Can we do accurate cosmology with weak lensing?

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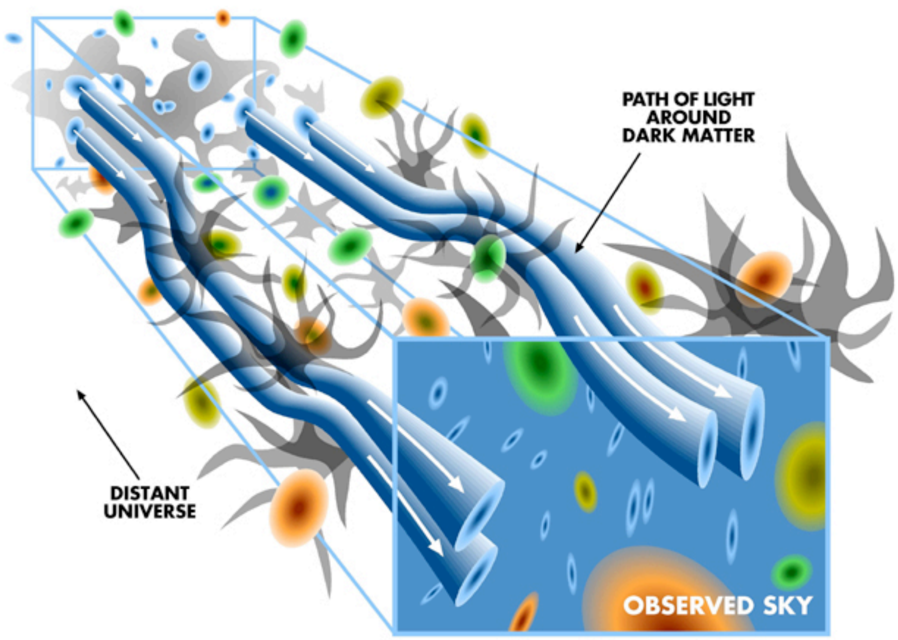
Lensing by large-scale structure



→ Cosmology?

The statistics of shape correlations as a function of angular scale and redshift can be used to *directly* infer the statistics of the matter density fluctuations.

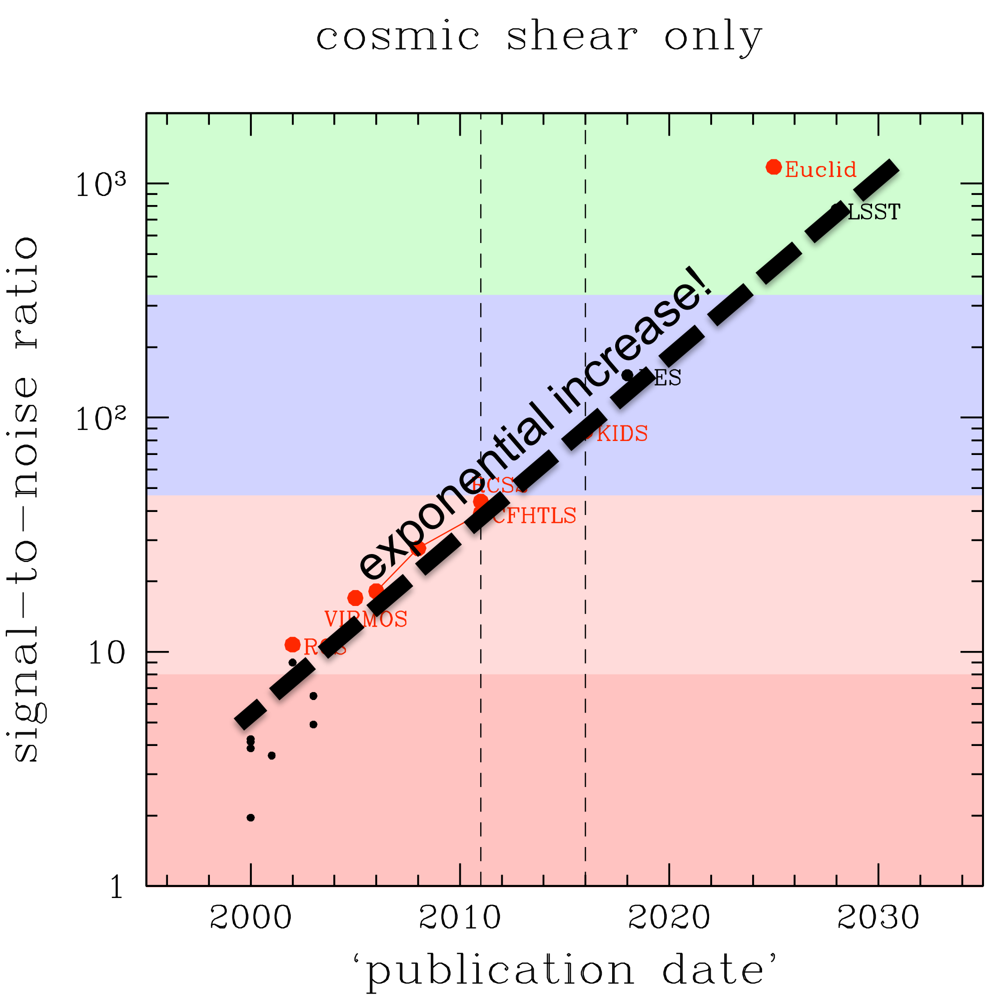
Cosmic shear

To make cosmic shear a precision probe of cosmology, all we need to do is to correlate shape measurements of large samples of galaxies. That is easy!

↓

We need to survey a large area of sky!

We are getting the numbers!



Dark energy physics

Dark energy constraints

Measurements

Detection

Precision ≠ Accuracy

For accurate cosmology we need:

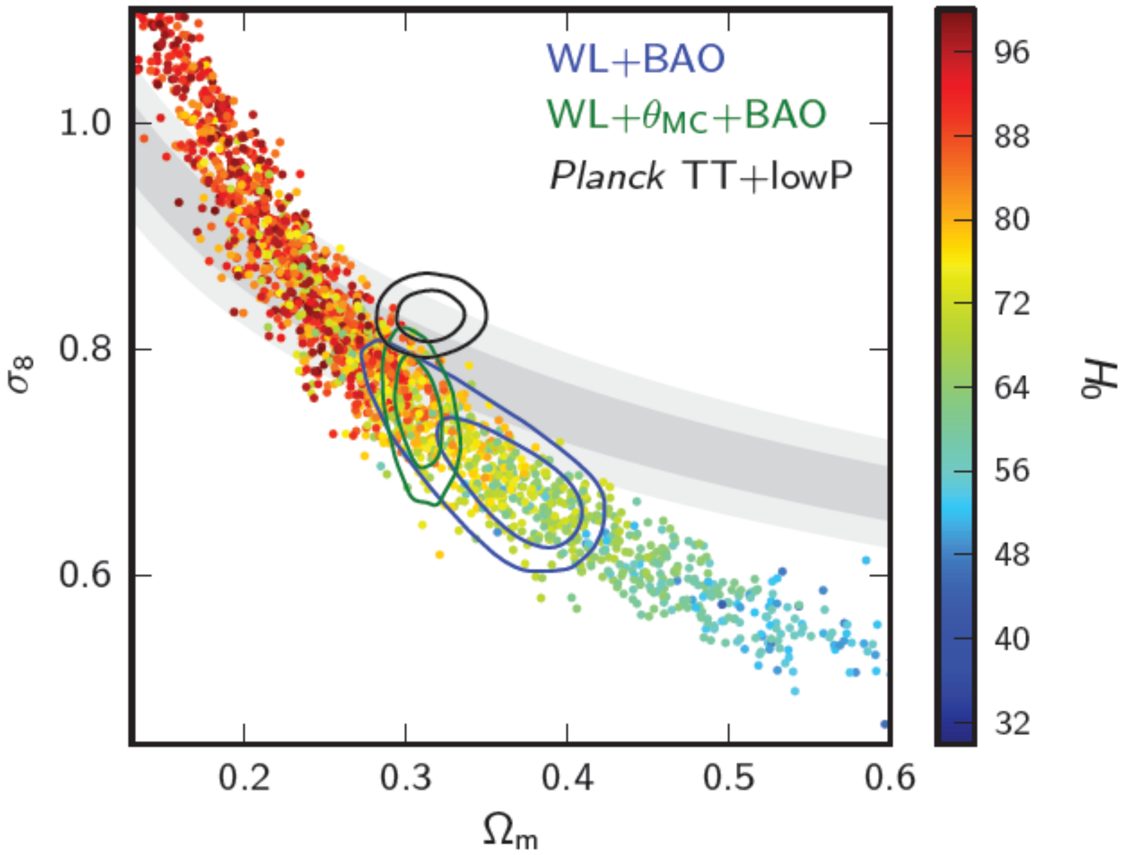
- accurate shapes for the sources
- accurate photometric redshifts
- accurate interpretation of the signal

The complications we have to deal with:

- Observational distortions are larger than the signal
- Galaxies are too faint for large spectroscopic surveys
- Sensitive to non-linear structure formation

Cosmology or astrophysics? Or systematics?

