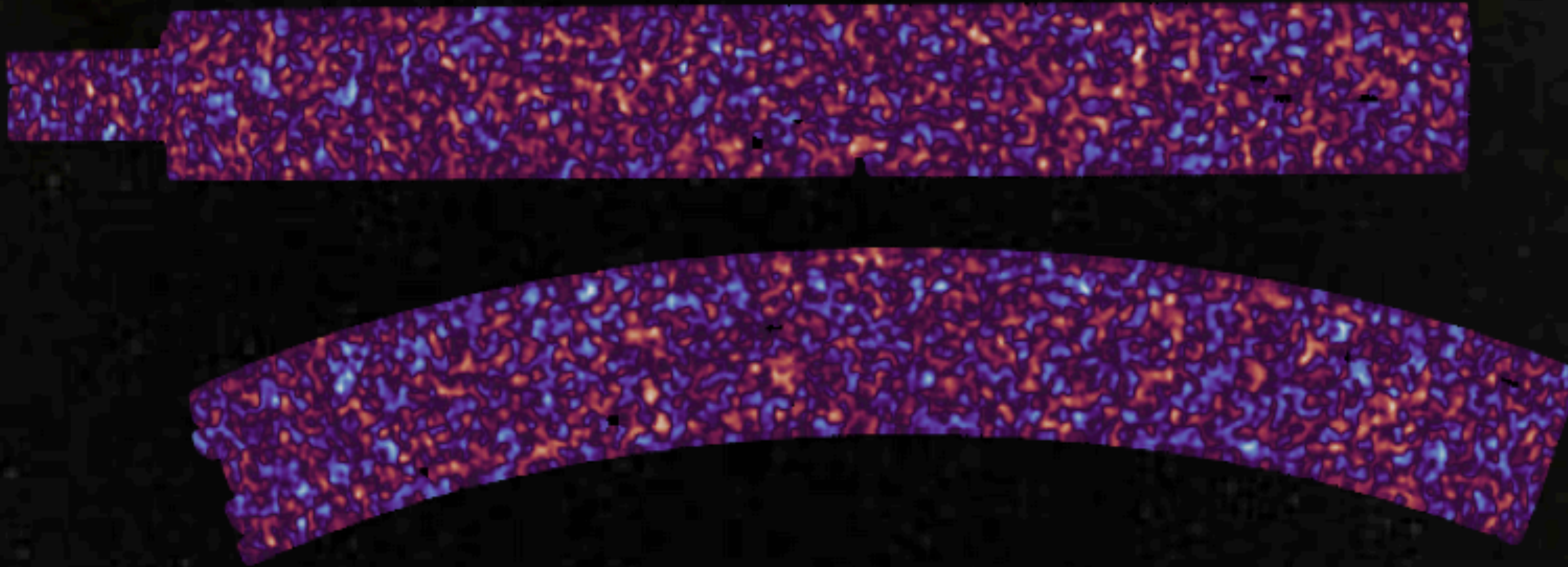




RUHR-UNIVERSITÄT BOCHUM

Benjamin Stölzner

KiDS-Legacy: Final cosmological constraints from the complete Kilo-Degree Survey

GGI workshop: Exploring New Frontiers in Cosmology

15th July 2026

Outline

- Kilo-Degree Survey and cosmic shear
- KiDS DR5 and KiDS-Legacy
- S_8 tension
- Internal consistency of the KiDS-Legacy dataset
- Follow-up analyses
- Conclusions

Kilo-Degree Survey (KiDS)



Image credit: ESO

- ESO survey, specifically designed for weak lensing science
- Covering 1347 deg² in four photometric bands
- Partner survey VIKING provides five near-infrared bands
- Median r-band 5 σ limiting magnitude: 24.8
- Median seeing: 0.7''

Kilo-Degree Survey (KiDS)

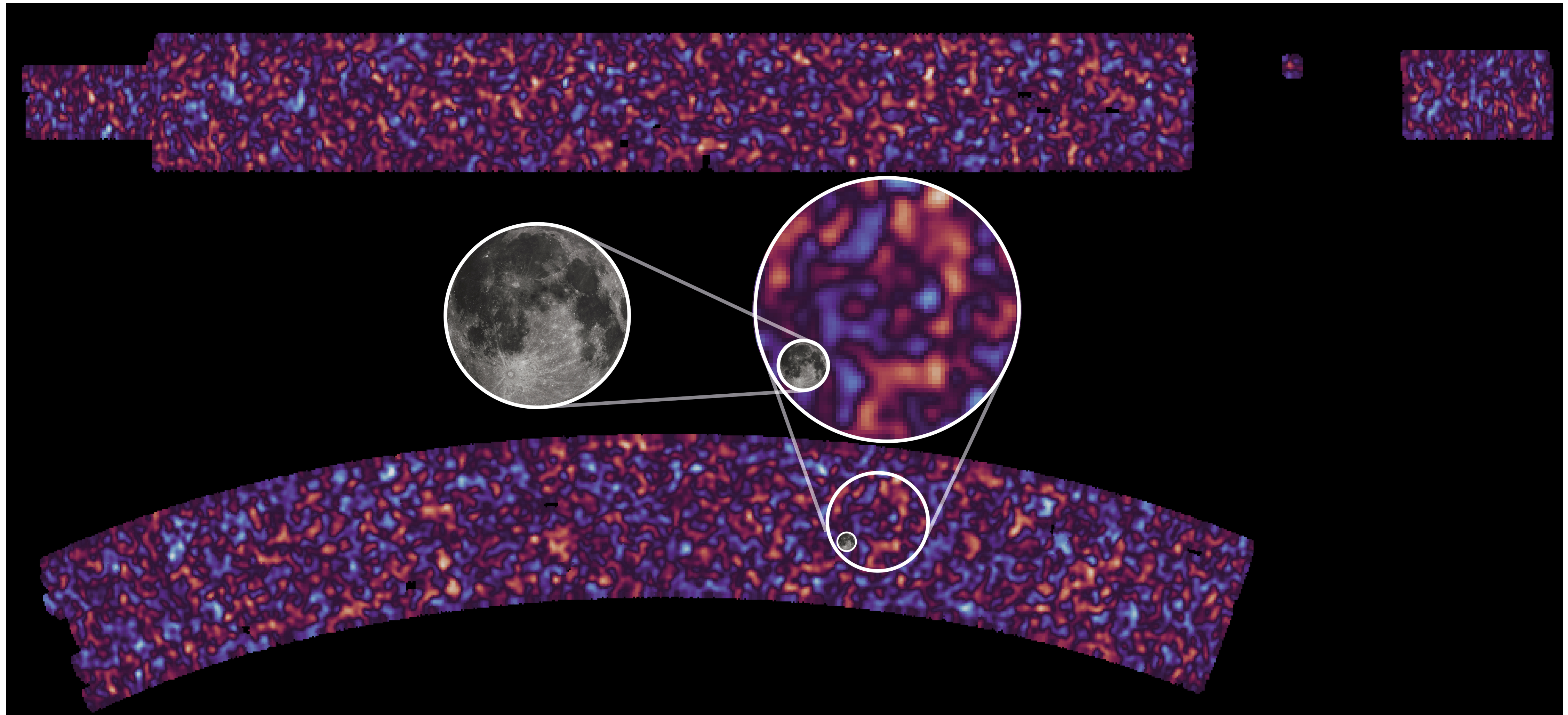


Image credit: R.Reischke, K.Kuijken, B.Giblin, and the KiDS team

Kilo-Degree Survey (KiDS)



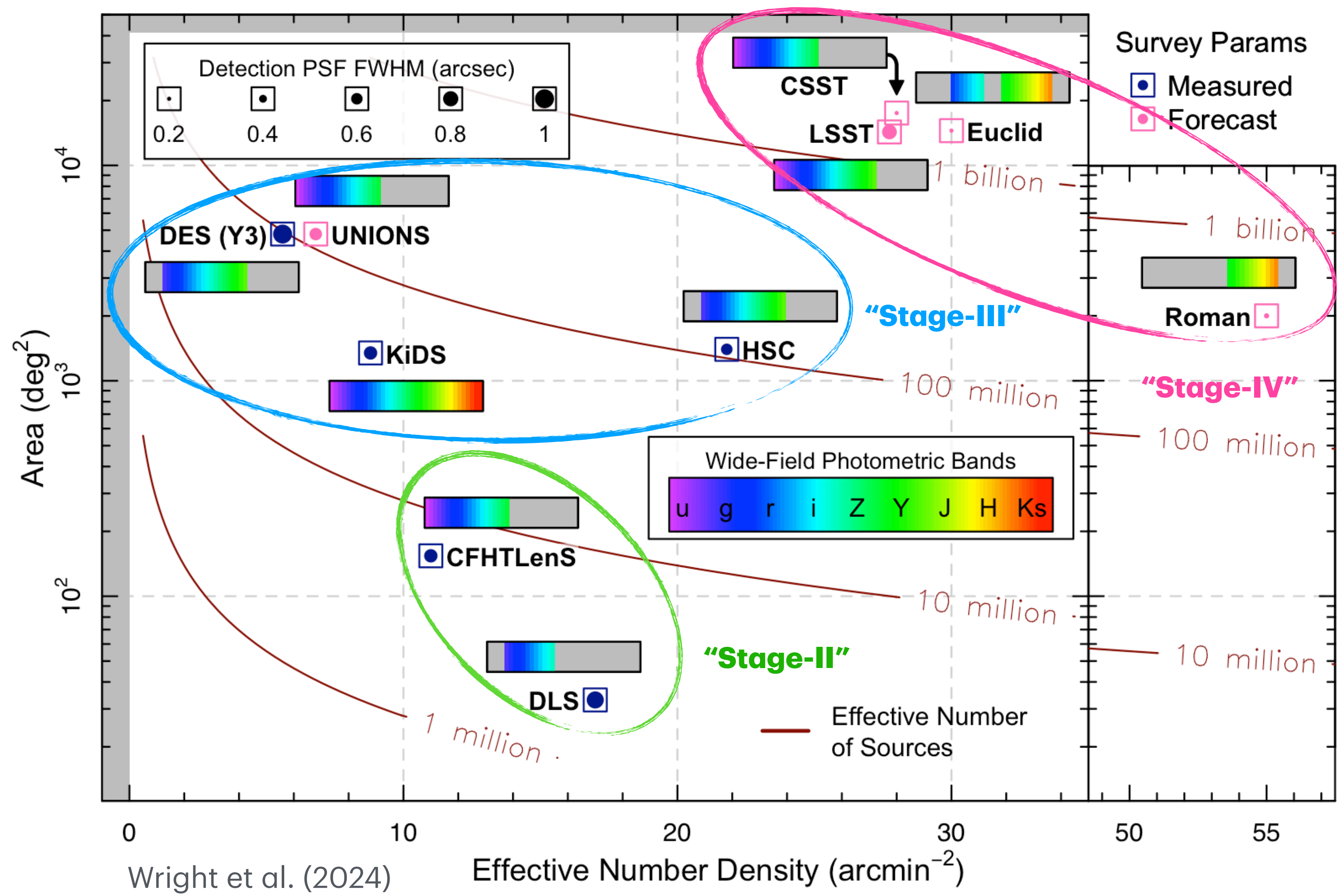
📷 Lead authors of the publications Dr. Benjamin Stölzner and Dr. Angus Wright (second and third from the left) from Ruhr University Bochum and Dr. Robert Reischke (right), formerly in Bochum, now at the University of Bonn, together with Professor Hendrik Hildebrandt from the Ruhr University Bochum who oversaw the evaluation of KiDS-Legacy. © RUB, Marquard

Kilo-Degree Survey (KiDS)

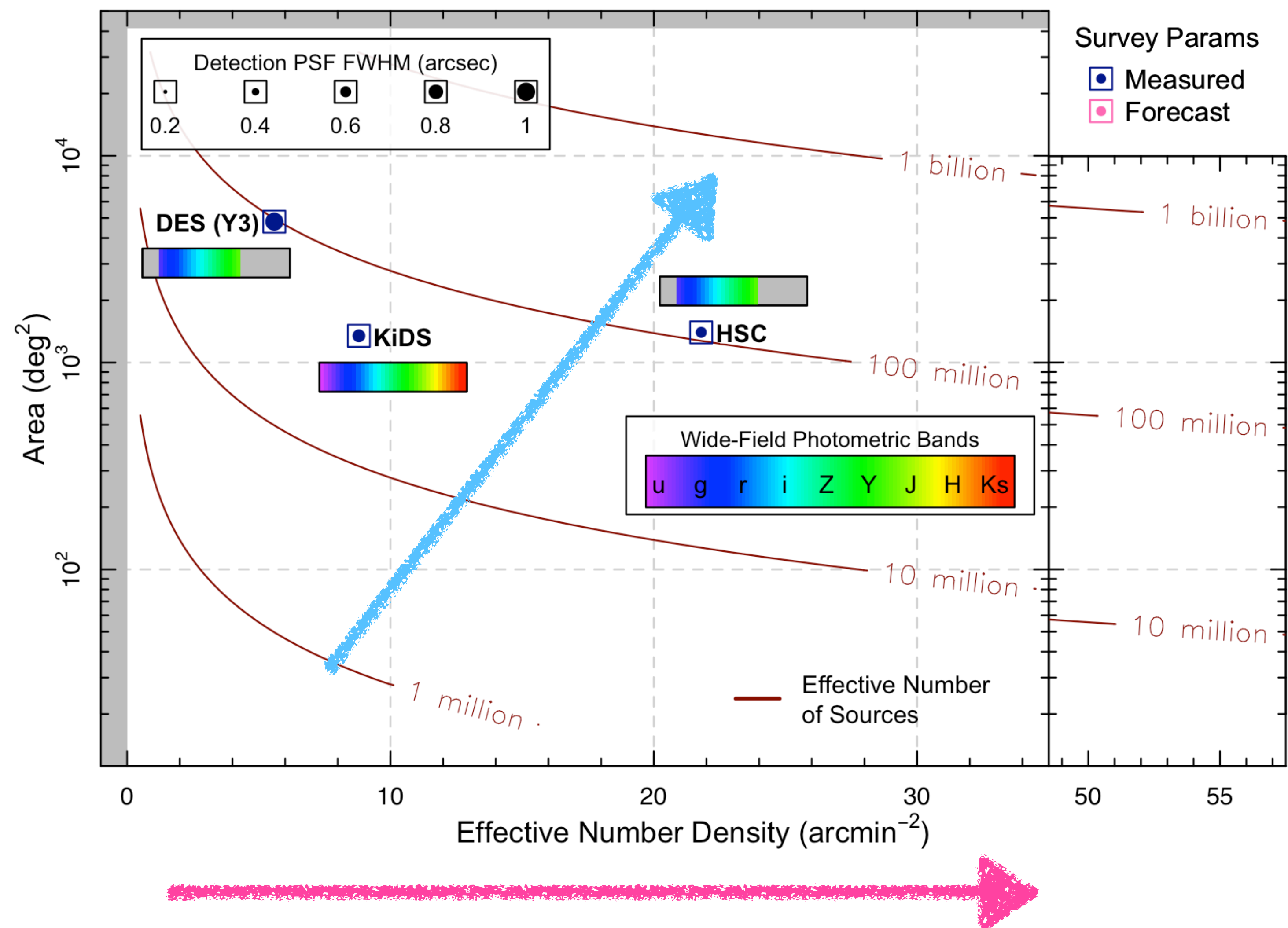


Image credit: KiDS team

Imaging surveys for cosmology



Imaging surveys for cosmology



Higher lensing SNR per unit area
Access to higher redshift samples

Lower statistical noise

Better line-of-sight localisation

Better shape measurement

Cosmic shear

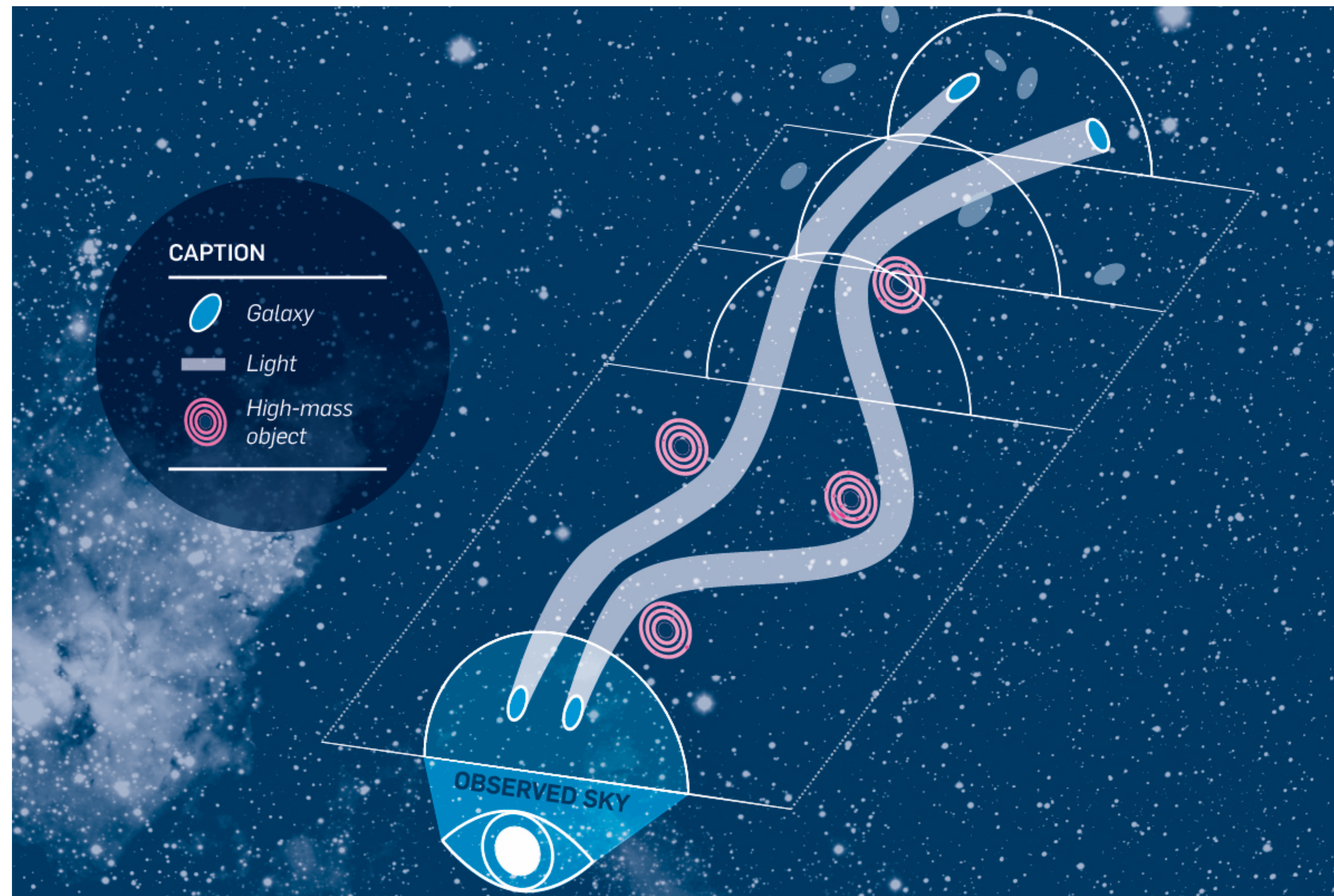


Image credit: RUB

Sensitive to:

- Matter distribution
- Geometry

Observables:

- Ellipticities
- Photometric redshift

Cosmic shear

Observations

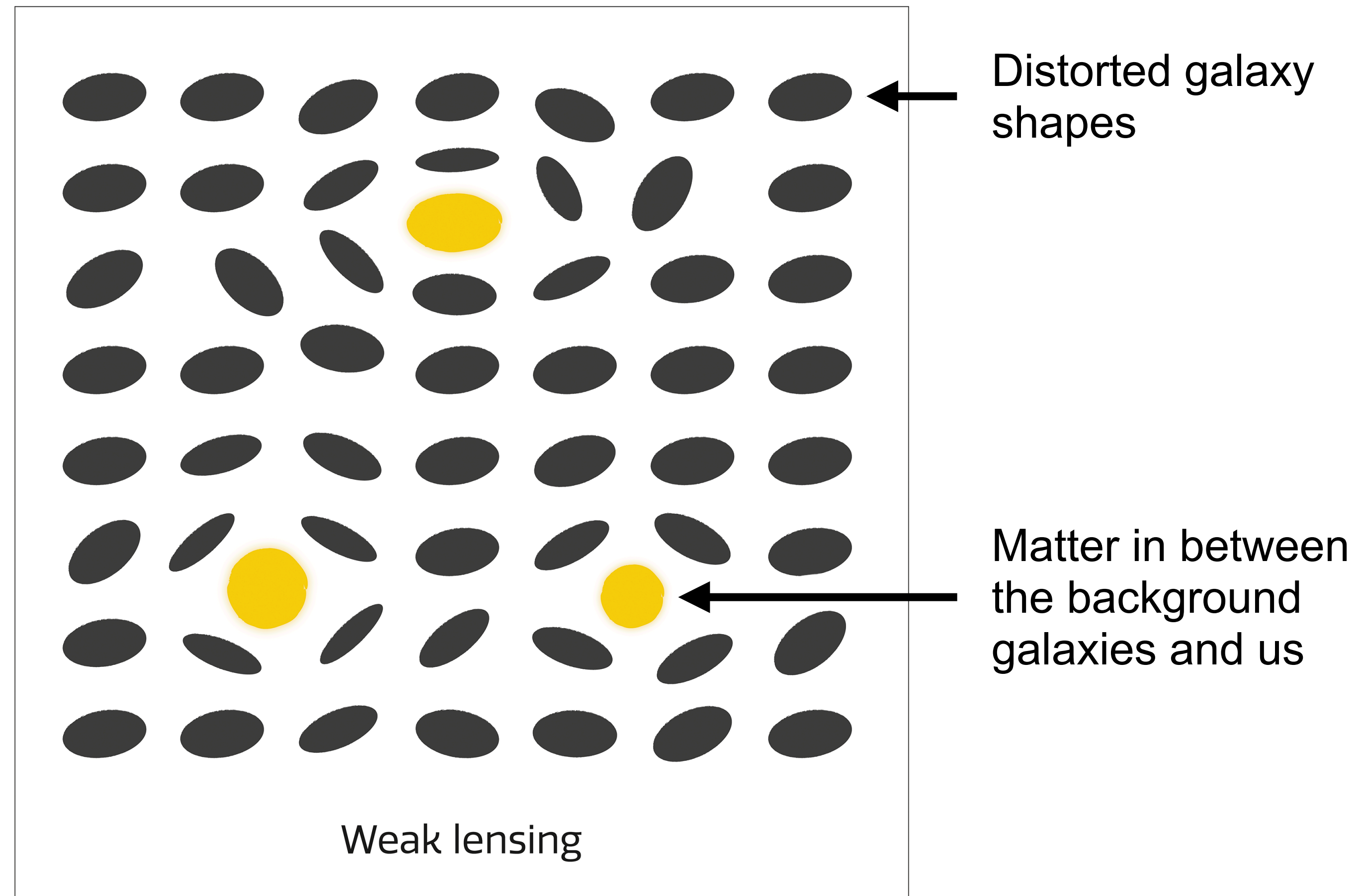


Image credit: NOIRLab/NSF/AURA

Observed shapes have two contributions:

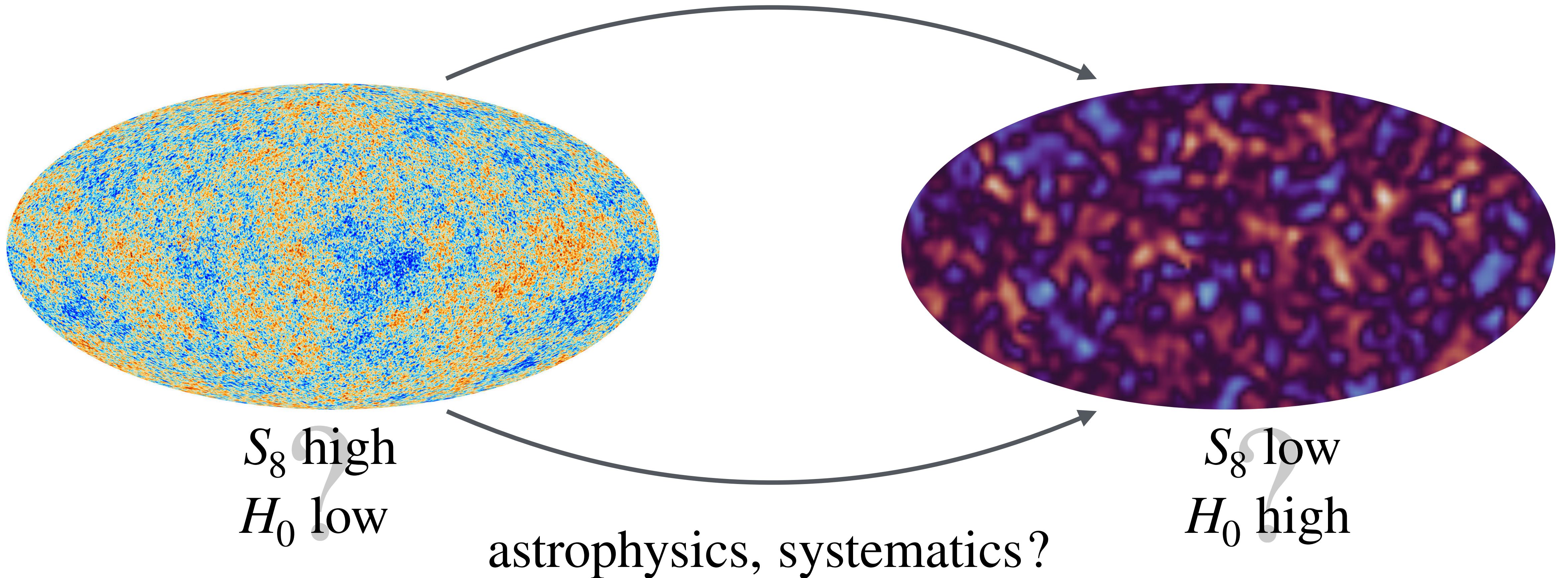
$$\gamma^{\text{observed}} \approx \gamma + \epsilon_{\text{intrinsic}}$$

Matter distribution is approximately Gaussian → two-point correlations capture most of the field information:

$$\xi_{\pm}(\theta) = \langle \gamma_t \gamma_t \rangle(\theta) \pm \langle \gamma_{\times} \gamma_{\times} \rangle(\theta)$$

Early vs late measurements

Λ CDM, GR, DE?



Intrinsic alignments

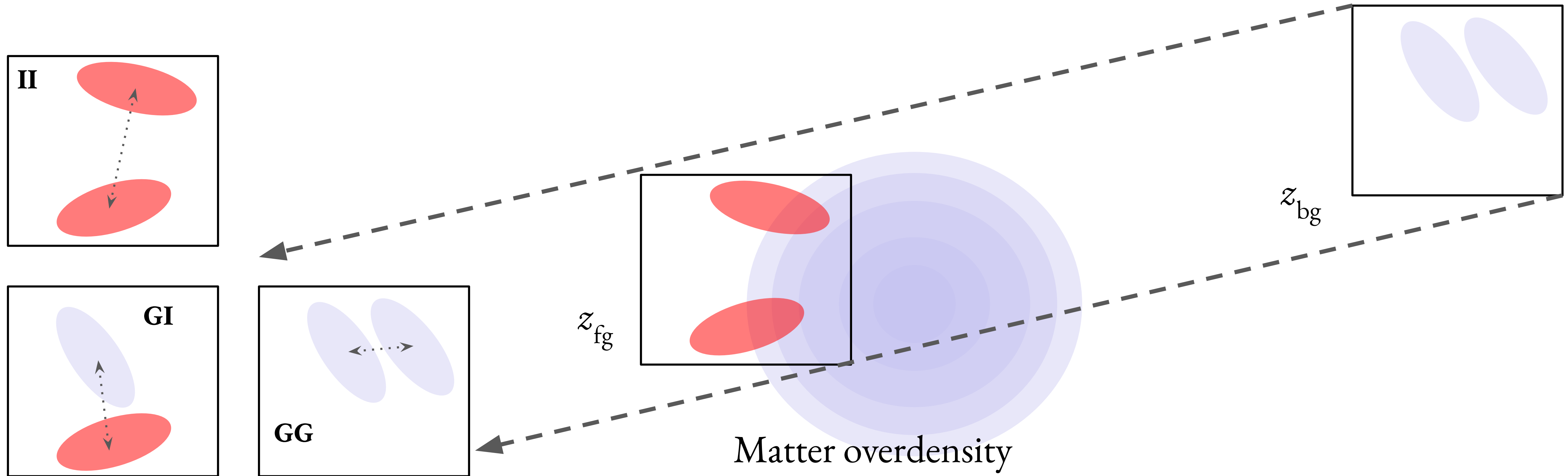
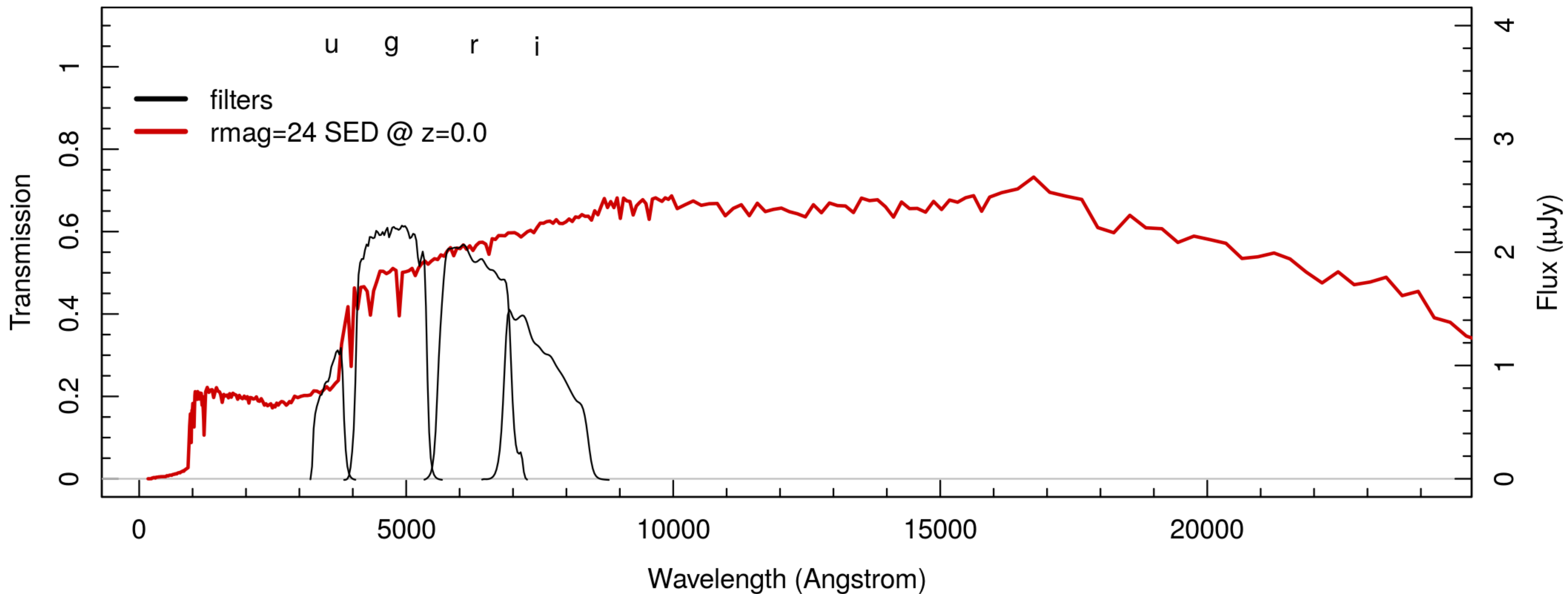


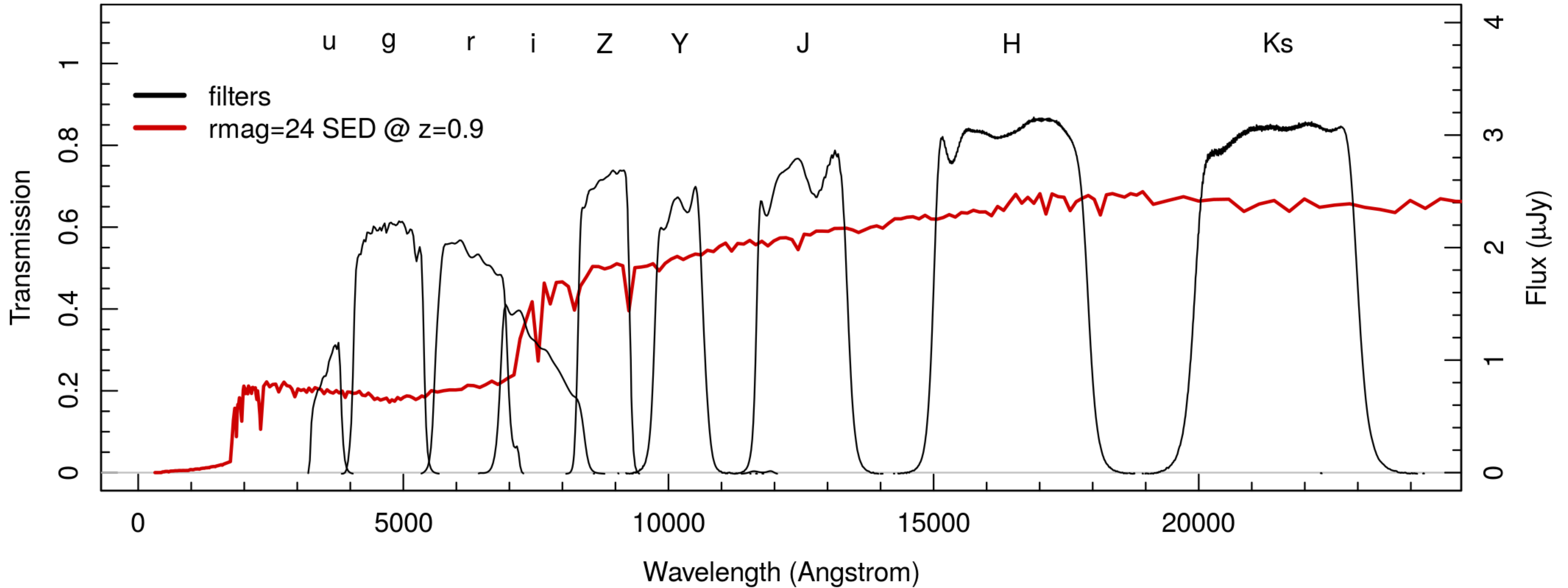
Image credit: Marika Asgari

$$C_{\epsilon\epsilon}(\ell) = C_{GG}(\ell) + C_{GI}(\ell) + C_{IG}(\ell) + C_{II}(\ell)$$

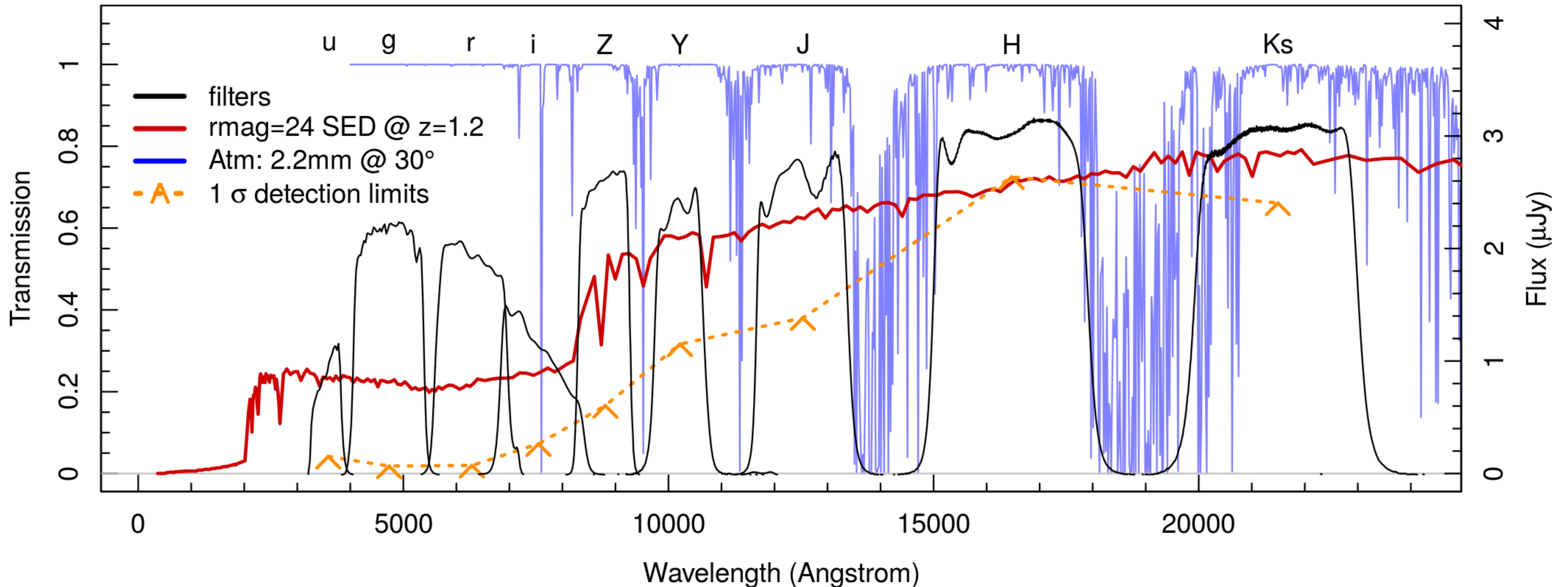
Photometric redshift



Photometric redshift

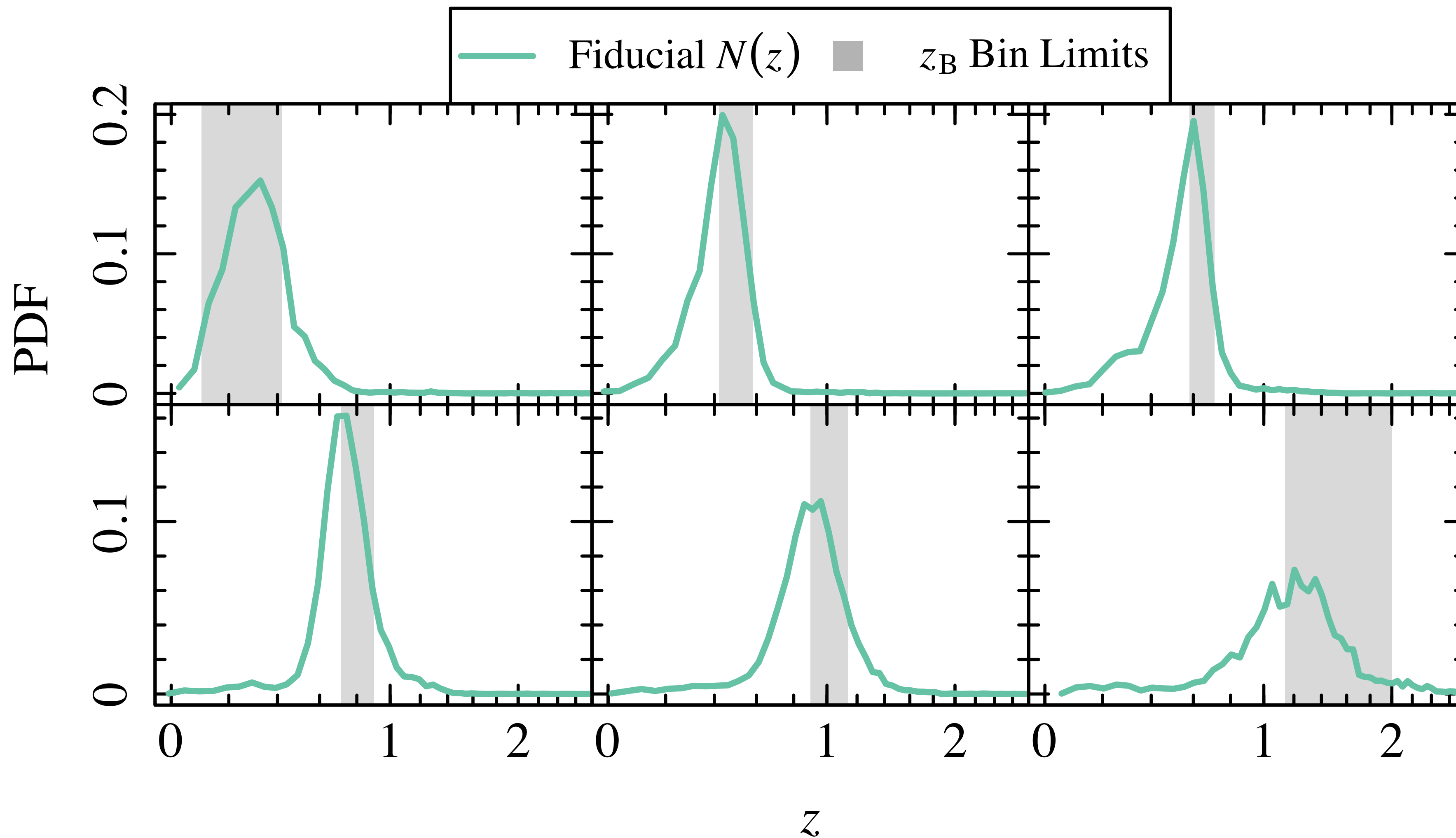


Photometric redshift



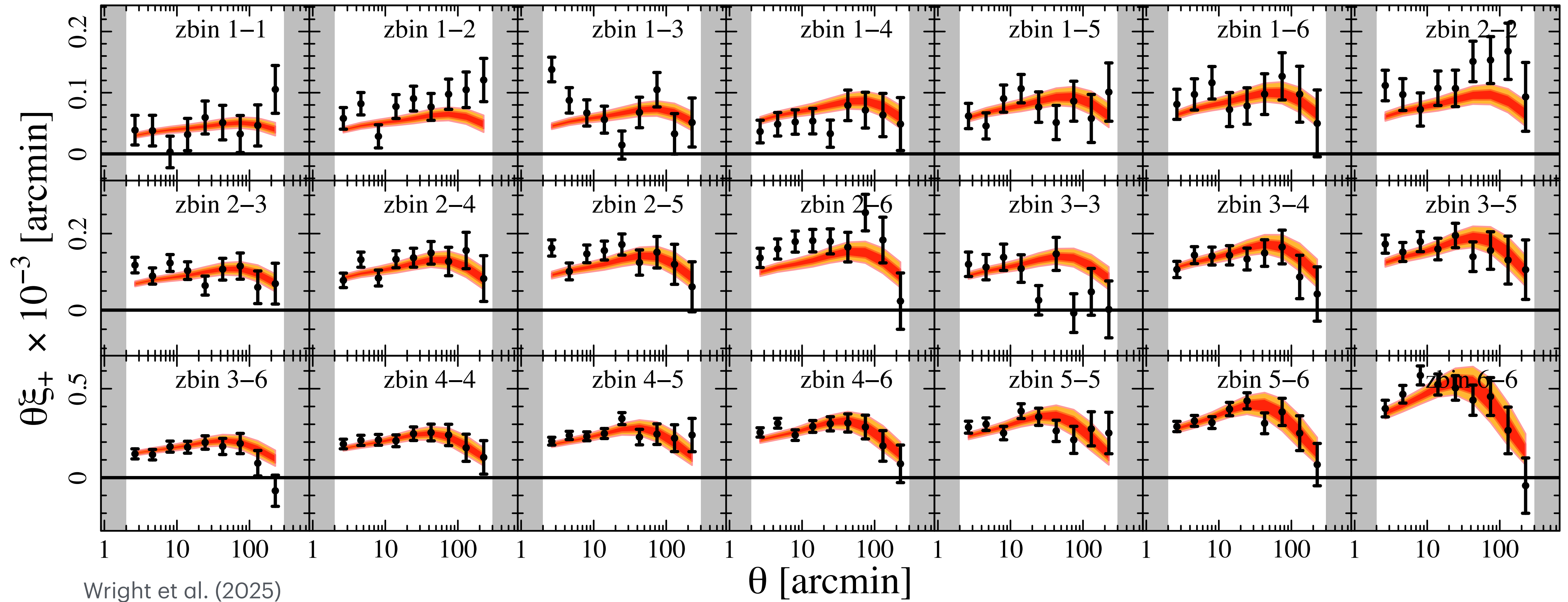
Use template-fitting codes (e.g. BPZ) to infer photometric redshift estimates per object

