Cosmology with the Kilo-Degree Survey

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Corfu

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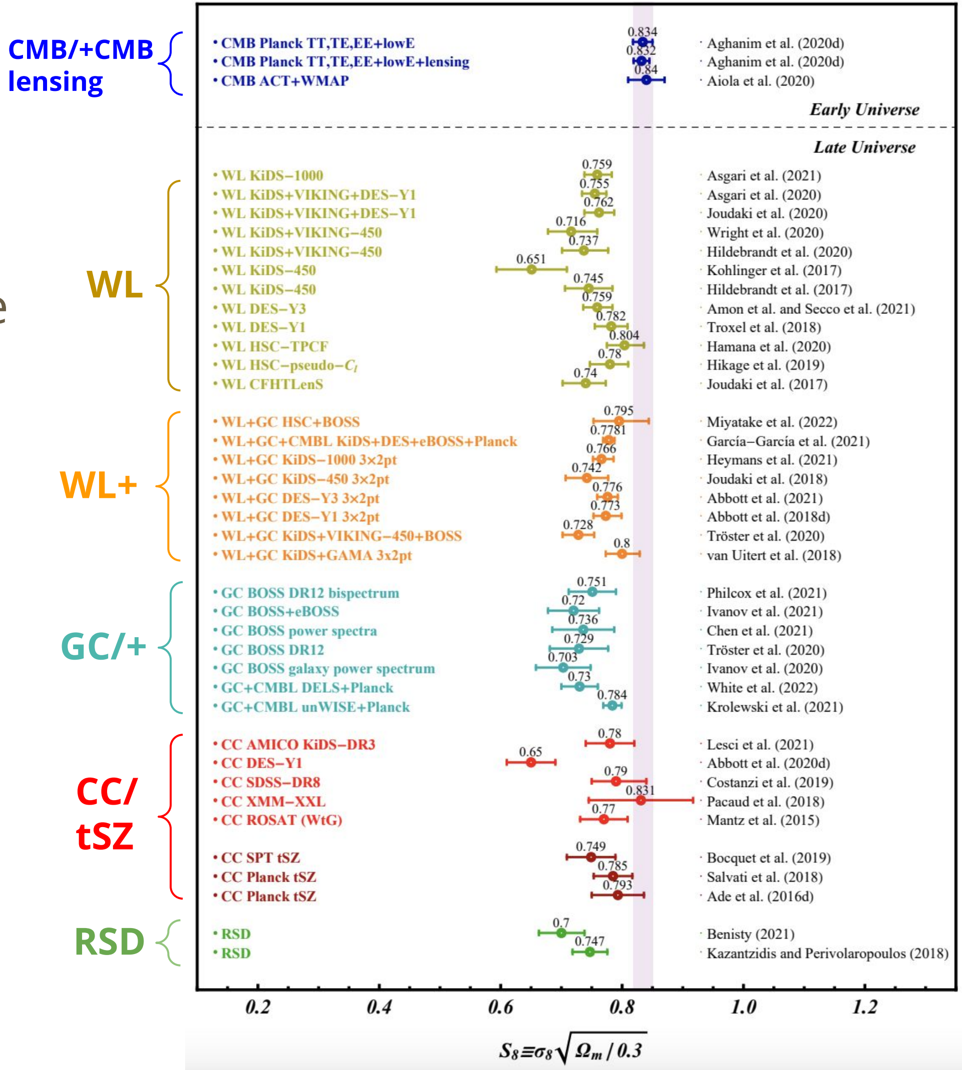
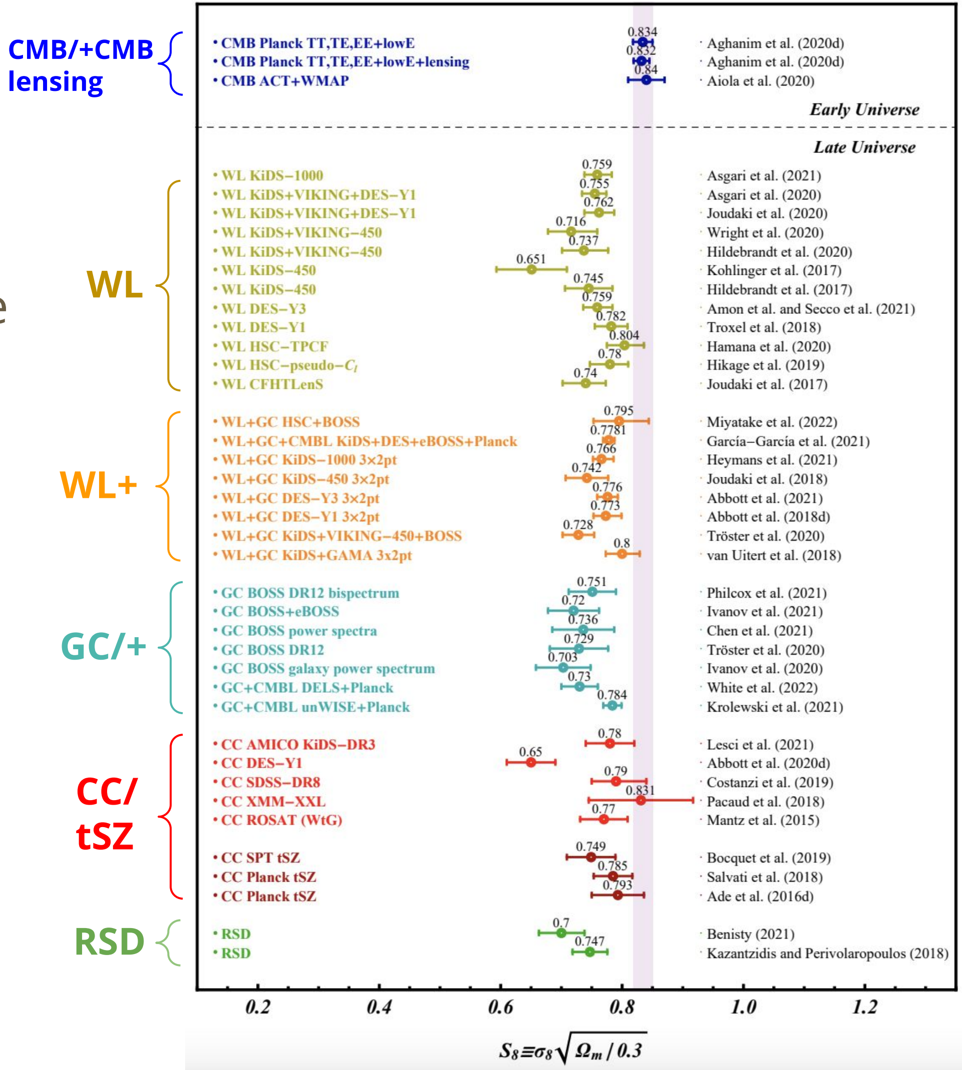
A summary of recent measurements

- See the Cosmology Intertwined white paper: 2203.06142



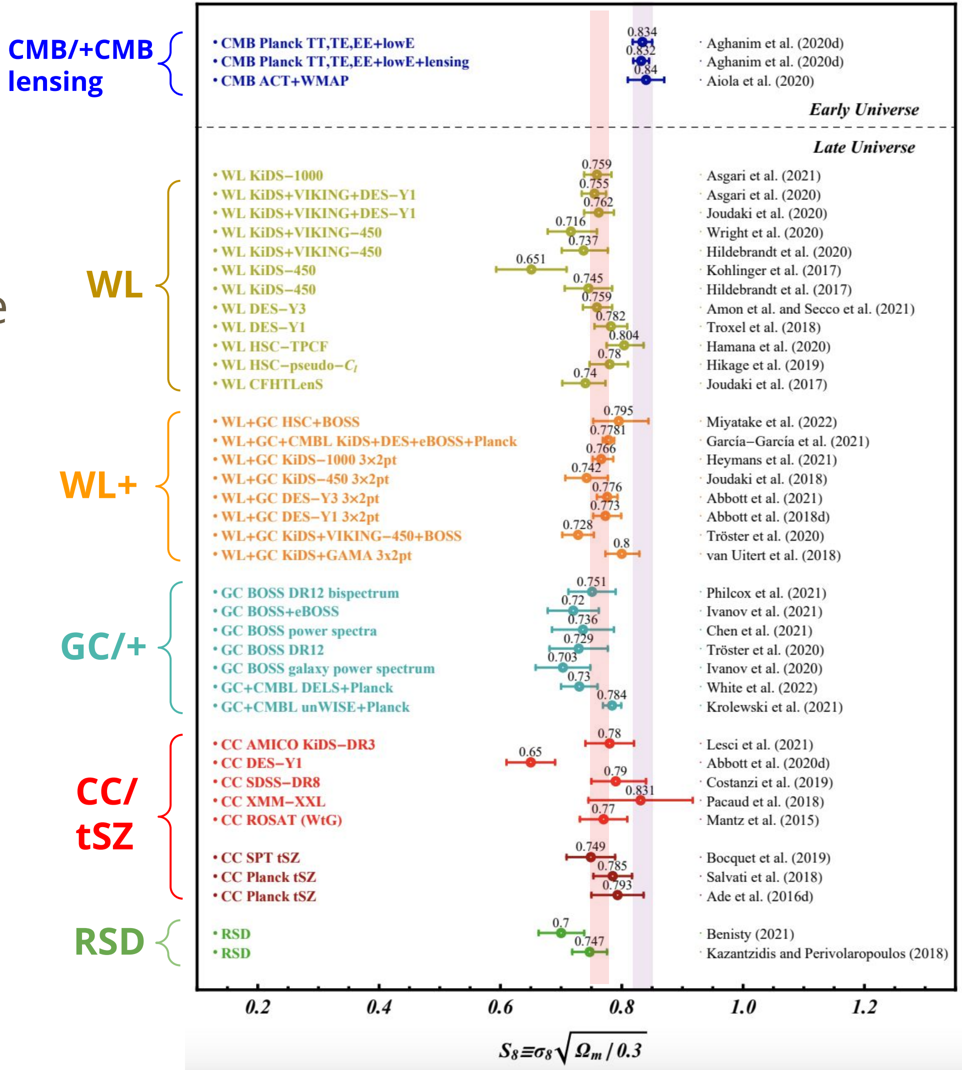
Is there really a tension?

- See the Cosmology Intertwined white paper: 2203.06142
- Early Universe measurements are higher



Is there really a tension?

- See the Cosmology Intertwined white paper: 2203.06142
- Early Universe measurements are higher
- Orange shaded region: my guesstimated combined S8 region from late Universe, to guide the eye.

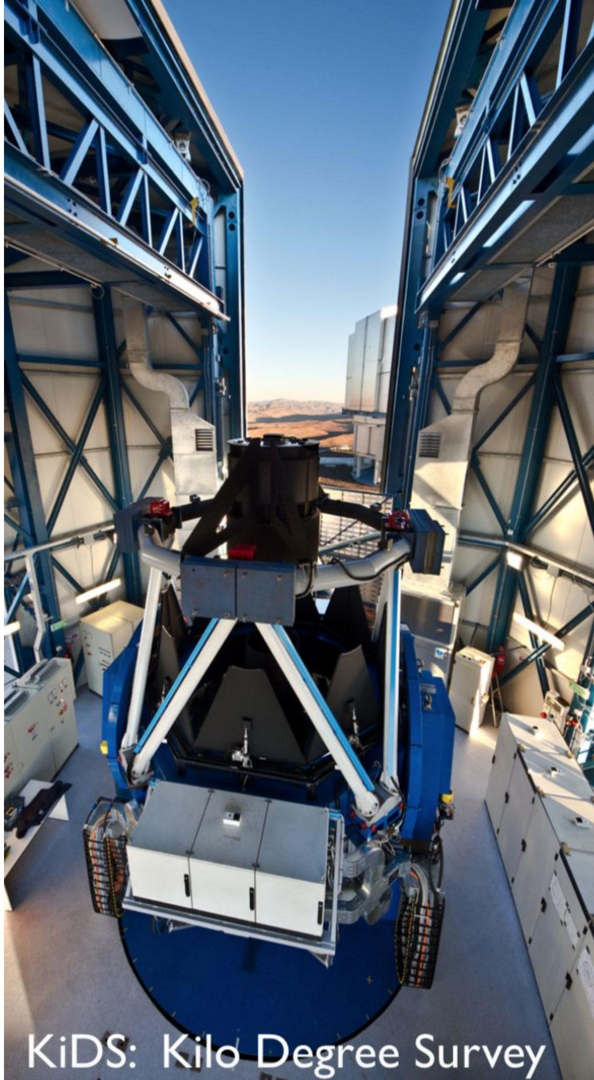


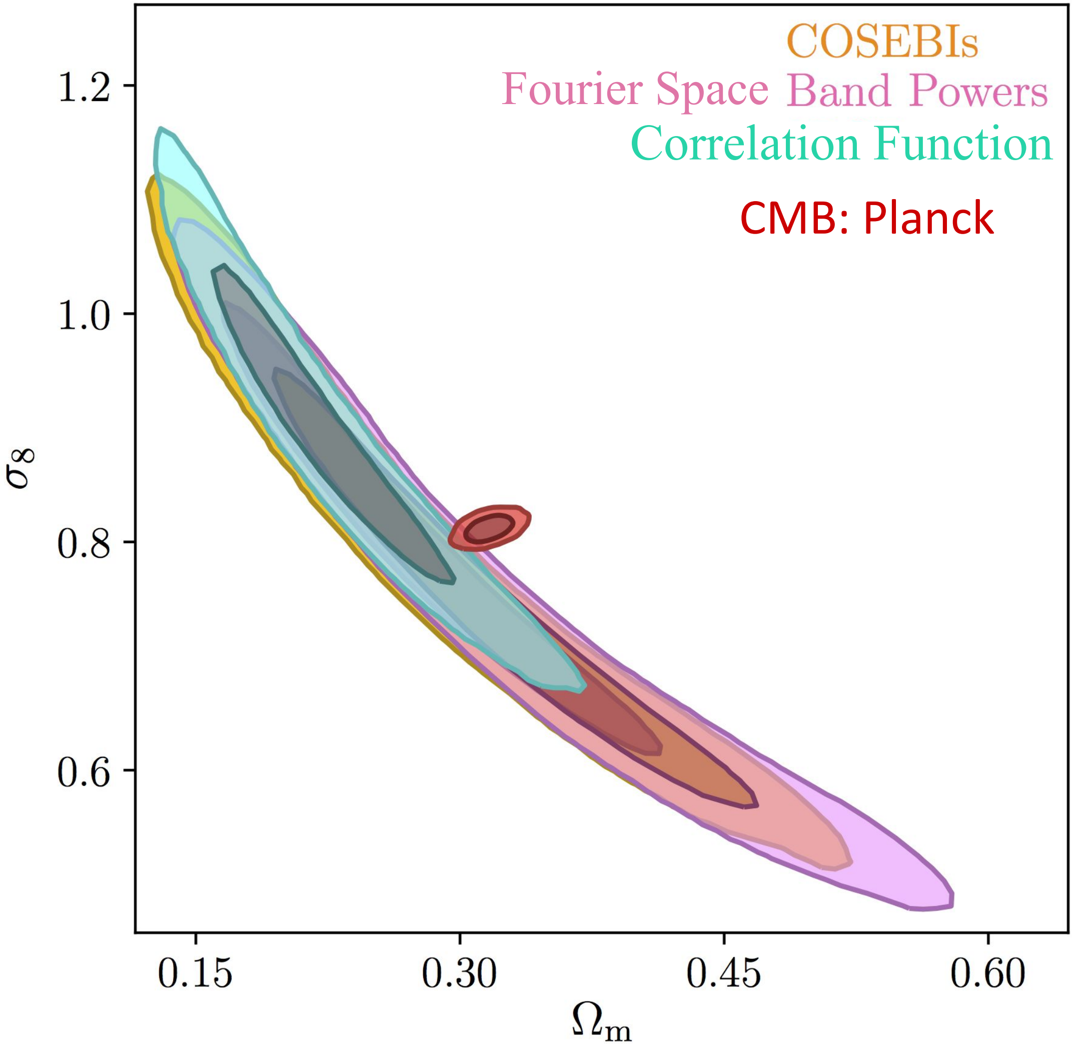
KiDS: Key Facts

- Weak lensing specific survey
- r-band with a mean seeing of 0.7" → Good shapes
- KiDS+VIKING: 9 photometric bands → Good redshifts