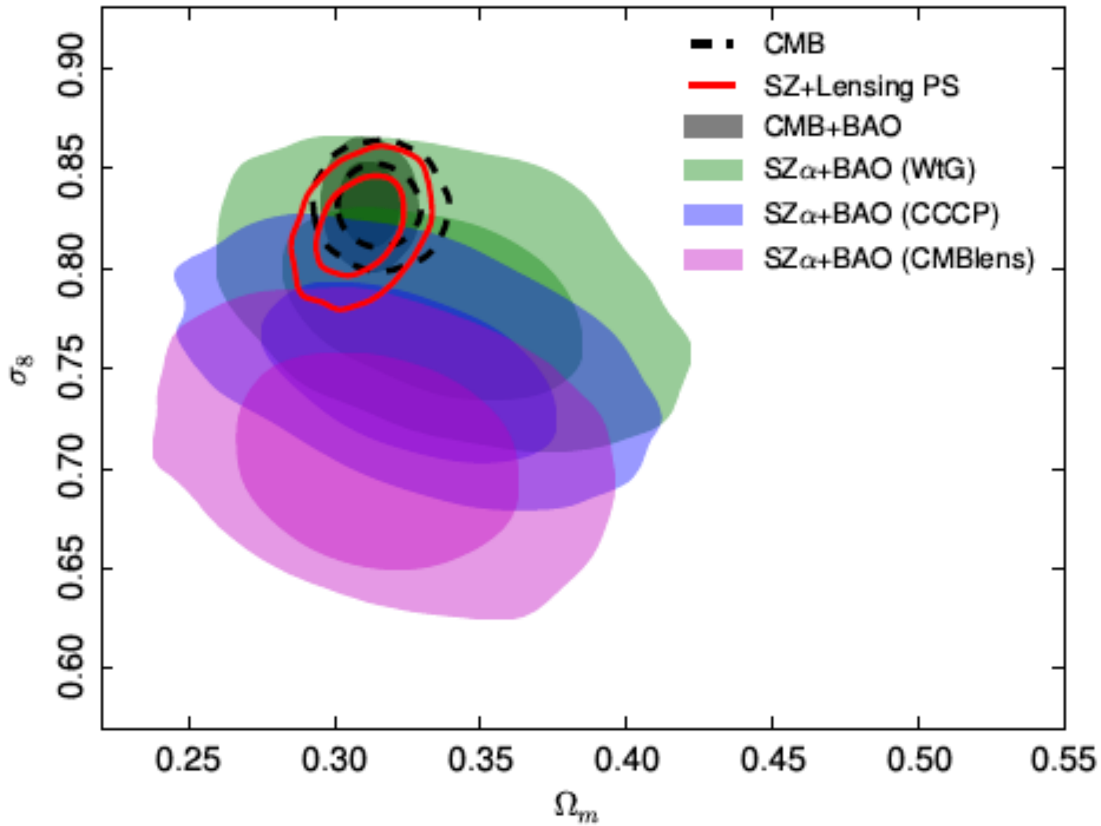
CFHTLenS vs Planck primary CMB results



Planck collaboration, XIII (2015)

Cosmology or astrophysics? Or systematics?

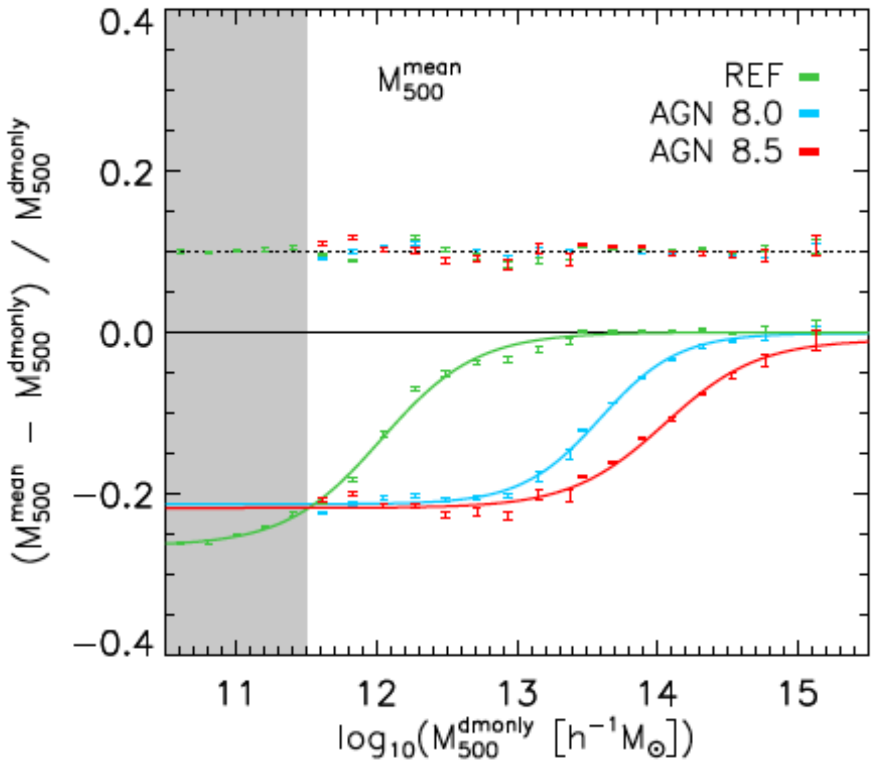
Planck cluster counts vs Planck primary CMB results



Planck collaboration, XXIV (2015)

Cluster cosmology and astrophysics

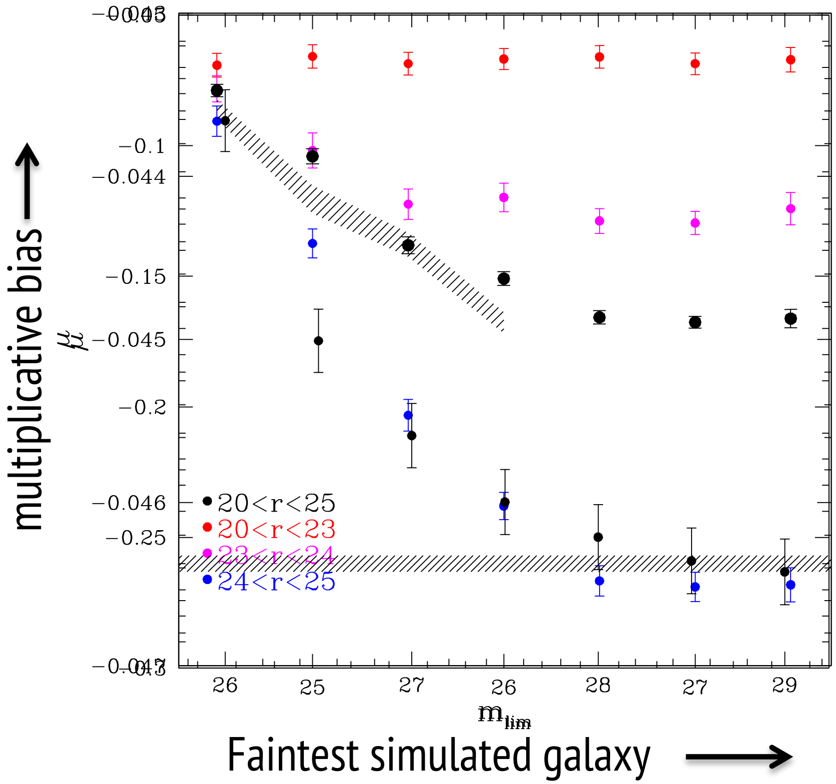
The cluster mass function is not very sensitive to astrophysics, but the mass proxies are! The mass-observable relation can be calibrated observationally using weak gravitational lensing.



