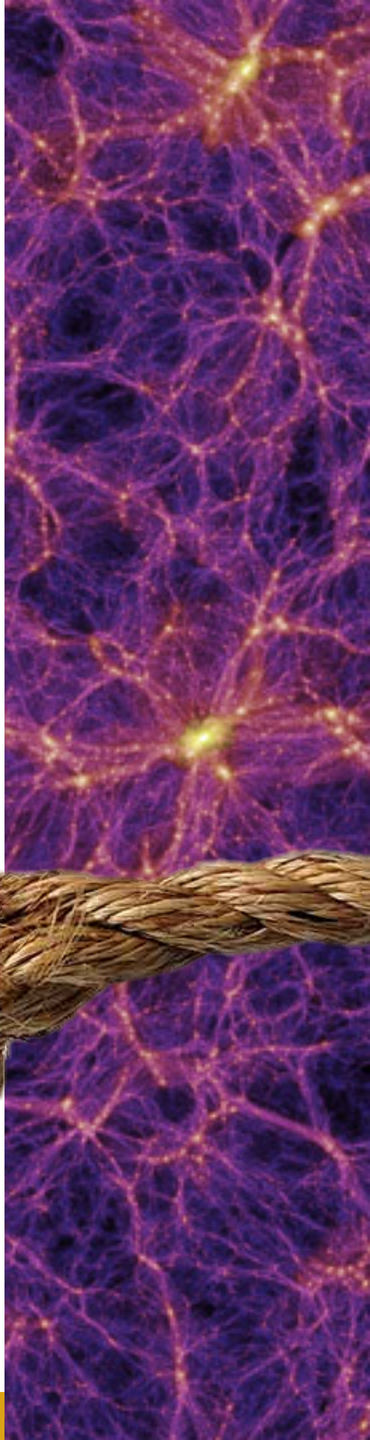
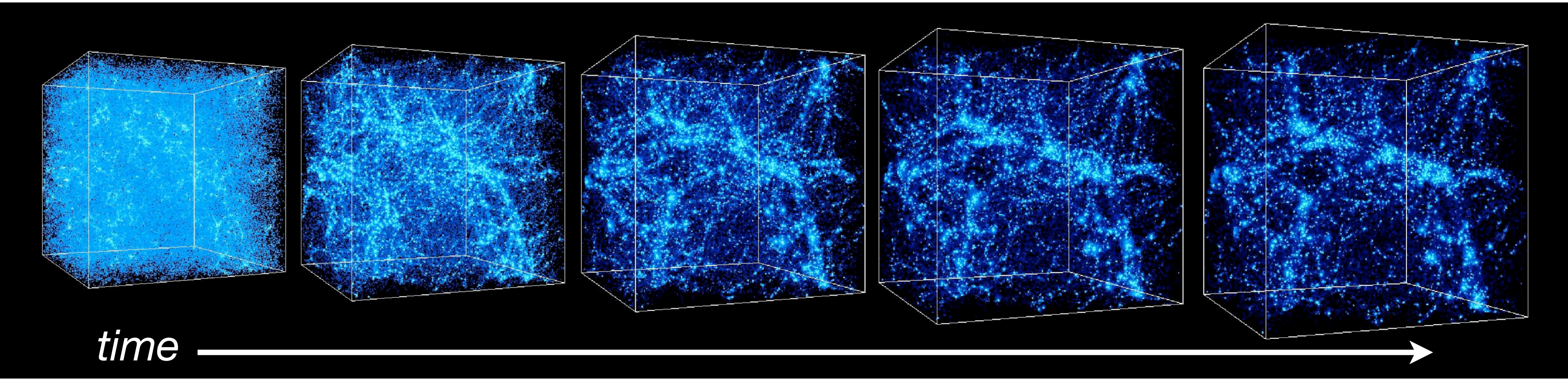