- 1000 deg^2 analysed
- 21 million galaxies

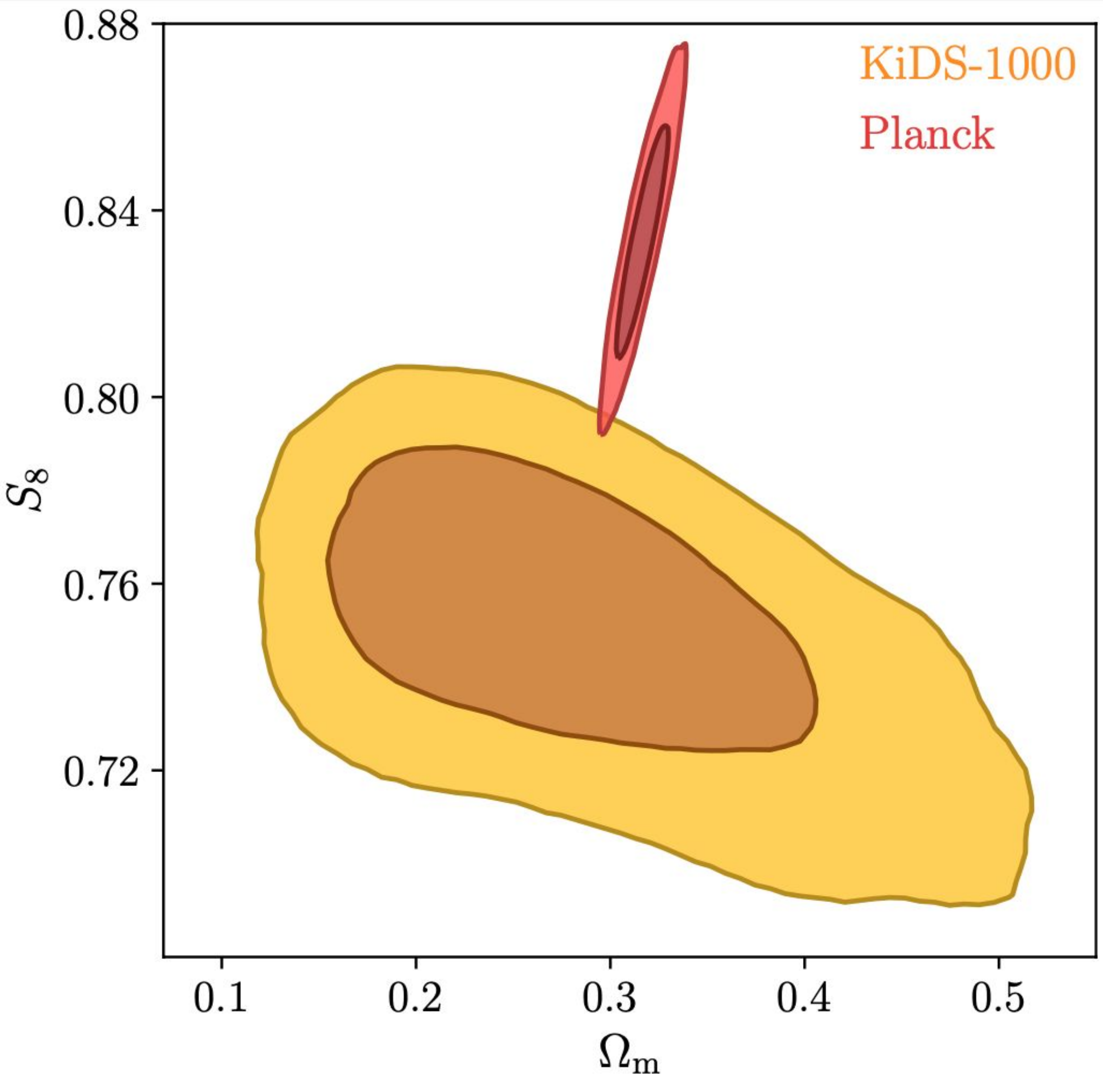
- Completed: 1350 deg^2





KiDS-1000 Cosmic Shear a blinded analysis

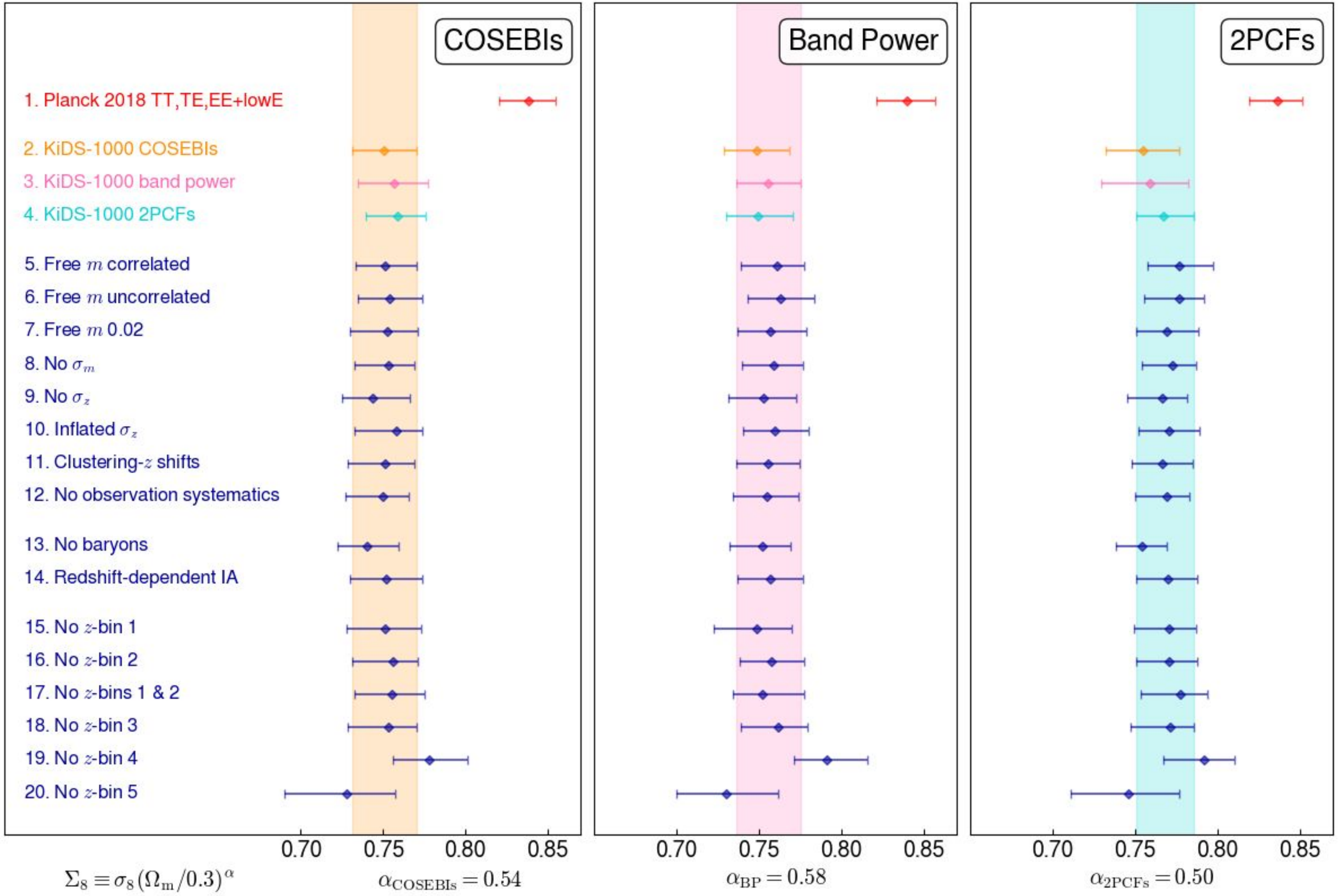
Asgari, Lin, Joachimi et al. 2021



$$S_8 = \sigma_8 \sqrt{\Omega_m / 0.3}$$

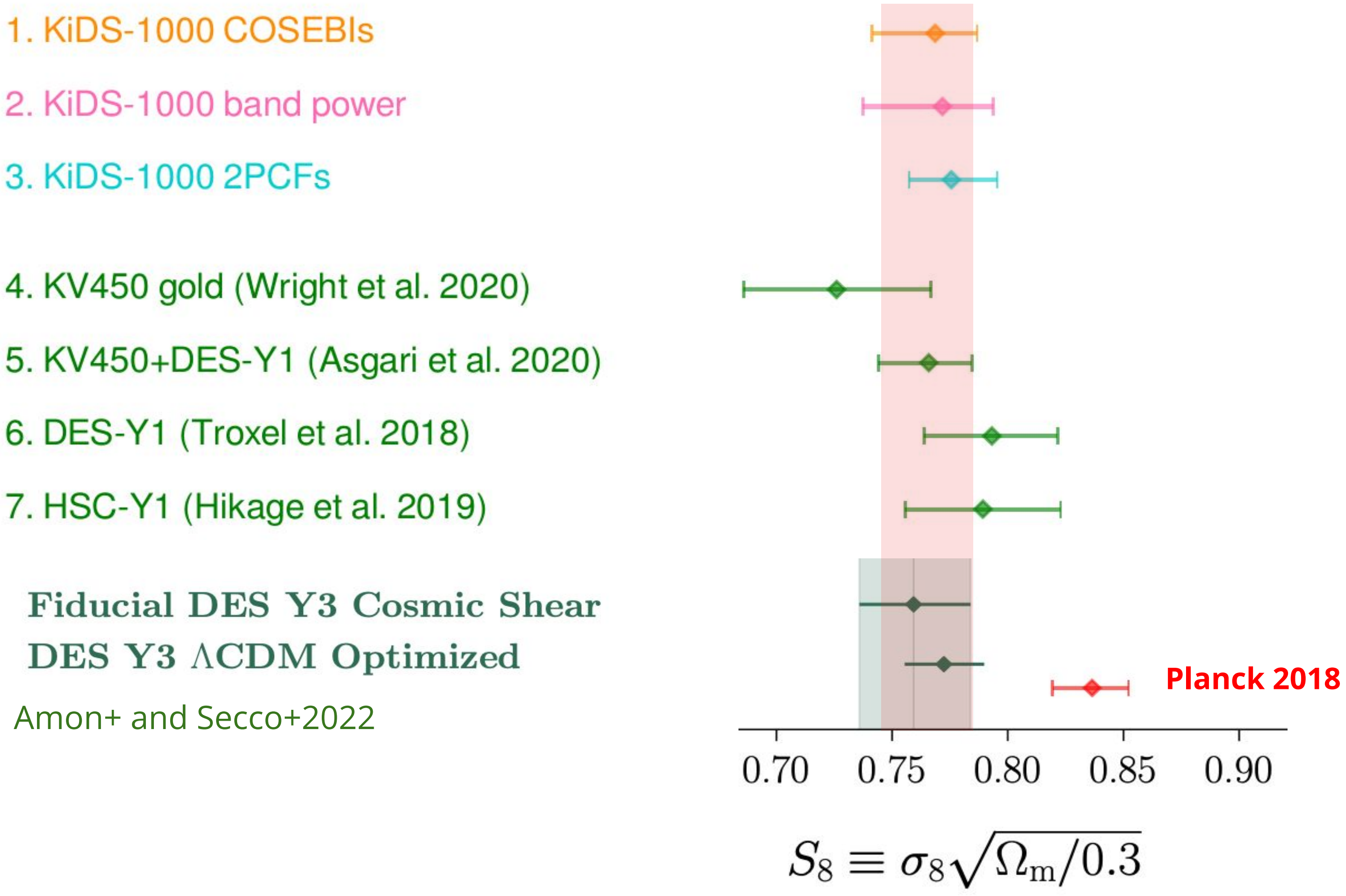
More than 3σ tension in S_8

Asgari, Lin, Joachimi et al. 2021



Asgari, Lin, Joachimi et al. 2020

Concordance between cosmic shear analysis

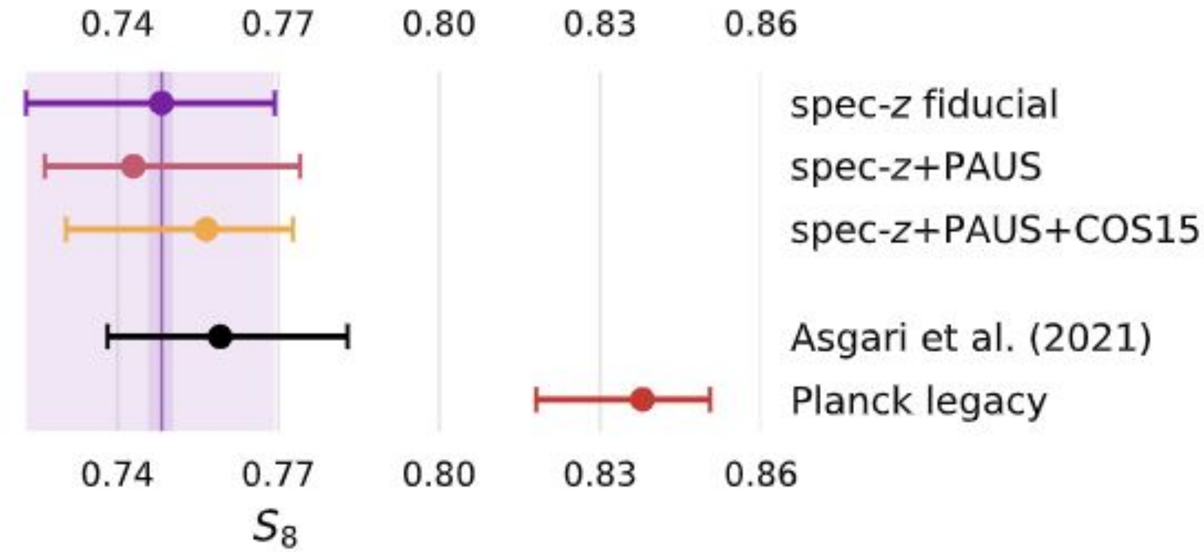


Amon+ and Secco+2022

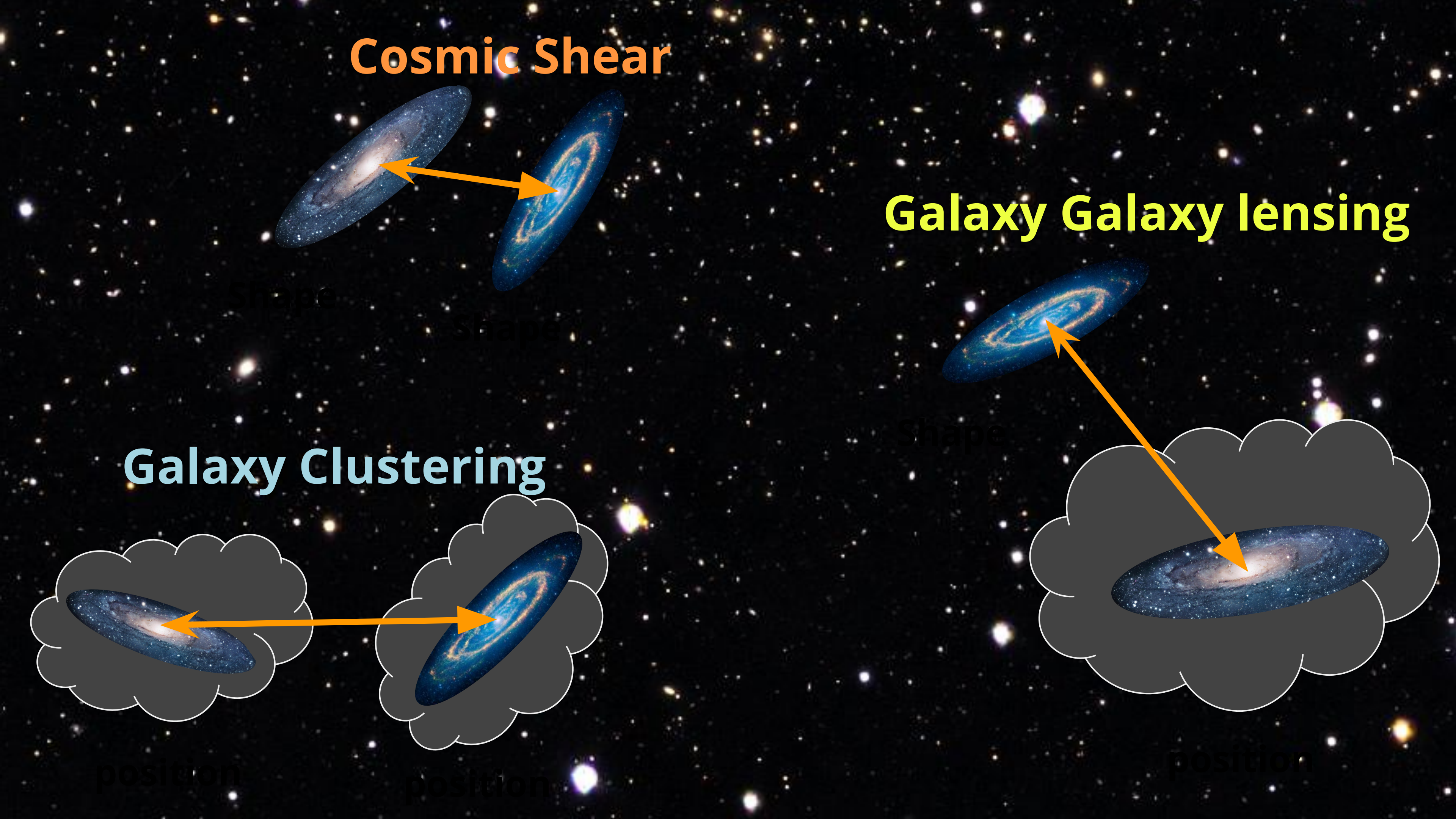
KiDS-1000 cosmic shear (PRESENT)

KiDS-1000 cosmic shear with larger redshift calibration samples

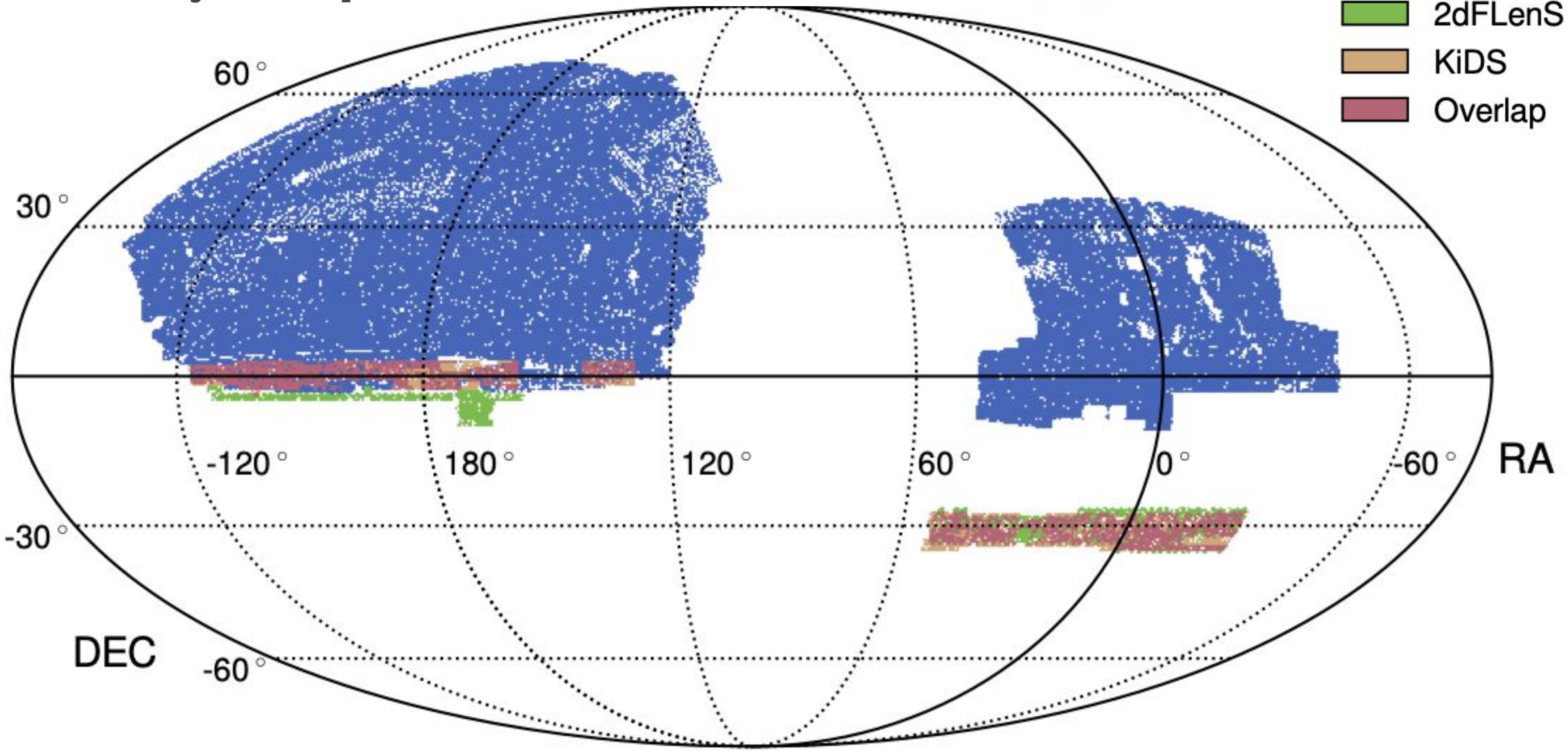
- Doubled spec-z calibration set
- Combined with precision photometric samples: COSMOS and PAUS
- Note: the samples are not identical



van den Busch et al. (2022): 2204.02396


Cosmic Shear
Galaxy Galaxy lensing
Galaxy Clustering

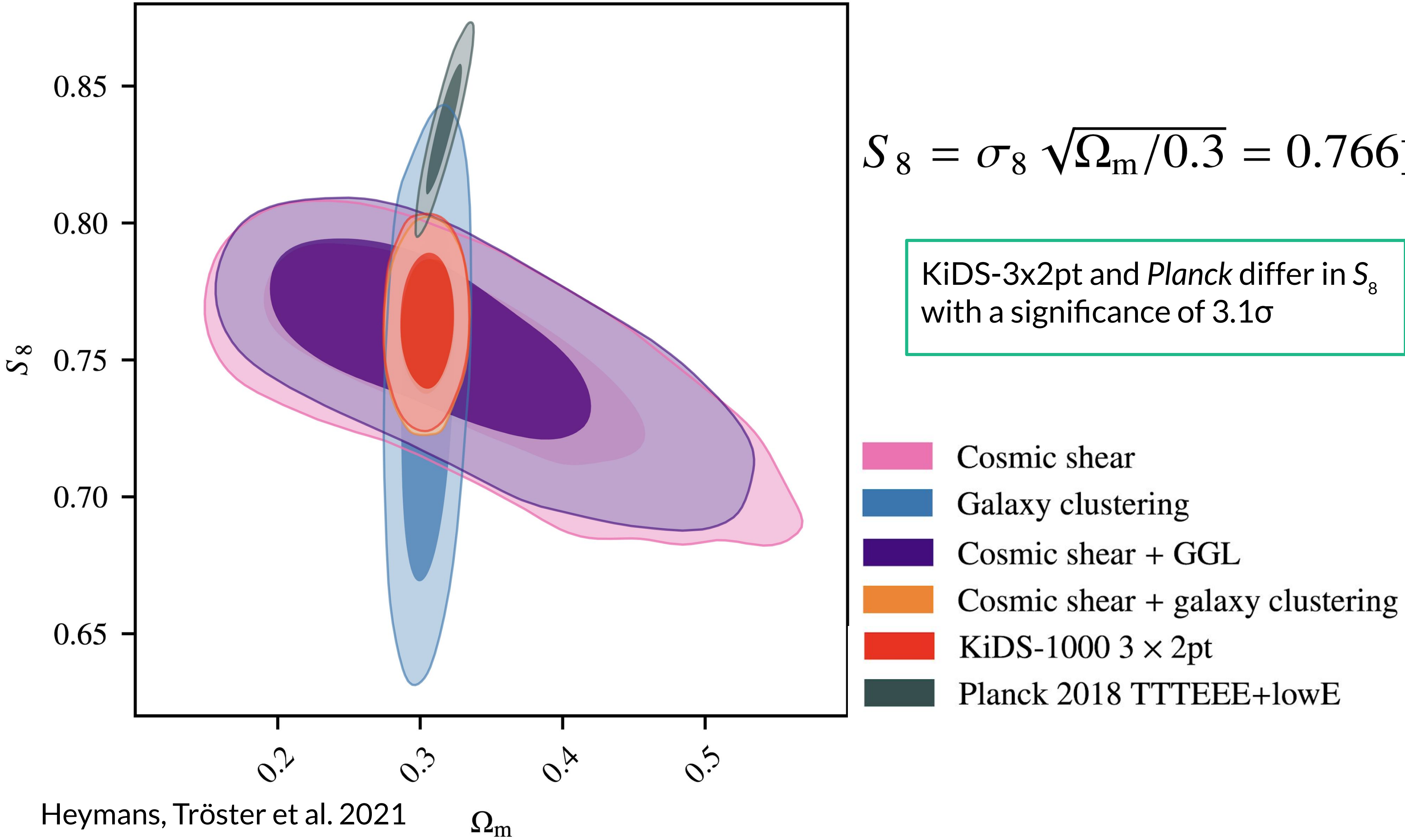
Survey Footprint



Joachimi, Lin, Asgari, Tröster, Heymans et al. 2021

$$S_8 = \sigma_8 \sqrt{\Omega_m/0.3} = 0.766^{+0.020}_{-0.014}$$

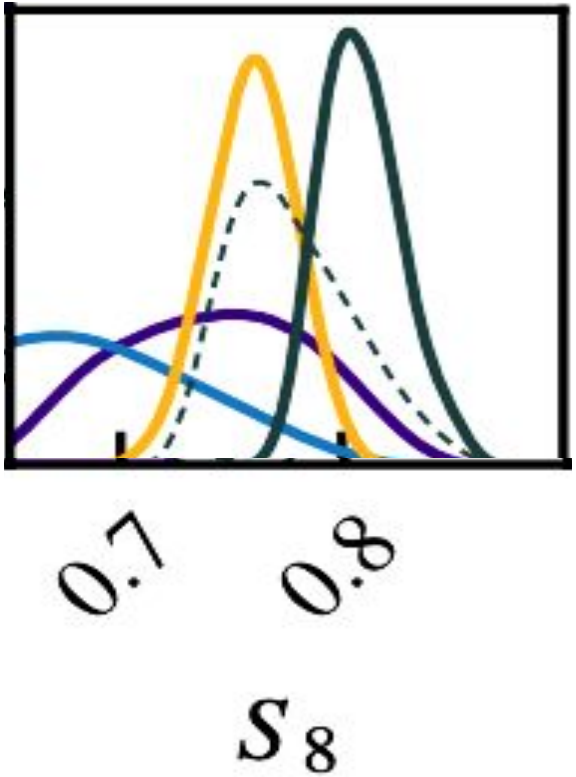
KiDS-3x2pt and *Planck* differ in S_8 with a significance of 3.1σ