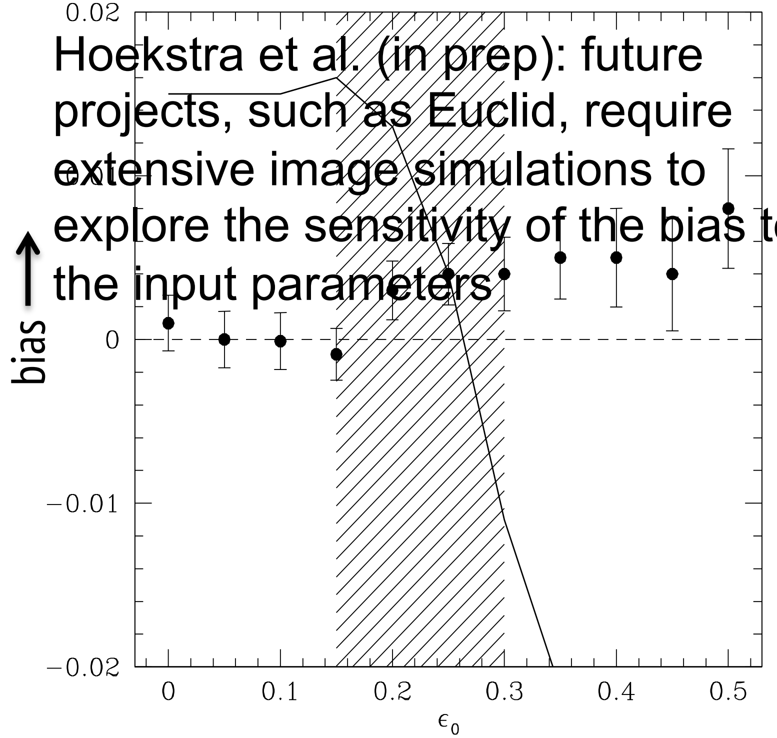
Velliscig et al. (2014)

Importance of *good* image simulations

The accuracy of weak lensing measurements can be determined using image simulations. However, the results are only meaningful if the simulations match the data!

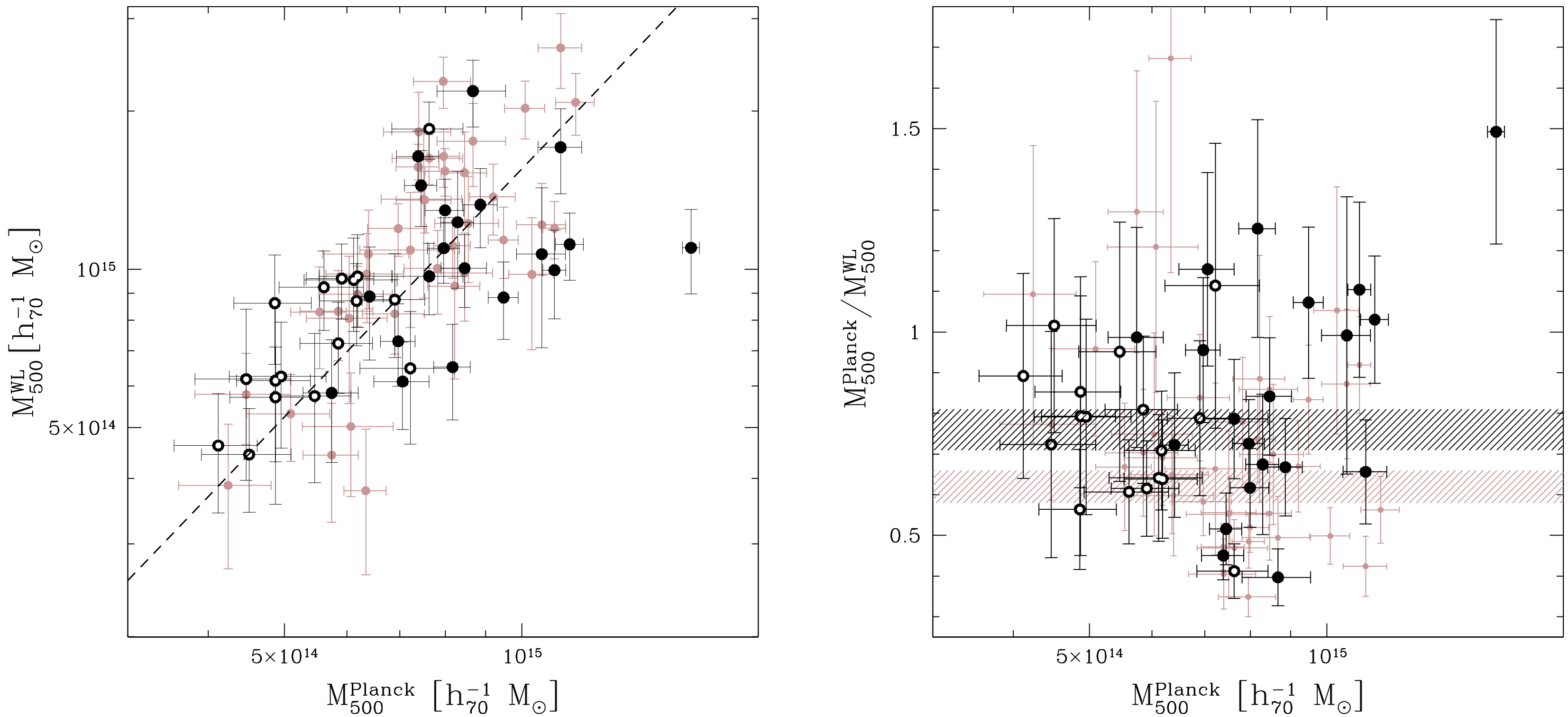


Hoekstra et al. (2015)



Hoekstra et al. (in prep): future projects, such as Euclid, require extensive image simulations to explore the sensitivity of the bias to the input parameters

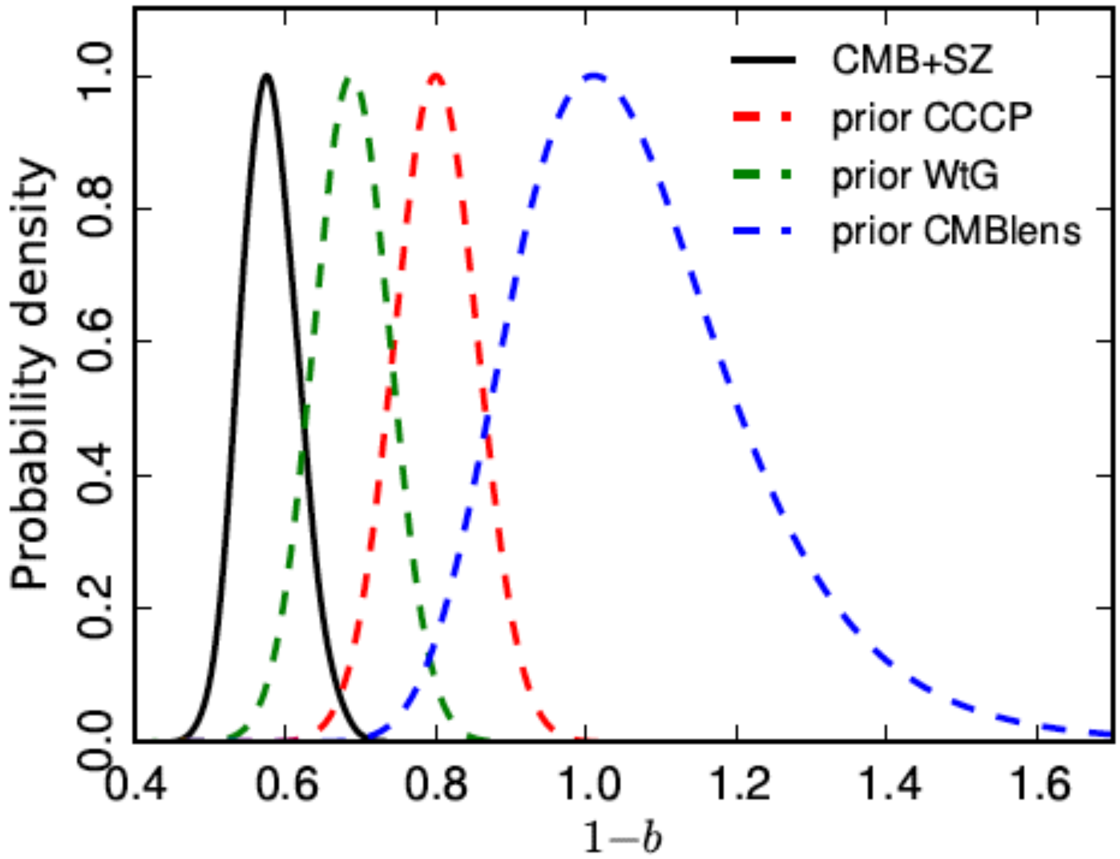
Calibration of *Planck* cluster masses



Hoekstra et al. (2015)

