Progress and challenges in large-scale structure weak lensing

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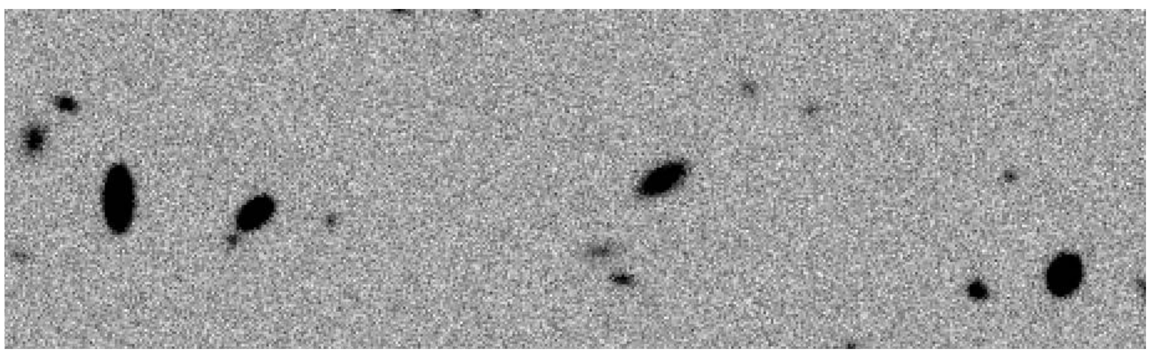
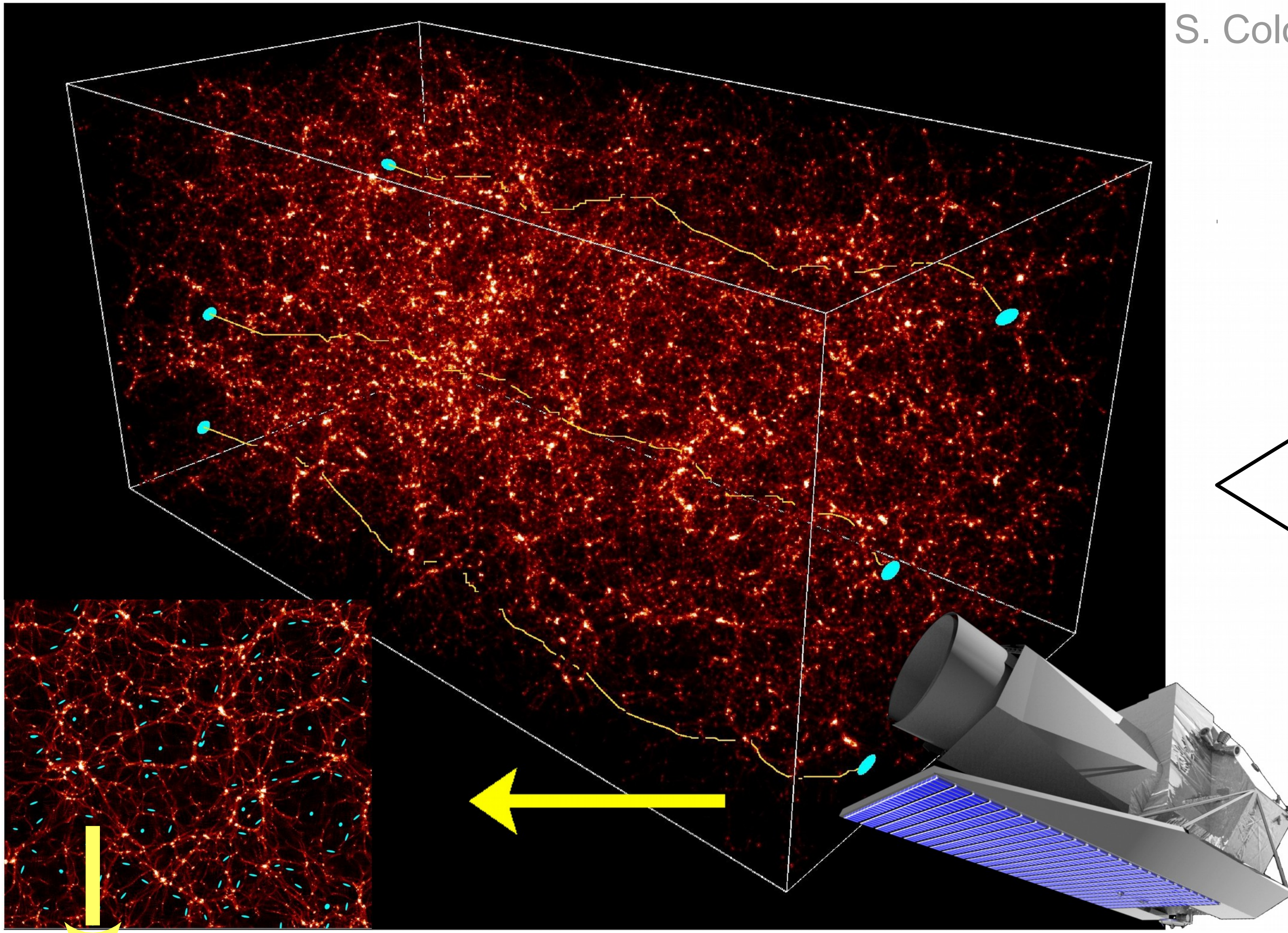


with H. Hildebrandt, H. Hoekstra, D. Kirk, T. Kitching, A. Taylor, M. Viola,
and KiDS & RCSLenS Collaborations, Euclid Weak Lensing SWG

LSS Symposium, Garching

July 24th, 2015

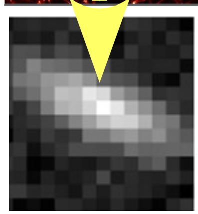
Cosmological weak lensing



S. Colombi

Euclid
LSST
WFIRST

DES
HSC
KiDS
RCSLenS



$\xrightarrow{\text{shear estimation}} \gamma \xrightarrow{\text{shear statistics}} \langle \gamma \gamma^* \rangle \xrightarrow{\text{inference}}$

