Improved cosmological constraints from KiDS+VIKING

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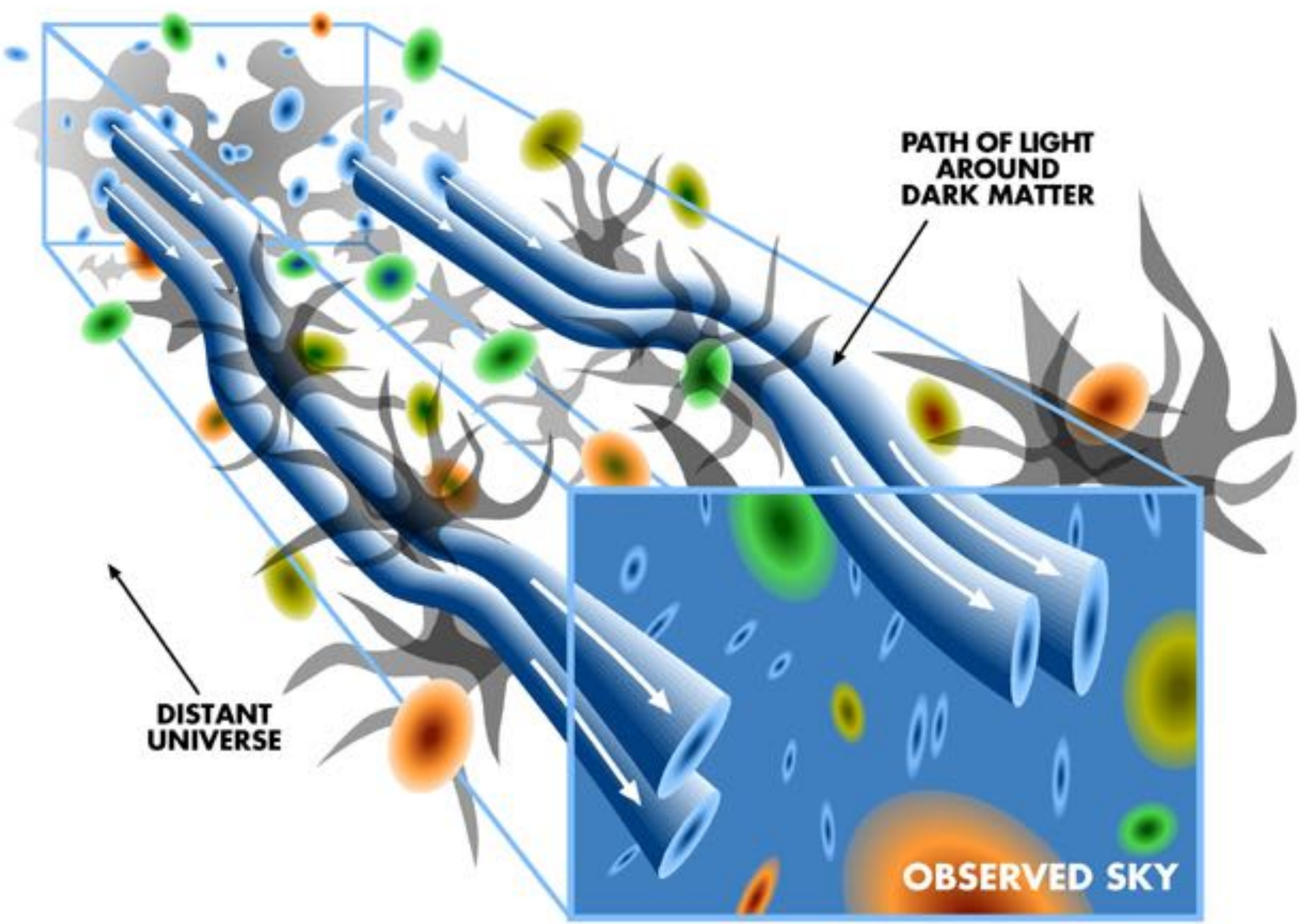
Cosmic shear



Wittman et al. (2000)

Sensitive to:

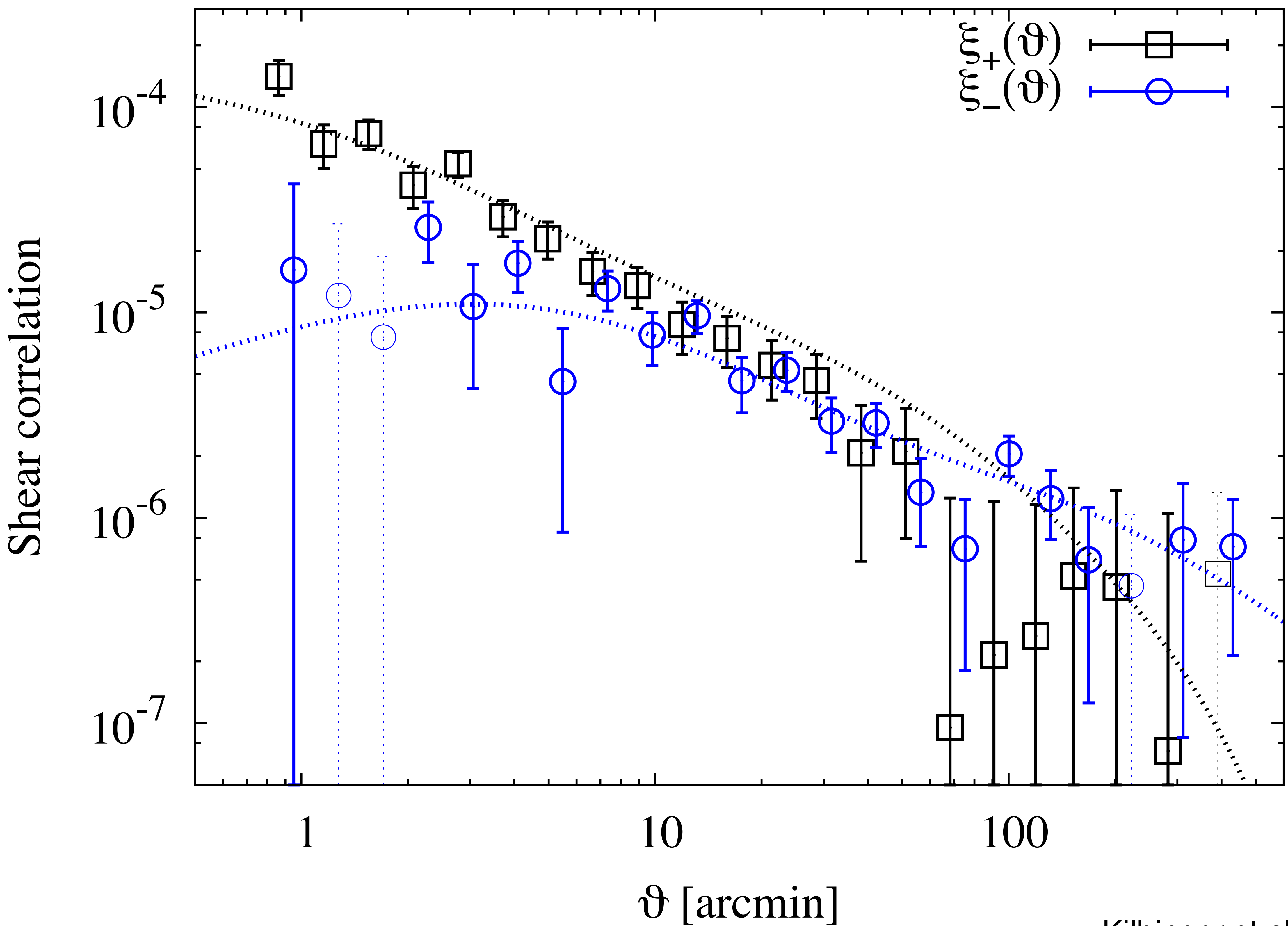
- Matter distribution
- Geometry

Observables:

- Ellipticities
- Photo-*z*

Statistical measurement of many galaxies

2pt shear correlation functions



Kilbinger et al. (2013)