Tomographic redshift bins

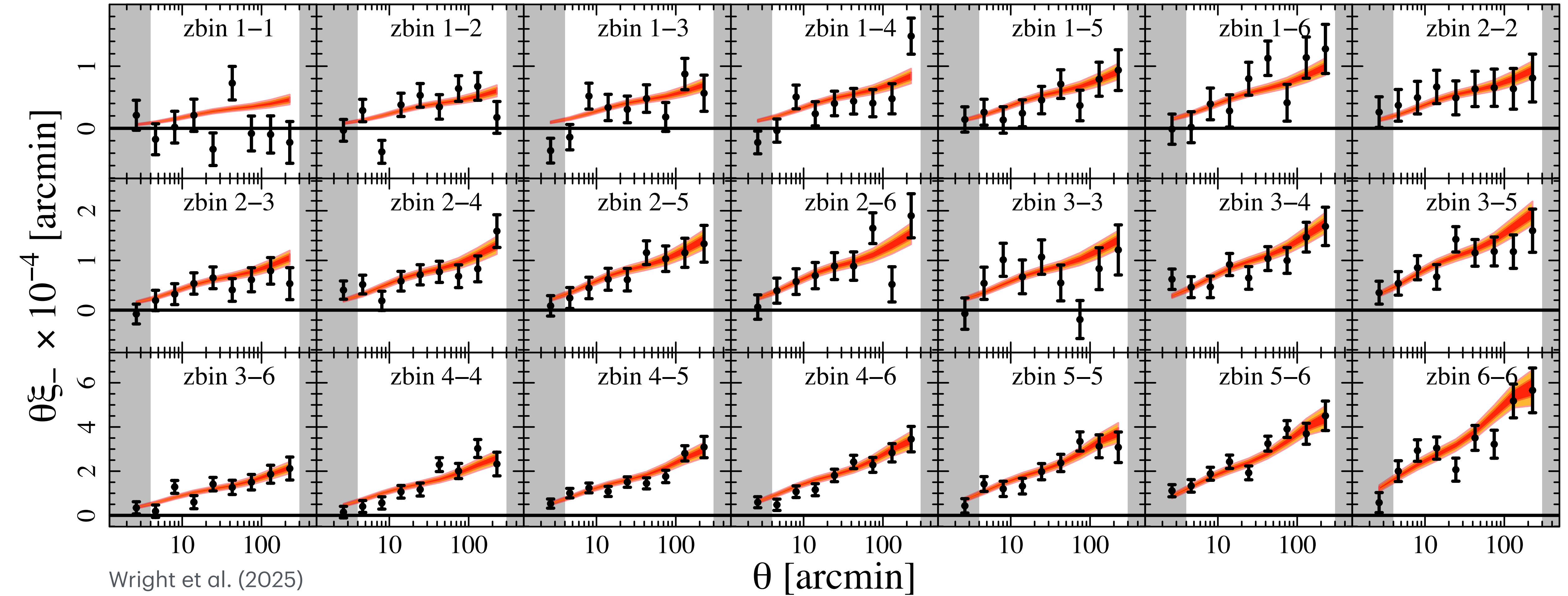


Equipopulated binning to optimise the signal-to-noise ratio (see Sipp et al. 2021)

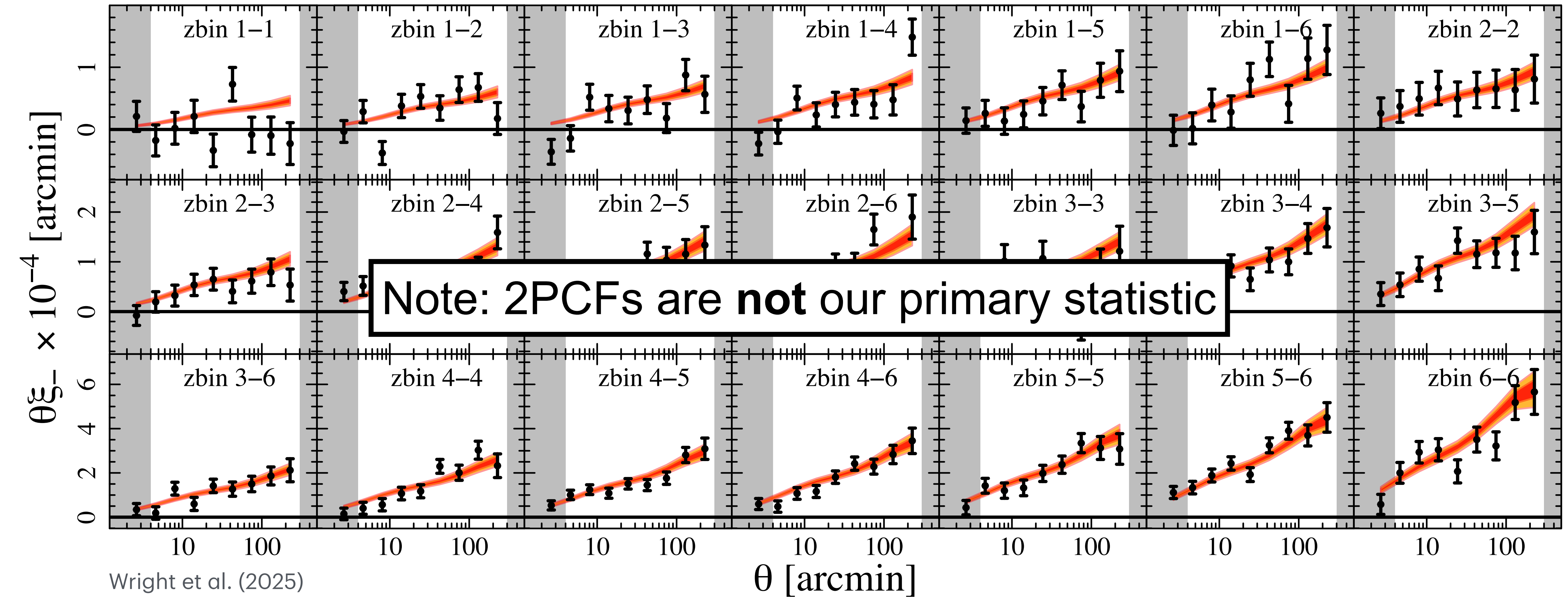
2PCF data vector



2PCF data vector

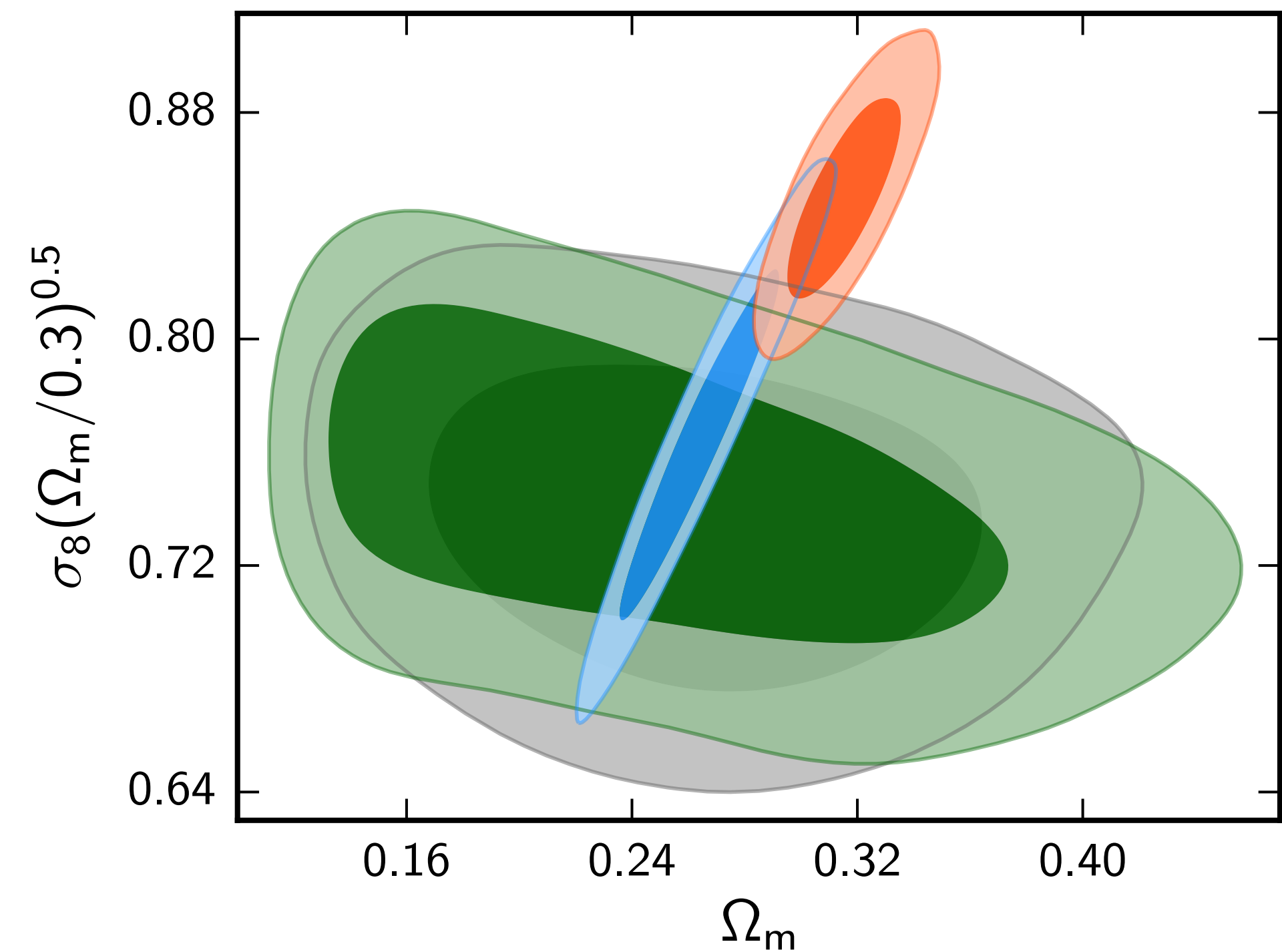
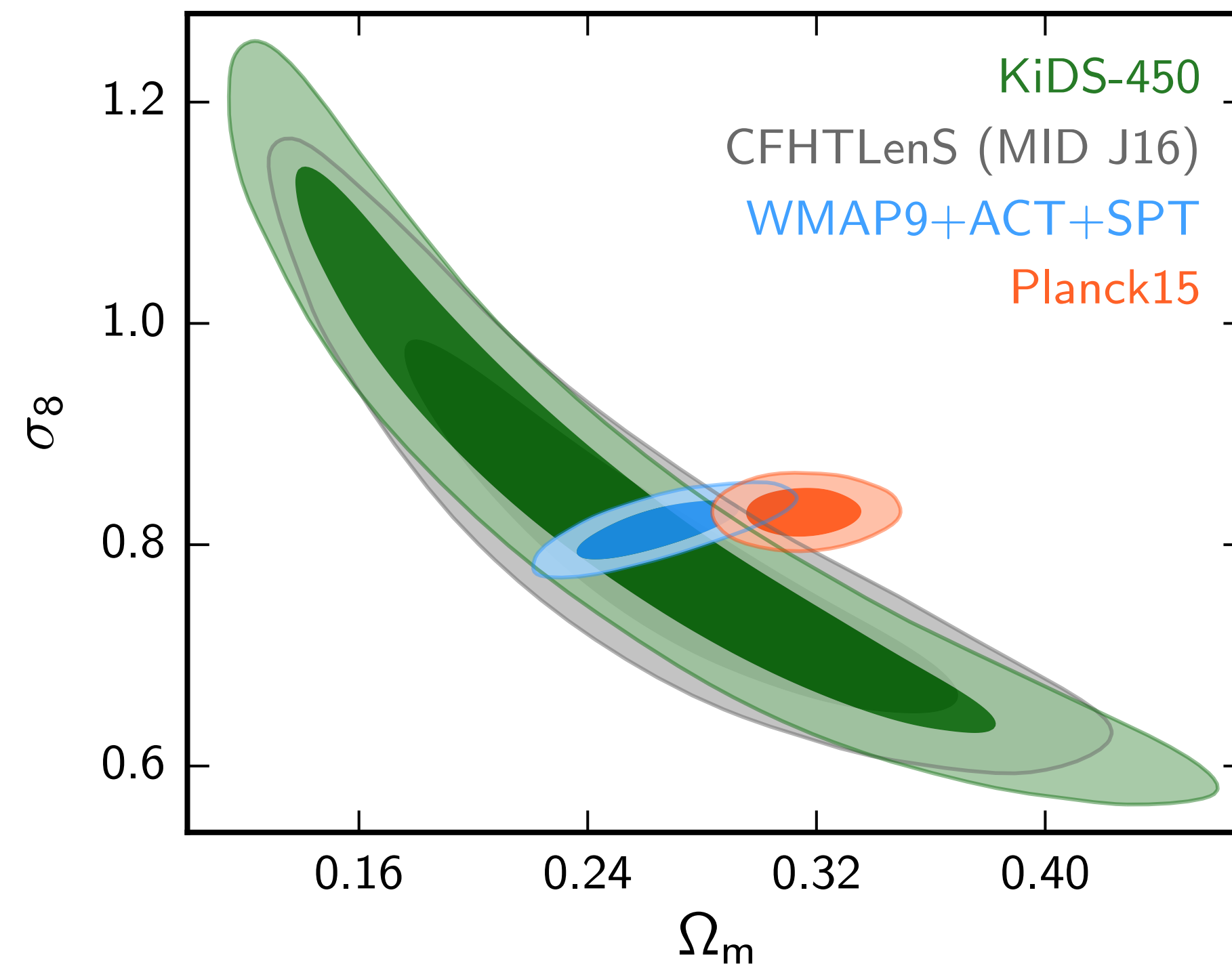


2PCF data vector



Cosmic shear constraints

KiDS-450

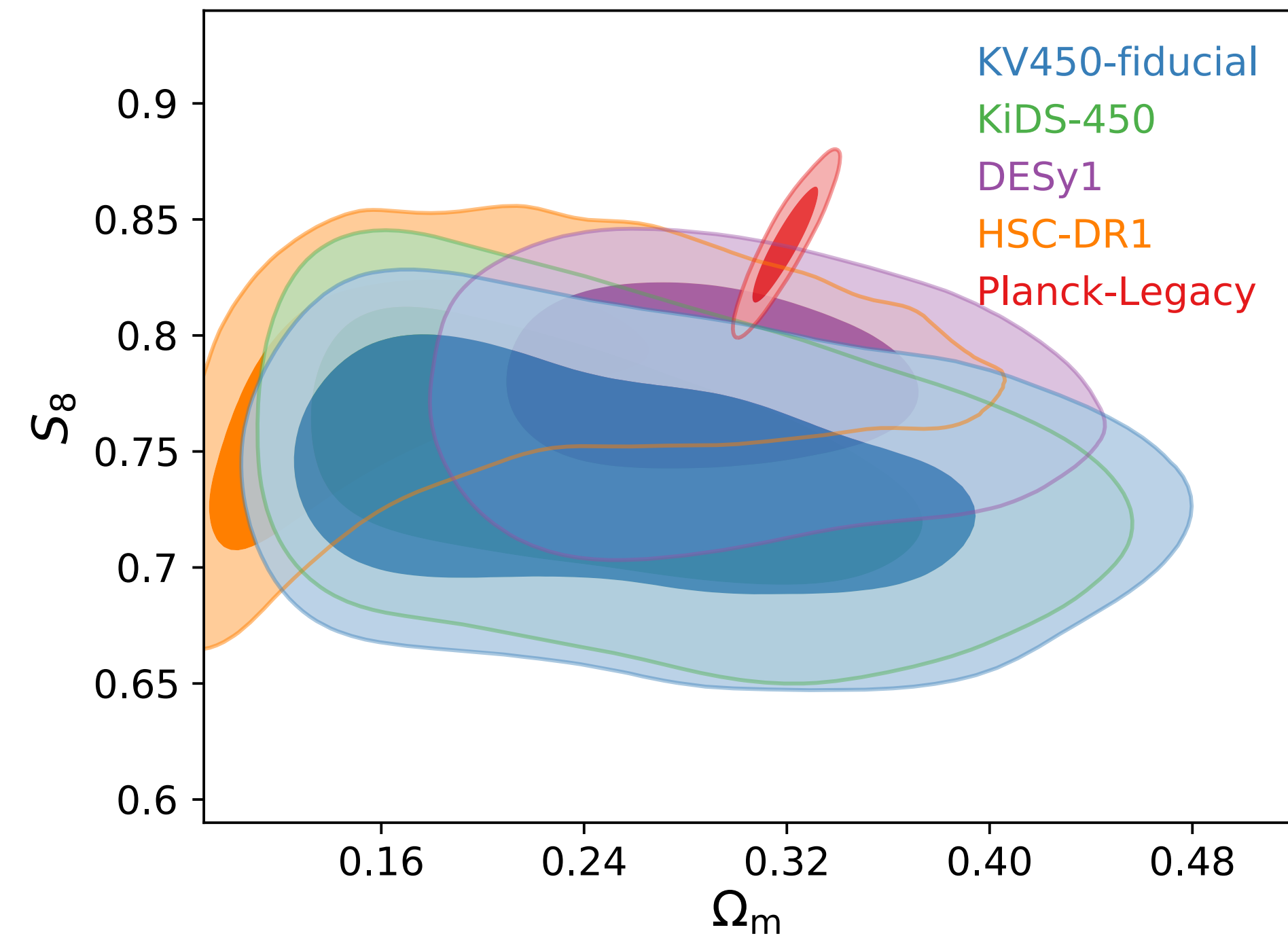
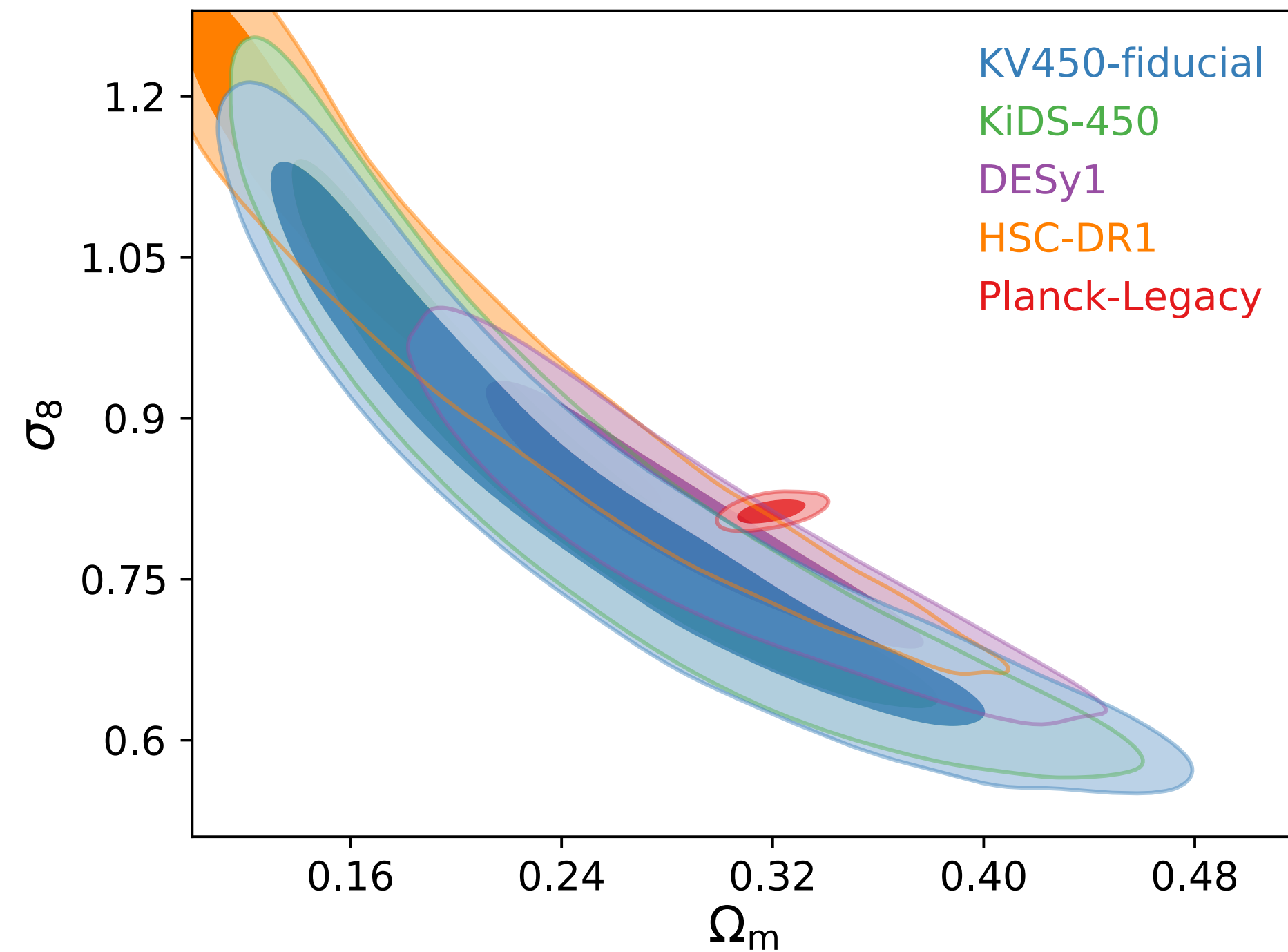


Hildebrandt et al. (2017)

"A 2.3σ tension in S_8 and 'substantial discordance' in the full parameter space is found with respect to the Planck 2015 results."

Cosmic shear constraints

KiDS+VIKING-450

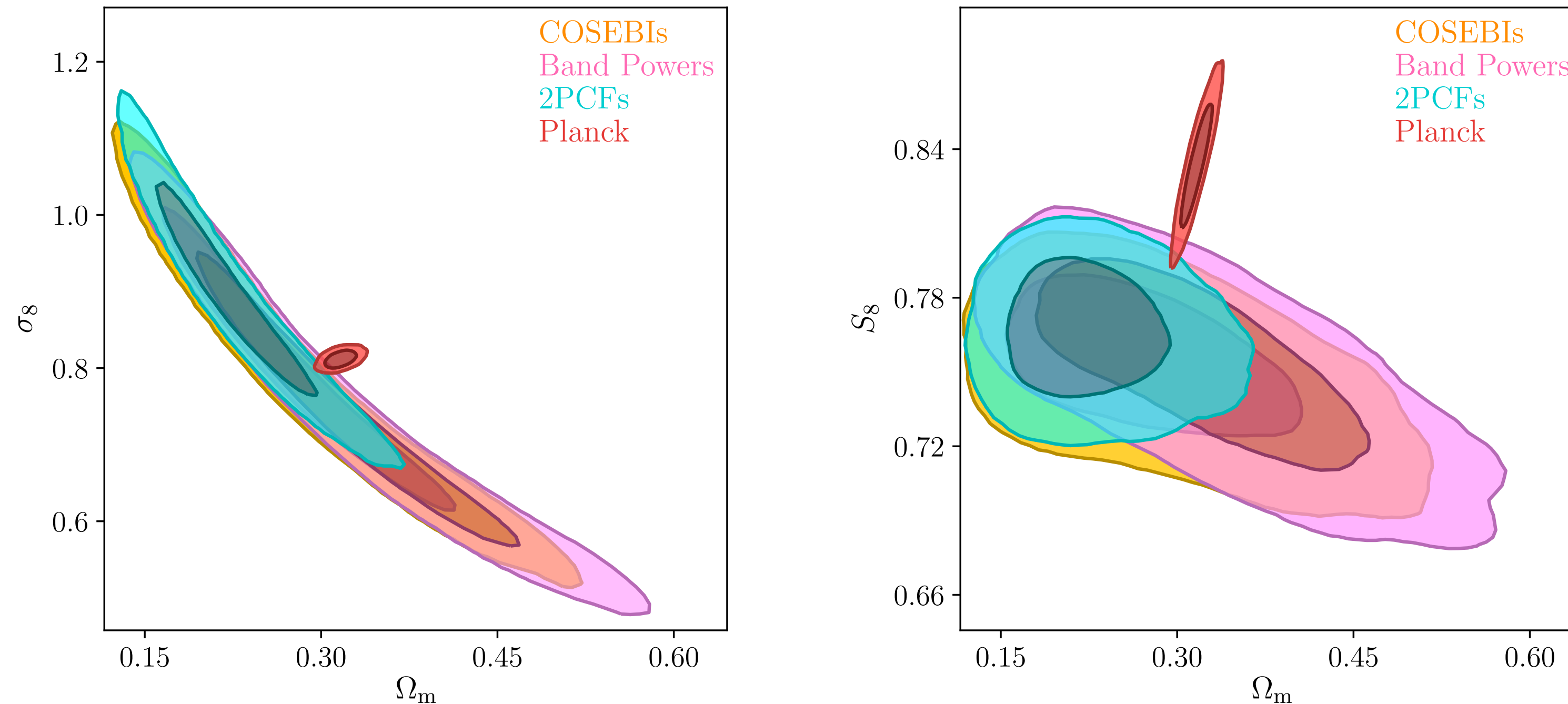


Hildebrandt et al. (2020)

“The tension between KiDS cosmic shear and the Planck-Legacy CMB measurements remains in this systematically more robust analysis, with S_8 differing by 2.3σ .”

Cosmic shear constraints

KiDS-1000

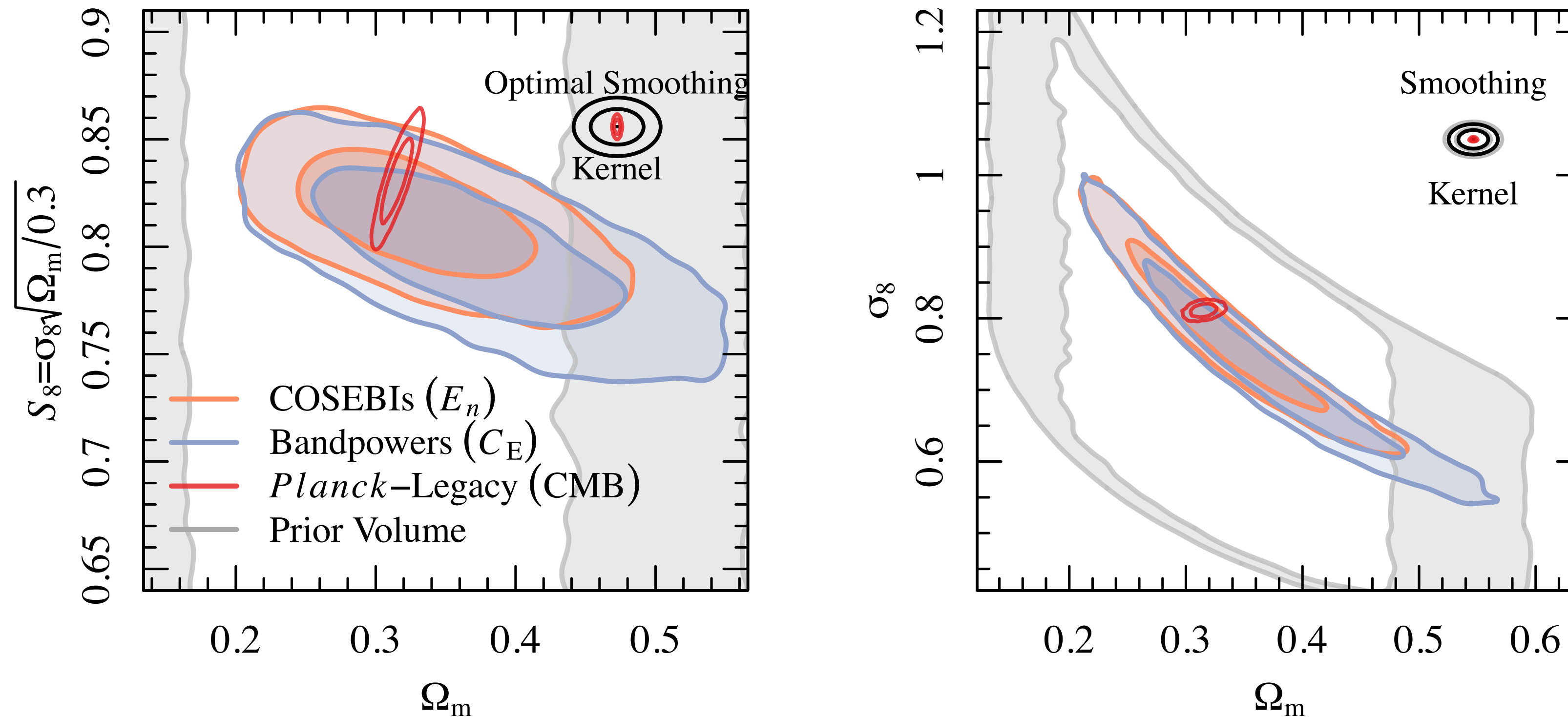


Asgari et al. (2021)

“Adopting a spatially flat standard cosmological model, we find $S_8 = \sigma_8(\Omega_m/0.3)^{0.5} = 0.759^{+0.024}_{-0.021}$ for our fiducial analysis, which is in 3σ tension with the prediction of the Planck Legacy analysis of the cosmic microwave background.”

Cosmic shear constraints

KiDS-Legacy



Wright et al. (2025)

“[...] the cosmological parameter $S_8 \equiv \sigma_8 \sqrt{\Omega_m / 0.3} = 0.815^{+0.016}_{-0.021}$ is found to be in agreement (0.73σ) with results from the Planck Legacy cosmic microwave background experiment.”

KiDS DR5 and KiDS-Legacy

Kilo-Degree Survey data release 5

Developments since DR4

See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

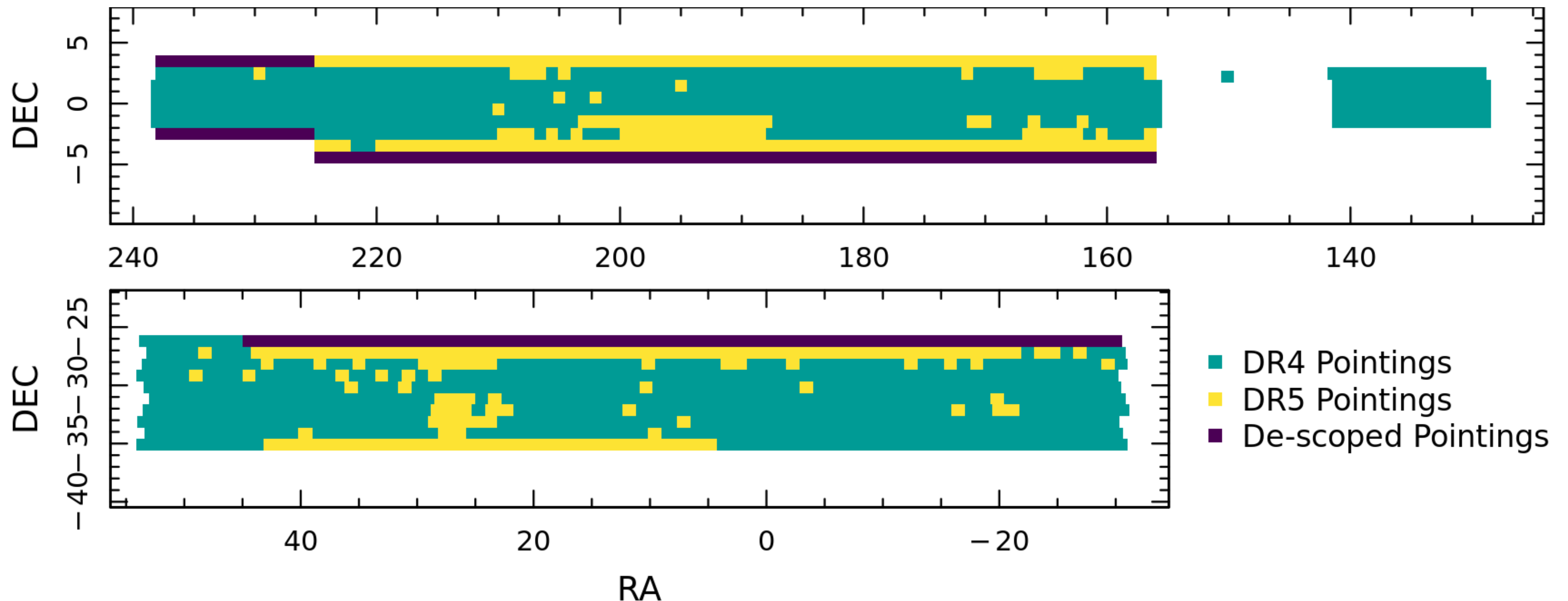
Developments since DR4

- Larger survey area (~34% increase over DR4)

See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

Developments since DR4



See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

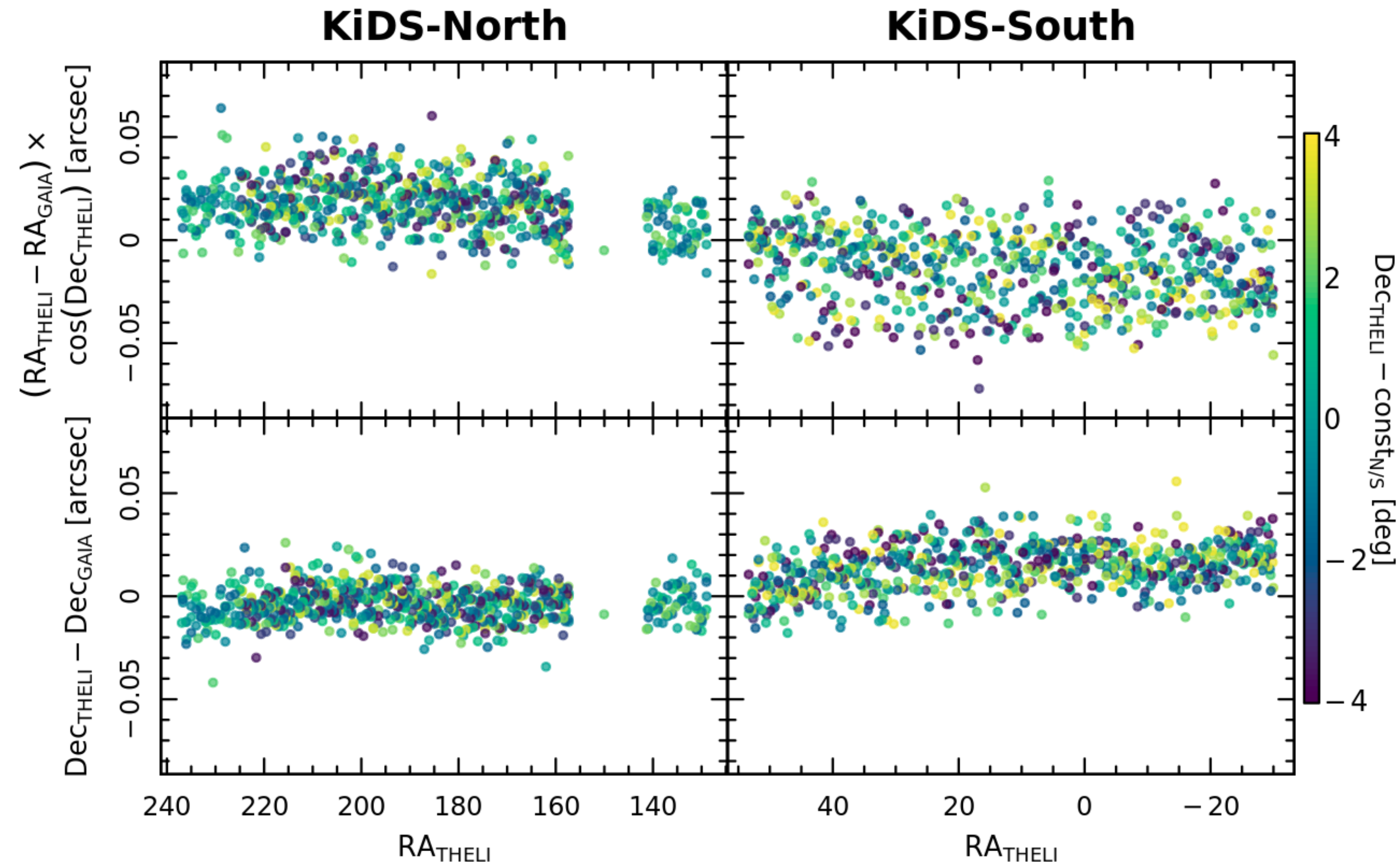
Developments since DR4

- Larger survey area (~34% increase over DR4)
- Improved astrometric calibration with GAIA and photometric calibrations (more accurate shape measurements and photo-z)