$\{\sigma_8, m_\nu\}$ DM

$\{w_0, w_a\}$ DE

$\{\Phi, \Psi\}$ mod. gravity

Shear estimation: noise bias

image brightness moments

$$Q_{ij} = \int dx\, dy\, I(x,y)\, x^i y^j$$

- linear in the image pixel values

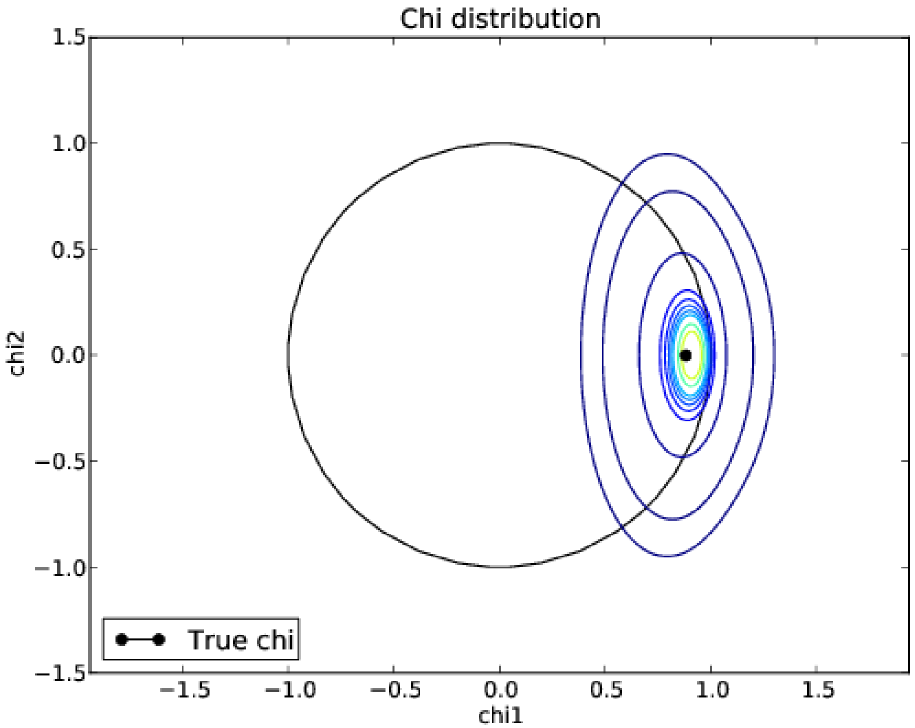
shear estimate

$$\chi = \frac{Q_{20} - Q_{02} + 2i\, Q_{11}}{Q_{20} + Q_{02}}$$

→ follows Marsaglia-Tin distribution

- mean/mode do not recover true value
- pdf extends beyond unit circle

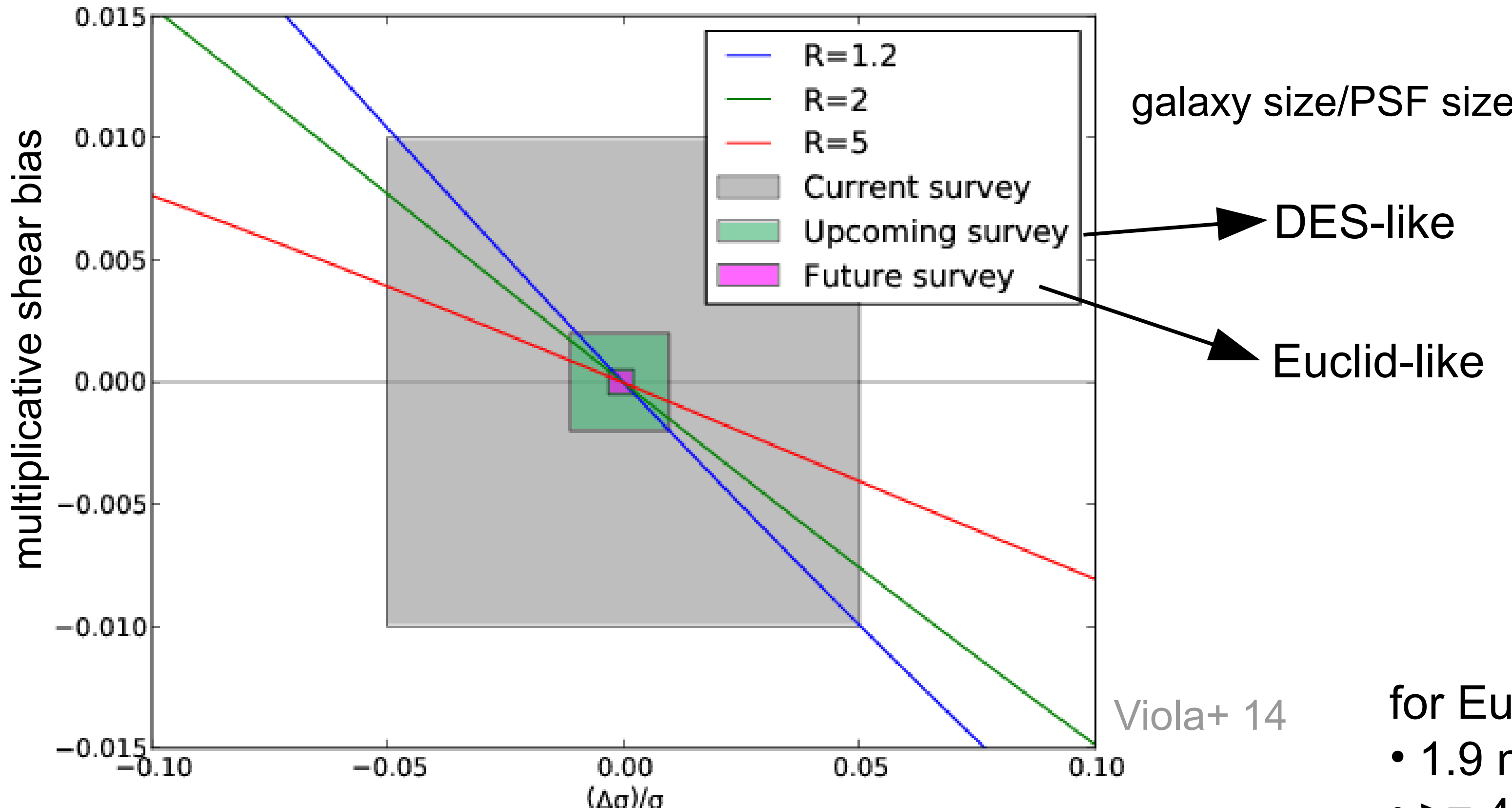
Viola+ 14



see also
Refregier+ 12
Miller+ 13
Kacprzak+ 13
Bernstein & Armstrong 14

Shear estimation: intrinsic ellipticities

Need a deep survey component to
1. calibrate noise bias on high S/N observations, or
2. extract intrinsic ellipticity distribution to put into image simulation

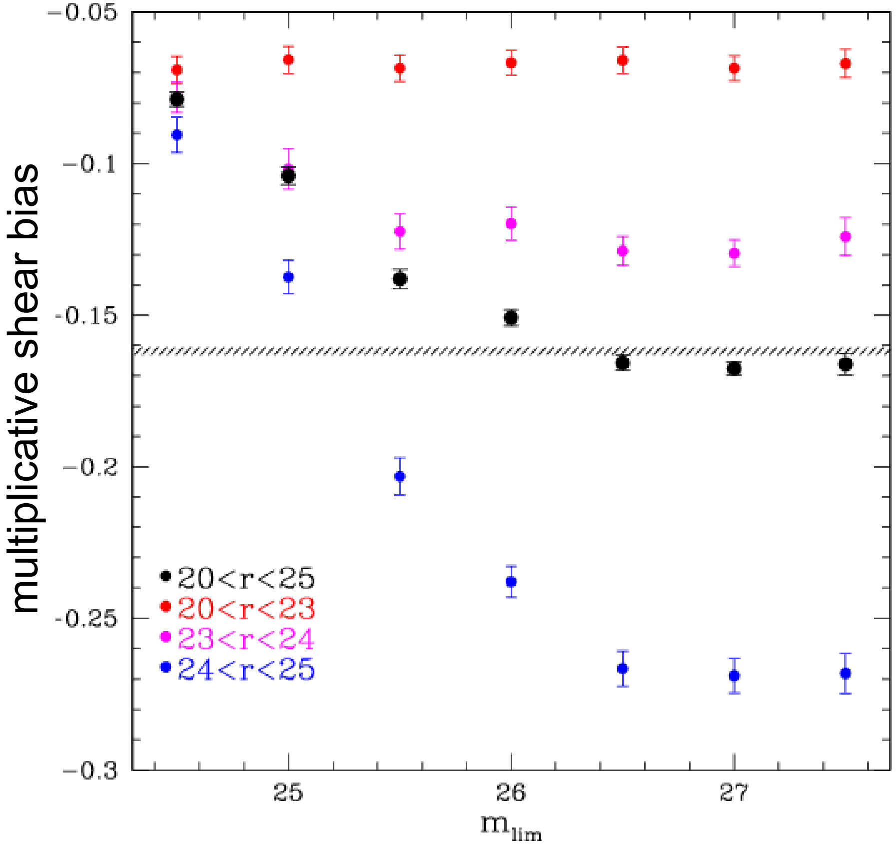


relative uncertainty in width of intrinsic ellipticity distribution

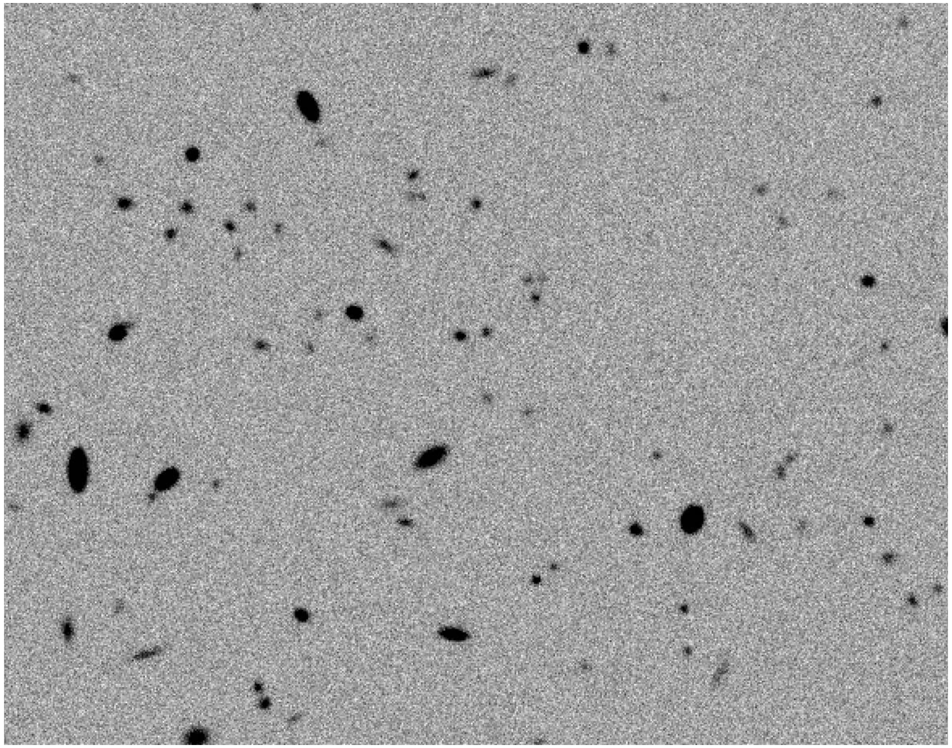
for Euclid:
- 1.9 mag deeper
- >= 45 deg^2

Shear estimation: calibration

Herbonnet, Hoekstra



Hoekstra+ 15

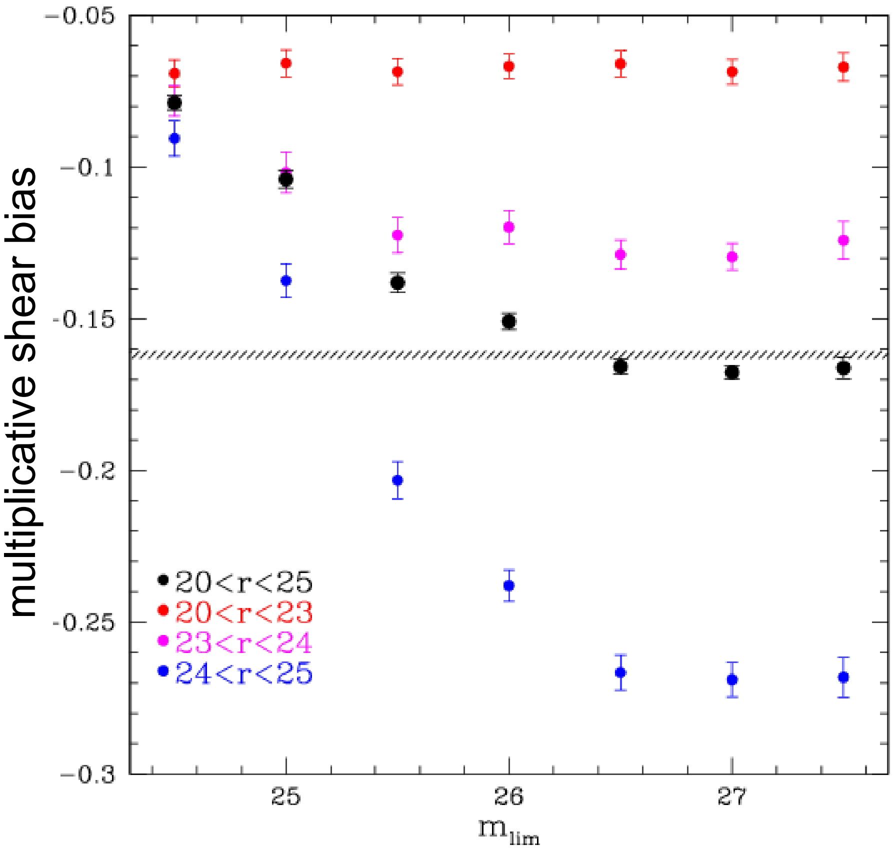


$m_{\mathrm{lim}} = 25$

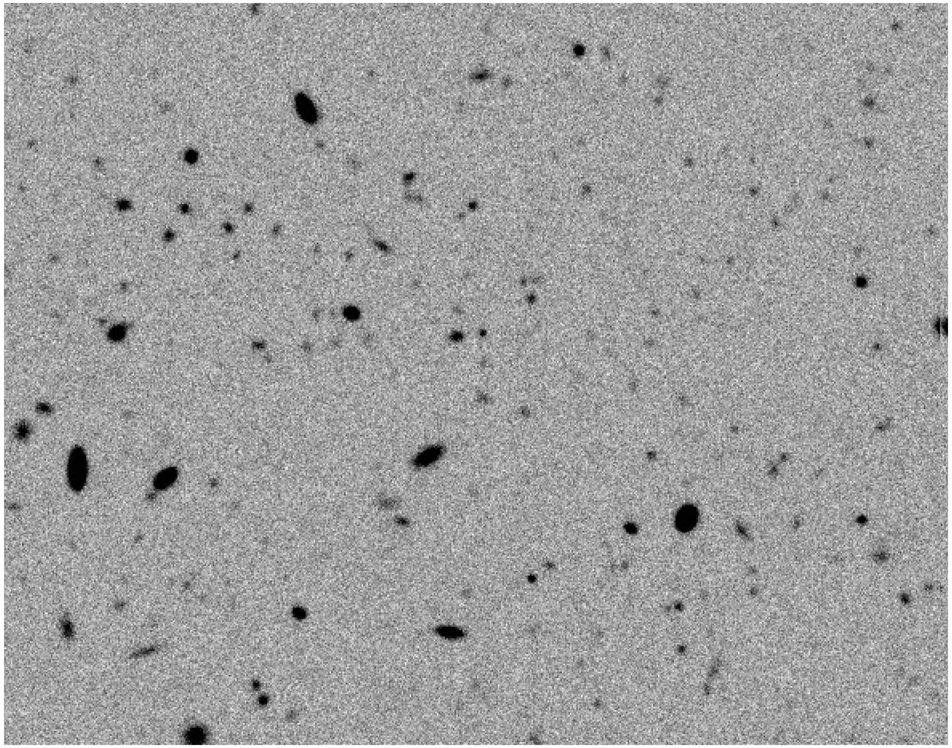
→ it seems likely all shear estimation algorithms will require calibration on simulations

