Cosmology with KiDS

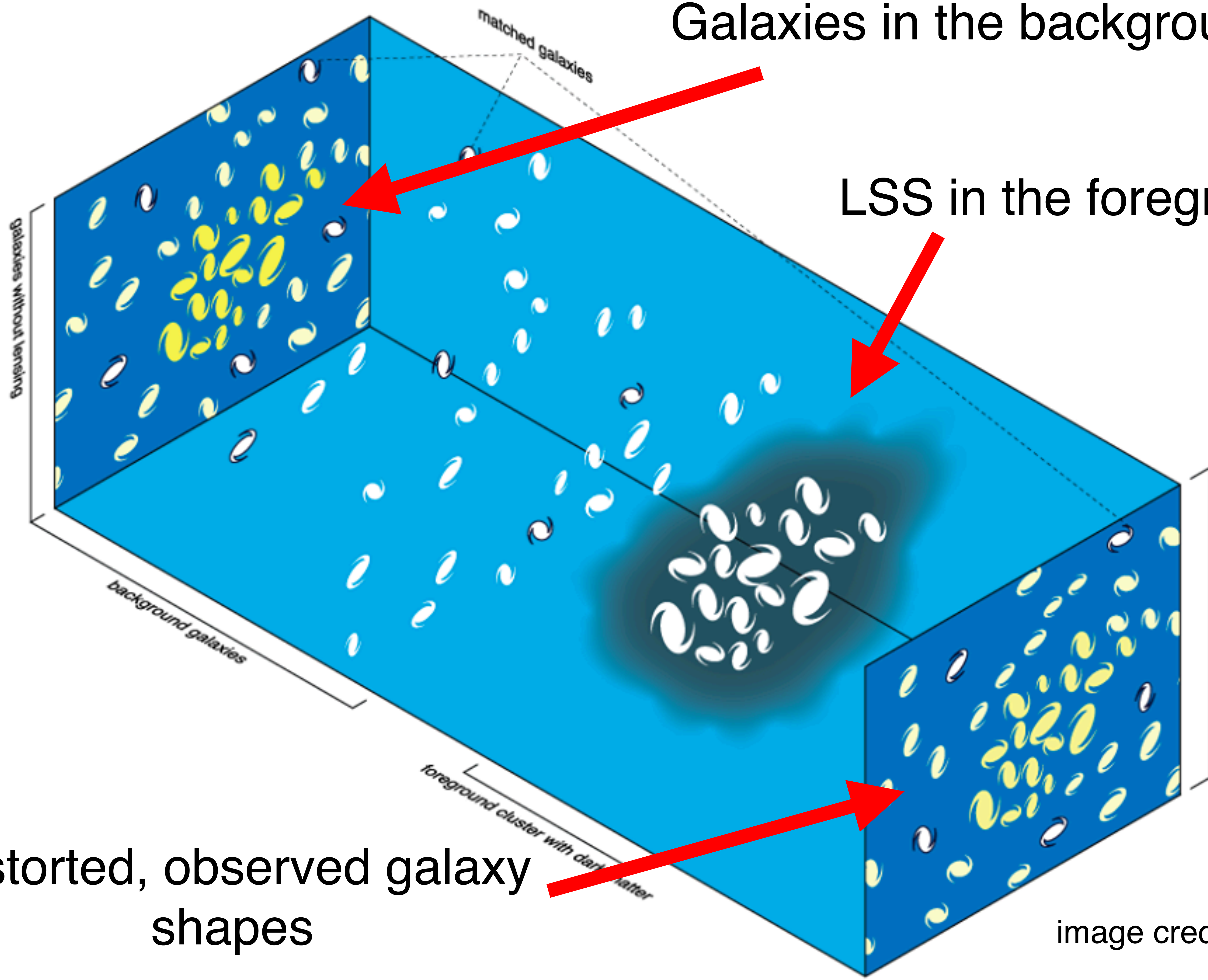
Edo van Uitert, KiDS collaboration

Recontres du Vietnam, Quy Nhon, July 9-15 2017

Weak gravitational lensing

Galaxies in the background

LSS in the foreground



Distorted, observed galaxy shapes

image credit: DES

Strength of the distortion depends on:

- Distances to foreground LSS and background galaxies
  Angular diameter distances (cosmology dependent)

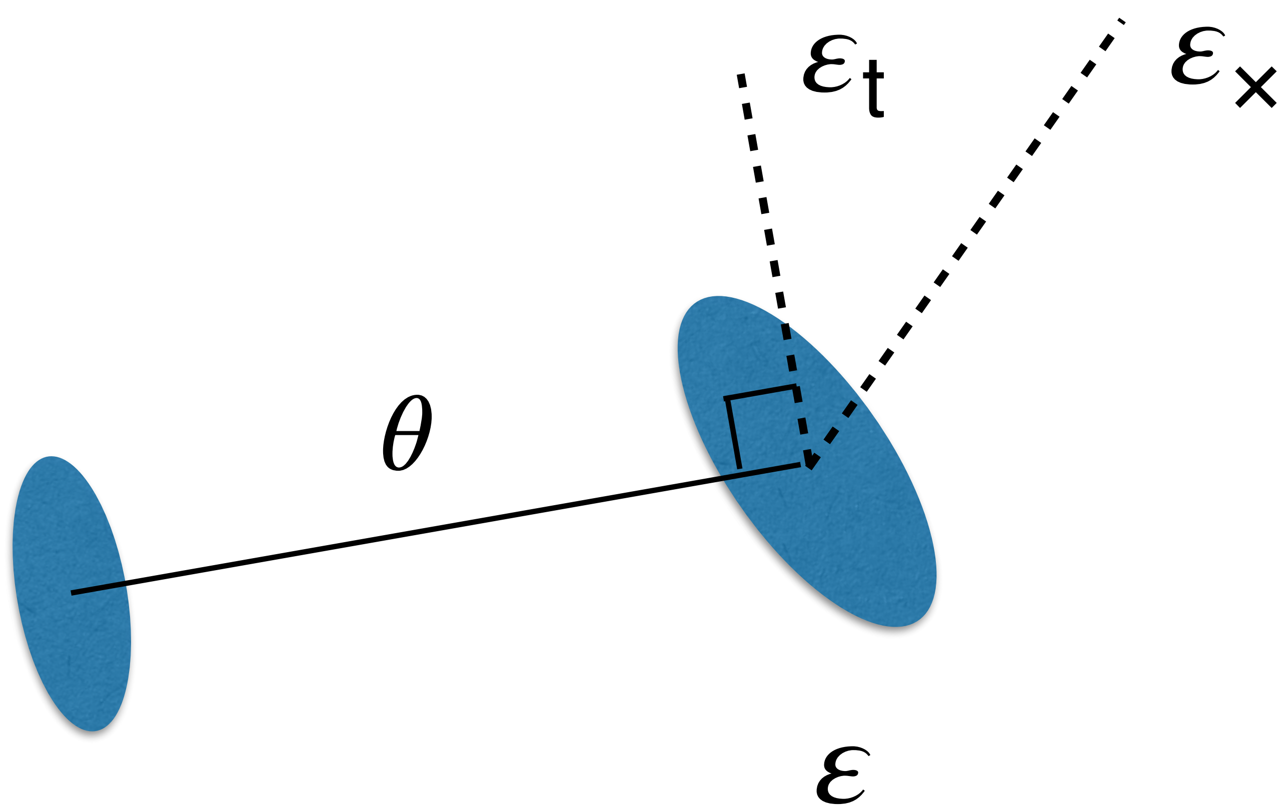
- Amount of structure in the foreground
  Power spectrum (cosmology dependent)

Extract correlated distortions: shear correlation functions

$$\hat{\xi}_{\pm}(\theta) = \frac{\sum_{ij} w_i w_j \left(\varepsilon_{\mathrm{t},i}\varepsilon_{\mathrm{t},j} \pm \varepsilon_{\times,i}\varepsilon_{\times,j}\right)}{\sum_{ij} w_i w_j}$$

ε = observed ellipticity of galaxy

w = shape measurement weight

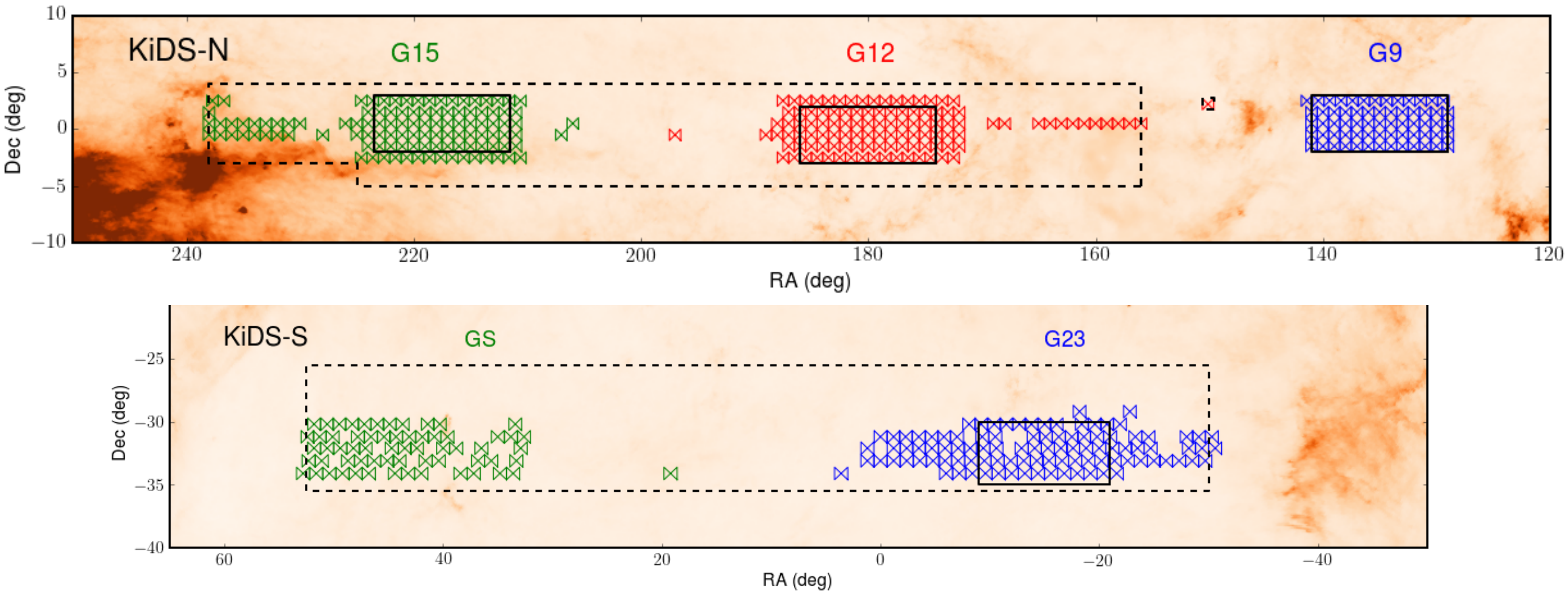


need shapes and distances

Several big WL programs ongoing

	KiDS	HSC	DES
Mirror [m]	2.6	8.2	4.0
Focus	Cassegrain	Prime	Prime
FOV [deg²]	1.0	1.8	3.0
Area [deg²]	**1350**	**1400**	**5000**
Filters	***ugri*(+*ZYJHKs*)**	***grizy***	***grizy***
Seeing [arcsec]	0.68	0.58	0.94
Source density [gal/arcmin²]	**~8**	**~22**	**~4-7 (SV)**
Depth	*r*~24	*i*~24.5	*r*~23-24 (SV)
WL Team	>30	>30	>120