Tension between LSS and CMB

Henk Hoekstra
Leiden University

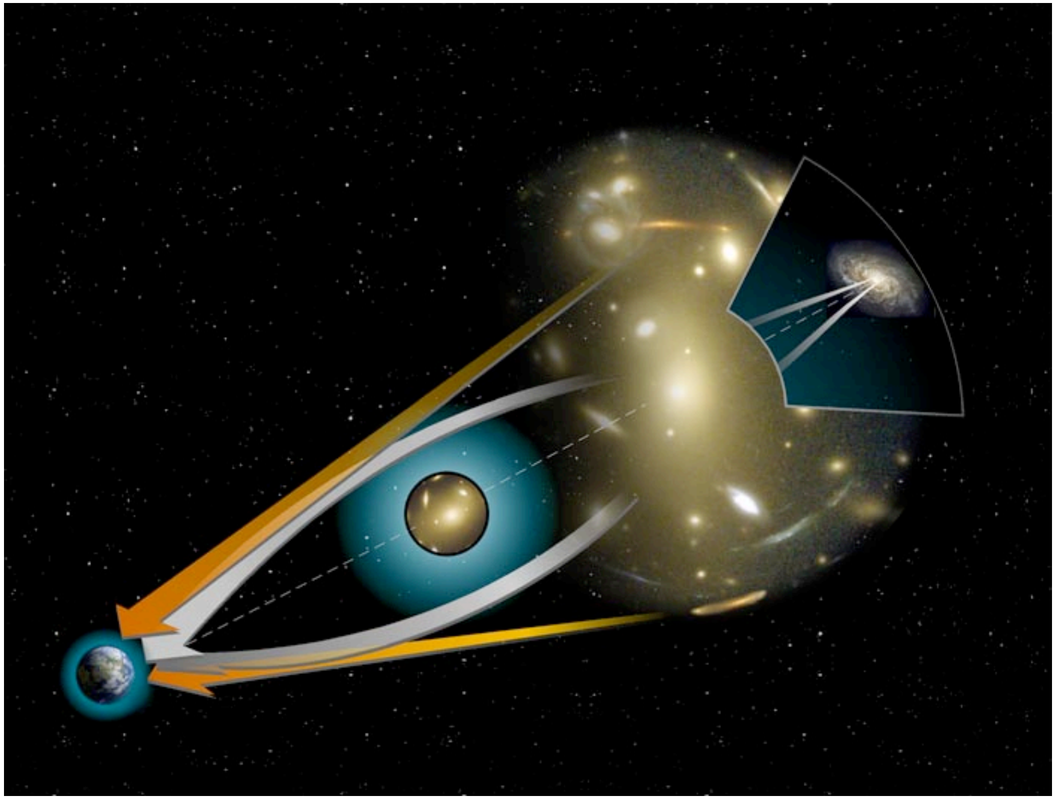
Clustering of matter



The cosmological parameters set the expansion history of the Universe and thus specify the growth of large-scale structures for a given theory of gravity.

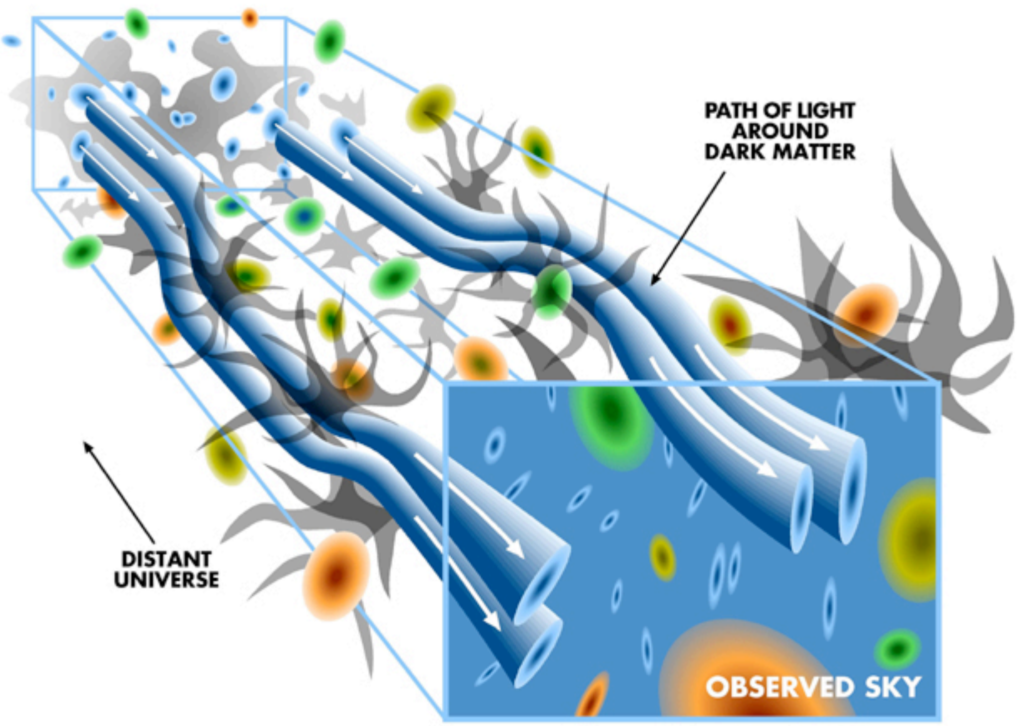
Statistics of density fluctuations → Cosmological parameters

Can we "see" the clustering of matter?