Shear estimation: calibration

Herbonnet, Hoekstra



Hoekstra+ 15

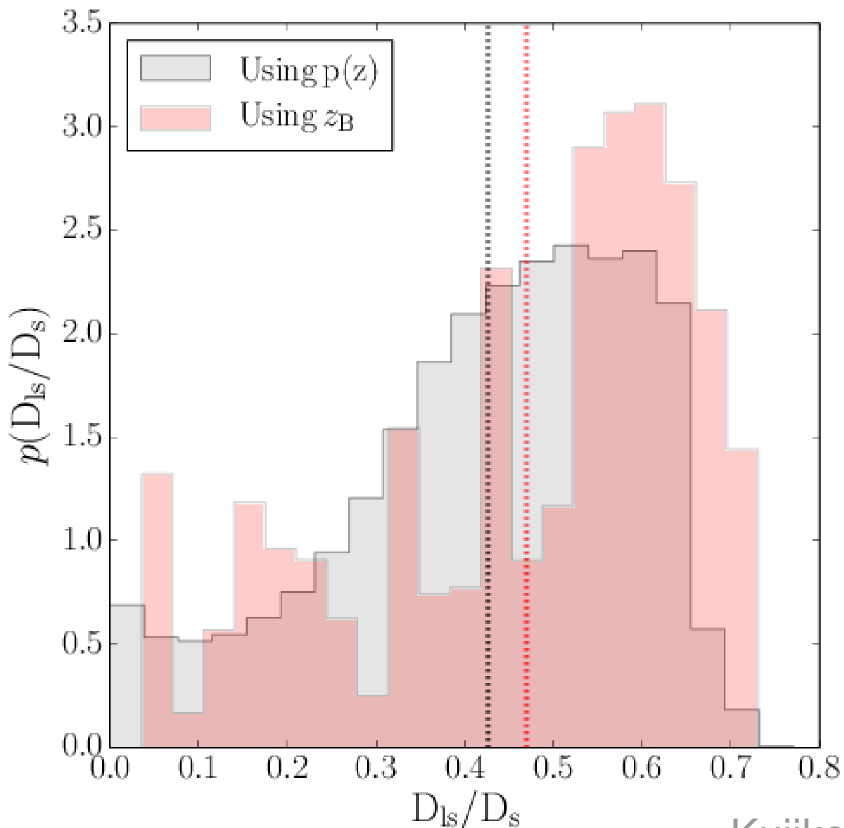


$$m_{\rm lim} = 27$$

→ it seems likely all shear estimation algorithms will require calibration on simulations

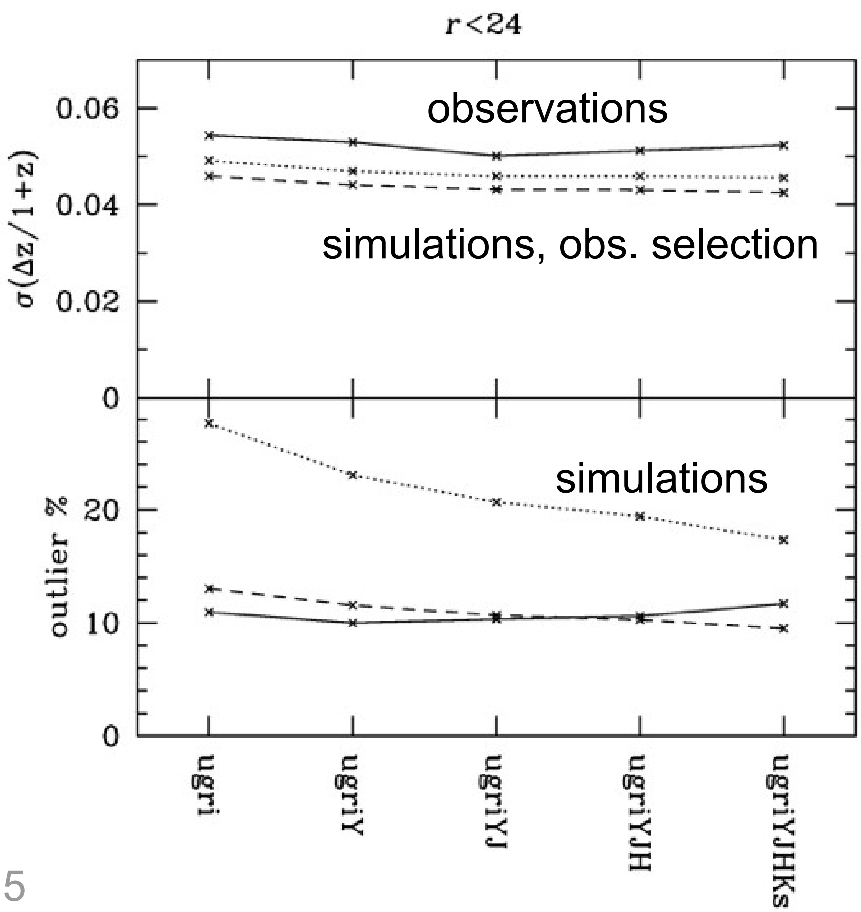
Photo-z: characterisation

lensing distance ratio



Kuijken+ 15

Hildebrandt+, in prep.



KiDS + VIKING

→ stacked pdf instead of max. posterior values

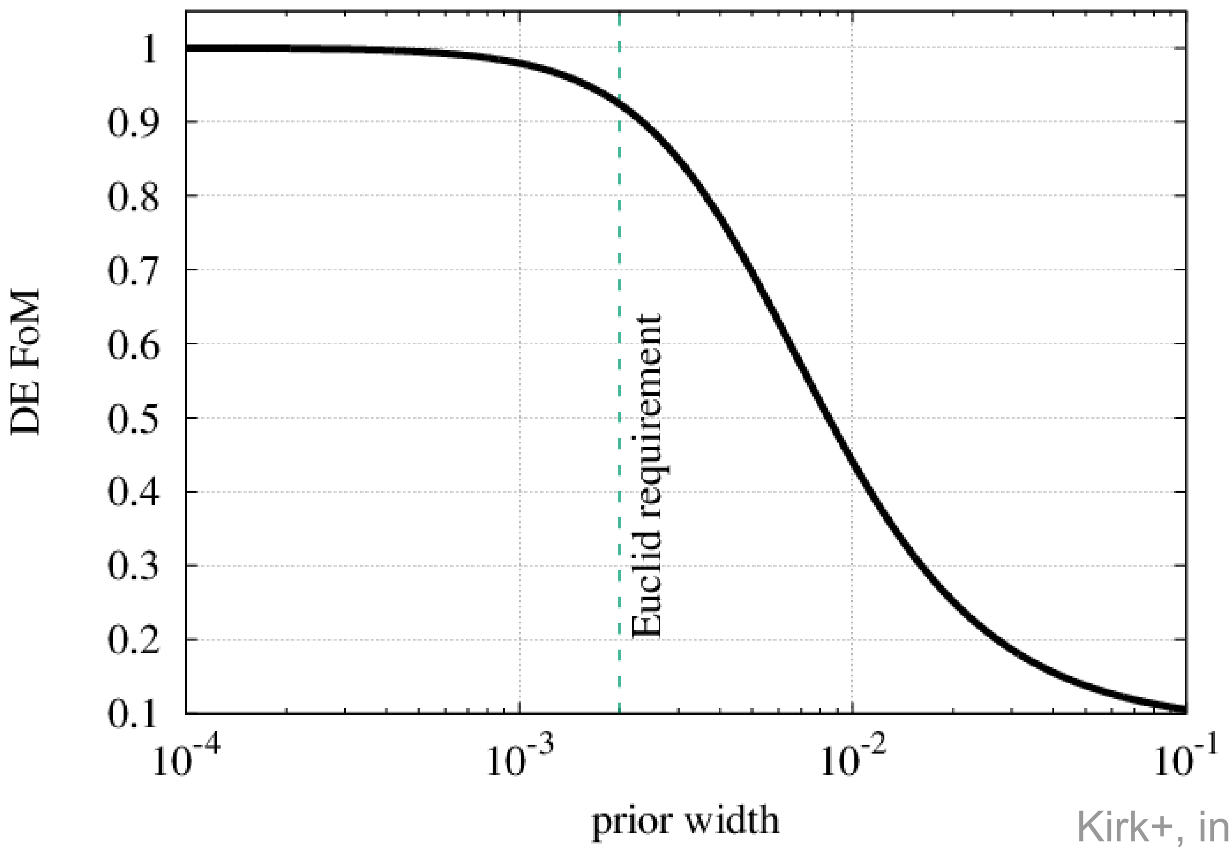
also Sanchez+ 14

→ need for deep spectroscopic redshifts

also Banerji+ 15

Photo-z: uncertainty in mean

effect of uncertainty in priors on mean of tomographic redshift bins

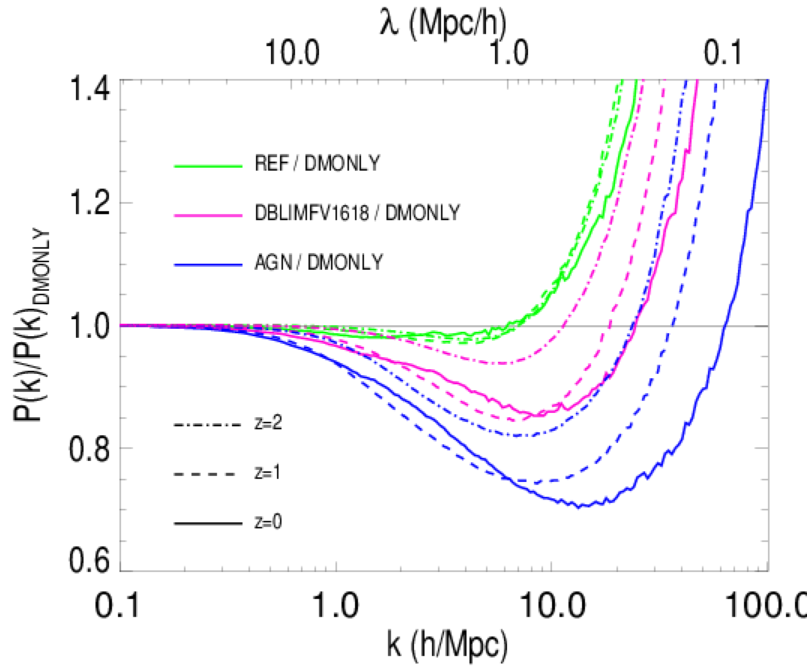


Kirk+, in prep.