Observation -> theory

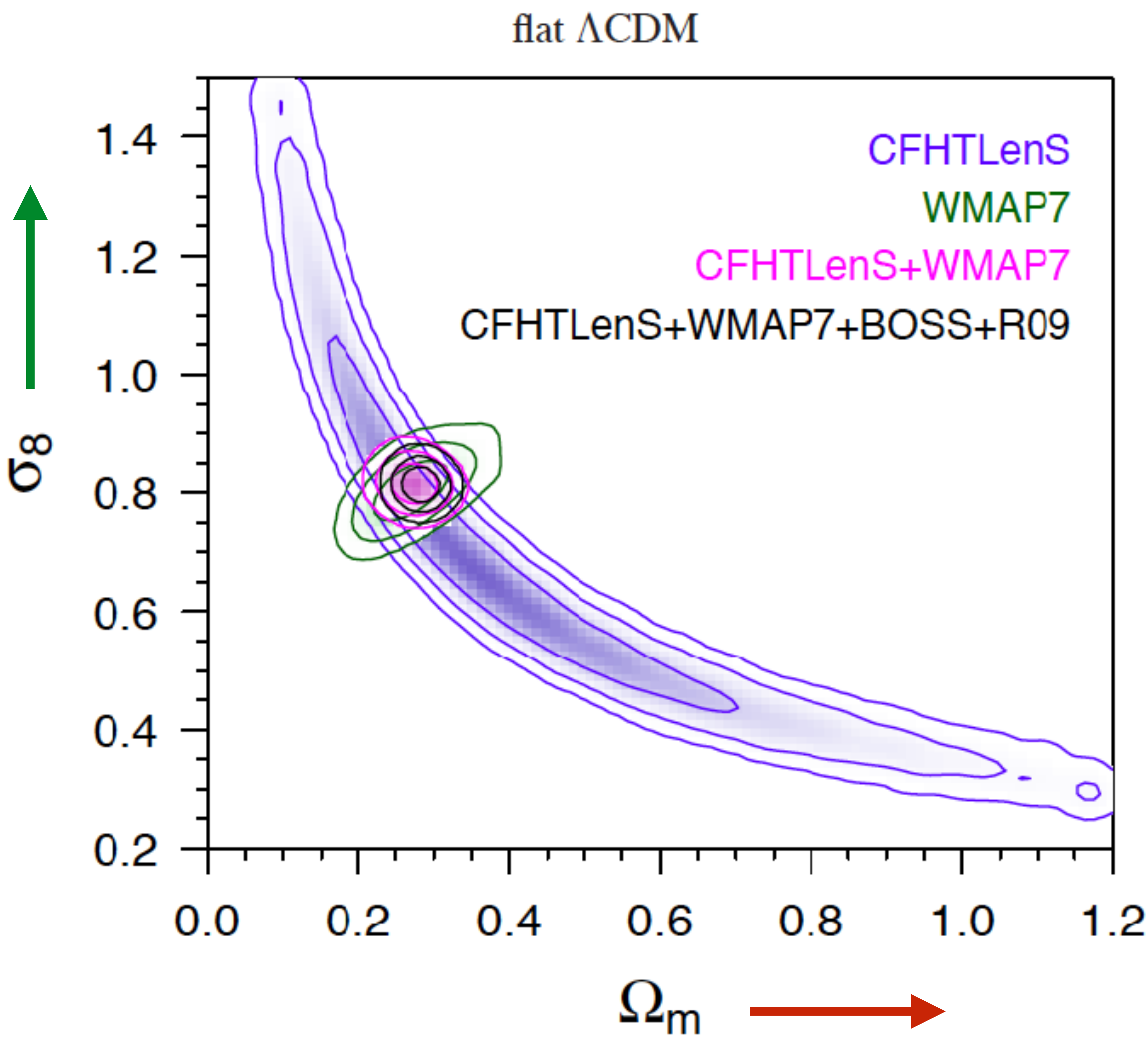
$$\xi_\pm(\theta) = \langle \gamma_\mathrm{t}\gamma_\mathrm{t}\rangle(\theta) \pm \langle \gamma_\times\gamma_\times\rangle(\theta)$$

$$\xi_+(\theta) = \int_0^\infty \frac{\mathrm{d}\ell\,\ell}{2\pi}\,\mathrm{J}_0(\ell\theta)\,P_\kappa(\ell)\ ; \quad \xi_-(\theta) = \int_0^\infty \frac{\mathrm{d}\ell\,\ell}{2\pi}\,\mathrm{J}_4(\ell\theta)\,P_\kappa(\ell)$$

$$P_\kappa(\ell) = \frac{9H_0^4\Omega_\mathrm{m}^2}{4c^4}\int_0^{\chi_\mathrm{h}} \mathrm{d}\chi\,\frac{g^2(\chi)}{a^2(\chi)}\,P_\delta\left(\frac{\ell}{f_K(\chi)},\chi\right)$$

$$g(\chi) = \int_\chi^{\chi_\mathrm{h}} \mathrm{d}\chi'\,p_\chi(\chi')\,\frac{f_K(\chi'-\chi)}{f_K(\chi')}$$

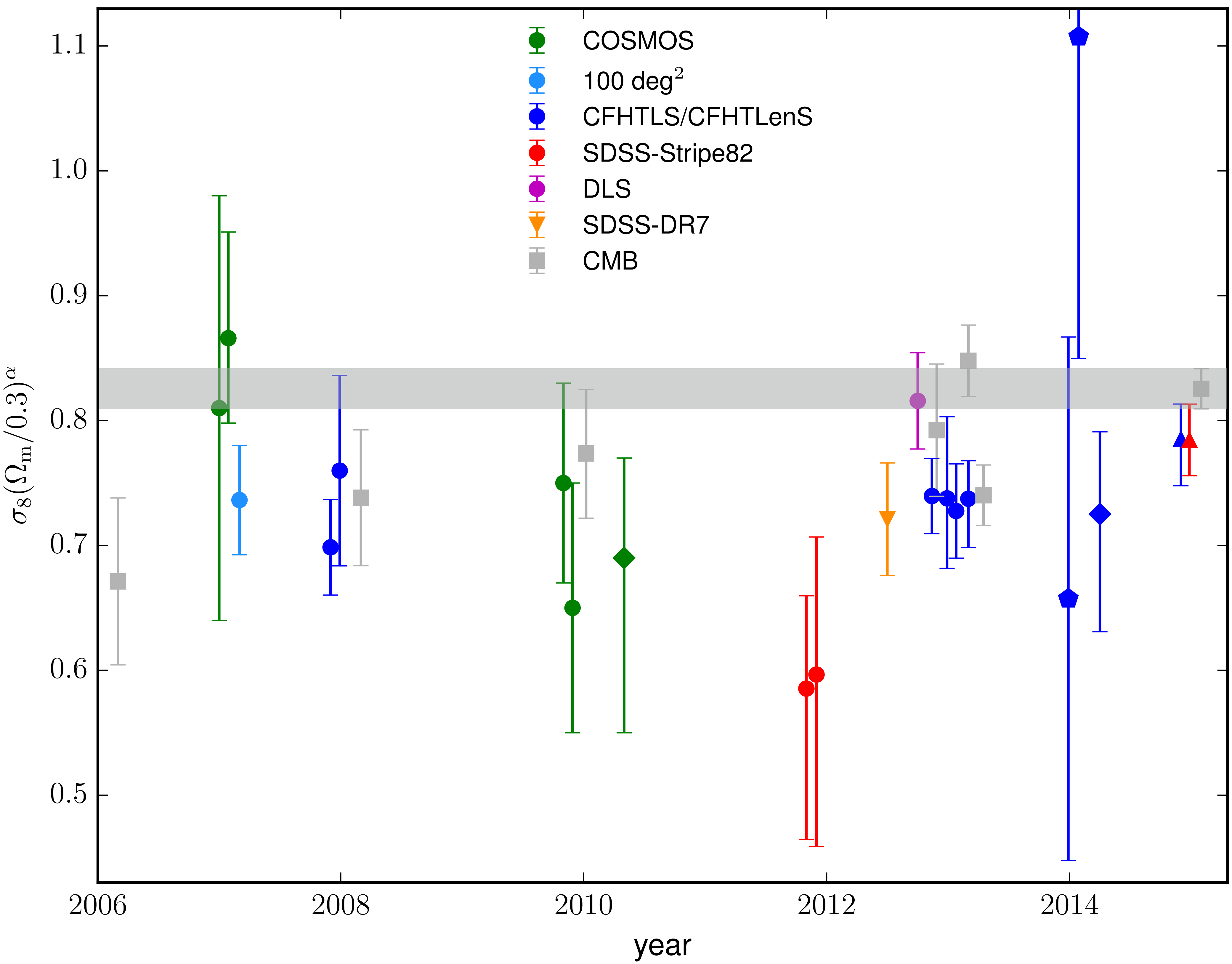
Cosmological constraints



Kilbinger et al. (2013)

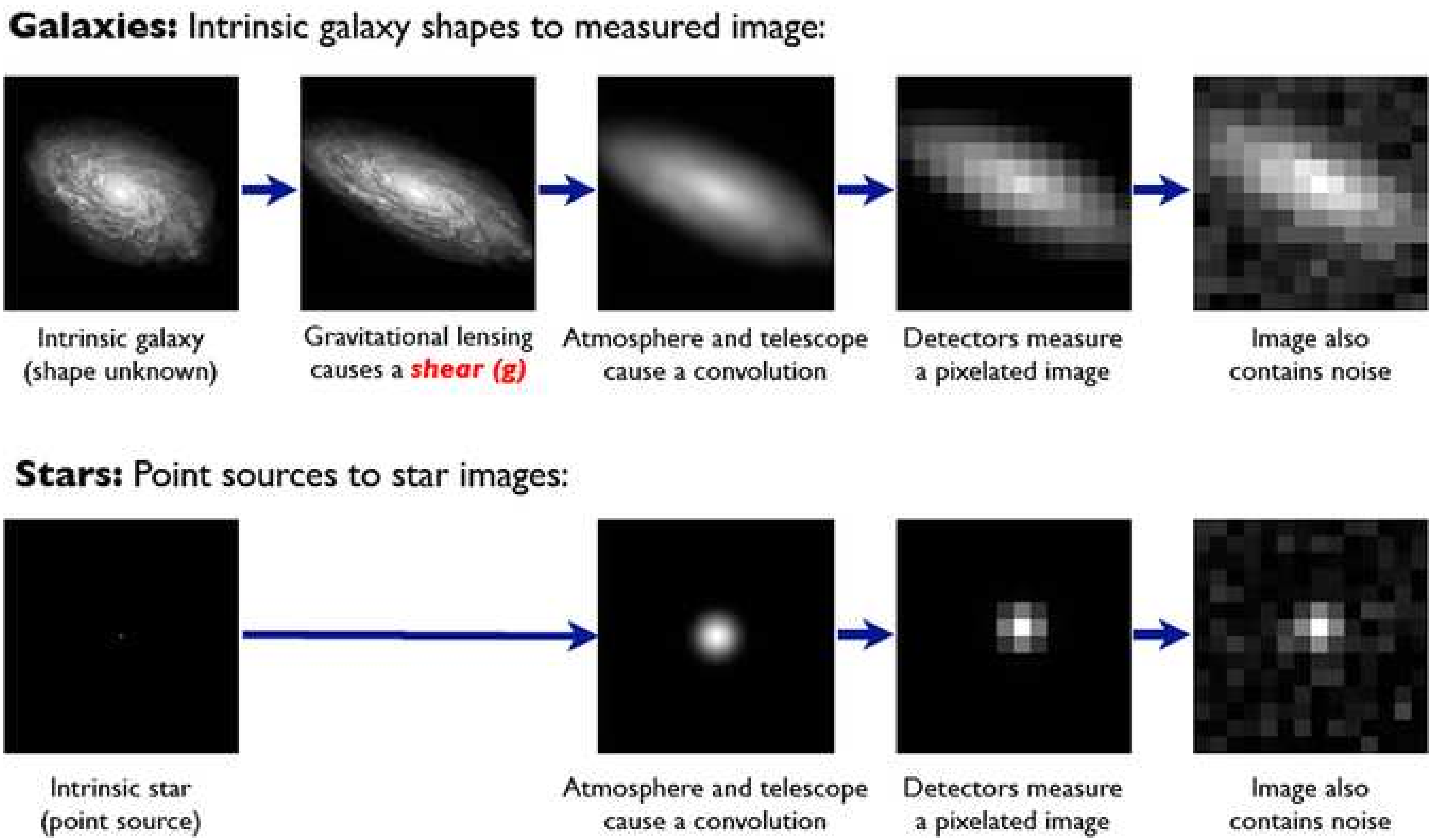
- Measure **amount** of **clustered** matter
- $S_8 = \sigma_8\,(\Omega_m/0.3)^{0.5}$