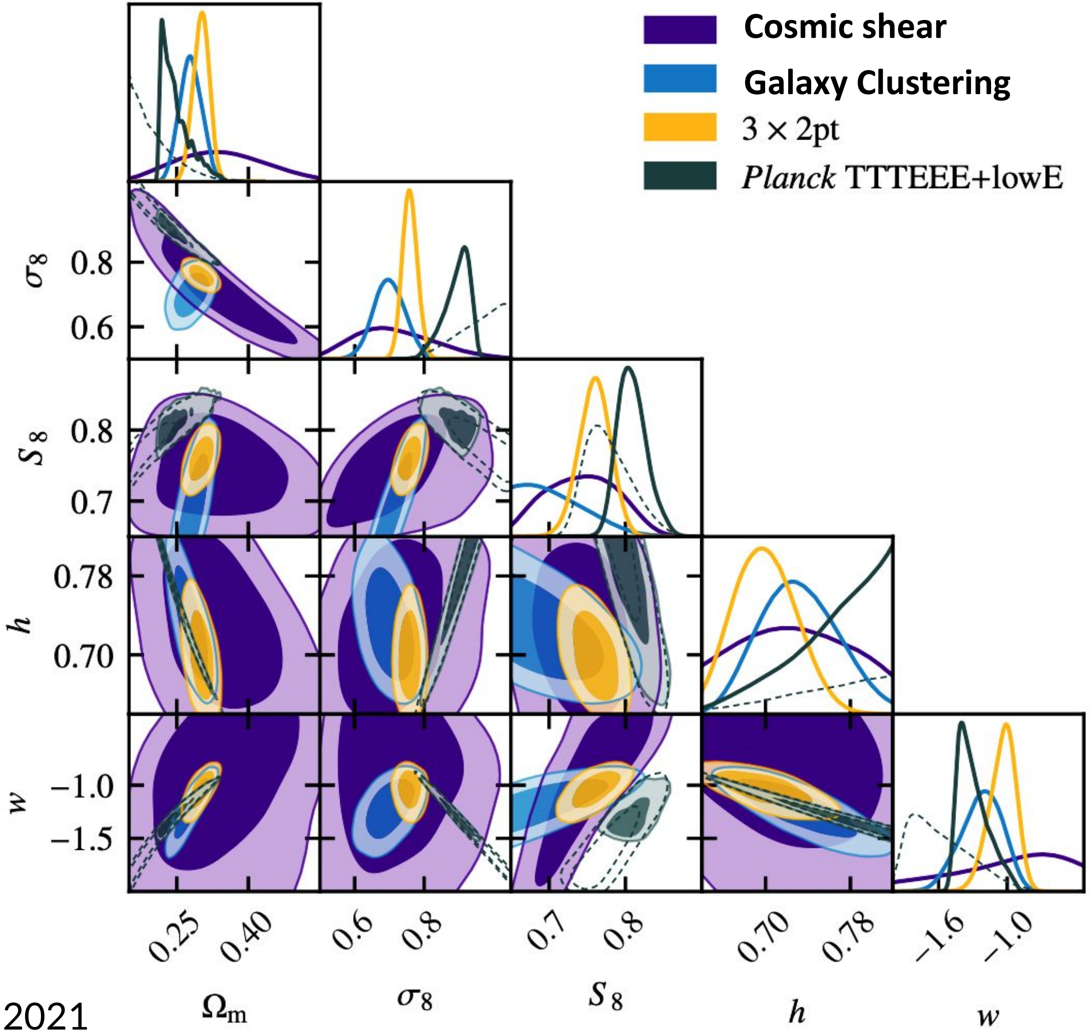


Heymans, Tröster et al. 2021

Extended models: wCDM

Tension in S8 is reduced. But …





Tröster et al. 2021

Extended models: wCDM

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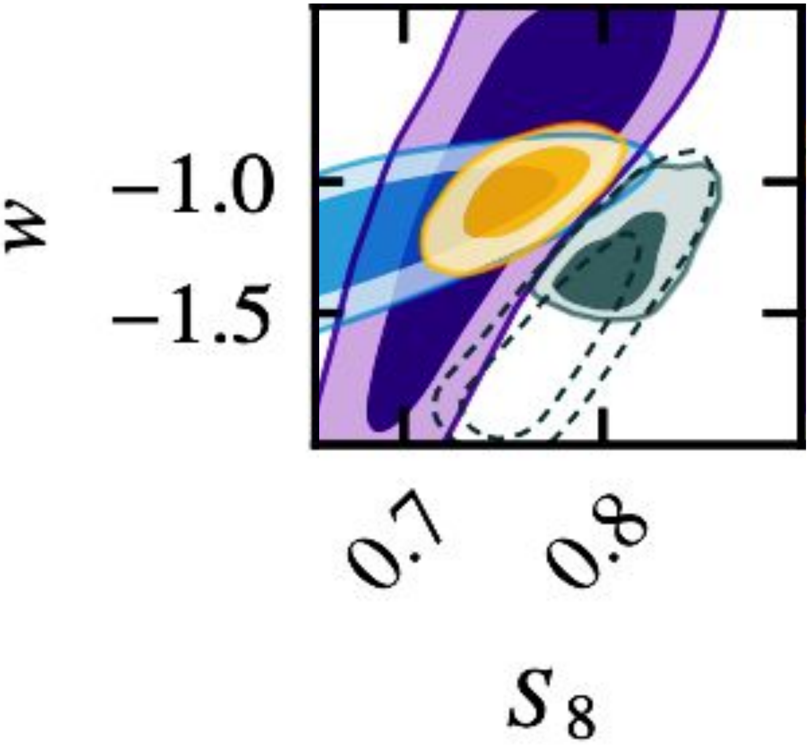
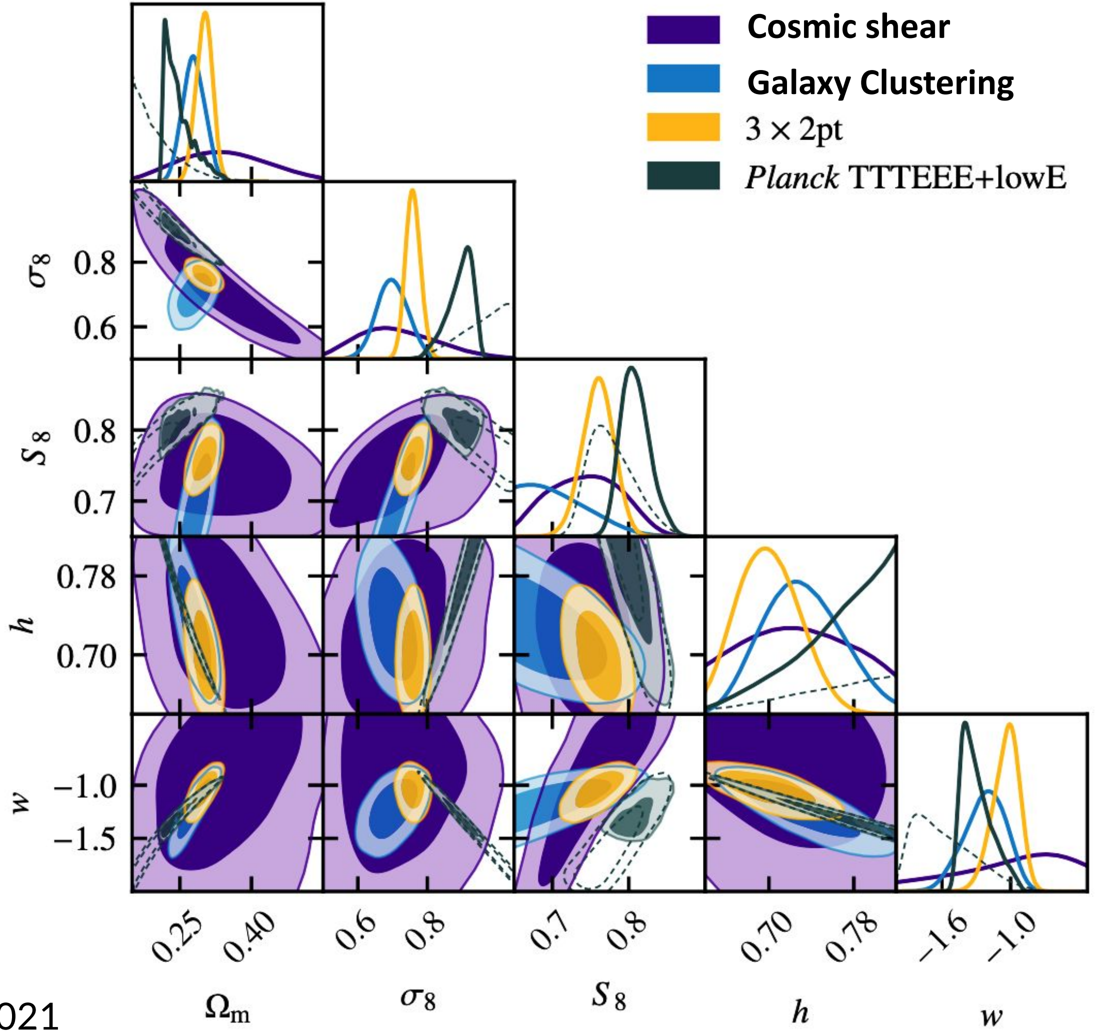
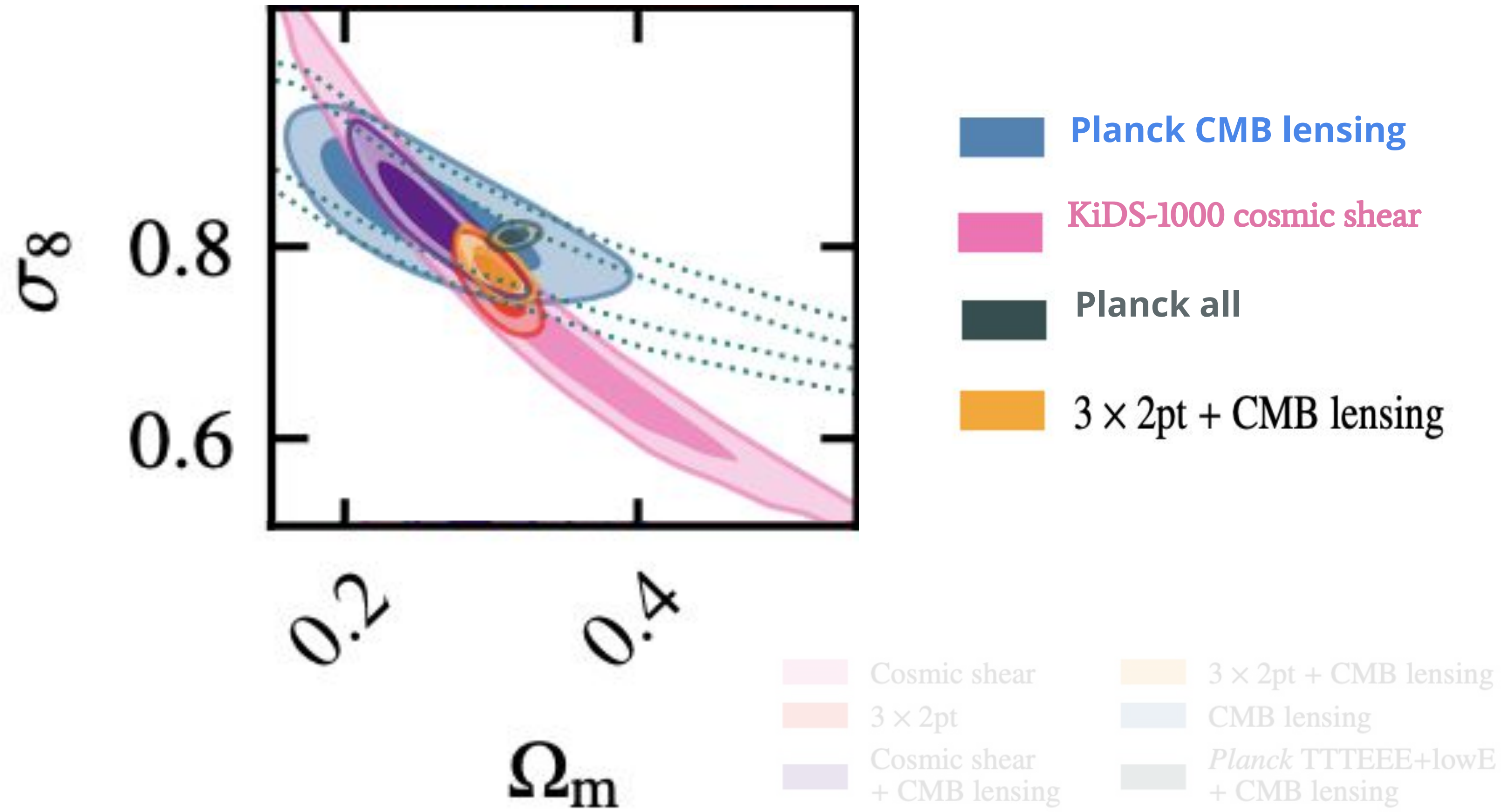




Tröster et al. 2021

What about CMB lensing?



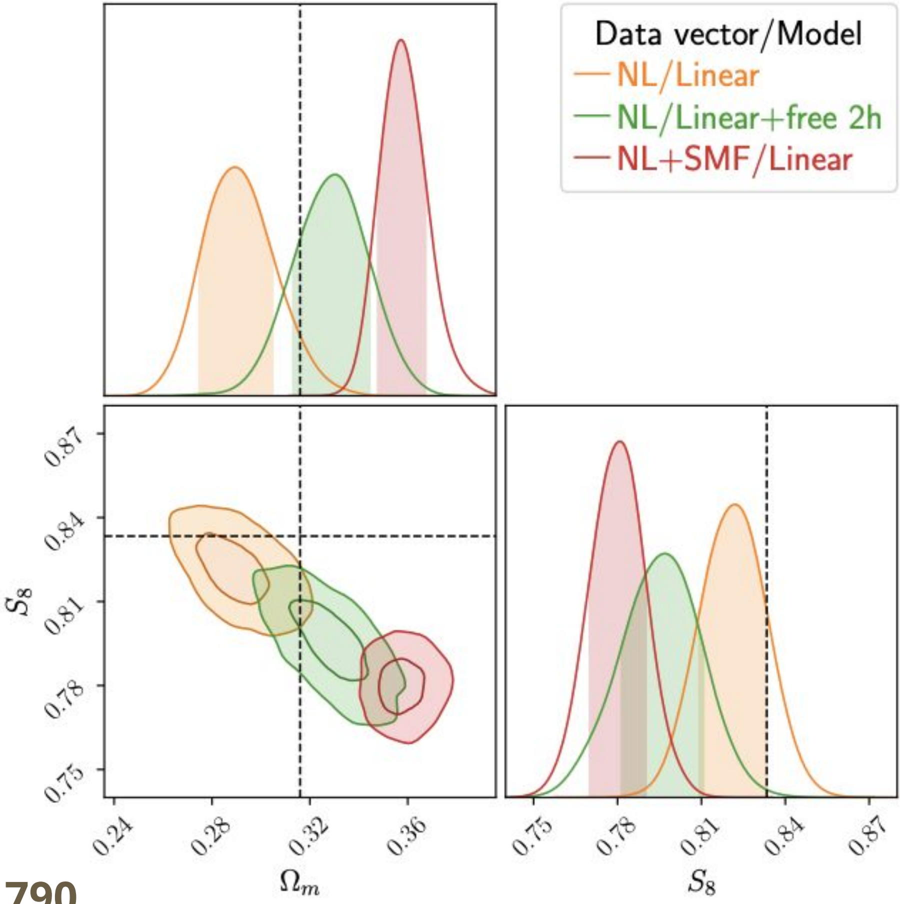
Tröster et al. 2021: KiDS-1000 extended cosmologies paper

KiDS-Legacy (FUTURE)

- ~350 square degrees of extra data (~17% smaller errors)
- Possible addition of a high redshift bin (+35% smaller errors*)
- Two shear measurement methods
- Multiband image simulations
- …

Towards a KiDS only 3x2pt: Non-linear halo bias (Future)

- Halos do not follow matter dist linearly
- Non-linear halo bias measured from the Dark Emulator (Nishimichi+2019)
- Forecast for a KiDS-like survey using Galaxy clustering + GGL



Mahony et al. (2022): 2202.01790

KiDS only 2x2pt+ analysis

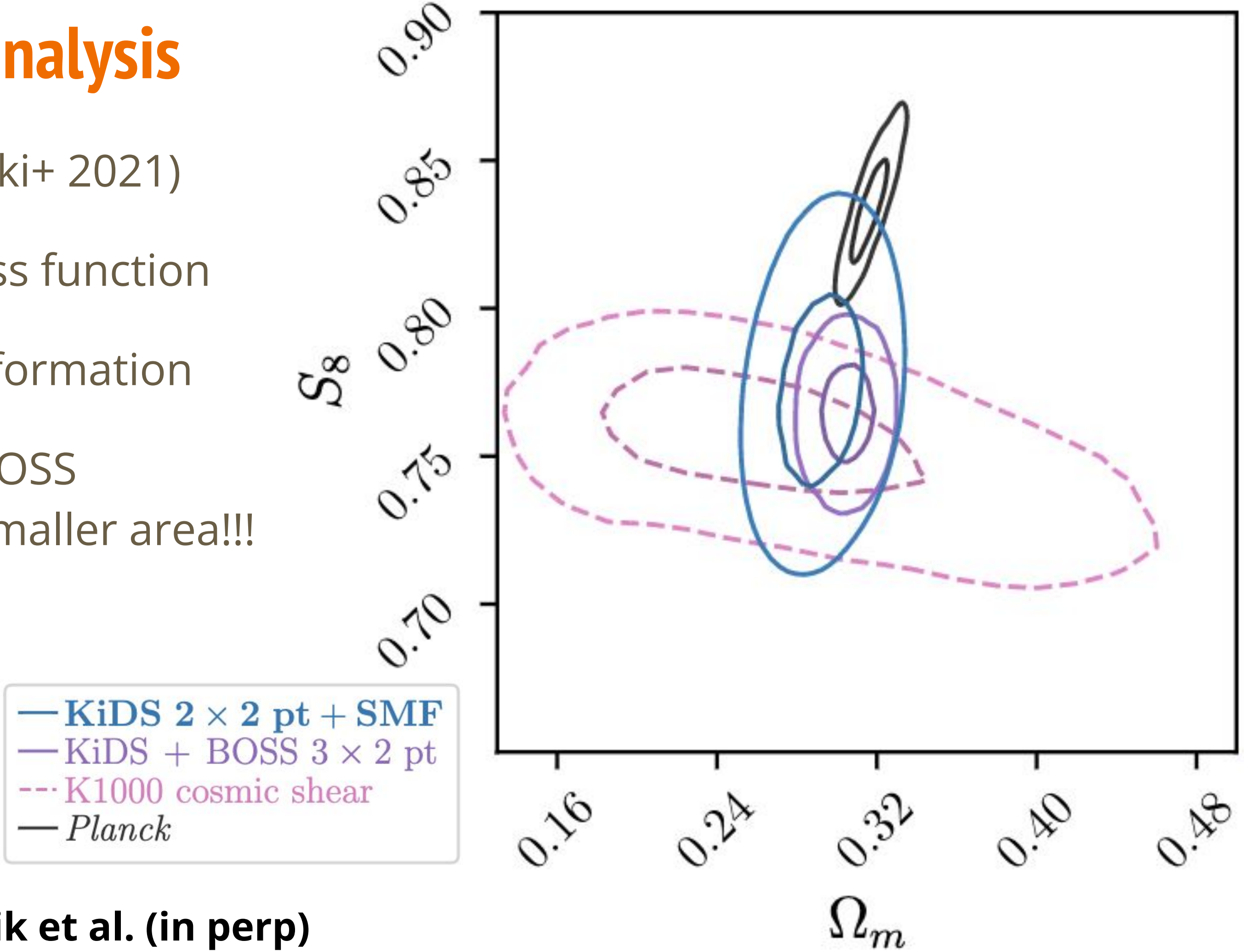
KiDS bright sample (Bilicki+ 2021)

Halo model + stellar mass function

Extracting small scale information

Same size contours as BOSS clustering, but 9 times smaller area!!!

Dvornik et al. (in perp)

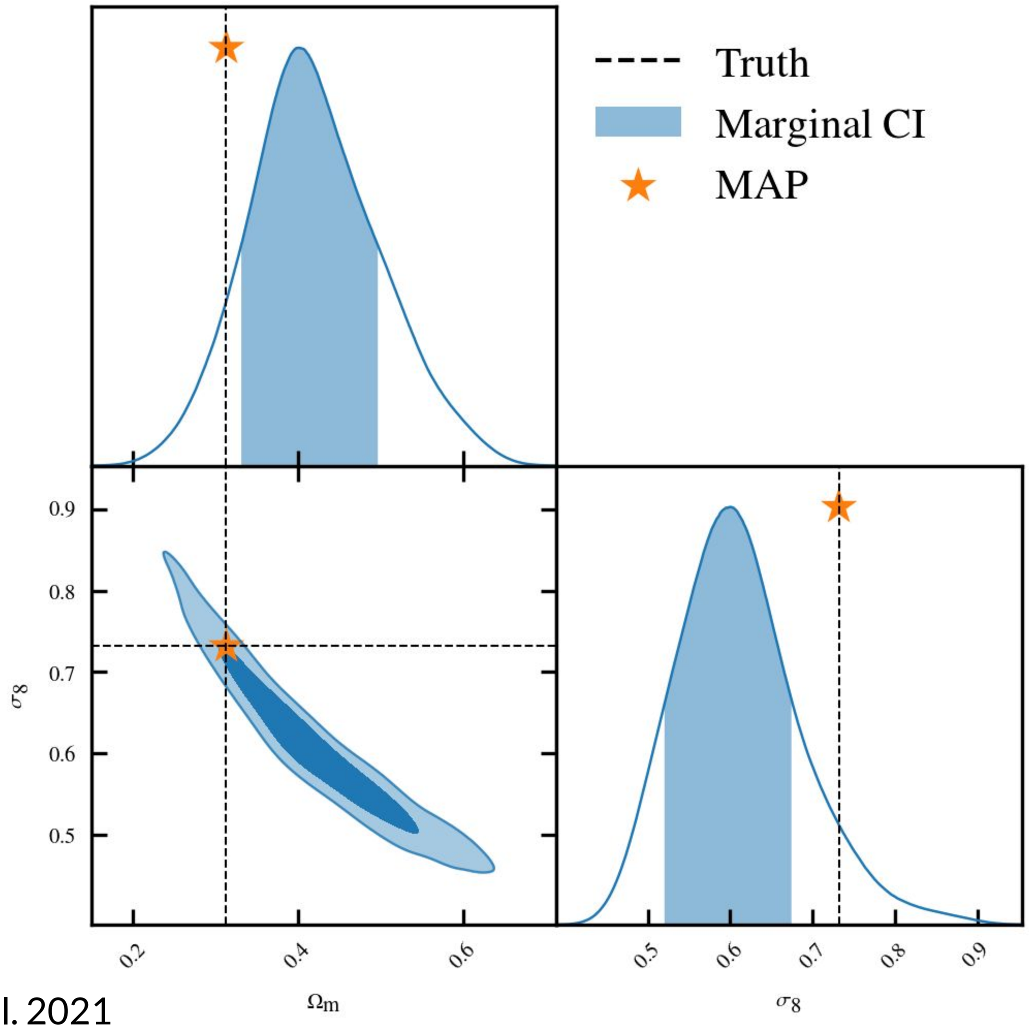


Parameter estimation and interpretation

Marginal distributions vs the truth

Cosmic shear + GGL

Noiseless mock data

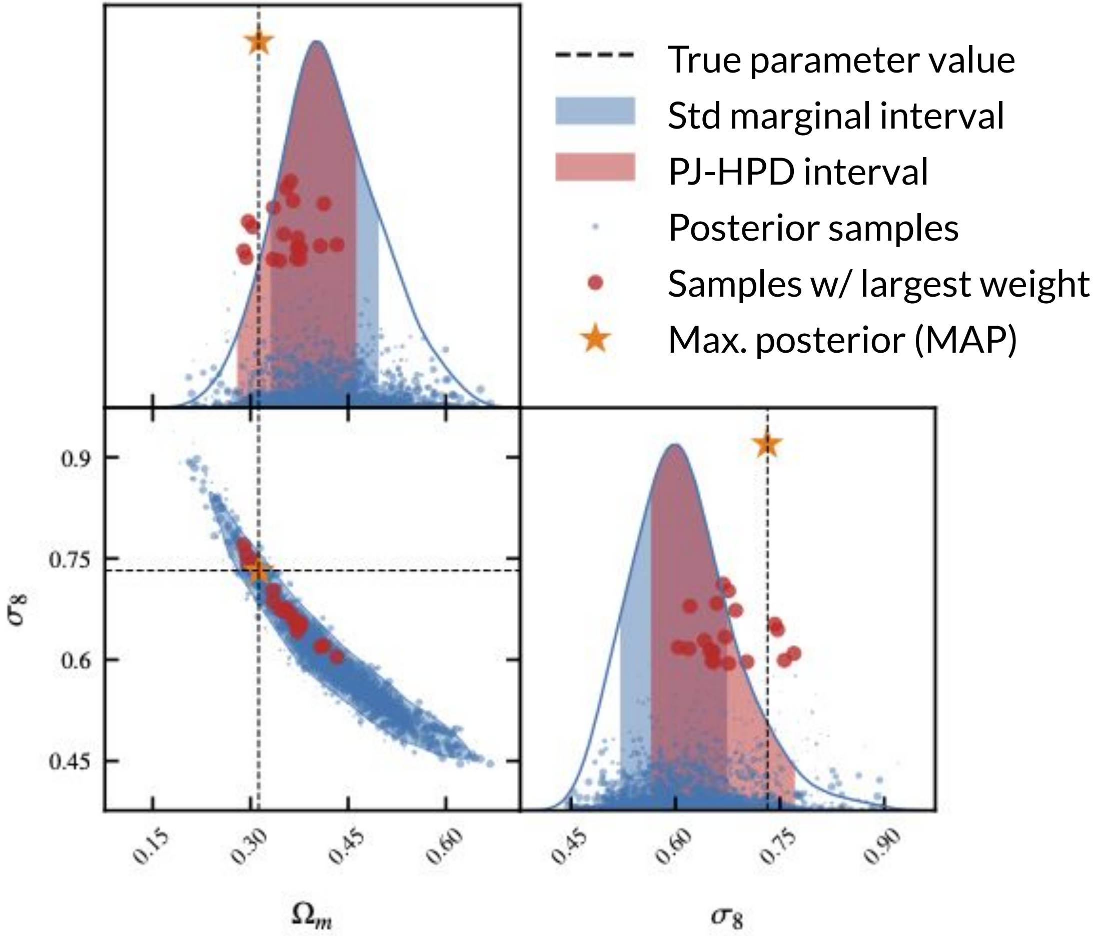


Based on Joachimi, Lin, Asgari, Tröster, Heymans et al. 2021

Reporting Parameter Constraints

The standard marginalised constraint on S_8 is typically lower than the global best-fit.

Our fiducial results quote the maximum posterior value and an associated credible interval (PJ-HPD).



Joachimi, Lin, Asgari, Tröster, Heymans et al. 2021

Goodness of fit and degrees of freedom

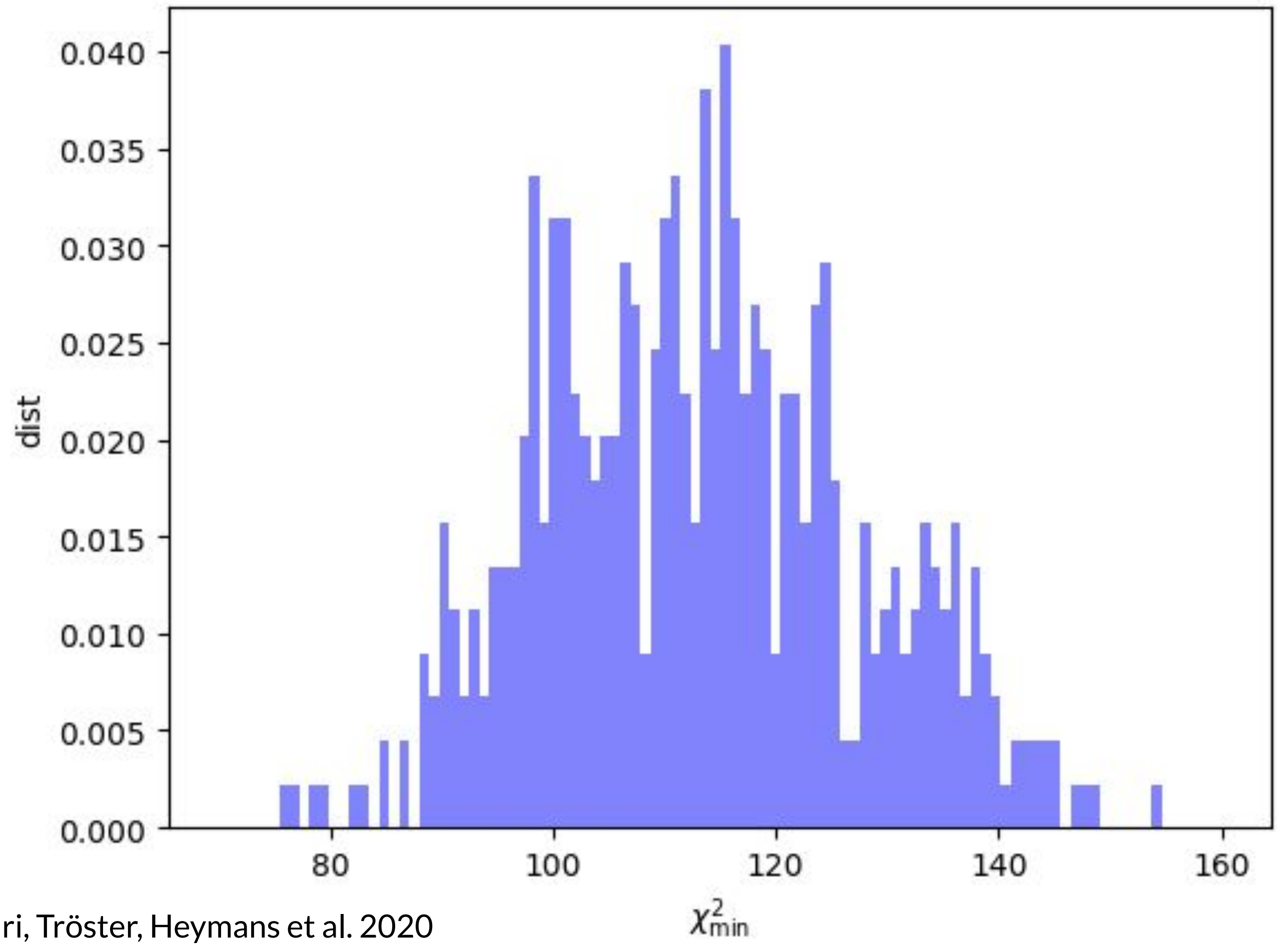
Example: Cosmic shear Mock data

analysis

Number of data points: 120

Number of free parameters: 12

Is DoF = # data points - # free parameters?