$$M_{Planck} = (0.76 \pm 0.05)\ M_{WL}$$

Perhaps it is the cosmology?



Planck collaboration, XXIV (2015)

Cosmology with galaxy clusters

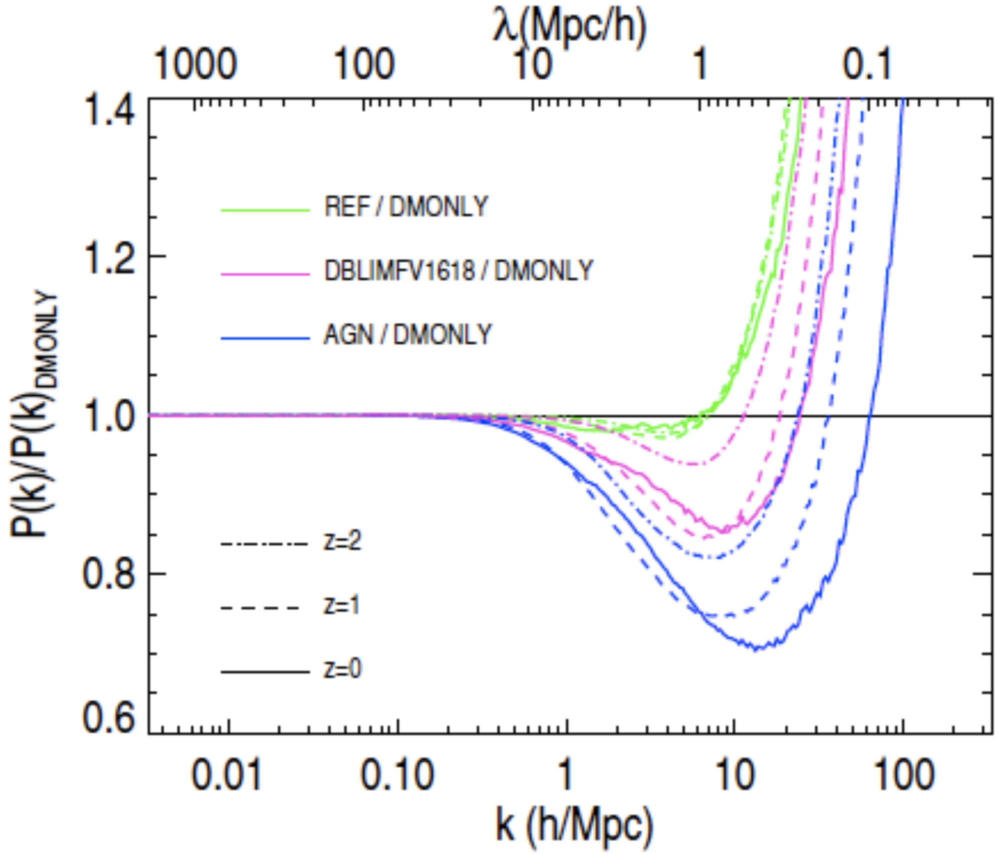
Although the relation between the cluster observables and the mass can be calibrated using weak lensing, many complications remain:

- Halo properties depend on cosmology and astrophysics
- The selection function depends on astrophysics

It is difficult to separate the astrophysics from the cosmology, especially when looking for subtle effects, such as evolving dark energy or modified gravity.

So we need to do cosmic shear after all?

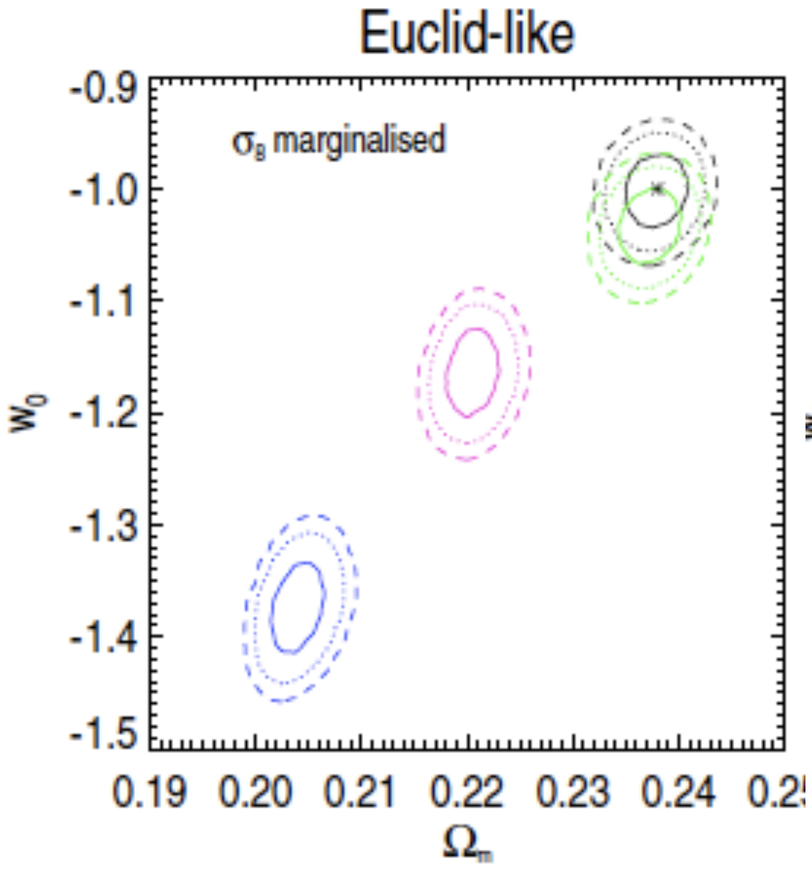
Baryonic physics



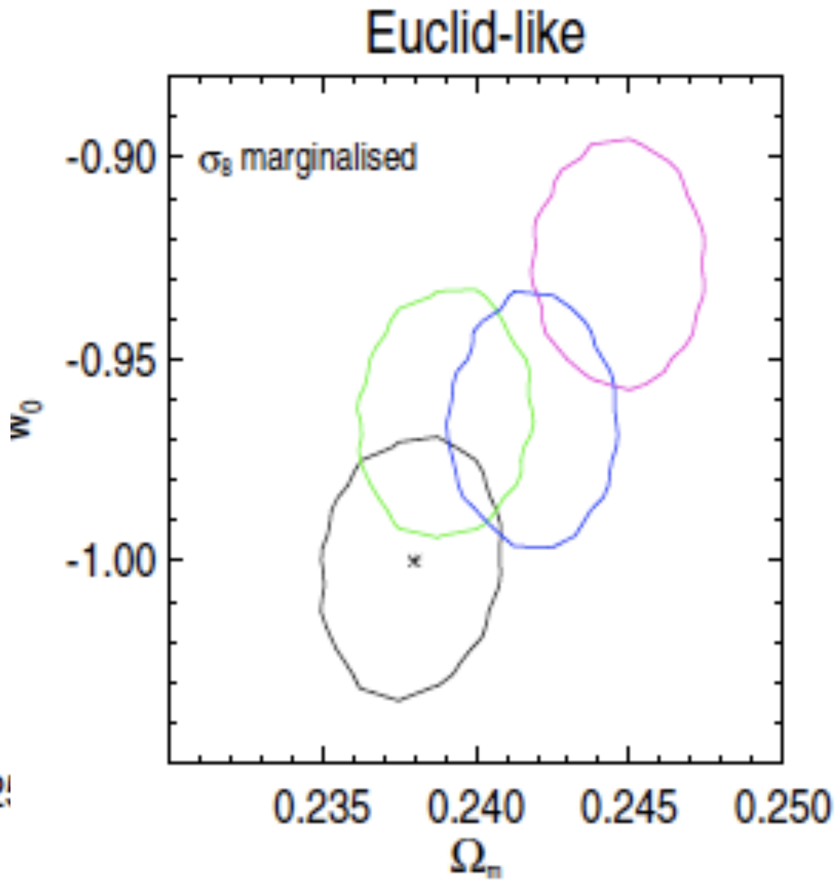
van Daalen et al. (2011)

Feedback can modify the matter power spectrum significantly!