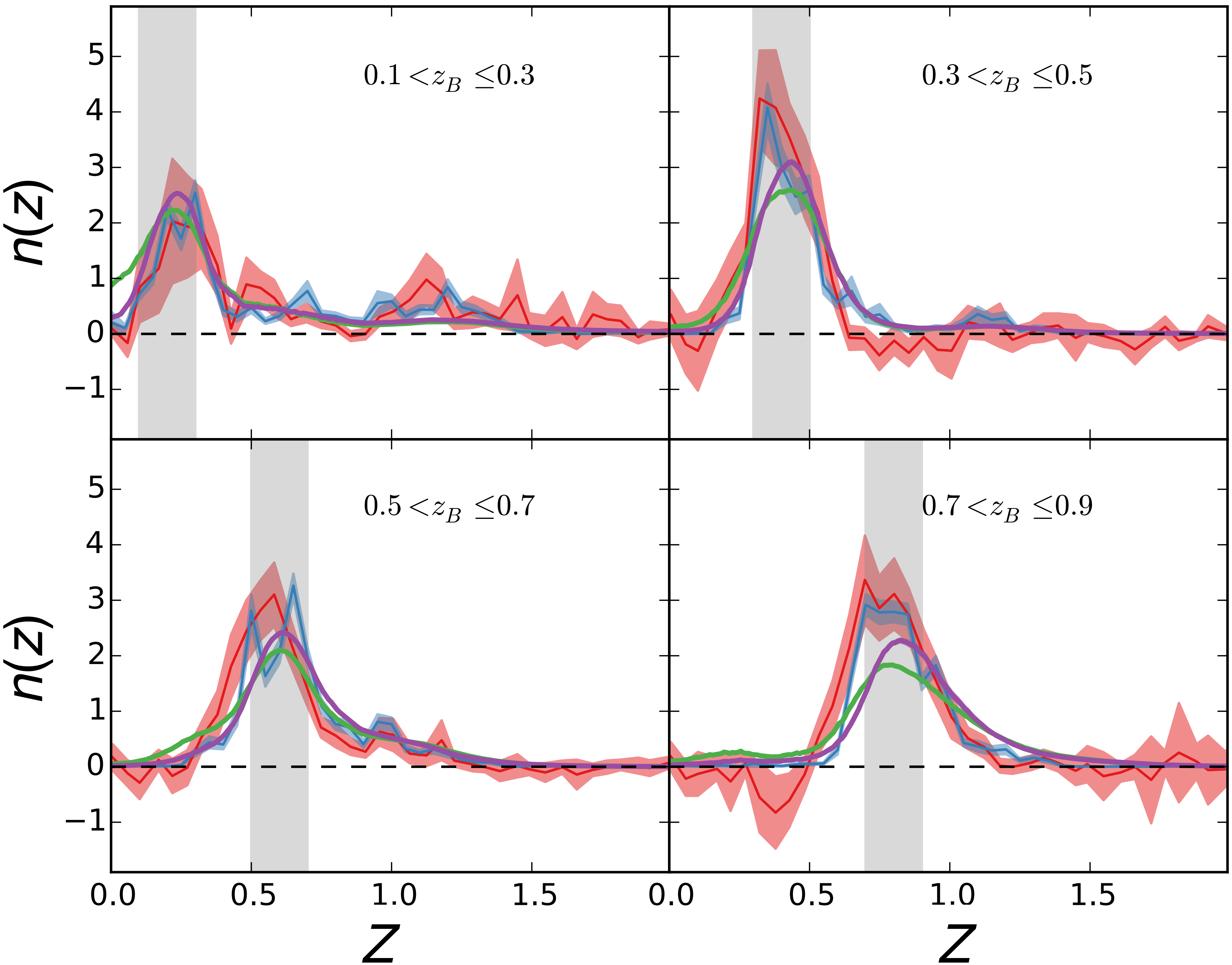
KiDS-450



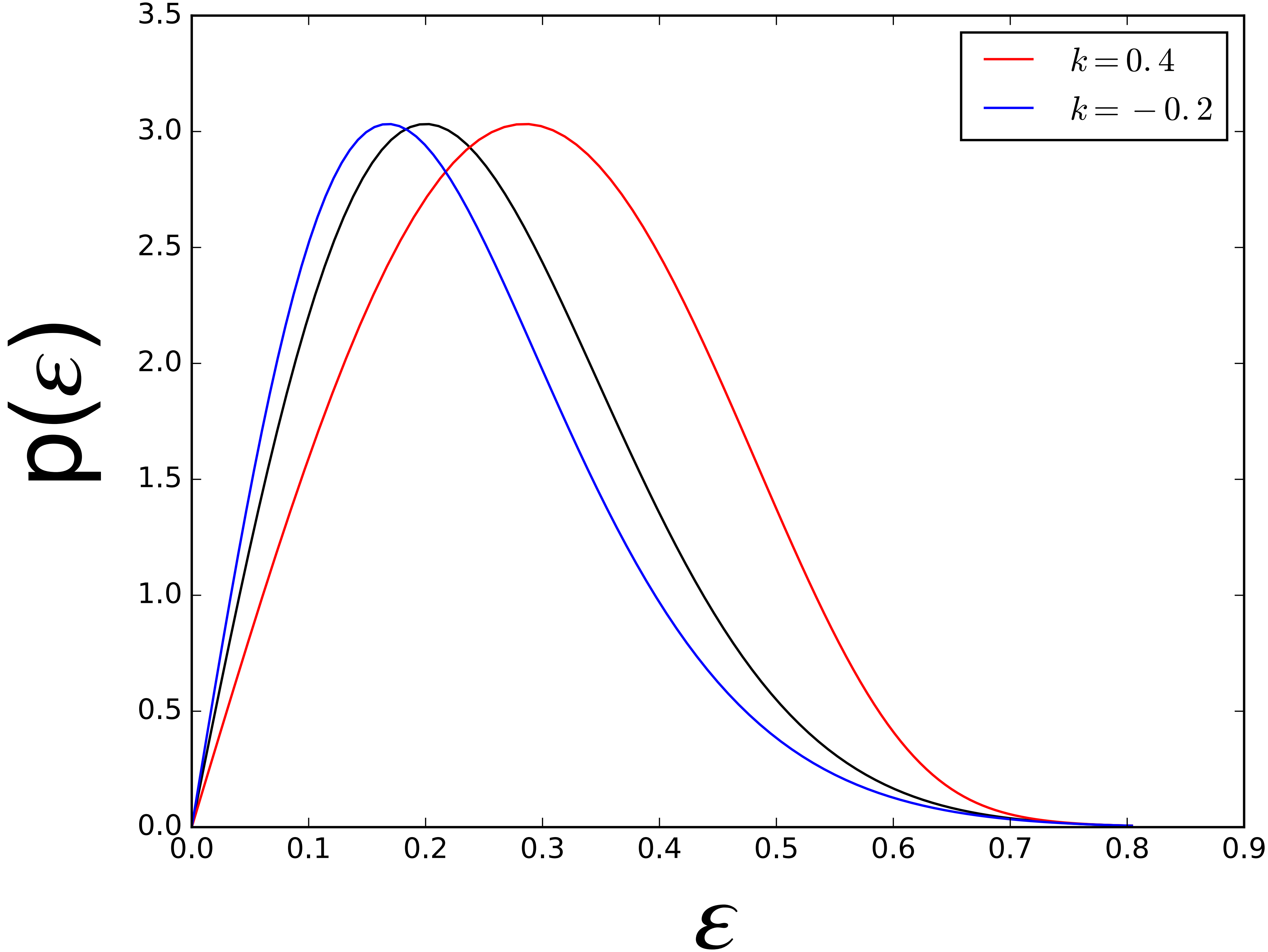
Hildebrandt, Viola et al. (2017)

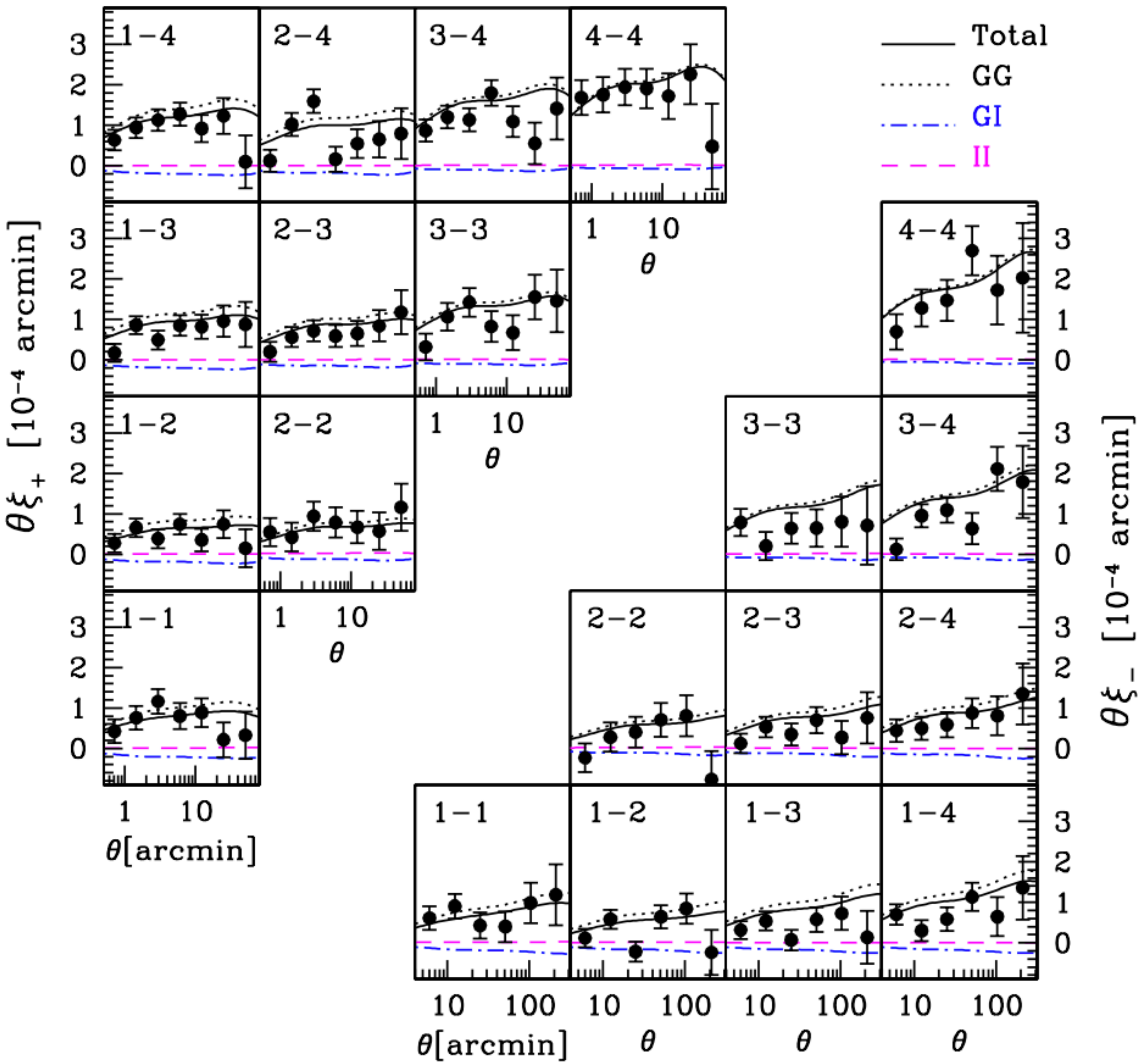
- 450 deg^2 (observations up to July 2015) (+ ~1000 deg^2)
- *ugri* coverage (+5 infrared bands from VIKING)
- Used for cosmic shear, galaxy-galaxy lensing (GGL), etc.