See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

Developments since DR4



See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

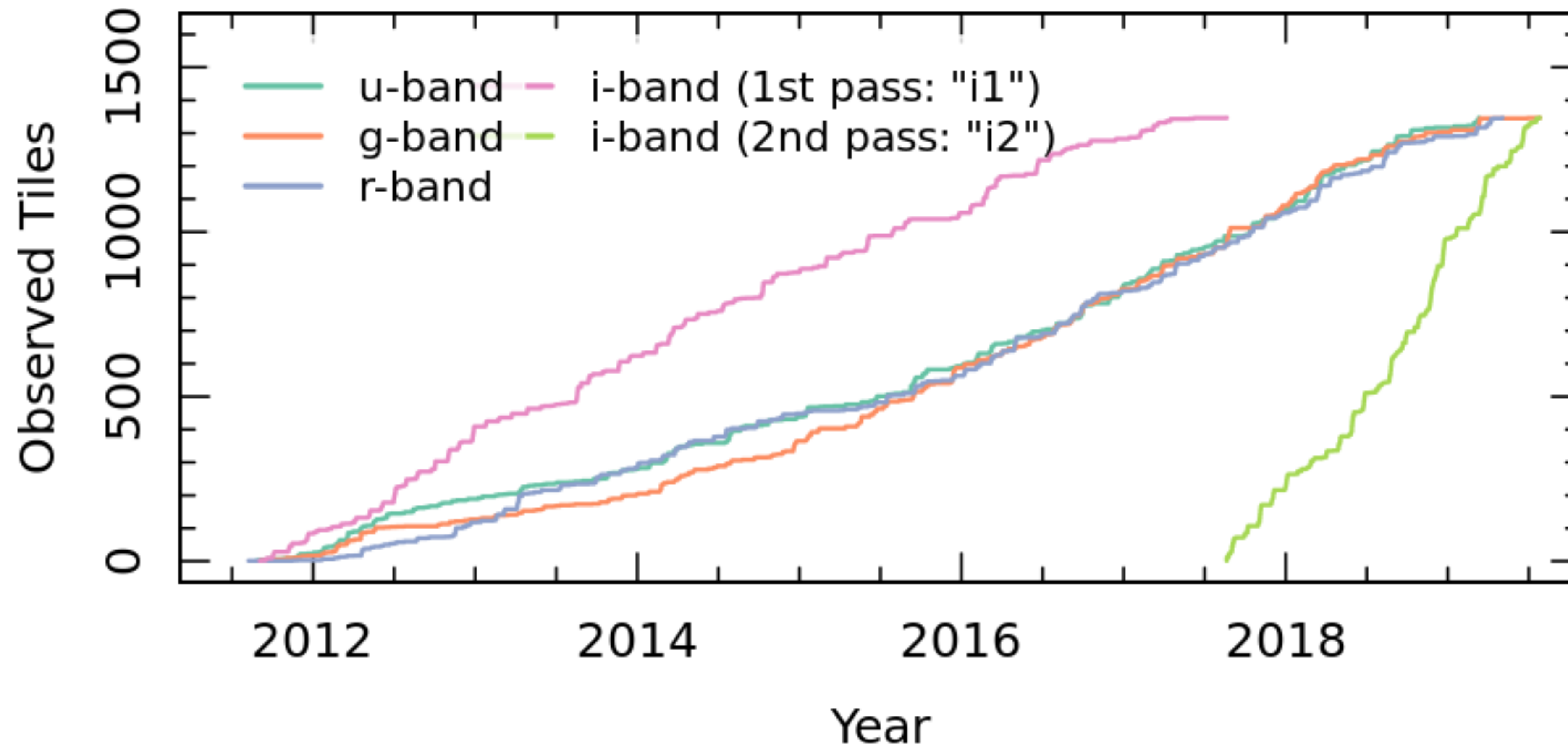
Developments since DR4

- Larger survey area (~34% increase over DR4)
- Improved astrometric calibration with GAIA and photometric calibrations (more accurate shape measurements and photo-z)
- Multi-epoch i-band observations (better photo- z & more control over observational systematics)

See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

Developments since DR4



See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

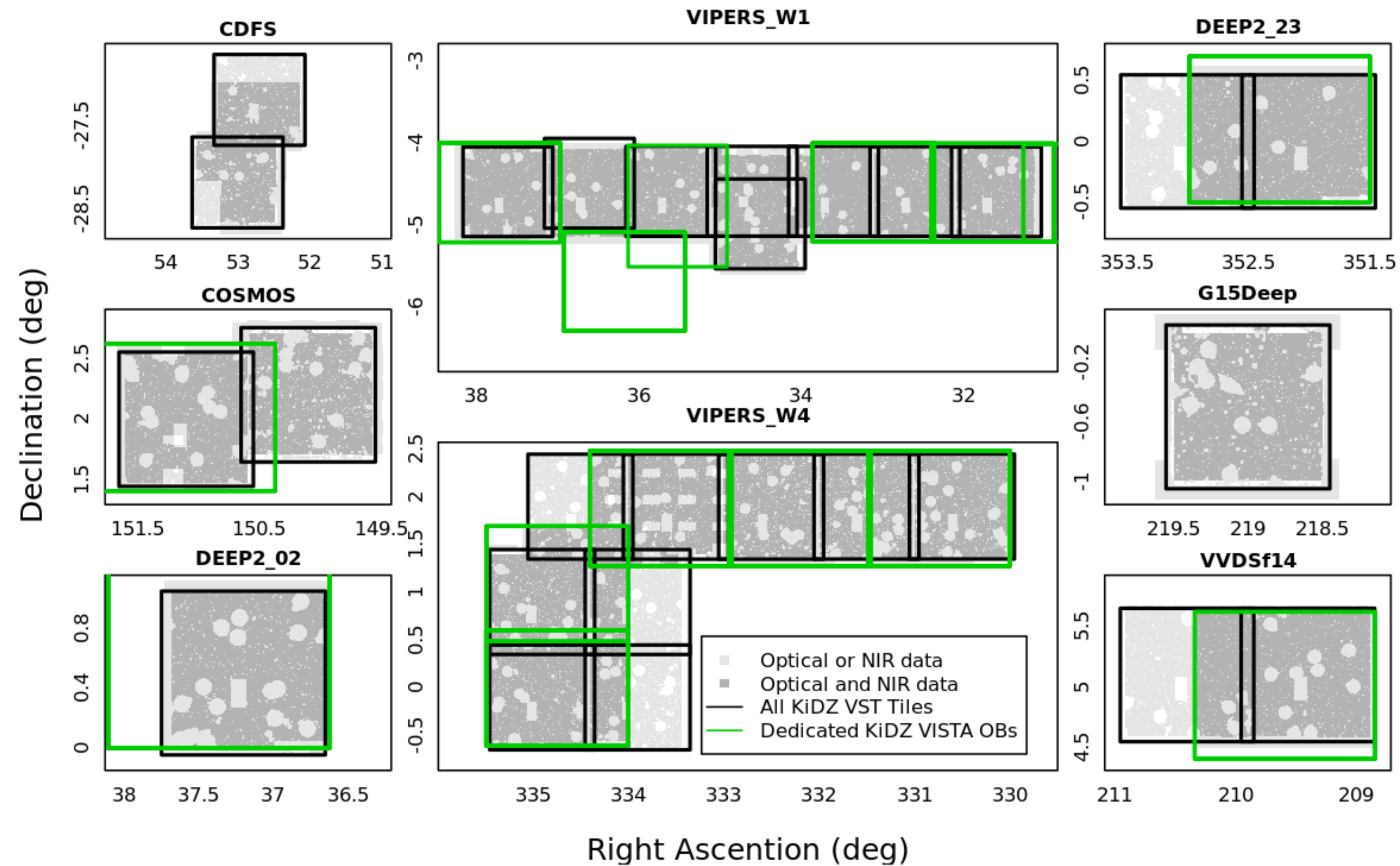
Developments since DR4

- Larger survey area (~34% increase over DR4)
- Improved astrometric calibration with GAIA and photometric calibrations (more accurate shape measurements and photo-z)
- Multi-epoch i-band observations (better photo- z & more control over observational systematics)
- Expanded spectroscopic redshift calibration sample “KiDZ” (more accurate photometric redshift calibration)

See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

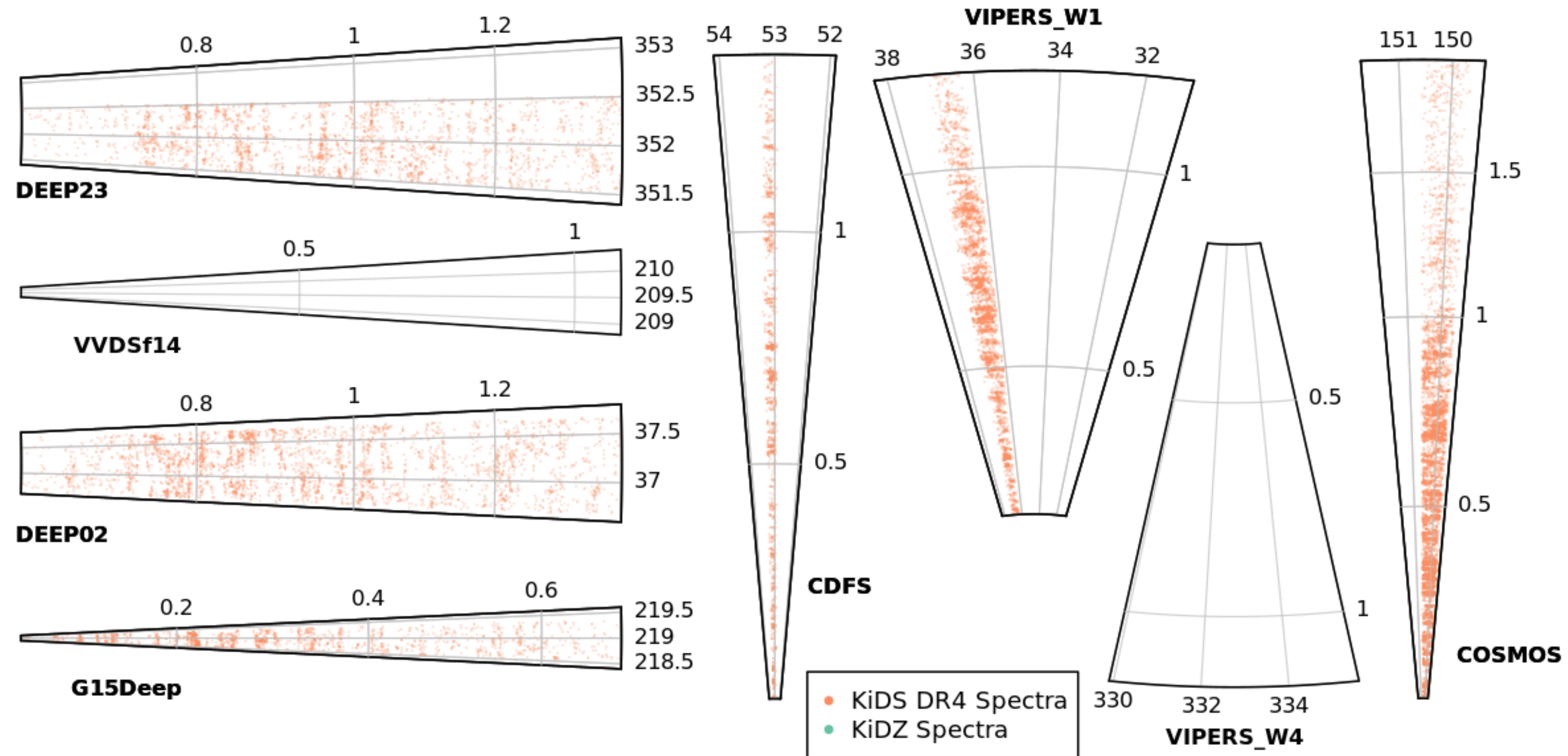
Developments since DR4



See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

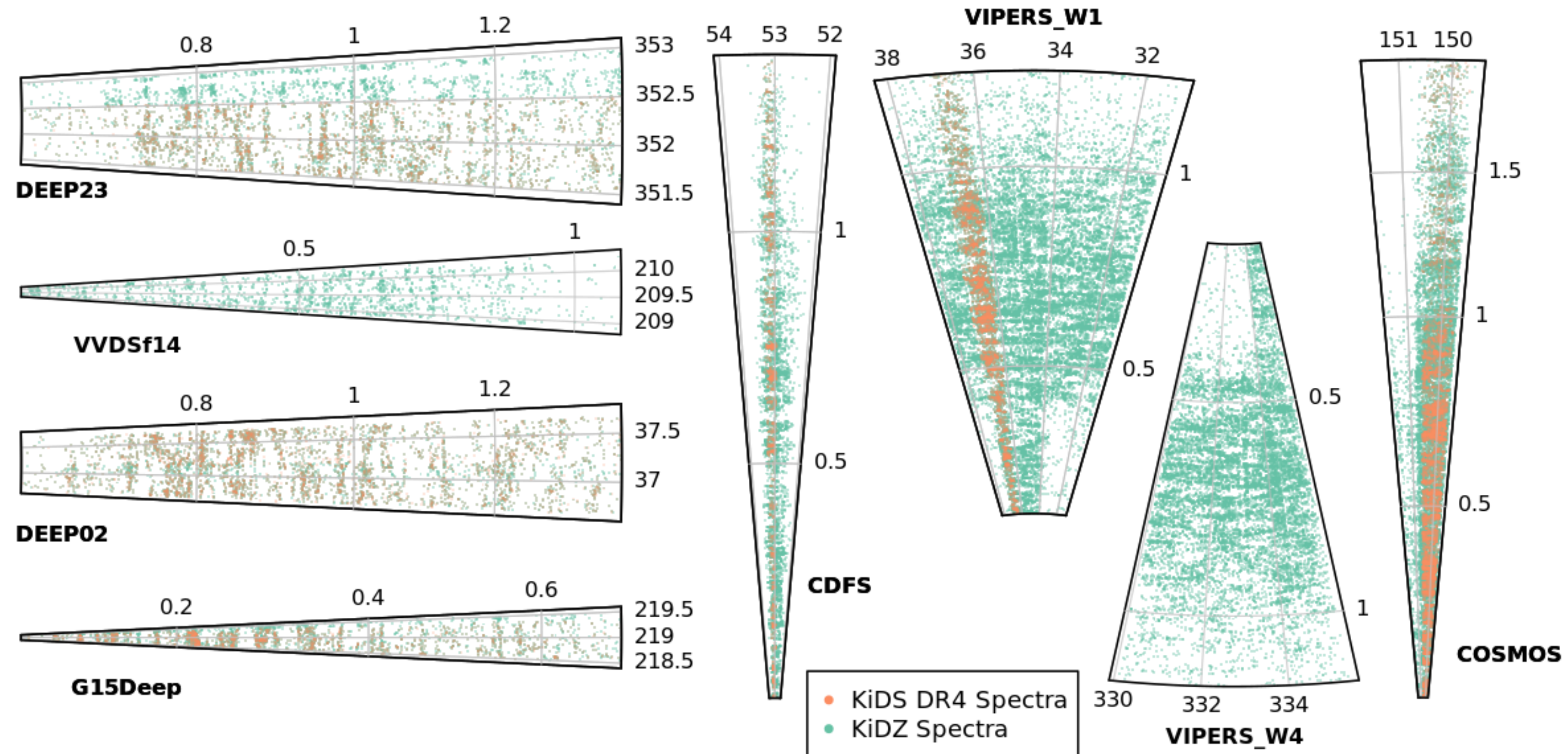
Developments since DR4



See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

Developments since DR4



See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

Kilo-Degree Survey data release 5

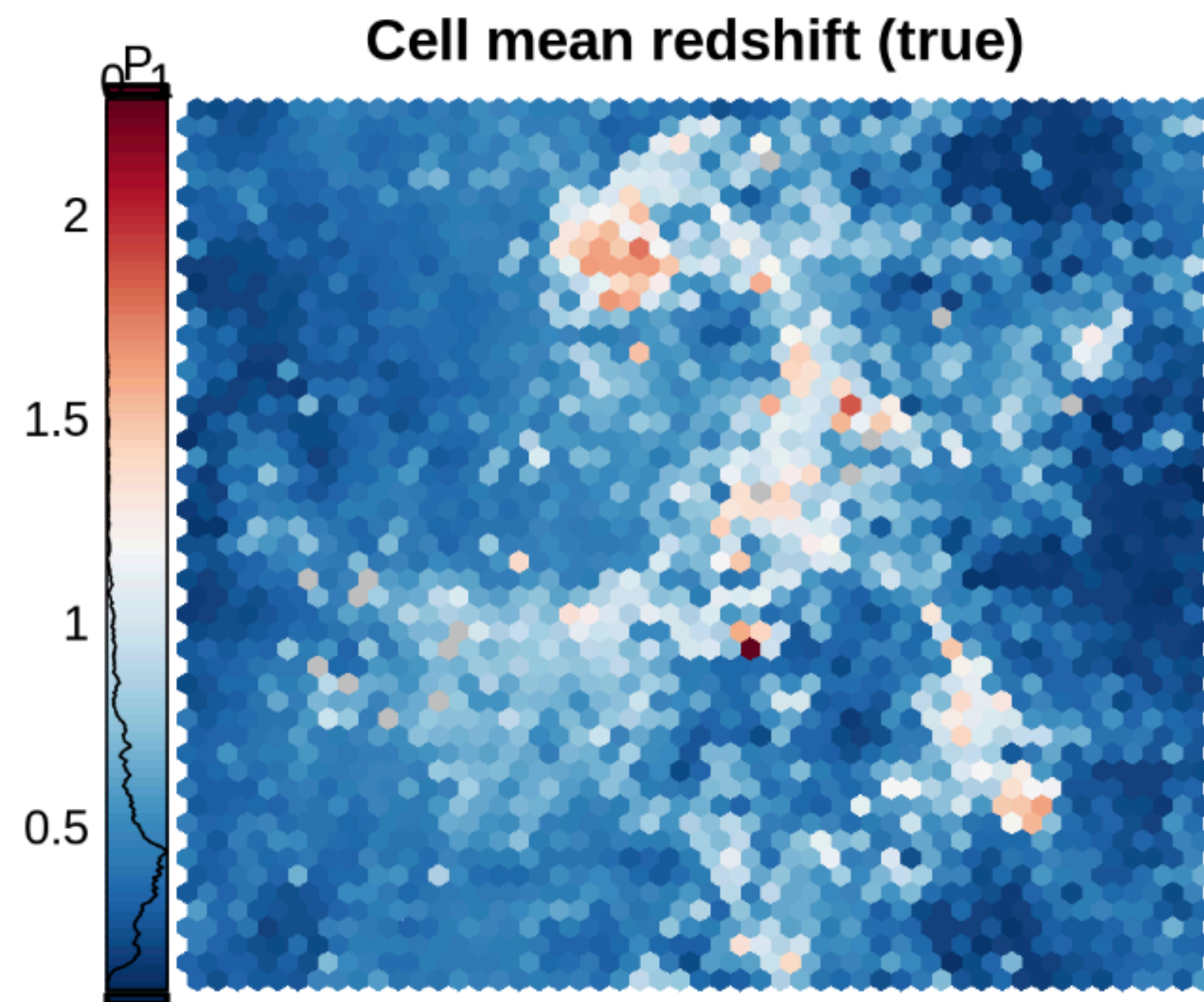
Developments since DR4

- Larger survey area ($\sim 34\%$ increase over DR4)
- Improved astrometric calibration with GAIA and photometric calibrations (more accurate shape measurements and photo- z)
- Multi-epoch i-band observations (better photo- z & more control over observational systematics)
- Expanded spectroscopic redshift calibration sample “KiDZ” (more accurate photometric redshift calibration)
- Improved selection function (enables photometric clustering)
- NIR Imaging releases (enables more sophisticated photo- z)

See Wright et al. (2024), [arXiv:2503.19439](https://arxiv.org/abs/2503.19439)

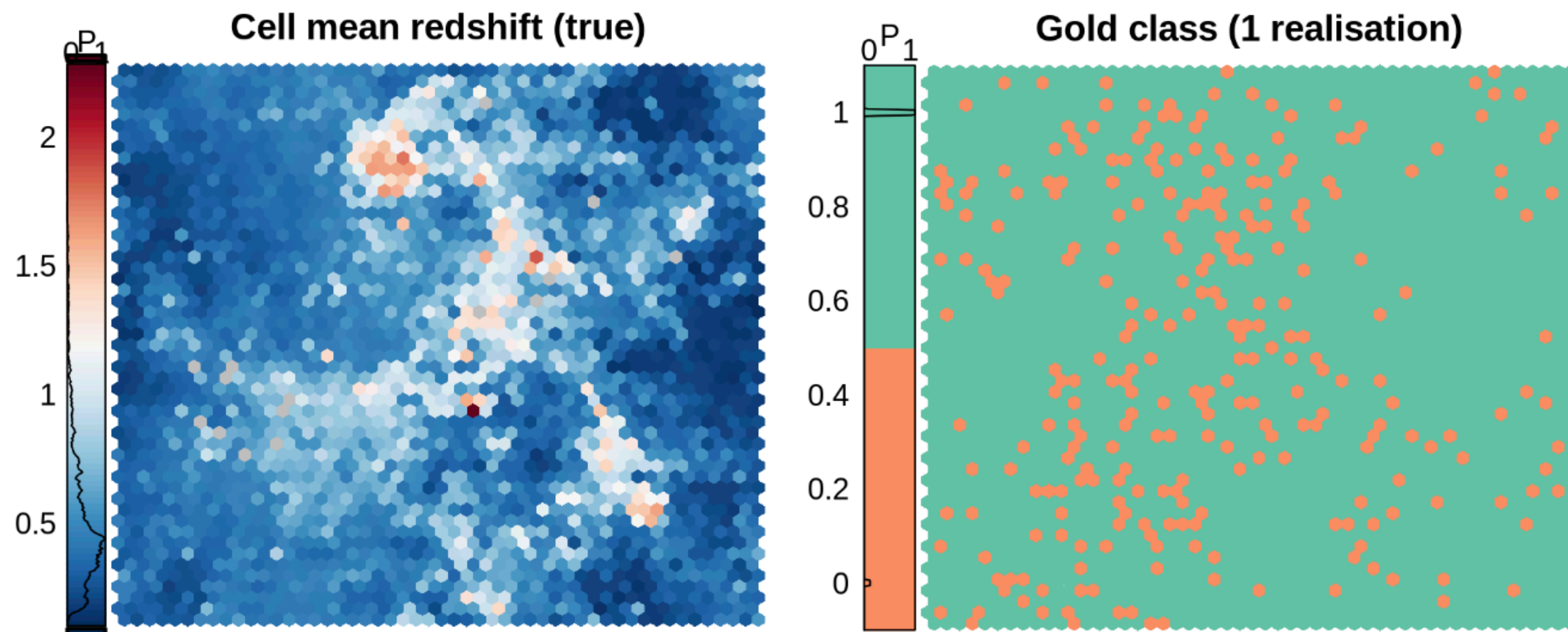
Redshift calibration with self-organising maps

1. Train a SOM on spectroscopic reference galaxies in colour-magnitude space (one SOM per tomographic bin)



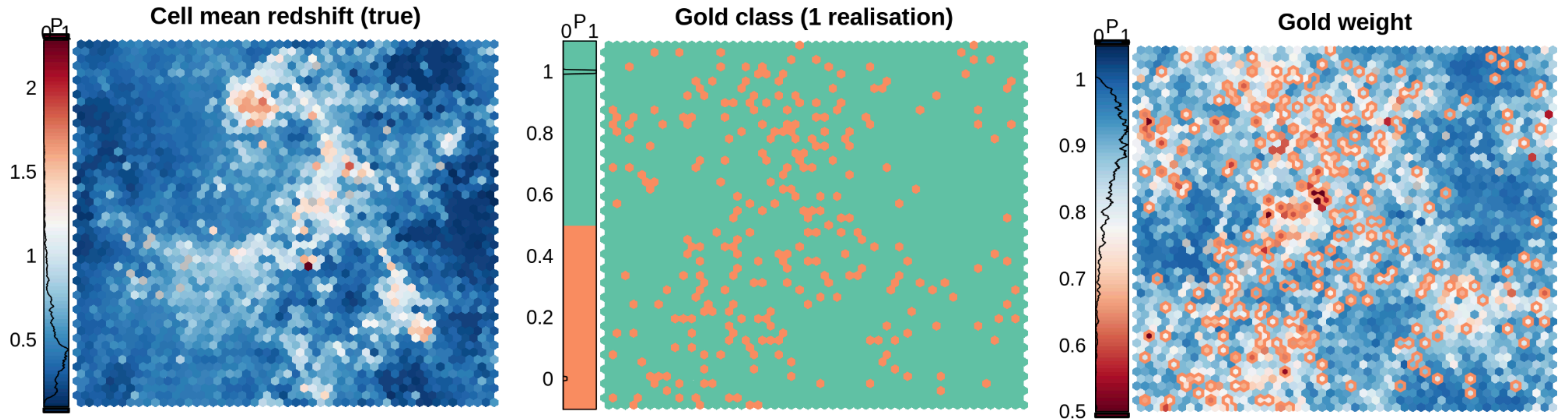
Redshift calibration with self-organising maps

2. Assign photometric galaxies to SOM cells and identify those represented by the spectroscopic sample (“gold class”)



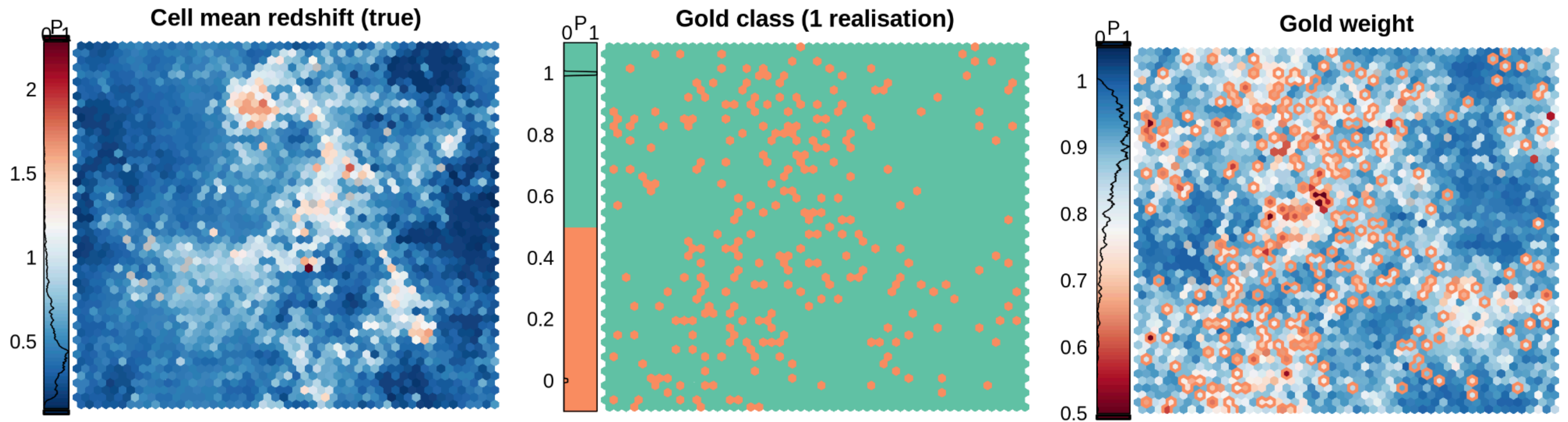
Redshift calibration with self-organising maps

3. Repeat this process multiple times and infer a gold weight per galaxy to account for SOM stochasticity



Redshift calibration with self-organising maps

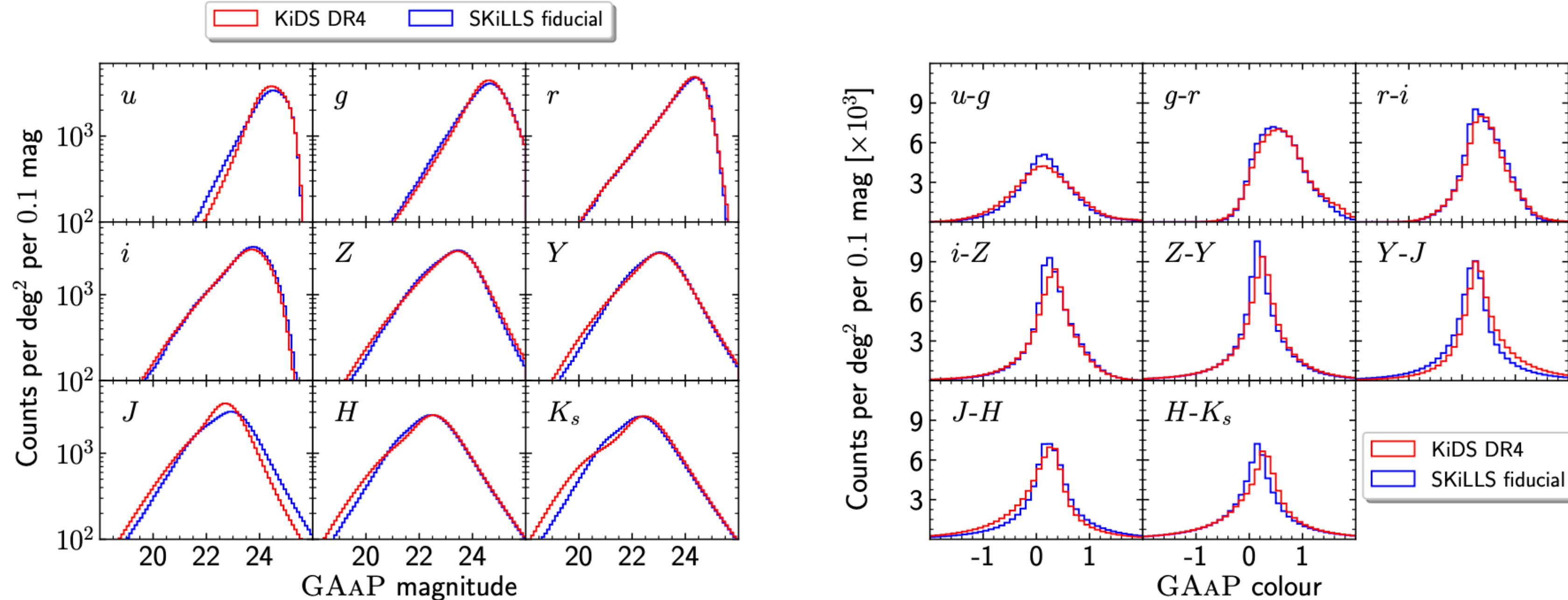
4. Construct $n(z)$ from SOM- and gold-weighted spectroscopic redshifts



Shear- and δz - calibration

SKILLS: SURFS-based KiDS-Legacy-Like Simulations

- Realistic multi-band image simulations
- Match KiDS galaxy colours, morphology, clustering and number density
- Provides a common framework for shear and redshift calibration



Shear calibration:

$$\gamma_{\text{obs}} = (1 + m) \gamma_{\text{input}} + c$$

Redshift bias calibration:

$$\delta z^i = \langle z_{\text{est}}^i \rangle - \langle z_{\text{true}}^i \rangle$$

See Li et al. (2023), [arXiv:2210.07163](https://arxiv.org/abs/2210.07163), https://github.com/KiDS-WL/MultiBand_ImSim

Intrinsic alignment modelling

Nonlinear linear alignment model (NLA):

Galaxy intrinsic ellipticities are linearly related to the local tidal field

$$P_{\delta I}(k, z) = -A_{\text{IA}} C_1 \rho_{\text{crit}} \frac{\Omega_{\text{m}}}{D(z)} P_{\text{m,NL}}(k, z),$$

$$P_{II}(k, z) = A_{\text{IA}}^2 \left(C_1 \rho_{\text{crit}} \frac{\Omega_{\text{m}}}{D(z)} \right)^2 P_{\text{m,NL}}(k, z),$$

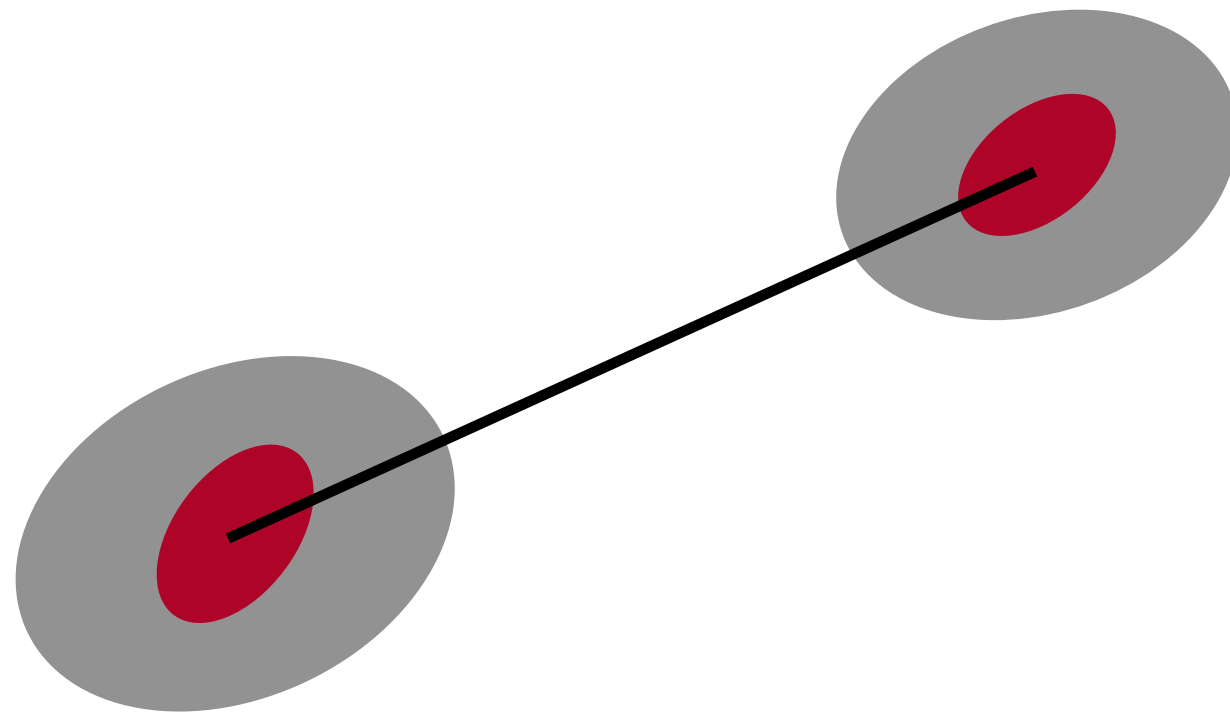
$$C_{XY}(\ell) = \int d\chi \frac{W_X(\chi) W_Y(\chi)}{f_K^2(\chi)} P_{XY} \left(\frac{\ell + 1/2}{f_K(\chi)}, z(\chi) \right)$$

Intrinsic alignment modelling

Intrinsic alignments depend on morphology

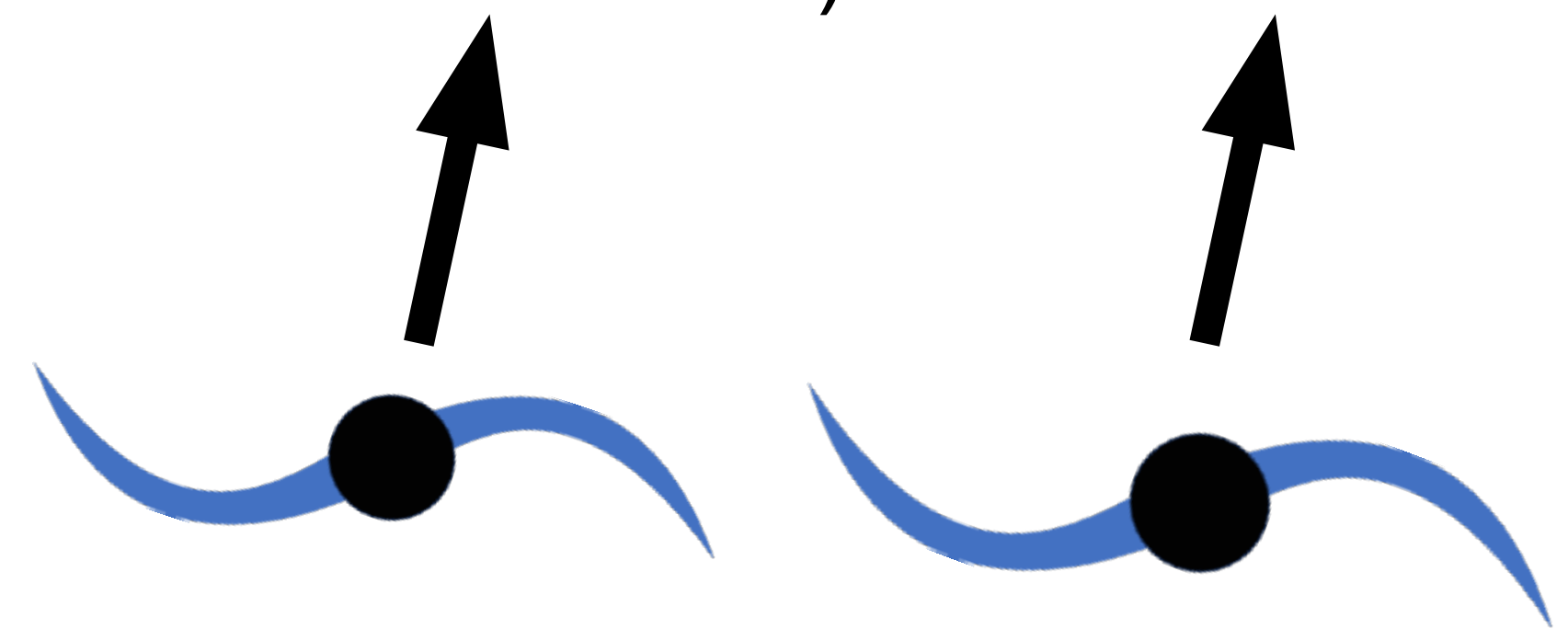
Pressure-supported, red, elliptical (early-type):

- Linearly related to tidal gravitational field
- Strong IA signal, amplitudes scales with halo mass via a power law (Fortuna et al. 2025)



Rotational-supported, blue, spiral (late-type):

- Quadratic in the tidal gravitational field
- IA signal consistent with zero (e.g. Johnston et al. 2019)



Model the IA amplitude for the evolving early-type galaxy population (NLA-M):