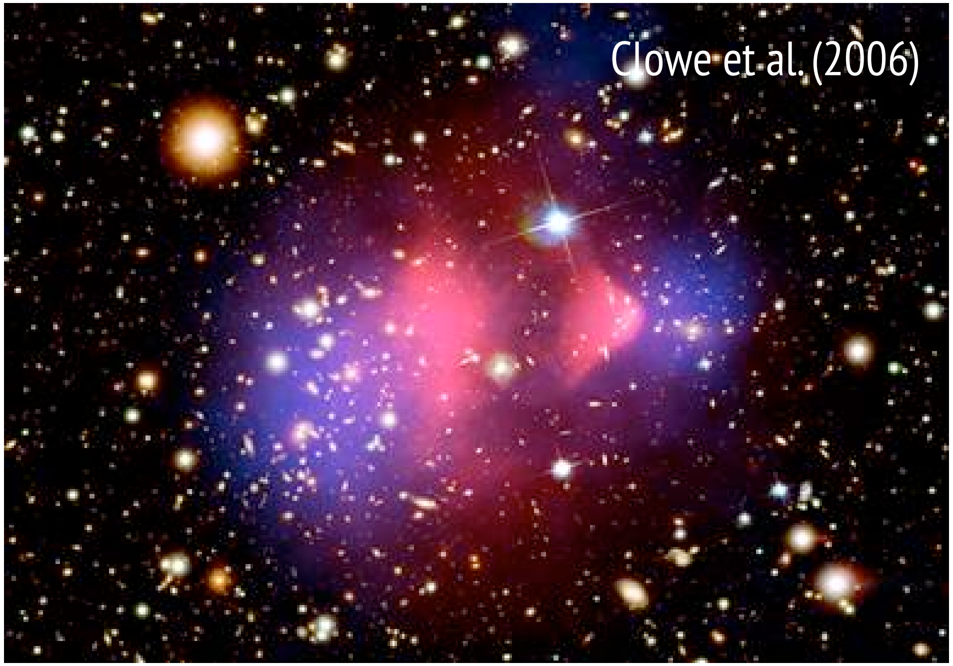
Density fluctuations in the universe affect the propagation of light rays, leading to correlations in the the *observable* shapes of galaxies.

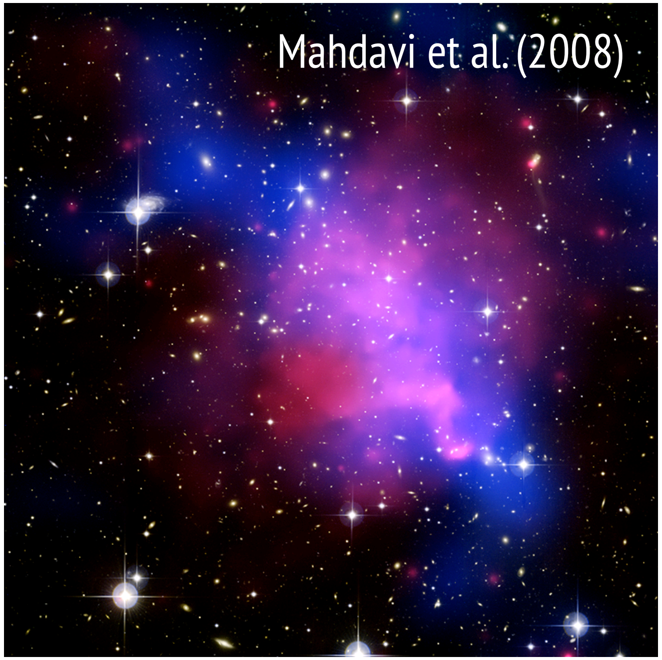
Cosmic shear: statistics of large-scale structure