Photometric redshift calibration



Galaxy ellipticities were blinded to avoid confirmation bias

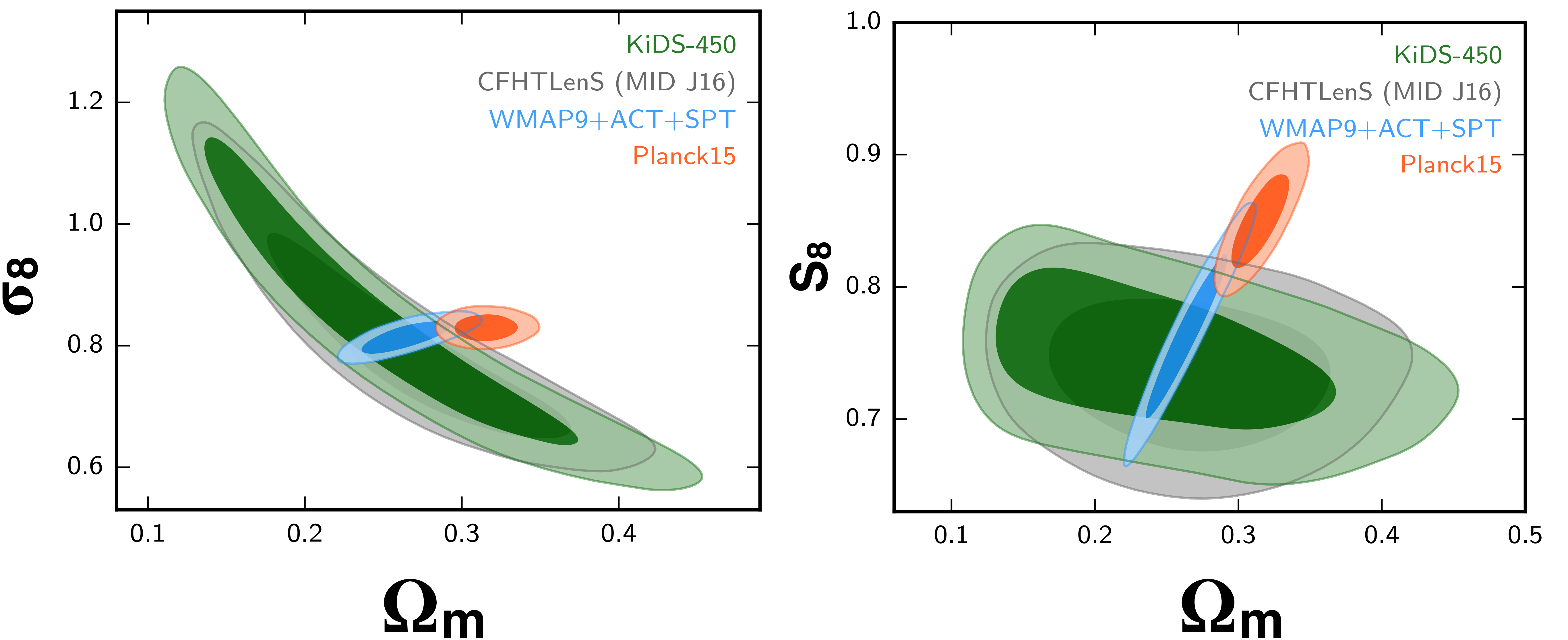




1−4
2−4
3−4
4−4
Total
GG
GI
II
1−3
2−3
3−3
1−2
2−2
1−1
3−3
3−4
2−2
2−3
2−4
1−1
1−2
1−3
1−4
$\theta\xi_+$ [10⁻⁴ arcmin]
$\theta\xi_-$ [10⁻⁴ arcmin]
θ[arcmin]
θ

KiDS-450: Results (blind-1)

$S_8 = \sigma_8 (\Omega_m/0.3)^{0.5}$

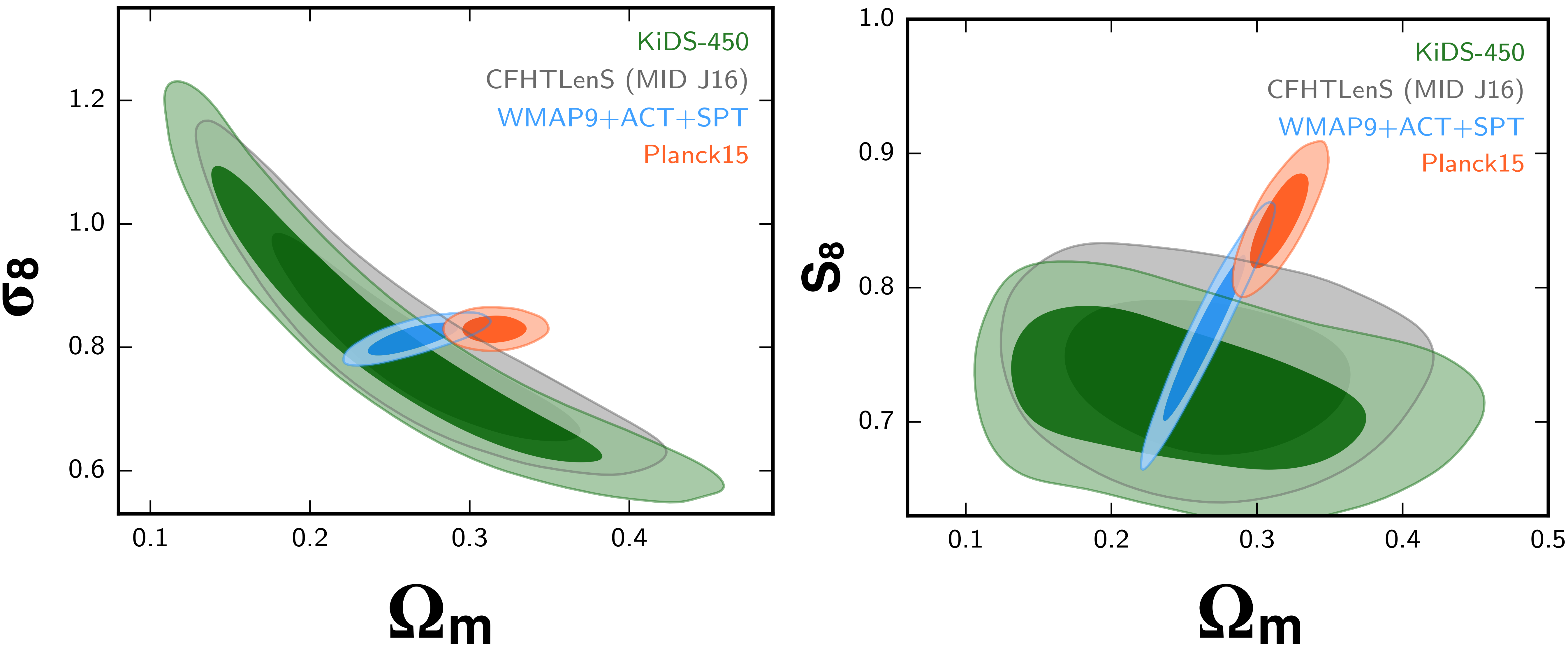


- $S_8 = 0.745 \pm 0.039$ 2.3σ discrepancy with Planck

Hildebrandt, Viola et al. (2017)

KiDS-450: Results (blind-2)

$S_8 = \sigma_8 (\Omega_m/0.3)^{0.5}$

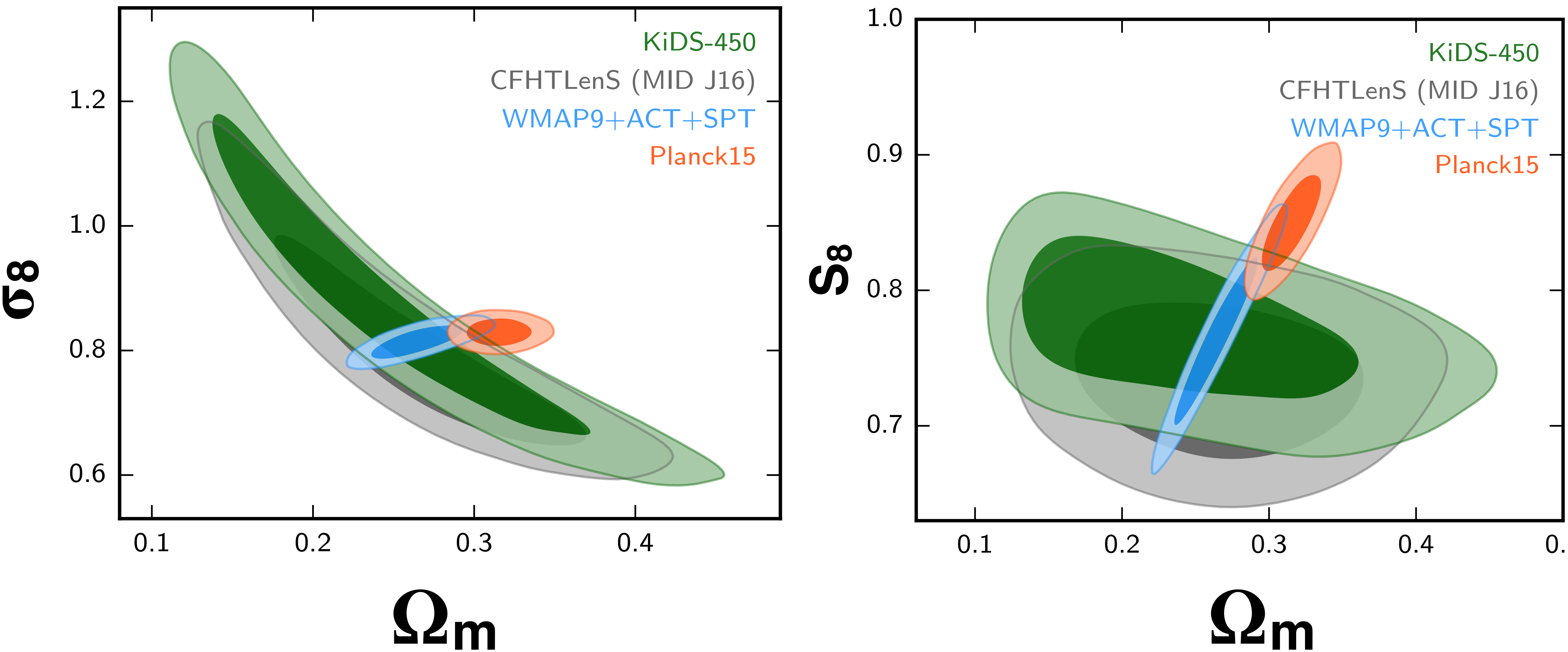


- $S_8 = 0.720 \pm 0.039$ 2.8σ discrepancy with Planck

Hildebrandt, Viola et al. (2017)