We cannot ignore the (g)astrophysics



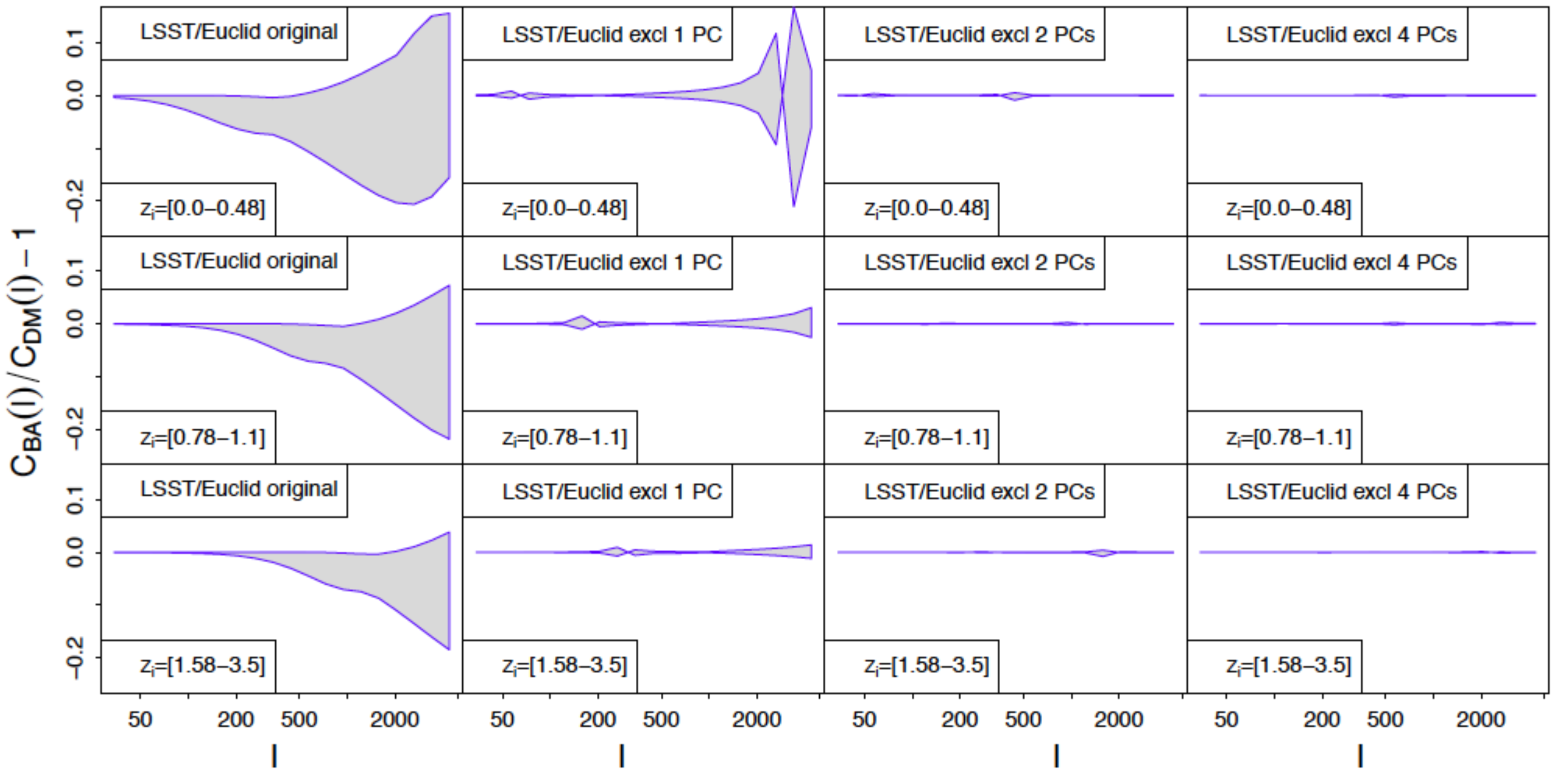
Feedback ignored



Accounted for feedback

Semboloni et al. (2011)

Treat as a nuisance?



Eifler et al. (2014): find the principal components of the changes to the power spectrum to account for baryon physics in real data. Seems to work when compared to simulations.

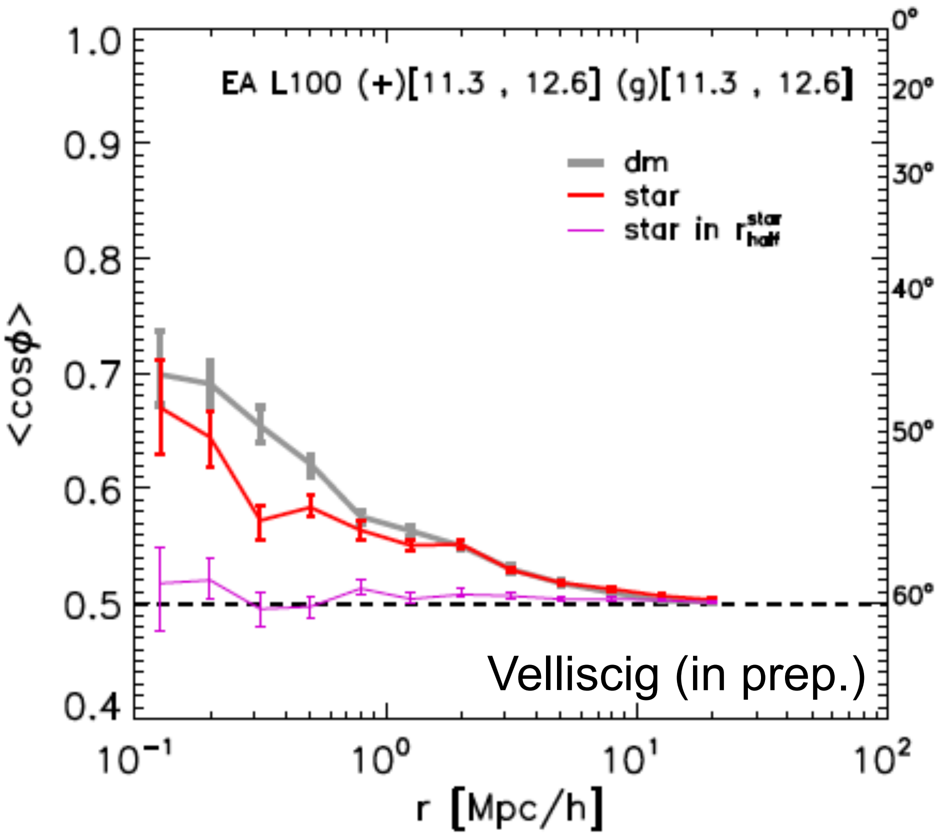
More complications: intrinsic alignments

The halos of galaxies are aligned due to tidal torques and the filamentary structure of the matter distribution. This is an old problem, going back to the question how galaxies obtain their angular momentum.