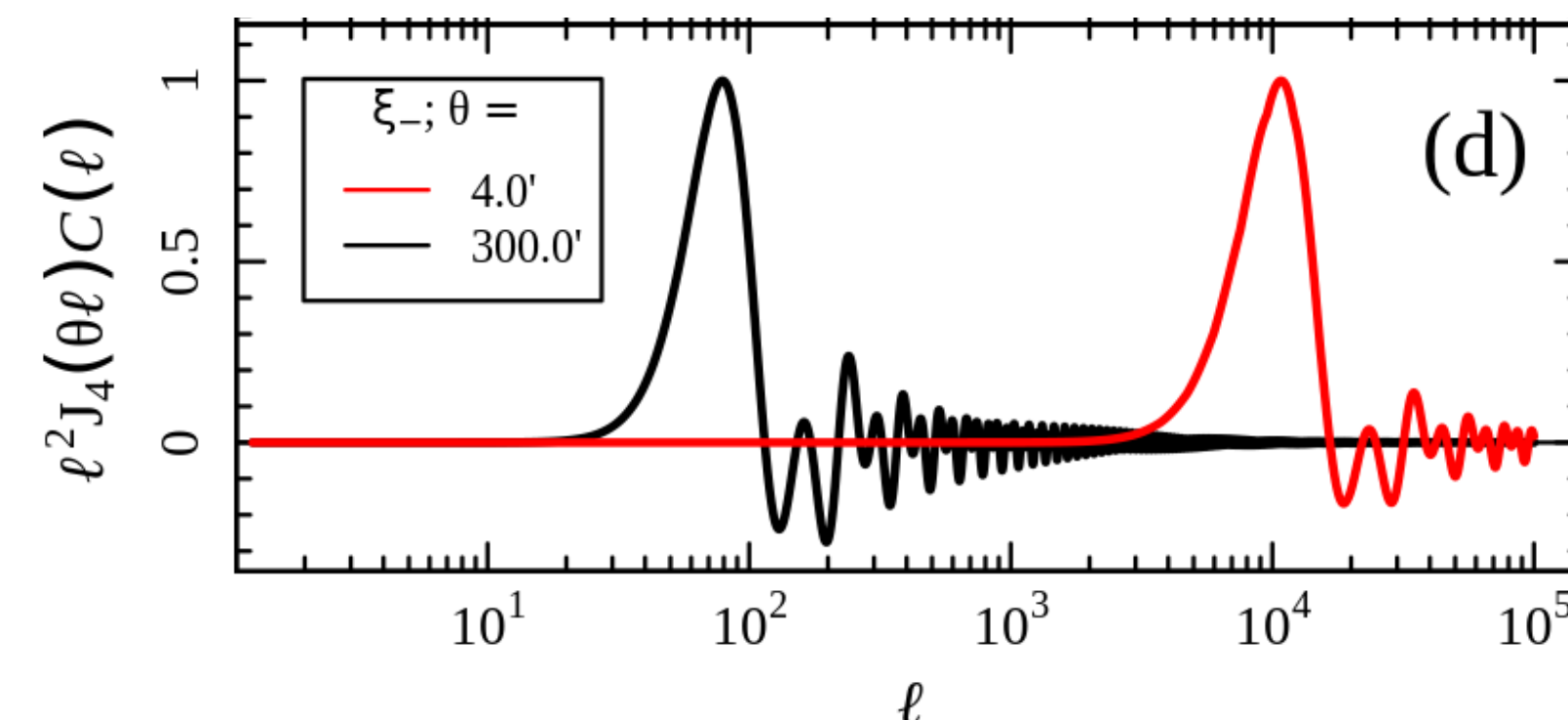
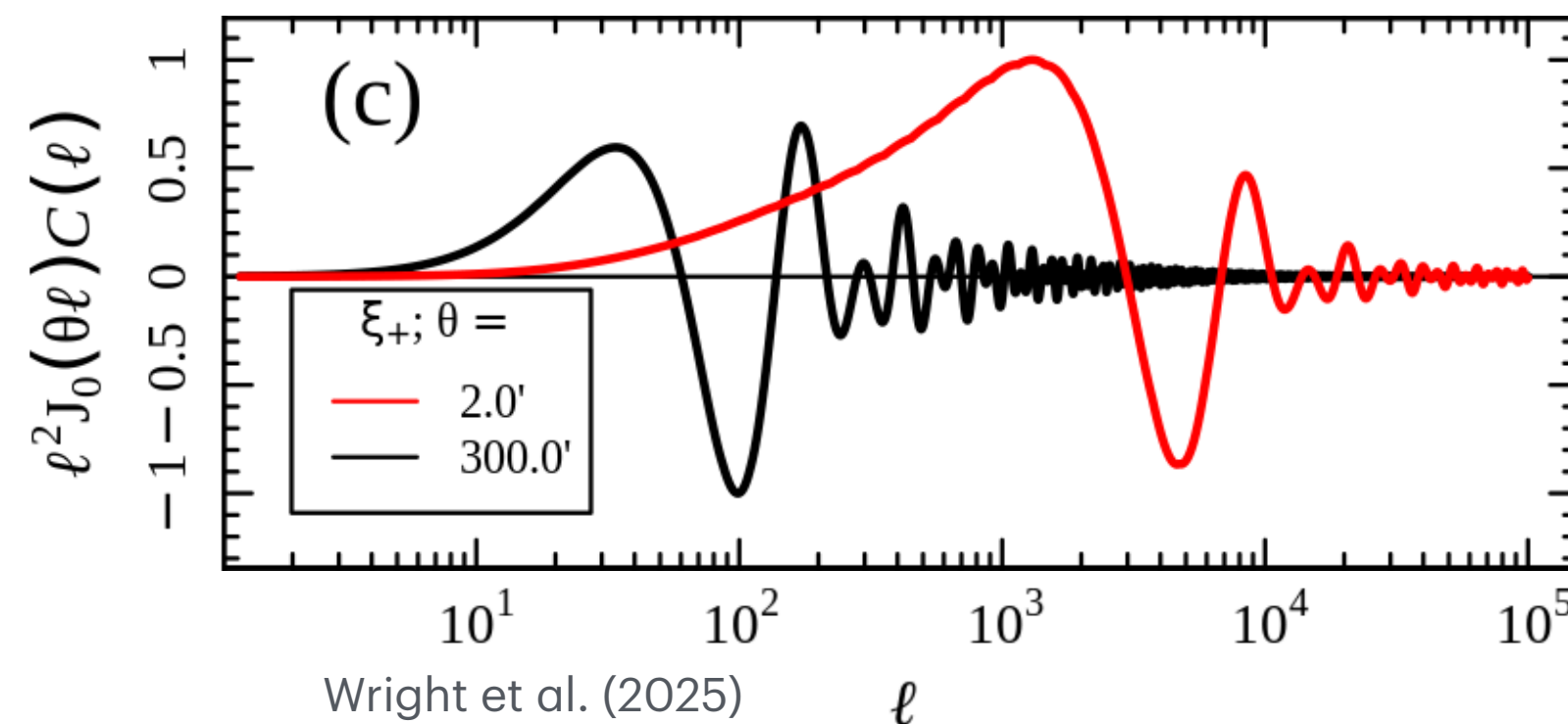
$$A_{\text{IA, total}}^{\text{massdep},i} = \hat{A}_{\text{IA}} f_r^i \left(\frac{\langle M_h^i \rangle}{M_{h, \text{pivot}}} \right)^\beta$$

Image credit: Christos Georgiou

Two-point correlation function

$$\xi_{\pm}(\theta) = \int_0^{\infty} \frac{\ell d\ell}{2\pi} \left[C_{\epsilon\epsilon,E}(\ell) \pm C_{\epsilon\epsilon,B}(\ell) \right] J_{0/4}(\ell\theta)$$

- $\xi_{\pm}$ mix E- and B-modes
- To first order, we expect cosmic shear to only produce E-modes
 ➔ B-modes can be used as a diagnostic tool if we can separate E- and B-modes



- Sensitive to a large range of physical scales in each angular bin
- Particularly sensitive to the effect of baryon feedback
 ➔ Requires careful selection of scale cuts

Primary summary statistics in KiDS-Legacy

COSEBIs

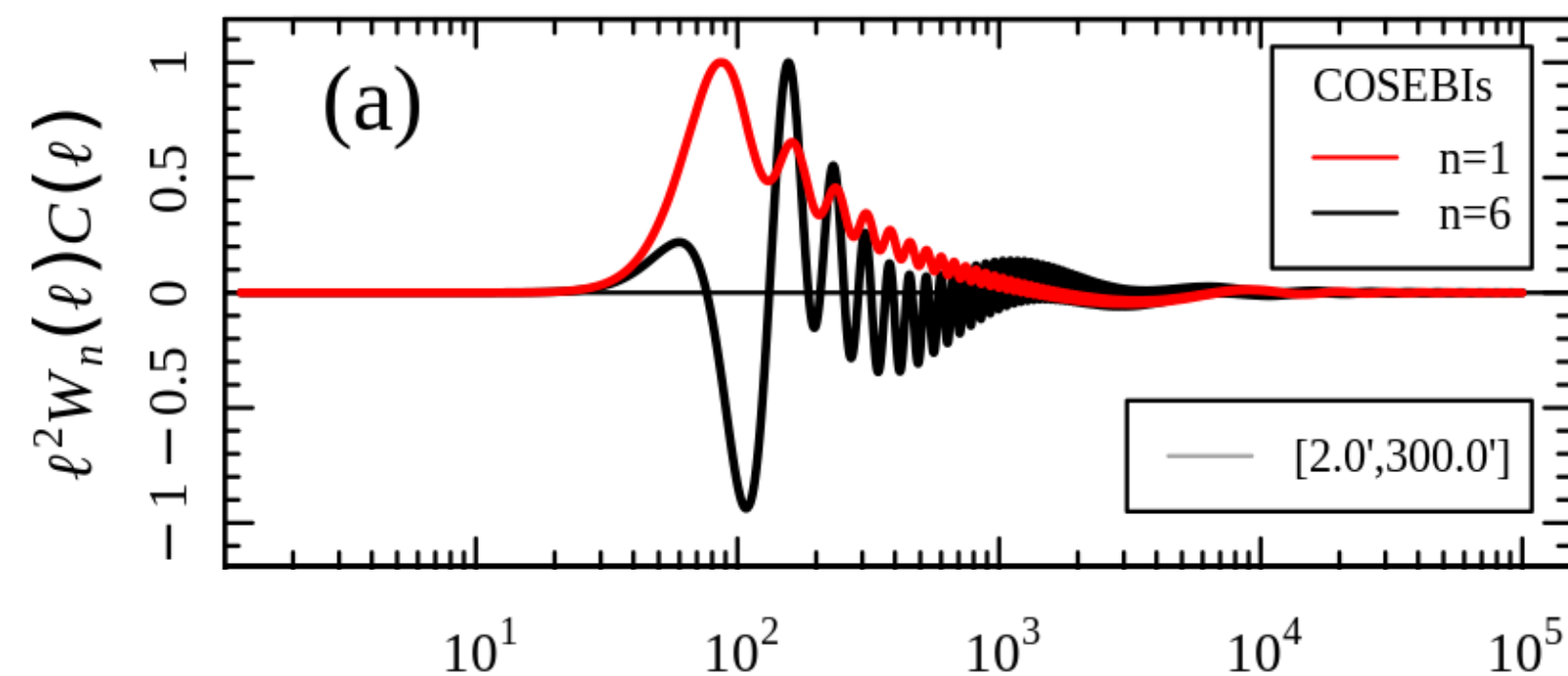
(Complete Orthogonal Sets of **E**-/**B**-mode Integrals)

Observable: $\hat{E}_n = \frac{1}{2} \int_{\theta_{\min}}^{\theta_{\max}} d\theta \theta [T_{+n}(\theta) \xi_+(\theta) + T_{-n}(\theta) \xi_-(\theta)]$

$\hat{B}_n = \frac{1}{2} \int_{\theta_{\min}}^{\theta_{\max}} d\theta \theta [T_{+n}(\theta) \xi_+(\theta) - T_{-n}(\theta) \xi_-(\theta)]$

Theory: $E_n = \int_0^\infty \frac{d\ell \ell}{2\pi} C_{EE}(\ell) W_n(\ell)$

$B_n = \int_0^\infty \frac{d\ell \ell}{2\pi} C_{BB}(\ell) W_n(\ell)$



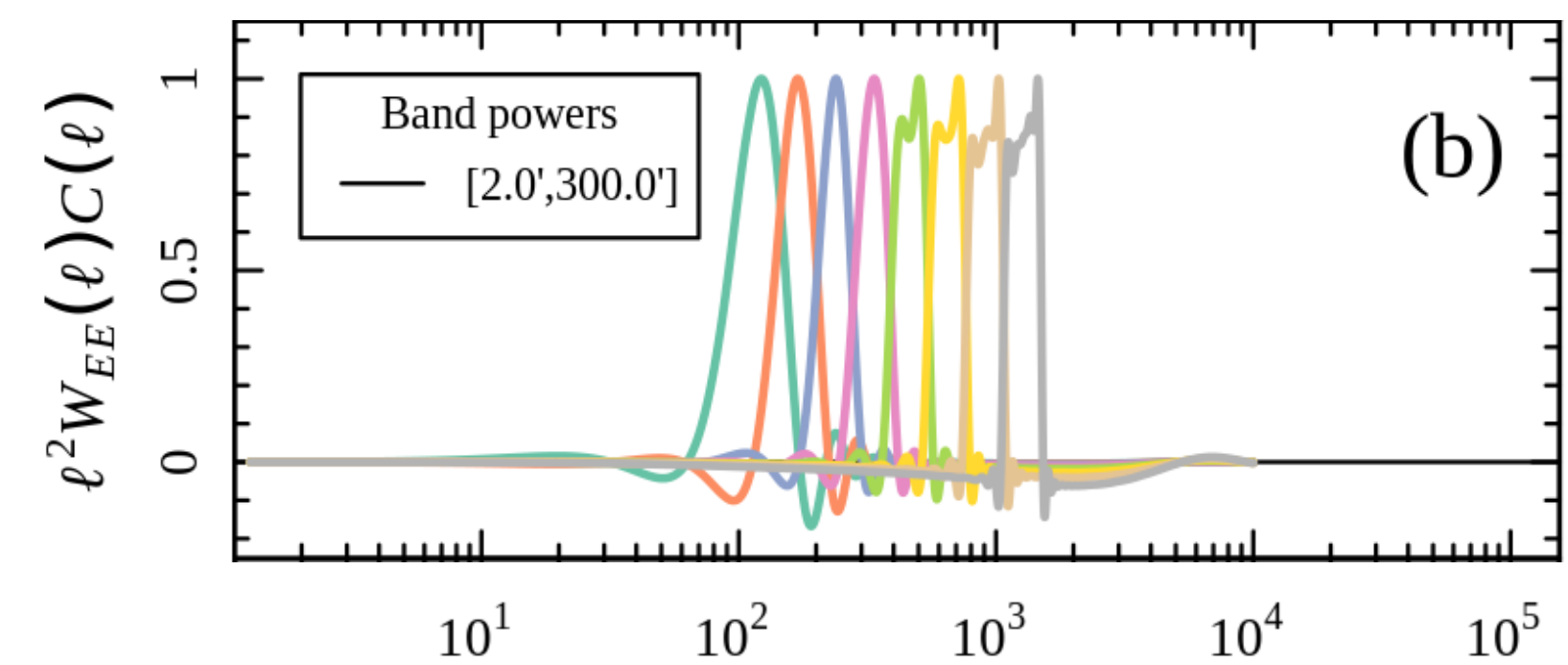
Band powers

(binned angular power spectra estimated through 2PCFs)

Observable: $\hat{C}_{E,B,l} = \frac{\pi}{\mathcal{N}_\ell} \int_0^\infty d\theta \theta T(\theta) [g_+^l(\theta) \xi_+(\theta) \pm g_-^l(\theta) \xi_-(\theta)]$

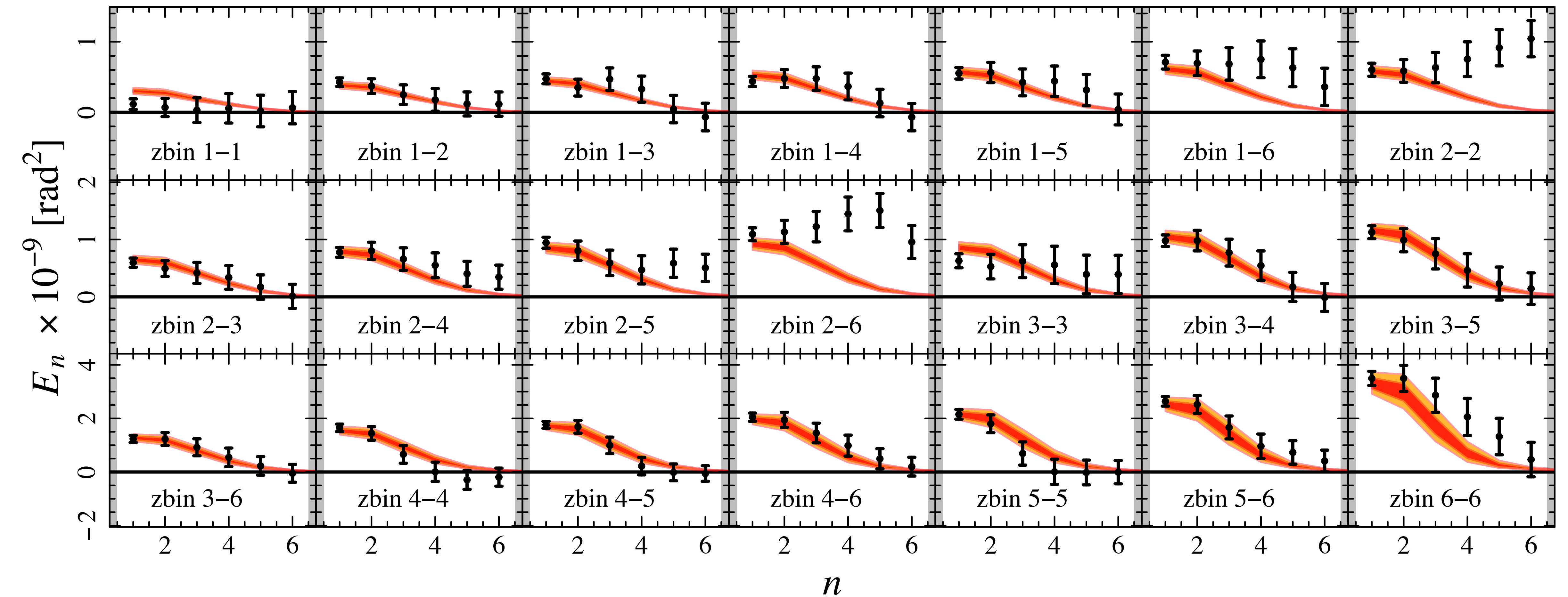
Theory: $C_{E,l} = \frac{1}{2\mathcal{N}_\ell} \int_0^\infty d\ell \ell [W_{EE}^l(\ell) C_{EE}(\ell) + W_{EB}^l(\ell) C_{BB}(\ell)]$

$C_{B,l} = \frac{1}{2\mathcal{N}_\ell} \int_0^\infty d\ell \ell [W_{BE}^l(\ell) C_{EE}(\ell) + W_{BB}^l(\ell) C_{BB}(\ell)]$



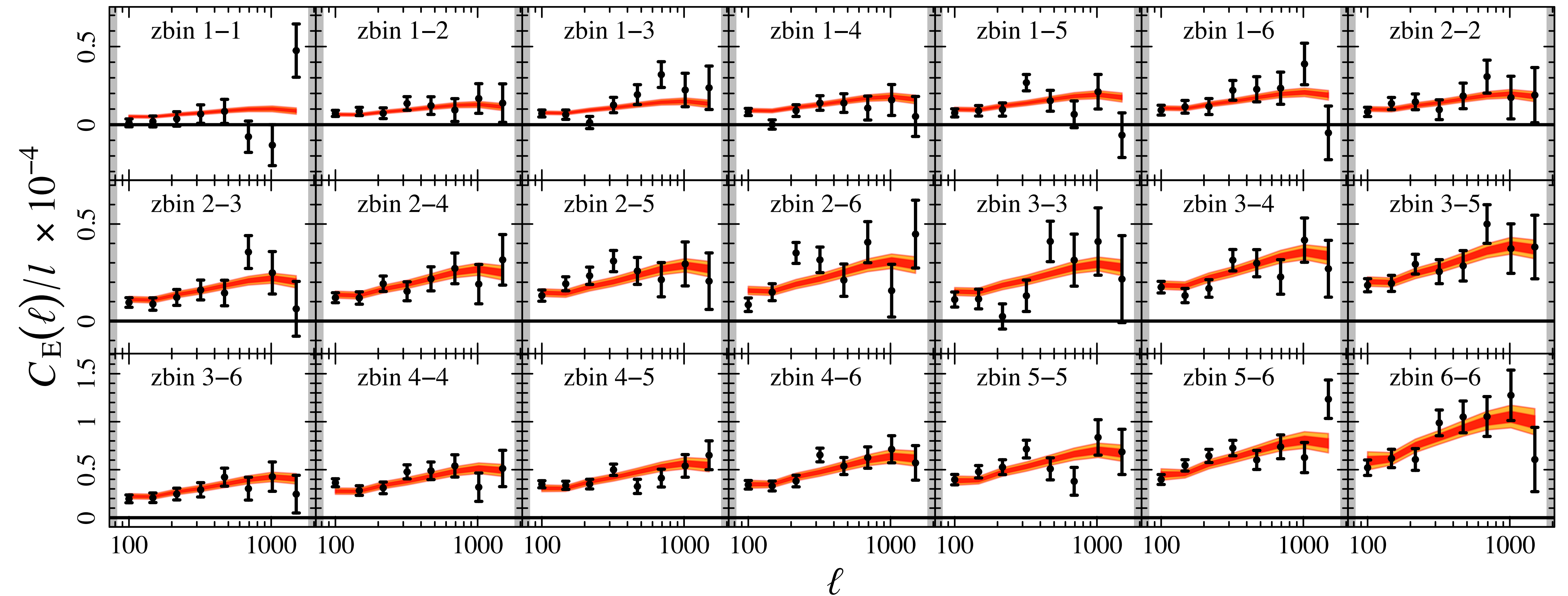
Data vector

COSEBIs



Data vector

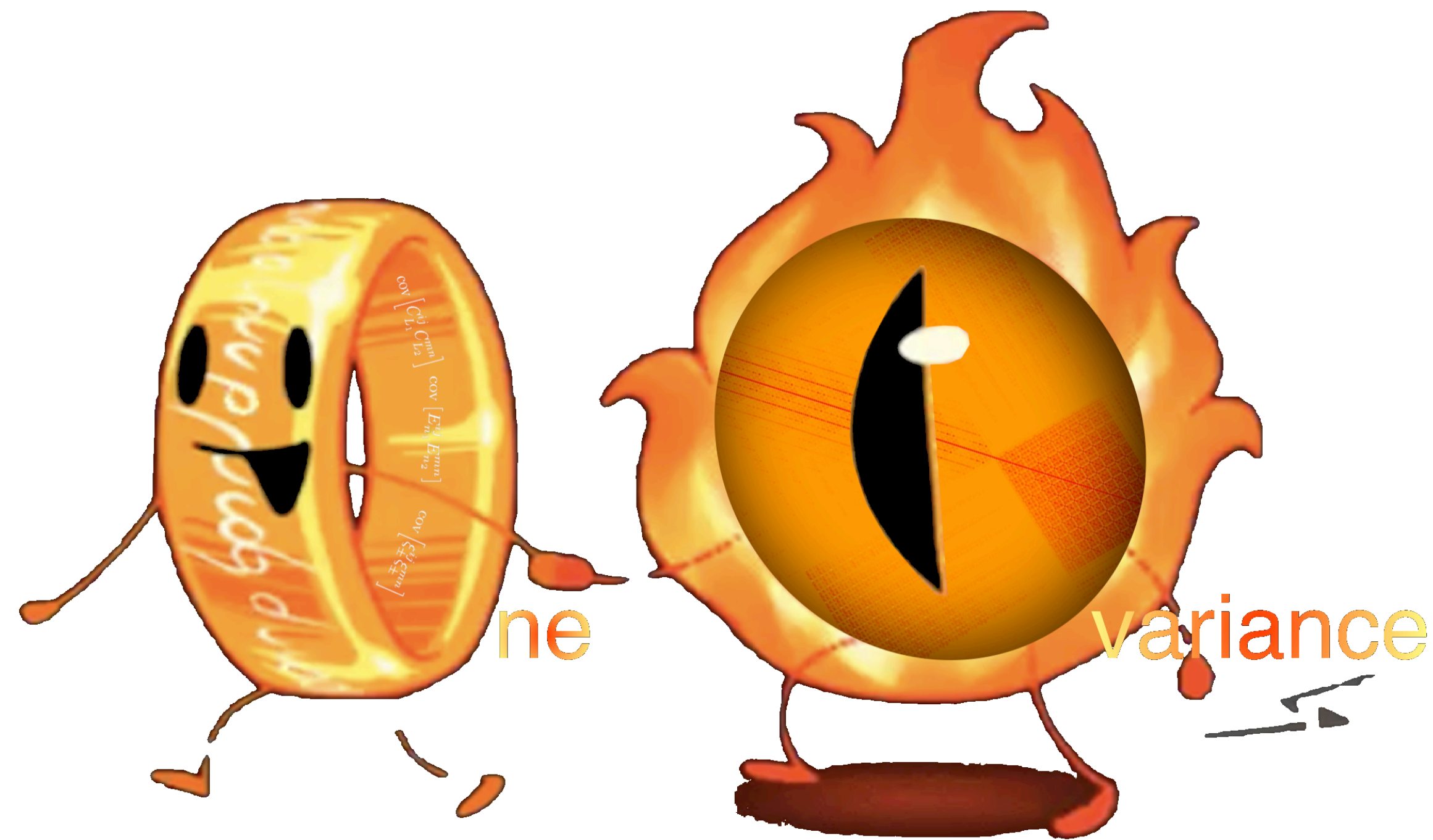
Band powers



OneCovariance

Open-source software for accurate covariance calculations for arbitrary combinations of two-point summary statistics across a variety of large-scale structure tracers

- Includes Gaussian, non-Gaussian and super-sample covariance terms

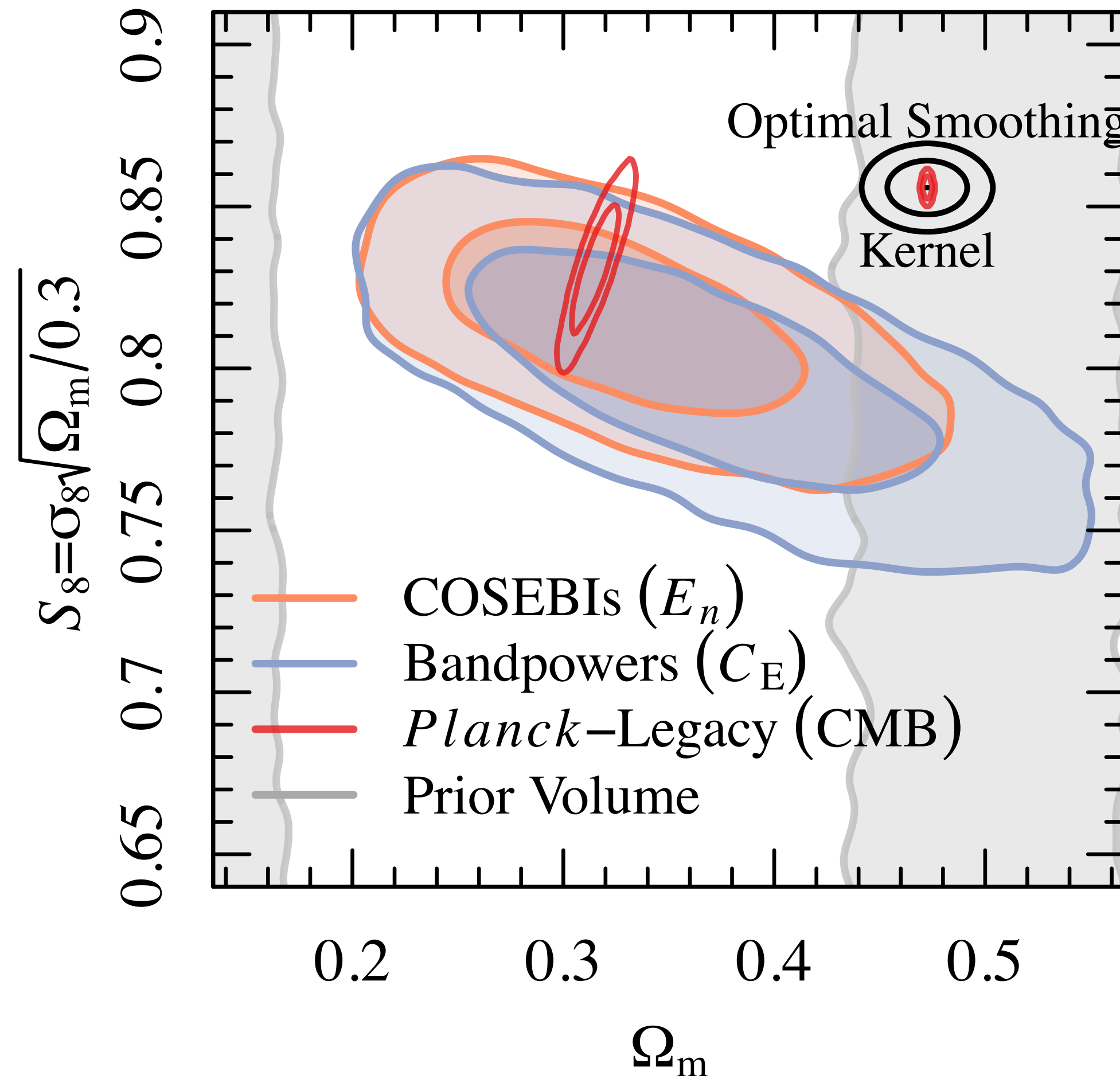


See Reischke et al. (2025), [arXiv:2410.06962](https://arxiv.org/abs/2410.06962), <https://github.com/rreischke/OneCovariance>

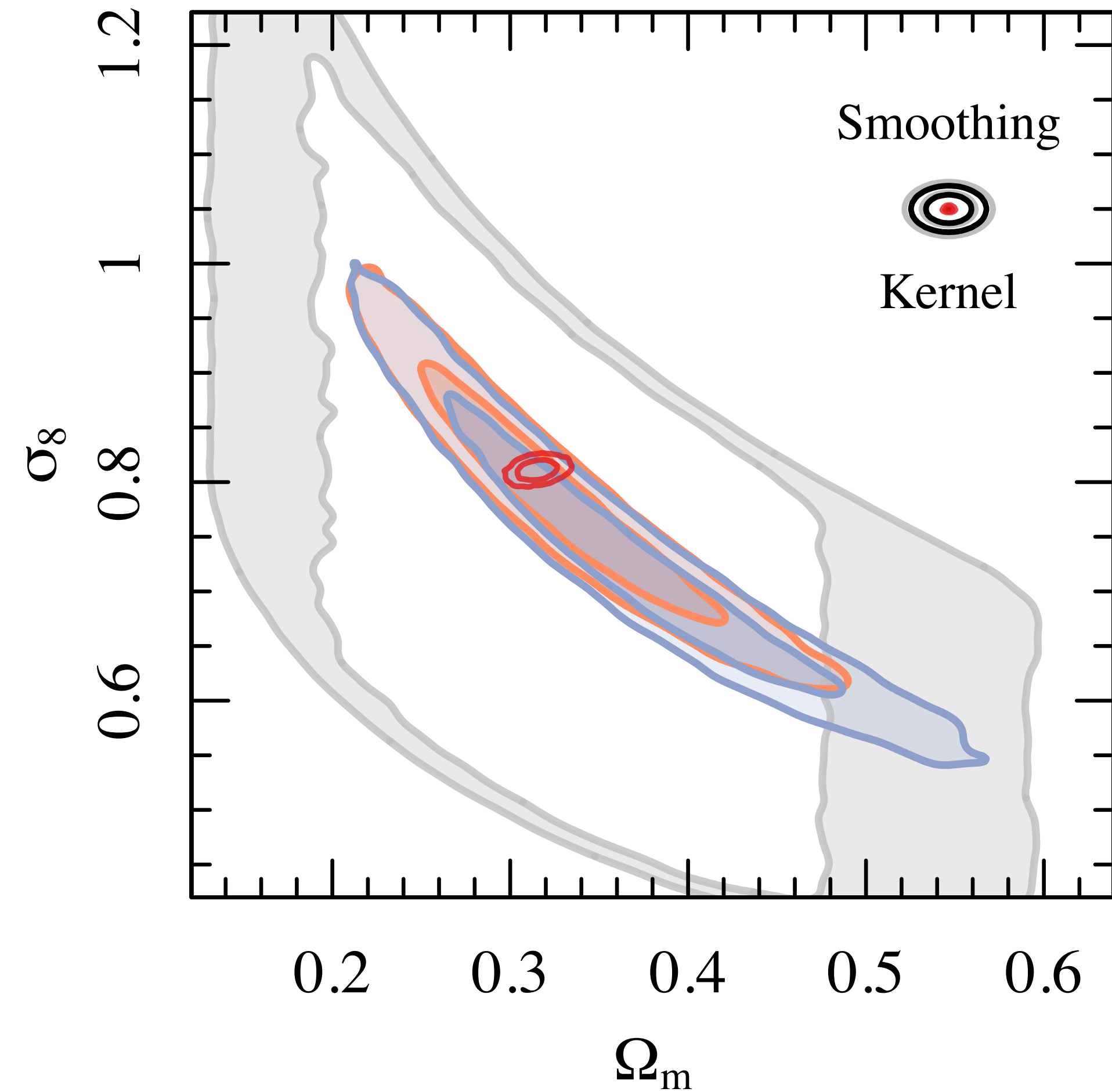
Overview of KiDS-Legacy analysis choices

	KiDS-450	KV450	KV450+	KiDS-1000	K1000+	K1000++	KiDS-Legacy
Publication	H+17	H+20	W+20	A+21	vdB+21	Li+23	W+25
Area [sqdeg.]	450	450	450	1000	1000	1000	1350
Filters	ugri	ugriZYJHK _s	ugriZYJHK _s	ugriZYJHK _s	ugriZYJHK _s	ugriZYJHK _s	ugri ₁₂ ZYJHK _s
Tomographic Bins	4	5	5	5	5	5	6
Photo-z range	(0.1, 0.9]	(0.1, 1.2]	(0.1, 1.2]	(0.1, 1.2]	(0.1, 1.2]	(0.1, 1.2]	(0.1, 2.0]
2pt statistic(s)	$\xi_{+/-}$	$\xi_{+/-}$	$\xi_{+/-}$	$\xi_{+/-}, C_{E/B}, E_n/B_n$	E_n/B_n	E_n/B_n	$\xi_{+/-}, C_{E/B}, E_n/B_n$
Scale cuts [arcmin]	[0.5, 300.0]	[0.5, 300.0]	[0.5, 300.0]	[0.5, 300.0]	[0.5, 300.0]	[2.0, 300.0]	[2.0, 300.0]
Shear calibration	SCHOOl	SCHOOl	SCHOOl	COLlege	COLlege	SKILLS	SKILLS
N(z) calibration	DIR	DIR	SOM	SOM	SOM	SOM	tomo. SOM
Calibration sample	~25k	~25k	~25k	~25k	~50k	~50k	~125k
Sample selection	N/A	N/A	Gold flag	Gold flag	Gold flag	Gold flag	Gold weight
Covariance	simple geometry	pair counts	pair counts	pc + var. depth	pc + var. depth	pc + var. depth	OneCovariance
P_{NL}	HMCode2016	HMCode2016	HMCode2016	HMCode2016	HMCode2016	HMCode2020	HMCode2020
Feedback model	1 par. m-c relation [2, 4]	1 par. m-c relation [2, 3.13]	1 par. m-c relation [2, 3.13]	1 par. m-c relation [2, 3.13]	1 par. m-c relation [2, 3.13]	$\log T_{AGN}$ [7.3, 8]	$\log T_{AGN}$ [7.3, 8.3]
IA model	NLA	NLA	NLA	NLA	NLA	NLA + F21 prior	MassDep

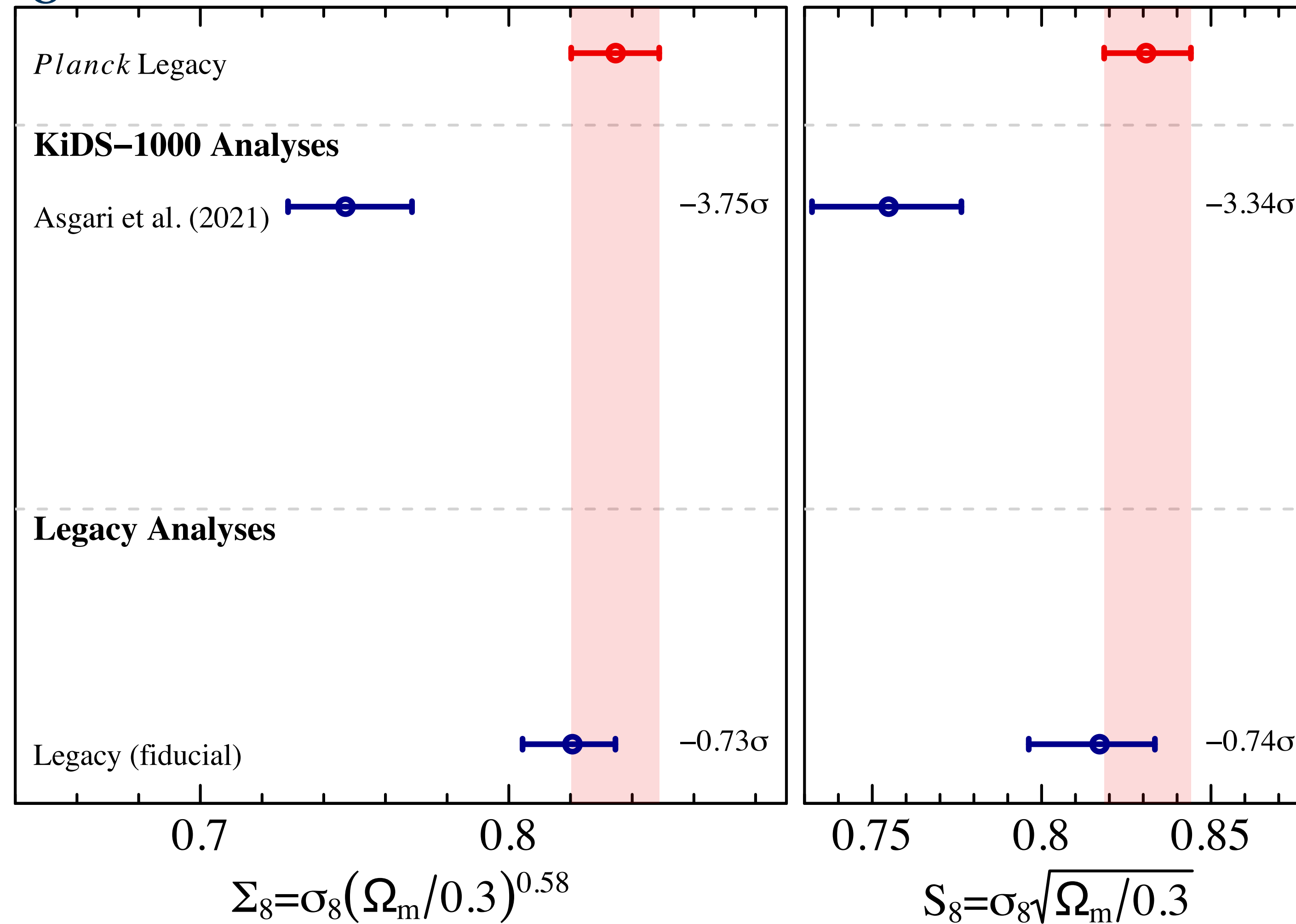
S_8 constraints



Wright et al. (2025)

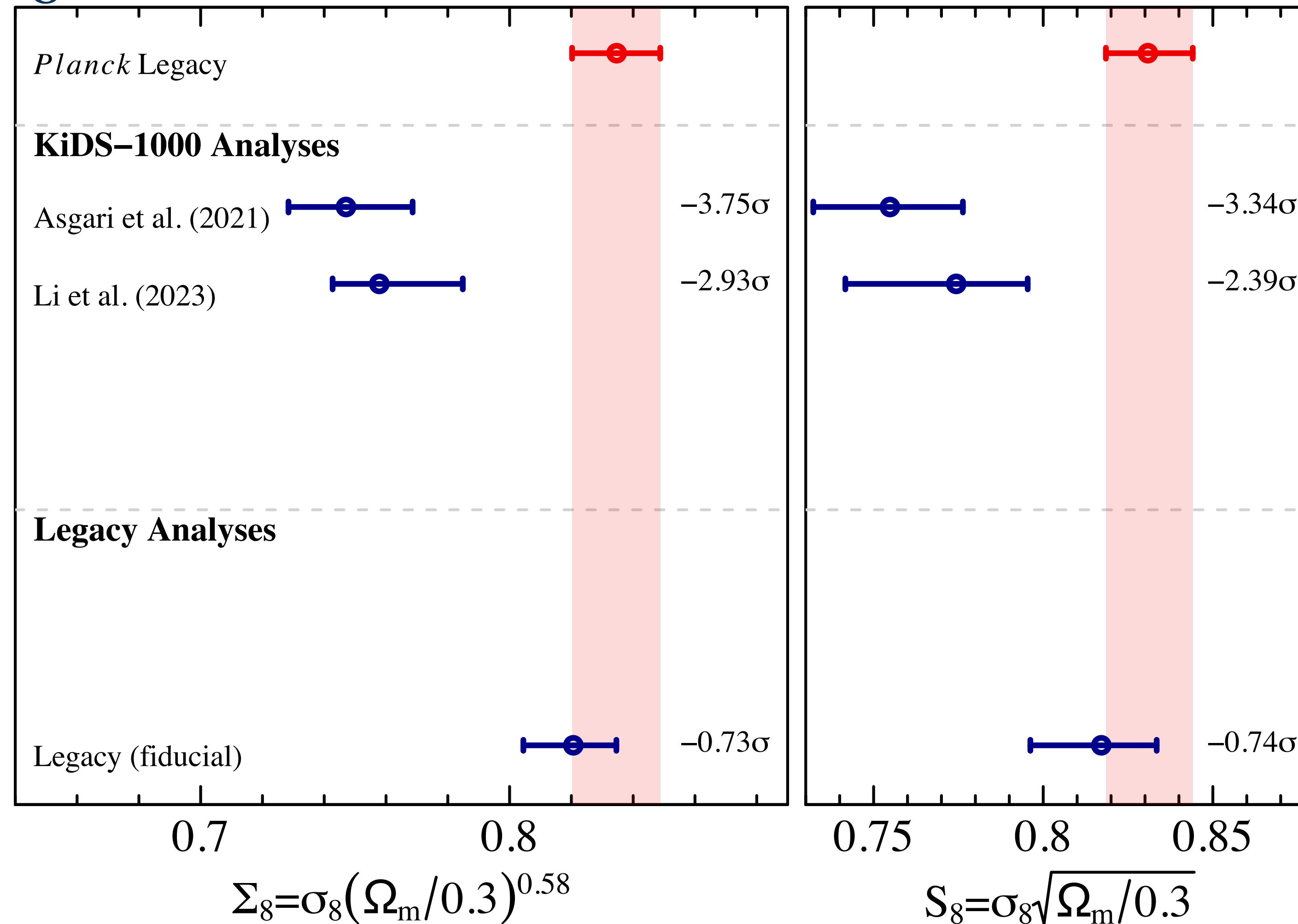


S_8 tension: post unblinding analyses



Wright et al. (2025)

S_8 tension: post unblinding analyses

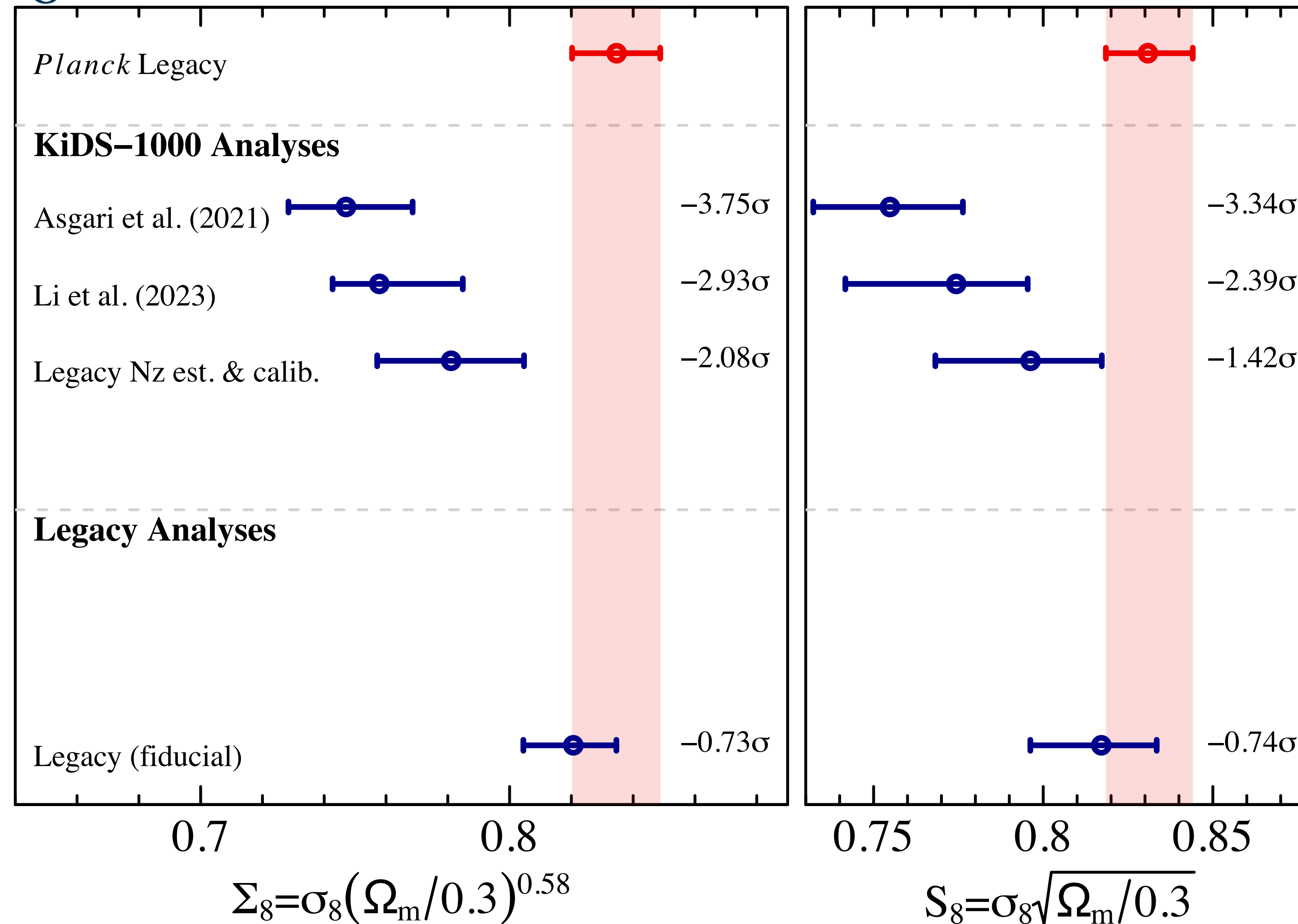


Li et al. (2023)

- enhanced galaxy shape measurements with an updated version of the lensfit code
- improved shear calibration achieved with a newly developed suite of multi-band image simulations.