KiDS-450: Results (blind-3)

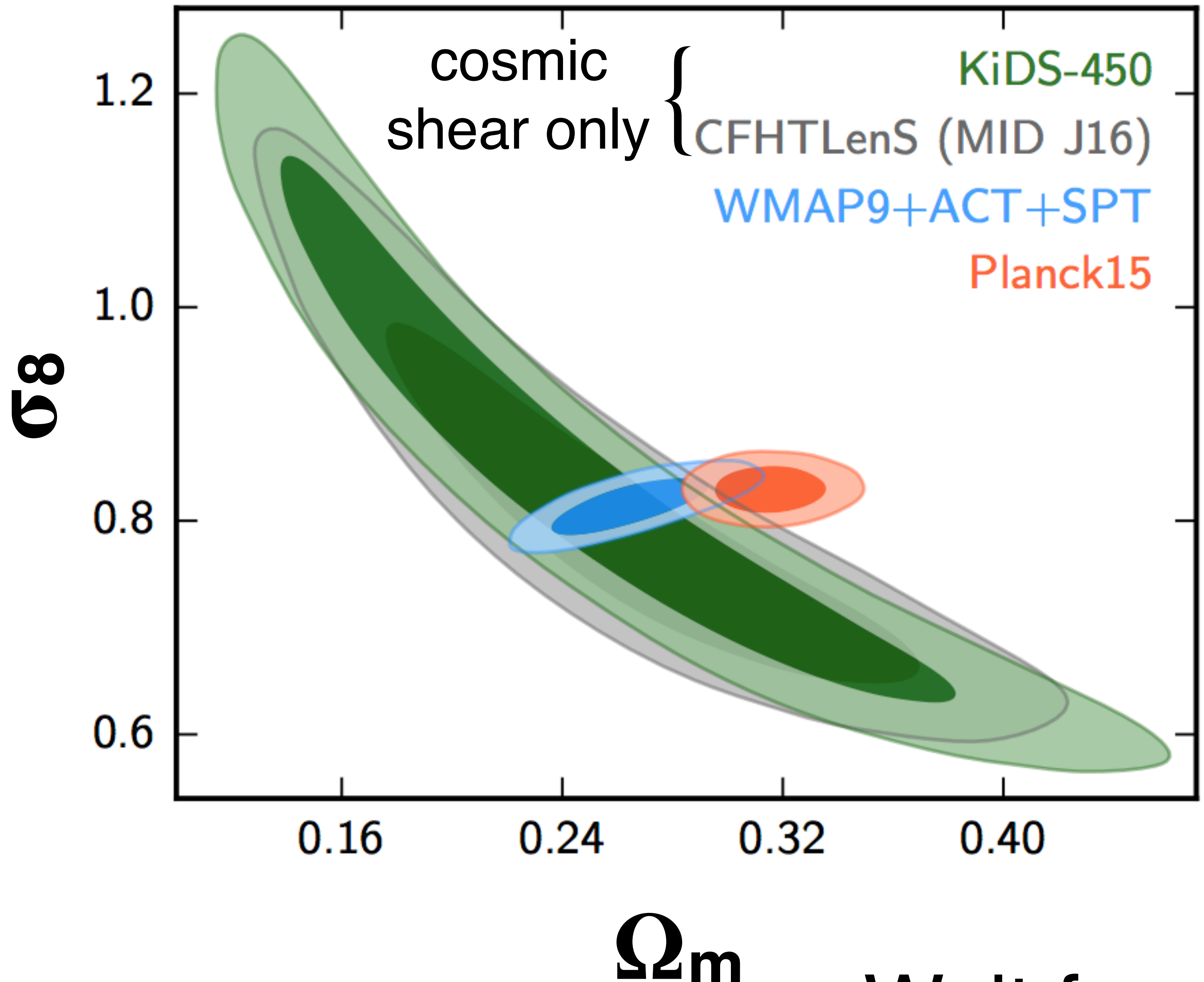
$S_8 = \sigma_8 \, (\Omega_m/0.3)^{0.5}$



- $S_8 = 0.772 \pm 0.039$ 1.7σ discrepancy with Planck

Hildebrandt, Viola et al. (2017)

KiDS-450 (Hildebrandt+17) : 2.3σ 'tension' with Planck

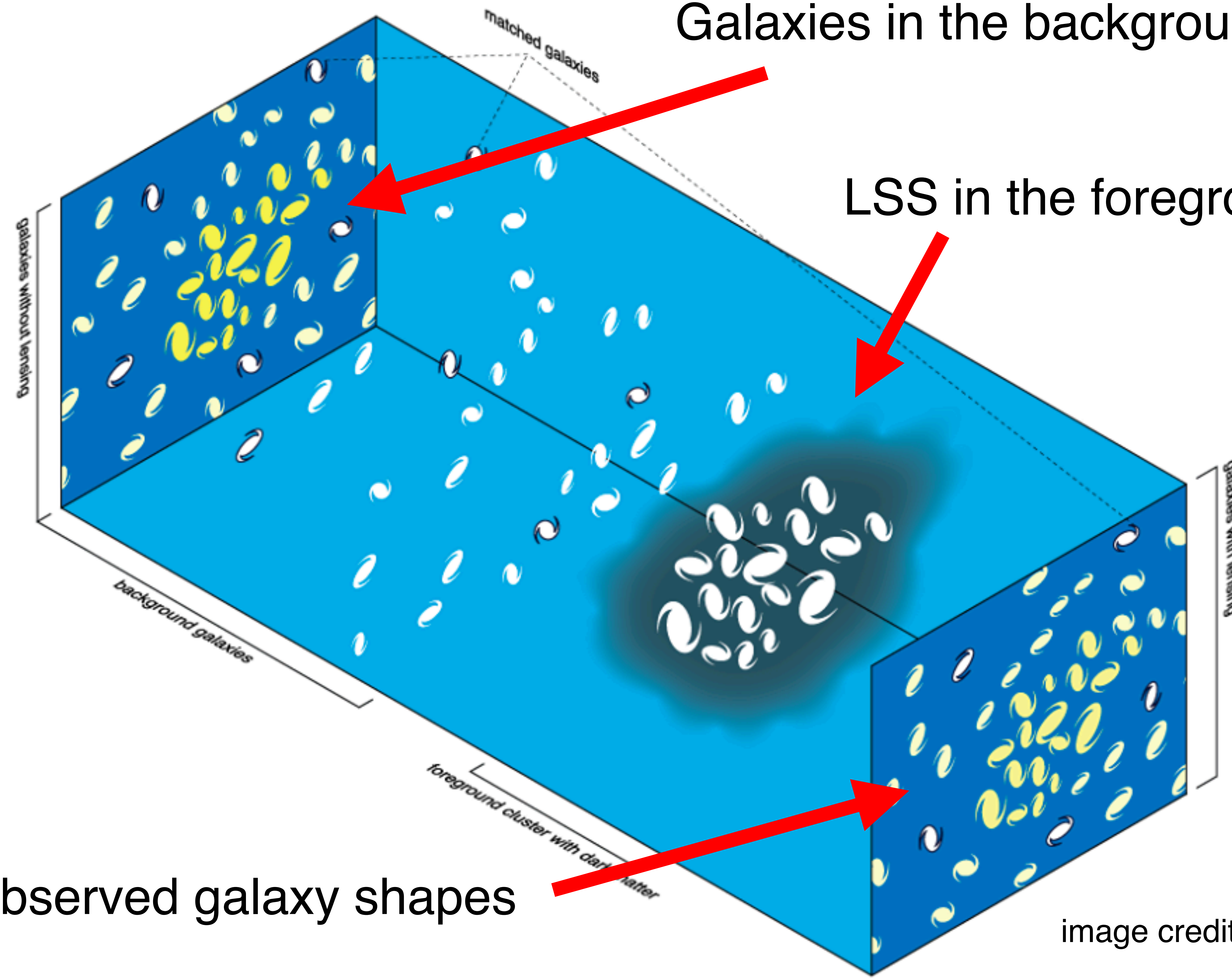


?

Wait for more data, or…

Galaxies in the background

LSS in the foreground



Observed galaxy shapes

image credit: DES

…combine different cosmological probes

- Include galaxy-galaxy lensing and clustering
- Exploit all available information
- Self-calibrates observational & systematic sources of bias (demonstrated on theory in e.g. Samuroff+17, Joachimi+10)
- Euclid will also self-calibrate