Based on Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

Goodness of fit and degrees of freedom

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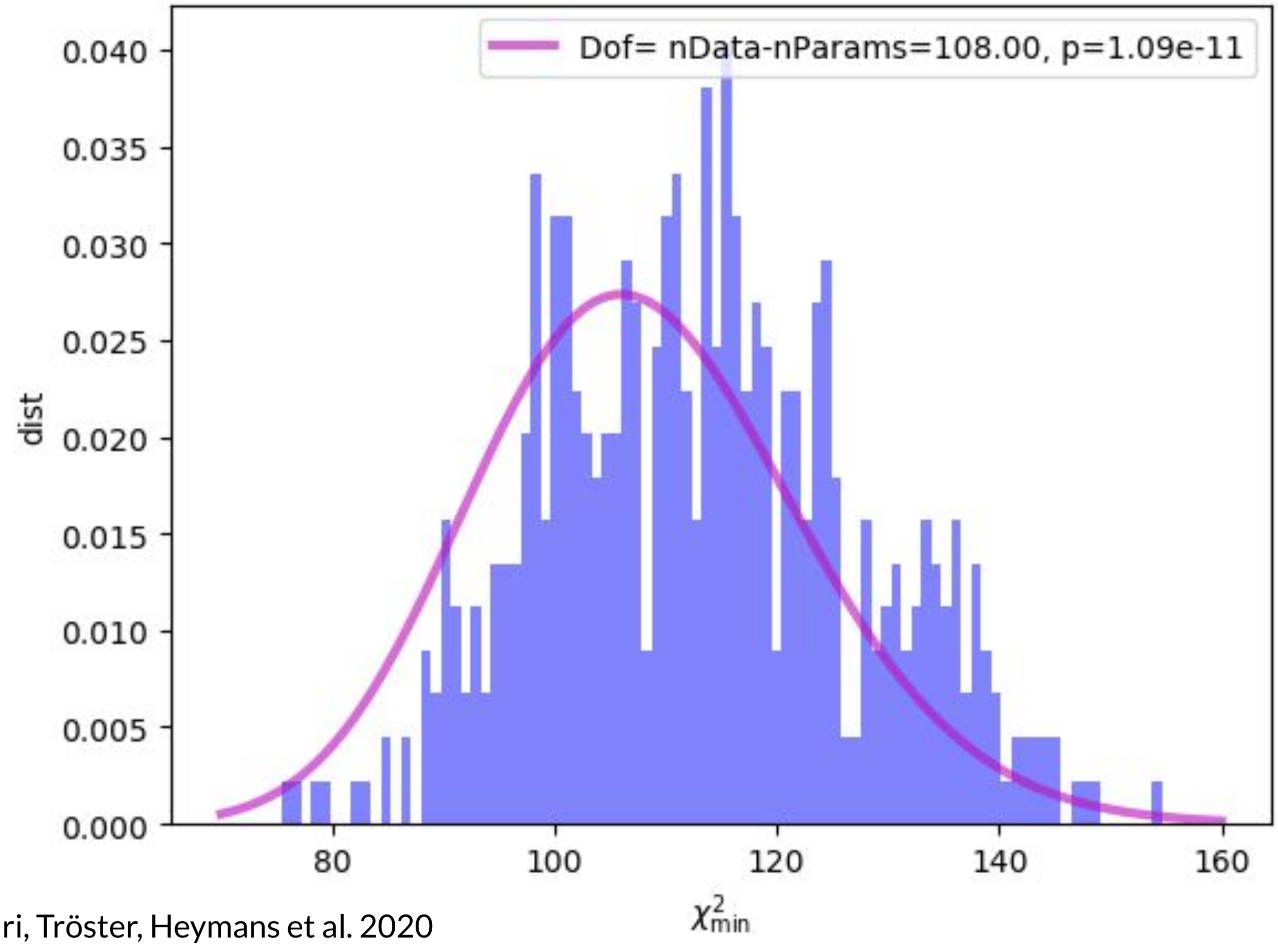
Is DoF = # data points - # free parameters?

What is the effective number of free parameters?



Based on Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

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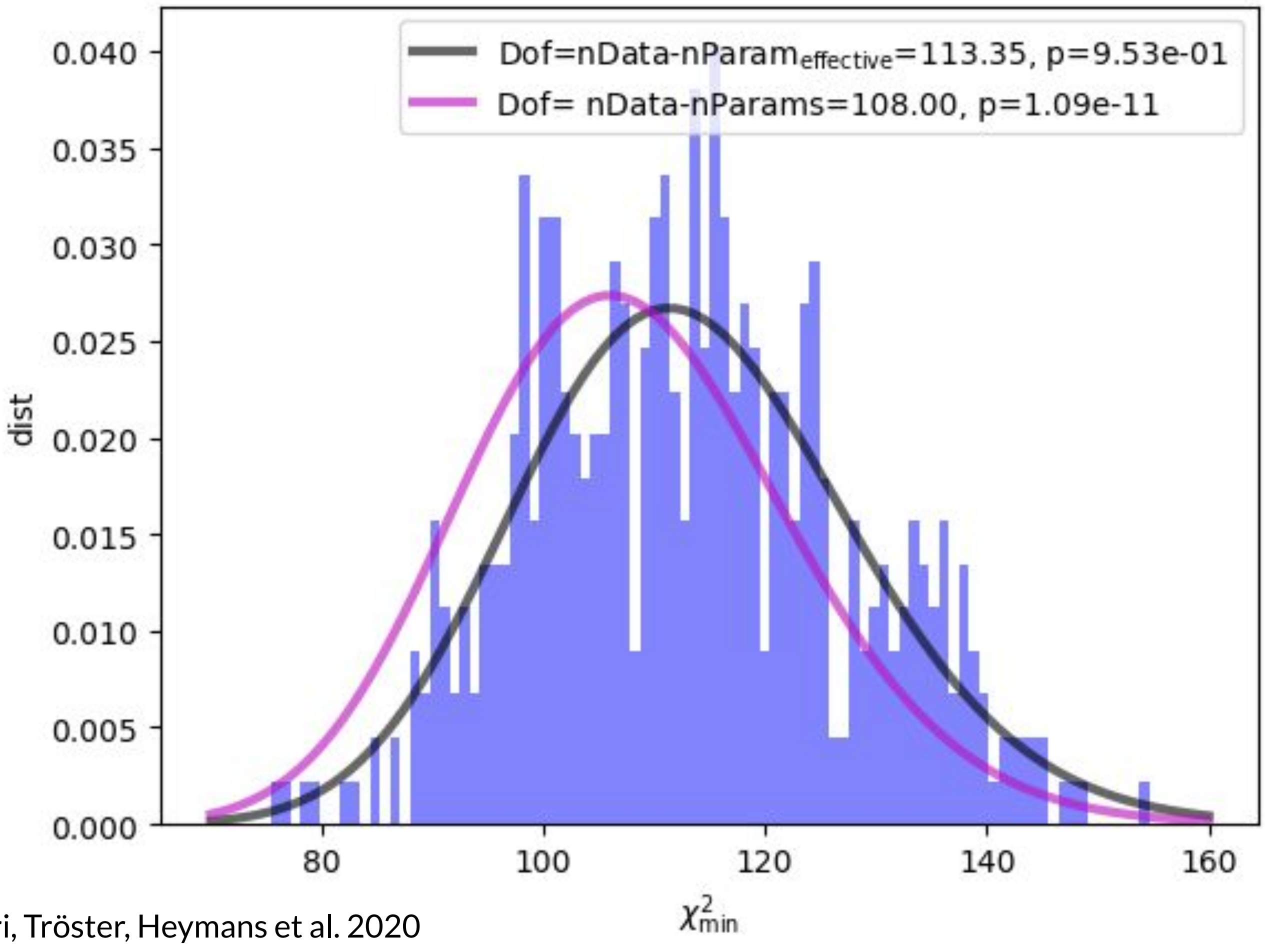


Based on Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

Goodness of fit and degrees of freedom

Example: Cosmic shear Mock

data analysis

Number of data points: 120

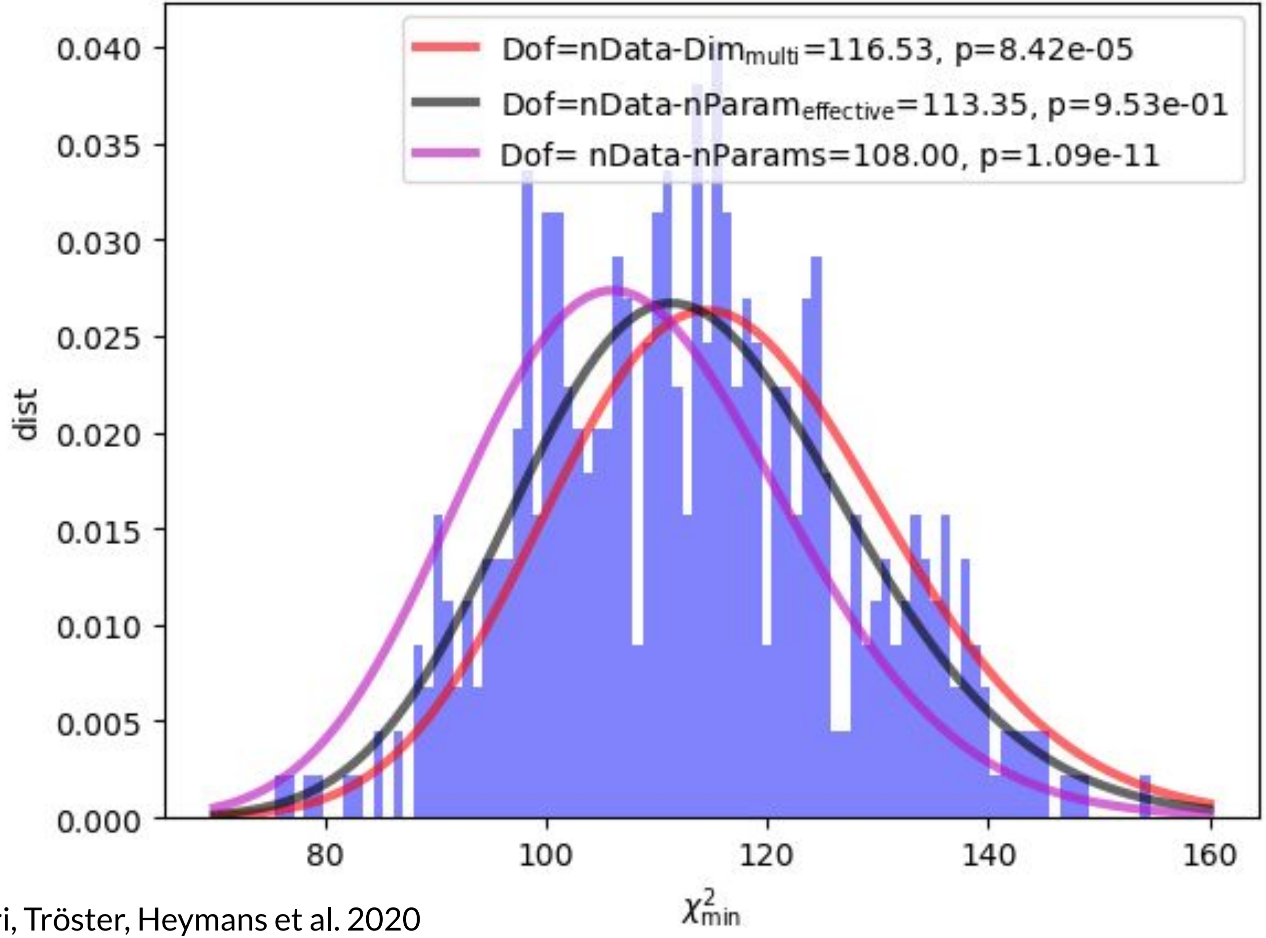
Number of free parameters: 12

What is the effective number of

free parameters?

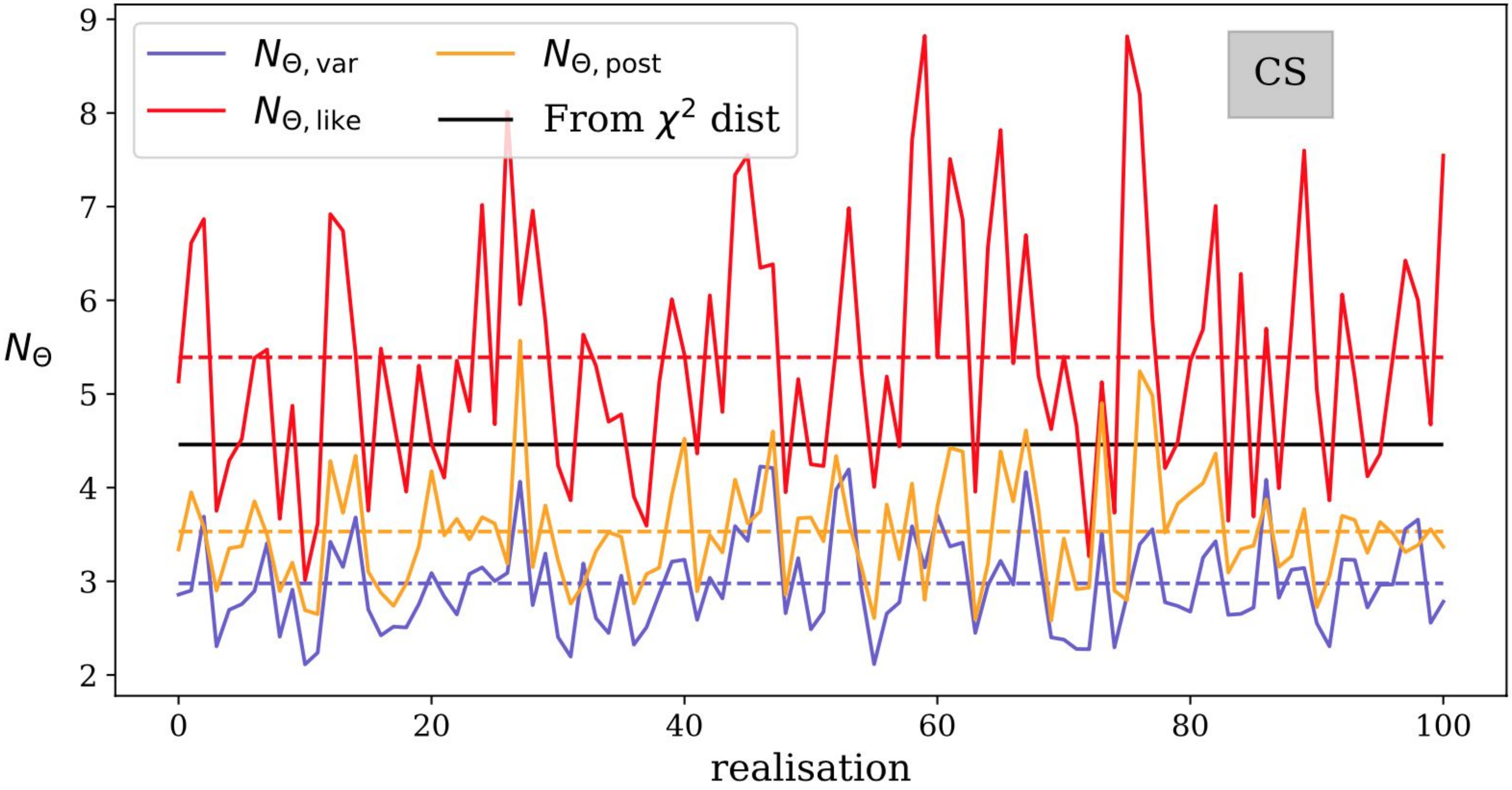
Can I estimate this using the

chain that I ran on the data?



Based on Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

Estimating the effective number of parameters, using chains



Joachimi, Lin, Asgari, Tröster, Heymans et al. 2021

Summary

- ~3σ Tension in S8 with Planck (assuming flat LCDM) in a blinded analysis
- All cosmic shear results lie on the low side of the Planck constraints
- The most up to date KiDS-1000 analysis shows an even larger tension
- We have ambitious plans for the KiDS-legacy analysis
- First KiDS only 3x2pt with the halo model
- Stay tuned for KiDS Legacy, exciting times!
- Be careful with your inference methods

Thanks to KiDS and all our funders

erc
European Research Council
Established by the European Commission

MARIE CURIE ACTIONS

NWO
Netherlands Organisation for Scientific Research

Alexander von Humboldt Stiftung/Foundation

MAX PLANCK GESELLSCHAFT

Gefördert durch DFG Deutsche Forschungsgemeinschaft

Ministry of Science and Higher Education
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THE ROYAL SOCIETY

Science & Technology Facilities Council

中国科学院
CHINESE ACADEMY OF SCIENCES

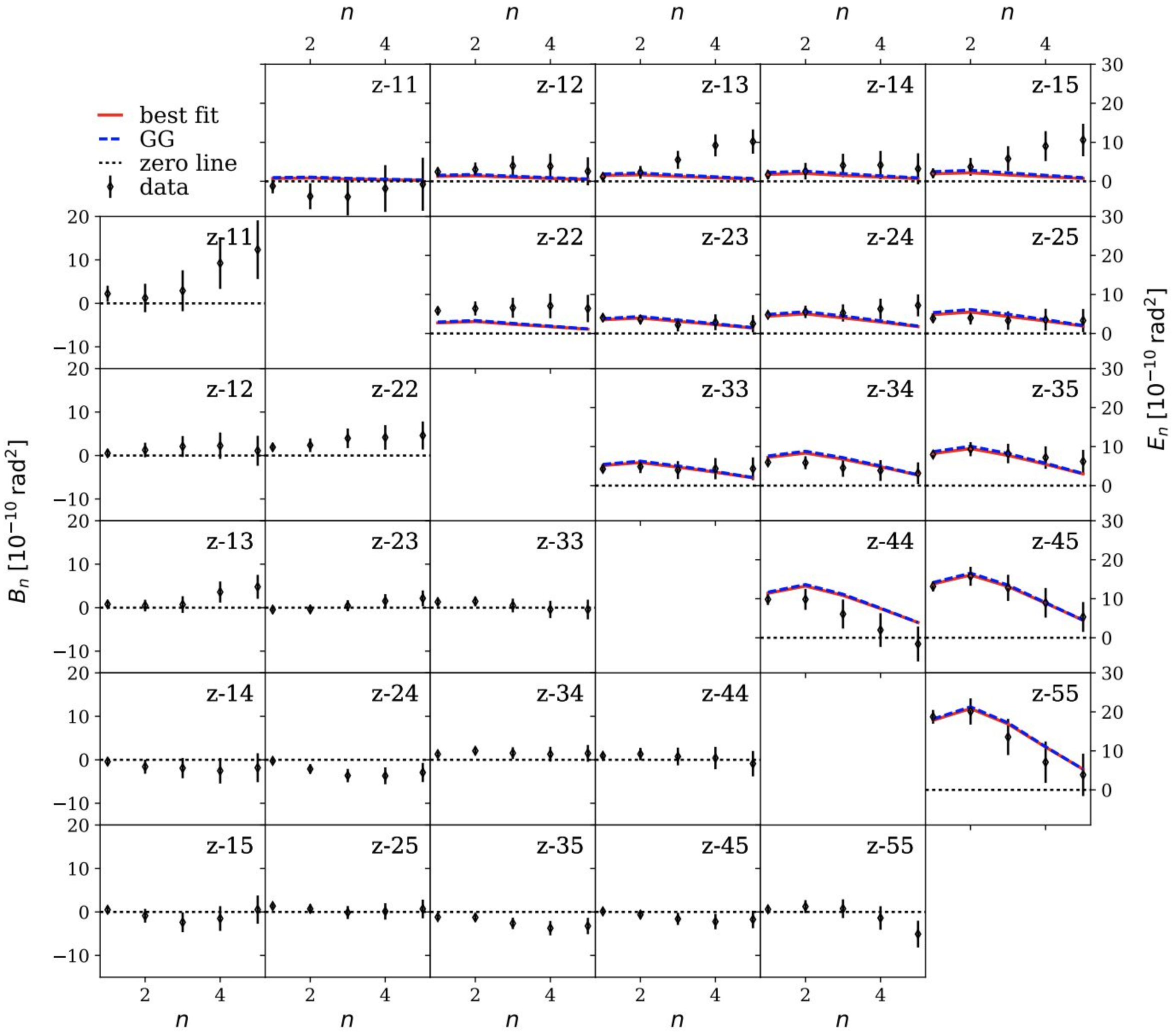
国家自然科学基金委员会
National Natural Science Foundation of China

Backup slides

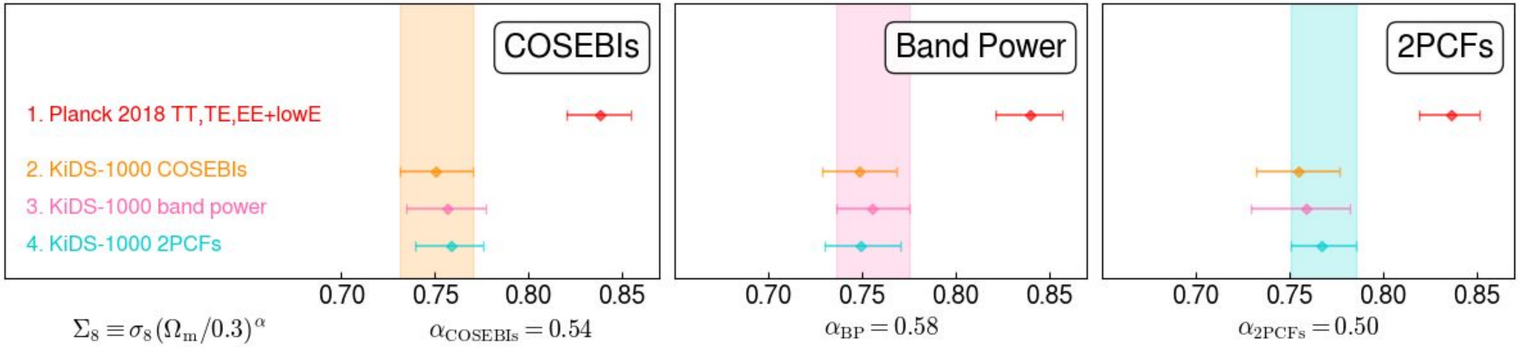
KiDS-1000 Cosmic Shear (PAST)

The theoretical model includes

- Cosmology: Flat ΛCDM
- Astrophysical effects
  - Baryon feedback
  - Intrinsic alignments
- Observational effects
  - Calibration Uncertainties



Asgari, Lin, Joachimi et al. 2021

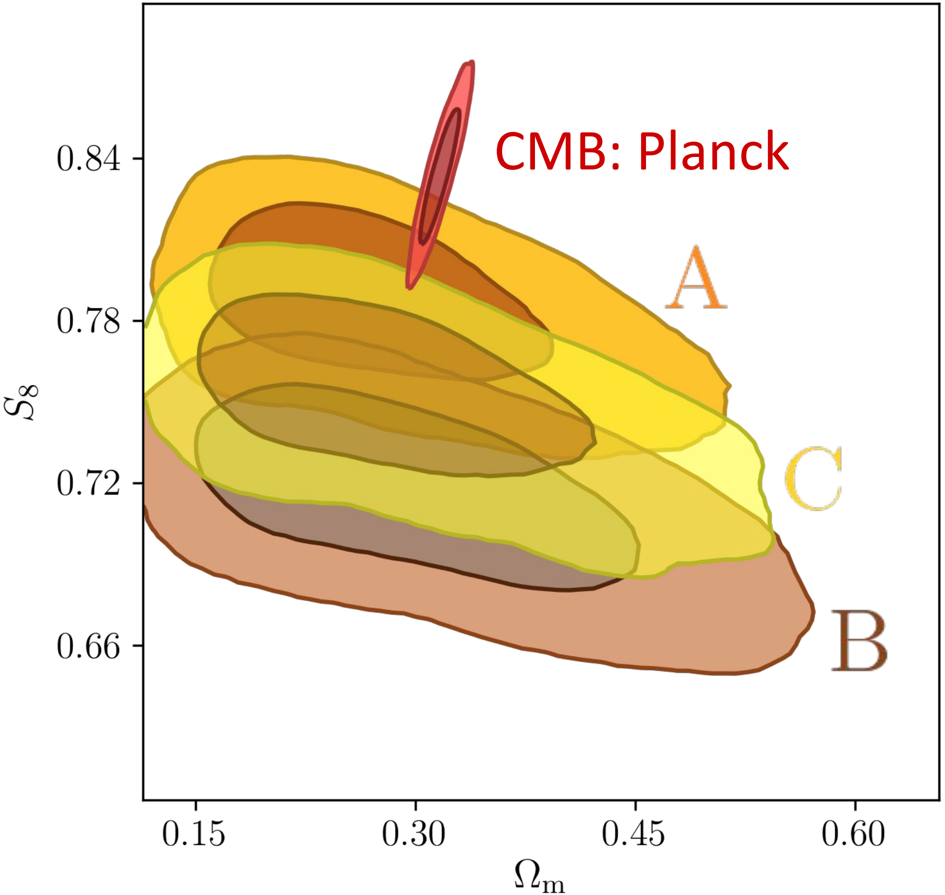


$$S_8 = \sigma_8(\Omega_{\rm m}/0.3)^{0.5}$$

$$\Sigma_8 = \sigma_8(\Omega_{\rm m}/0.3)^{\alpha}$$

Asgari, Lin, Joachimi et al. 2020

Blinded analysis: KiDS-1000 cosmic shear (PAST)

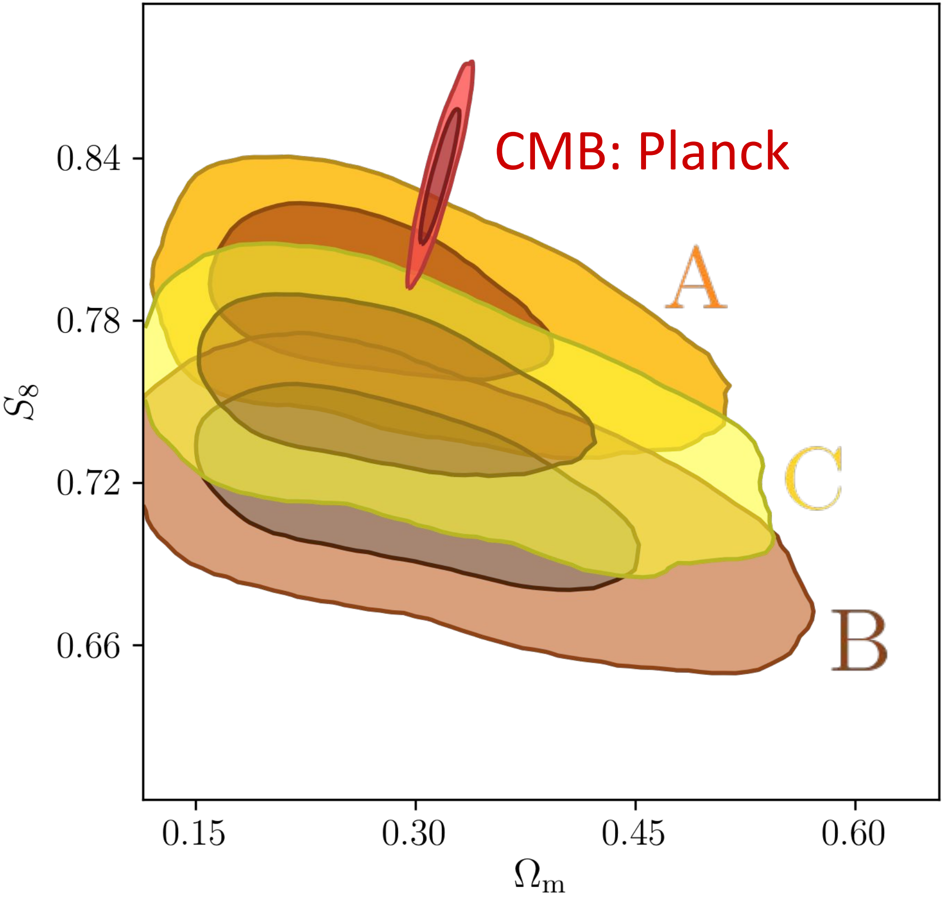


$$S_8 = \sigma_8 \sqrt{\Omega_m/0.3}$$

This is where we were 3 weeks before submission of the papers.