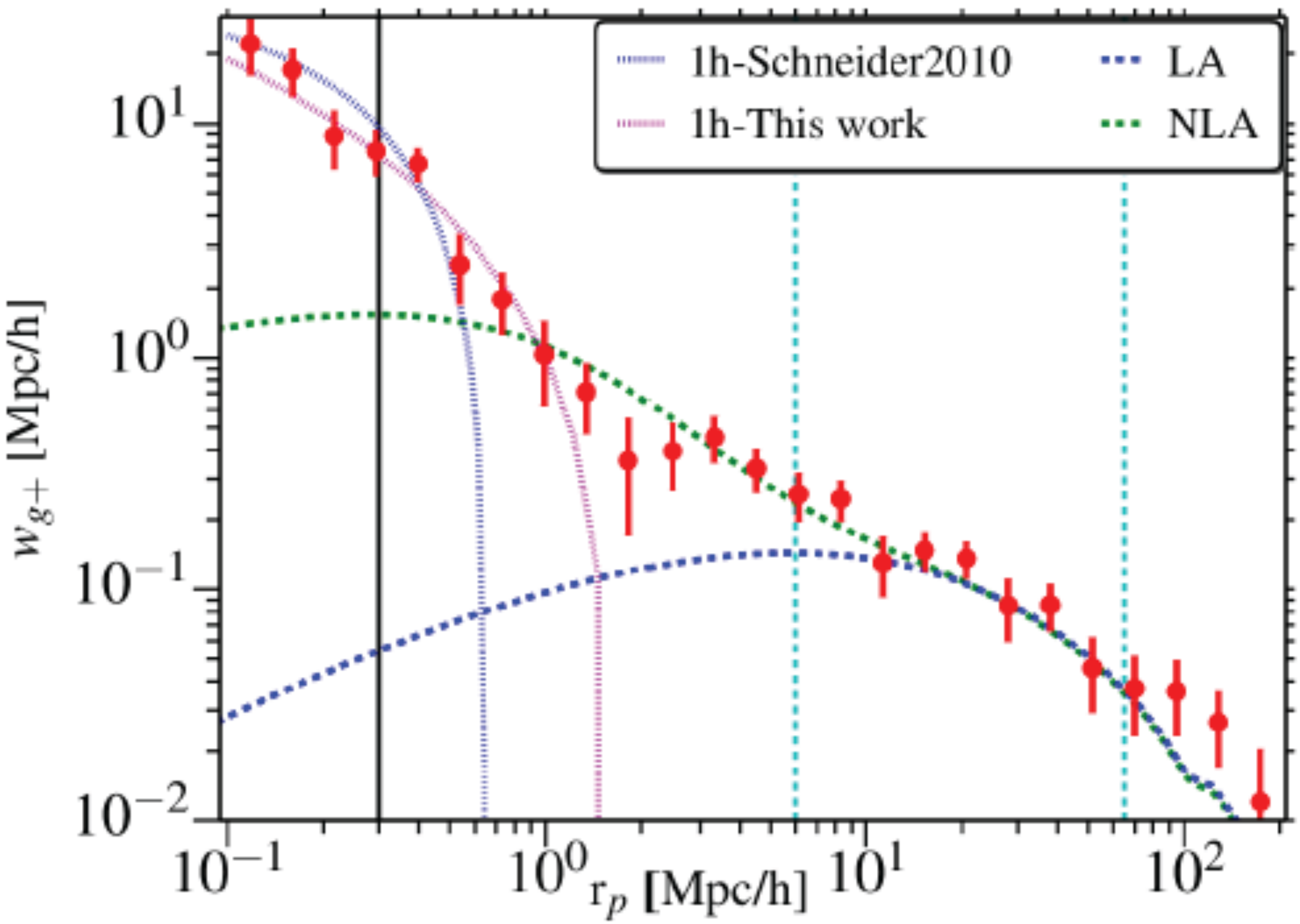
We expect intrinsic alignments of galaxies, but the details depend on galaxy formation.

Intrinsic Alignments: more astrophysics

Baryon physics leads to misalignments: the distribution of stars in galaxies differs from the dark matter.

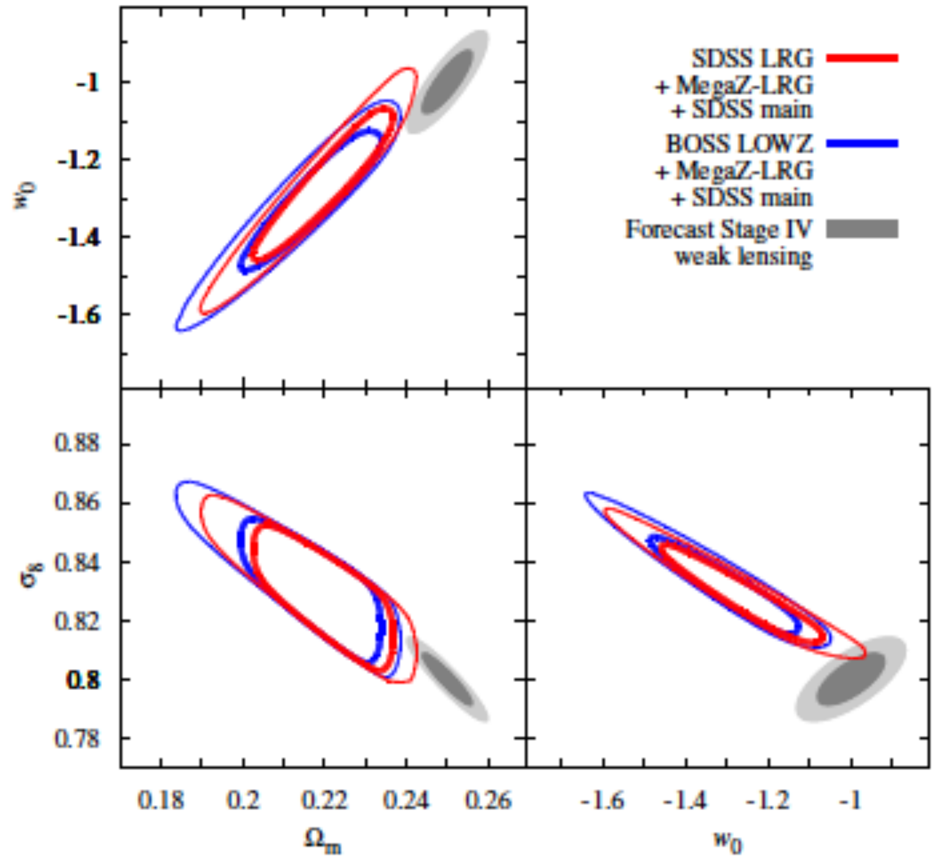


Intrinsic alignments: they do exist!



Singh et al. (2014)

Intrinsic alignments: they cannot be ignored!



Joachimi et al. (2015)