S_8 results over the years



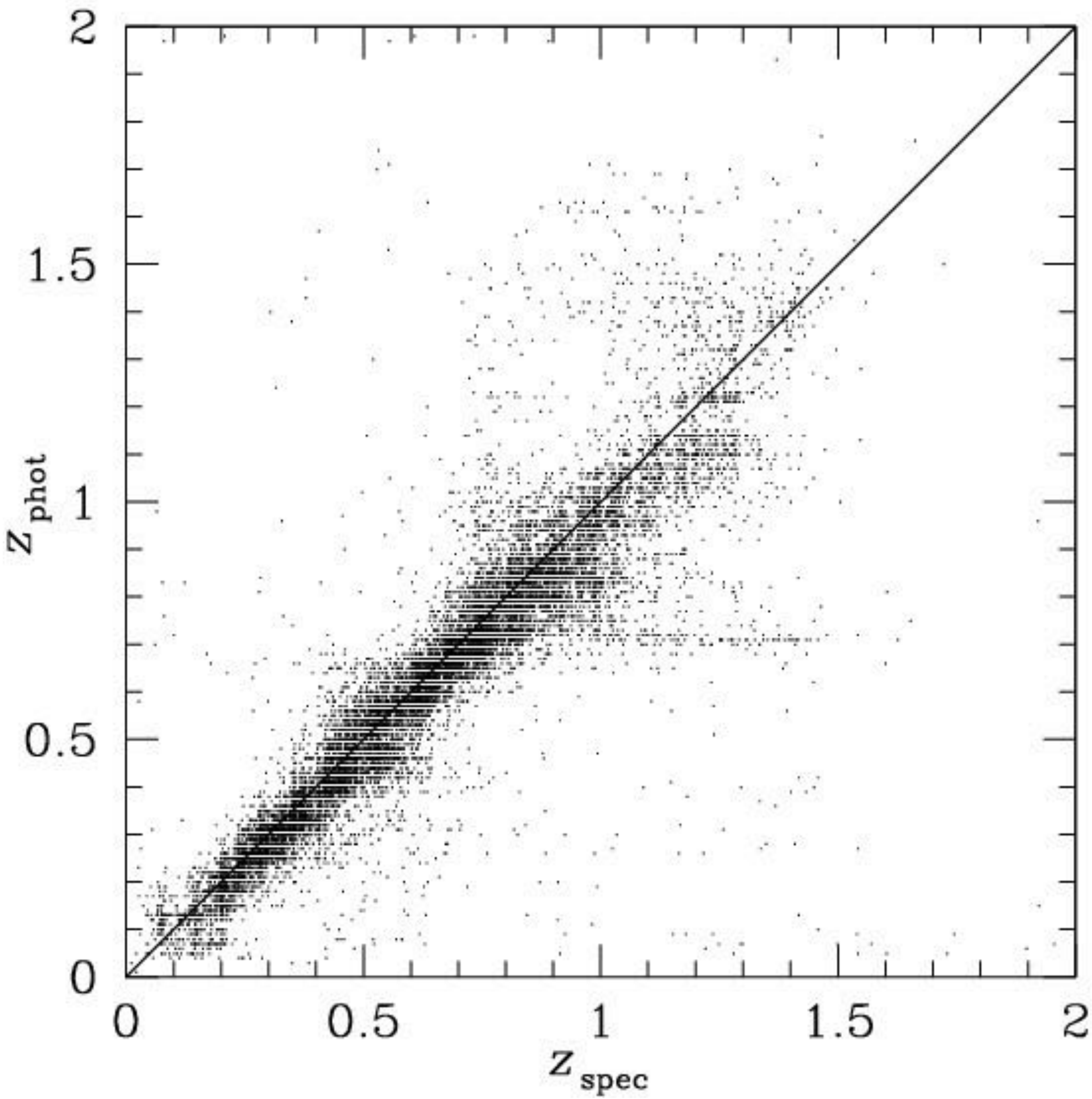
Kilbinger (2015)

Shape measurements



Bridle et al. (2009)

Photometric redshifts



Hildebrandt et al. (2012)

Map this error distribution with spectroscopic calibration data.

Requires re-weighting.