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

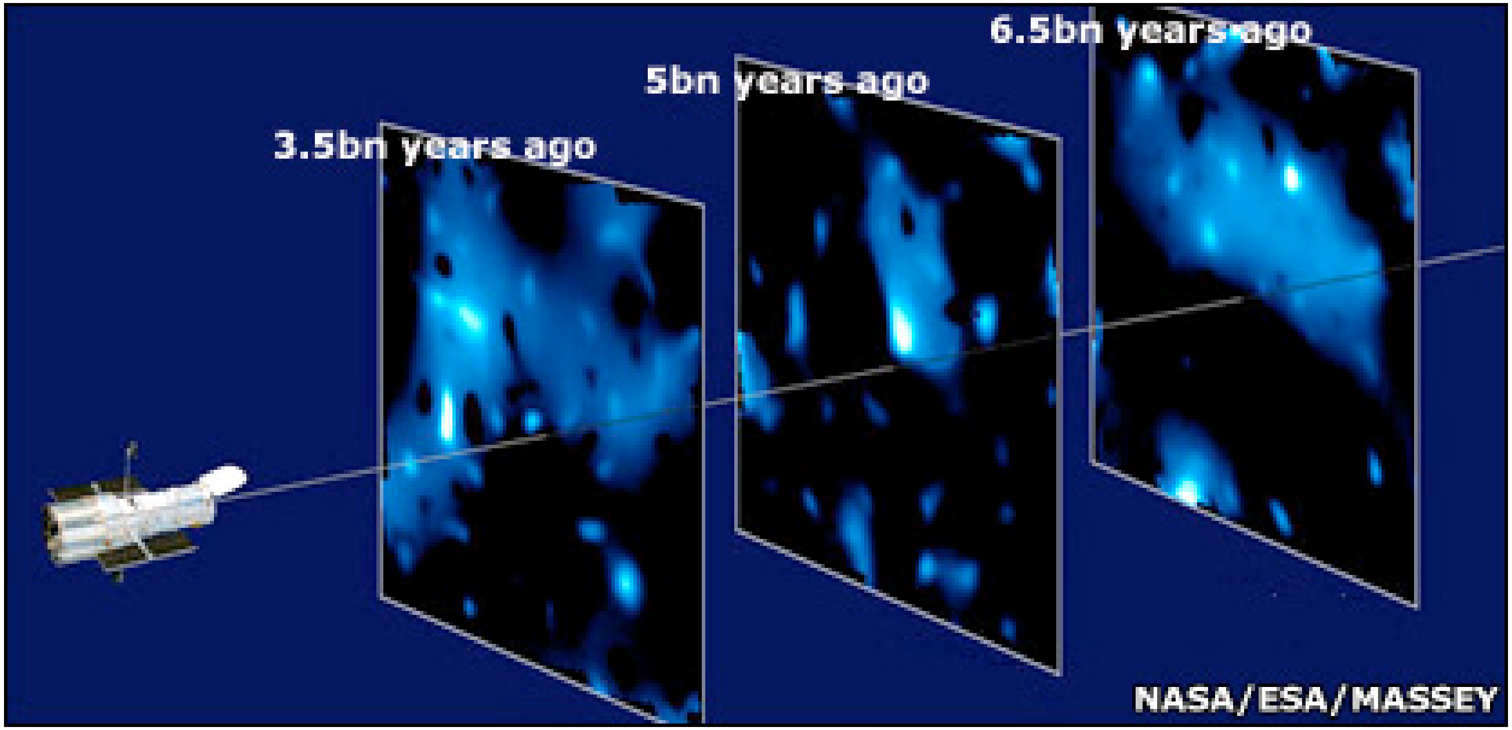
We can see dark matter!