- bias in the mean accounts for unidentified catastrophic redshift failures

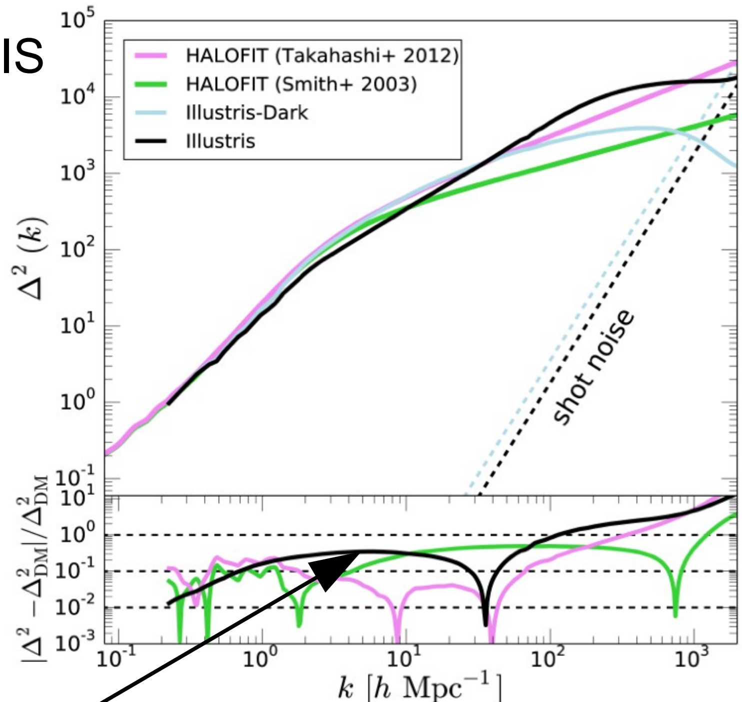
(Amara & Refregier 07)

Baryon feedback: impact



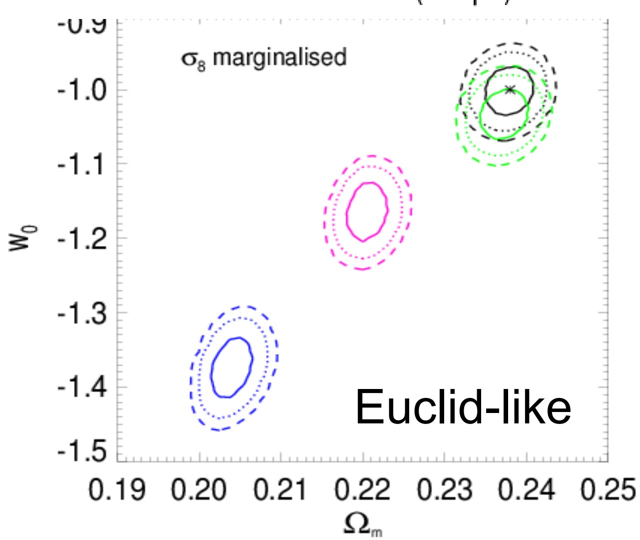
OWLS

ILLUSTRIS



Vogelsberger+ 14

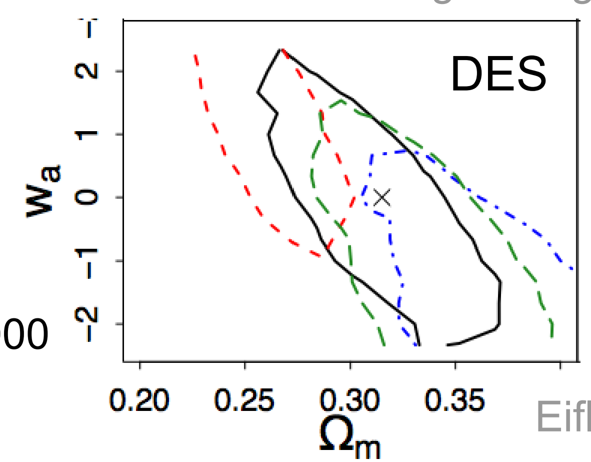
suppression 35%
@ k=5 h/Mpc



l<6000

Semboloni+ 11

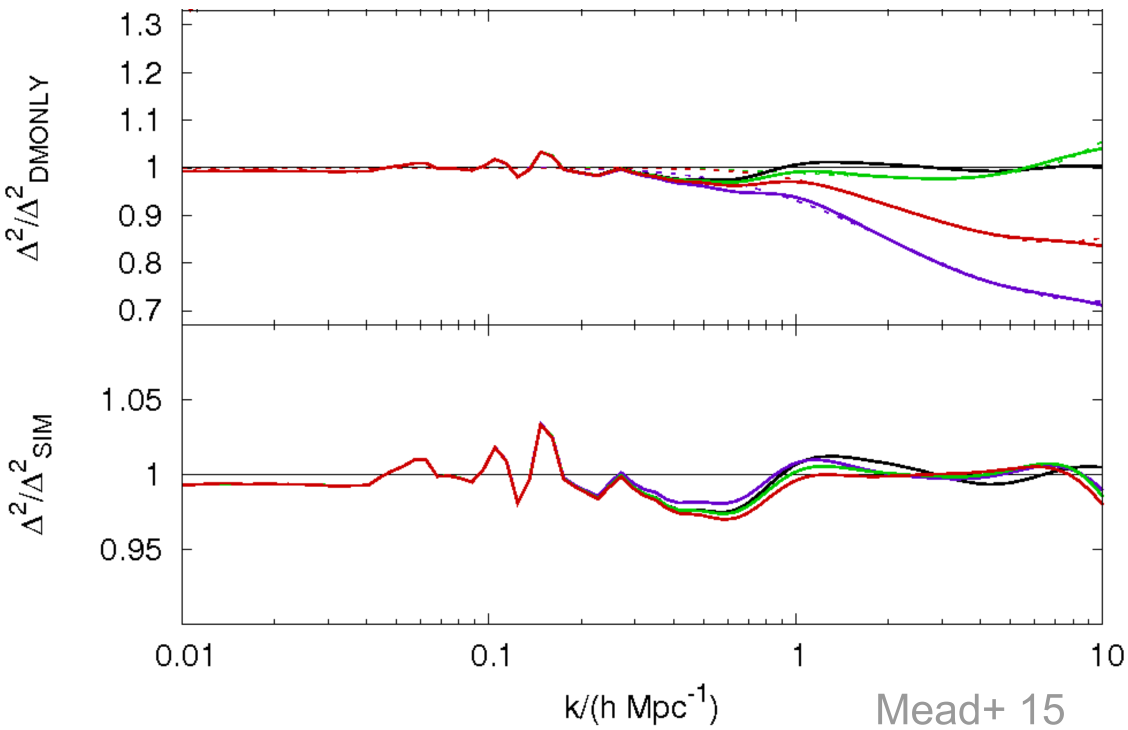
l<5000



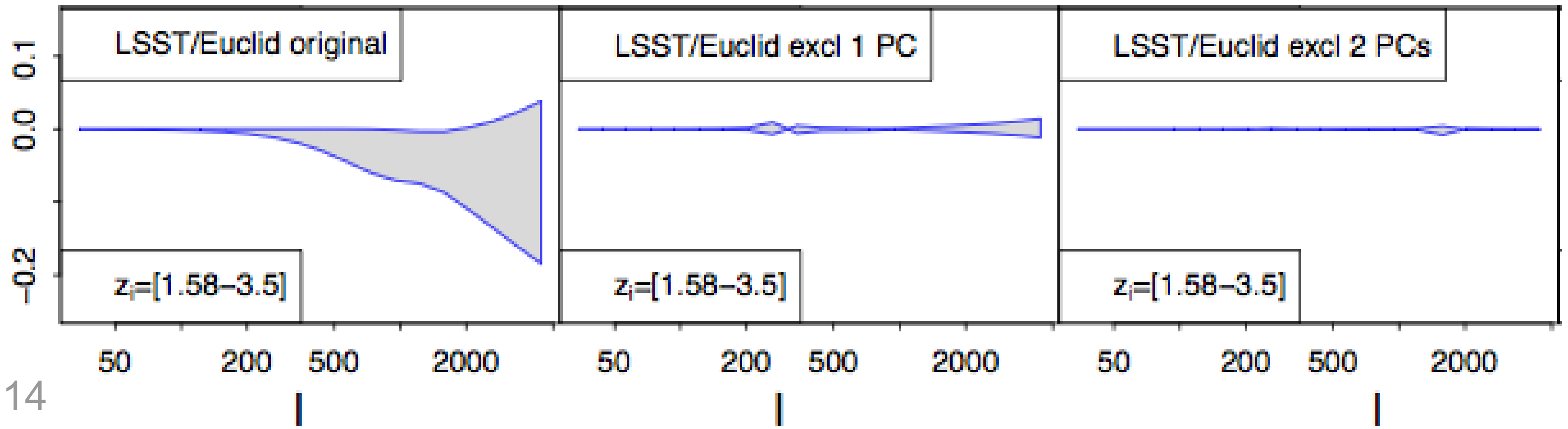
Eifler+ 14

Baryon feedback: modelling

- two parameters suffice to model feedback (halo size & concentration)
- prefer physical parameters over nuisance parameters → calibration/ validation