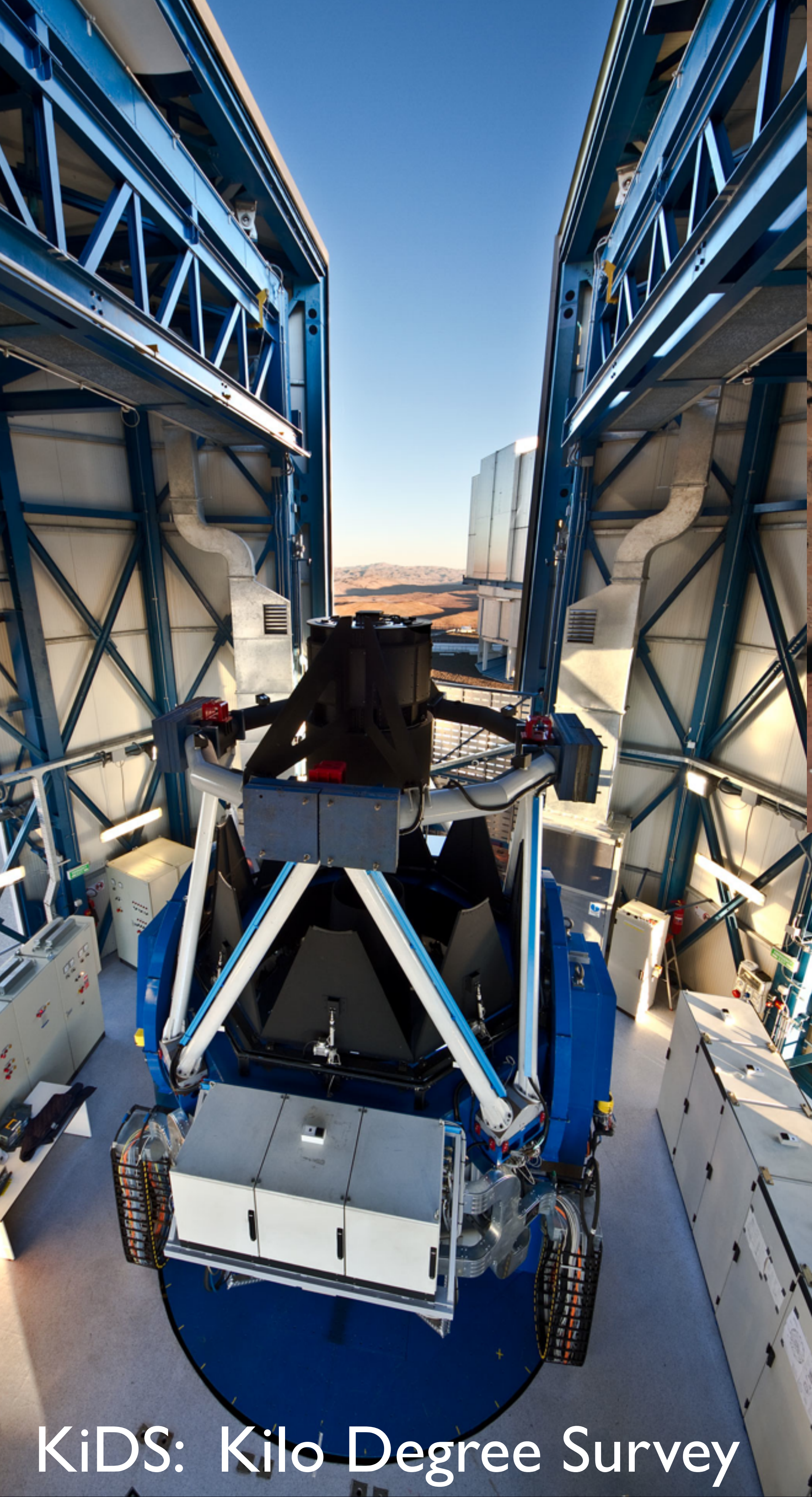
Systematic errors

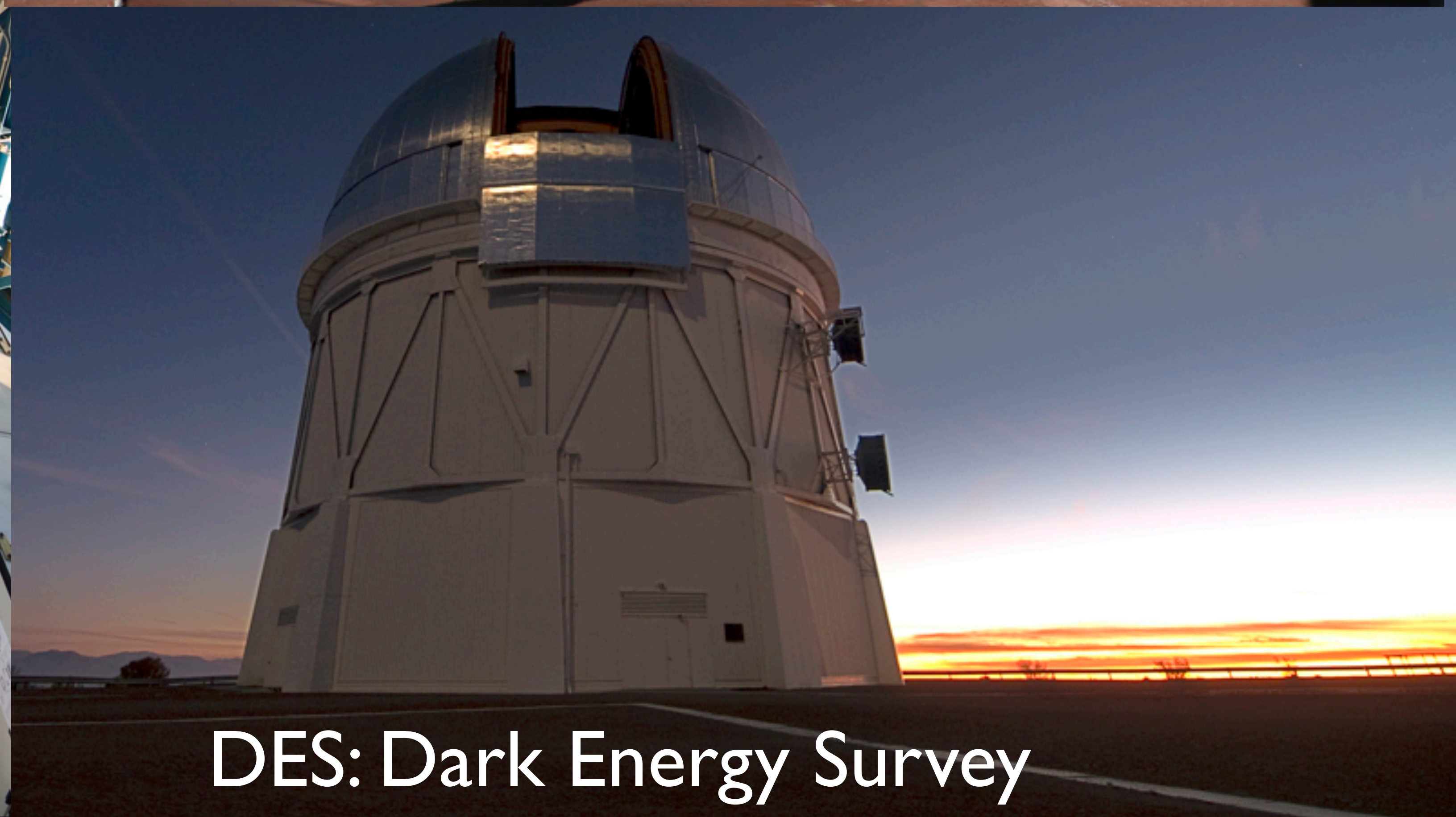
- Shapes measurement systematics:
  - PSF residuals
  - B modes
  - Multiplicative and additive biases

- Photo-z systematics:
  - Calibration sample and technique
  - Inhomogeneous multi-band data

- Theoretical systematics:
  - Intrinsic alignments
  - Baryon feedback
  - Covariance estimate

- **Psychological systematics:**
  - **Blinding**


KiDS: Kilo Degree Survey

HSC: Hyper-Suprime Cam Survey

DES: Dark Energy Survey

KiDS vs. HSC vs. DES

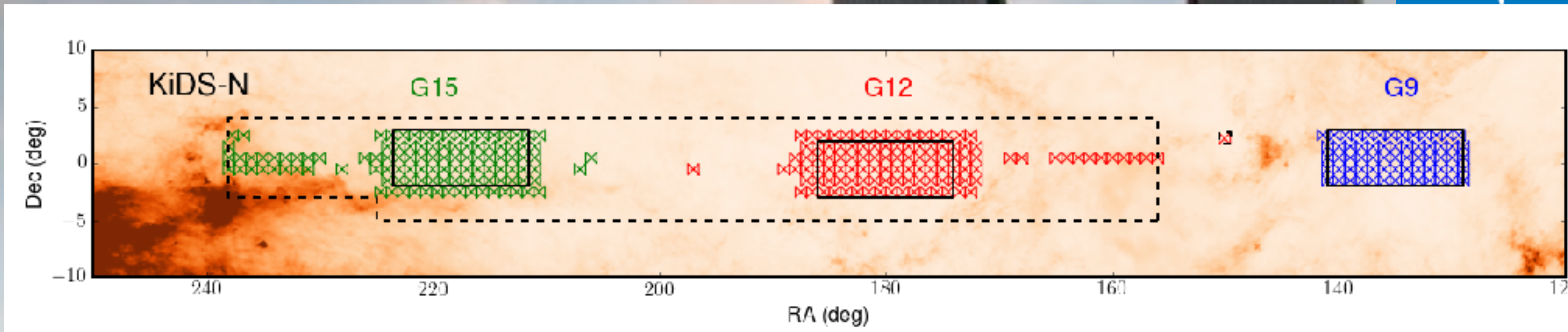
	KiDS(+VIKING)	HSC	DES
Mirror [m]	2.6	**8.2**	4.0
Focus	**Cassegrain**	Prime	Prime
FOV [deg²]	1.0	1.8	**3.0**
Area [deg²]	1350	1400	**5000**
Filters	***ugri***(+*ZY****JHK***$_{s}$)	*grizy*	*griz(y)*
Seeing [arcsec]	**0.68**	**0.58**	0.94
Source density [gal/arcmin²]	~8	**~22**	~5-7
Depth	*r*~24	*i*~24.5	*r*~23-24
spec-z	GAMA, SDSS, 2dFLenS, WiggleZ, deep fields	GAMA, SDSS, 2dFLenS, WiggleZ, deep fields	deep fields, (SDSS)
WL Team	>30	>30	**>130**