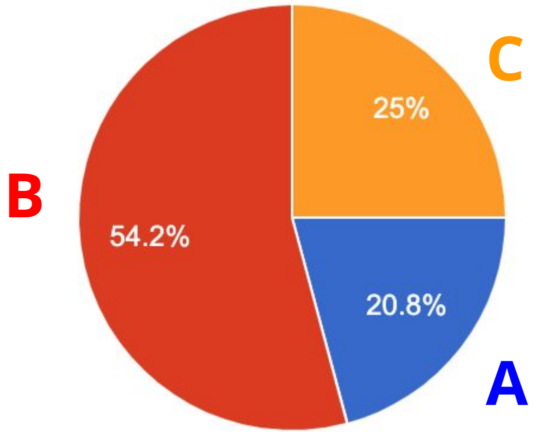
Based on Asgari, Lin, Joachimi et al. 2021

Blinded analysis: KiDS-1000 cosmic shear (PAST)



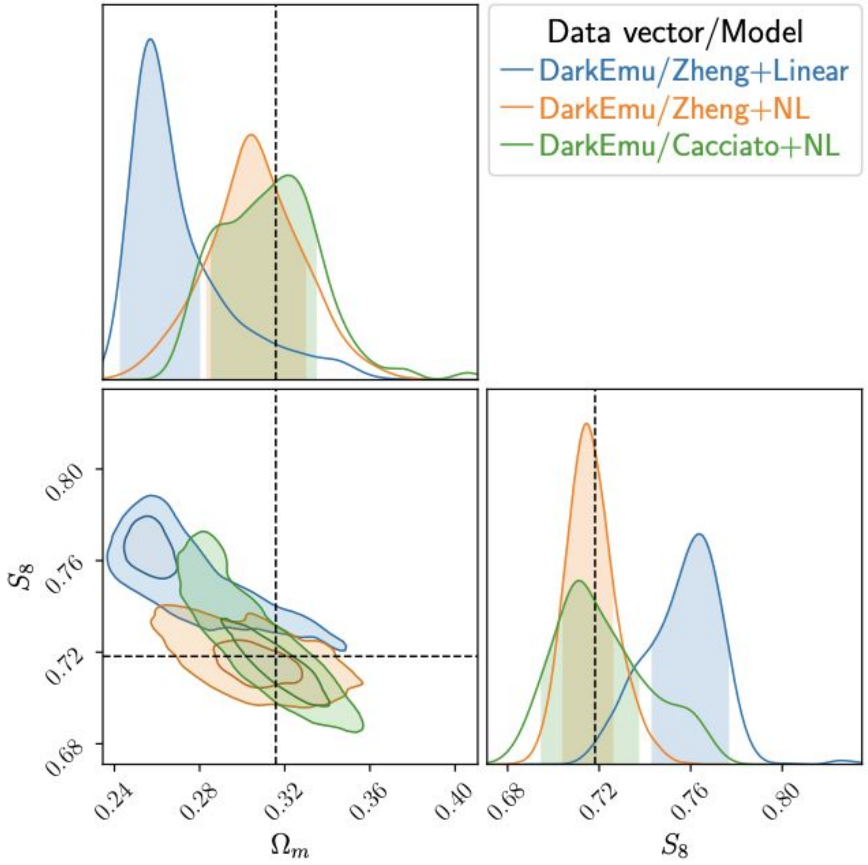
Choose the one that you would like to be the truth.

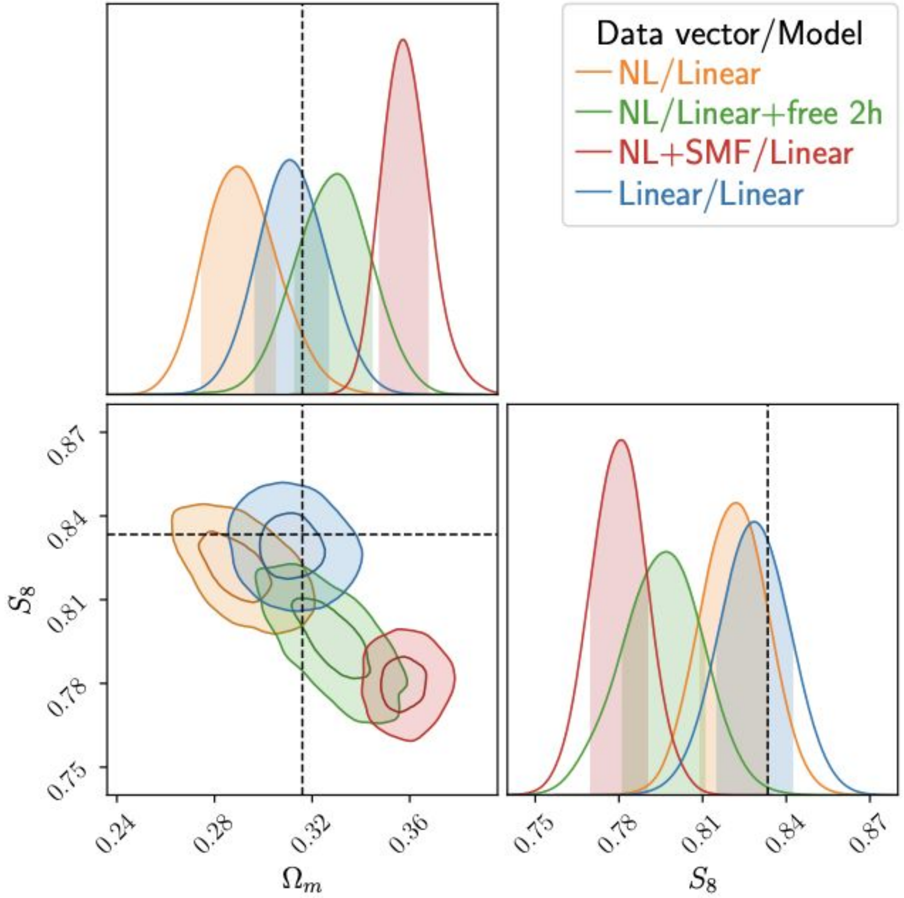
24 responses



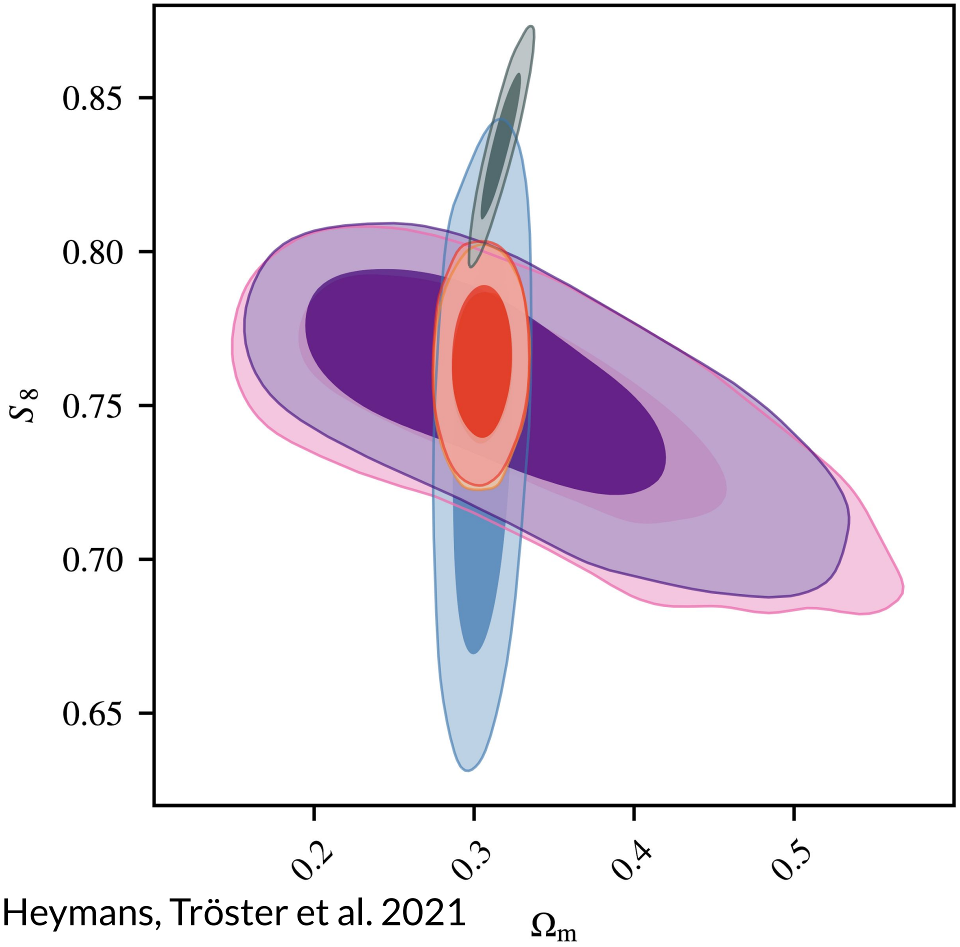
Based on Asgari, Lin, Joachimi et al. 2021

Non linear halo bias

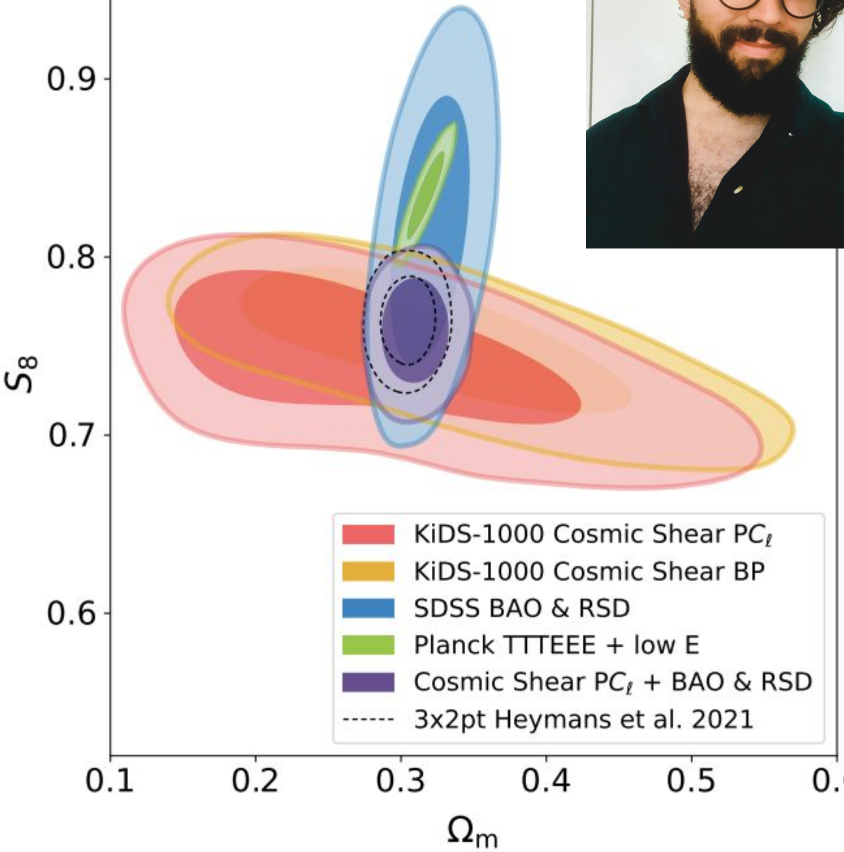




Consistency between Probes and *Planck*



Heymans, Tröster et al. 2021

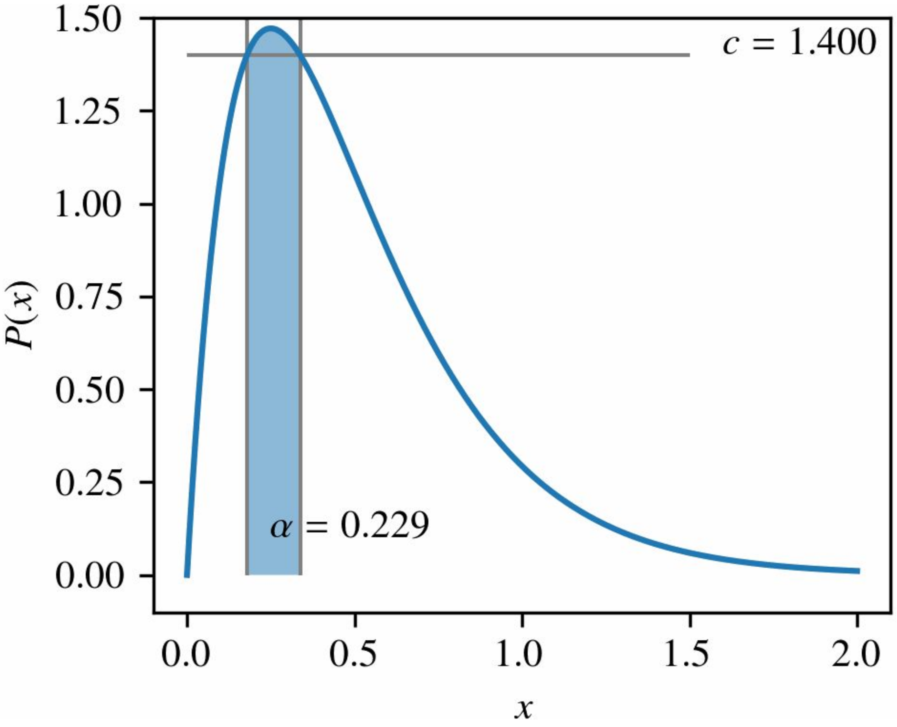


Loureiro et al. (2022): 2110.06947

Highest posterior density (HPD) CI

$$H = \{x : P(x) > c\}$$

$$\int_{P(x)>c} \mathrm{d}x\, P(x) = \alpha$$

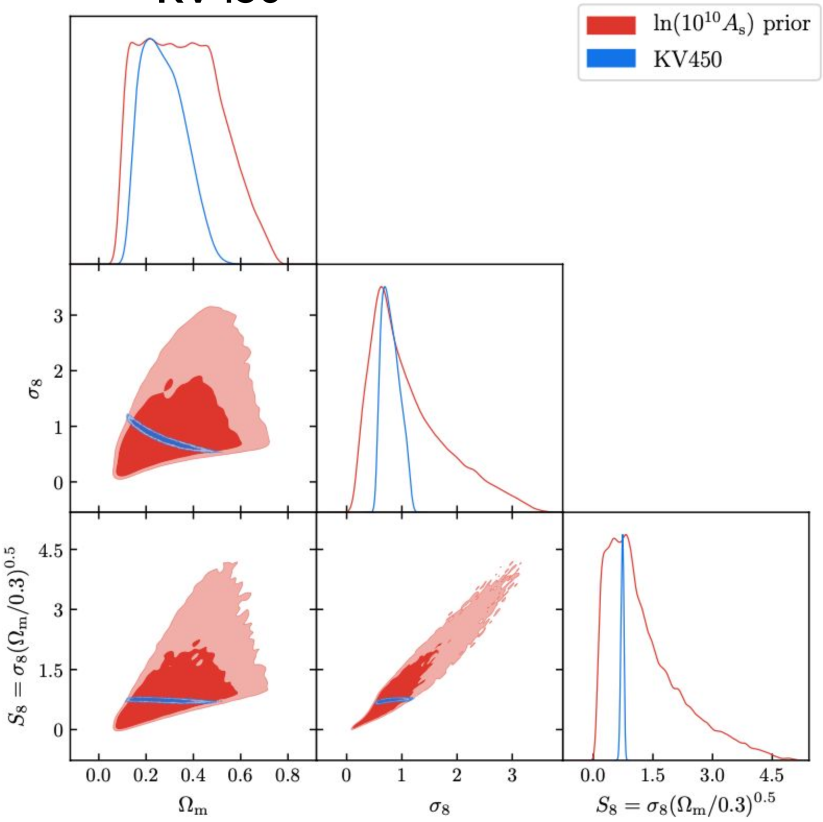


What is the appropriate coverage α in higher dimensions?

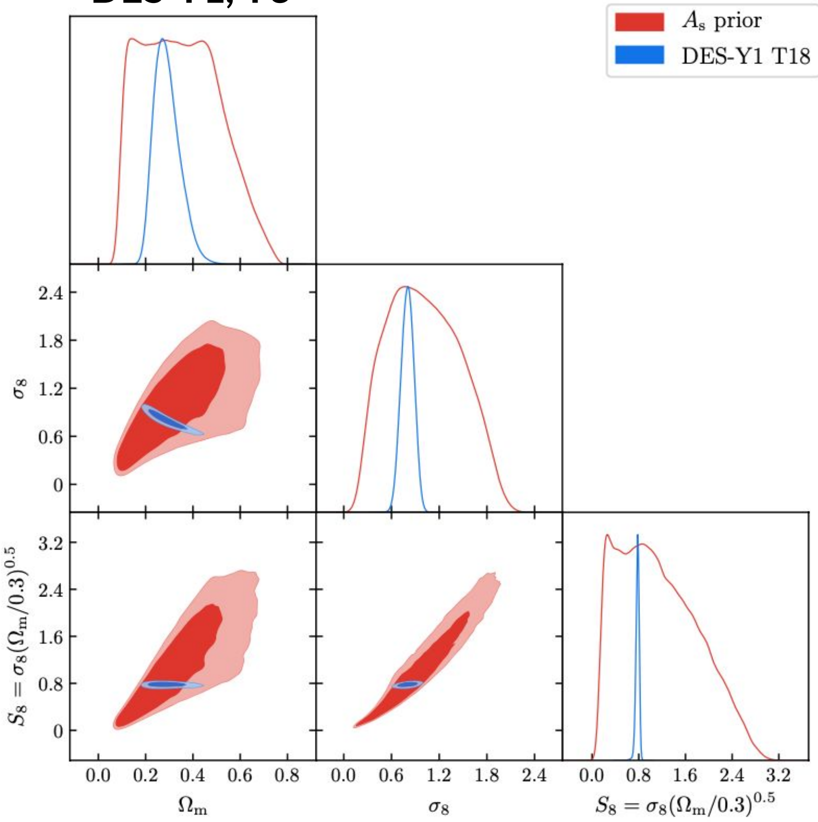
Credit: Tilman Tröster

sigma_8 and Omega_m constraints are prior dominated

KV450



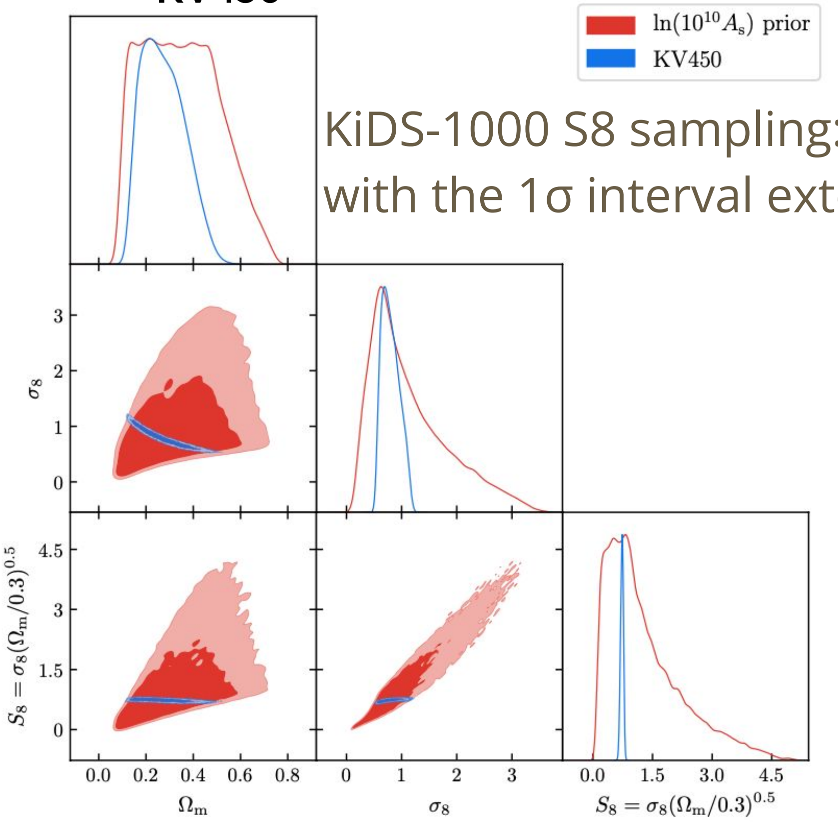
DES-Y1, Y3



Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

sigma_8 and Omega_m constraints are prior dominated

KV450



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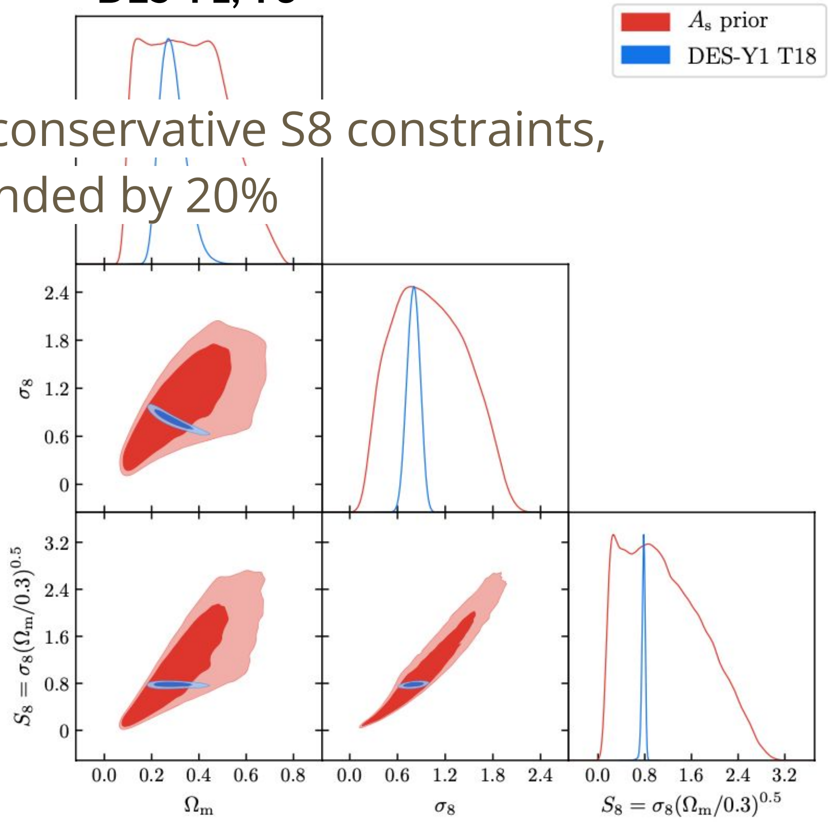
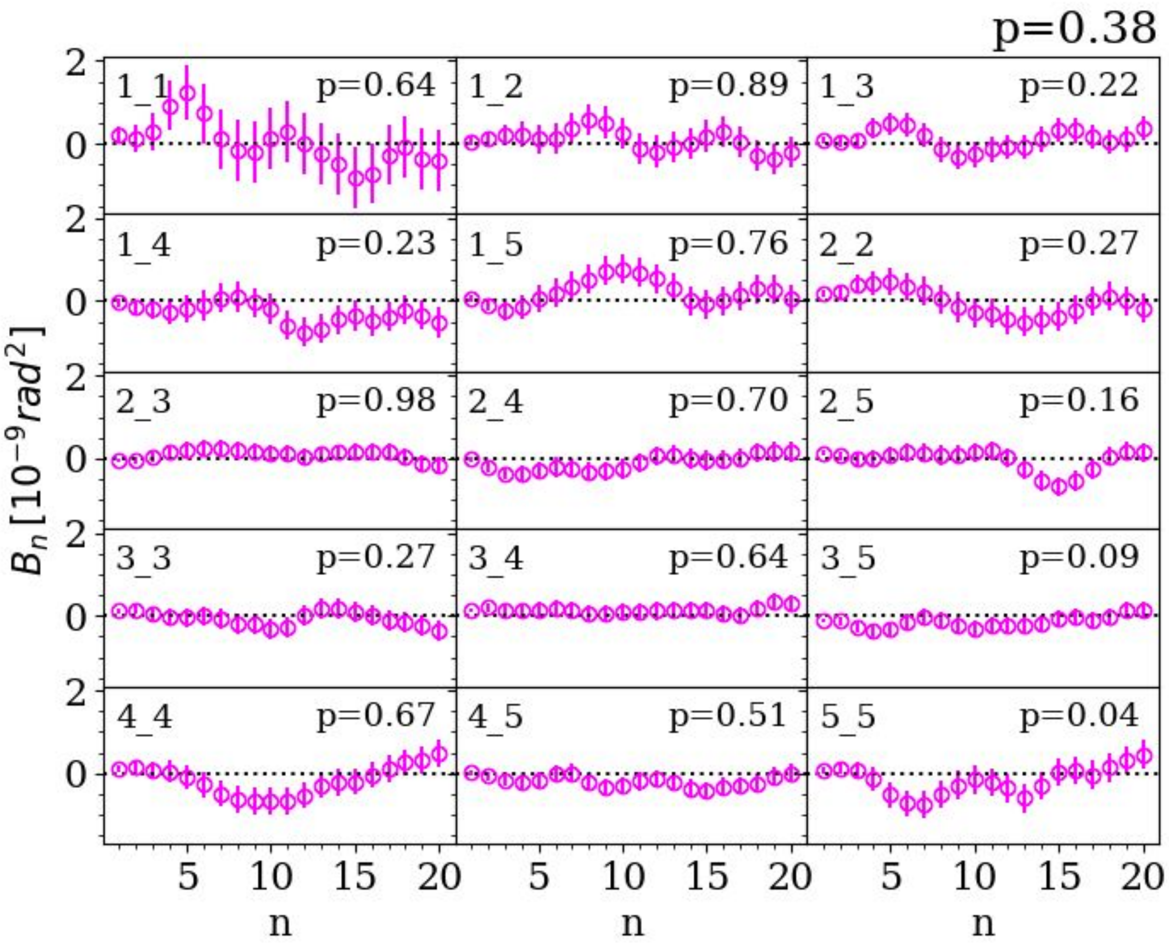