We need to demonstrate that this works on data

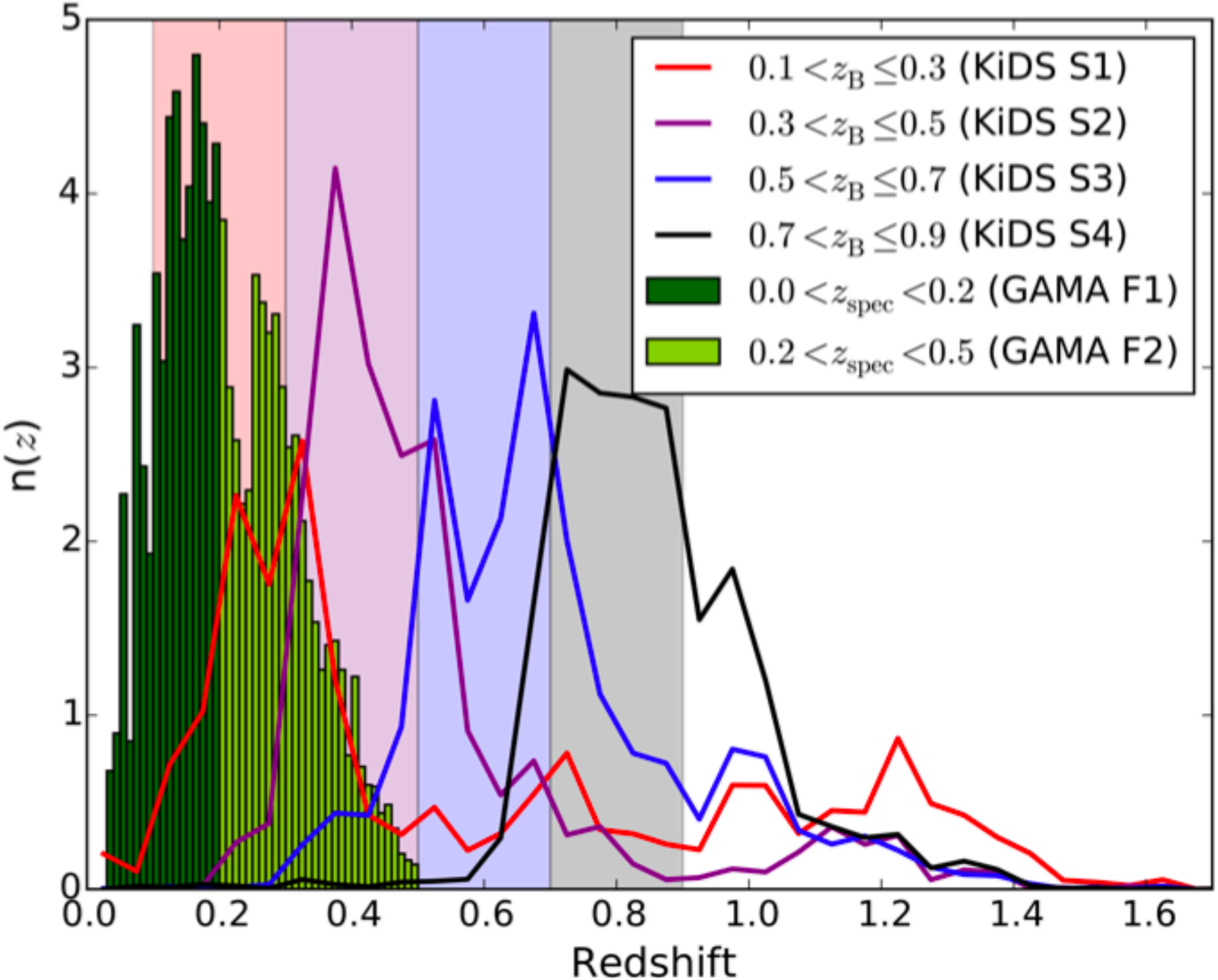
How to combine probes?

- Usually at the likelihood level (hard if correlated)
- Optimally done within the same framework
- Account for nuisance parameters that simultaneously affect different observables

KiDS fully covers **GAMA**

- Spec-*z* survey, highly complete to $R<19.8$
- Perfectly suited as foreground sample for galaxy-galaxy lensing (GGL) with KiDS
- Overlap exploited in various GGL studies (*Viola+15, Sifón+15, van Uitert+16,17, Brouwer+16,17, Dvornik+17*)

Redshift distributions



GAMA clustering nearly indep. of cosmic shear

KiDS UCL

Combine cosmic shear, GGL and angular clustering

- Put probes on same angular frequency scales: use power spectra

- Follows methodology of Schneider et al. (2002)

Power spectrum — Kernel — Real space stat.

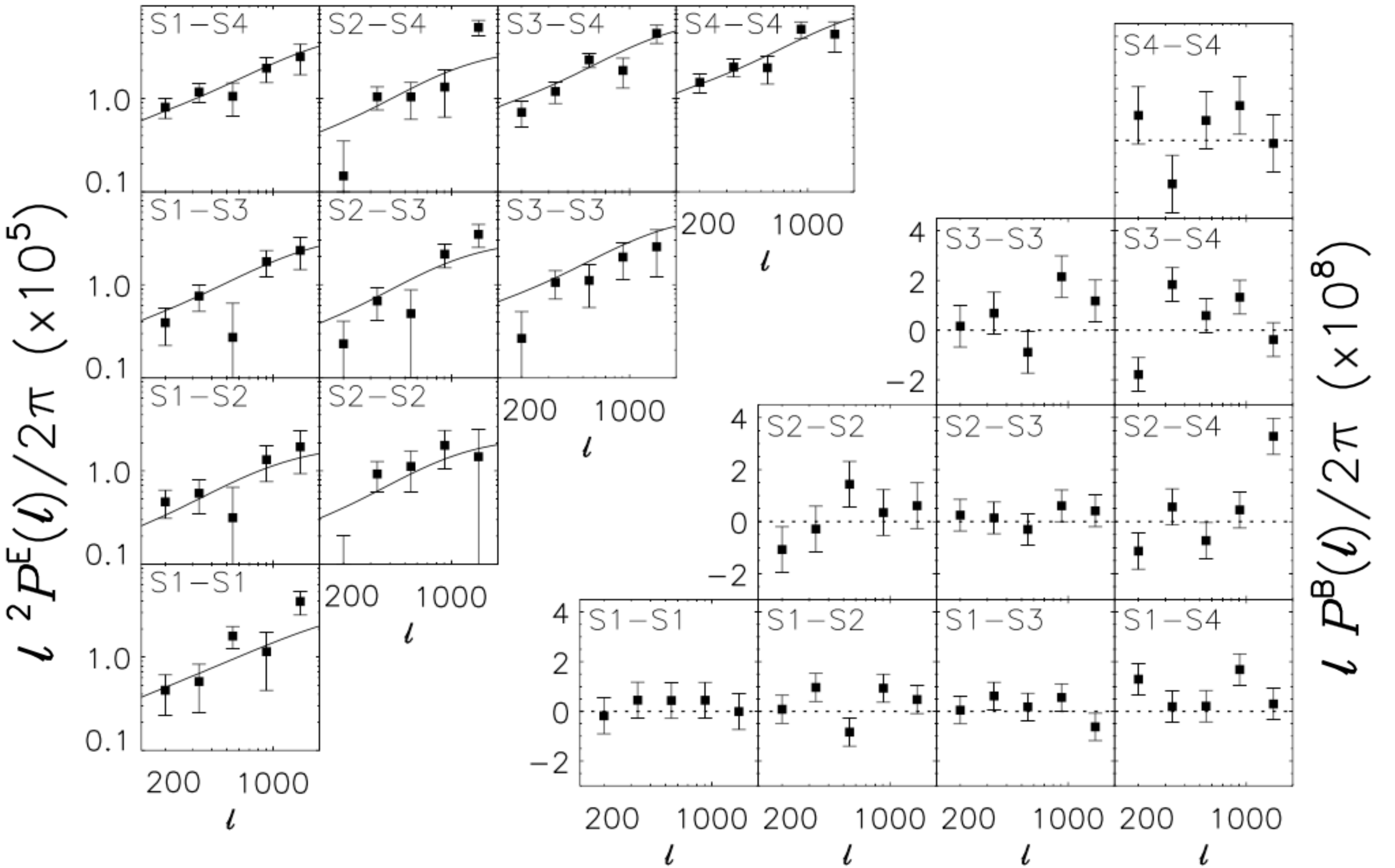
$$P(\ell) = \int \mathrm{d}\theta\, \mathrm{F}(\ell\theta)\, \xi(\theta)$$

- Practically unbiased over wide ℓ ranges

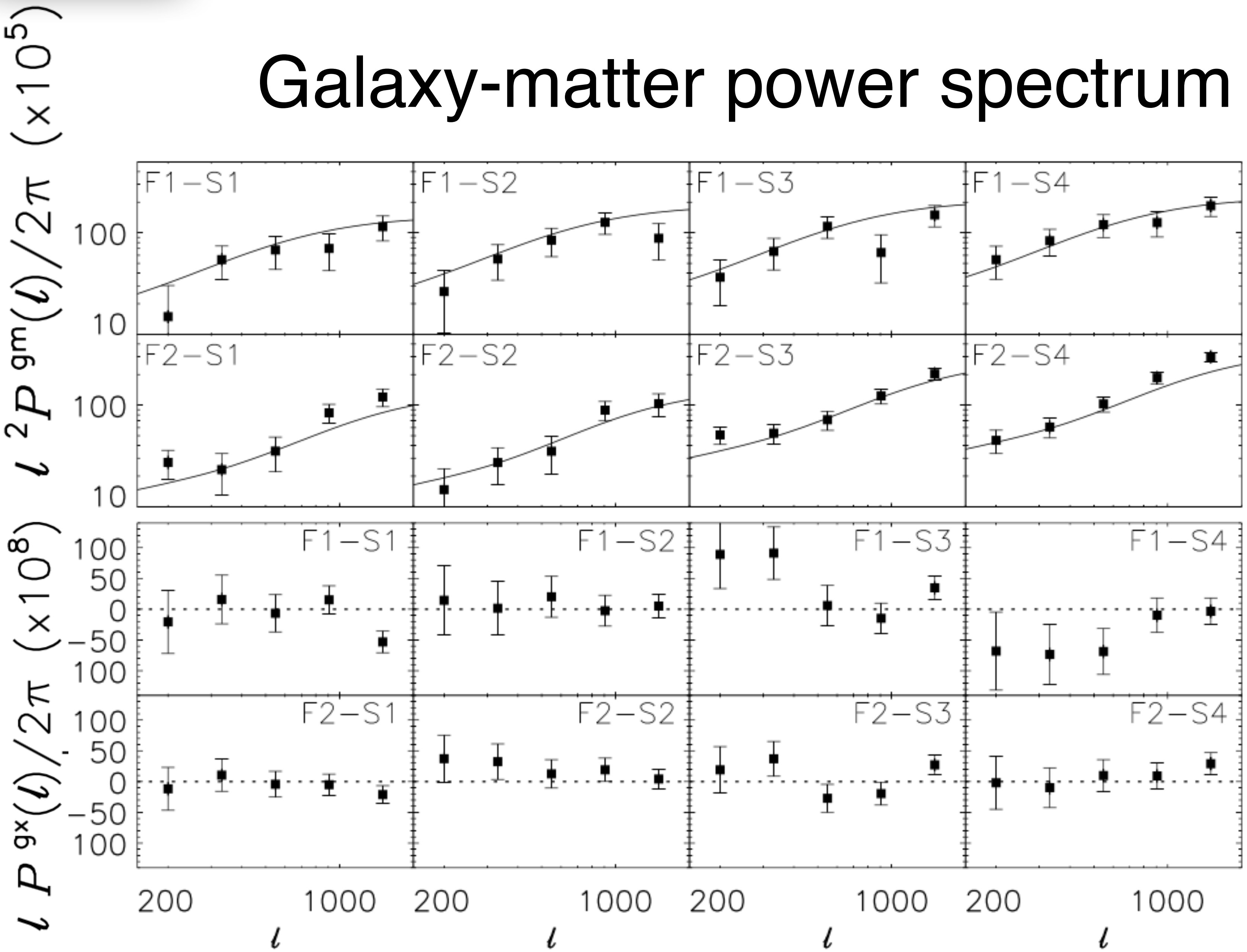
- Extended to galaxy-matter cross-correlation and angular galaxy correlation function