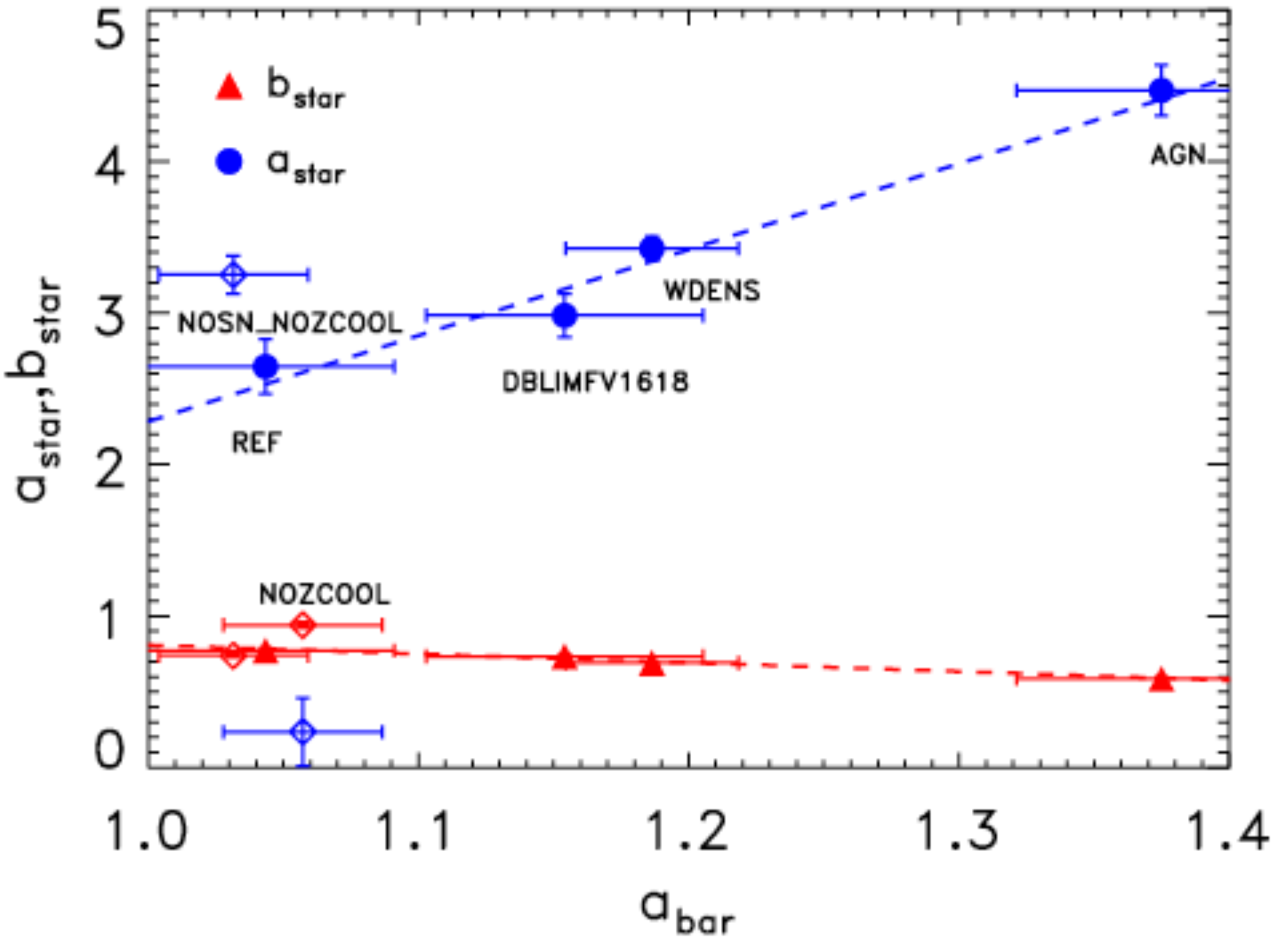
Related problems?

We know (too) little about intrinsic alignments of galaxies:

- How do they depend on galaxy type?
- Can we use predictions from hydro-simulations?
- Can we use a hybrid of hydro and N-body results?

- How are IA mitigation strategies affected by mitigation strategies for baryon feedback?

What if the simulations are too simple?



Semboloni et al. (2013)

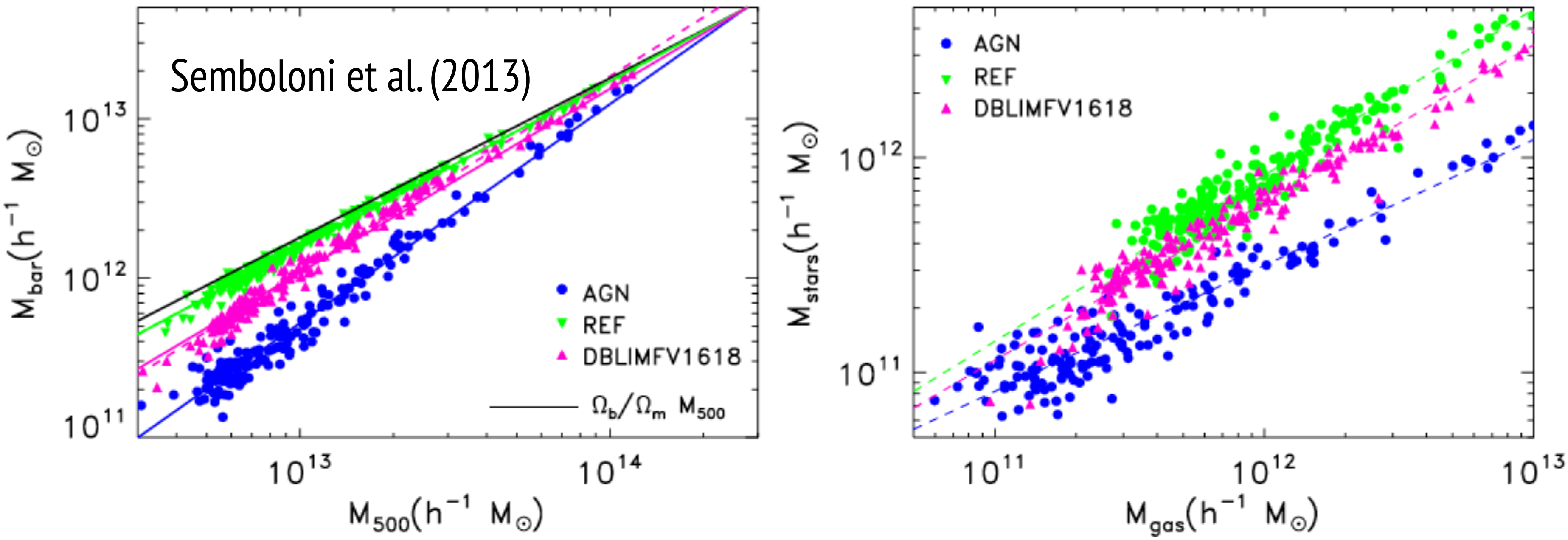
Astrophysics: problem or opportunity?

For accurate cosmology we need correct astrophysics.

Marginalizing over nuisance parameters with uninformative priors reduces the performance of a survey, implying a new cost-benefit analysis would be needed: one might wish to consider a different strategy instead…

Marginalizing over nuisance parameters is not a solution! Rather, we should improve our understanding of astrophysics and learn something new!

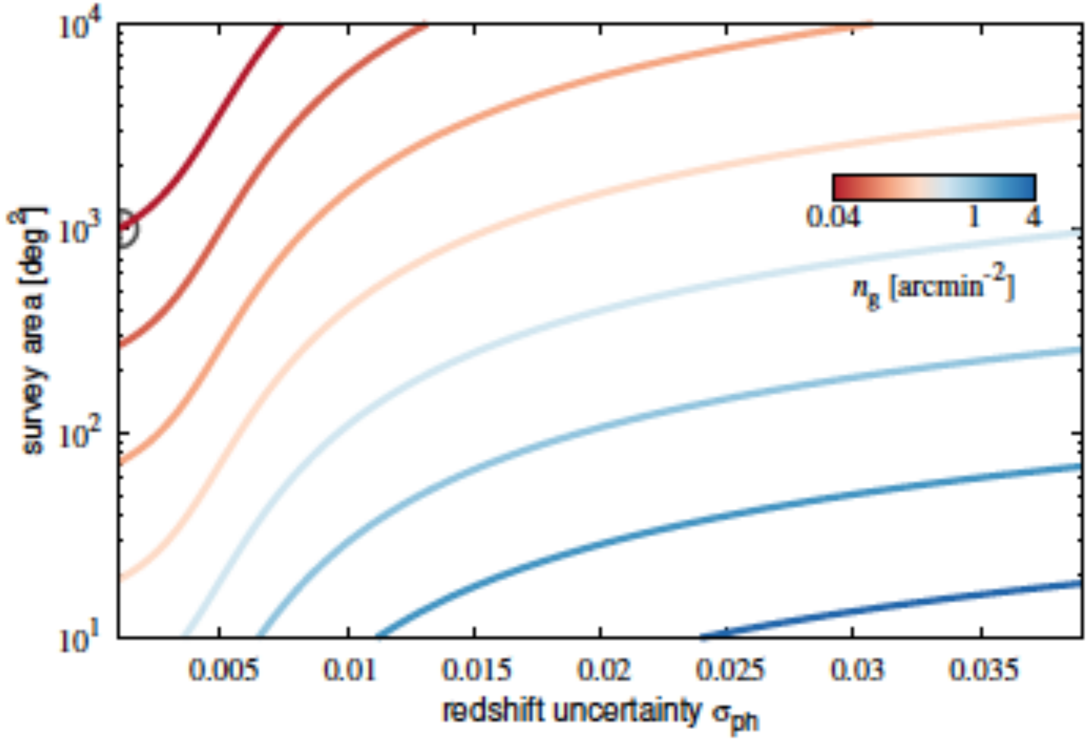
Feedback changes scaling relations



We should constrain the scaling relations observationally, especially by studying the properties of groups of galaxies: see the talk by Massimo Viola a recent result from KiDS.