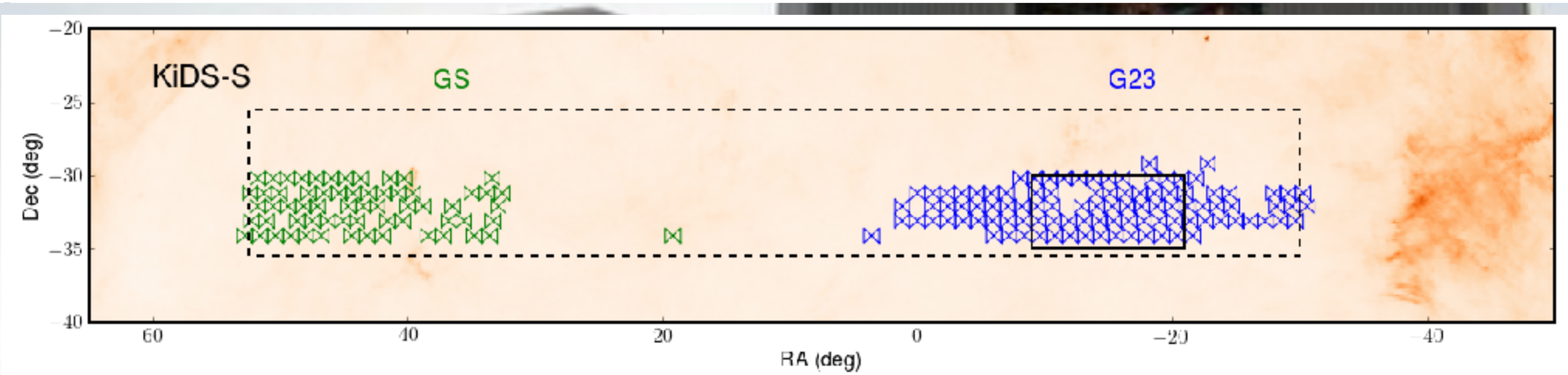

KiDS
ESO

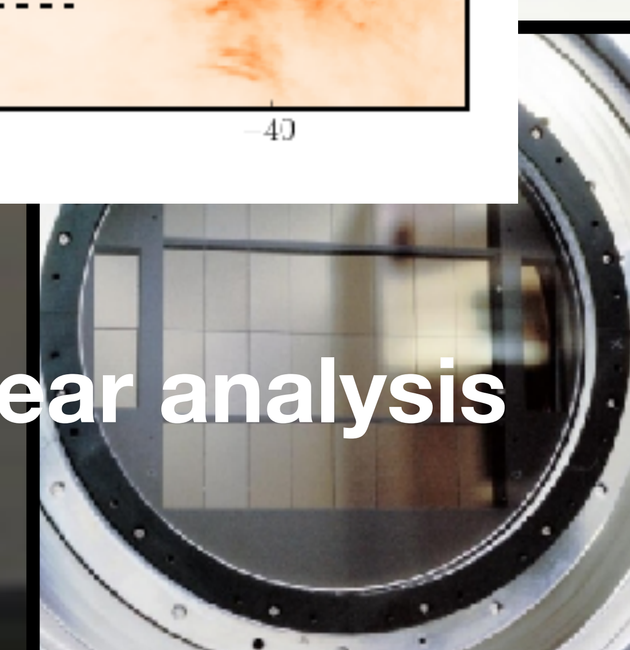
2001

2002

KiDS-450



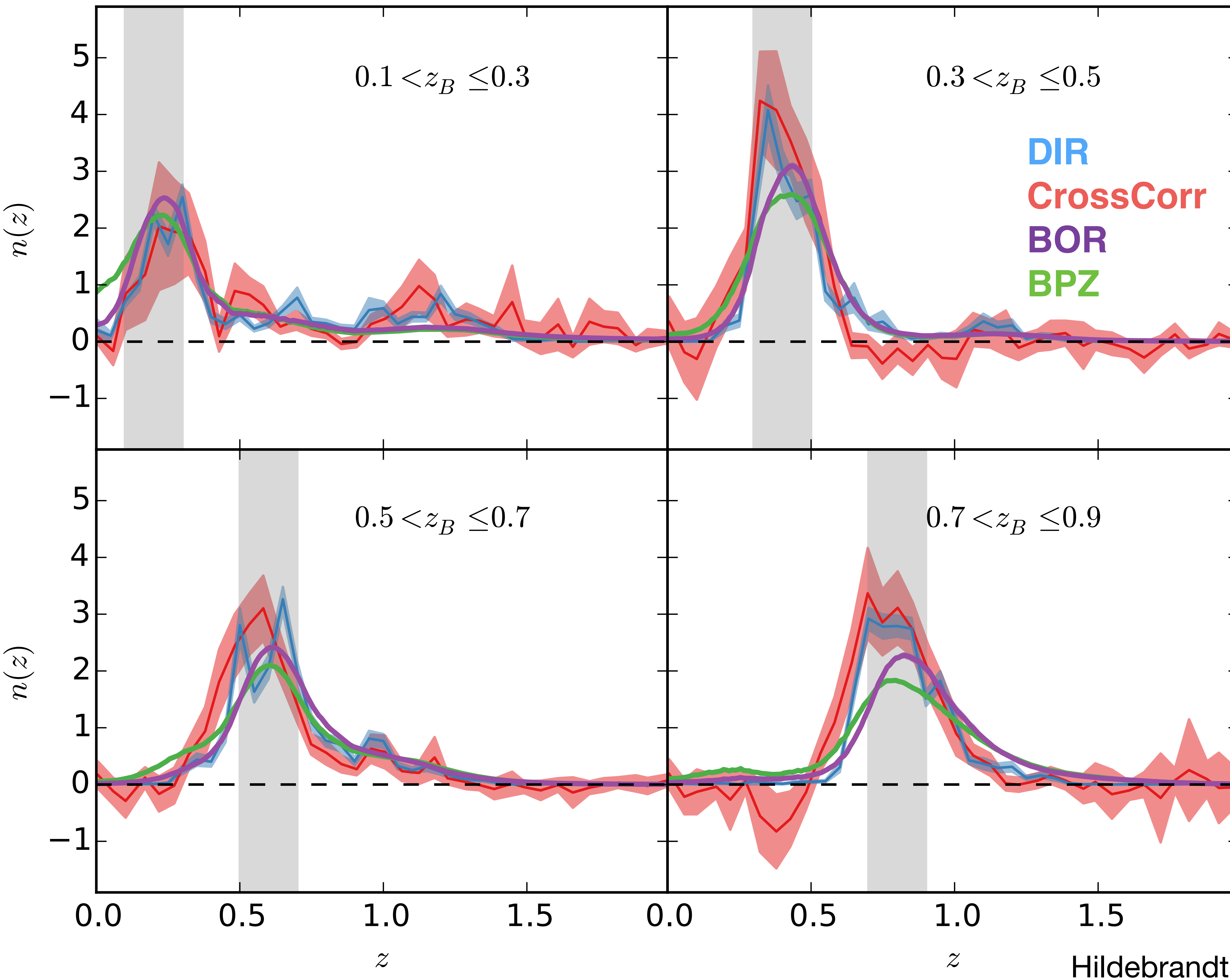




4-bin (0.1<z_{phot} < 0.9) tomographic cosmic shear analysis

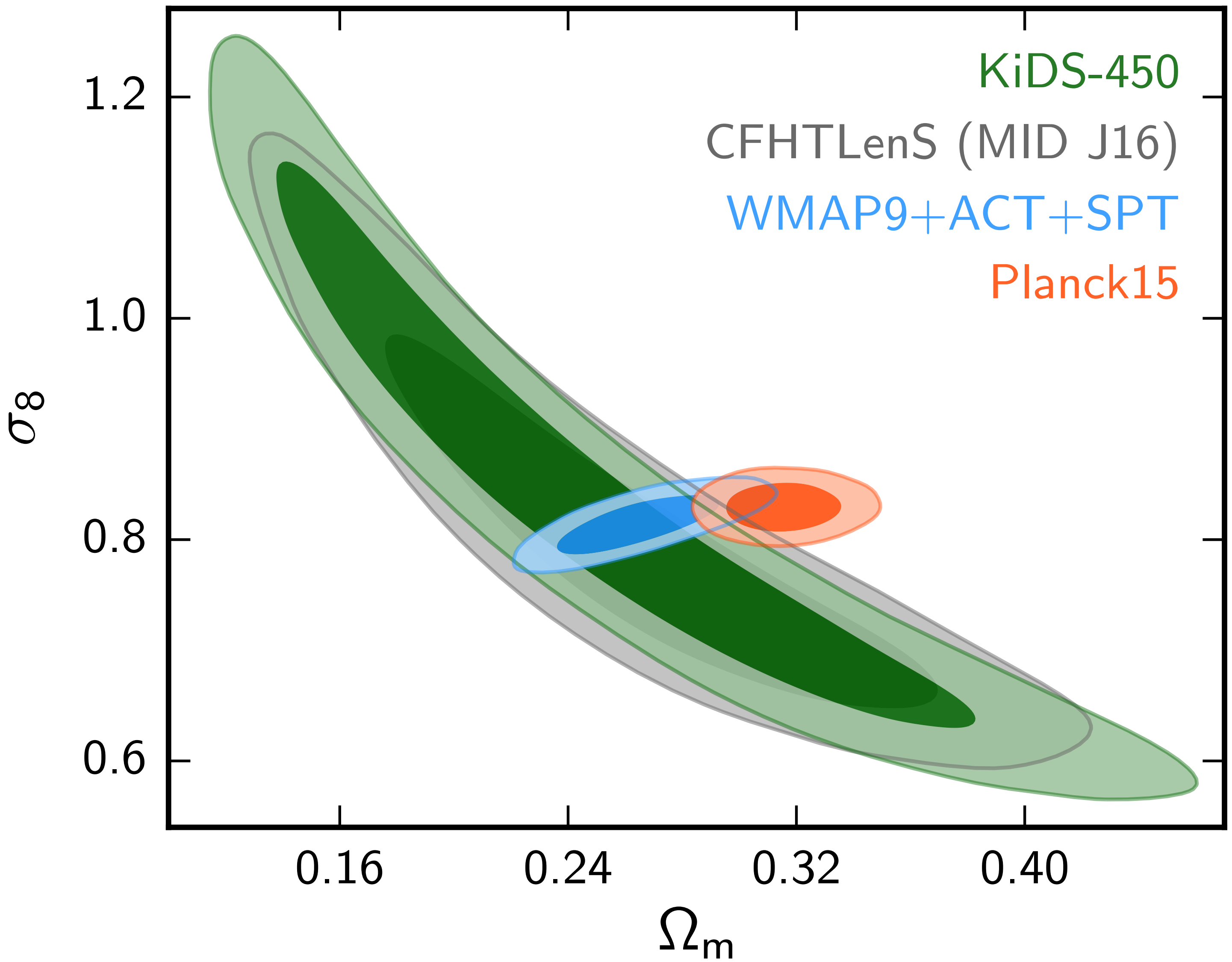
Hildebrandt et al. (2017)

Redshift distributions



Hildebrandt et al. (2017)

Result



$S_8 = \sigma_8\sqrt{(\Omega_m/0.3)} = 0.745 \pm 0.039$

Systematics error as big as statistical error (0.027)

- Still tension with Planck!
- 2.3σ discrepancy in full parameter space
- Fully public -> "Problems with KiDS", Efstathiou & Lemos

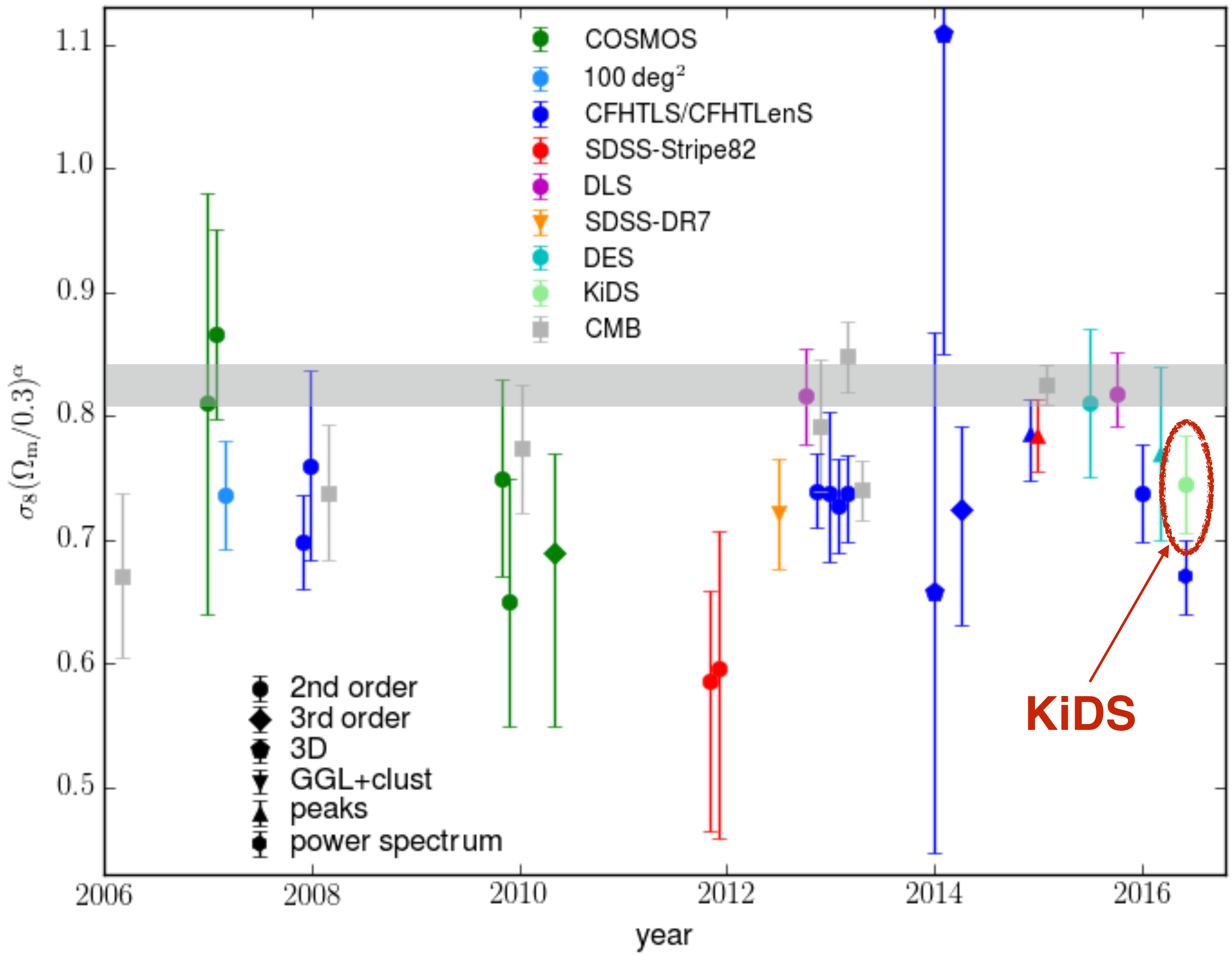
Hildebrandt et al. (2017)