E-modes of cosmic shear power spectrum

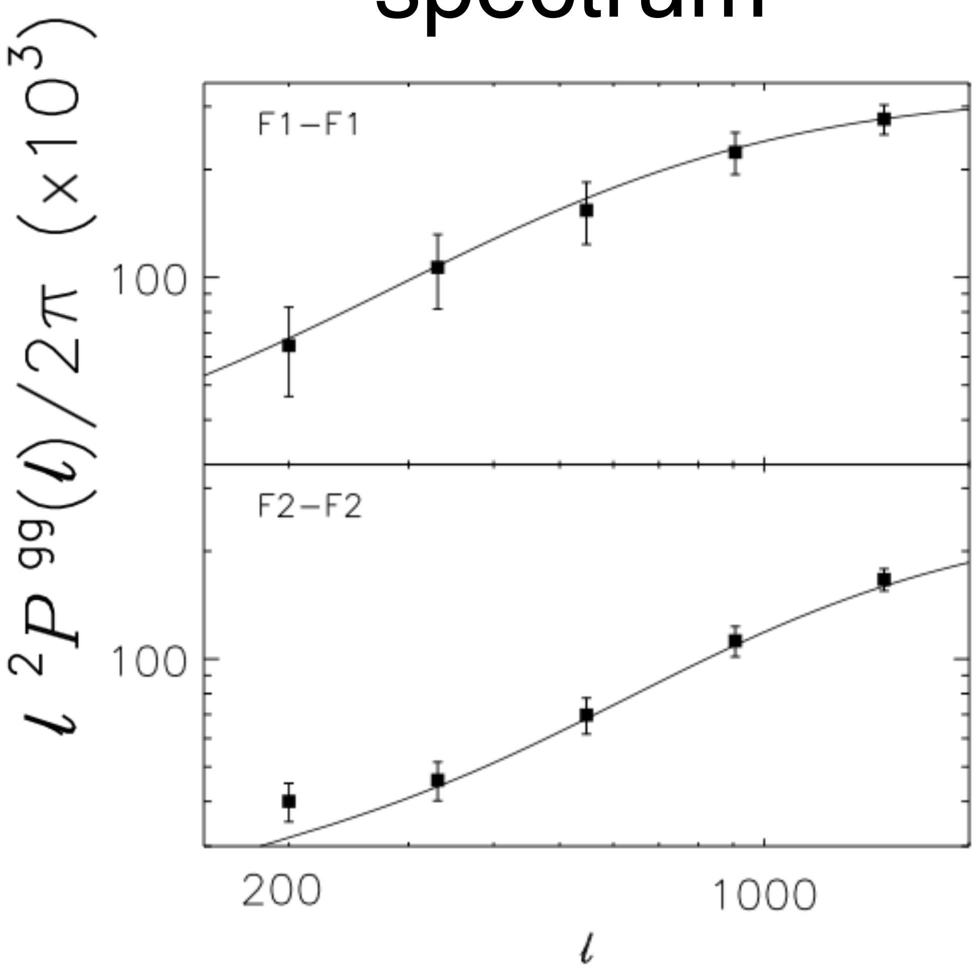
B-modes



Galaxy-matter power spectrum



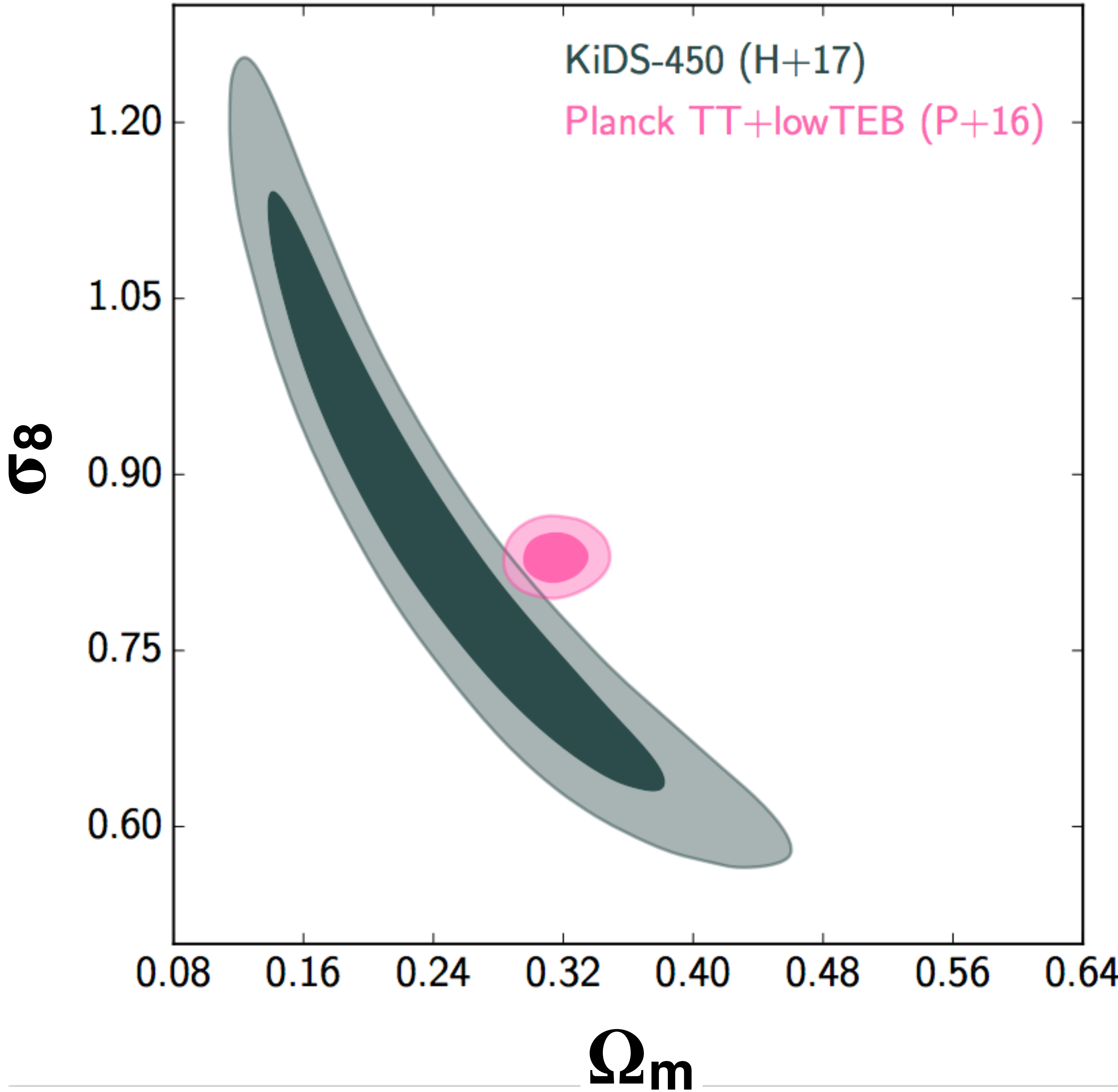
Angular power spectrum

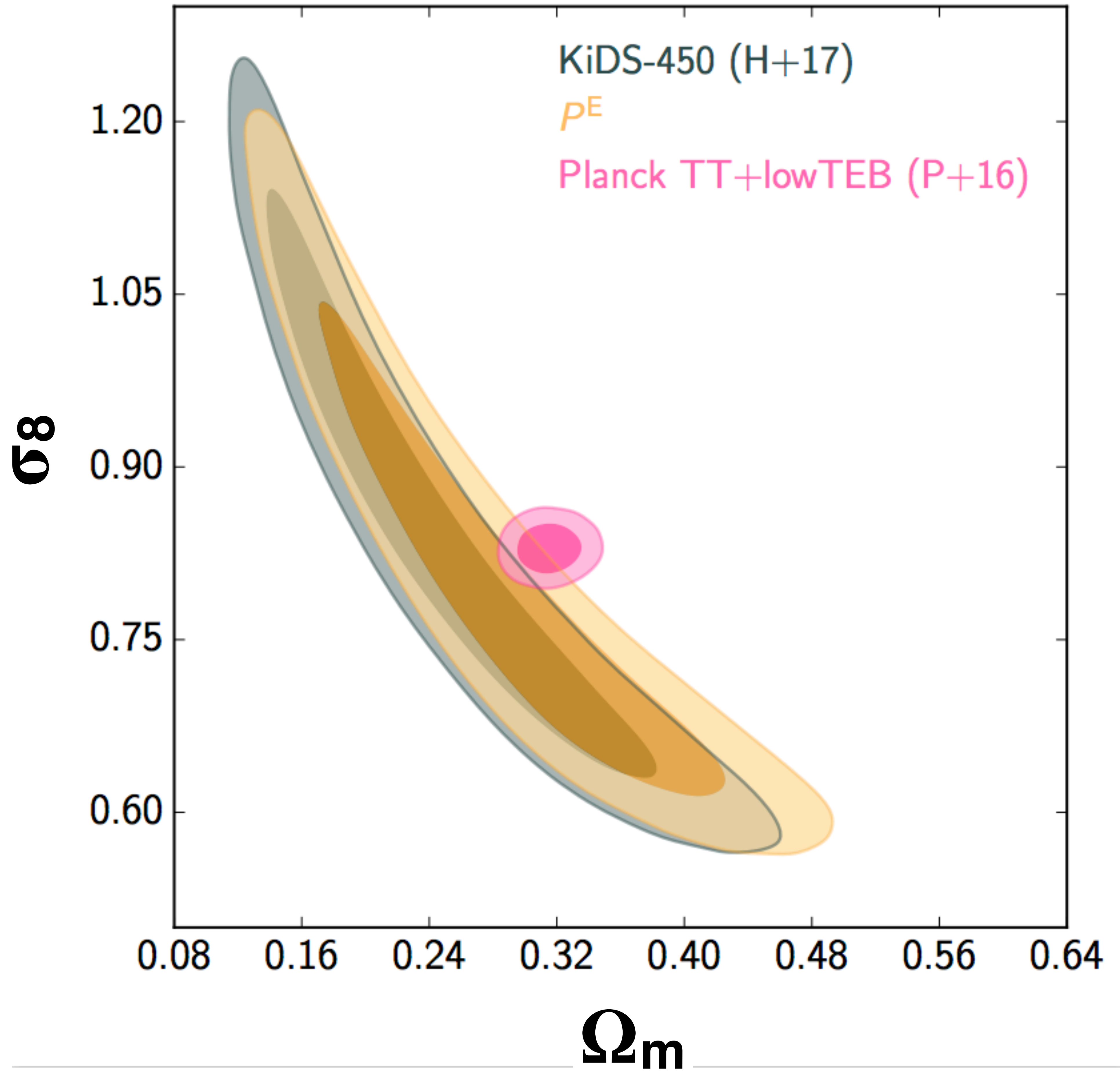


+ Analytical covariance matrix, accounts for all cross-correlations

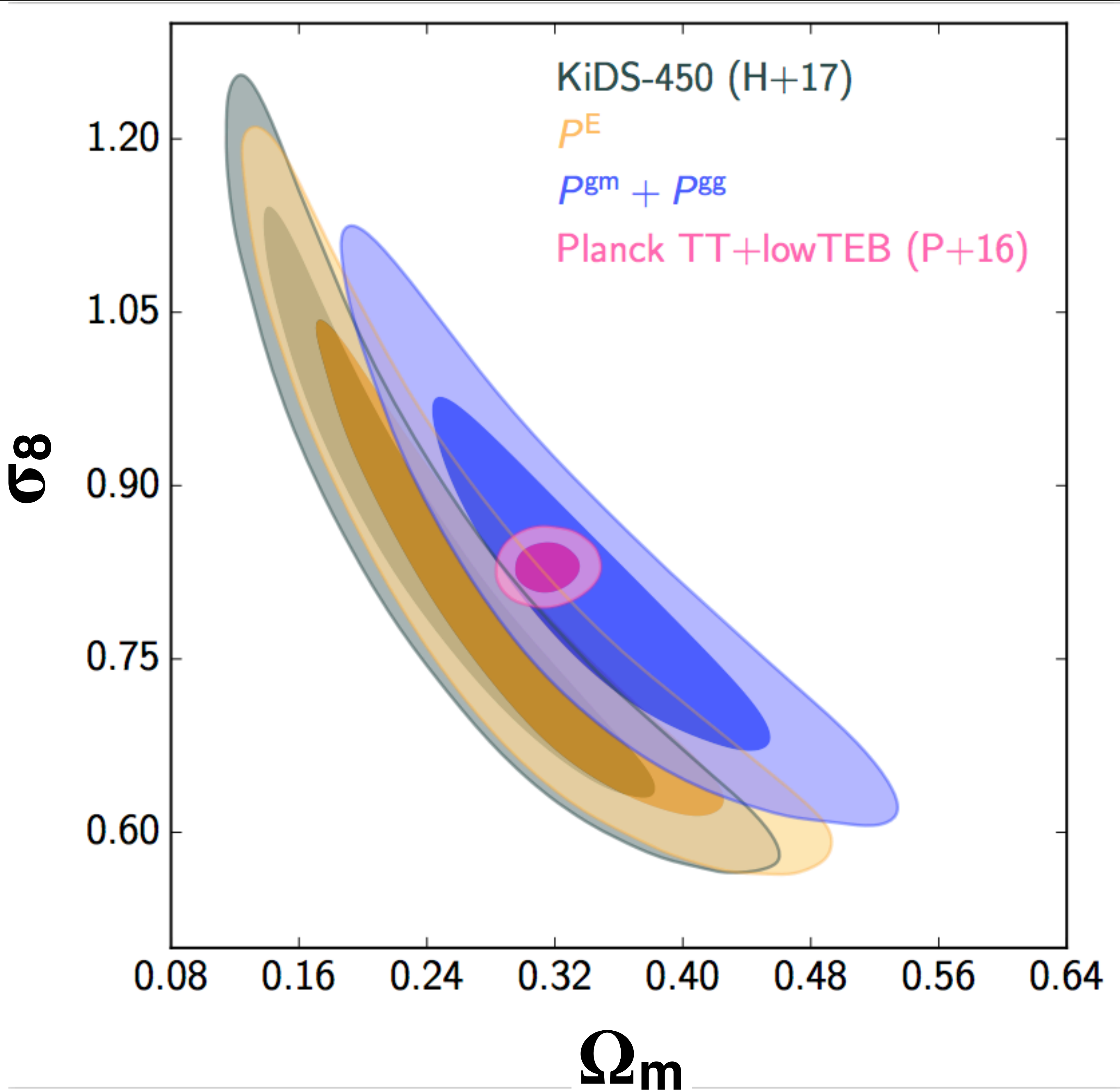
Model the signal with cosmoMC+ (Lewis & Bridle 2002)

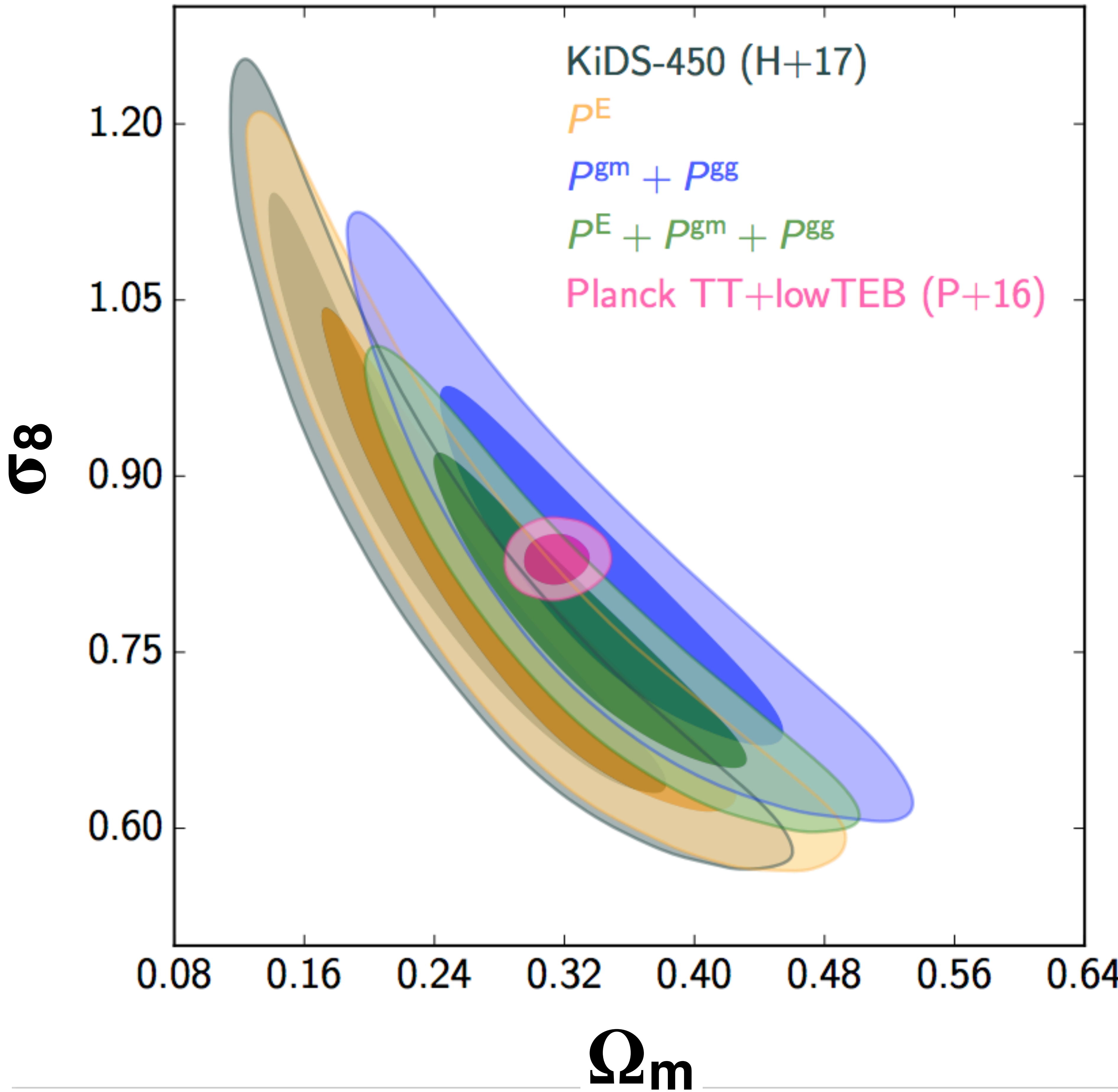