Better IA observations

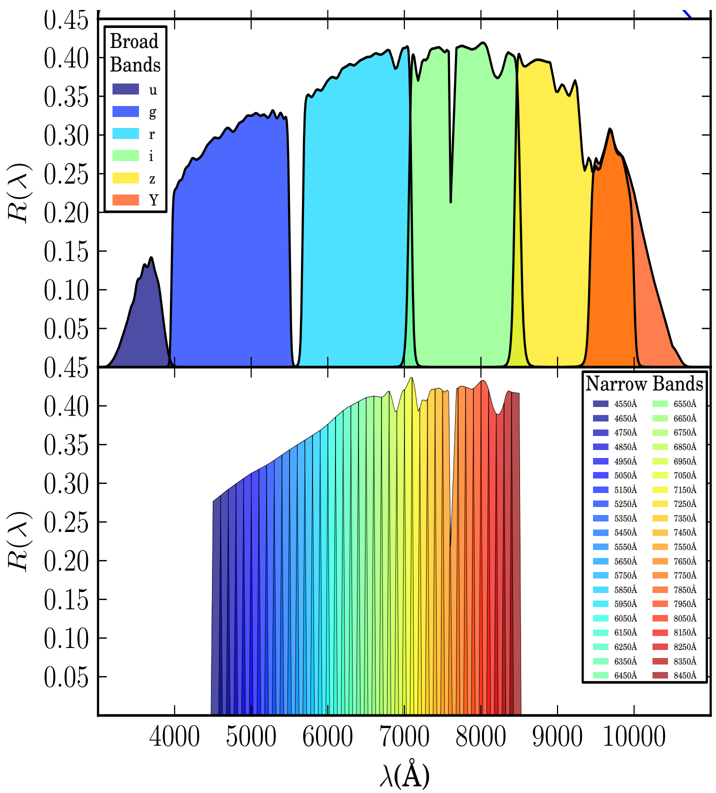
To improve constraints on intrinsic alignment models we need dense coverage with good redshift precision.

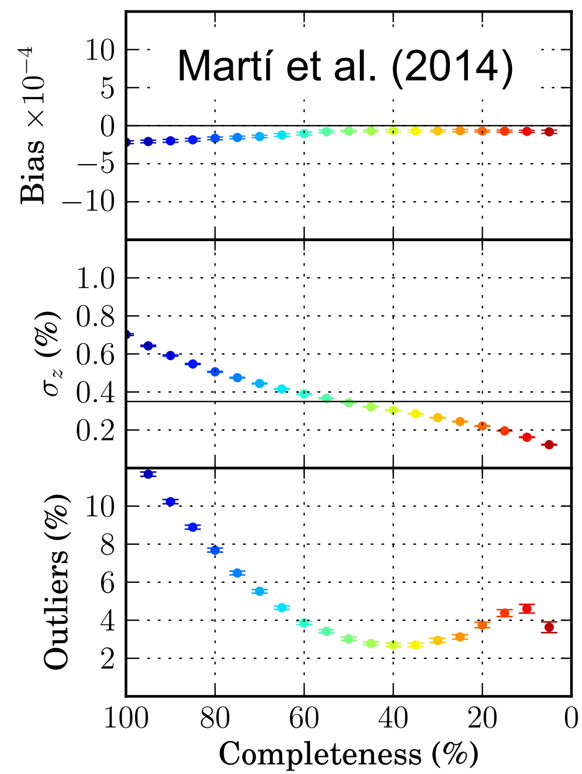


Joachimi et al. (2015)

PAUCam Survey

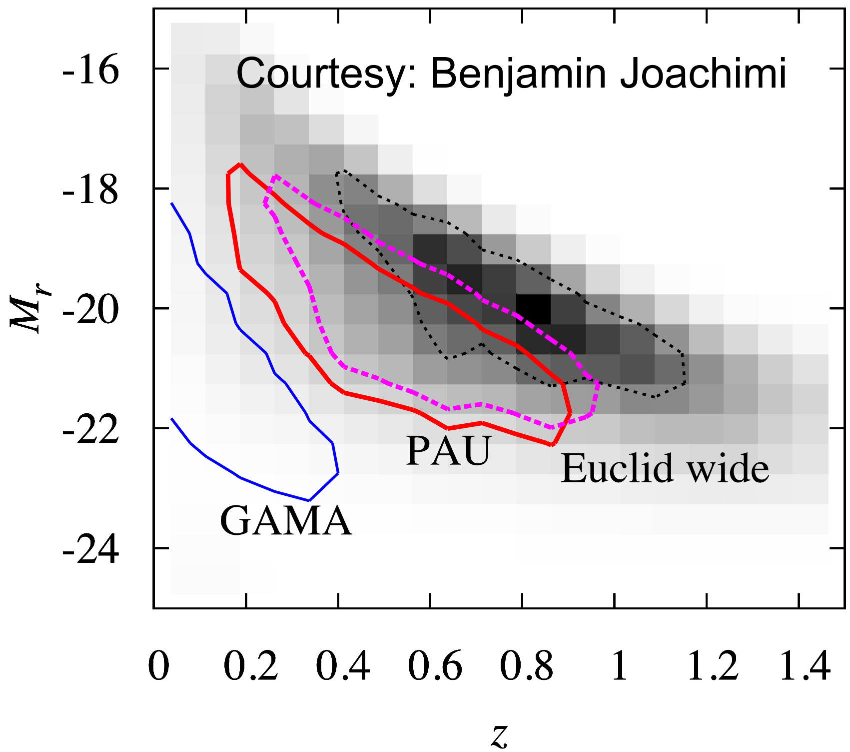
A 40 narrow-band survey can deliver the coverage and redshift precision we need. The PAUCam has been commission and a pilot survey will start in the fall!

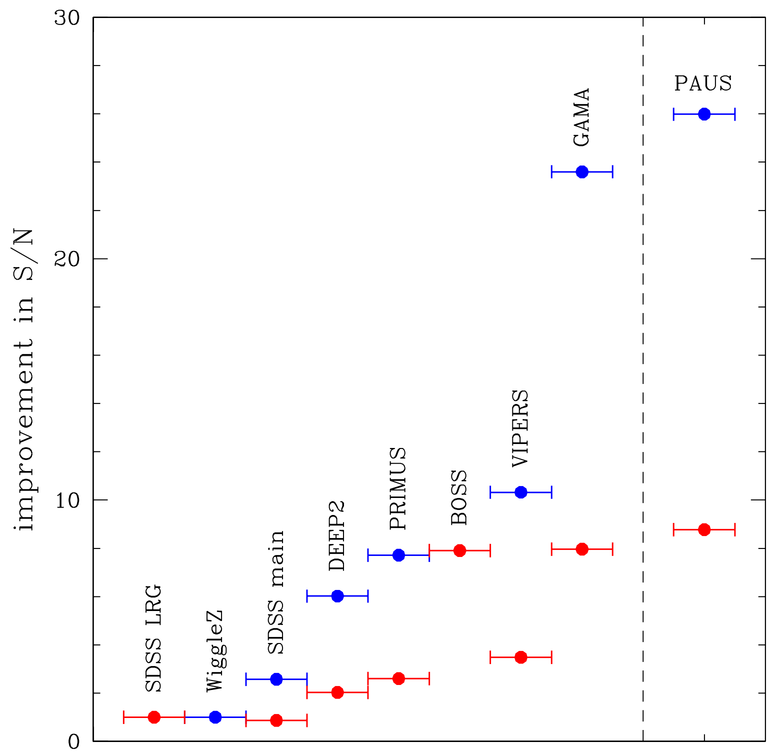




PAUCam Survey

The PAUCam Survey will improve constraints for higher redshift galaxies and blue galaxies in particular.





Conclusions

Approaches to correct cosmology for incorrect astrophysics are valuable, but should be considered plan B as the reduction in performance is typically large.

Plan A should be to understand the astrophysical biases better through a combination of dedicated observations and improves simulations.

Then we can infer *Correct* Astrophysics, and do *Accurate* Cosmology with weak gravitational lensing!