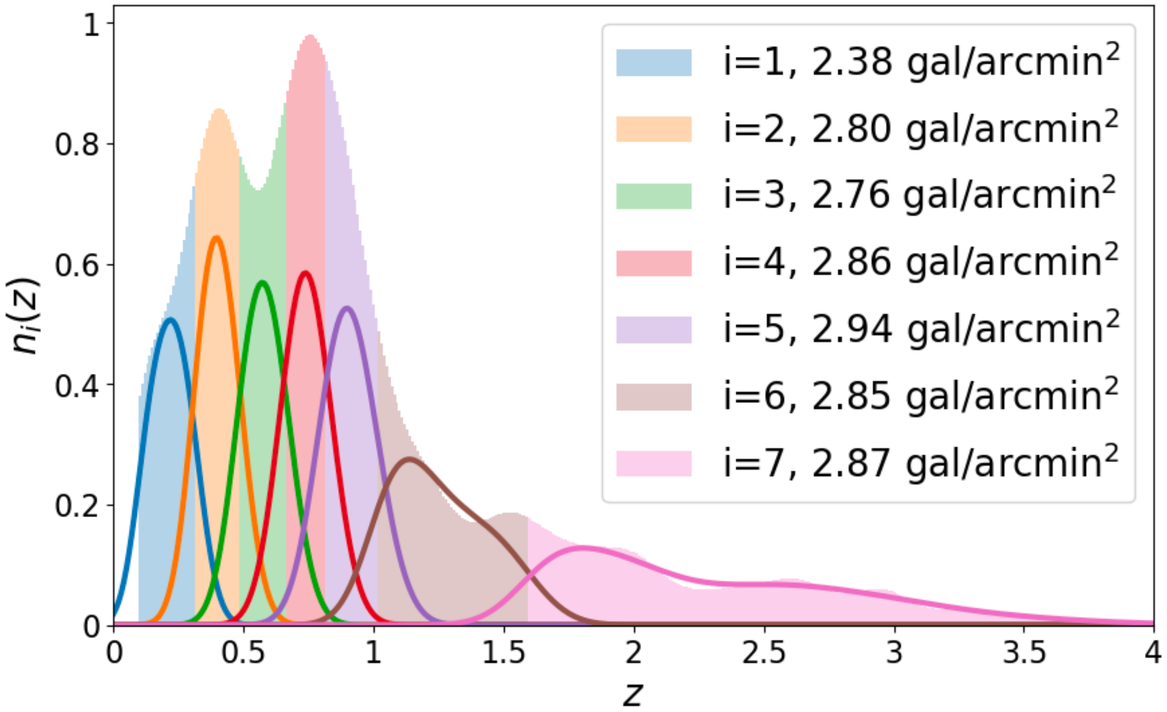




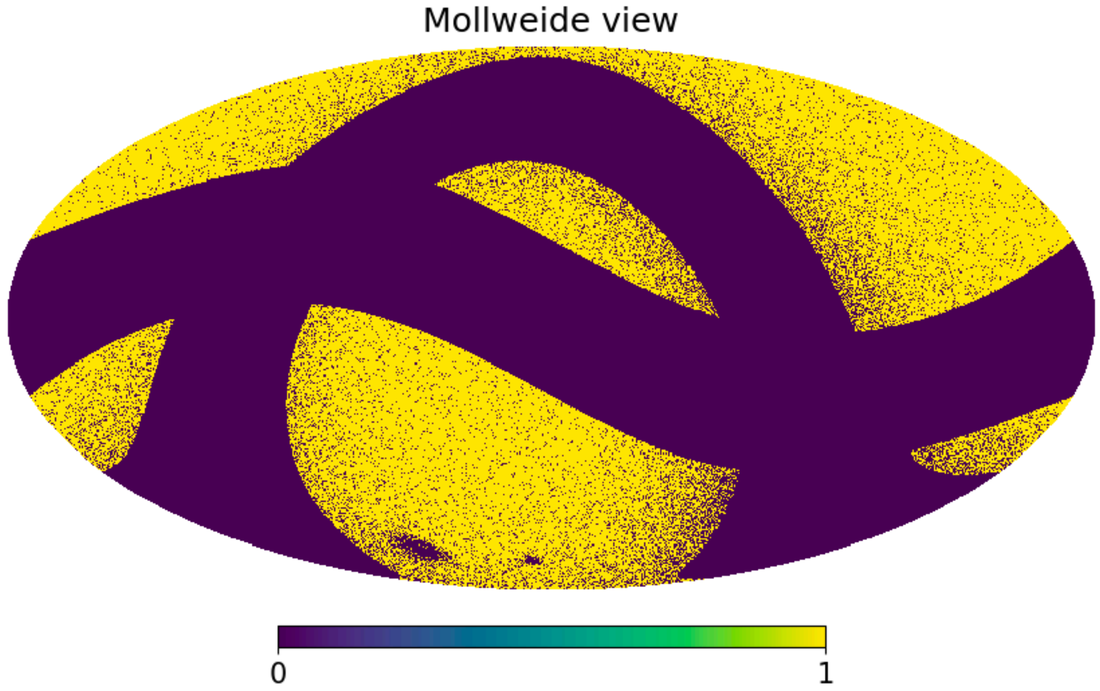




CSST forecast