Systematic error budget

Scenario	Relative error on S_8
Total error	5.2 %
Statistical error	3.7 %
Systematic error	3.6 %
Shear calibration	1.65 %
Intrinsic alignments	1.67 %
Baryon feedback	2.63 %
Photo-z errors (DIR)	0.84 %
Photo-z errors (CC)	16.1 %

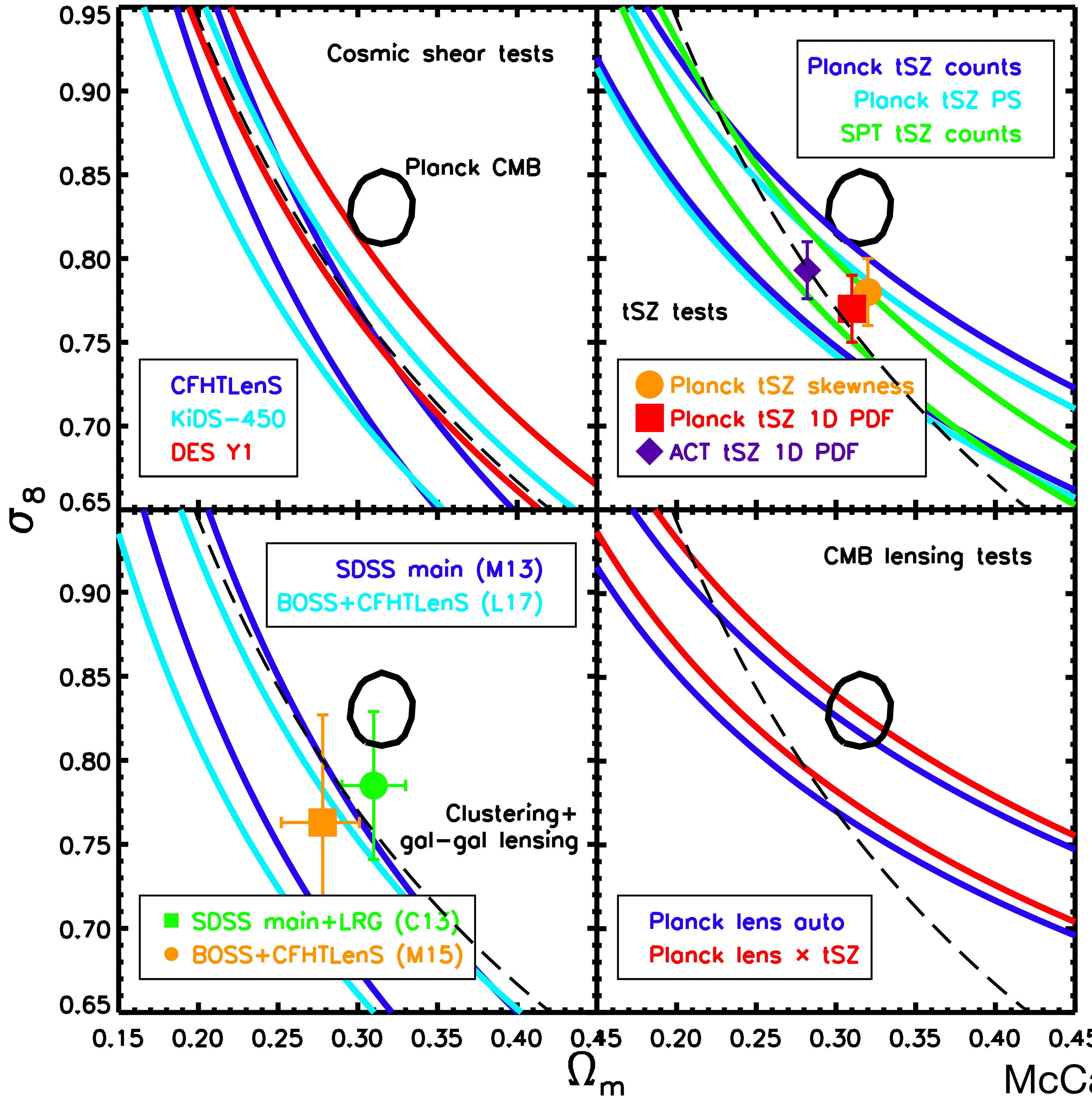
- Sample variance in DIR calibration unaccounted for.
- Survey inhomogeneities in DIR unaccounted for.
- Need to improve a lot on CC.

S_8 results over the years



Kilbinger (private communication)

Other probes



McCarthy et al. (2017)

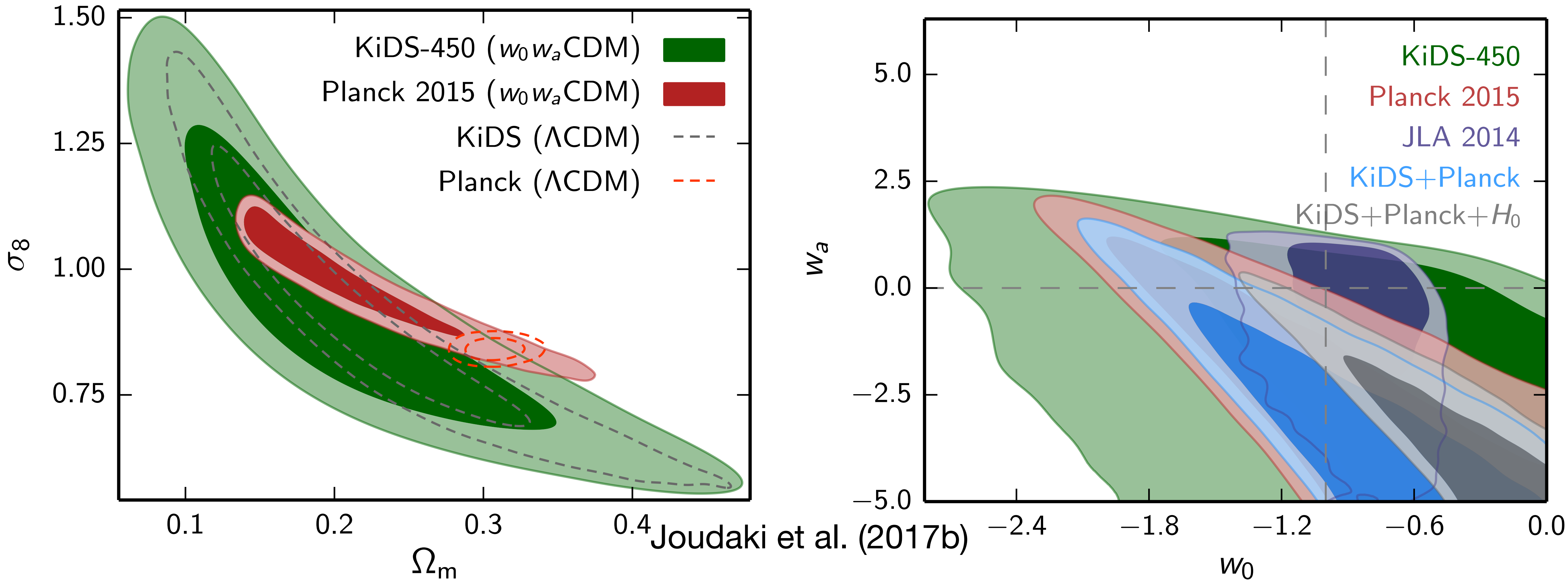
Extended cosmologies

- Massive neutrinos
- Non-zero curvature
- Evolving dark energy
- Modified gravity
- Running spectral index

Joudaki et al. (2017b)