Wright et al. (2025)

S_8 tension: post unblinding analyses

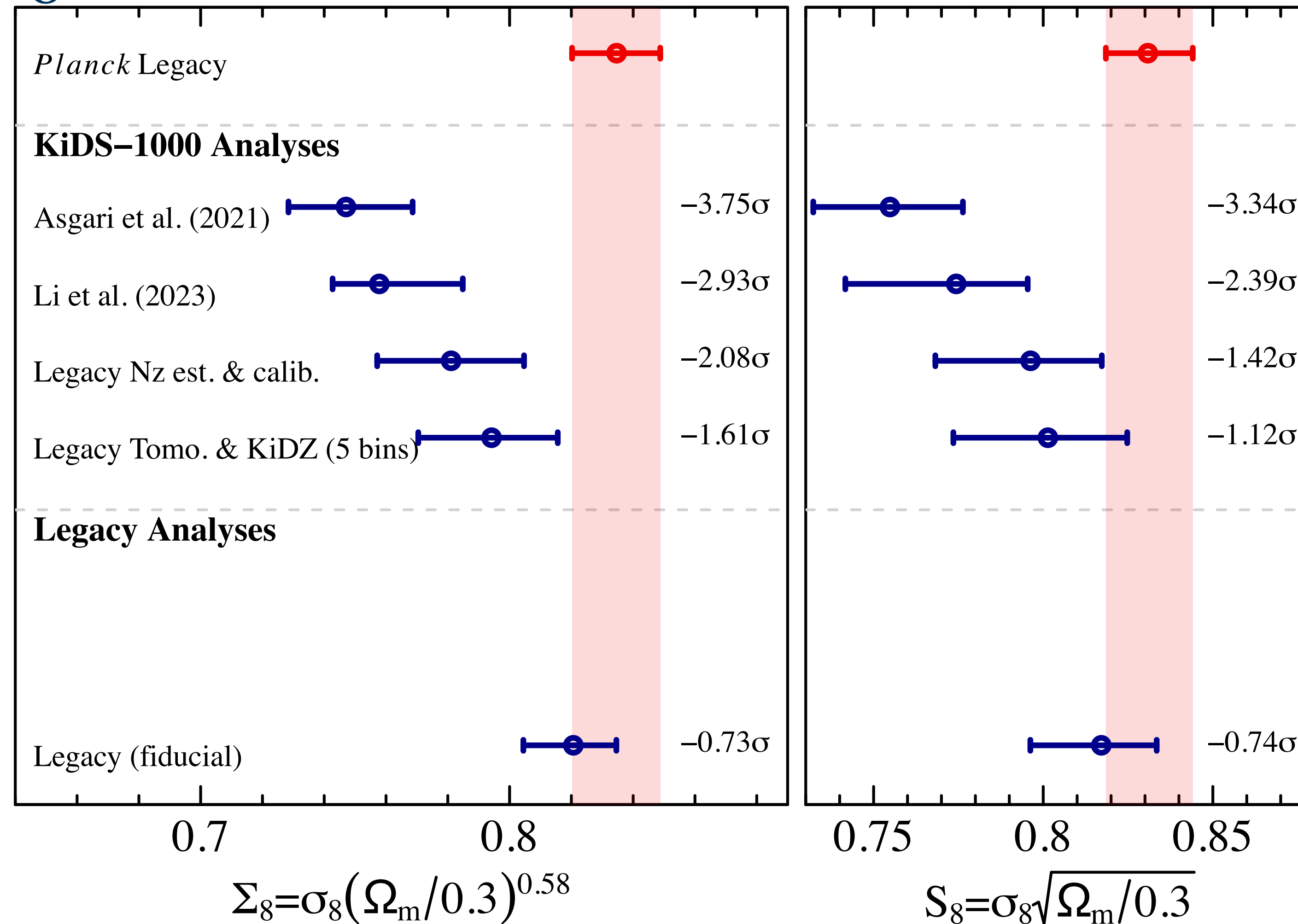


Legacy Nz est. & calib

- using the original KiDS-1000 redshift calibration sample
- updating to SKiLLS image simulations
- sample selection via gold-weight

Wright et al. (2025)

S_8 tension: post unblinding analyses

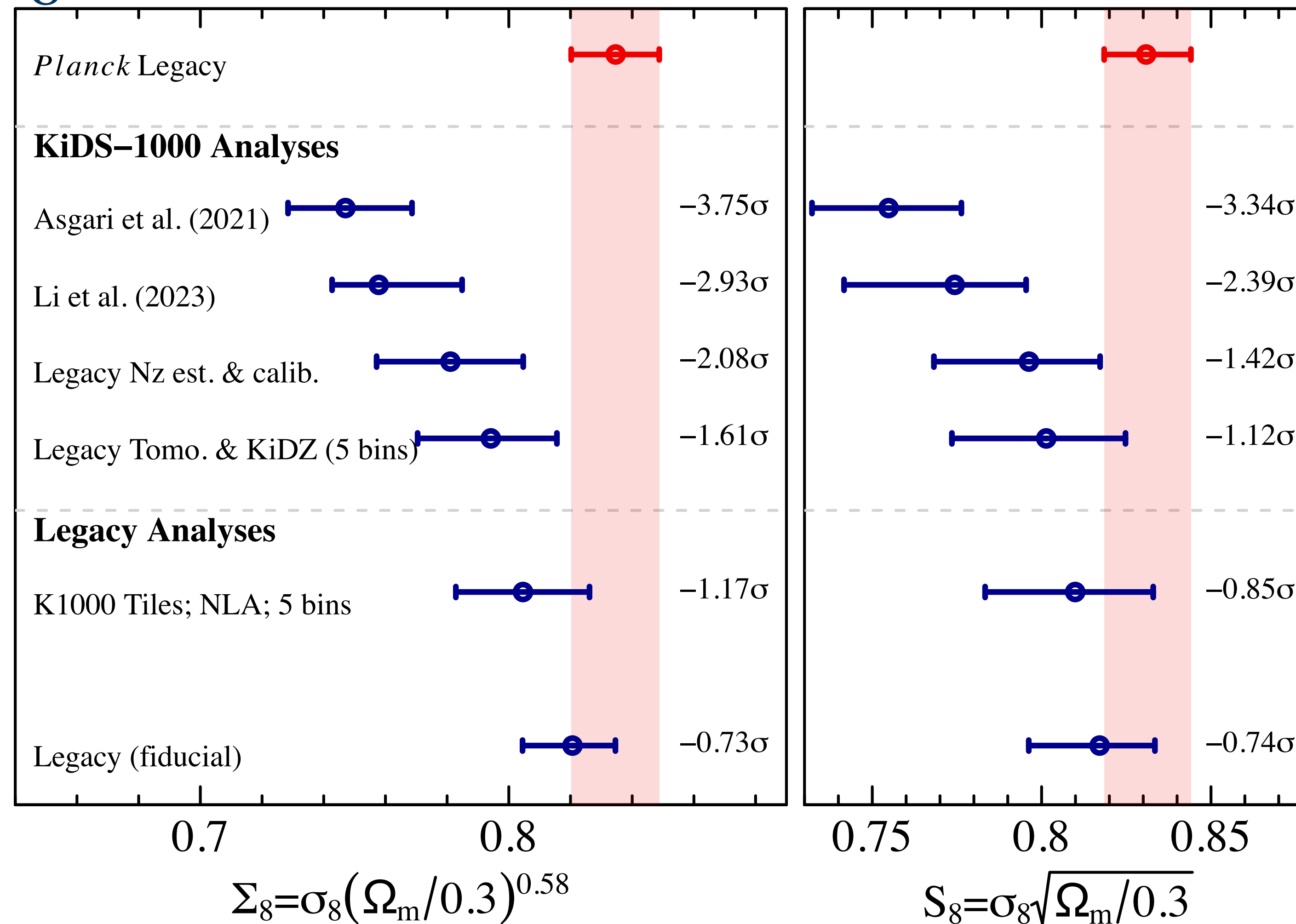


Legacy Tomo. & KiDZ

- new tomographic bin limits (excluding the sixth bin)
- new redshift calibration sample from KiDZ

Wright et al. (2025)

S_8 tension: post unblinding analyses

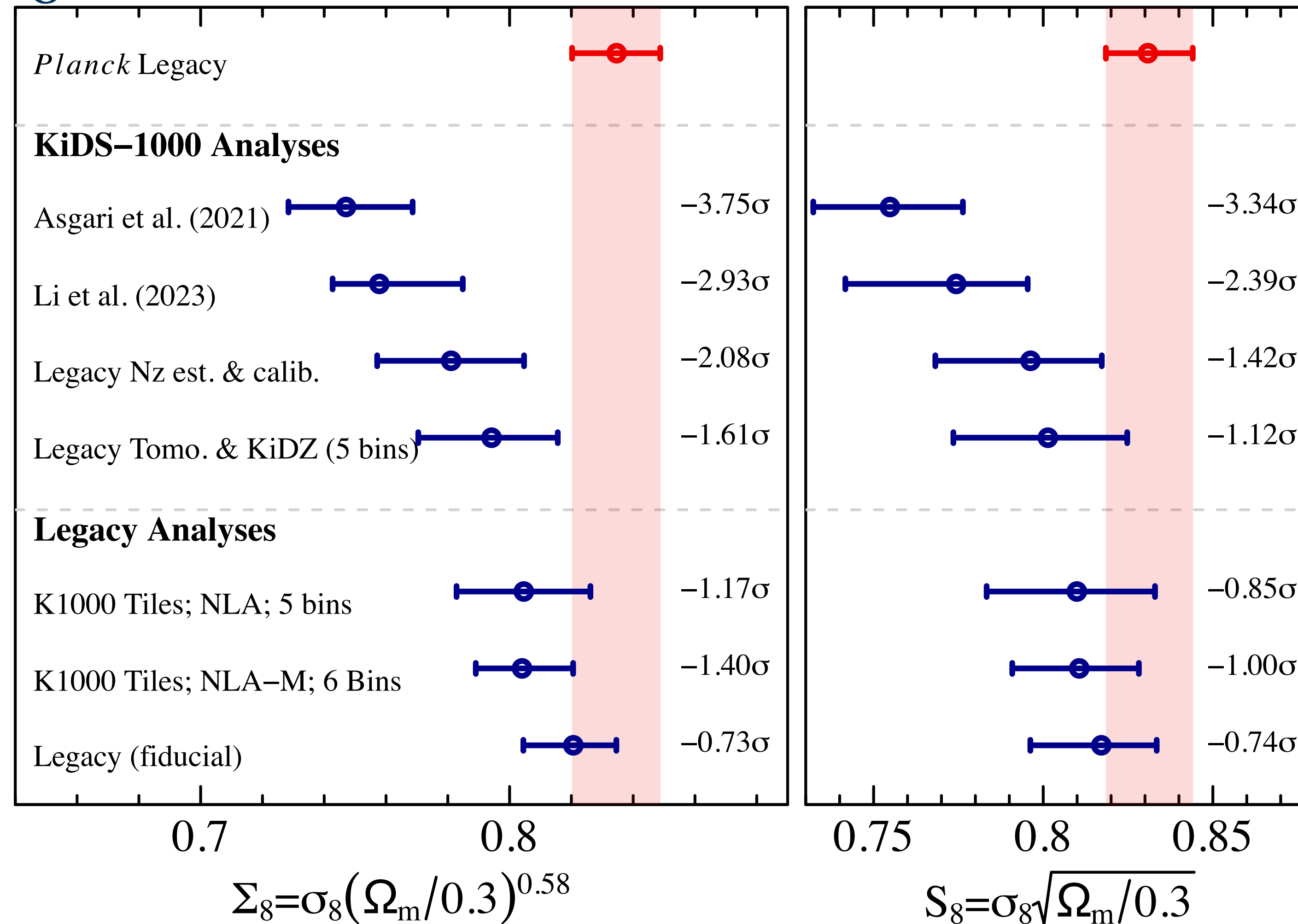


K1000 Tiles; NLA; 5 bins

- KiDS-Legacy in the footprint of KiDS-1000, excluding the sixth bin

Wright et al. (2025)

S_8 tension: post unblinding analyses

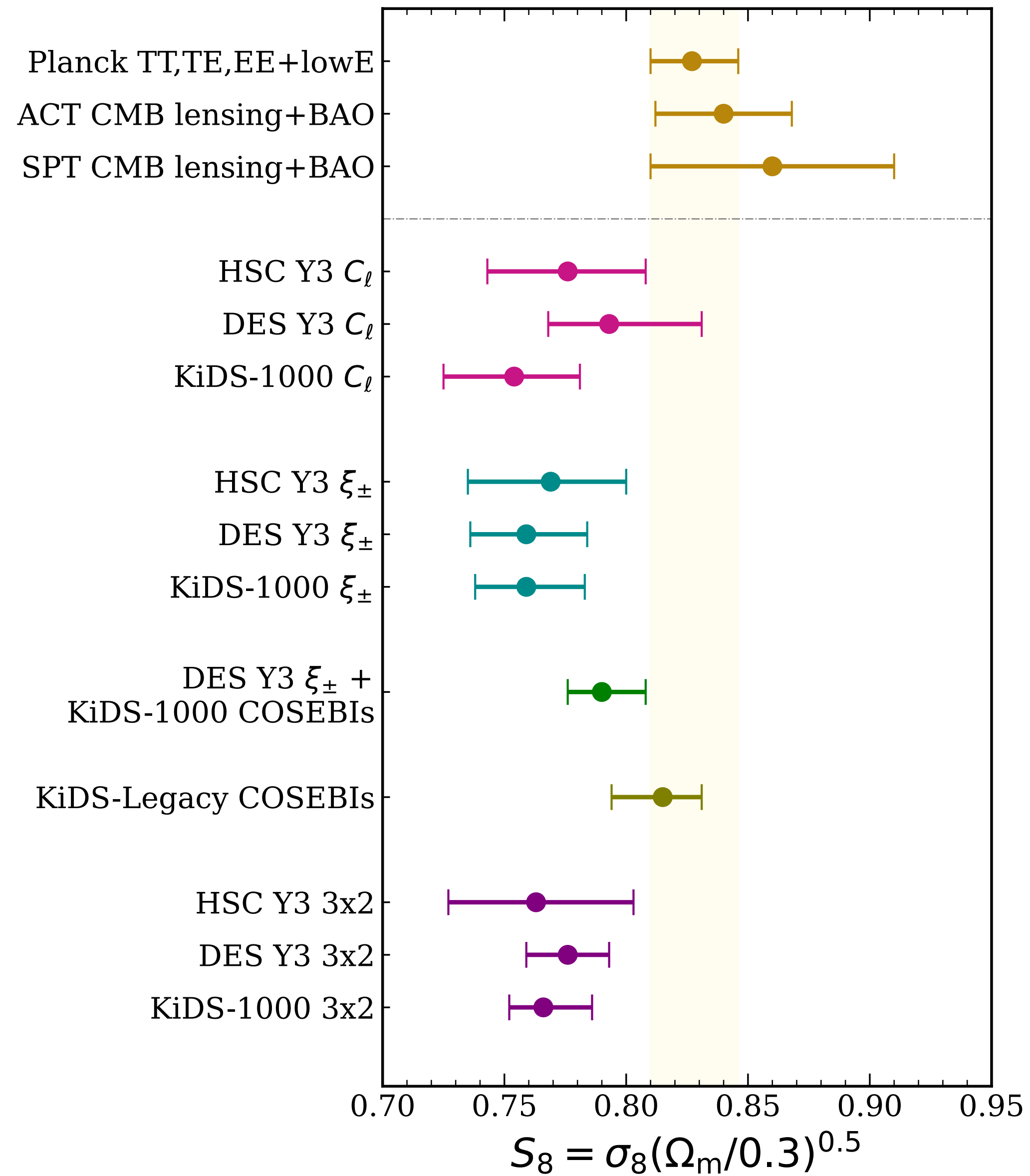


K1000 Tiles; NLA-M; 6 bins

- KiDS-Legacy in the footprint of KiDS-1000, adding the sixth tomographic bin
- using the mass-dependent intrinsic alignment model

Wright et al. (2025)

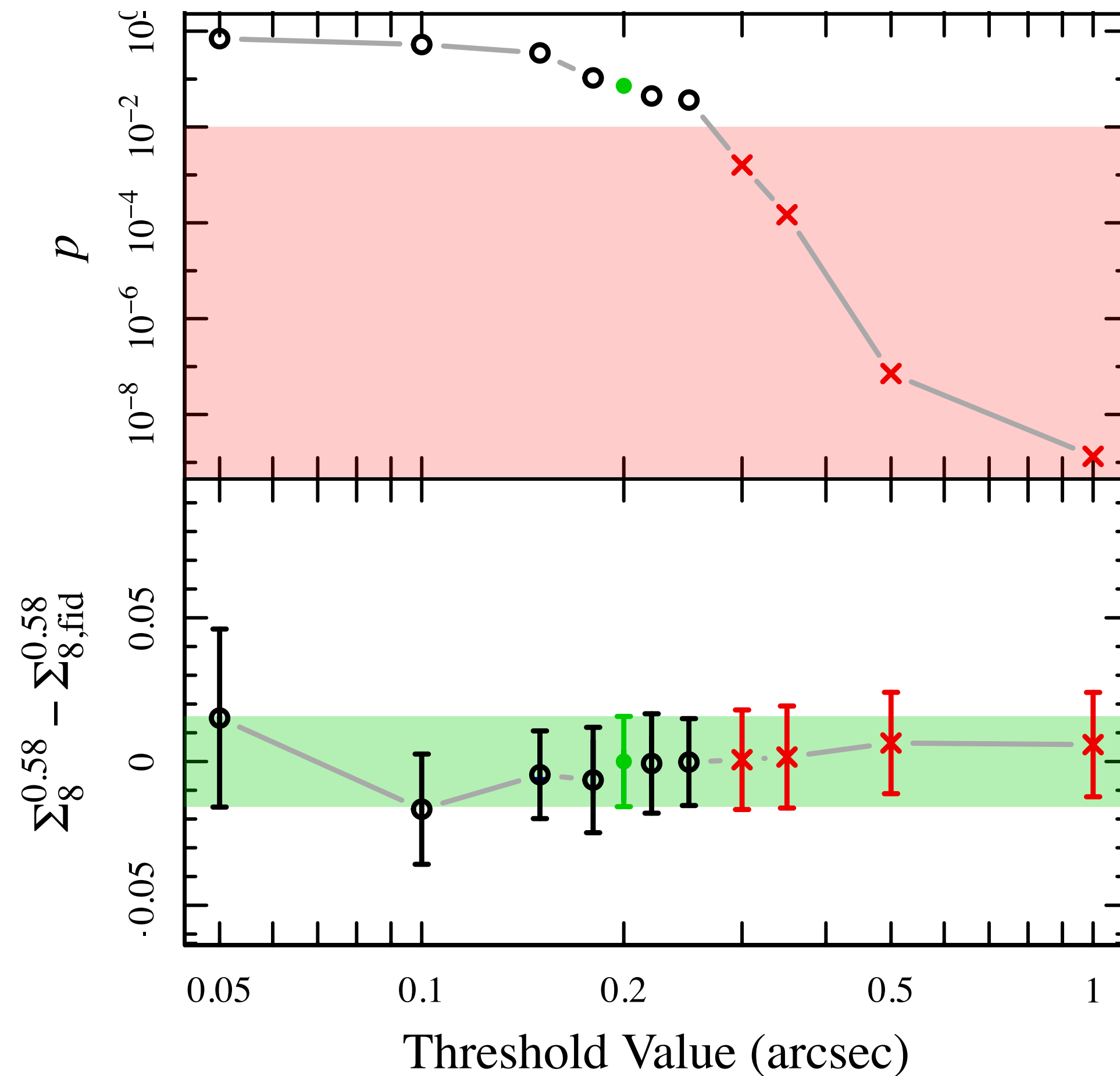
S_8 tension



Di Valentino et al. (2025)

B-modes

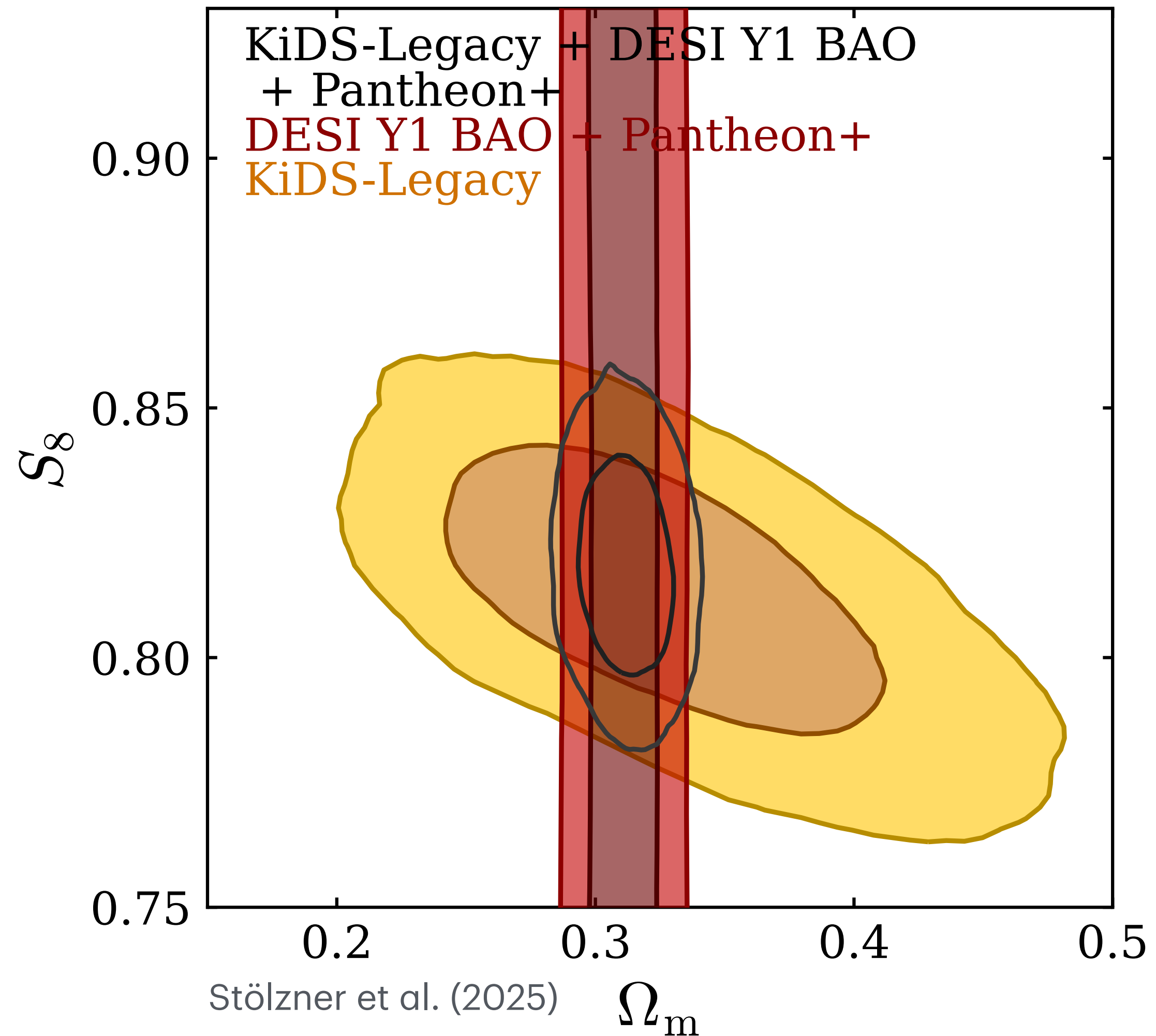
Improved astrometric solutions can also trigger new failure modes



Wright et al. (2025)

- Updated imaging astrometric and photometric calibration
- New astrometric solution is much closer to the ground truth (Gaia) than previous calibrations
- Change in astrometric calibration sample triggered a failure in the astrometric solution for a fraction of survey chips
- Caught by our null tests!

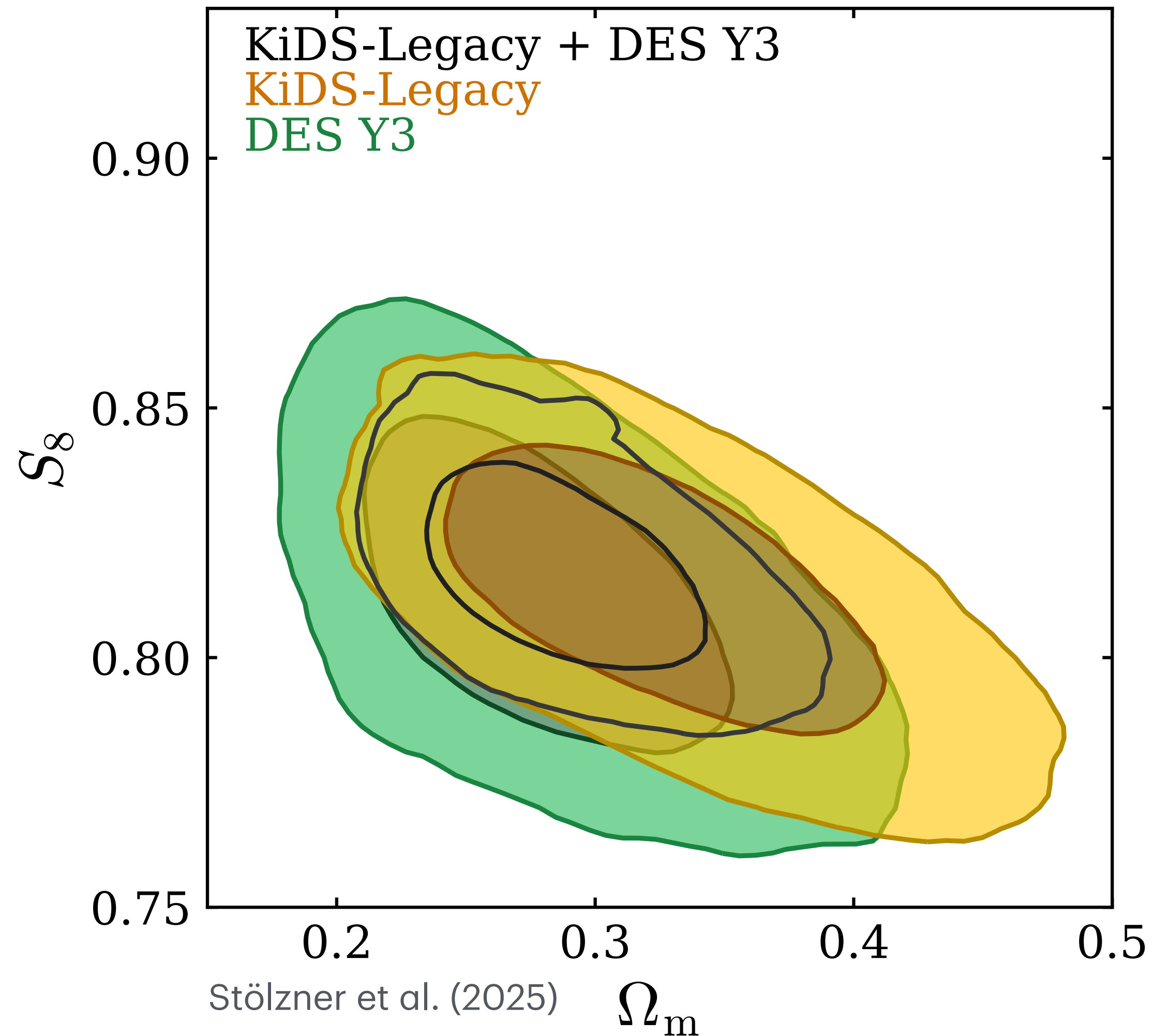
Combination with external datasets



DESI Y1 BAO: $N_\sigma = 0.44$
(Adame et al. 2025)

Pantheon+: $N_\sigma = 0.23$
(Scolnic et al. 2022; Brout et al. 2022)

Combination with external datasets

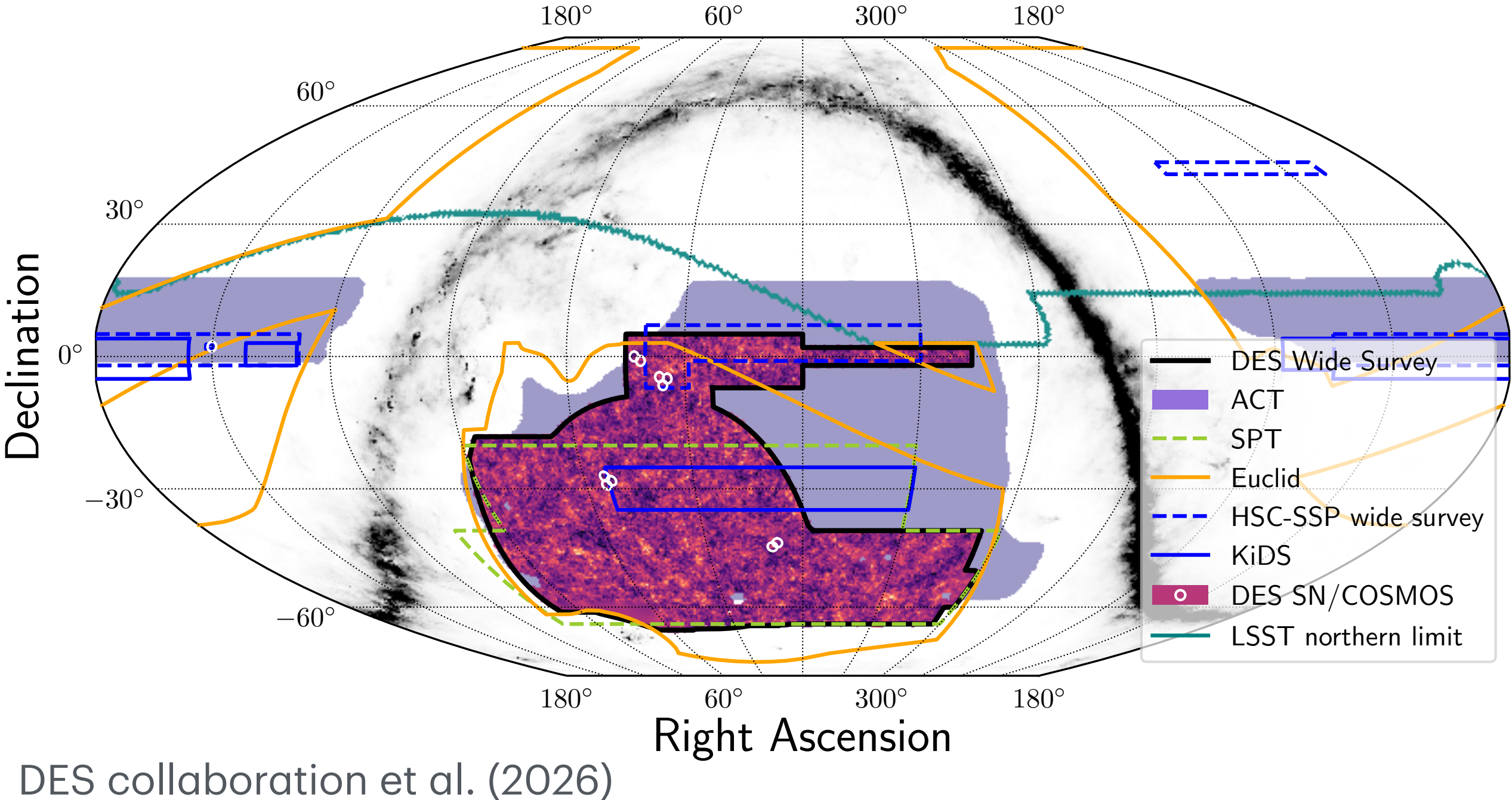
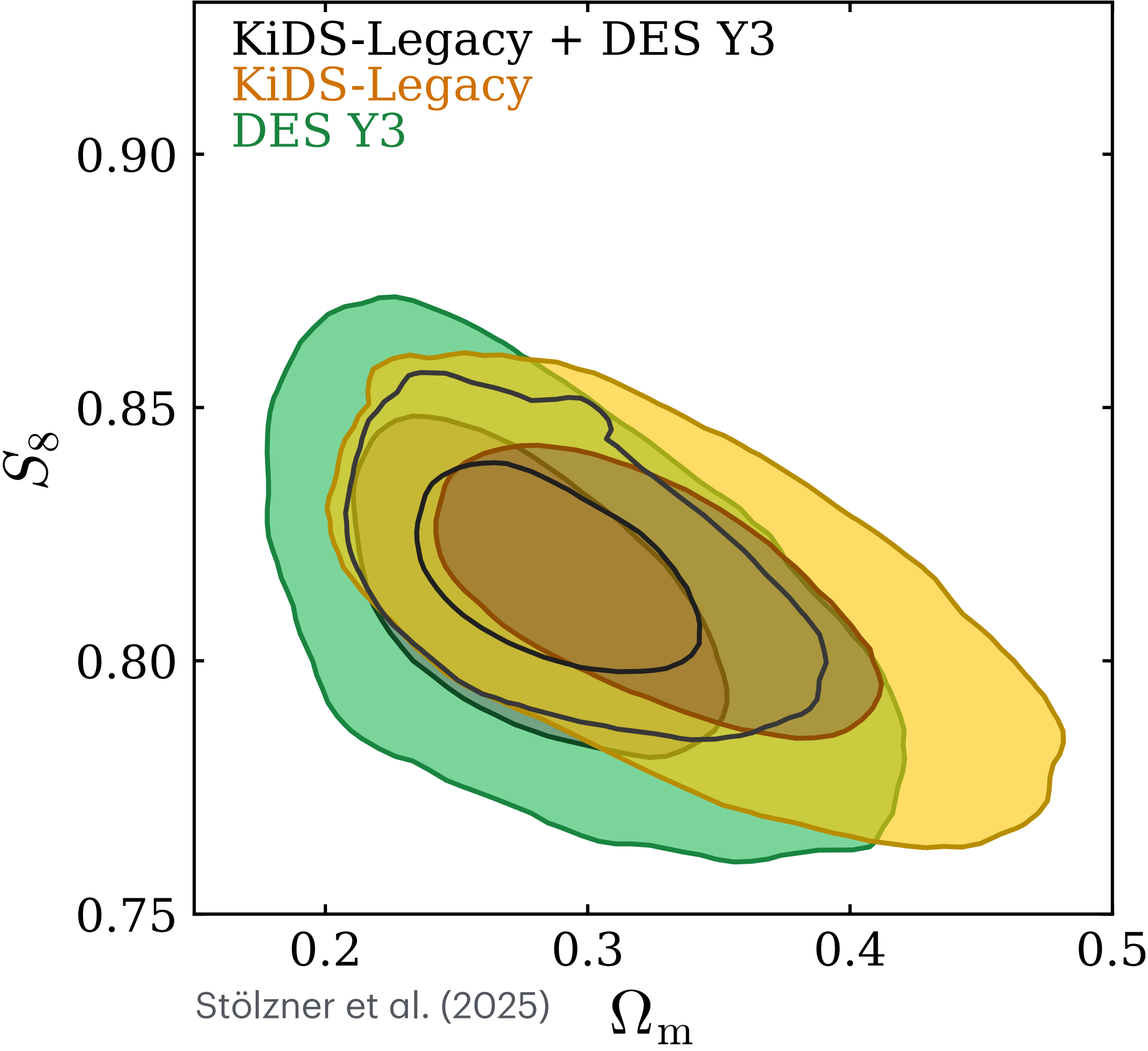