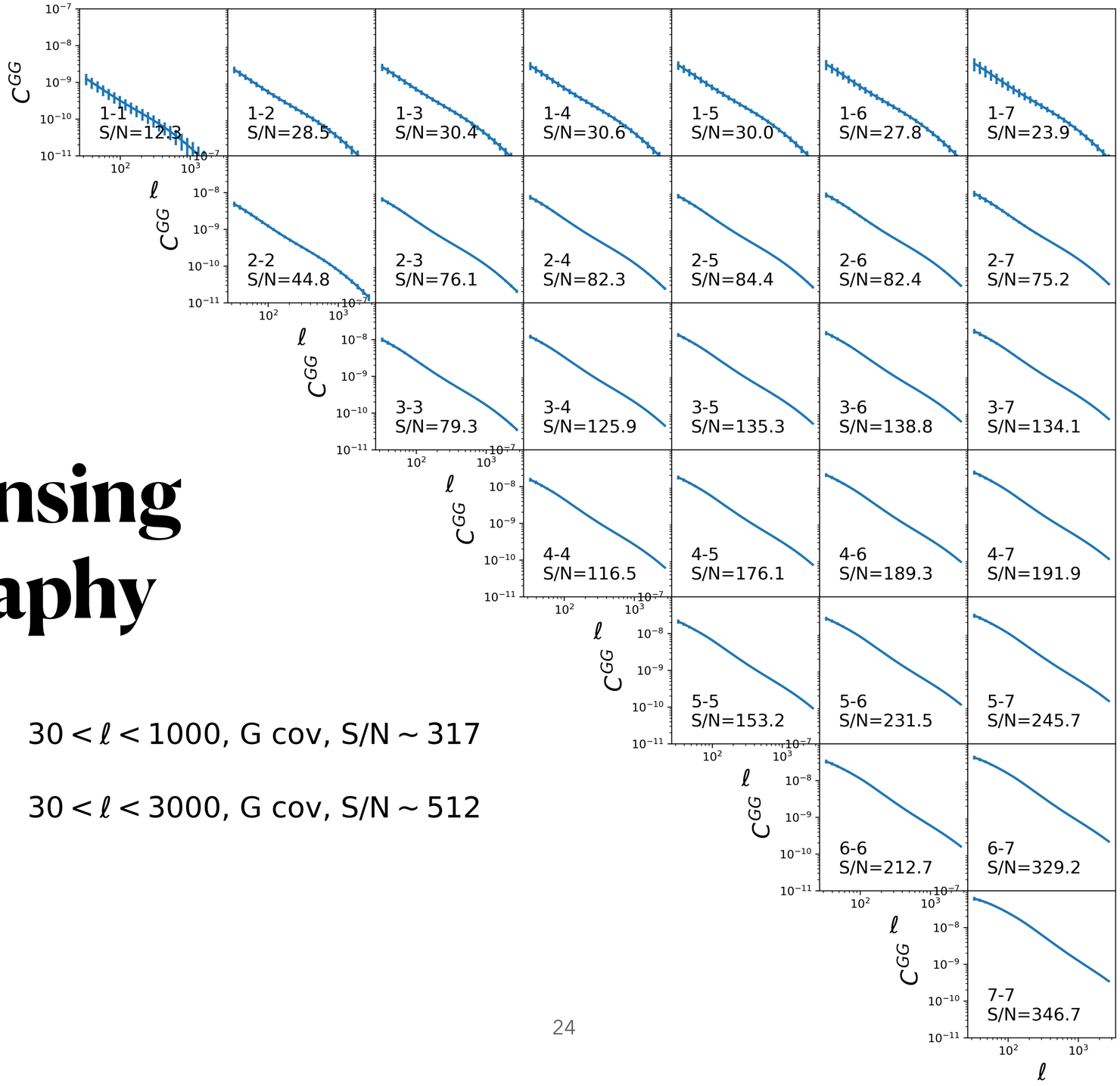
Galaxy number density 20 gal/arcmin^2



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!