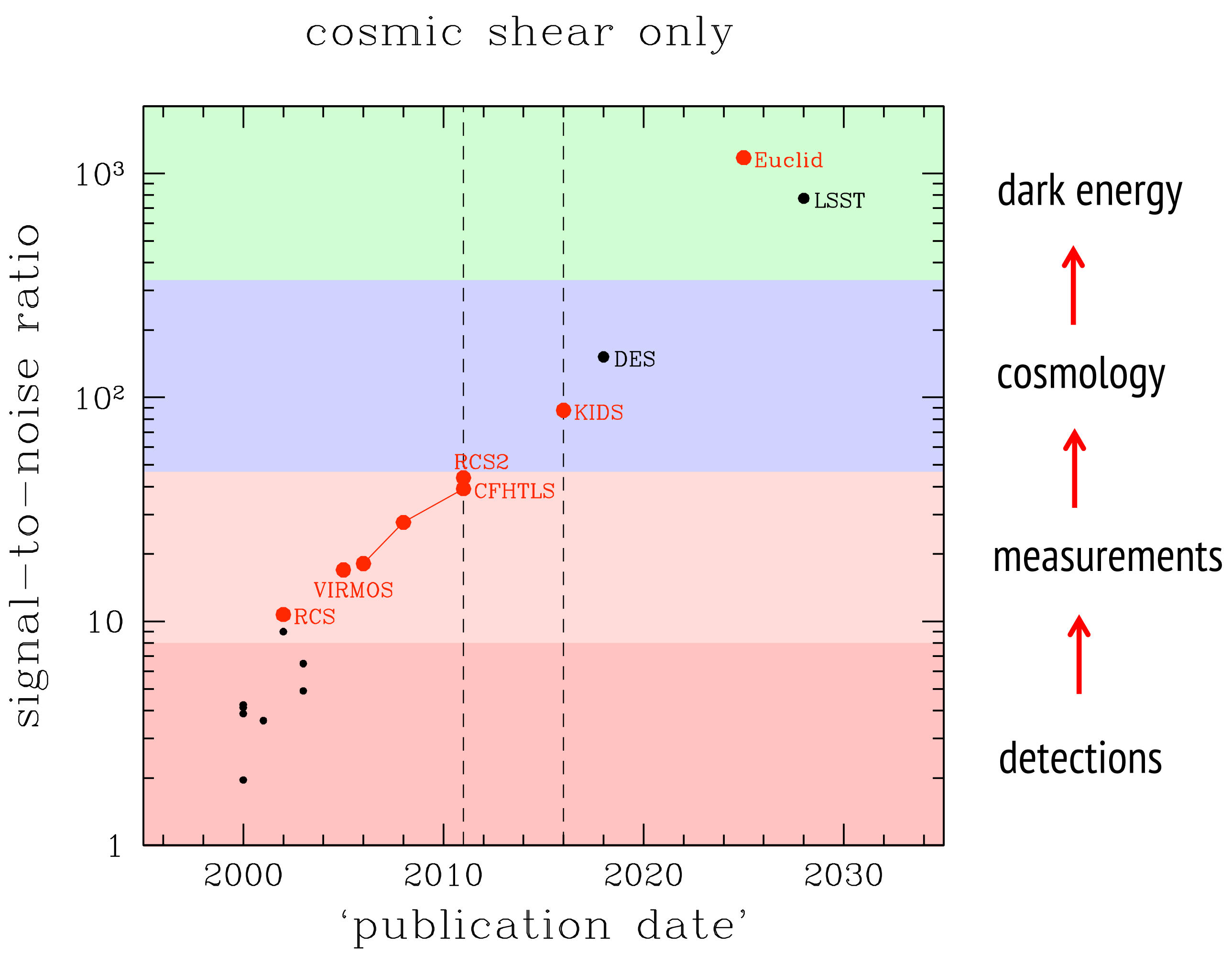
By averaging the shapes of many galaxies it is possible to reconstruct the (projected) matter distribution, independent of the dynamical state of the object of interest (e.g. a cluster of galaxies)

3d mapping of the Universe



We need to measure the matter distribution as a function of redshift: in addition to the shapes, weak lensing tomography requires photometric redshifts for the individual sources.

The precision is increasing...