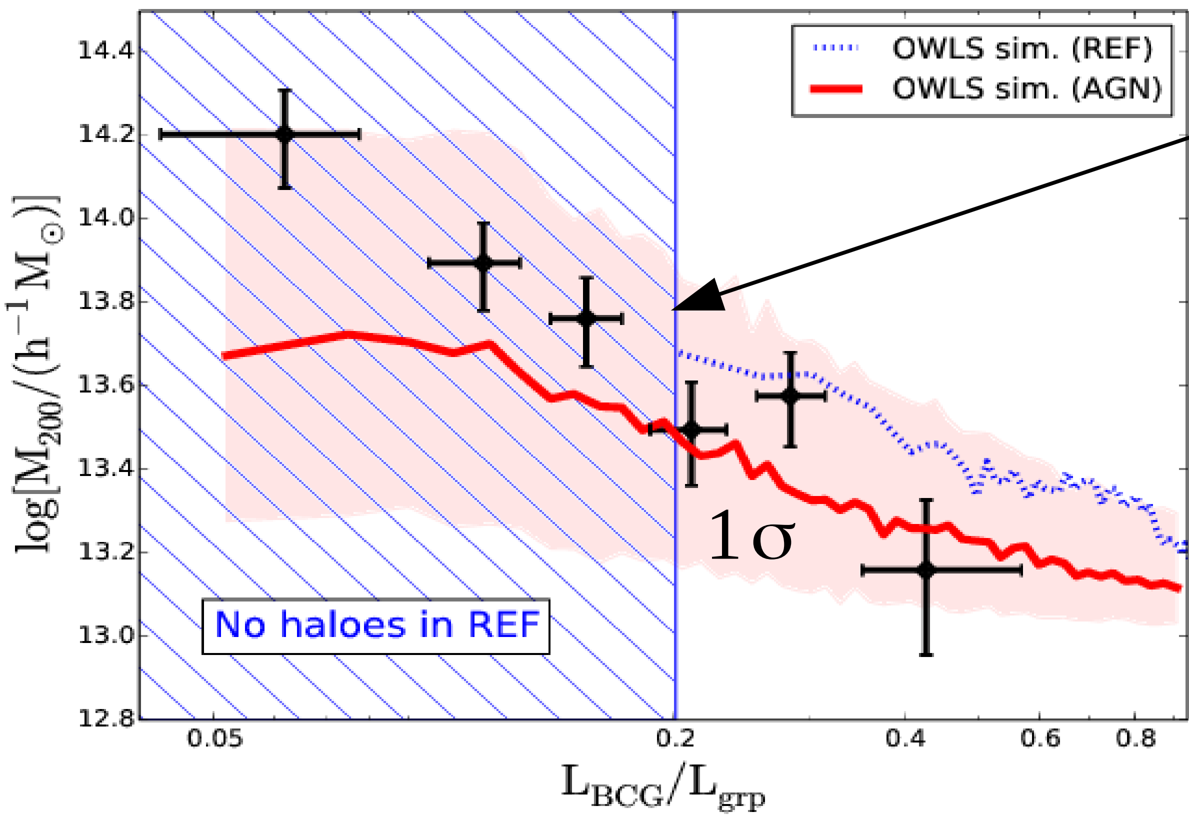
Mead+ 15



Eifler+ 14

Baryon feedback: external calibration

KiDS early-science: GAMA group weak lensing



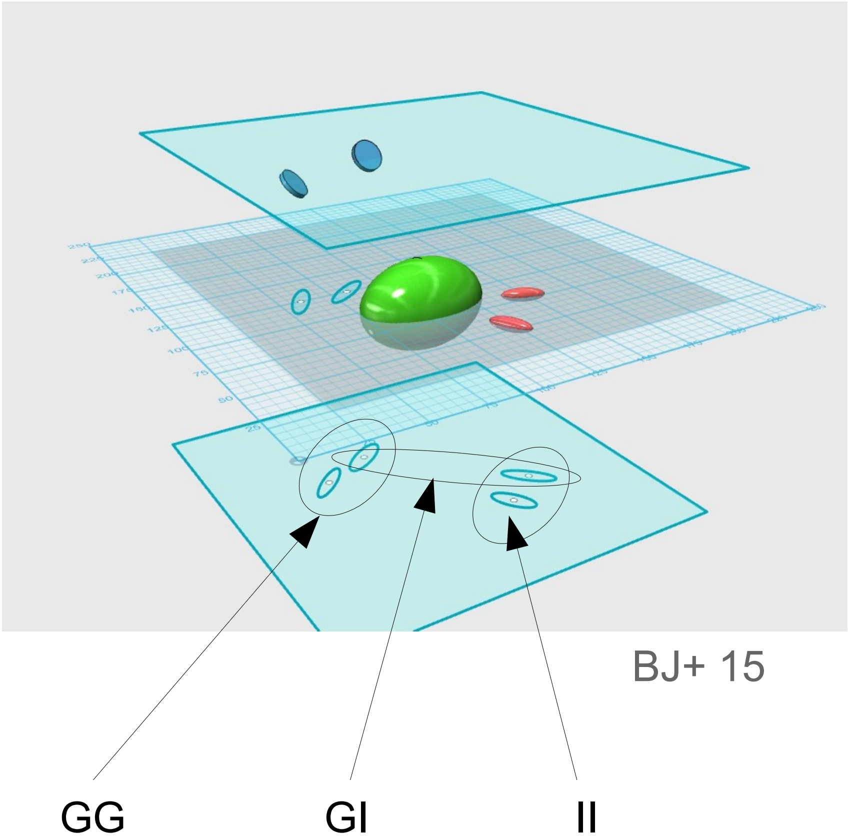
cooling too efficient

Viola+ 15

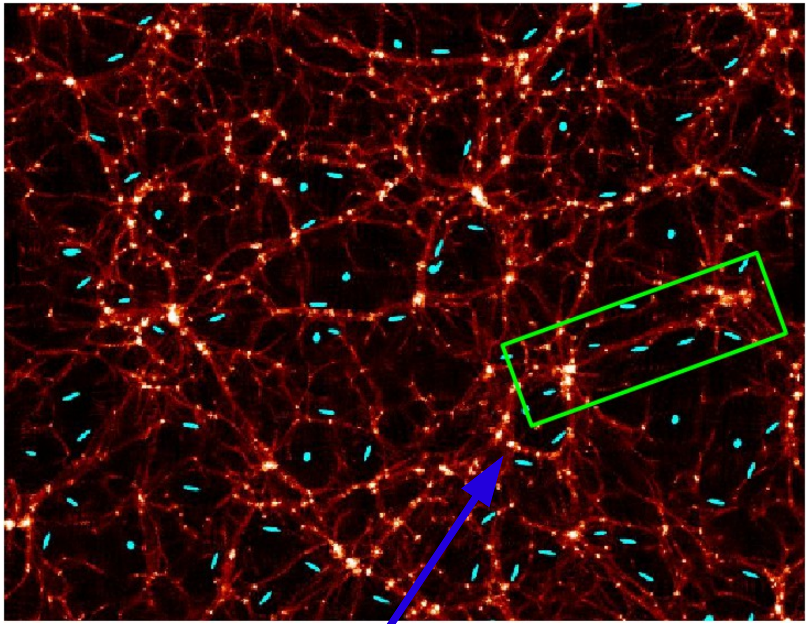
→ use galaxy-halo measurements to calibrate/ put priors on feedback models

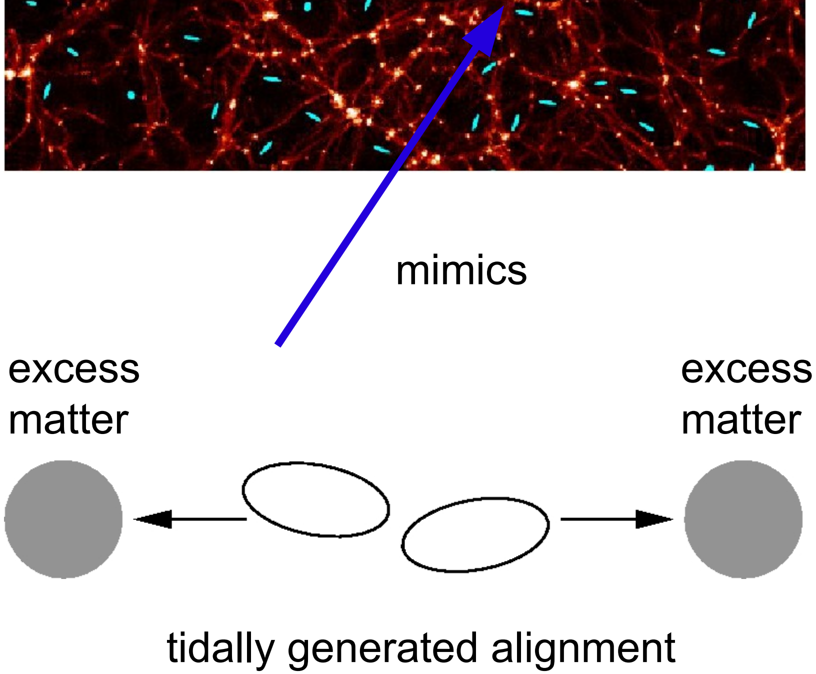
Intrinsic alignments: the problem

$$\underbrace{\langle \epsilon_i \epsilon_j \rangle}_{\text{observed}} = \underbrace{\langle \gamma_i \gamma_j \rangle}_{\text{GG}} + \underbrace{\langle \epsilon_i^{s} \epsilon_j^{s} \rangle}_{\text{II}} + \underbrace{\langle \gamma_i \epsilon_j^{s} \rangle + \langle \epsilon_i^{s} \gamma_j \rangle}_{\text{GI}}$$