Evolving dark energy

$$p = w\,\rho\,c^2, \quad w(a) = w_0 + (1\text{-}a)w_a, \quad a = 1/(1+z)$$



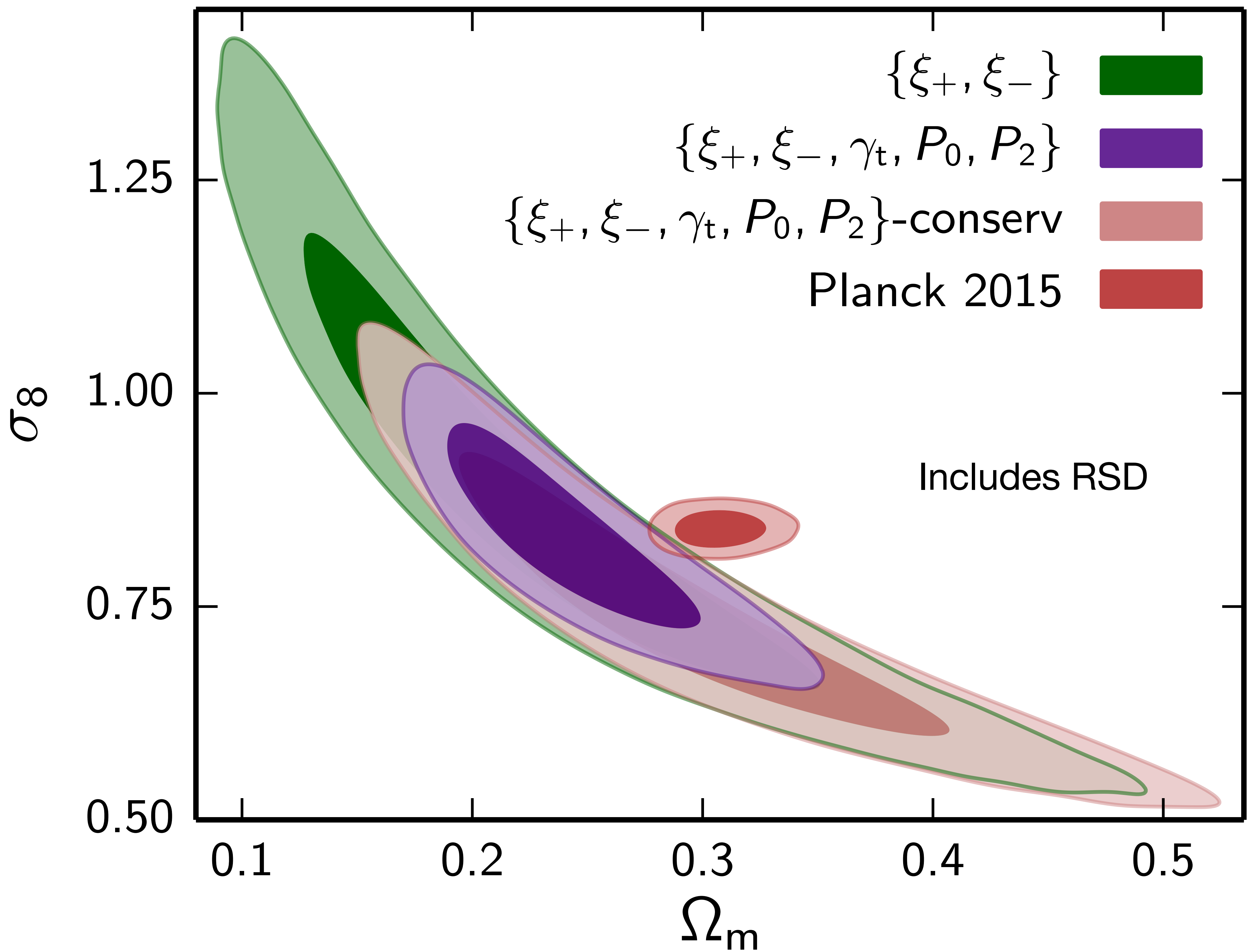
Joudaki et al. (2017b)

- Resolves tension between KiDS and Planck.
- Only extension that is moderately favoured by the data.
- Resolves tension between Riess et al. (2016) and Planck.

Combined probes

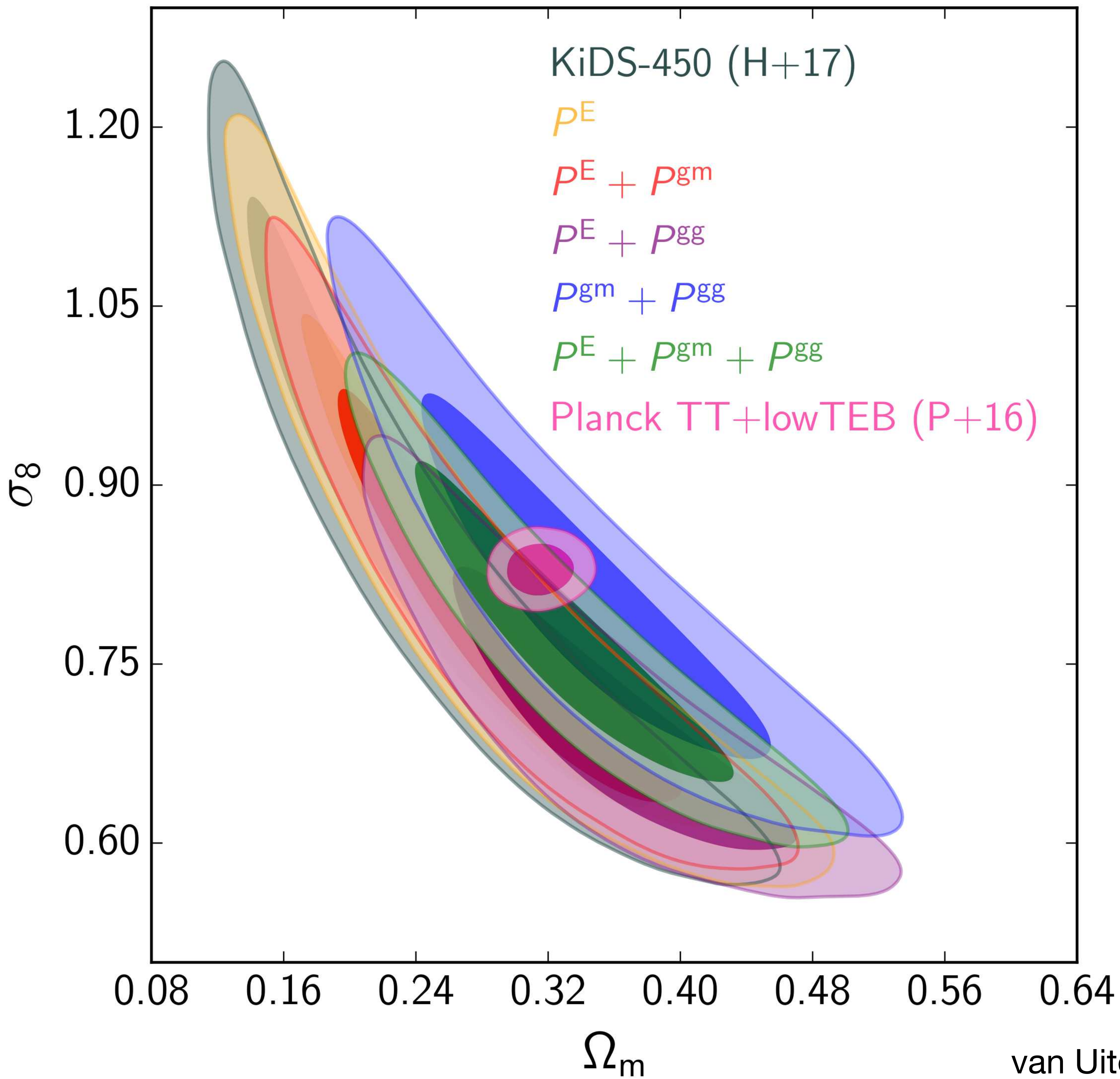
- Cosmic shear $\langle\gamma\gamma\rangle$
- Galaxy clustering $\langle\delta\delta\rangle$ (e.g. galaxy redshift survey)
- Galaxy-galaxy lensing $\langle\delta\gamma\rangle$
- Break degeneracies
- Increase precision
- Lose some of the benefits of cosmic shear

KiDS + 2dFLenS/BOSS



Joudaki et al. (2018)