DESI Y1 BAO: $N_\sigma = 0.44$
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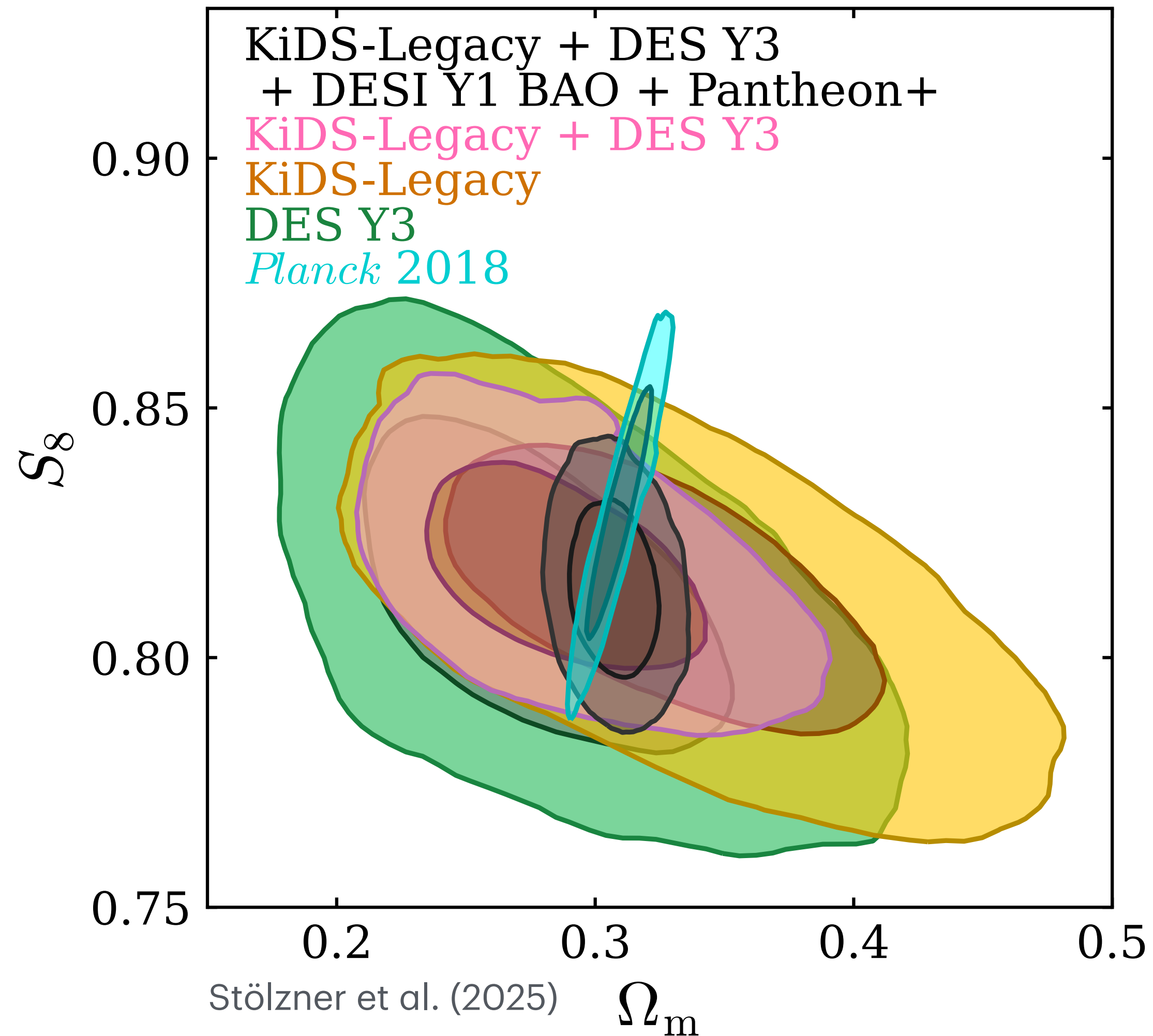
Pantheon+: $N_\sigma = 0.23$
(Scolnic et al. 2022; Brout et al. 2022)

DES Y3: $N_\sigma = 0.58$
(Dark Energy Survey and Kilo-Degree Survey Collaboration et al. 2023)

Combination with external datasets



Combination with external datasets



DESI Y1 BAO: $N_\sigma = 0.44$
(Adame et al. 2025)

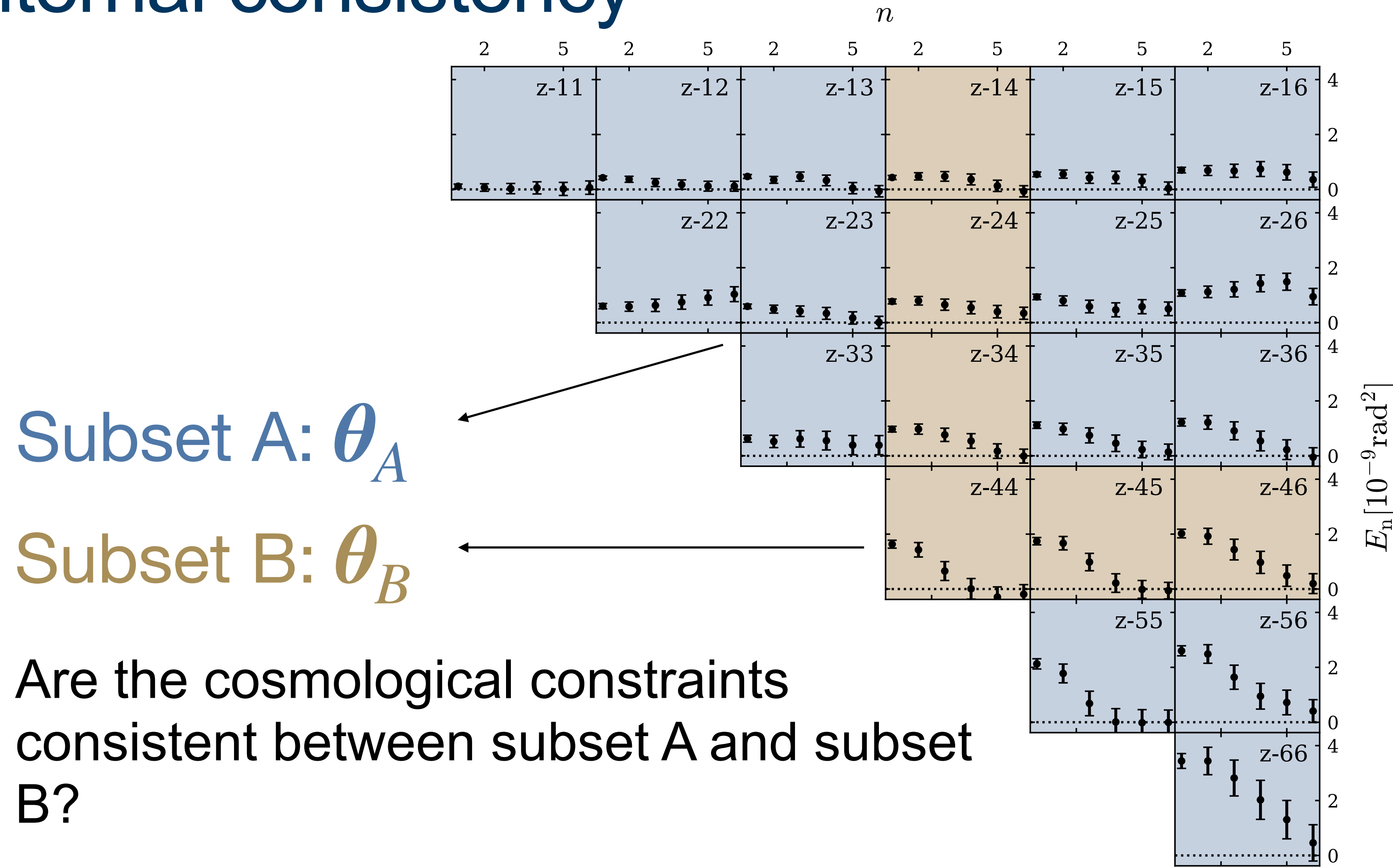
Pantheon+: $N_\sigma = 0.23$
(Scolnic et al. 2022; Brout et al. 2022)

DES Y3: $N_\sigma = 0.58$
(Dark Energy Survey and Kilo-Degree Survey Collaboration et al. 2023)

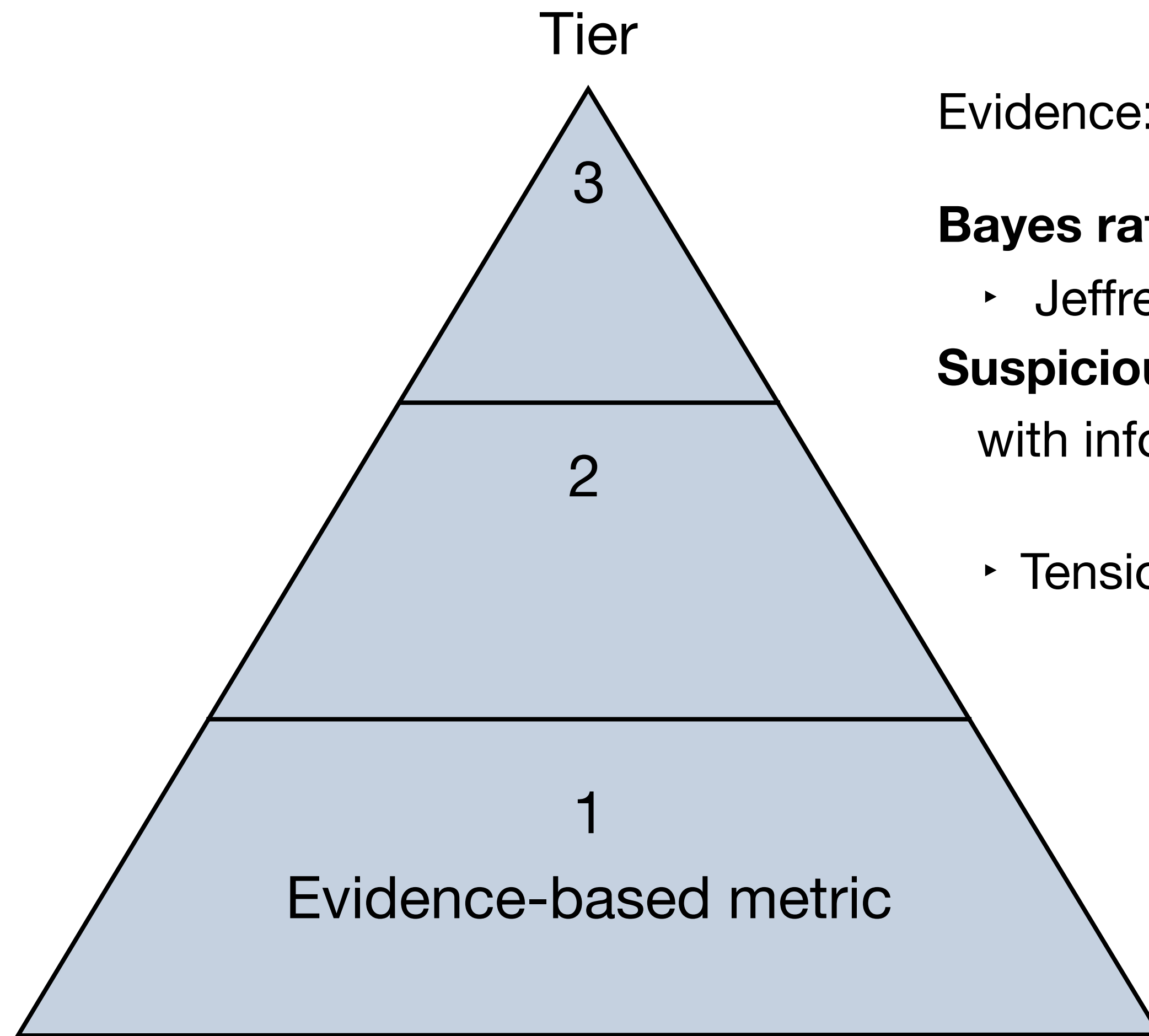
$$S_8 = 0.814^{+0.011}_{-0.012}$$
$$\Omega_m = 0.307^{+0.011}_{-0.011}$$

Internal consistency

Internal consistency



Internal consistency Metrics



Evidence: $\mathcal{Z} = \int d\theta \mathcal{L}(\theta) \pi(\theta)$

Bayes ratio: $\ln R = \ln \mathcal{Z}_{\text{fiducial}} - \ln \mathcal{Z}_{\text{split}}$

▸ Jeffreys' scale

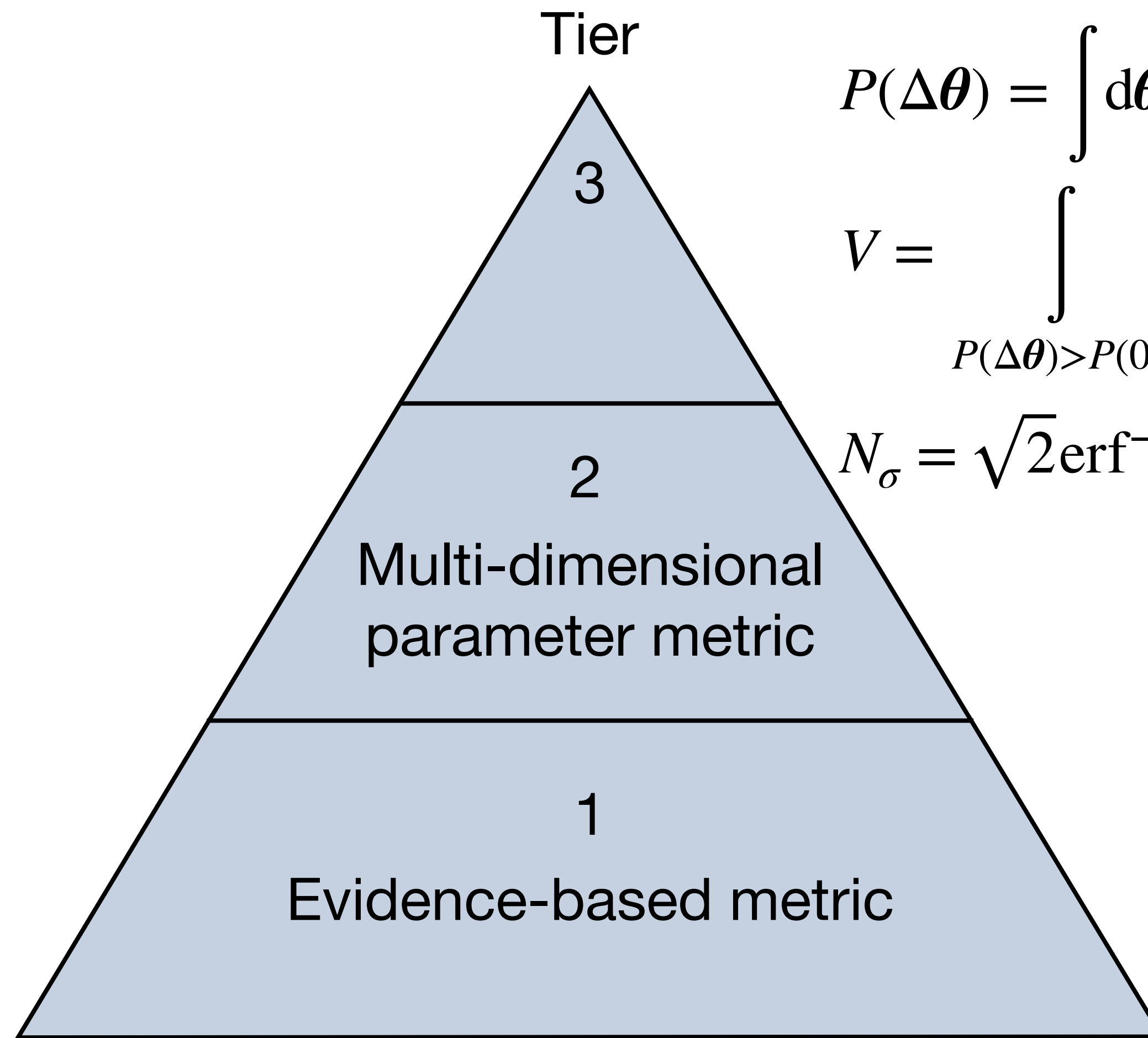
Suspiciousness: $\ln S = \ln R - \ln I$ (Handley & Lemos 2019)

with information ratio $\ln I = \mathcal{D}_{\text{split}} - \mathcal{D}_{\text{fiducial}}$ and KL divergence $\mathcal{D}$

▸ Tension probability: $p_t = \int_{d-2 \ln S}^{\infty} dx \chi_d^2(x), N_\sigma = \sqrt{2} \text{erf}^{-1}(1 - p_t)$

Internal consistency Metrics

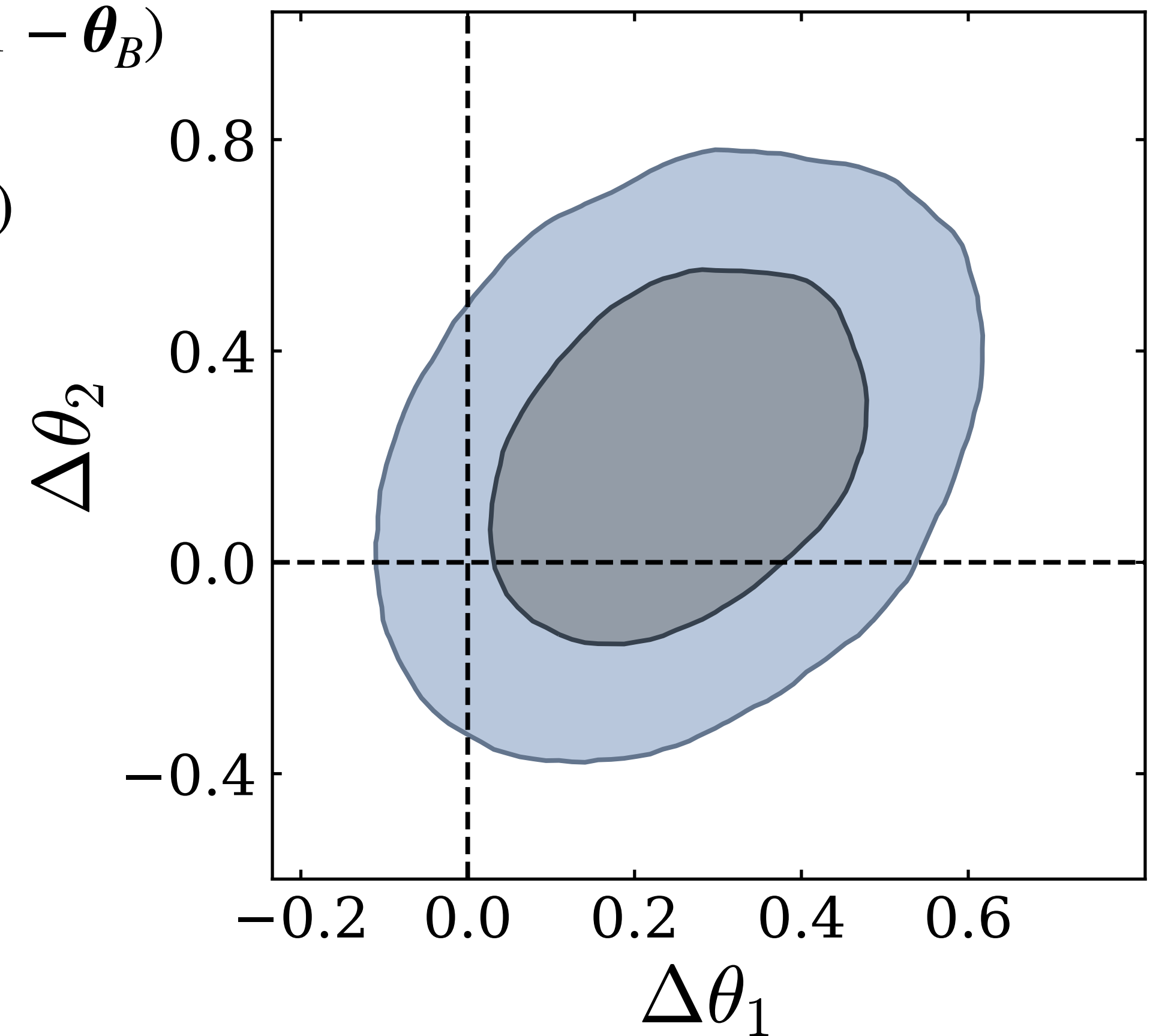
Posterior distribution of the difference between parameters in the split cosmological model: $\Delta\theta = \theta_A - \theta_B$



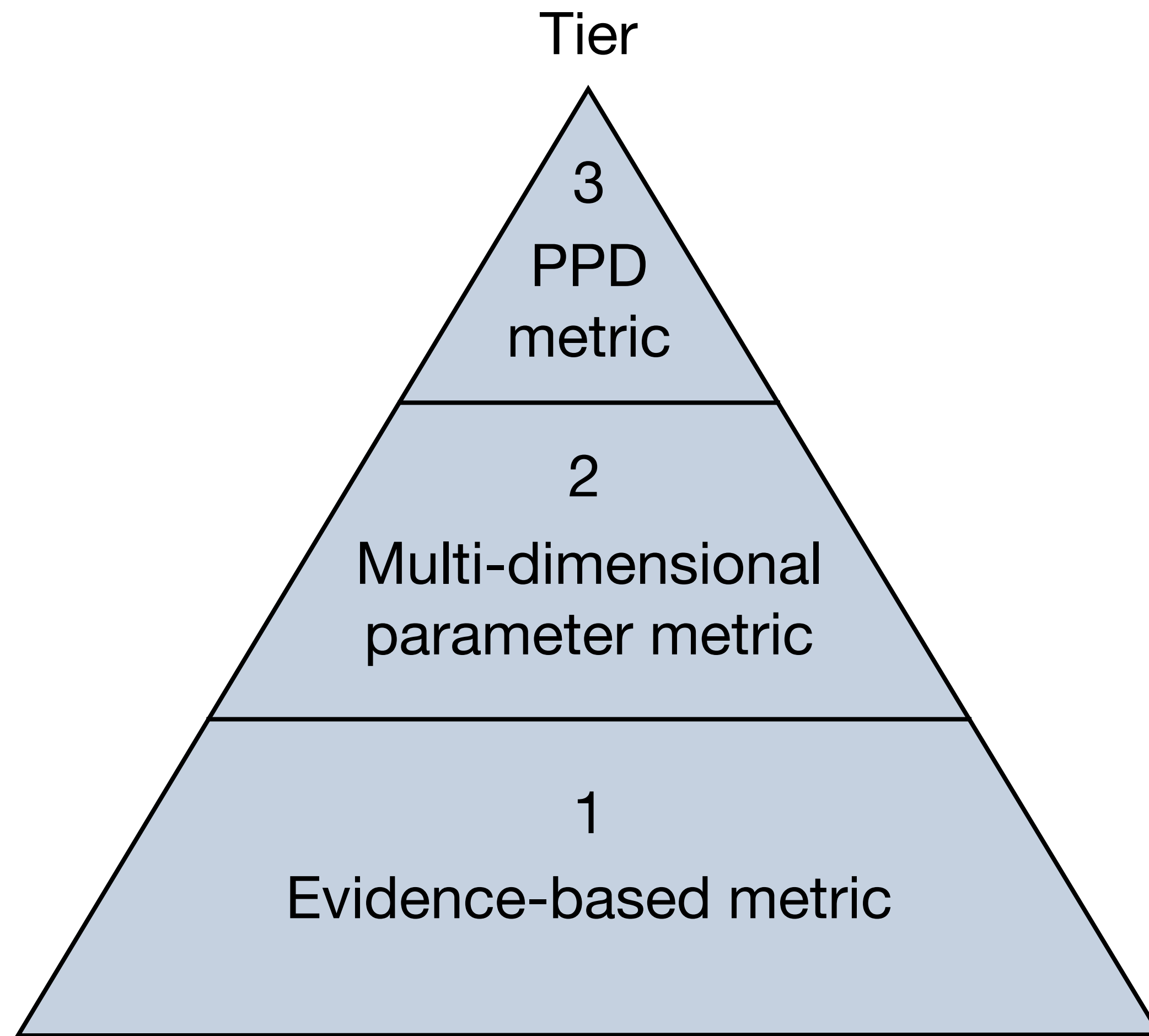
$$P(\Delta\theta) = \int d\theta_A P^{\text{marg}}(\theta_A, 1 - \theta_B)$$

$$V = \int_{P(\Delta\theta) > P(0)} d\Delta\theta P(\Delta\theta)$$

$$N_\sigma = \sqrt{2} \text{erf}^{-1}(1 - V)$$

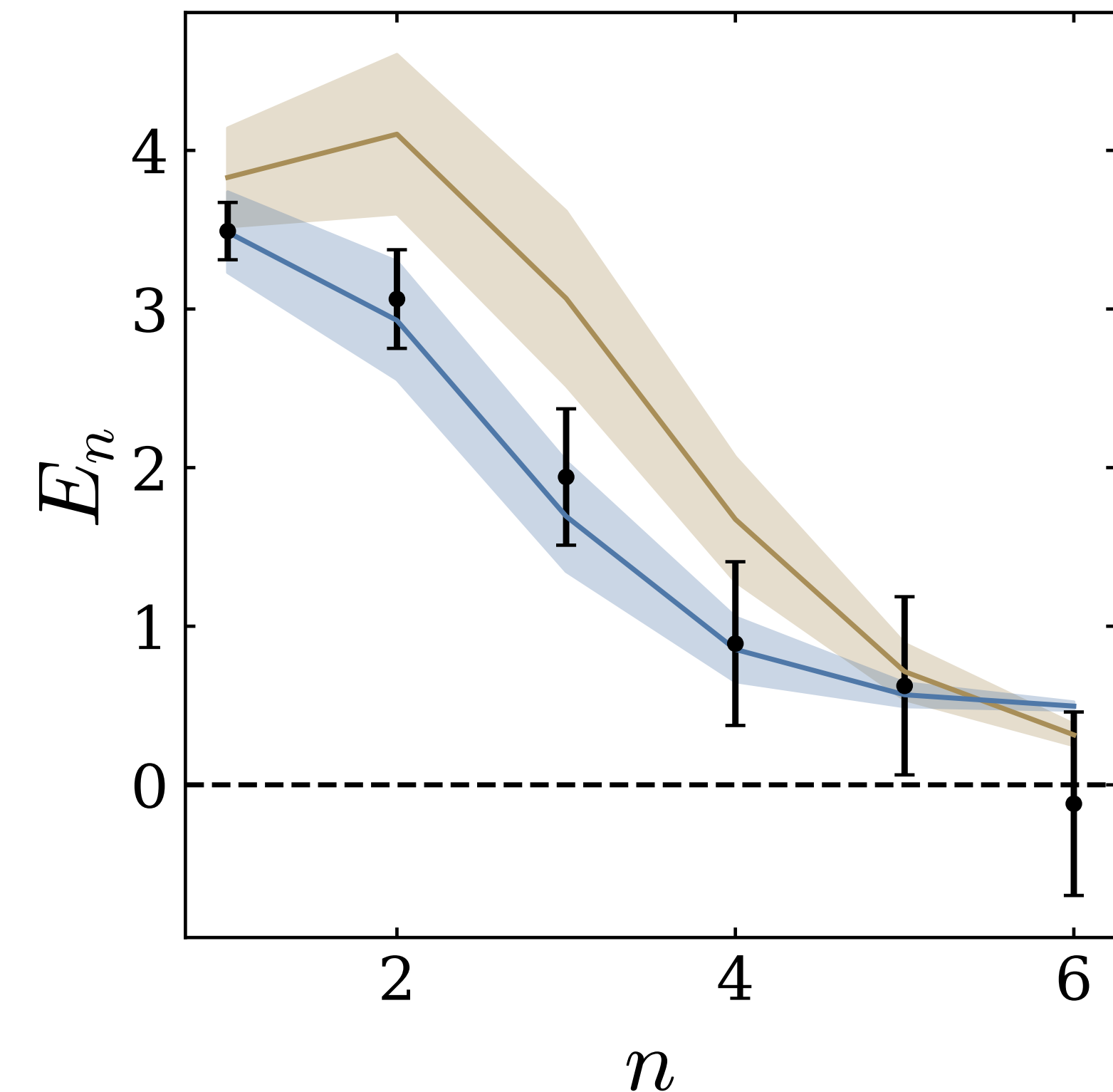


Internal consistency Metrics



Posterior predictive distribution:

$$P(\hat{d} | d, \mathcal{M}) = \int d\theta P(\hat{d} | \theta, \mathcal{M}) P(\theta | d, \mathcal{M})$$



Test if the observed data in subset A is compatible with the PPD inferred from subset B (and vice versa)

- Draw data realisations d^{sim} and infer p-value from $\chi^2 [d_A^{\text{sim}}, t_A(\theta_B)] > \chi^2 [d_A, t_A(\theta_B)]$

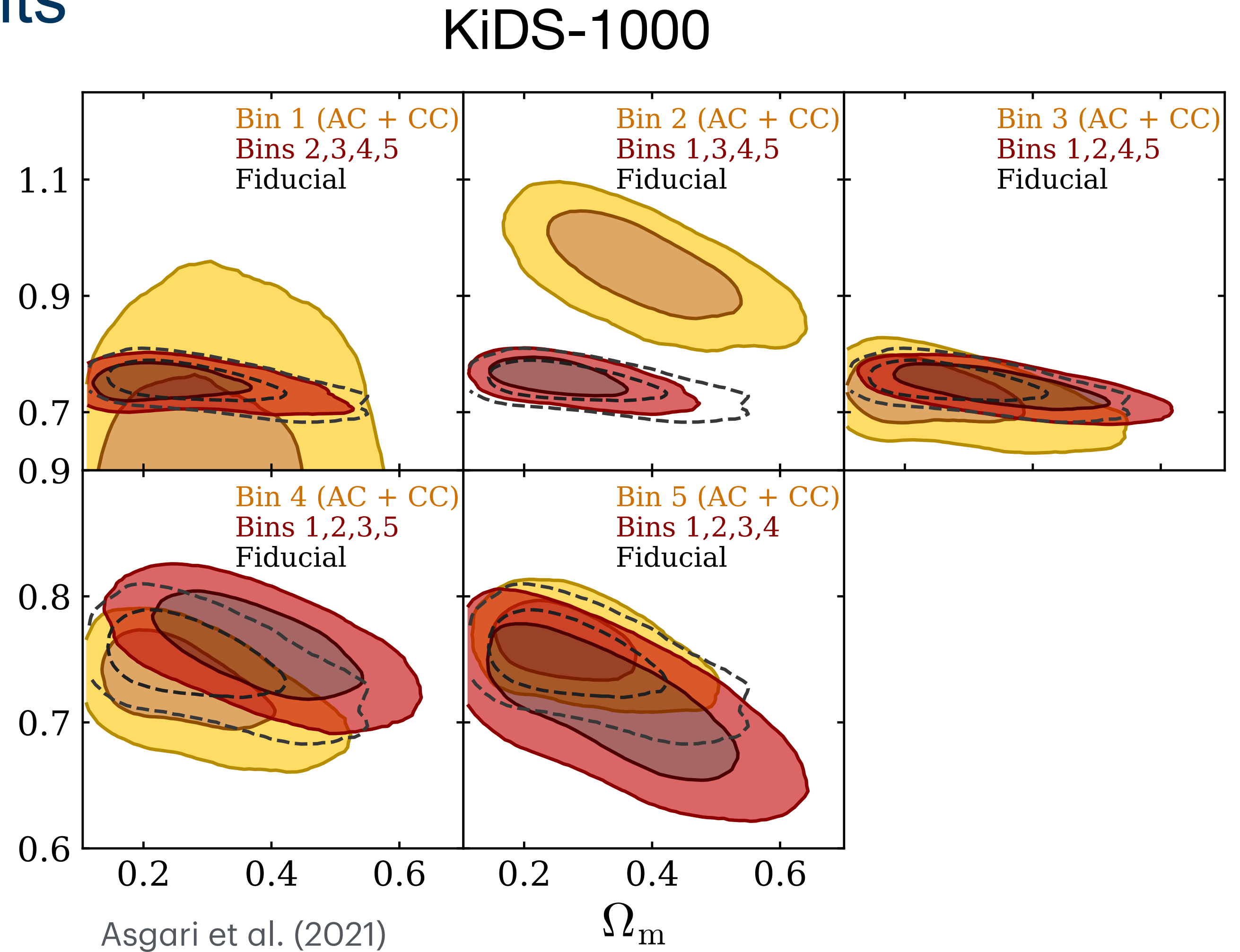
Internal consistency

Results: Datavector-level splits

Redshift bins

$$N_{\sigma}^{\text{Bin 2}} = 2.7$$

- Removing Bin 2 from the KiDS-1000 data vector has a **negligible** impact on S_8



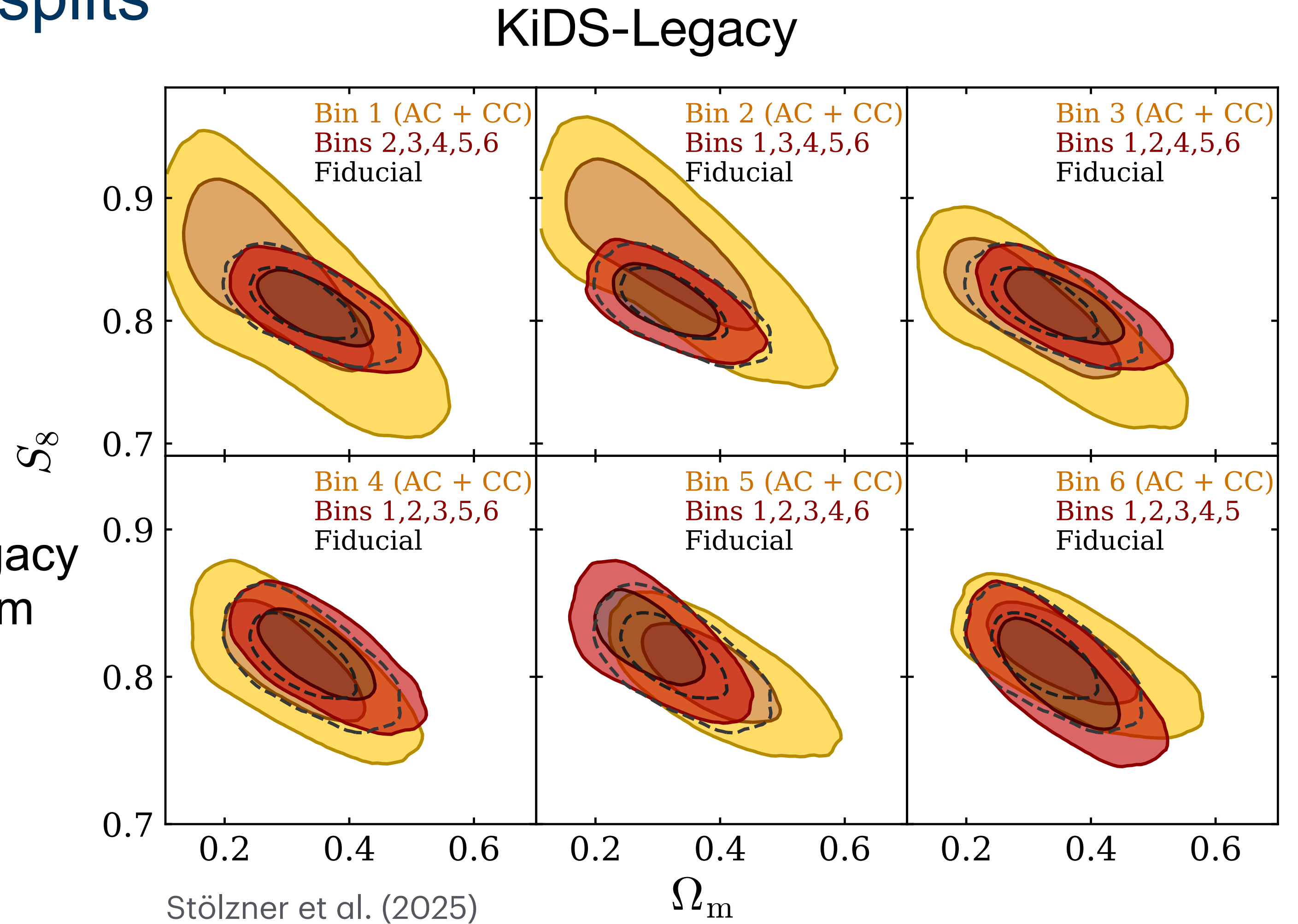
Internal consistency

Results: Datavector-level splits

Redshift bins

$$N_{\sigma}^{\text{Bin 2}} = 1.09$$

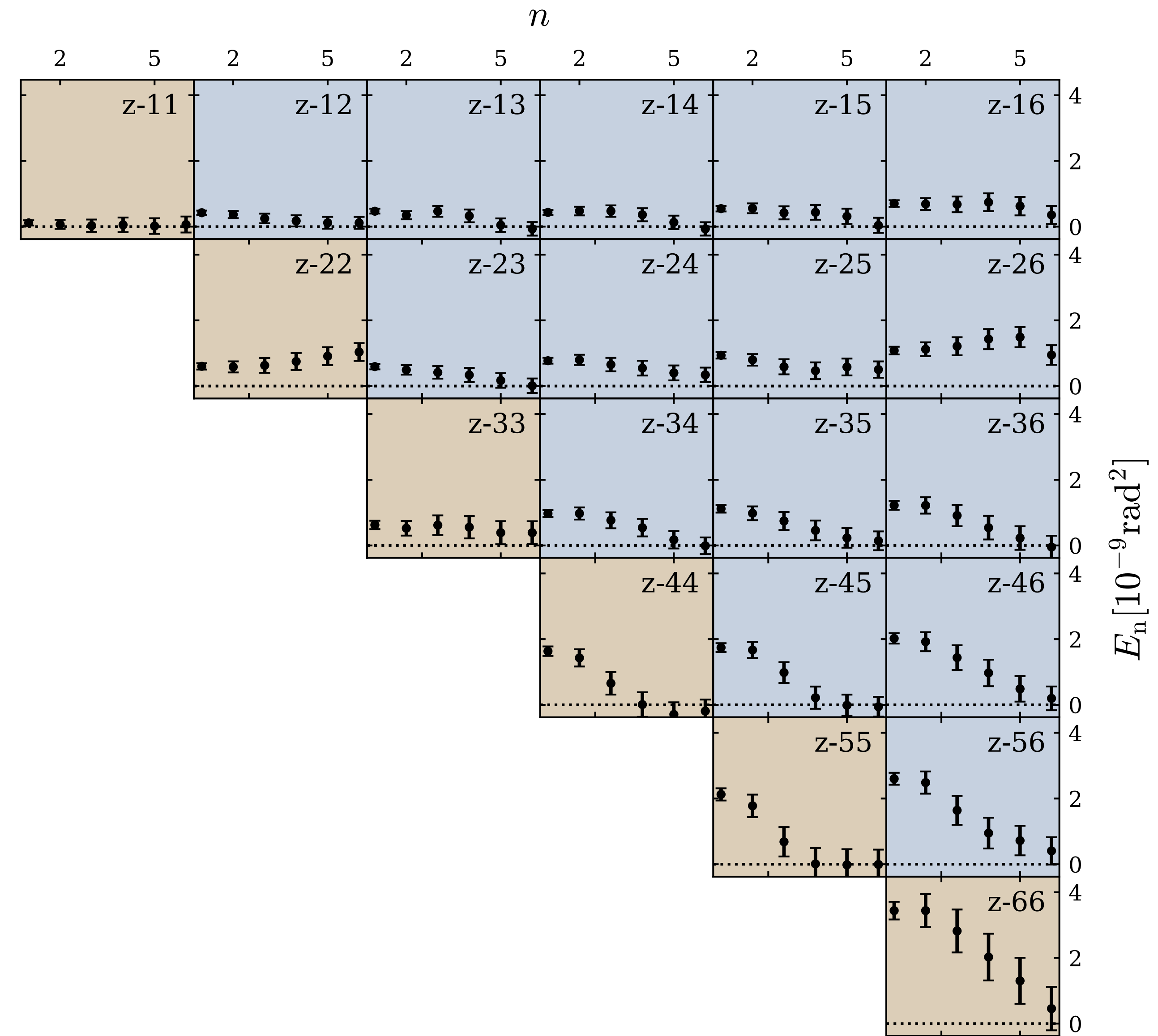
- Better agreement between all tomographic redshift bins in KiDS-Legacy
- **Note:** Tomographic bin limits differ from KiDS-1000