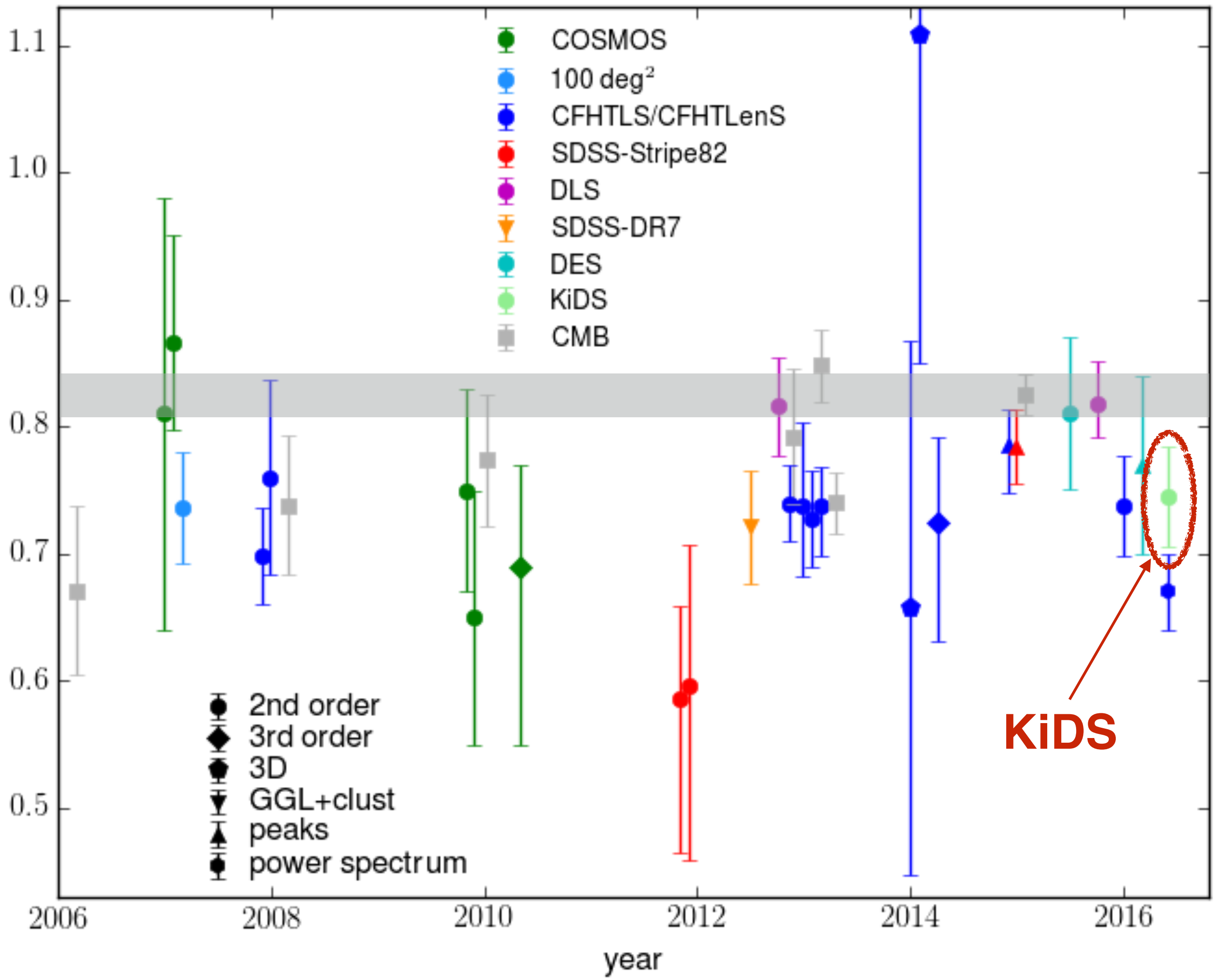


Cosmic shear constraints over the years

Kilbinger et al. (2015; updated)

"clumpiness"