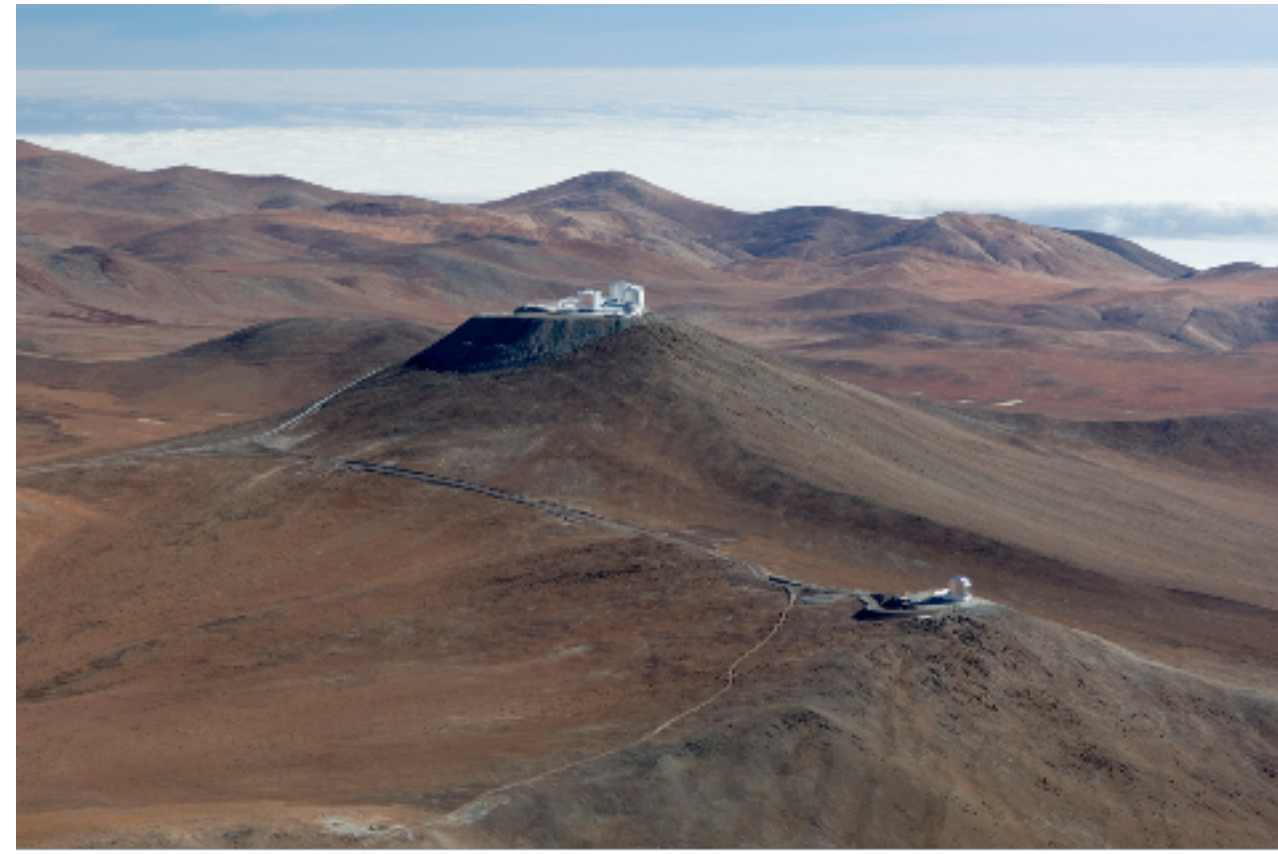
KiDS + GAMA clustering

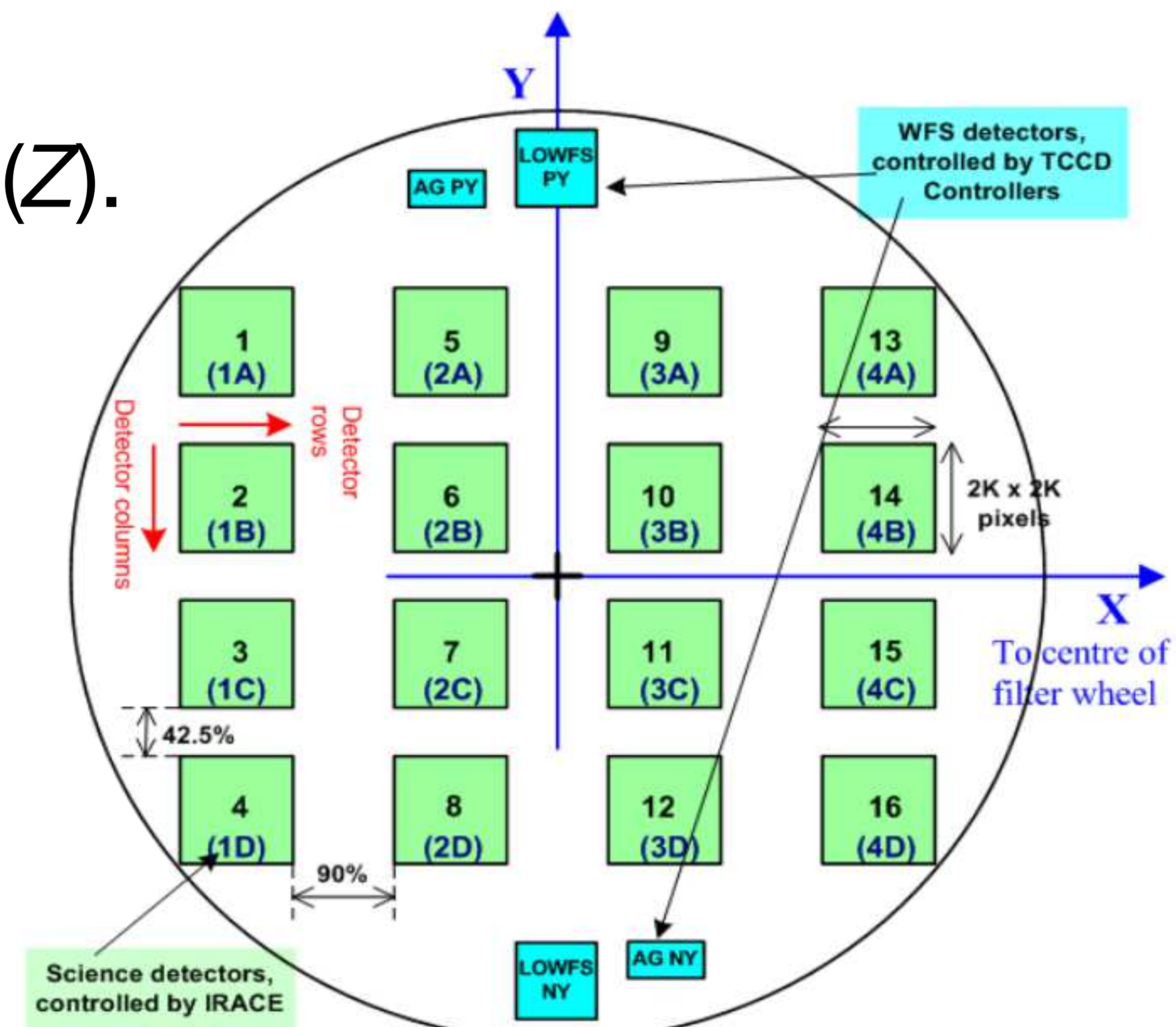


van Uitert et al. (2017)

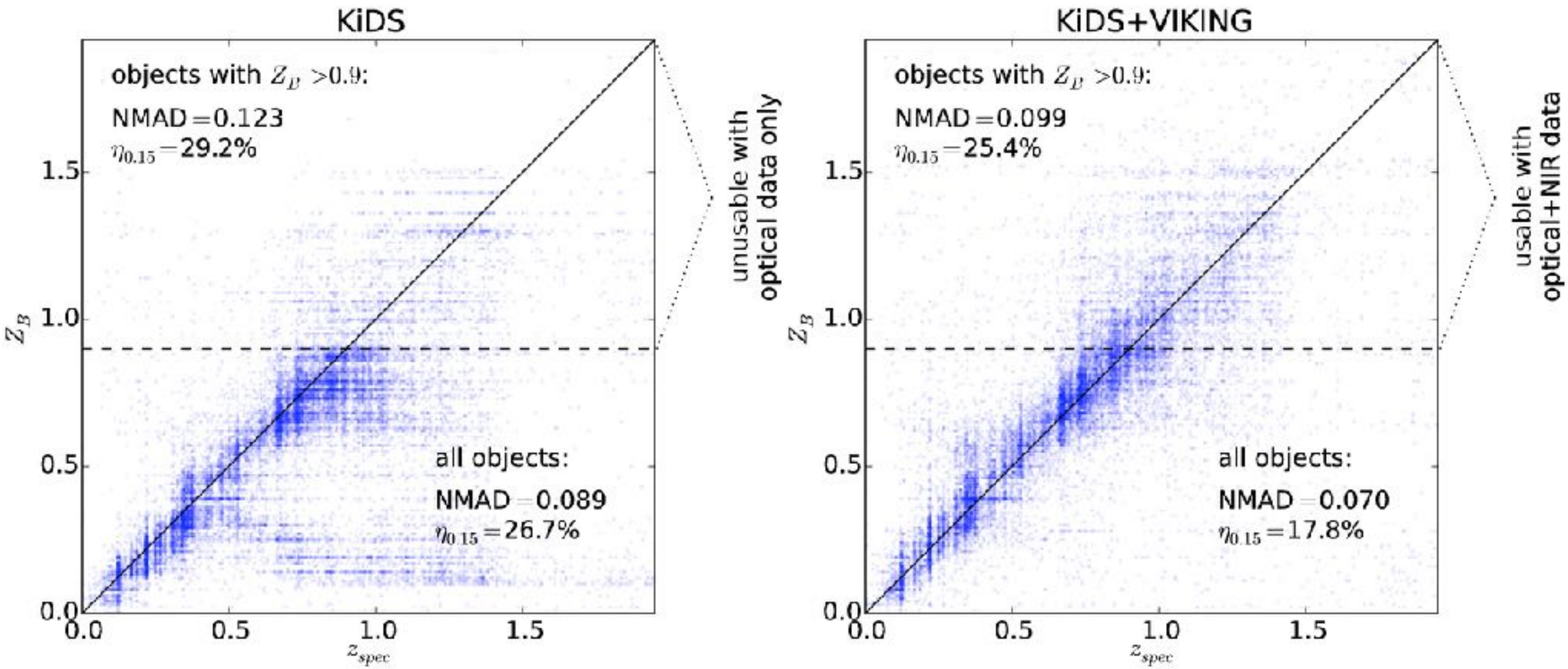
VIKING@VISTA

- Same footprint as KiDS.
- Already finished (1350deg^2).
- $ZYJHK_s$ images.
- 5σ depths of 21.2 (K_s) to 23.1 (Z).





Benefits of NIR



Wright et al. in preparation

KiDS-VIKING 450

- Add VIKING $ZYJHK_s$-bands to KiDS-450 *ugri*-bands.
- Improved photo-z.
- Define five new tomographic bins ($0.1 < z_{phot} < 1.2$).
- Include a lot of lessons learned in the last couple of years.
- Expectation: More precise (~20%) and more systematically robust cosmological results.
- Leverage large-area spec-z surveys for CC.

KV450 other improvements

- Covariance with more realistic shape noise -> better χ^2
- More realistic image simulations
- New priors for IA and baryon feedback
- Pre-defined data splits

Summary & Outlook

- Cosmic shear measures S_8 with CMB-like precision.
- Tension between Planck and some cosmic shear measurements (KiDS-450). Systematics? New physics??
- Very exciting times:
  - KiDS+VIKING ~1100deg^2 now, 1350deg^2 in early 2019.
  - DES has tripled area and doubled depth.
  - Waiting for first HSC cosmic shear results.
- Prepare with today's surveys for Euclid / LSST / WFIRST.