Internal consistency

Results: Datavector-level splits

Auto-correlation vs cross-correlation

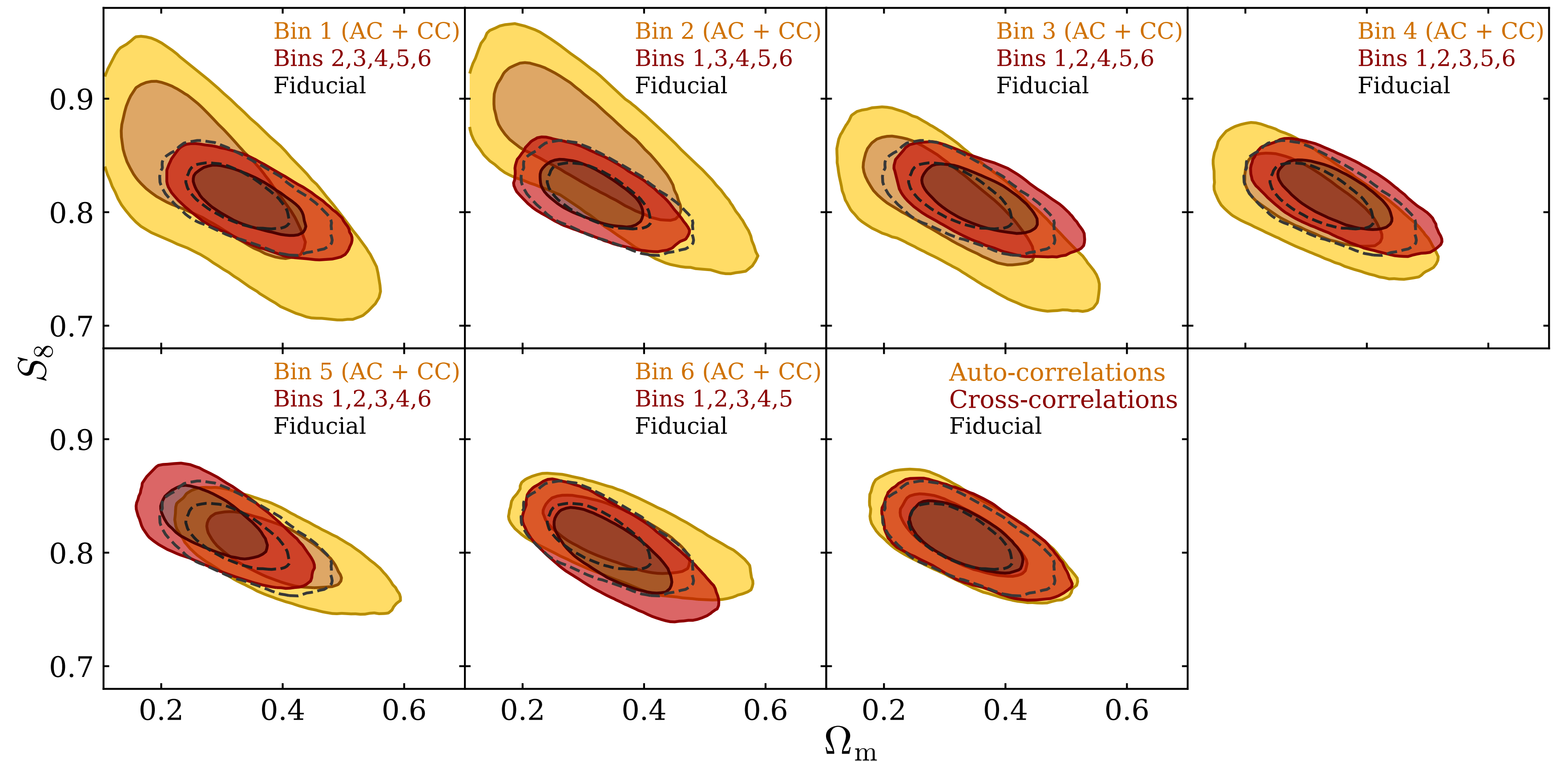


Internal consistency

Results: Datavector-level splits

Auto-correlation vs cross-correlation

$$N_{\sigma}^{\text{AC/CC}} = 0.06$$



Stölzner et al. (2025)

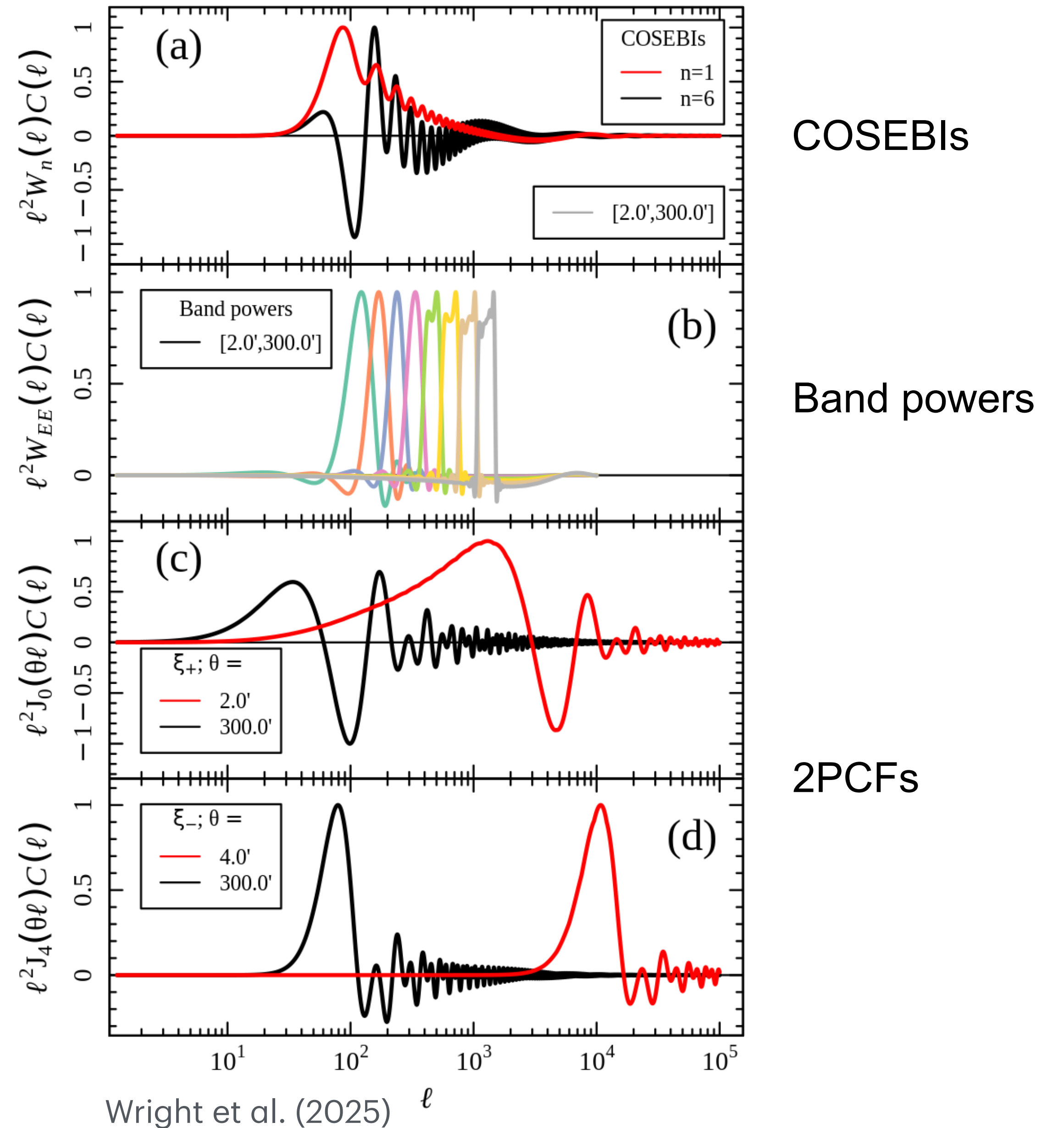
Internal consistency

Results: Datavector-level splits

Scales

- Employ all three summary statistics: COSEBIs, Band powers, and 2PCFs
- Modelled via a linear transformation of the cosmic shear power spectrum:

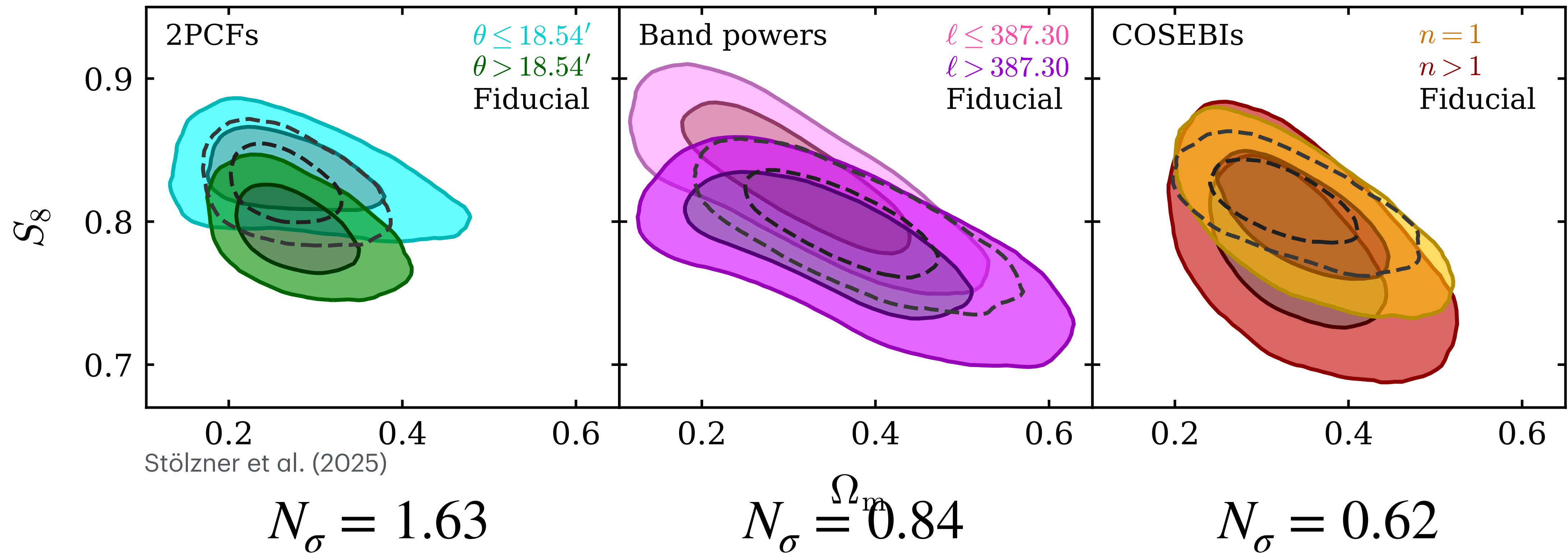
$$S^{ij} = \int_0^\infty d\ell C_{\epsilon\epsilon}^{ij}(\ell) W_S(\ell)$$



Internal consistency

Results: Datavector-level splits

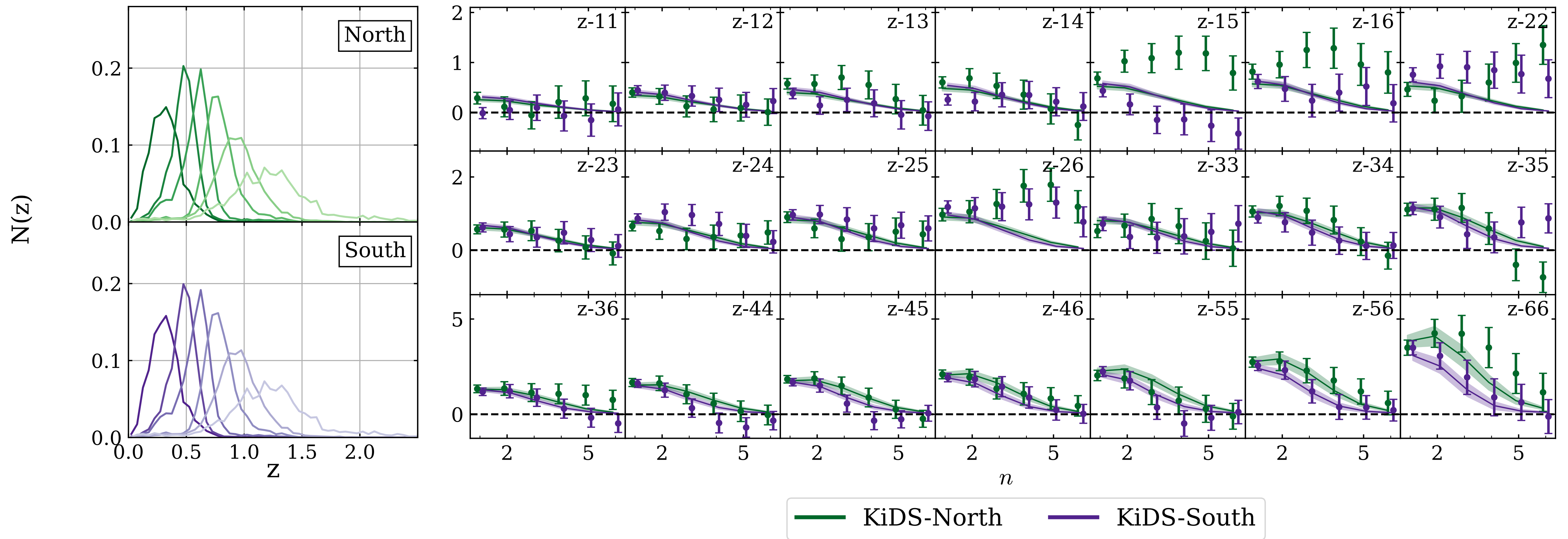
Scales



Internal consistency

Results: Catalogue-level splits

North vs South

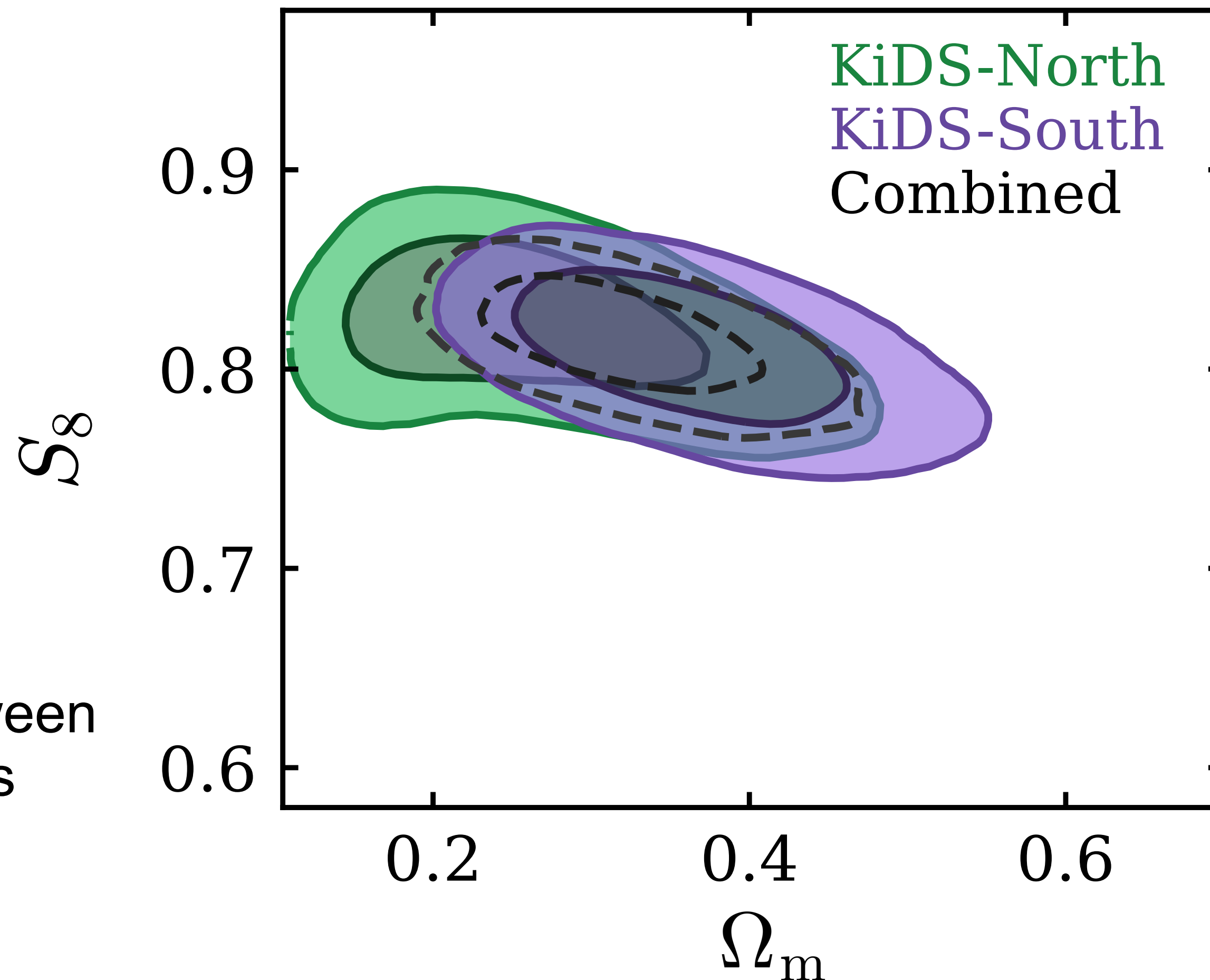


Internal consistency

Results: Catalogue-level splits

North vs South

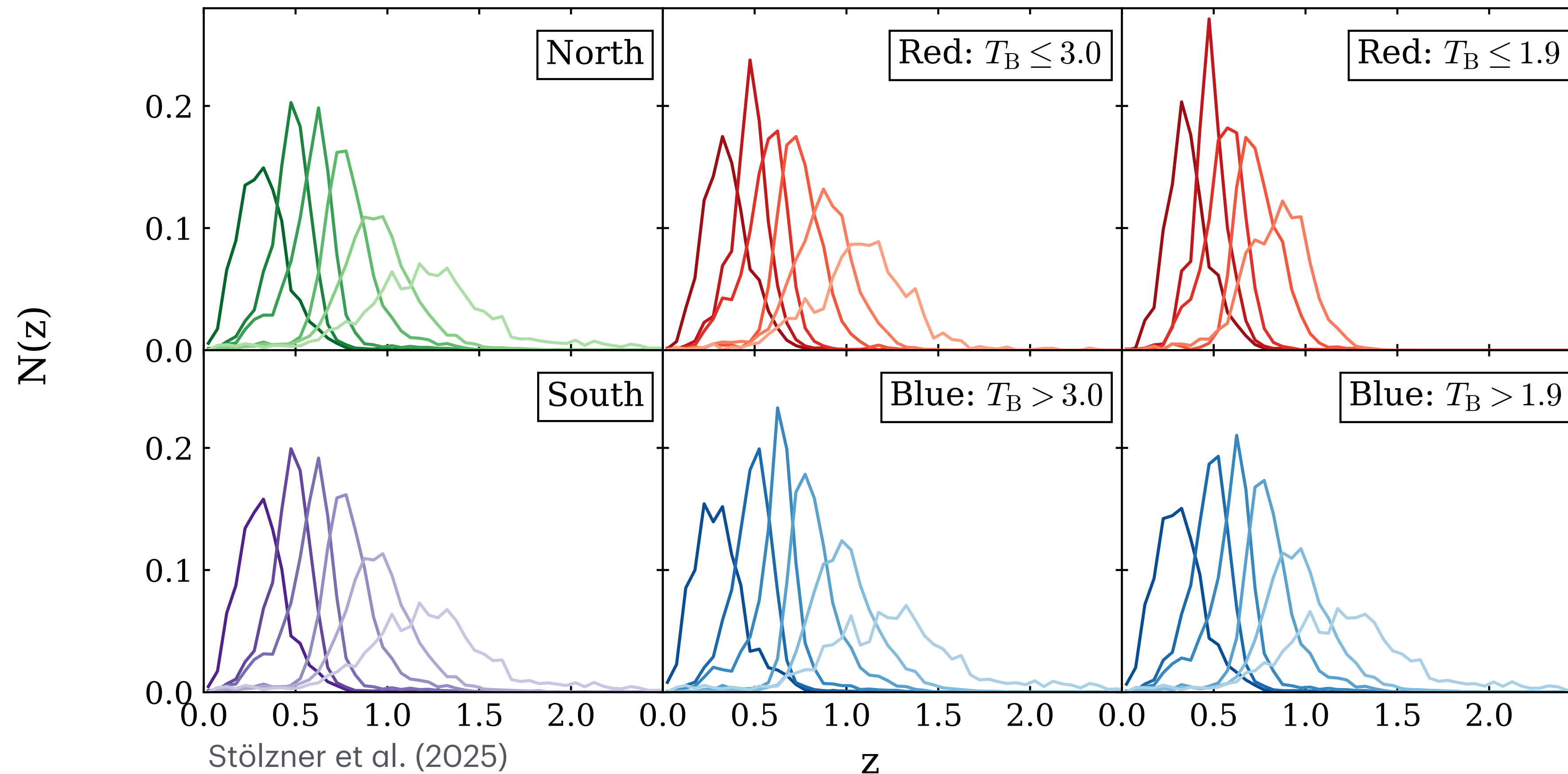
- No cross-correlation between hemispheres
- $N_{\sigma}(\Delta S_8) = 0.36$
- $N_{\sigma}(\Delta \Omega_m) = 1.09$
- $N_{\sigma}(\Delta(S_8, \Omega_m)) = 0.60$
- Overall, high consistency between hemispheres across all metrics



Internal consistency

Results: Catalogue-level splits

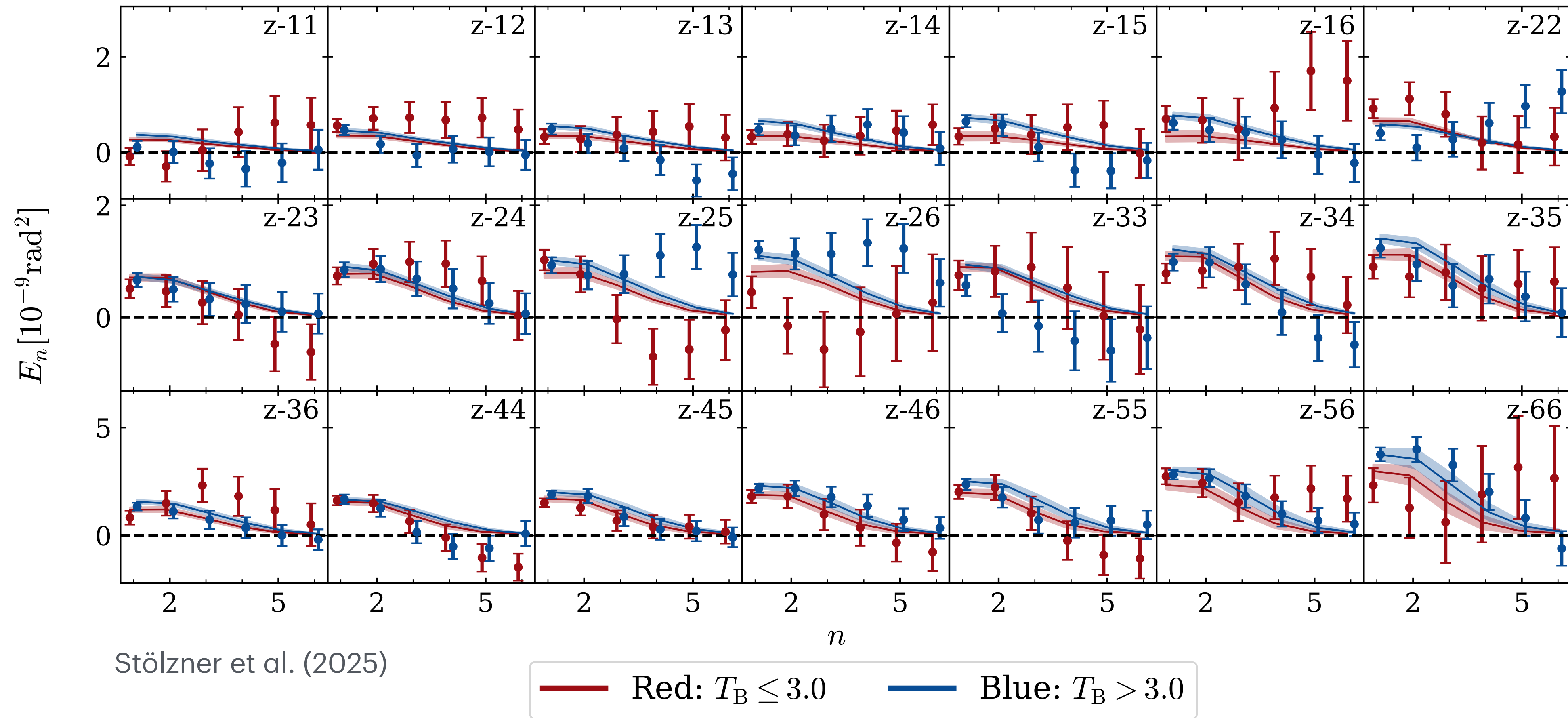
Red galaxies vs blue galaxies



Internal consistency

Results: Catalogue-level splits

Red galaxies vs blue galaxies



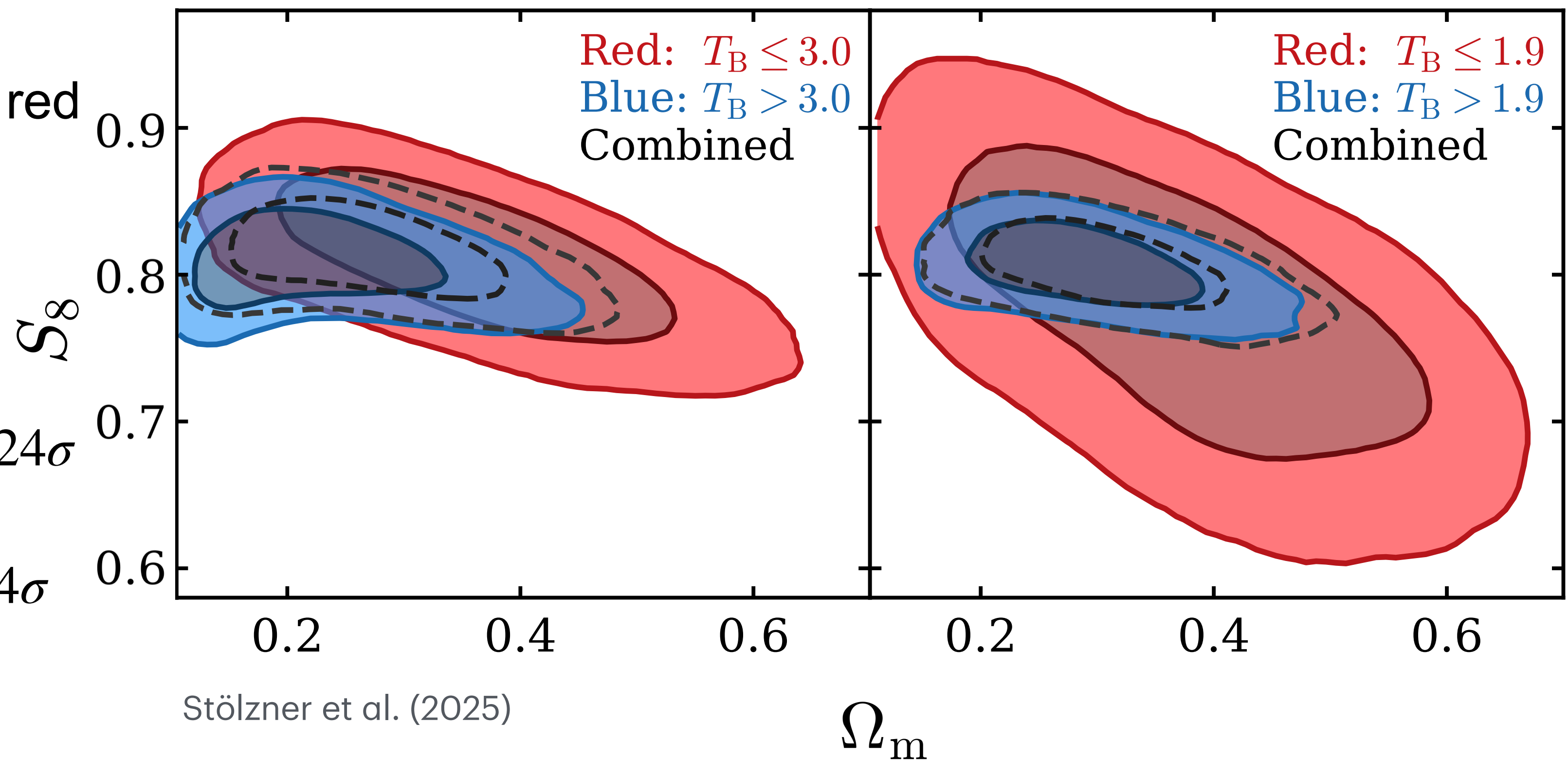
Stölzner et al. (2025)

Internal consistency

Results: Catalogue-level splits

Red galaxies vs blue galaxies

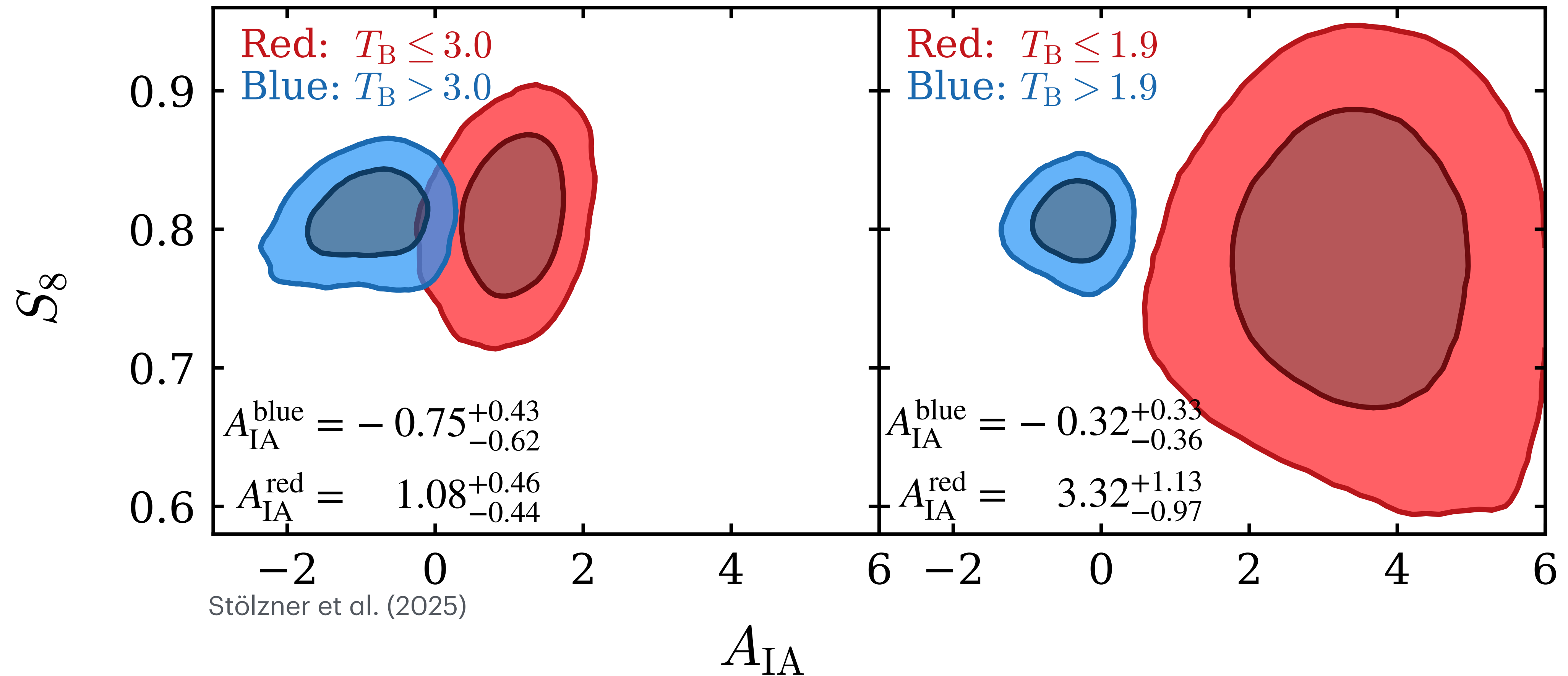
- Significant correlation between red and blue galaxy samples
- $T_B = 3.0$: ~33% red galaxies
- $T_B = 1.9$: ~16% red galaxies
- Tier 2 metric: **Consistent** at $N_\sigma^{T_B=3.0} = 0.74\sigma$ and $N_\sigma^{T_B=1.9} = 0.24\sigma$
- Tier 1 metric: **Discrepant** at $N_\sigma^{T_B=3.0} = 2.61$ and $N_\sigma^{T_B=1.9} = 2.84\sigma$



Internal consistency

Results: Catalogue-level splits

Red galaxies vs blue galaxies



Follow-up analyses

Extended cosmological models

Models

dynamical dark energy: w_0, w_a

variable neutrino mass: $\sum m_\nu$

curvature: Ω_K

Data

KiDS: KiDS-Legacy cosmic shear catalogue

CMB: SPT 3G D1 + ACT DR6 + Planck 2018 lensing
+ primary (SPA)

Lensing: KiDS + DES Y3 + CMB lensing

Low-z: KiDS + DES Y3 + DESI DR2 BAO + eBOSS
DR16 RSD

See Reischke et al. (2026), [arXiv:2512.11041](https://arxiv.org/abs/2512.11041)

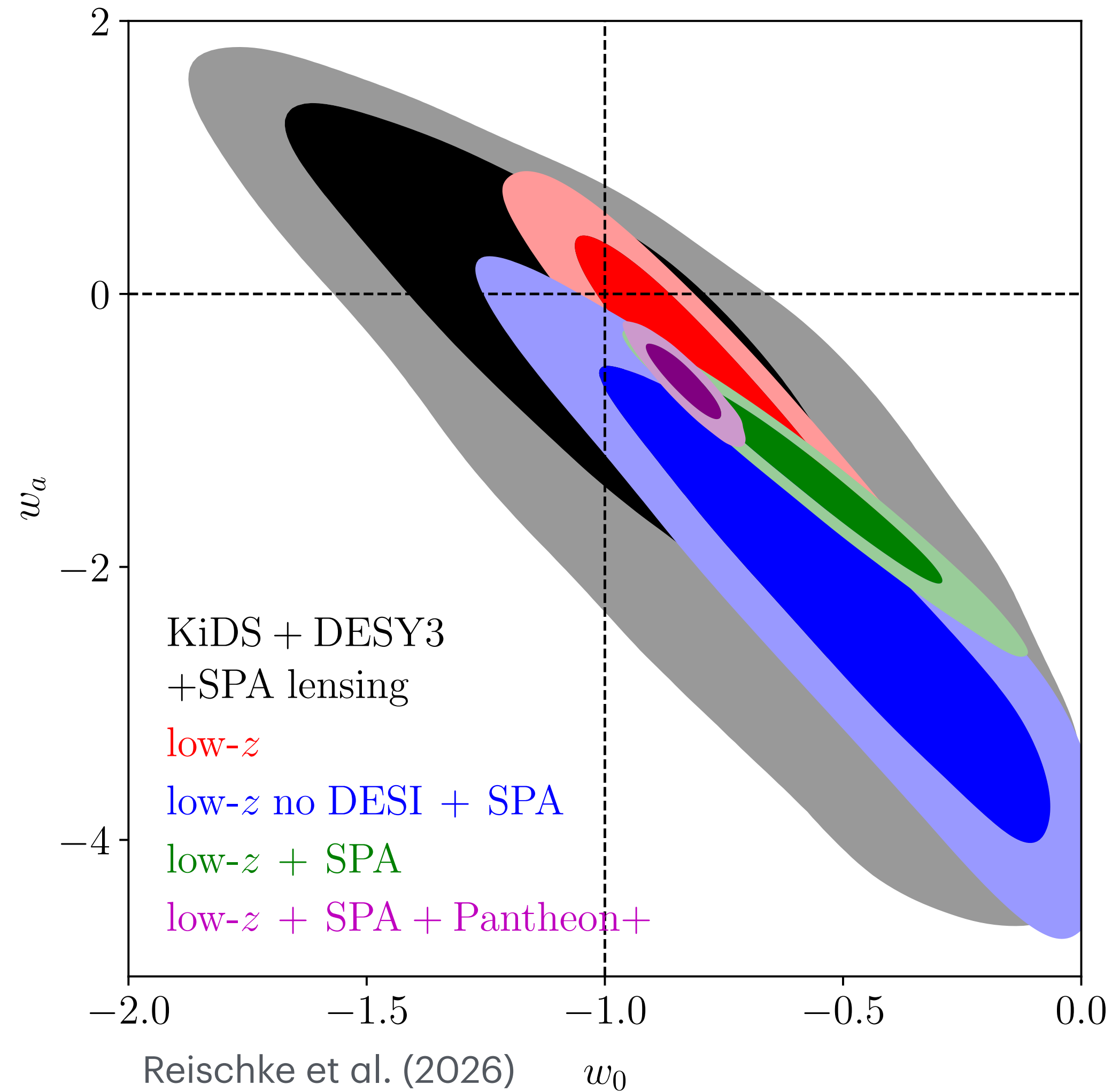
Dynamical dark energy

KiDS-Legacy only (68%)

$$w_0 = -1.1^{+0.5}_{-0.5} \quad (w_0\text{CDM})$$

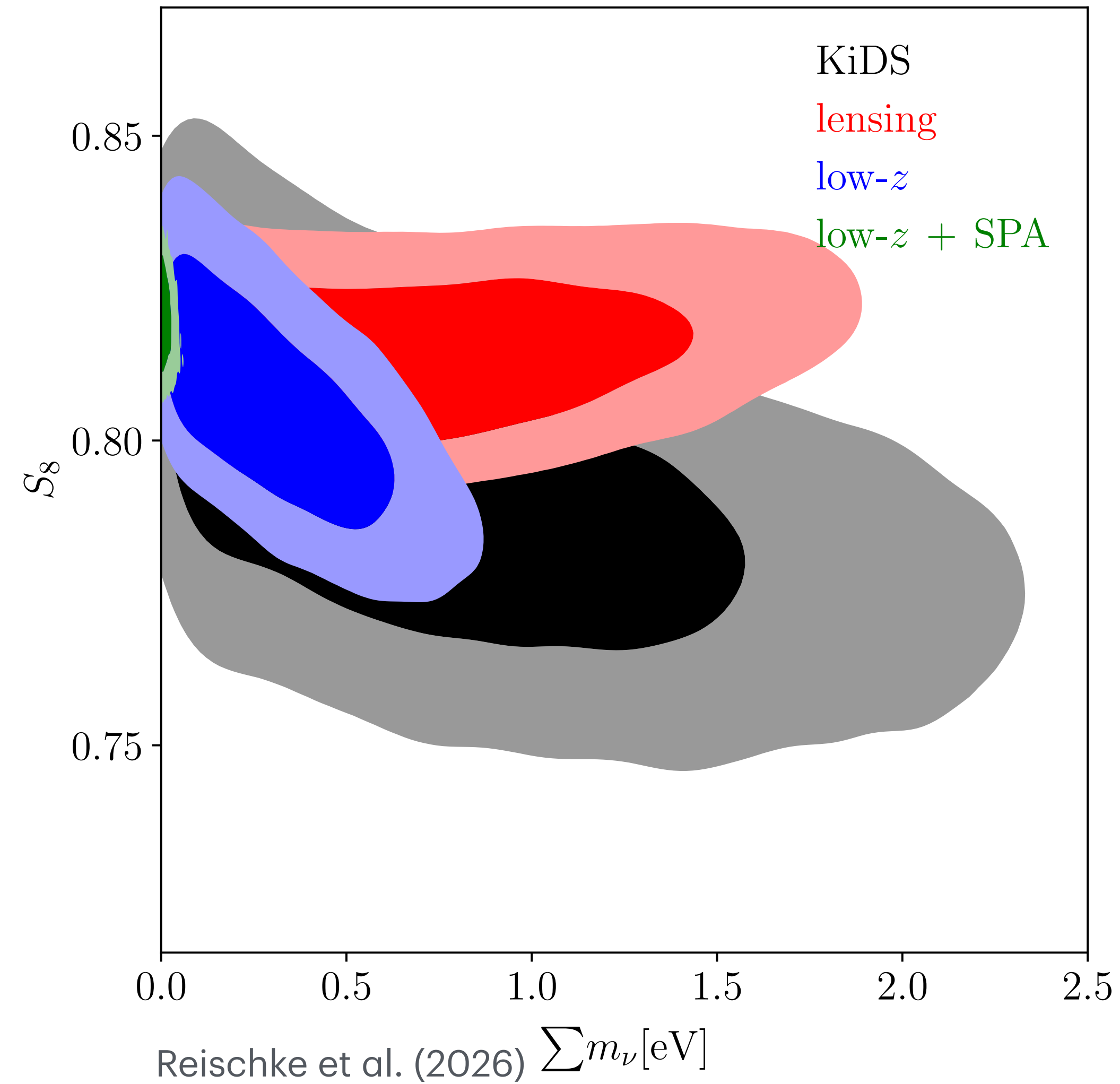
$$w_0 = -1.0^{+0.7}_{-0.7} \quad (w_0w_a\text{CDM})$$