BJ+ 15



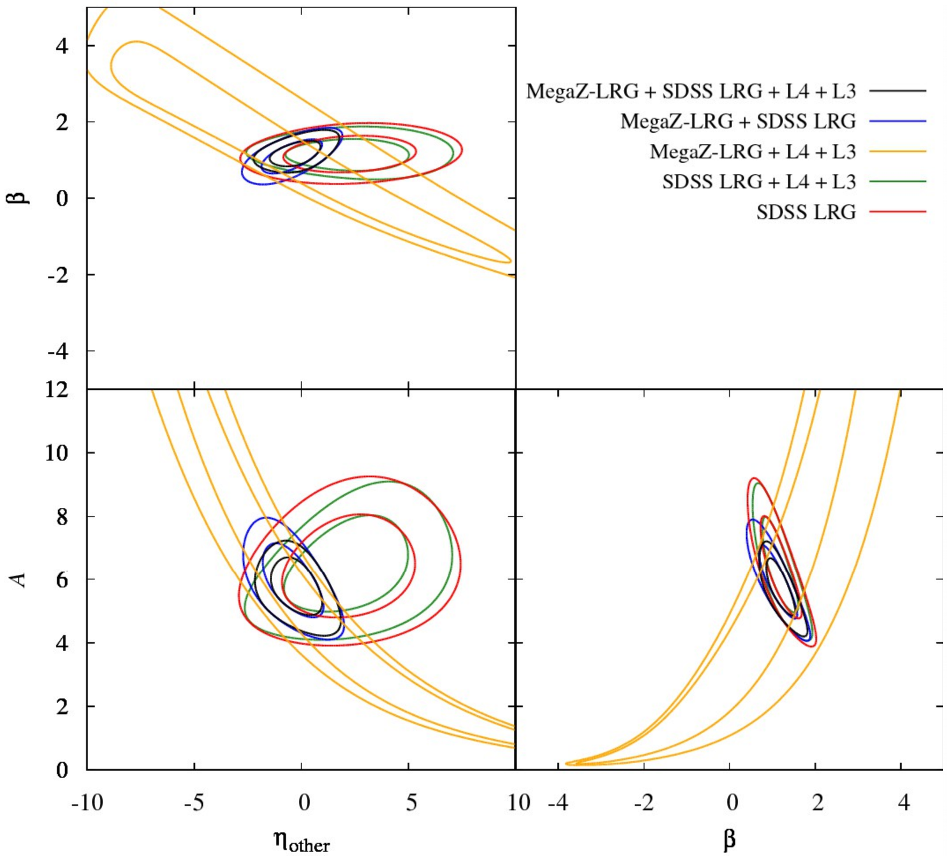


Intrinsic alignments: impact

$$P_{\mathrm{gI}}^{\mathrm{model}}(k,z,L) = A\, b_{\mathrm{g}}\, P_{\delta\mathrm{I}}(k,z) \left(\frac{1+z}{1+z_0}\right)^{\eta_{\mathrm{other}}} \left(\frac{L}{L_0}\right)^{\beta}$$