$$S_8 \equiv \sigma_8 \sqrt{\frac{\Omega_m}{0.3}}$$



Precision ≠ Accuracy

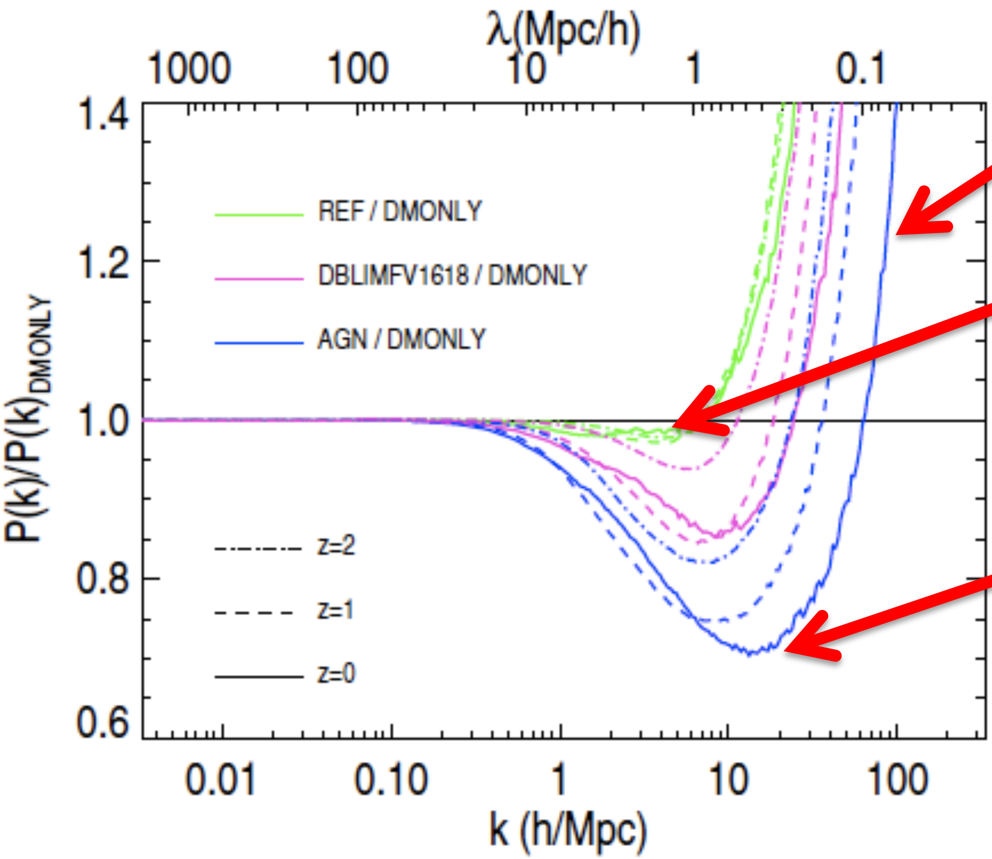
For accurate cosmology we need:

- 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

Baryonic physics changes the power spectrum



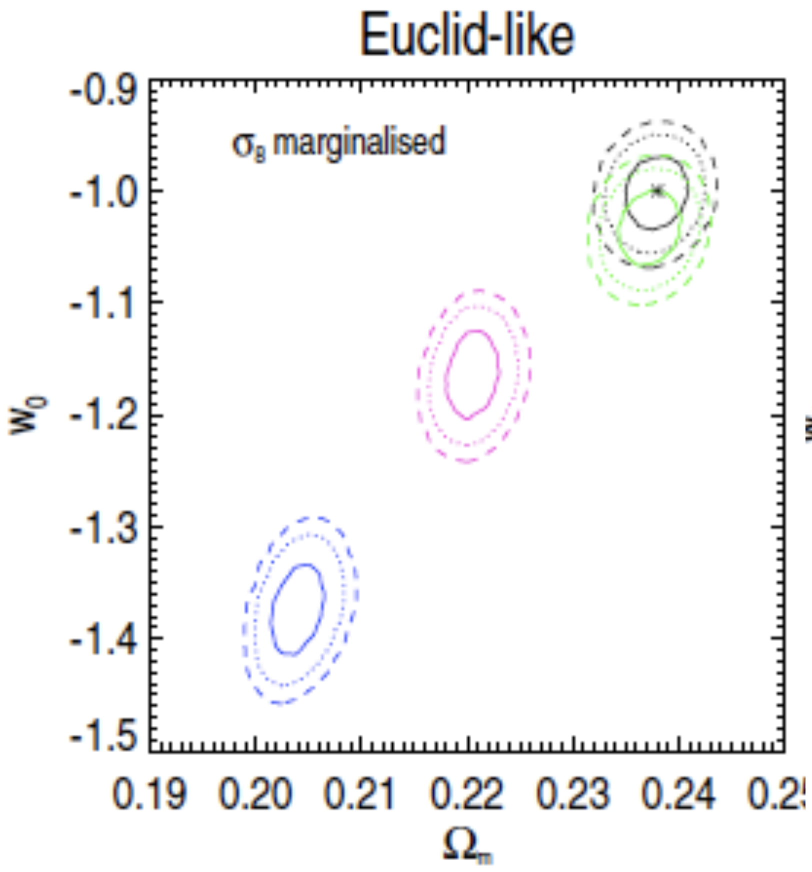
Gas cooling increases the density fluctuations