$$w_a = -1.3^{+1.9}_{-2.0} \quad (w_0w_a\text{CDM})$$



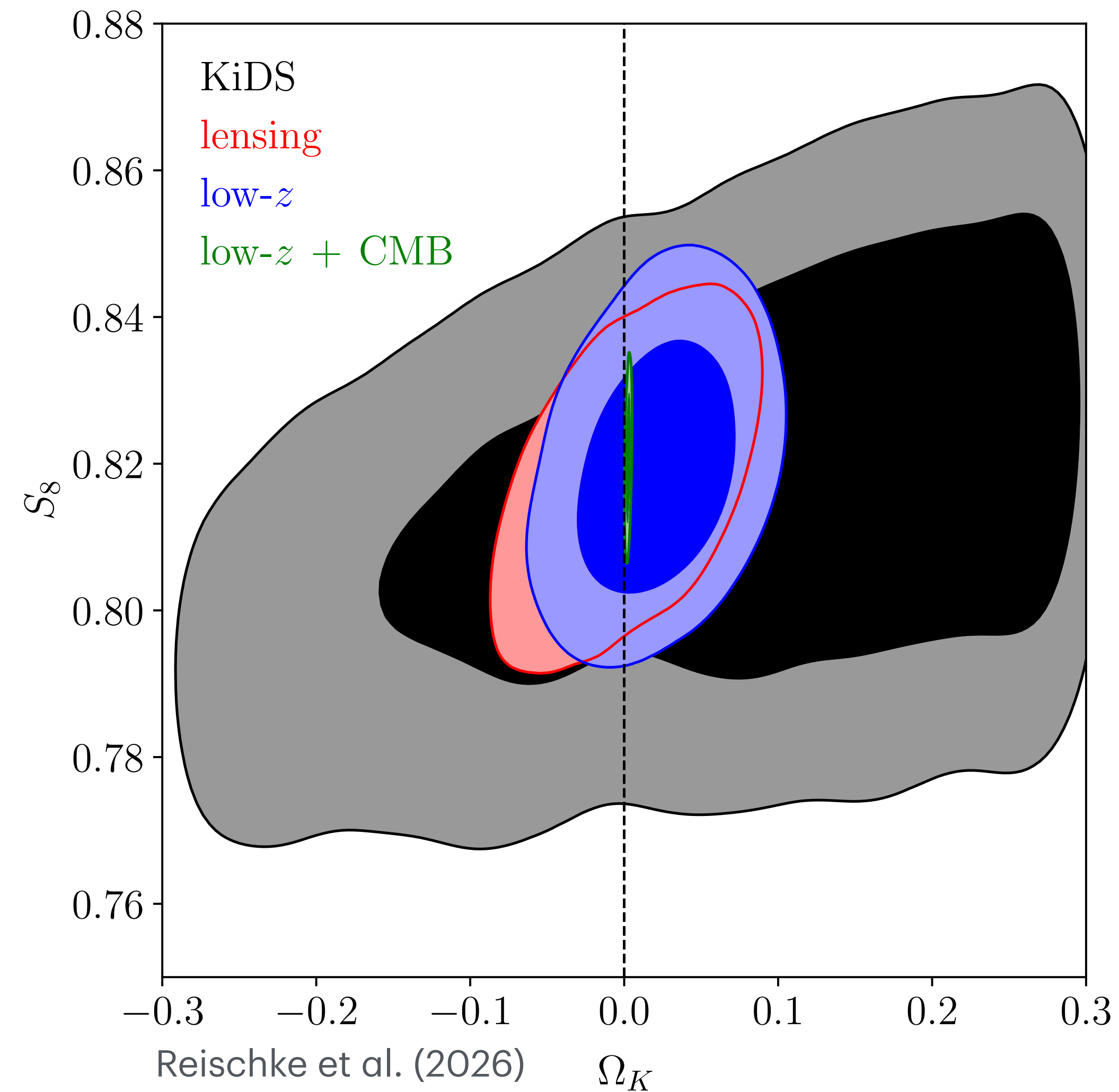
Variable neutrino mass

KiDS-Legacy only (95%)
 $\sum m_\nu \leq 1.85 \text{ eV}$

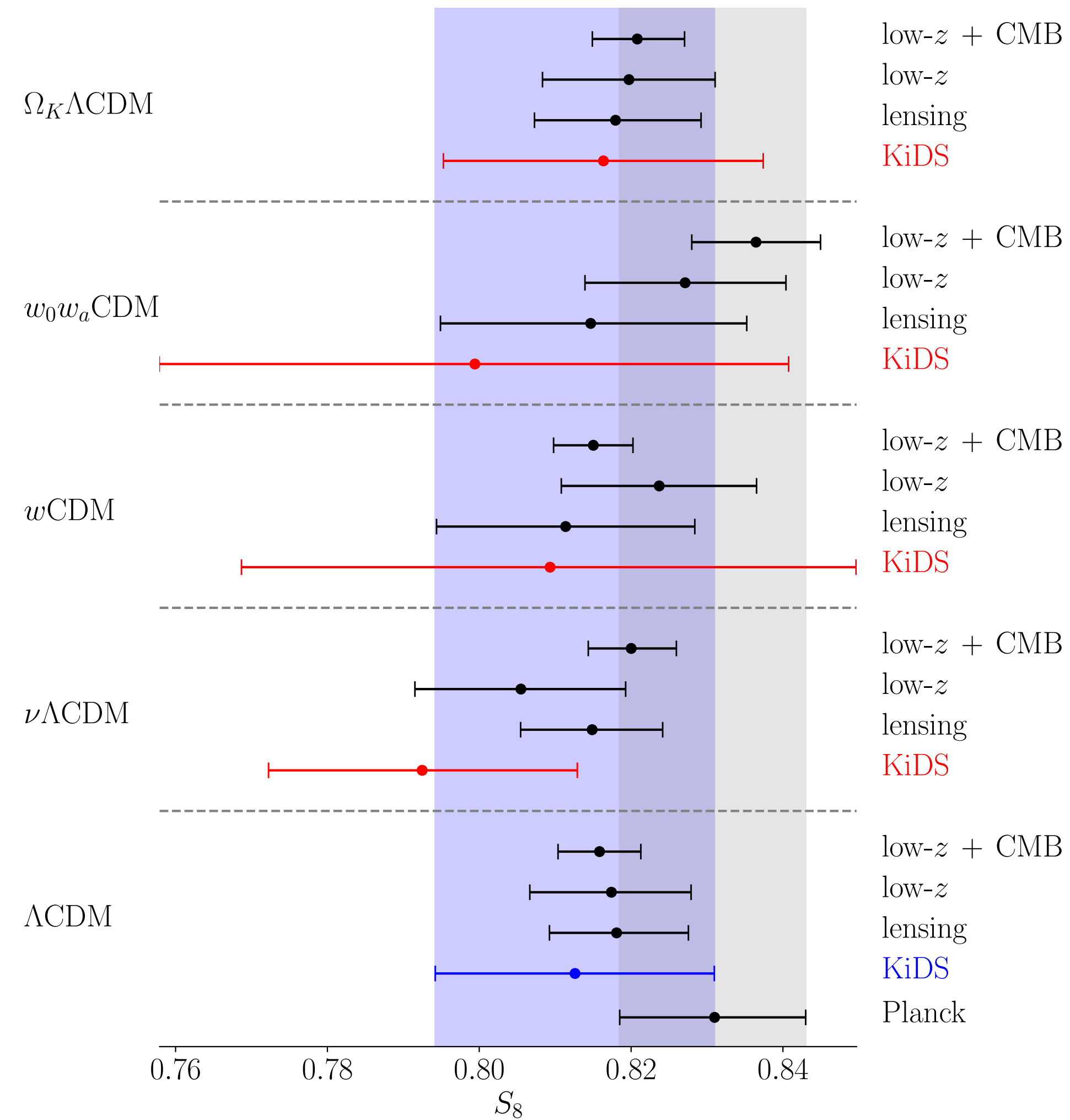


Curvature

All lensing (68%)
 $\Omega_k = 0.0 \pm 0.04$



S_8 consistency



Reischke et al. (2026)

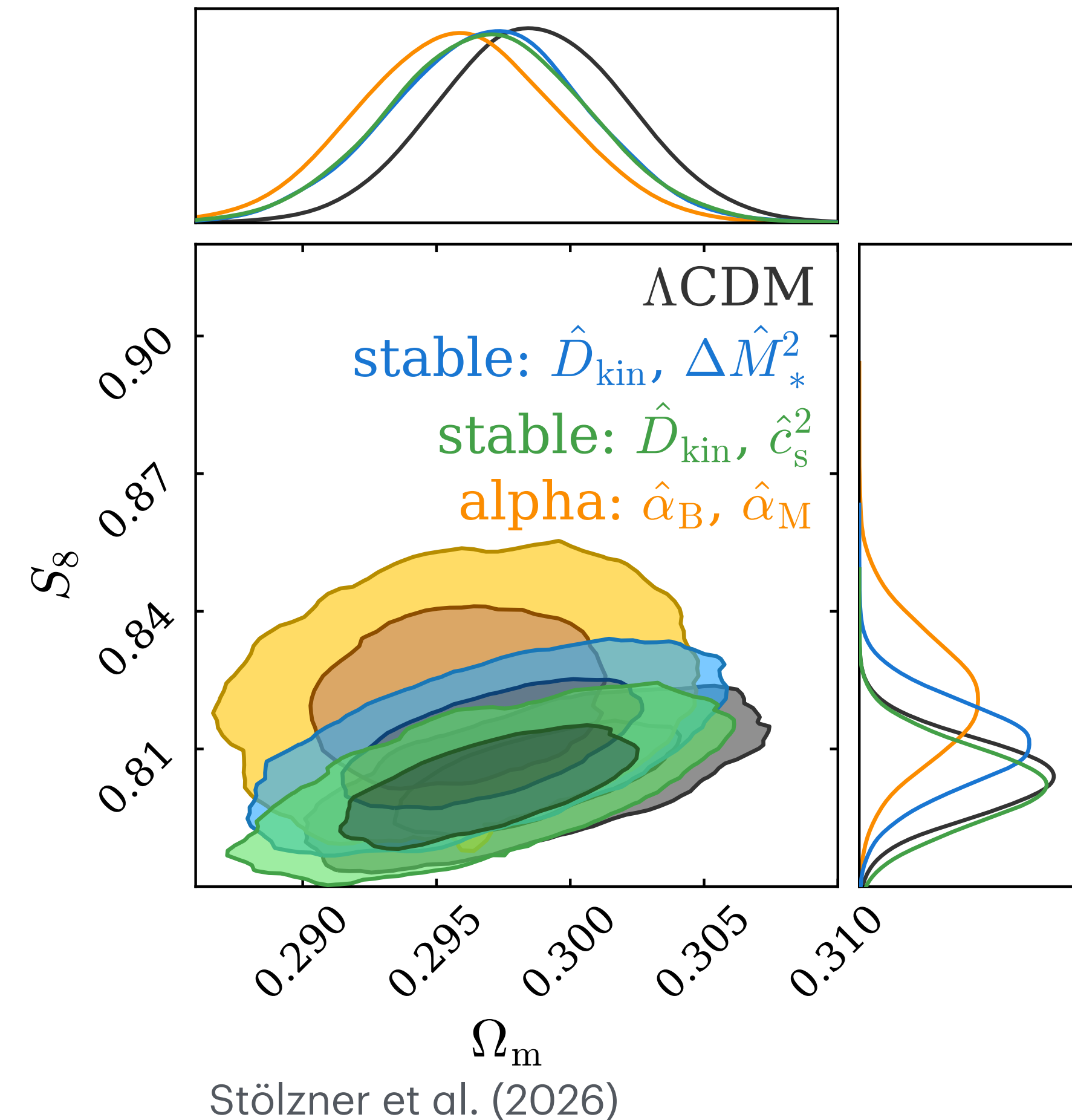
Constraints on Horndeski gravity

See my talk next week!

Or have a look at Stölzner et al. (2026),
[arXiv: 2512.11039](https://arxiv.org/abs/2512.11039)

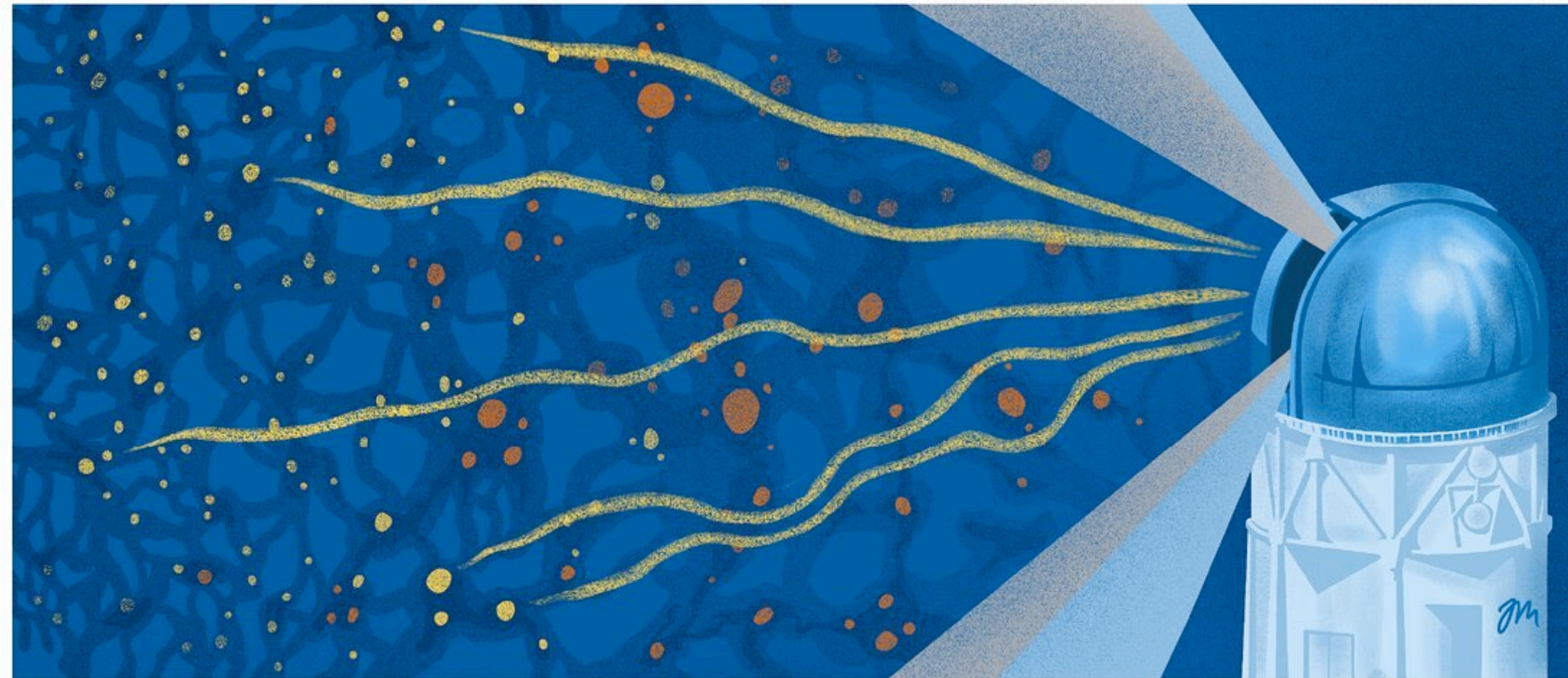


Current data show no significant
preference for modified gravity over GR



KiDS-Legacy 3x2pt

Joint analysis of cosmic shear, galaxy clustering, and galaxy-galaxy lensing

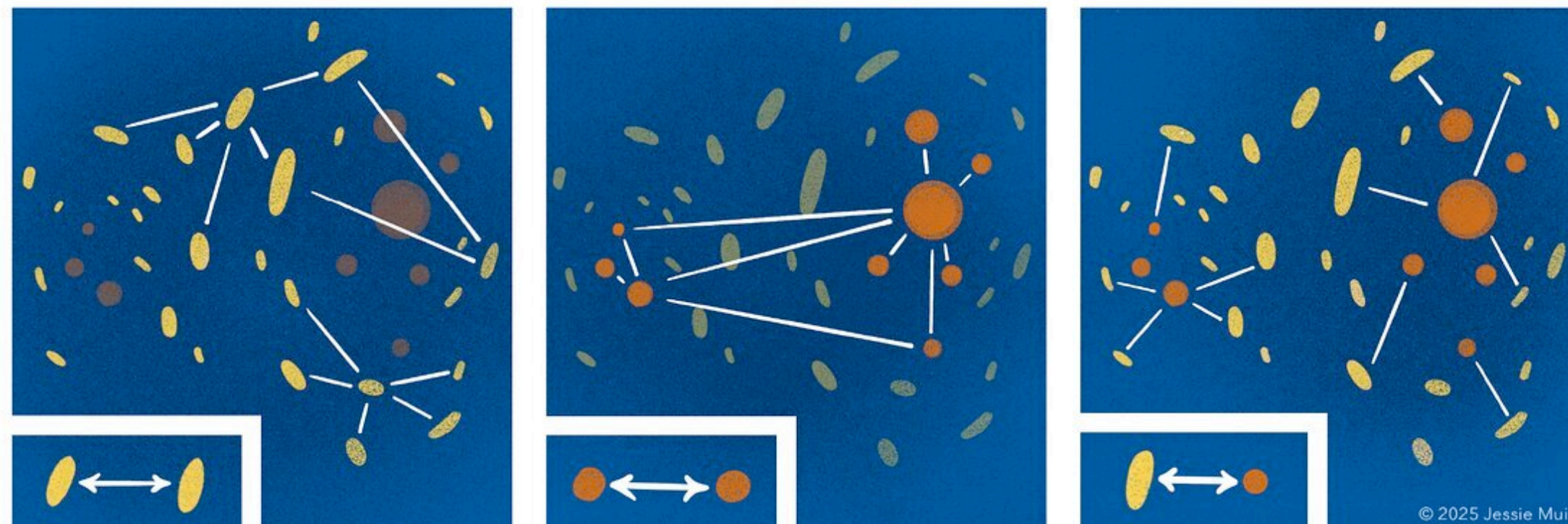


Source sample: KiDS-Legacy

Lens sample: KiDS-Bright

- Highly complete flux-limited sample
- Machine learned photometric redshifts from GAMA

+ stellar mass function (1-point statistic)
(See Dvornik et al (2023), [arXiv:2210.03110](https://arxiv.org/abs/2210.03110))



Cosmic shear

Galaxy
clustering

Galaxy-
Galaxy

Image credit: Jessie Muir



<https://github.com/KiDS-WL/onepower>

KiDS-Legacy 6x2pt

Spectroscopic samples

- galaxy spectra used to infer galaxy redshift: accurate galaxy position

Photometric samples:

- Broad-band fluxes used to obtain redshift estimates: accurate distributions obtainable
- Galaxy shapes also measured

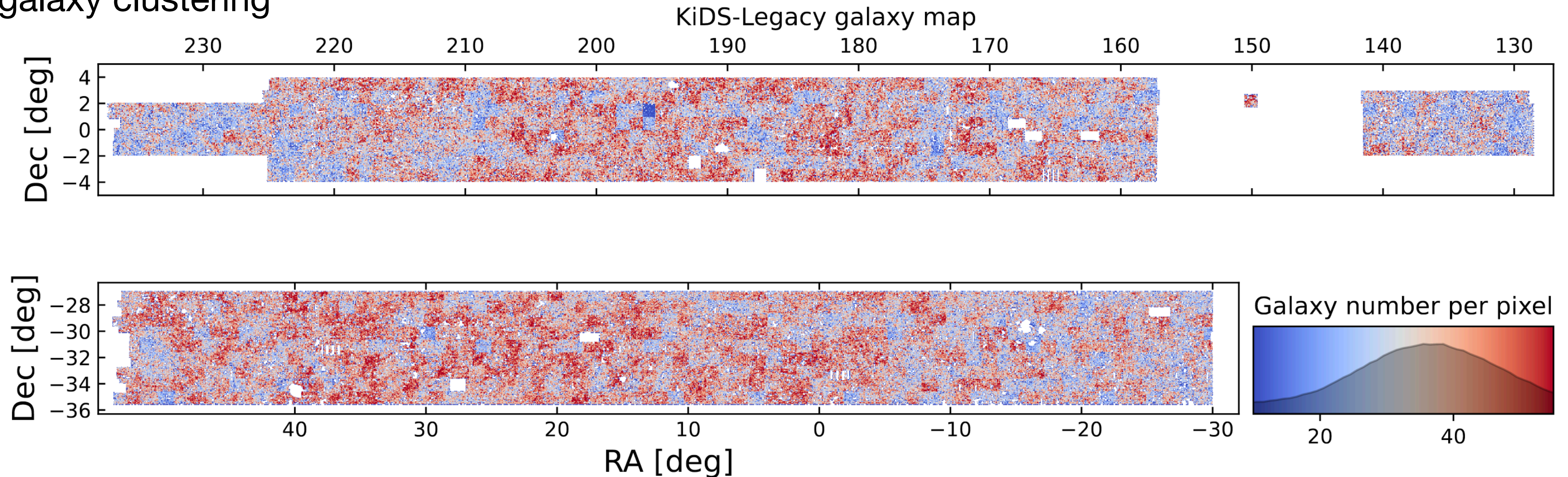
Combine into 6 correlation functions at the 2pt level

Spec position	Phot position	Phot shear	
Spec g-g	Spec/phot g-g	Spec GGL	Spec position
	Phot g-g	Phot GGL	Phot position
		Cosmic shear	Phot shear

KiDS-Legacy 6x2pt

Observational systematics in galaxy clustering

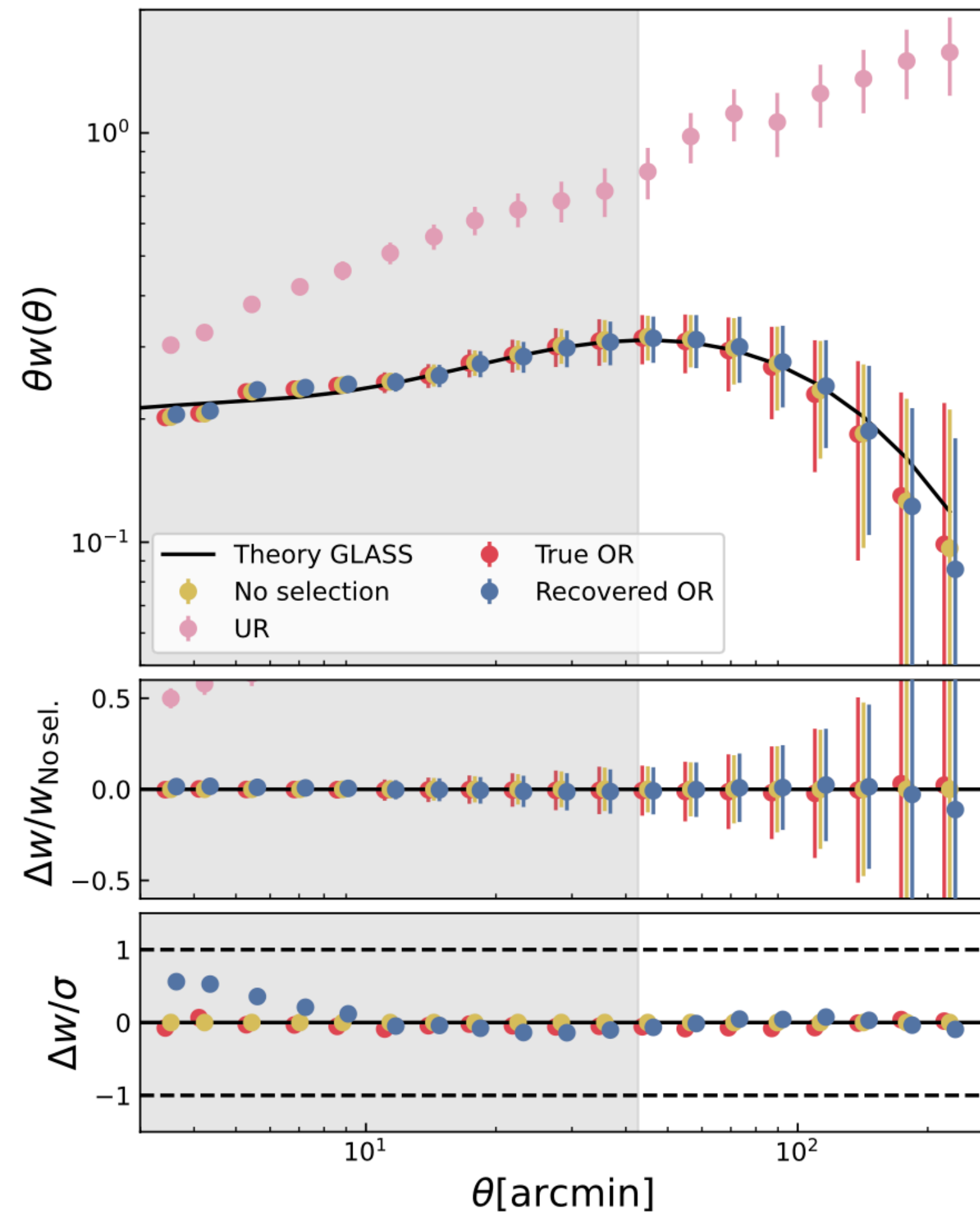
- Galaxy density is affected by observing conditions (background level, PSF, extinction, stellar density, ...)
- These effects are strongest near the survey magnitude limit, contaminating measurements of galaxy clustering



Yan et al. (2025)

KiDS-Legacy 6x2pt

Correcting observational systematics in galaxy clustering



Yan et al. (2025)

- Learn the survey selection function using self-organising maps and hierarchical clustering
 - Generate random catalogues that reproduce the survey selection function
- ➡ **“Organised randoms”**
See Yan et al. (2025), [arXiv: 2410.23141](https://arxiv.org/abs/2410.23141)

Data availability

- KiDS DR5 available at ESO (see also the data release description document and documentation on the KiDS website)
- KiDS-Legacy weak lensing catalogue and KiDZ redshift calibration sample available on the KiDS website
- SKiLLS image simulations: https://github.com/KiDS-WL/MultiBand_ImSim
- CosmoPipe (End-to-end catalogues-to-cosmology pipeline): <https://github.com/AngusWright/CosmoPipe>
- CosmoSIS configuration files, data vectors, redshift distributions, and covariance matrices available on the KiDS website (COSEBIs, Band powers, and 2PCFs)
- CosmoSIS pipeline configuration file (including data) within the CosmoSIS standard library (COSEBIs only)

Conclusions

- There is no S_8 tension
- KiDS-Legacy is fully consistent with CMB constraints from Planck
- A combination of effects moved KiDS from $\sim 3\sigma$ to $\sim 0.7\sigma$
- KiDS-Legacy is the most internally and externally consistent KiDS cosmic shear analysis
- Follow-up analyses show good consistency with Λ CDM
- While the final cosmic shear analysis is done, the survey will enable exciting multi-probe analyses

Backup slides

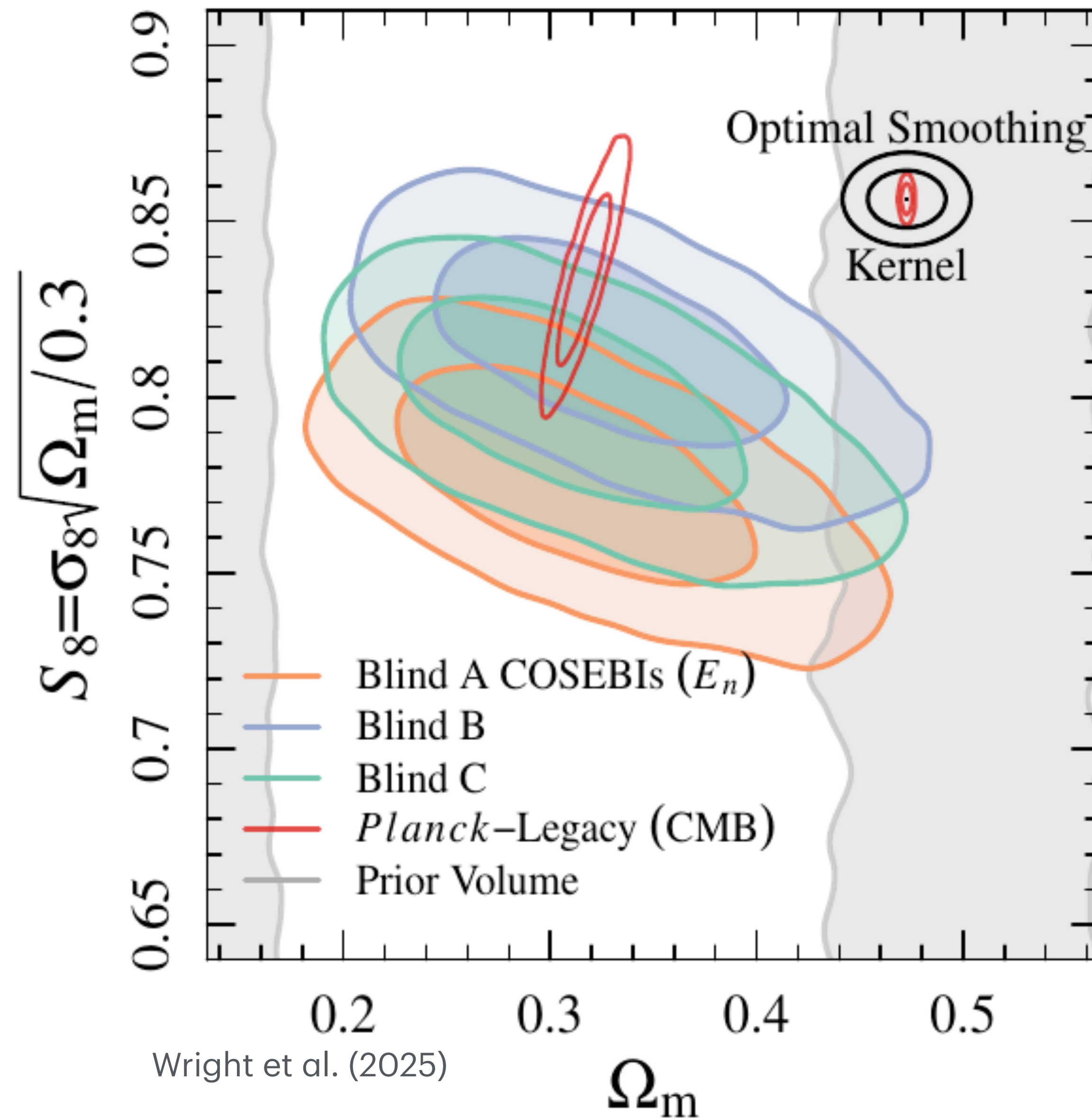
Blinded results

Tension with Planck:

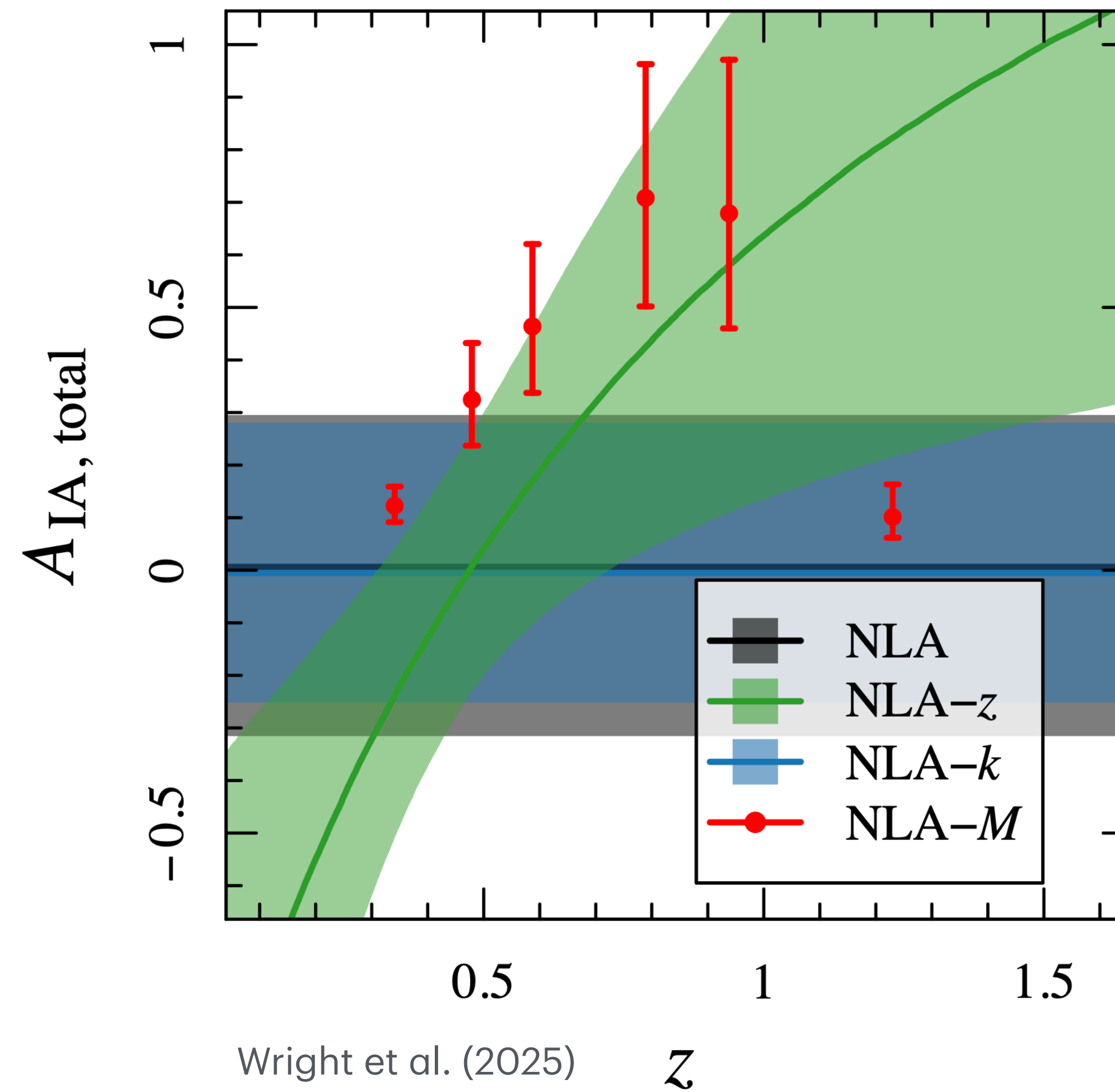
Blind A: $N_\sigma = 2.72$

Blind B: $N_\sigma = 0.73$

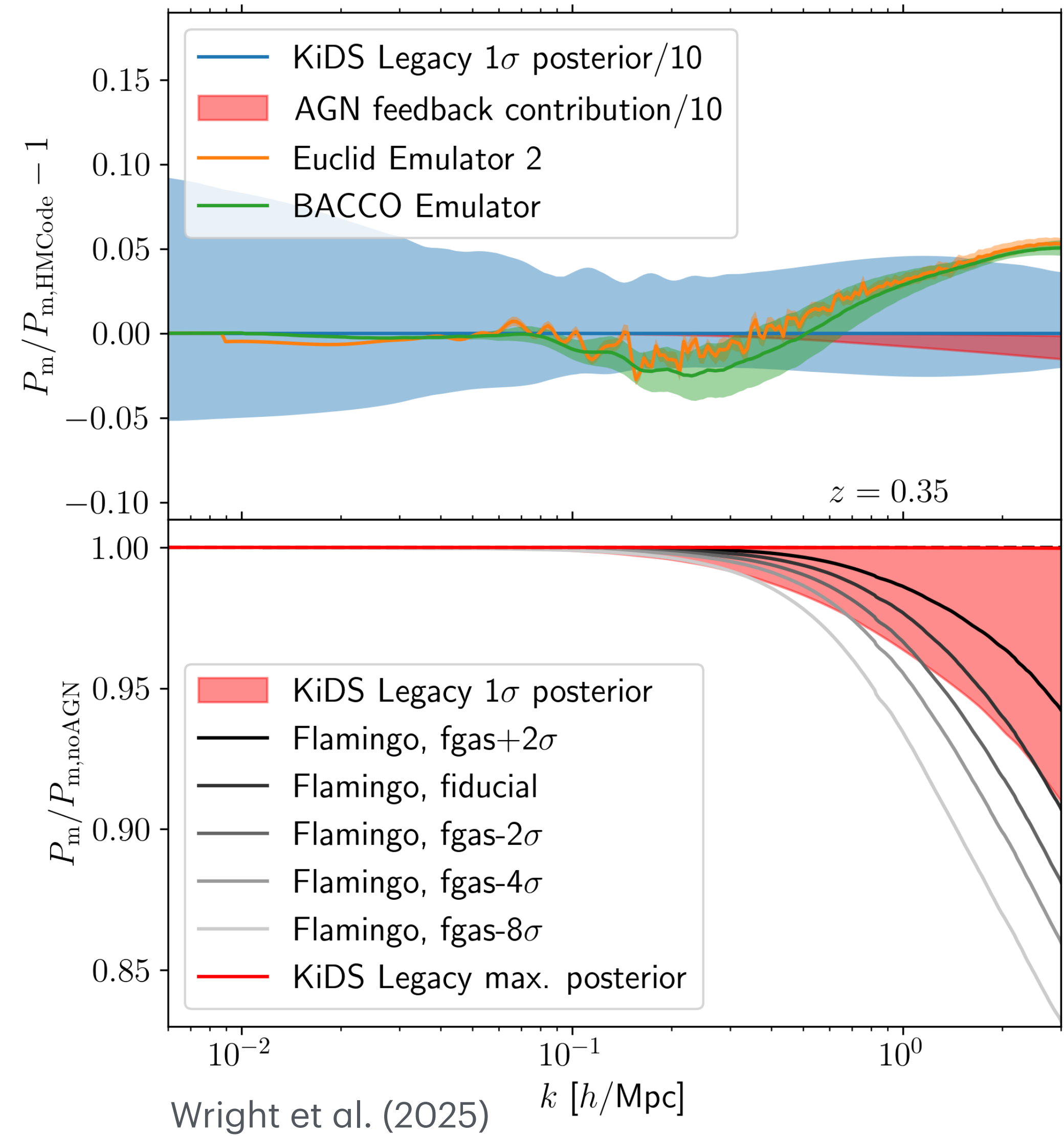
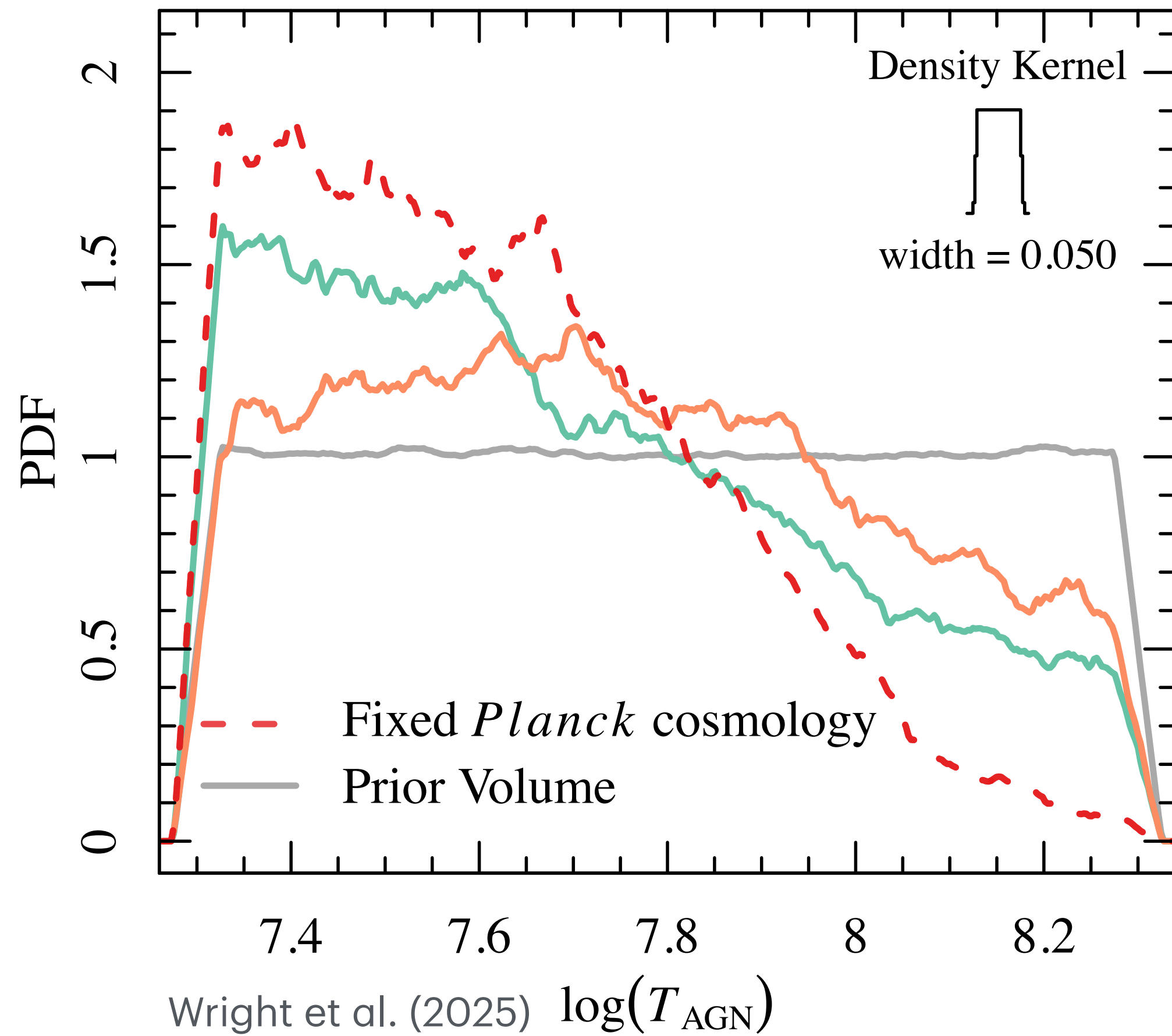
Blind C: $N_\sigma = 1.73$



Intrinsic alignments



Baryon feedback



Extended cosmologies

KiDS-Legacy consistency