- Based on extended version of Joudaki+17
- Includes intrinsic alignment, baryonic feedback on matter power spectrum
- Simultaneously models galaxy-galaxy lensing (Joudaki+ in prep.) and clustering
- Assume a constant and scale-independent effective galaxy bias (in Fourier space)

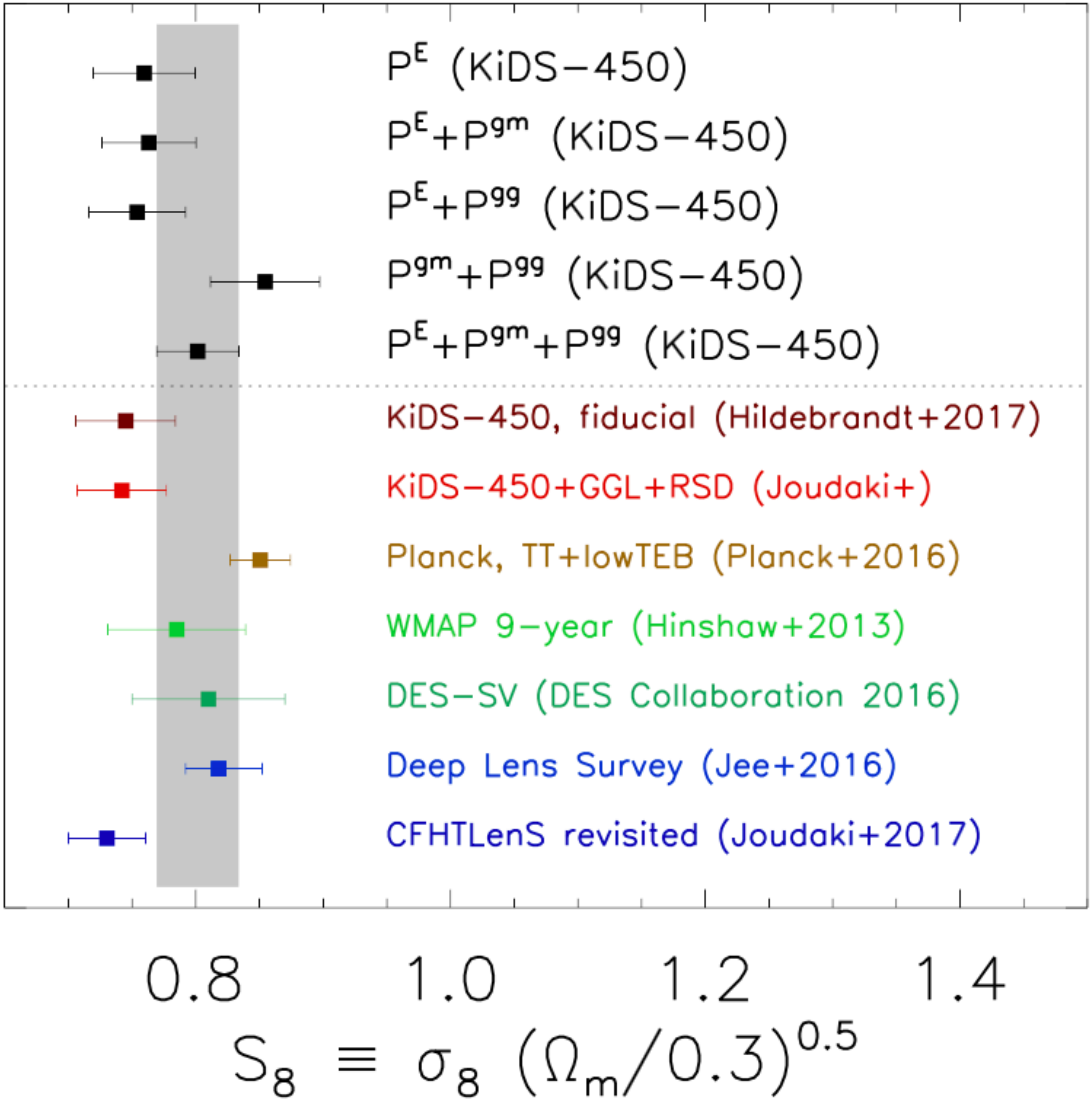

KiDS-450 (H+17)
Planck TT+lowTEB (P+16)
1.20
1.05
0.90
0.75
0.60
σ8
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
Ωm