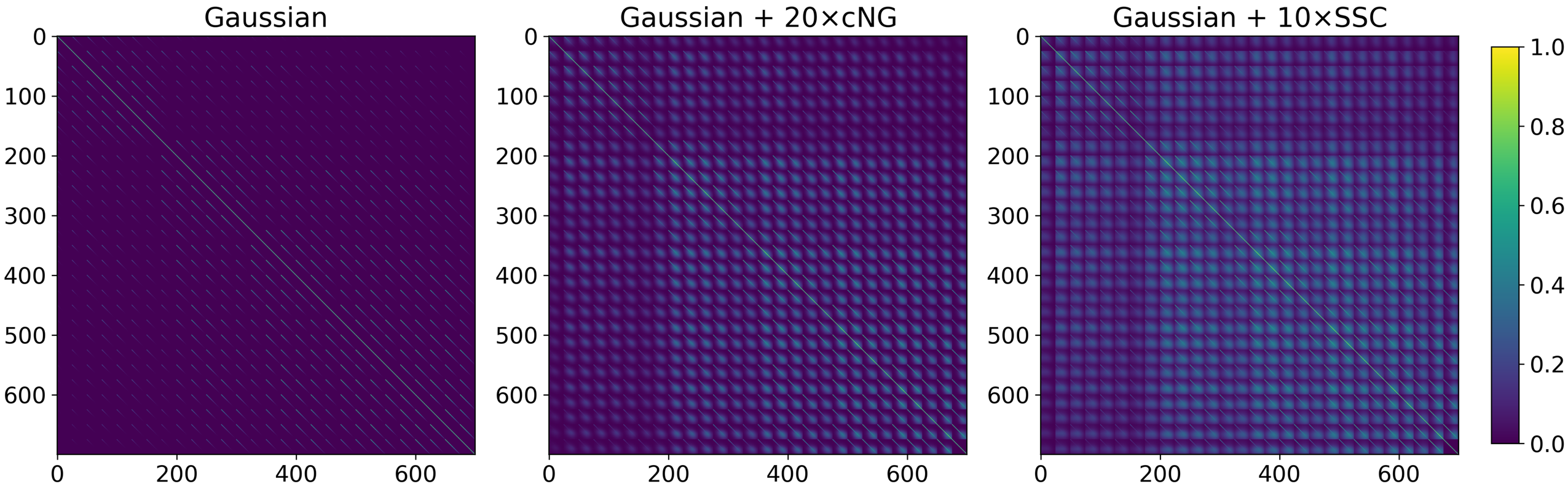
CSST lensing tomography



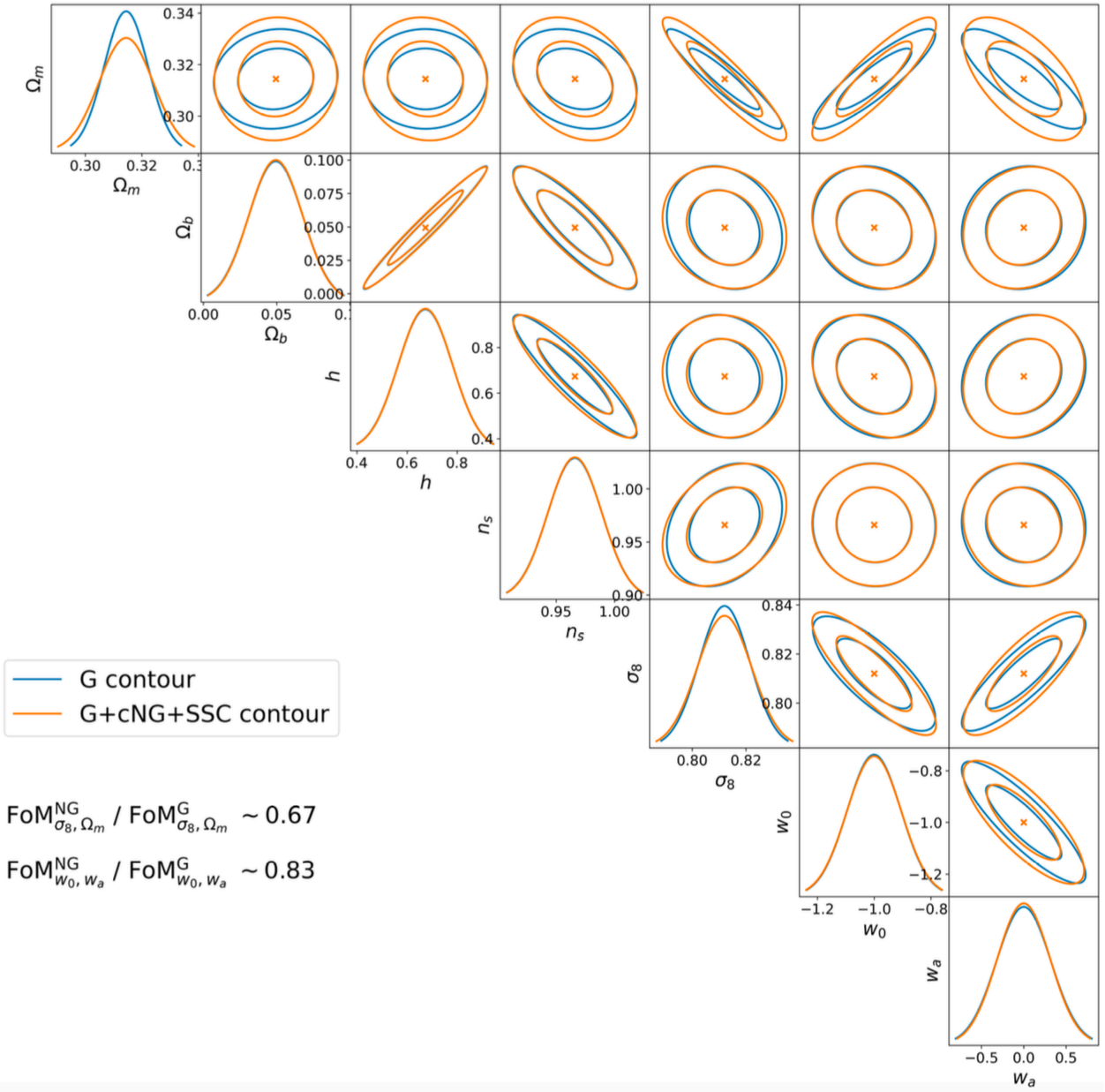
$30 < \ell < 1000$, G cov, S/N ~ 317

$30 < \ell < 3000$, 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