KiDS-1000 S8 sampling: conservative S8 constraints, with the 1σ interval extended by 20%

Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

Shape measurement and Shear null tests

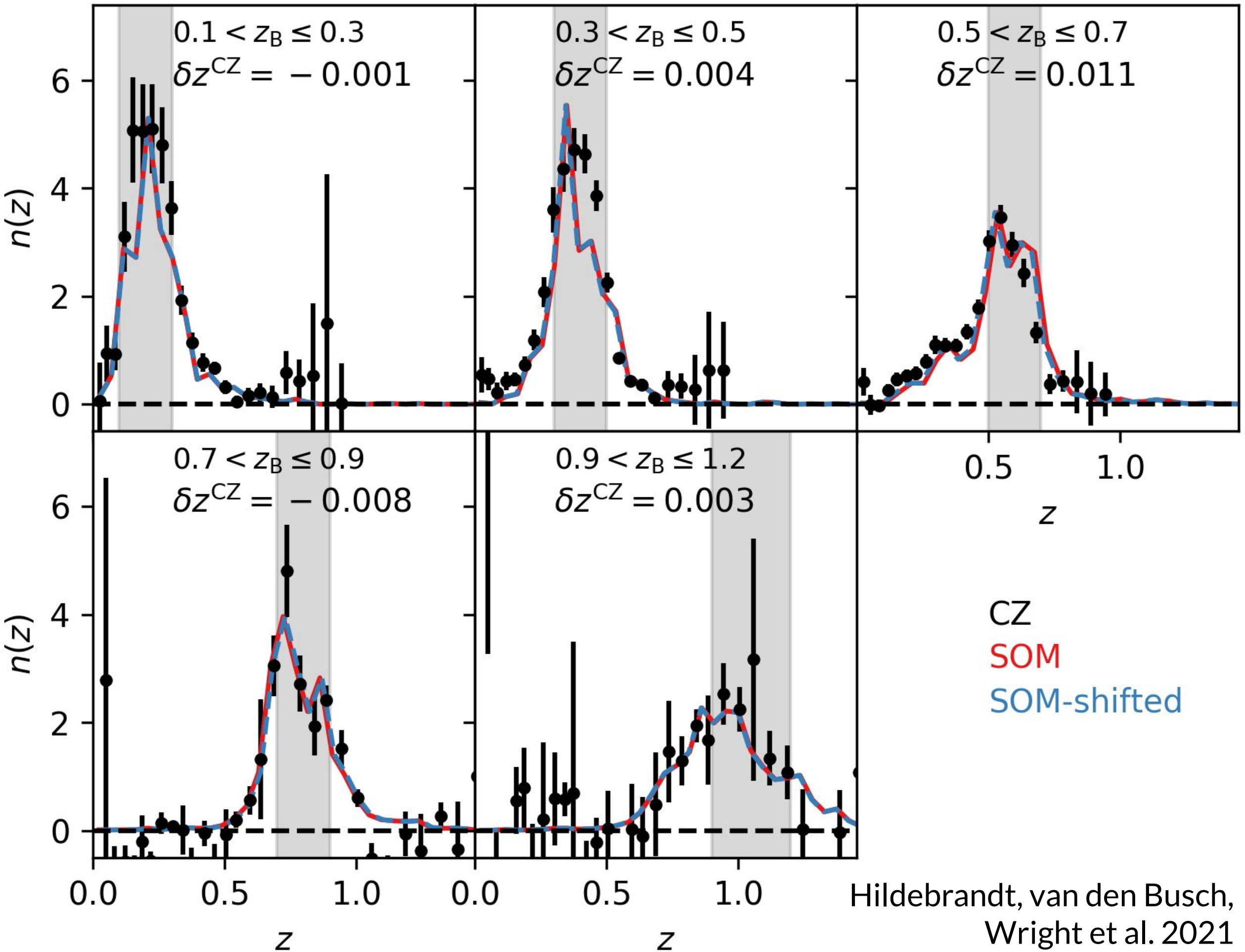
- B-modes consistent with pure noise
- Purity of the point-source sample validated with optical-NIR colours
- PSF model accuracy size/shape requirements easily met
- Instrumental defects quantified
- Shear-ratio test passed



Giblin, Heymans, Asgari et al. 2021

Redshift Distributions

We find no significant offset between the SOM and CZ redshift distributions



Hildebrandt, van den Busch, Wright et al. 2021

KiDS-1000 core cosmology papers

Cosmic Shear Cosmology: Asgari, Lin, Joachimi et al. (arXiv: 2007.15633)

Combined Probe Cosmology: Heymans, Tröster et al. (arXiv: 2007.15632)

Extended Cosmology: Tröster et al. (arXiv:2010.16416)

Methodology: Joachimi, Lin, Asgari, Tröster, Heymans et al. (arXiv: 2007.01844)

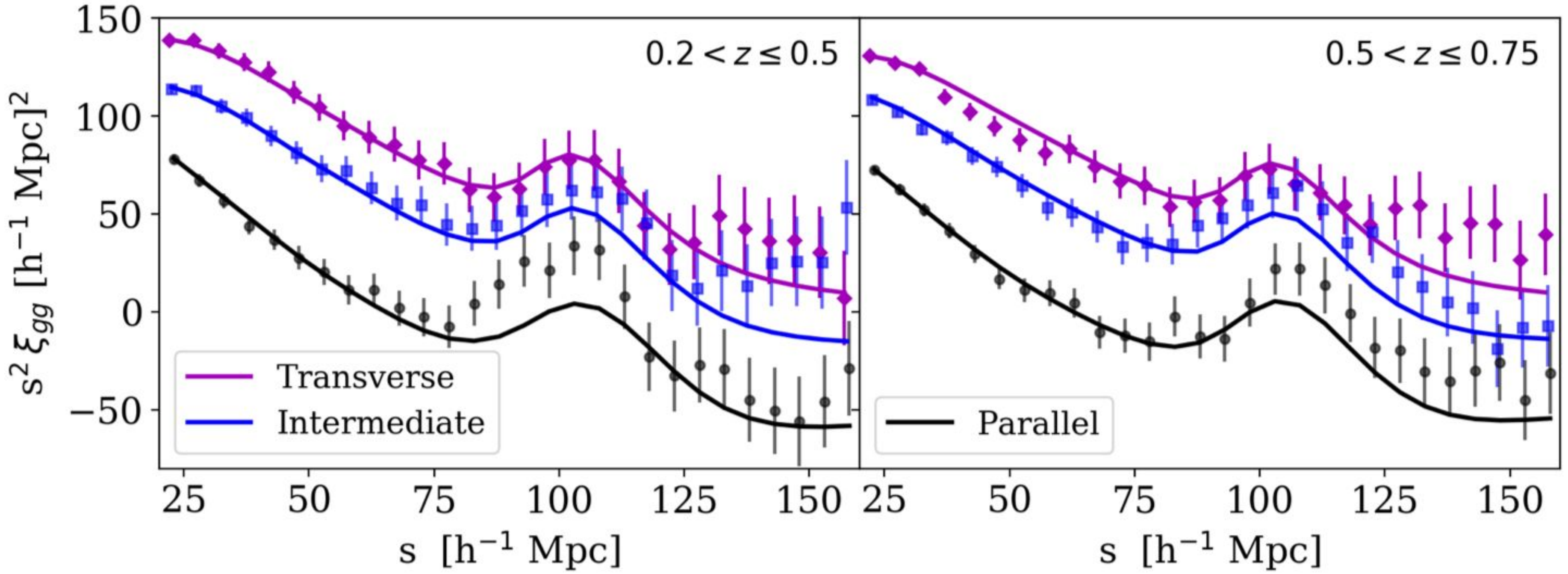
Photometric Redshifts: Hildebrandt, van den Busch, Wright et al. (arXiv: 2007.15635)

Shear Measurements: Giblin, Heymans, Asgari et al. (arXiv: 2007.01845)

Link **to other KiDS talks on the KiDS consortium youtube page.**

3x2pt: Cosmic Shear + Clustering +

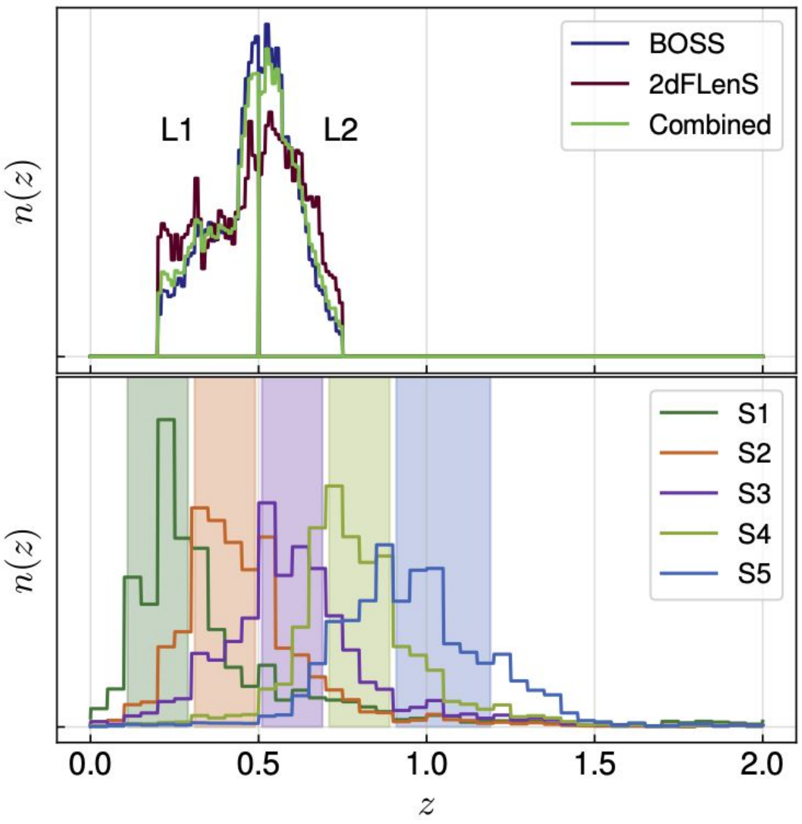
Anisotropic Galaxy Clustering: RSD + BAO



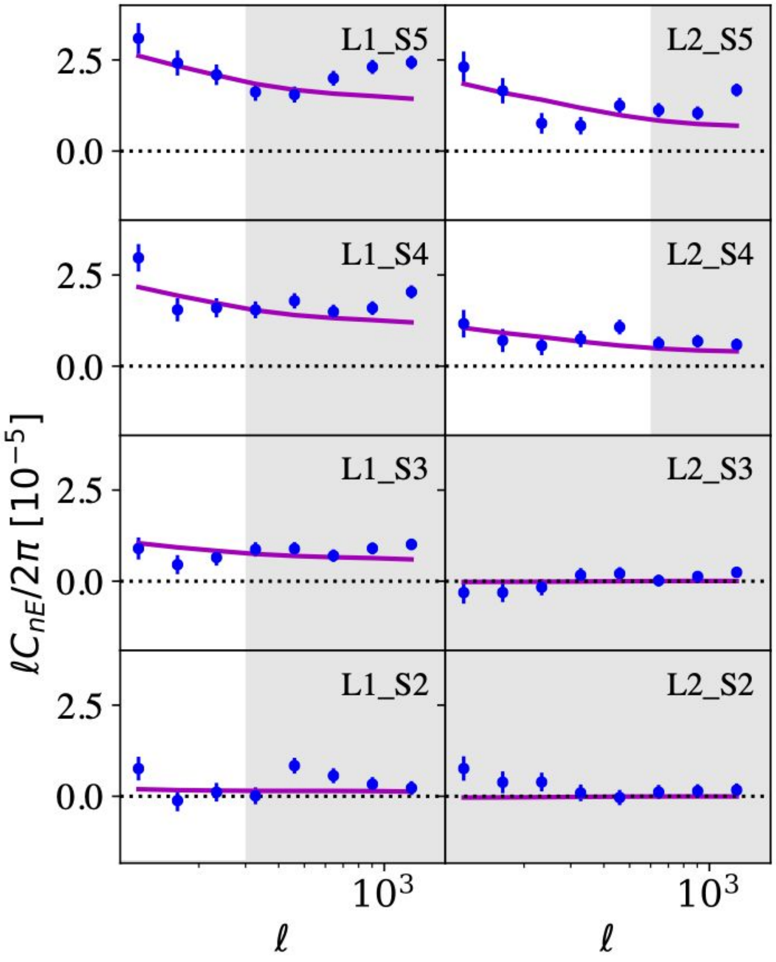
Theoretical Predictions includes non-linear galaxy bias model

BOSS DR12: Sanchez et al. 2017

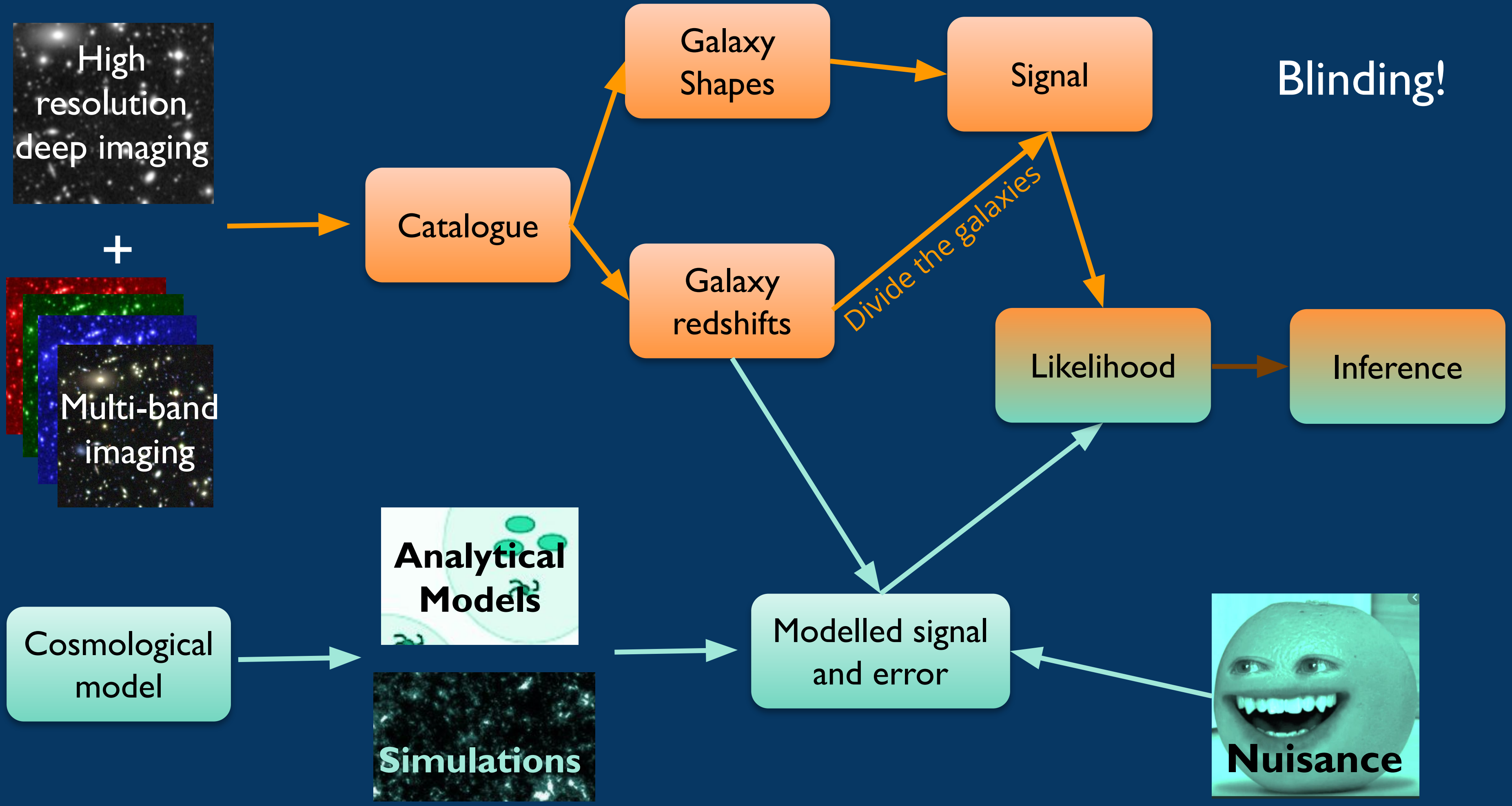
3x2pt: Cosmic Shear + Clustering + Galaxy-Galaxy Lensing



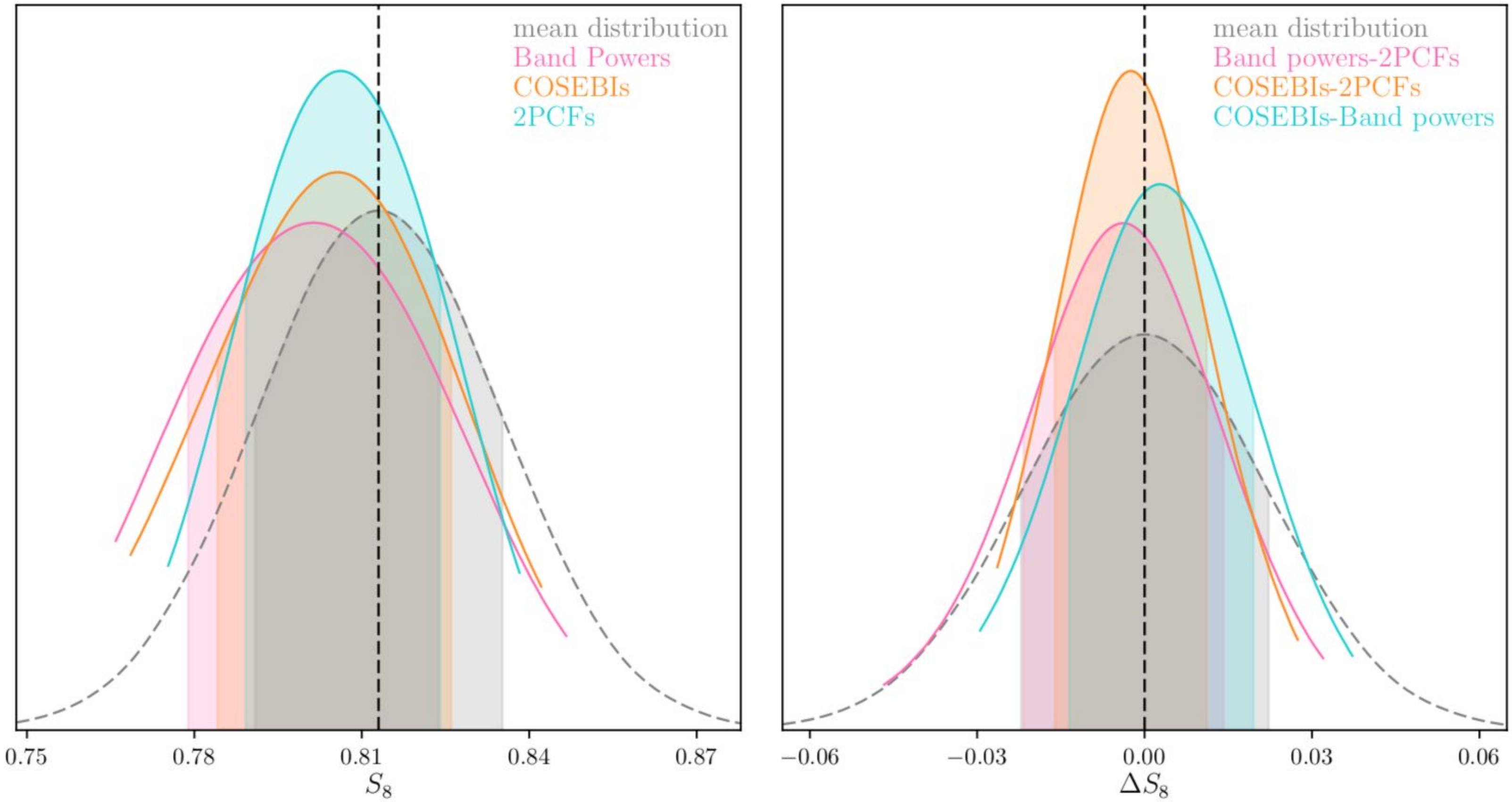
Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020



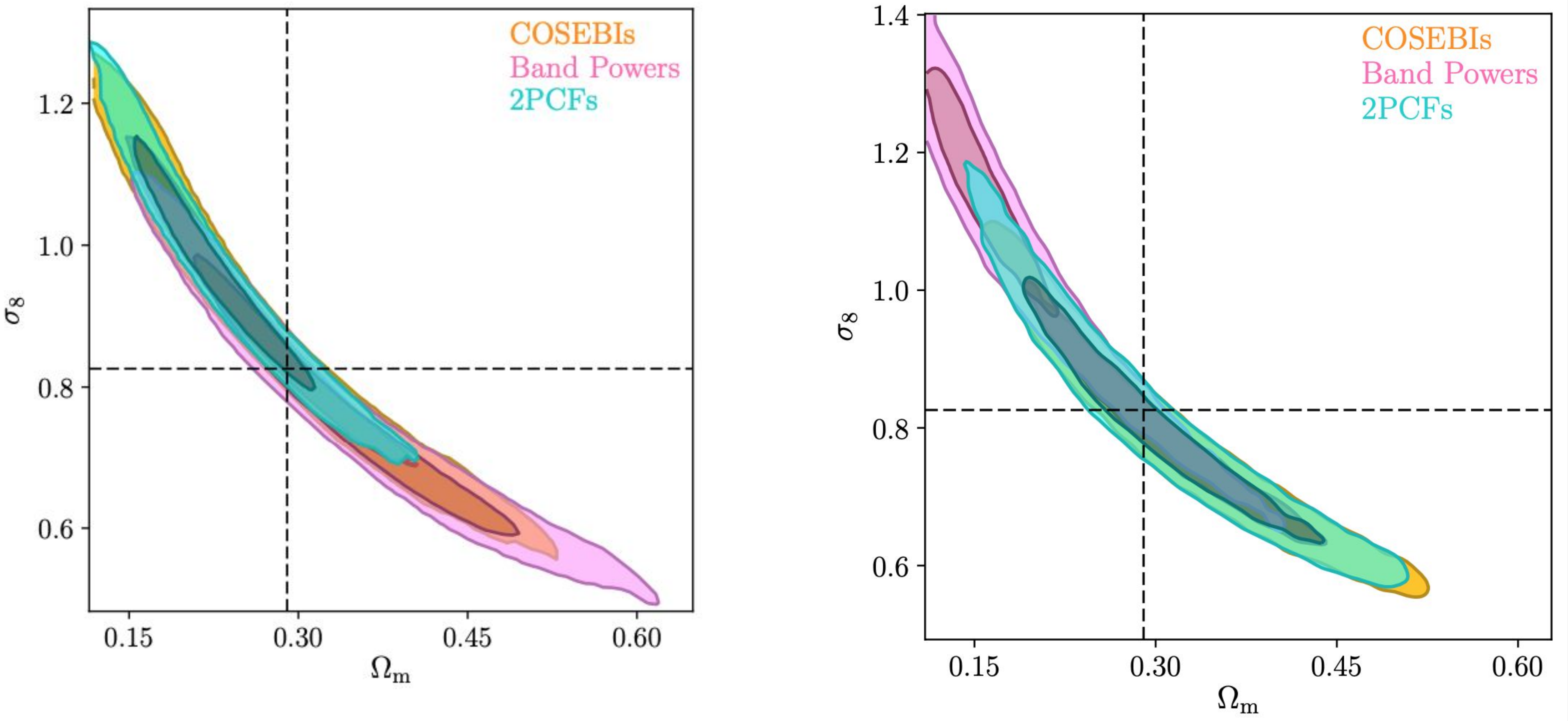
Heymans, Tröster et al. 2020


High resolution deep imaging
+
Multi-band imaging
Catalogue
Galaxy Shapes
Galaxy redshifts
Signal
Divide the galaxies
Blinding!
Likelihood
Inference
Cosmological model
Analytical Models
Simulations
Modelled signal and error
Nuisance