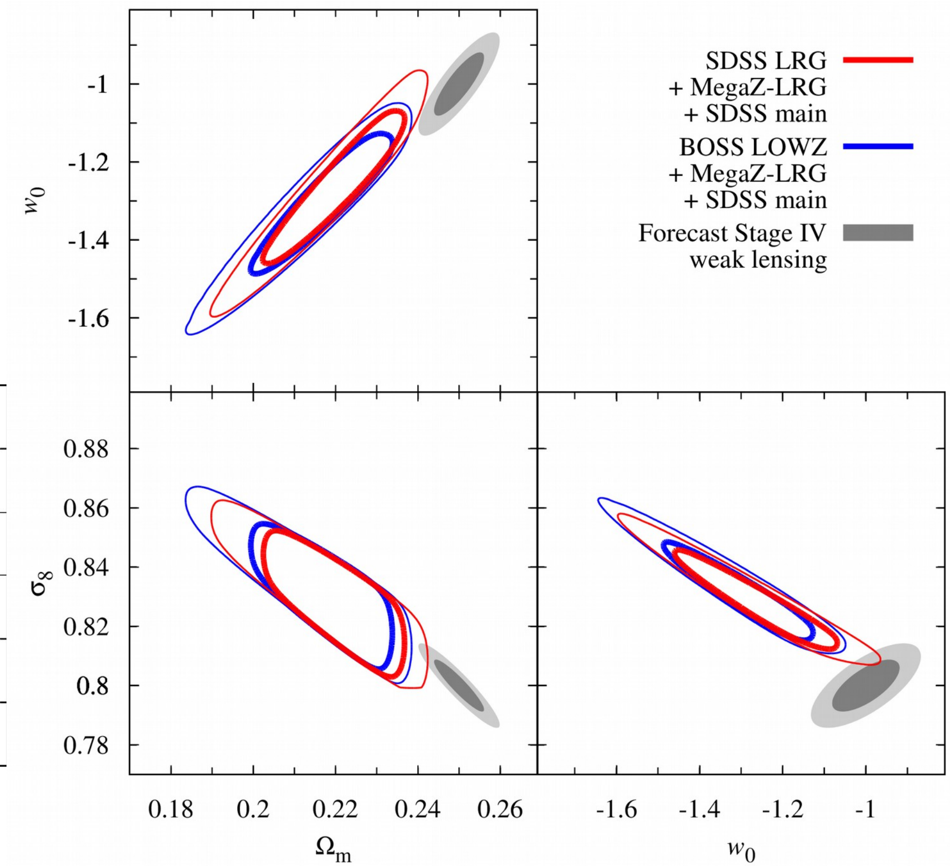
3-parameter model

<u>model constraints</u>



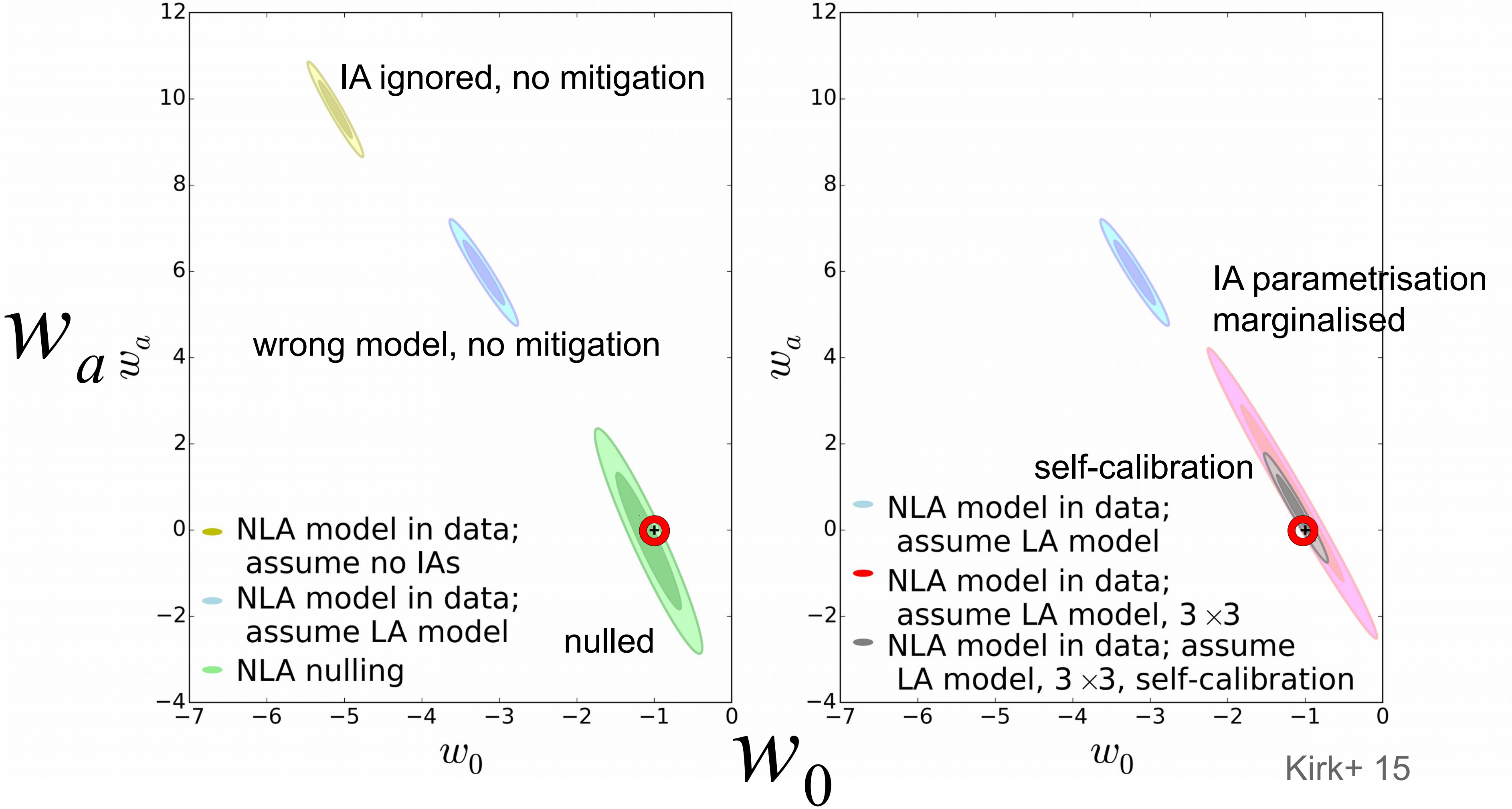
BJ+ 11

<u>bias on cosmology</u>



BJ+ 15

Intrinsic alignments: mitigation

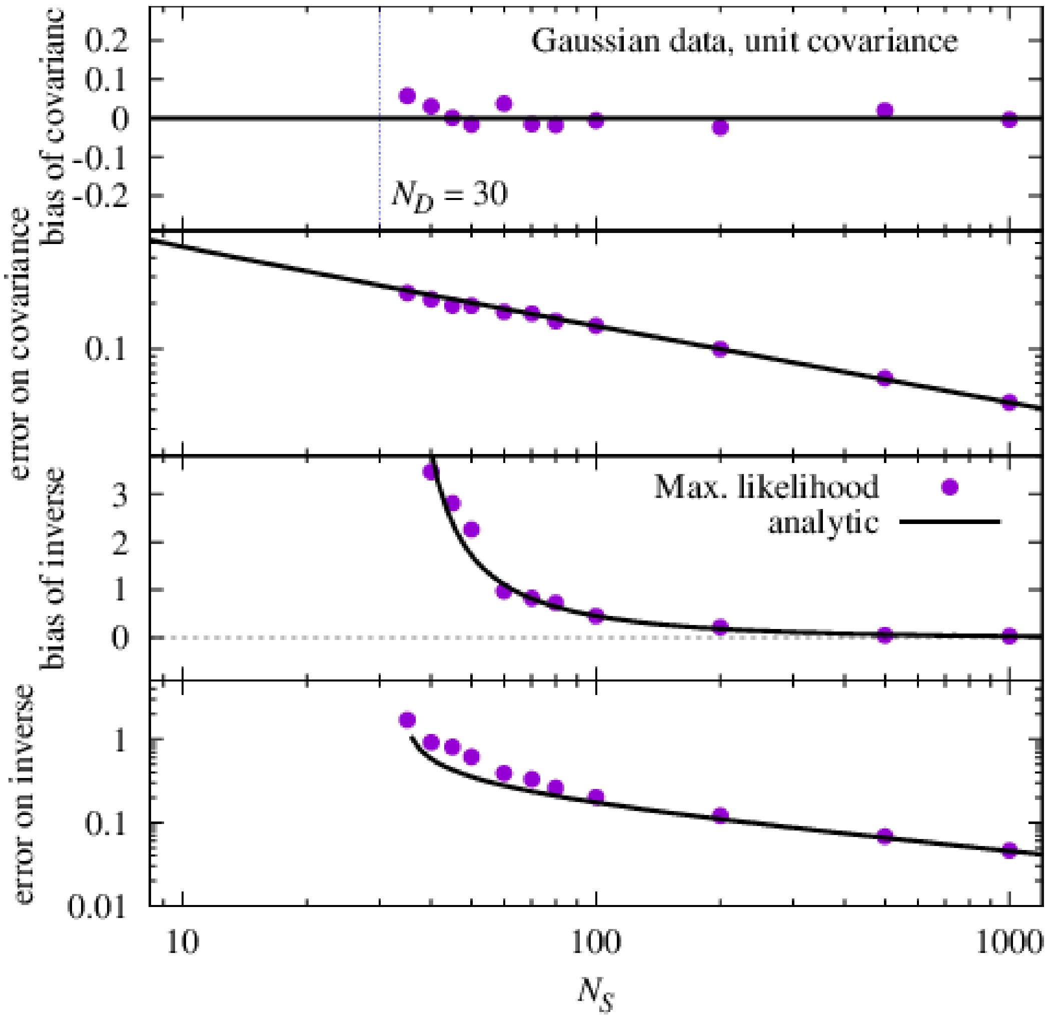


Kirk+ 15

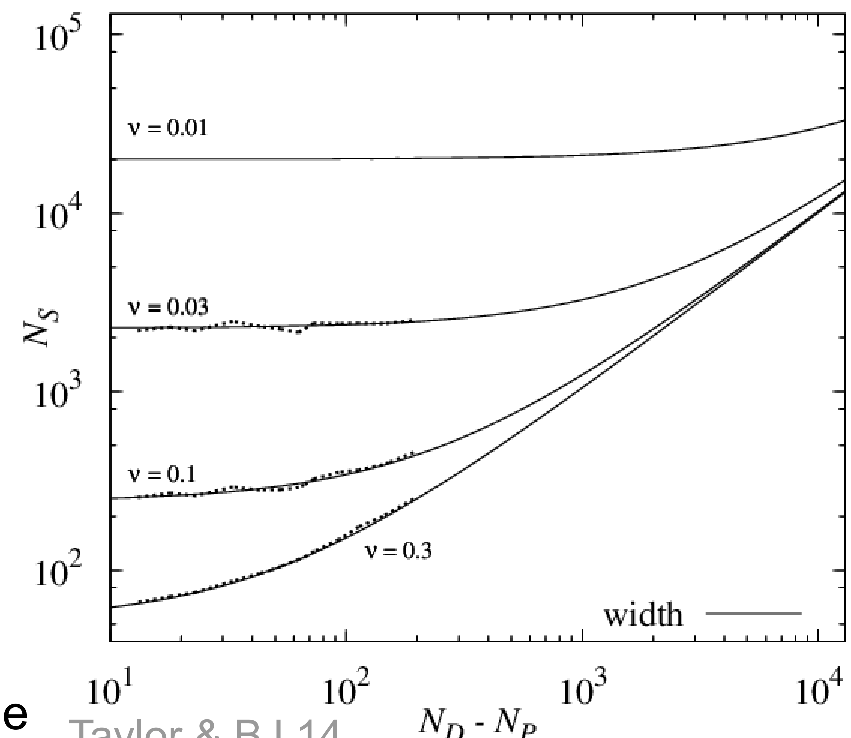
- nulling works, but removes substantial amount of cosmological information
- self-calibration works, and recovers most/all of the constraints
- red/blue galaxy split may work as well (Krause+ 15)

Error determination: noise biases

scaling of errors/biases with no. of realisations



relative error in parameter covariance

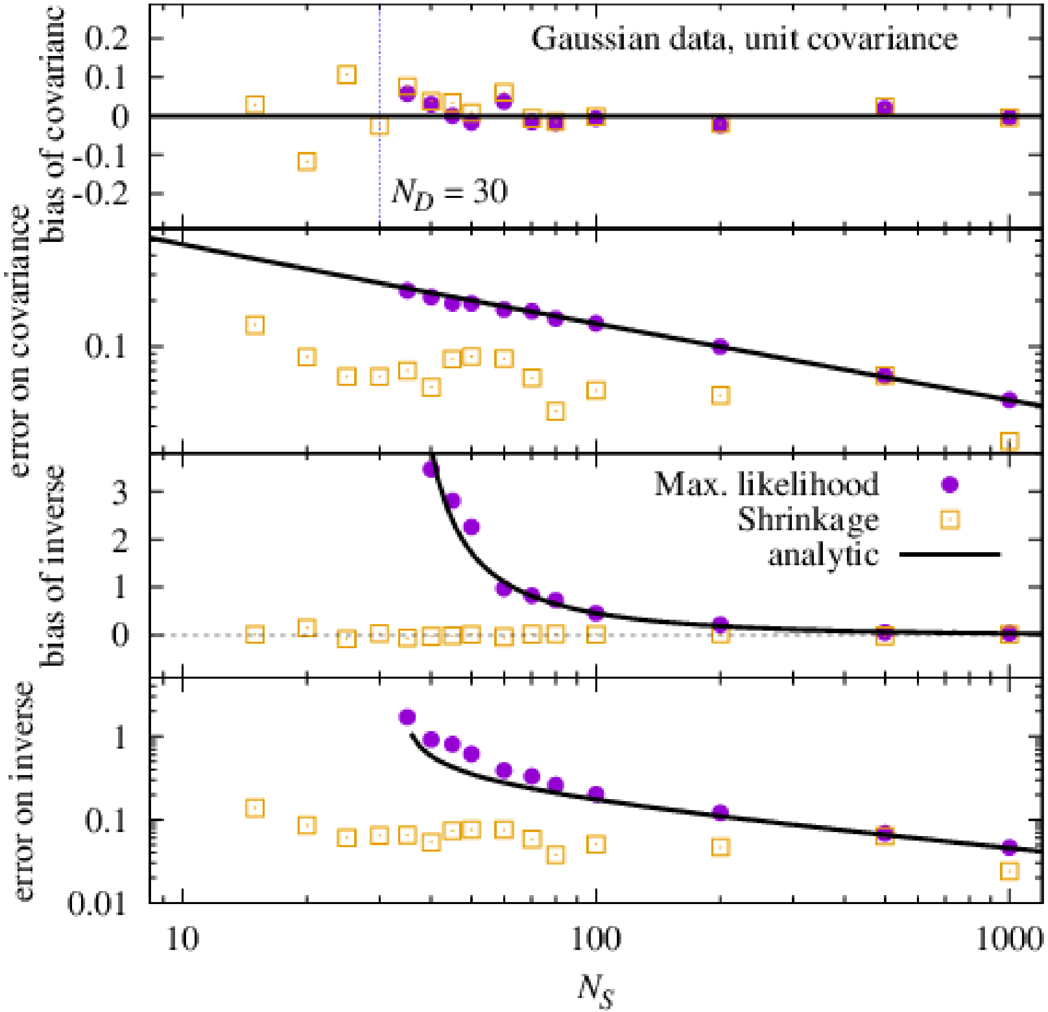


- bias and variance of inverse covariance diverge

Taylor & BJ 14

Error determination: covariance estimators

scaling of errors/biases with no. of realisations

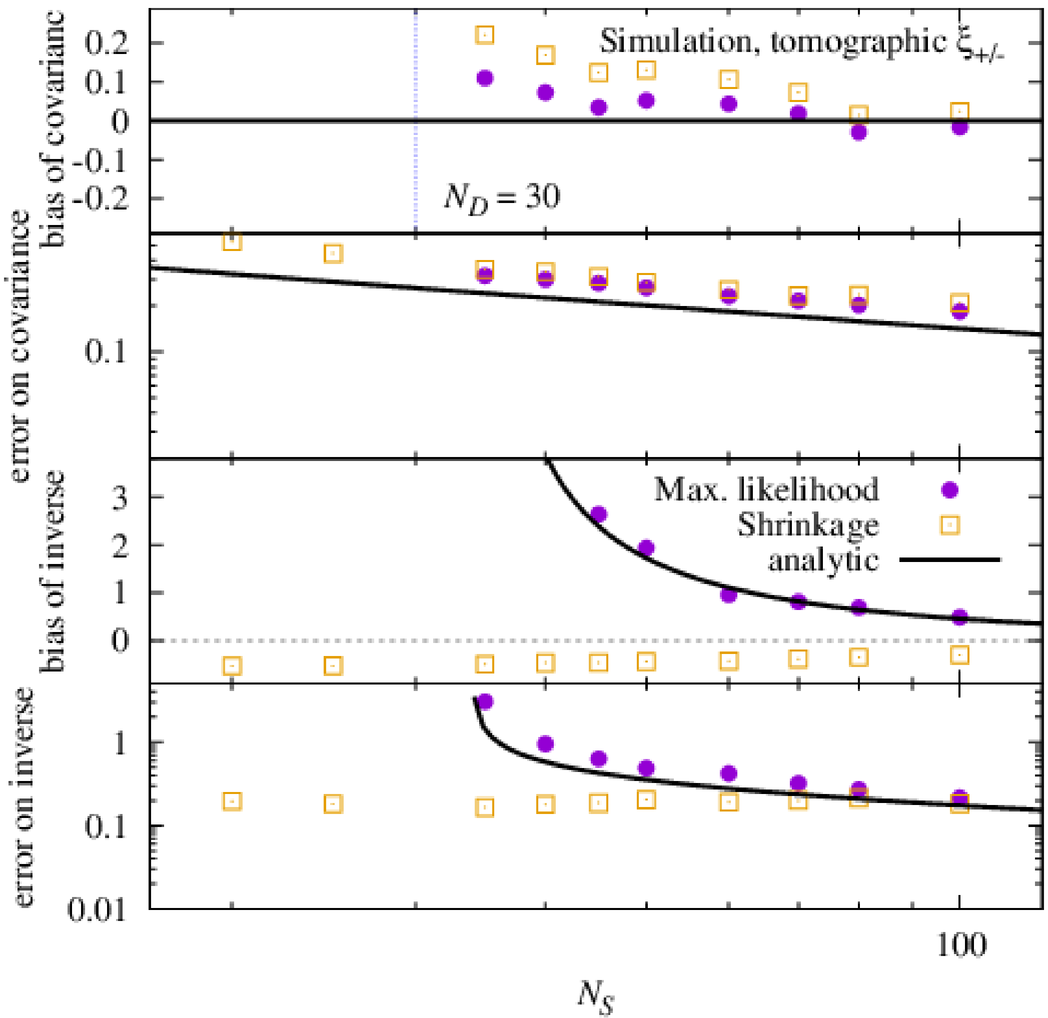


- non-linear shrinkage estimator
- no prior/extra information used

(Lam 15)