KiDS-450 (H+17)
P^{E}
Planck TT+lowTEB (P+16)
1.20
1.05
0.90
0.75
0.60
σ_8
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
Ω_m

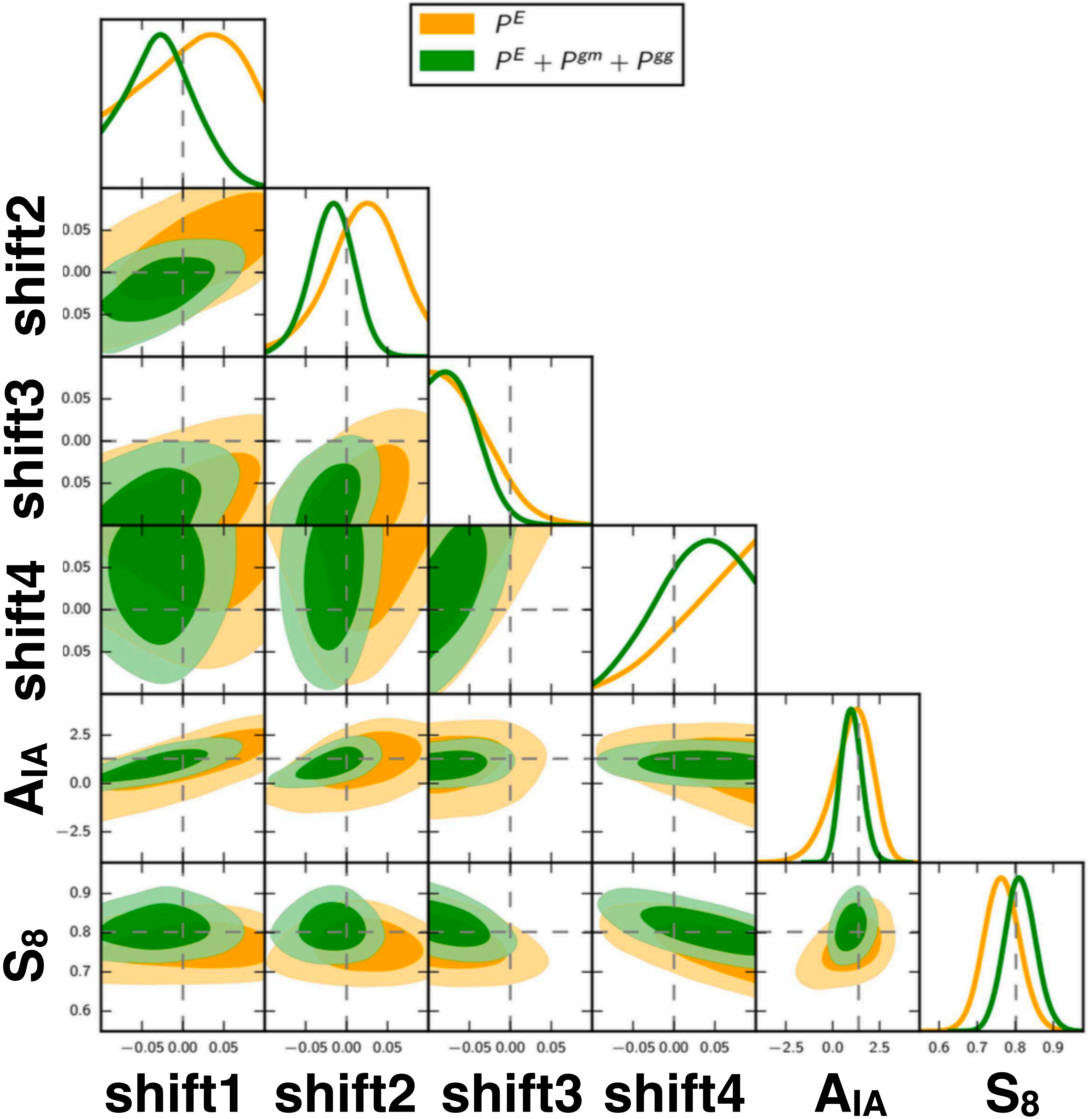

KiDS-450 (H+17)
P^{E}
$P^{gm} + P^{gg}$
Planck TT+lowTEB (P+16)
1.20
1.05
0.90
0.75
0.60
σ_8
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
Ω_m


KiDS-450 (H+17)
P^{E}
$P^{gm} + P^{gg}$
$P^{E} + P^{gm} + P^{gg}$
Planck TT+lowTEB (P+16)
1.20
1.05
0.90
0.75
0.60
σ_8
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
Ω_m

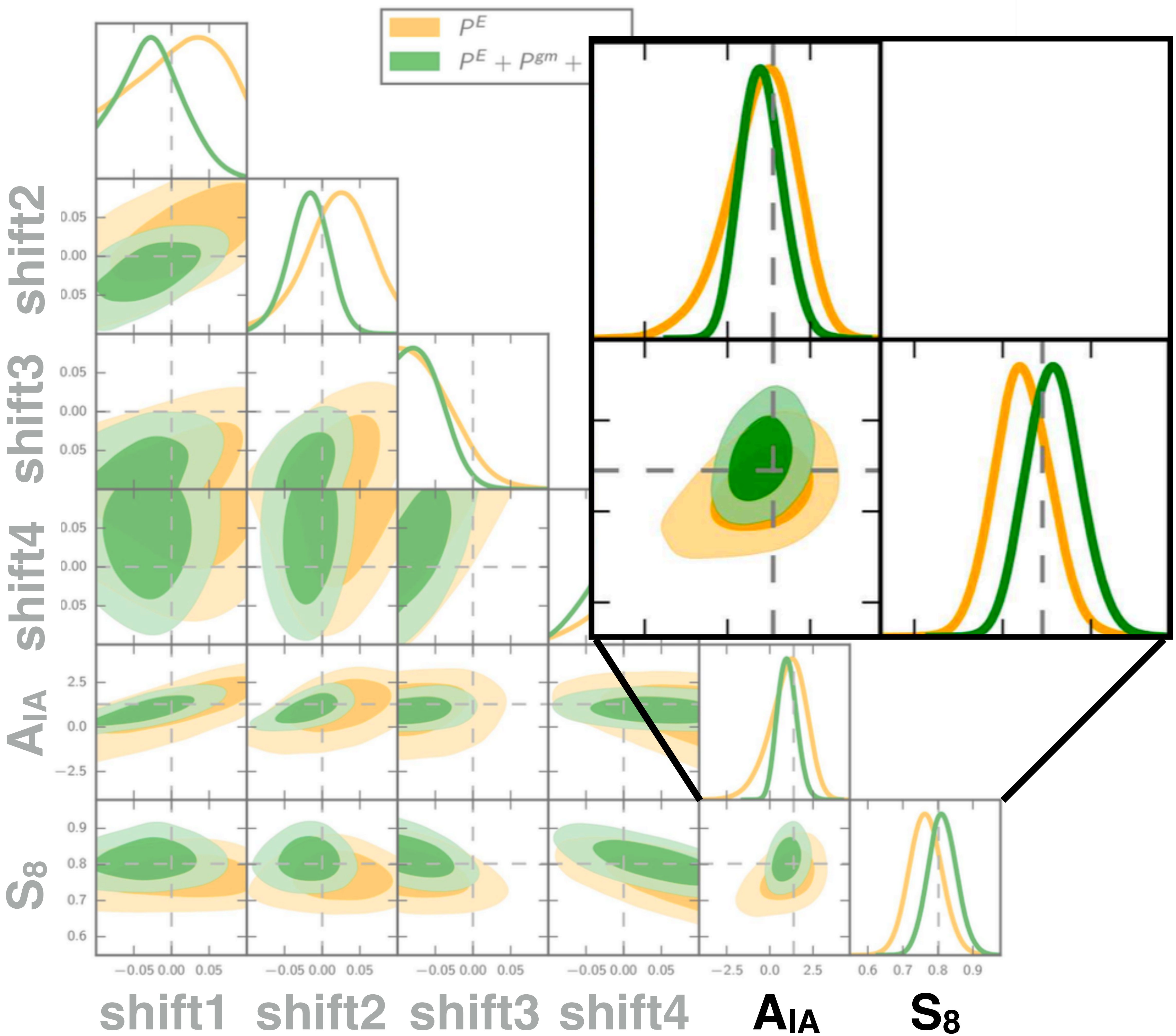

P^E (KiDS−450)
P^E+P^gm (KiDS−450)
P^E+P^gg (KiDS−450)
P^gm+P^gg (KiDS−450)
P^E+P^gm+P^gg (KiDS−450)
KiDS−450, fiducial (Hildebrandt+2017)
KiDS−450+GGL+RSD (Joudaki+)
Planck, TT+lowTEB (Planck+2016)
WMAP 9−year (Hinshaw+2013)
DES−SV (DES Collaboration 2016)
Deep Lens Survey (Jee+2016)
CFHTLenS revisited (Joudaki+2017)
0.8
1.0
1.2
1.4
$S_8 \equiv \sigma_8 (\Omega_m/0.3)^{0.5}$

One major contaminant: intrinsic alignment

- Galaxies are not randomly oriented, but align with LSS
- Biases cosmological inference if unaccounted for
- Use ‘non-linear linear alignment model’: 1 free param, $\mathbf{A_{IA}}$
- Cosmic shear and galaxy-galaxy lensing both affected: $\mathbf{A_{IA}}$ better constrained when including P^{gm} in fit


P^E
$P^E + P^{gm} + P^{gg}$
shift1
shift2
shift3
shift4
A_{IA}
S_8
−0.05 0.00 0.05
−2.5 0.0 2.5
0.6 0.7 0.8 0.9

KiDS



P^E
$P^E + P^{gm} +$
shift2
shift3
shift4
A_{IA}
S_8
0.05
0.00
0.05
2.5
0.0
−2.5
0.9
0.8
0.7
0.6
−0.05 0.00 0.05
−2.5 0.0 2.5
0.6 0.7 0.8 0.9
shift1
shift2
shift3
shift4
A_{IA}
S_8

KiDS

UCL

Joint analysis of three cosmological probes with KiDS+GAMA

- Including P^{gm}+P^{gg}: error on $S_8 = \sigma_8 (\Omega_m/0.3)^{0.5}$ shrinks 21%
- Results consistent with Planck and fiducial KiDS-450

Benefits of self-calibration:

- Optimally exploit the data
- Self-consistently model & marginalise over nuisance parameters
- Improve your cosmology constraints and learn about astrophysics

More details in arxiv:1706.05004

vuitert@ucl.ac.uk