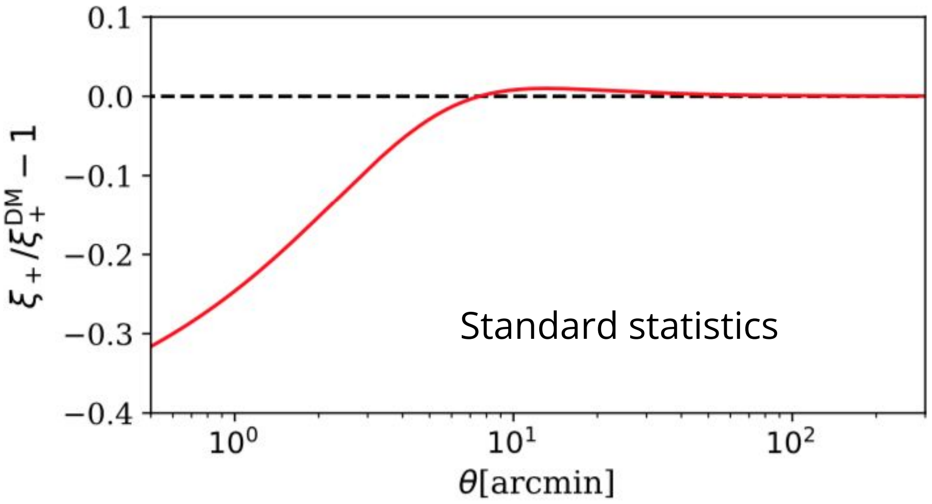
Mock data analysis: difference between 2pt Stats

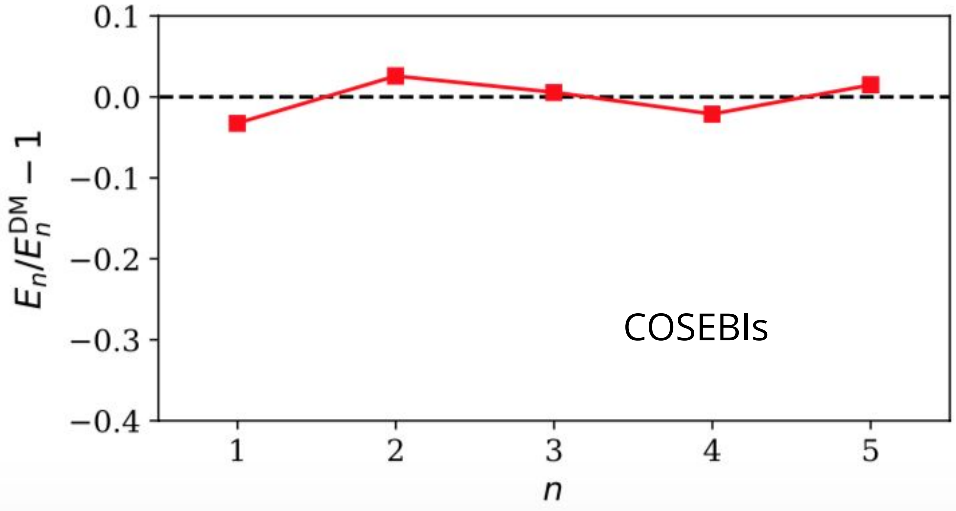


2 instances of mock data results



Sensitivity to baryon feedback and the choice of statistics



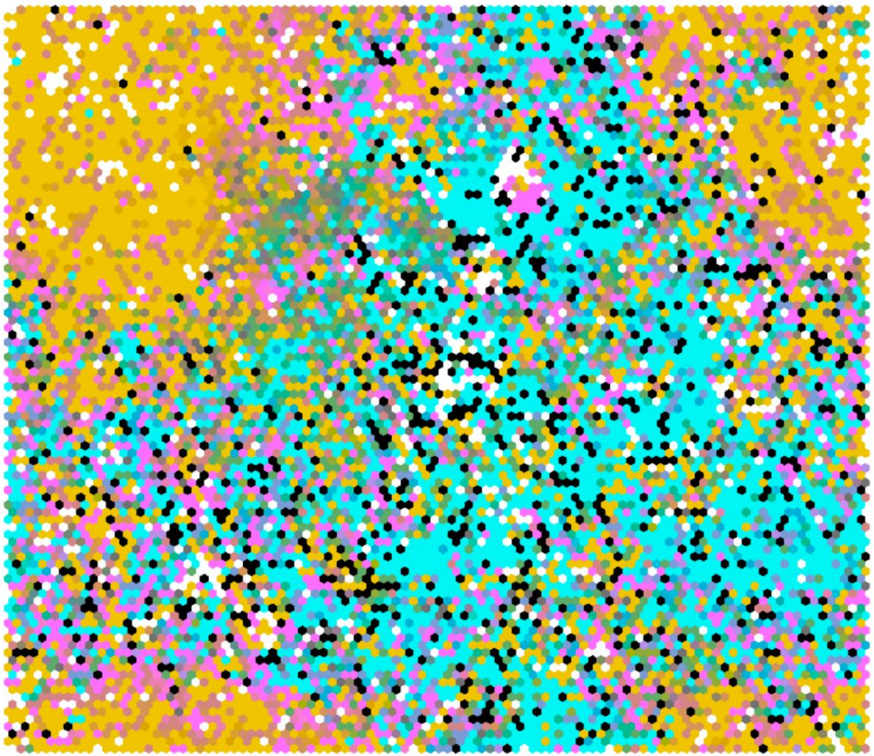


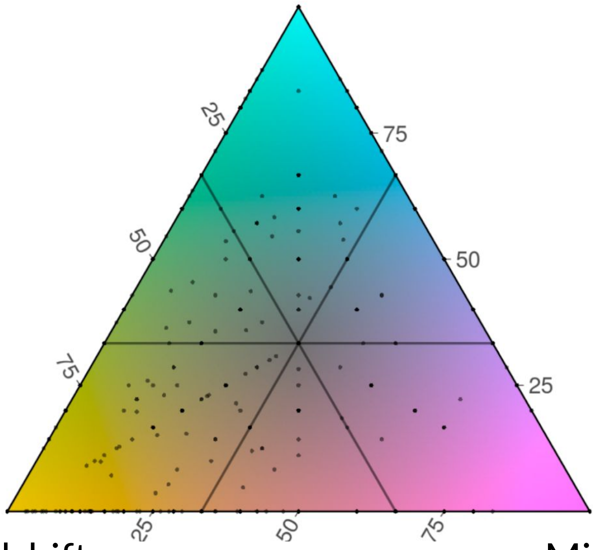
Based on Asgari et al. (2020)

Photometric Redshift Calibration with Spectroscopy

Accurate redshift calibration is integral to the interpretation of cosmic shear.

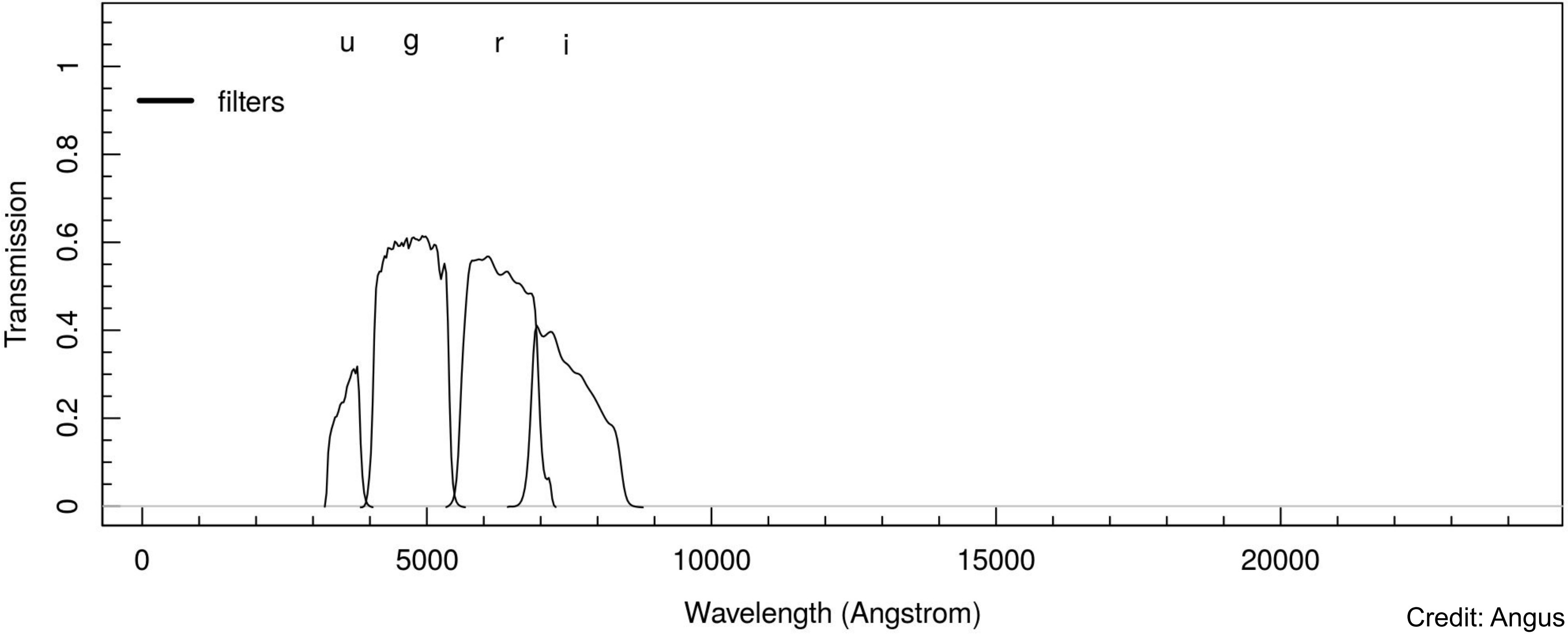
Self-Organising Map: SOM





Wright, Hildebrandt, van den Busch & Heymans 2020

What about photo-z: KiDS & VIKING



Credit: Angus Write

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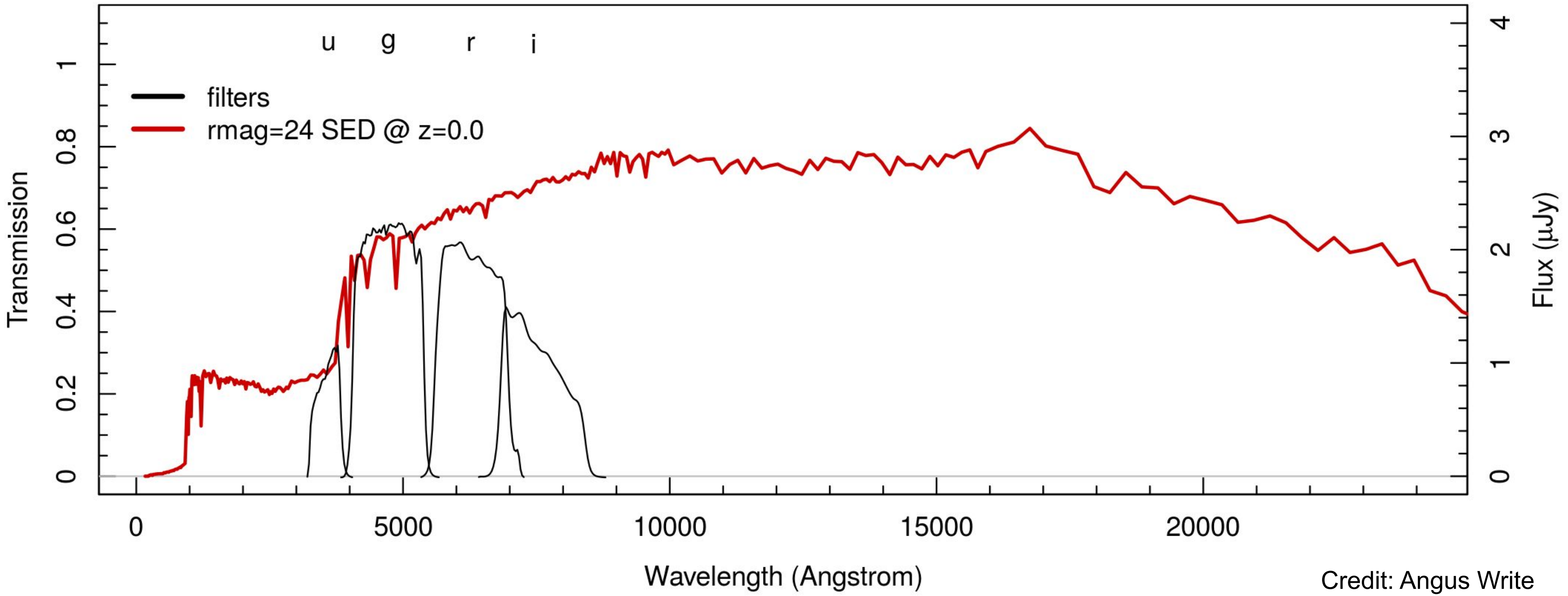

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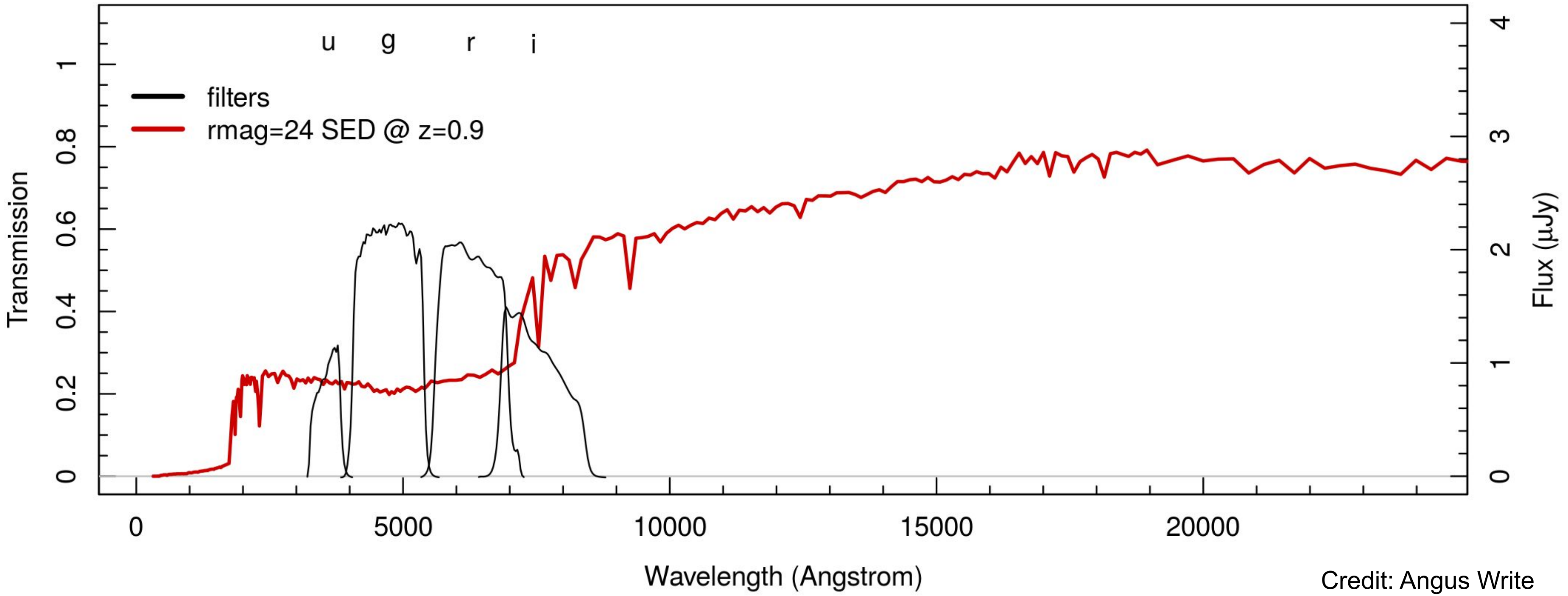

Credit: Angus Write

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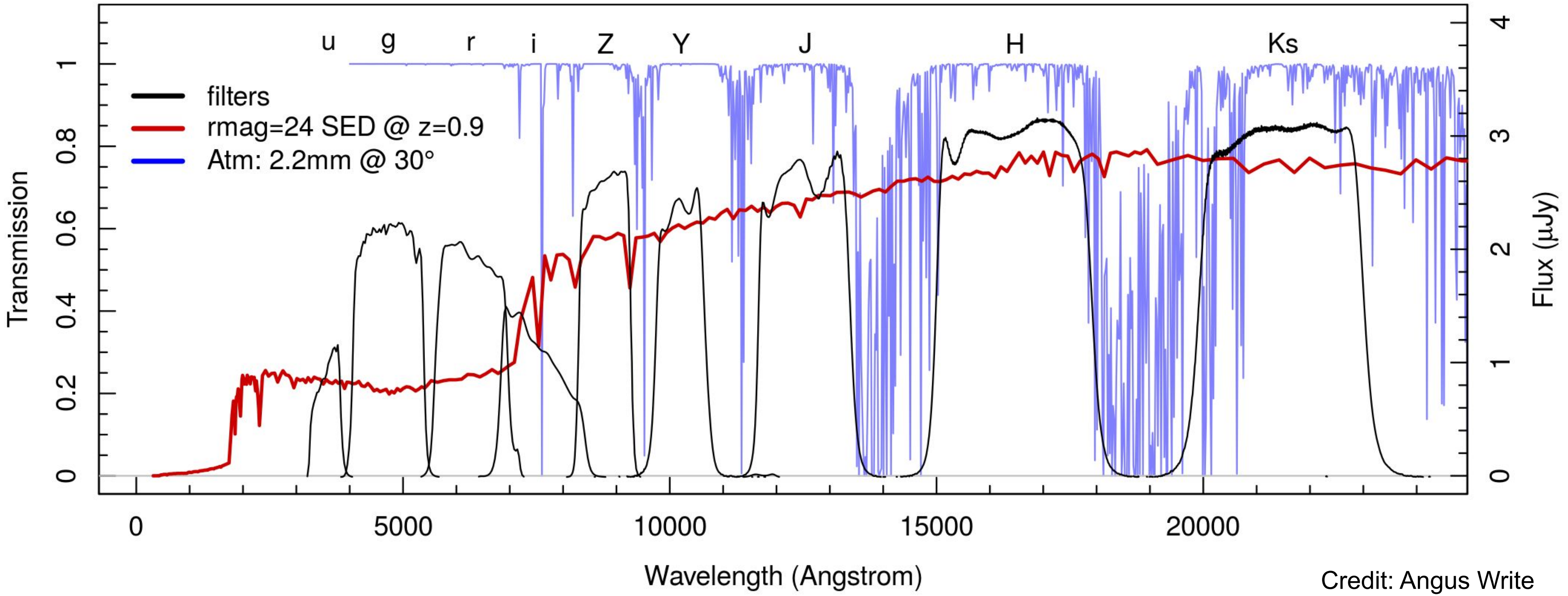

Credit: Angus Write

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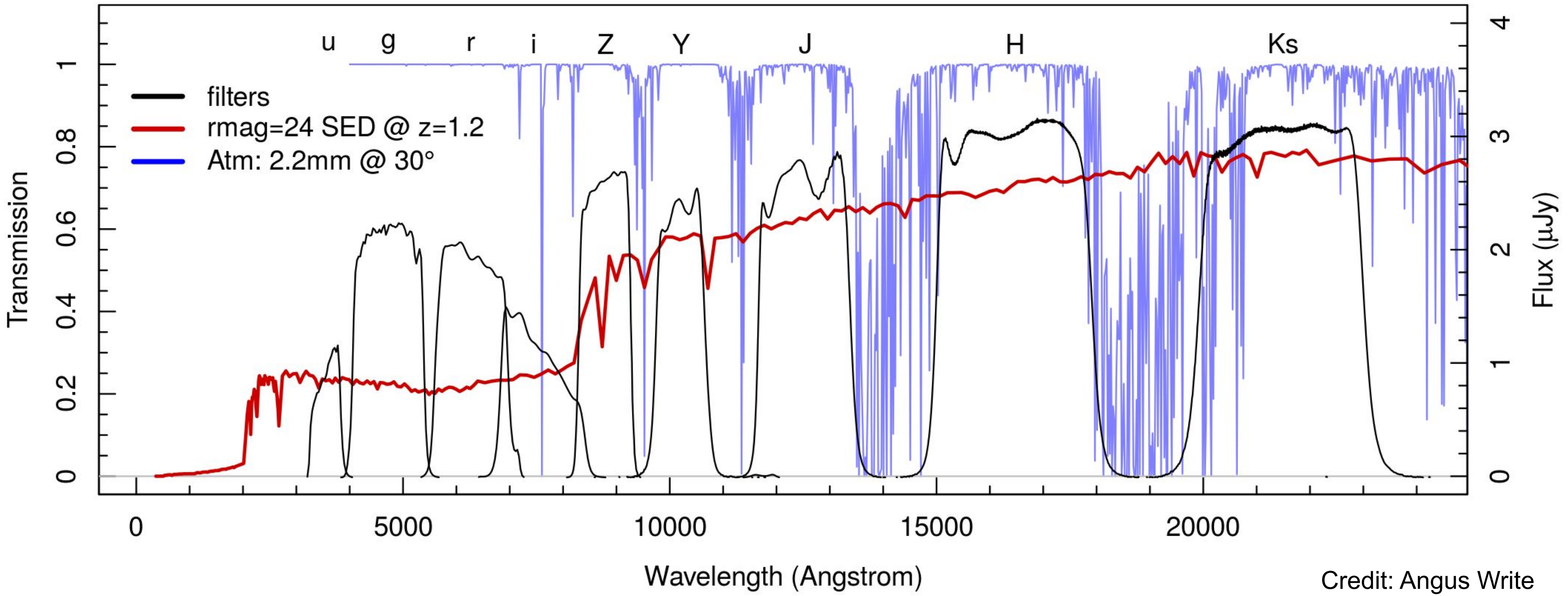
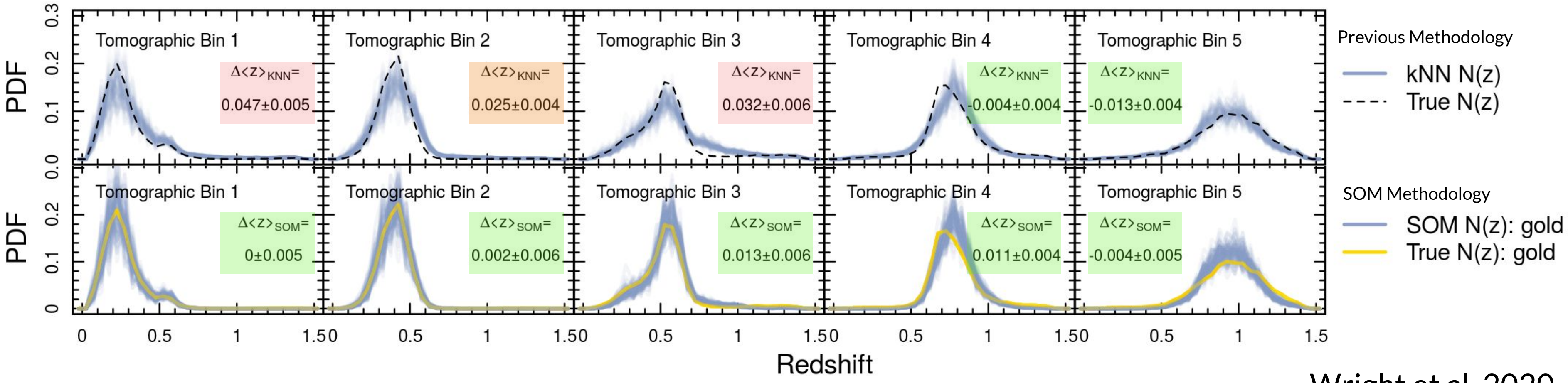