Error determination: covariance estimators

scaling of errors/biases with no. of realisations



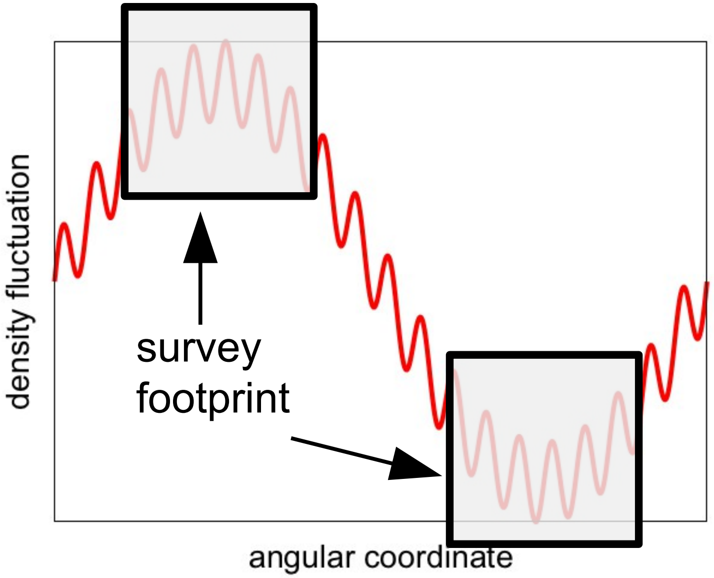
- non-linear shrinkage estimator
- no prior/extra information used

(Lam 15)

Data vector:

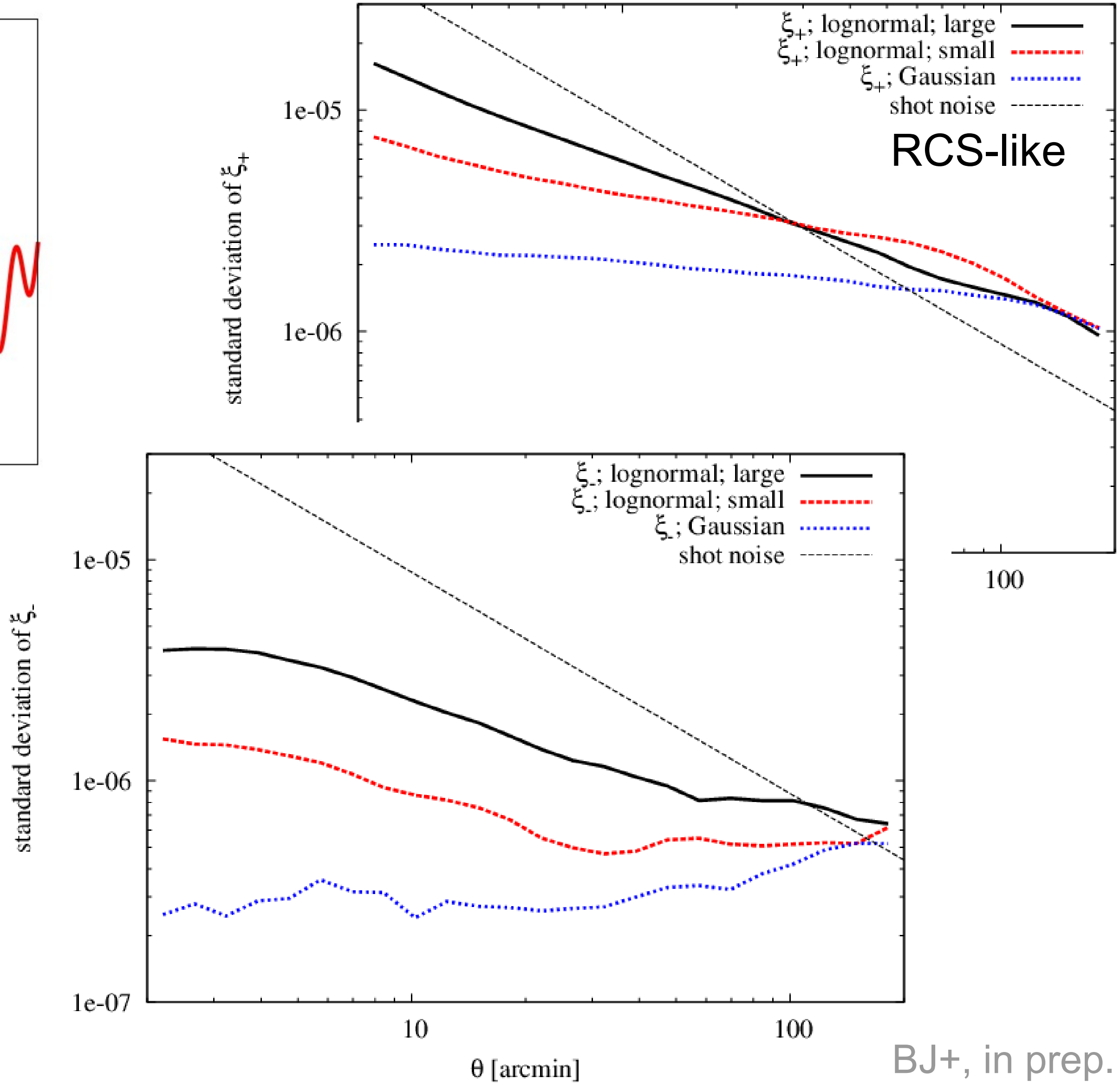
- Euclid-like N-body lightcones
- CFHTLenS mask applied
- 2 tomographic bins
- shear correlation functions

Error determination: super-sample covariance



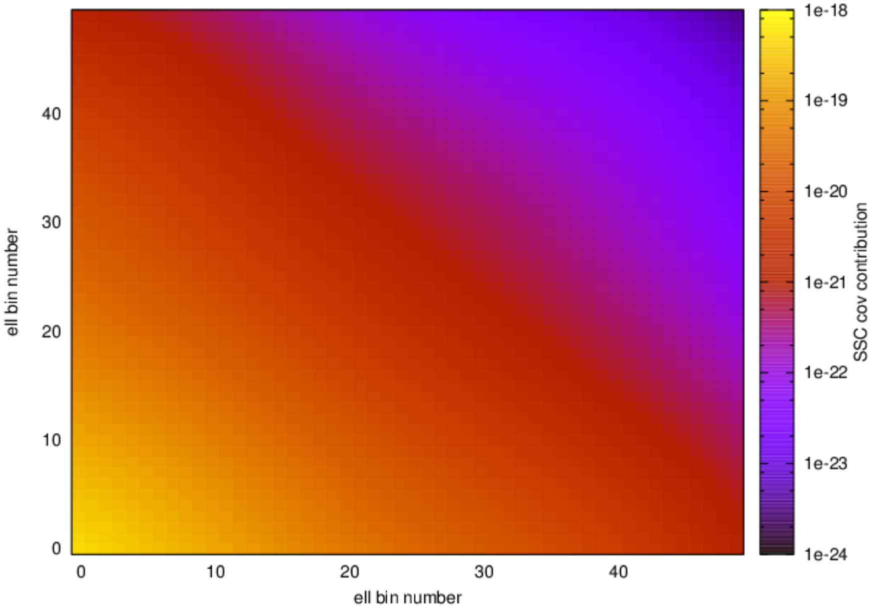
- super-survey modes couple to in-survey modes if non-Gaussian
- SSC contribution can attain same size as in-survey non-Gaussian covariance

Takada & Hu 13



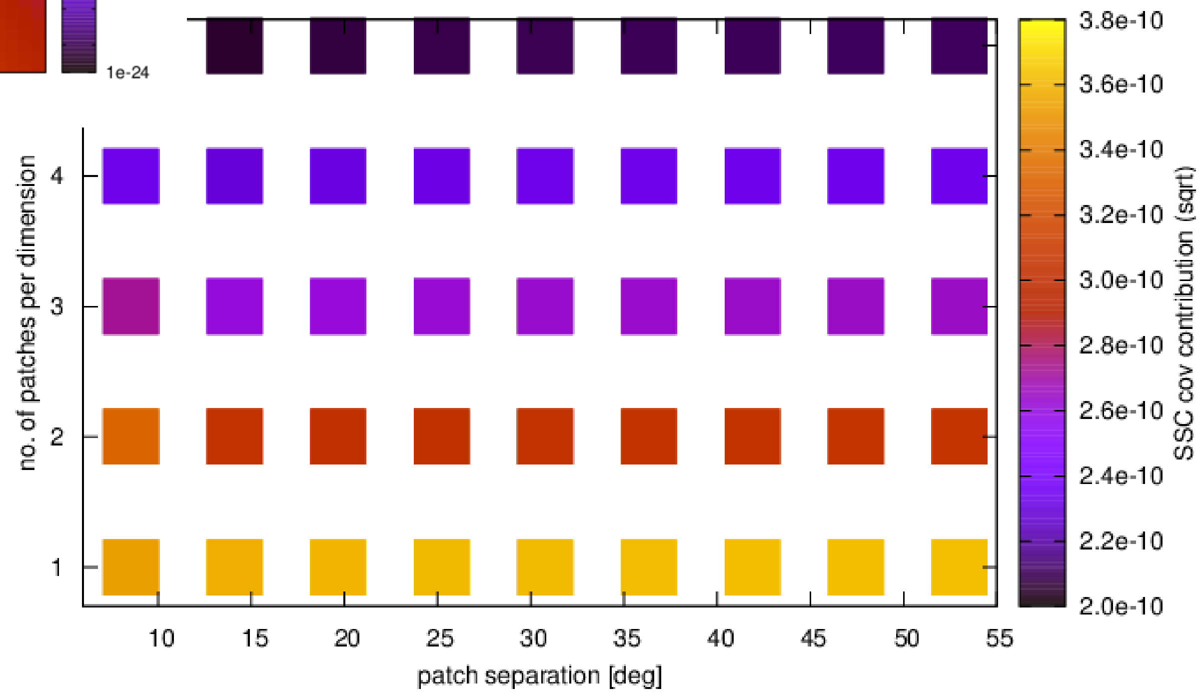
BJ+, in prep.

Error determination: super-sample covariance



BJ+, in prep.

see also
Takahashi+ 14



- SSC more significant on off-diagonals
- SSC suppressed for multiple survey patches

Conclusions

Key topics in weak lensing cosmology have seen good progress recently but still face major challenges:

- *shear estimation* methodology and calibration;
- *photometric redshift* characterisation;
- modelling *baryonic effects* on non-linear matter power spectrum;
- mitigating *intrinsic galaxy alignments*;
- precise and accurate *errorbars* on weak lensing statistics.

Lessons learnt:

- Precision cosmology with weak lensing is impossible without detailed understanding of the galaxy samples involved.

- A thorough understanding of all statistical properties and tools involved is vital for precision cosmological analyses of large-scale structure.