Credit: Angus Write

Photometric Redshift Accuracy: mocks



Wright et al. 2020

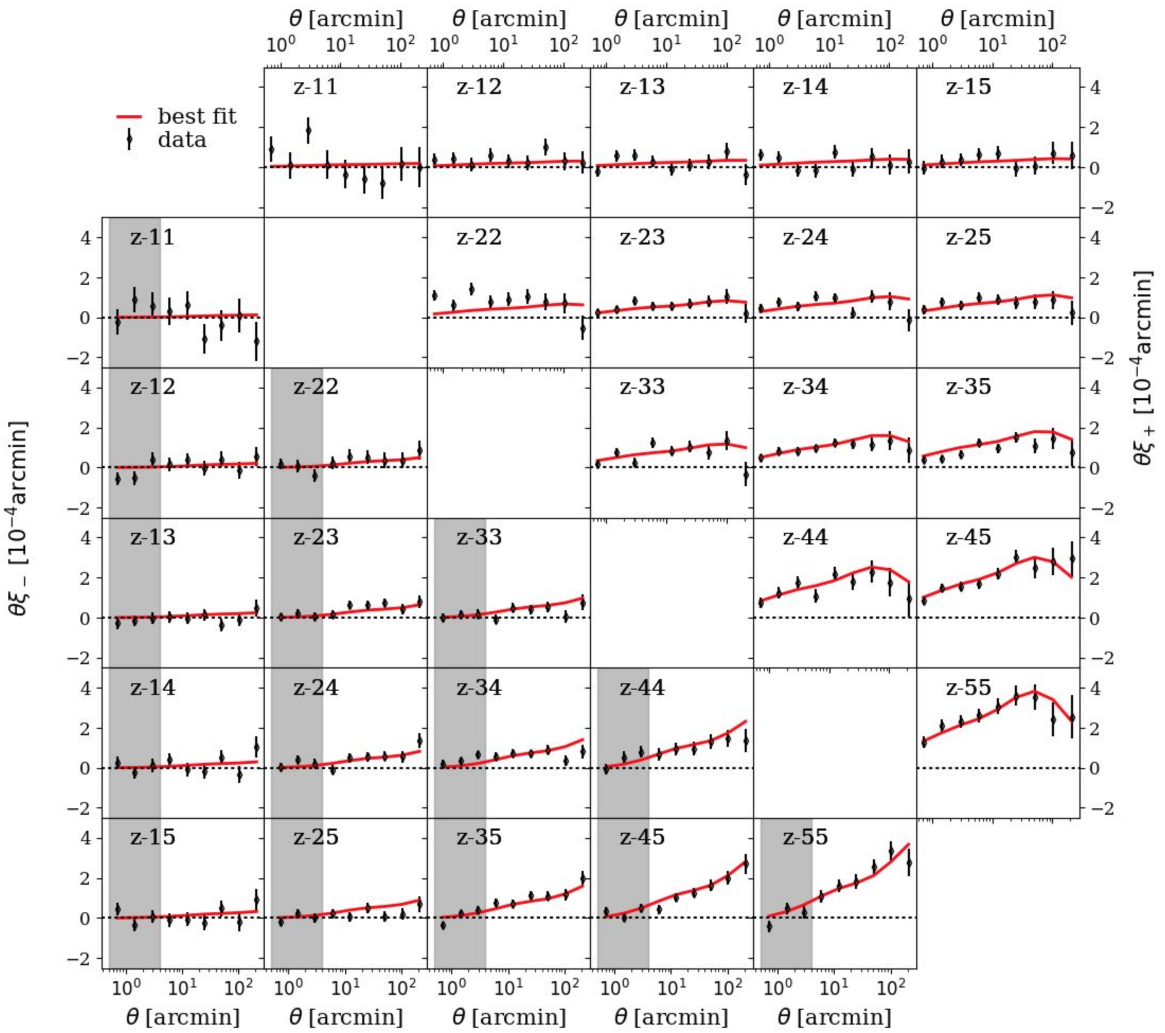
The advantage of the SOM: we trade number density precision for accuracy.

KiDS Analysis	Number density per sq arcmin	Uncertainty in the mean redshift range
KV450 (kNN)	7.4	0.011 - 0.039
KiDS-1000 (SOM)	6.2	0.008 - 0.012

Cosmic Shear

The theoretical model includes

- Flat ΛCDM
- Intrinsic Galaxy Alignments
- Baryon Feedback
- Photometric Redshift Calibration Uncertainty
- Shear Calibration Uncertainty (m)



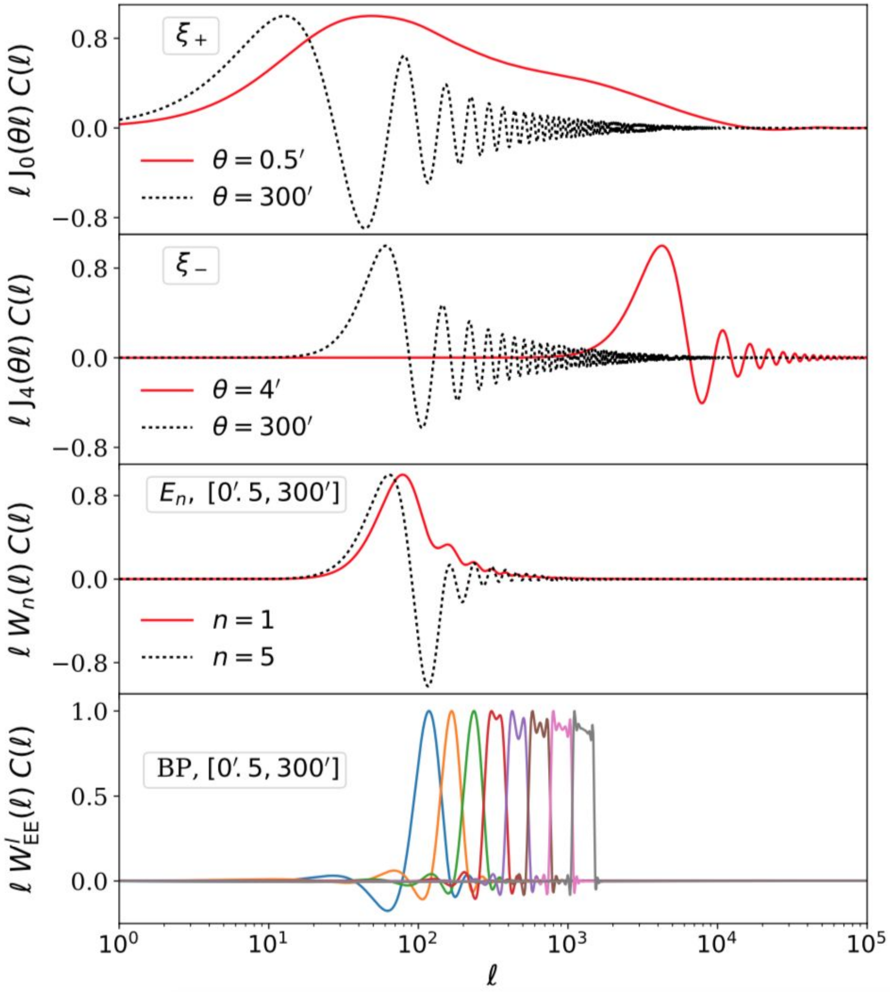
Asgari, Lin, Joachimi et al. 2021

$$S_x = \int_0^\infty \mathrm{d}\ell \, \ell \, C(\ell) \, W_x(\ell)$$

Correlation functions (2PCFs)

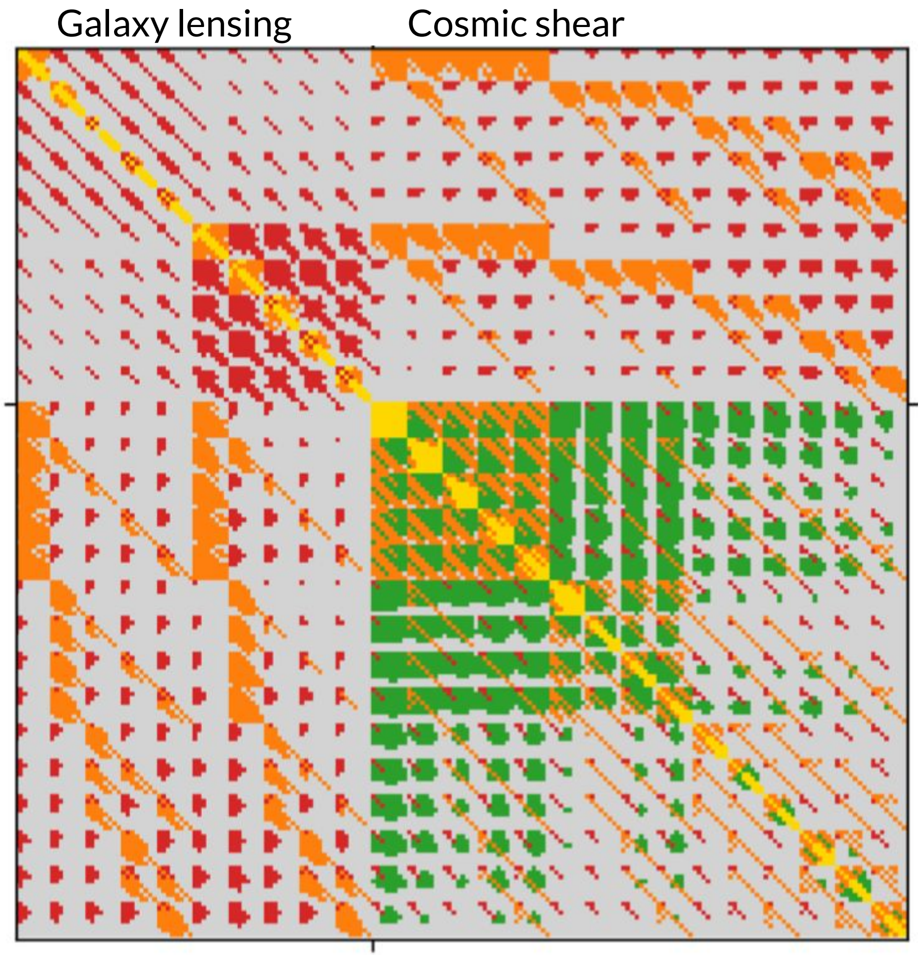
COSEBIs

Band powers



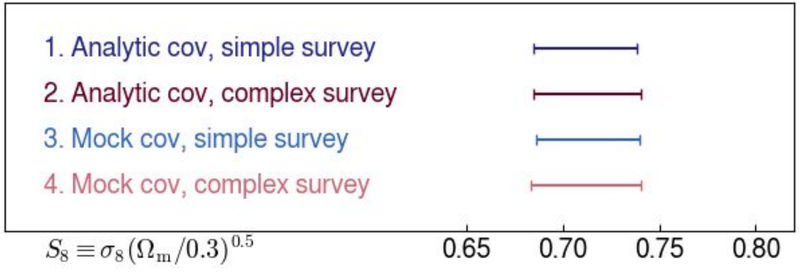
Asgari, Lin, Joachimi et al. 2020

Validating the analytical Covariance Matrix



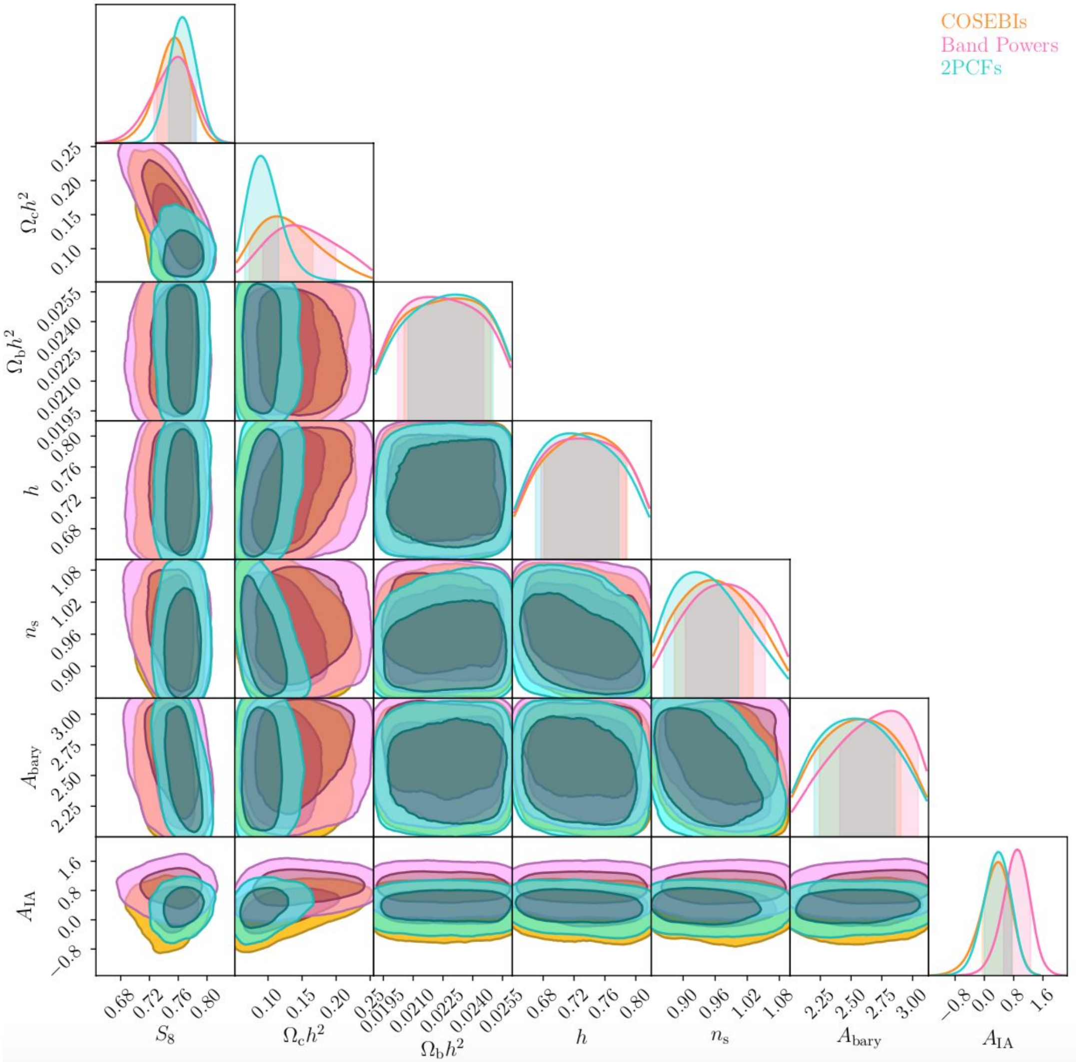
The analytical covariance has contributions from multiple sources.

We find consistent constraints using mock or analytical covariances.



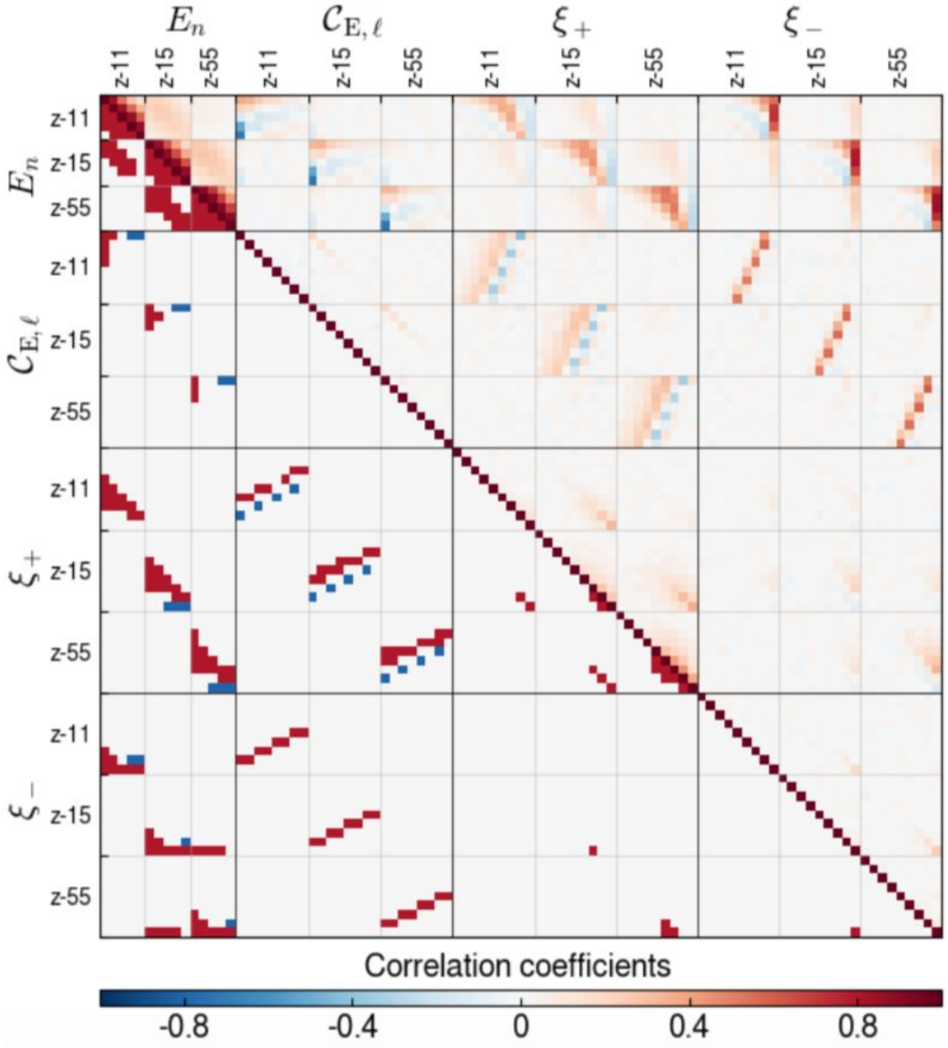
Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

Sampled parameters



Cross-covariance

- From Salmo mocks
- Z-bins: 1 and 5

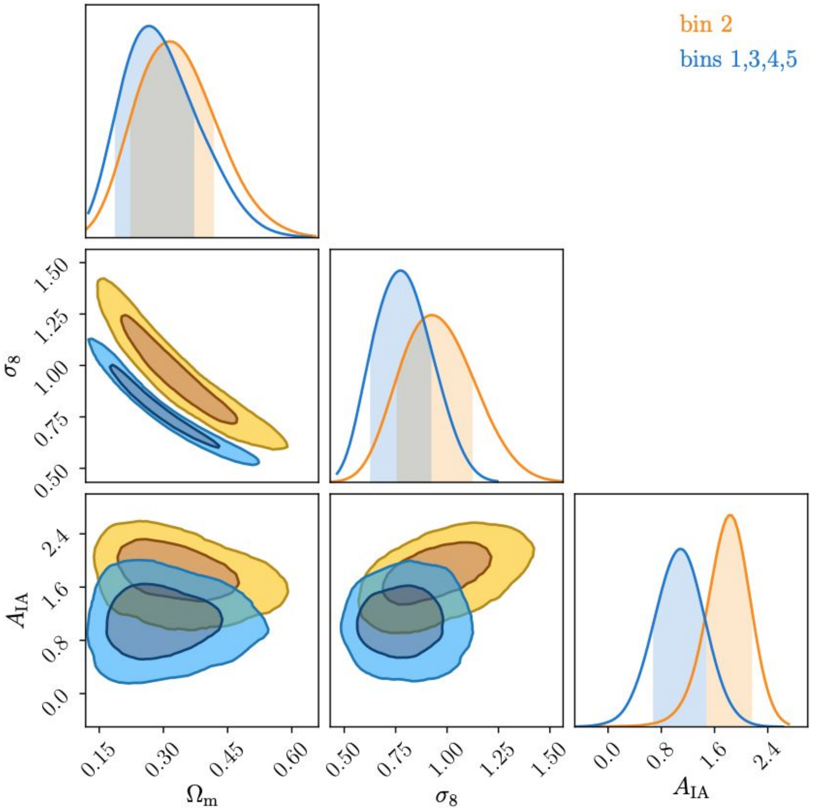


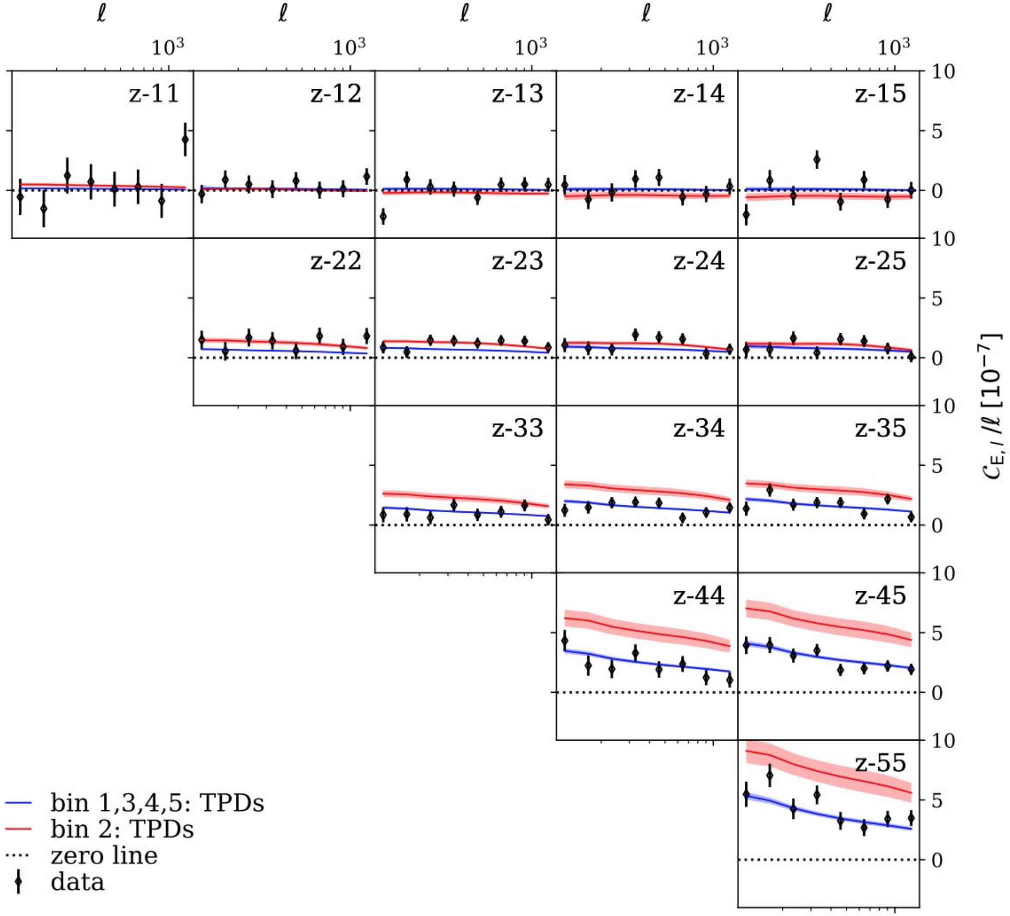
Internal consistency Bayesian tests

	data split	$\log_{10} R$(trad.)	$\log_{10} R$(import.)	$\ln S$	$\Delta(S_8, A_{IA})$	$\Delta(S_8)$	$\Delta(A_{IA})$
COSEBIs	z-bin 1 vs. all others	0.57	1.12	0.22	0.7σ	1.4σ	0.1σ
	z-bin 2 vs. all others	−1.89	−1.56	−8.82	2.2σ	2.7σ	2.1σ
	z-bin 3 vs. all others	1.69	2.47	0.14	0.1σ	0.1σ	0.5σ
	z-bin 4 vs. all others	0.95	1.82	−2.06	1.2σ	1.1σ	1.4σ
	z-bin 5 vs. all others	0.82	1.47	−2.77	1.3σ	1.3σ	1.2σ
BP	z-bin 1 vs. all others	0.05	0.65	−0.25	1.6σ	$2.0.\sigma$	0.4σ
	z-bin 2 vs. all others	−2.46	−1.76	−9.61	2.8σ	3.0σ	1.5σ
	z-bin 3 vs. all others	1.56	2.26	0.23	0.1σ	0.2σ	0.1σ
	z-bin 4 vs. all others	0.05	0.75	−3.64	1.5σ	1.6σ	1.5σ
	z-bin 5 vs. all others	1.25	2.00	−0.75	1.0σ	0.8σ	1.4σ
2PCFs	z-bin 1 vs. all others	1.20	2.00	0.99	0.3σ	1.1σ	0.1σ
	z-bin 2 vs. all others	−2.07	−1.23	−9.92	2.2σ	2.4σ	2.1σ
	z-bin 3 vs. all others	2.35	3.13	0.42	0.7σ	1.2σ	0.5σ
	z-bin 4 vs. all others	0.69	1.14	−4.65	0.9σ	1.1σ	1.2σ
	z-bin 5 vs. all others	0.78	1.61	−3.93	1.0σ	0.7σ	1.5σ

Asgari, Lin, Joachimi et al. 2020

Bin 2 versus others





Asgari, Lin, Joachimi et al. 2020