Gas pressure smoothens the density fluctuations

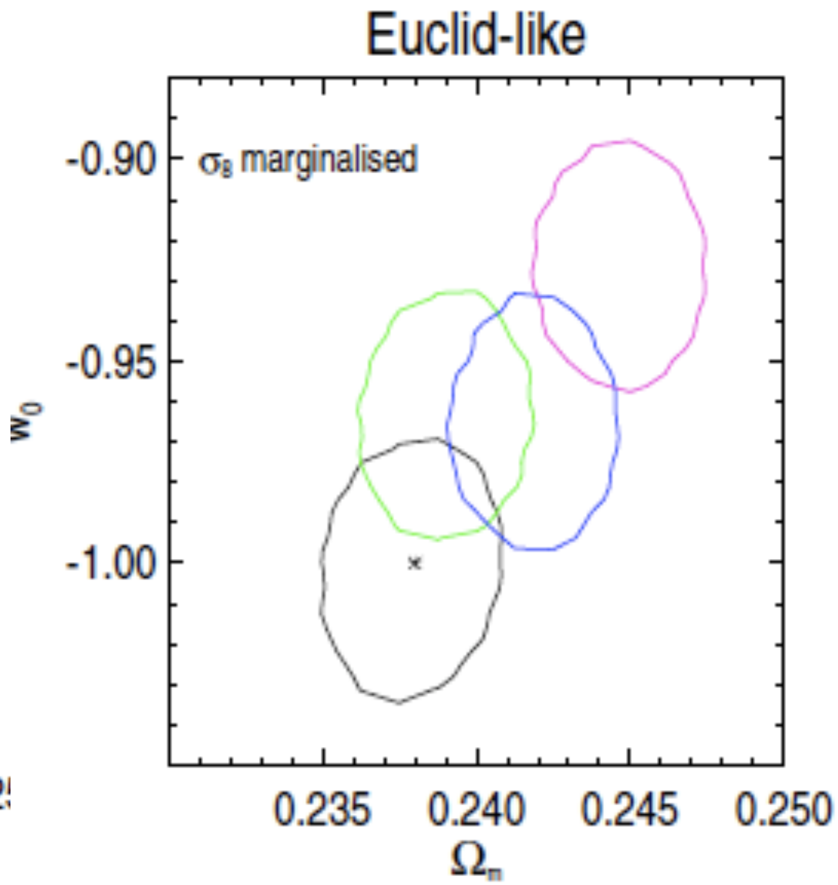
AGN removes gas from galaxy groups

Semboloni et al. (2011)

We cannot ignore the (g)astrophysics



Feedback ignored

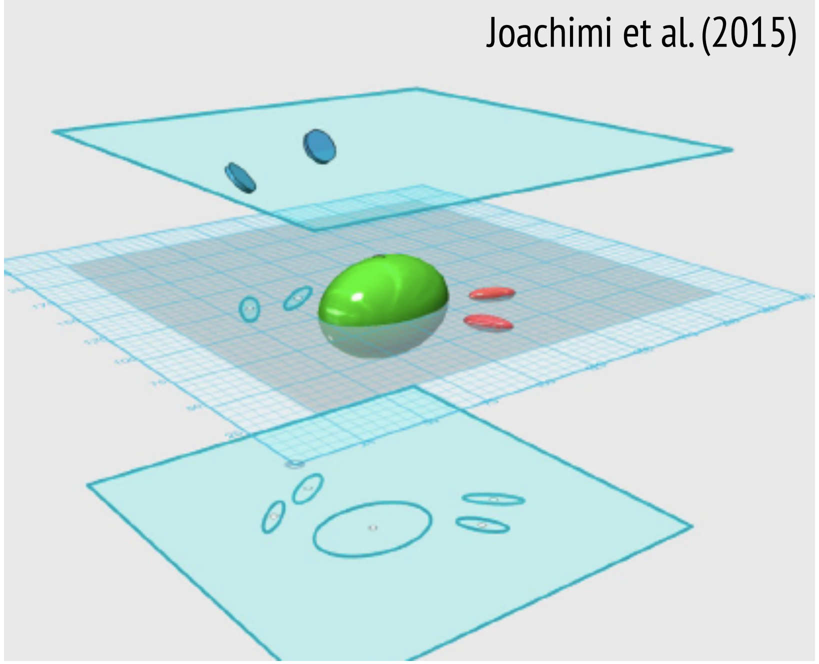


Accounted for feedback

Semboloni et al. (2011)

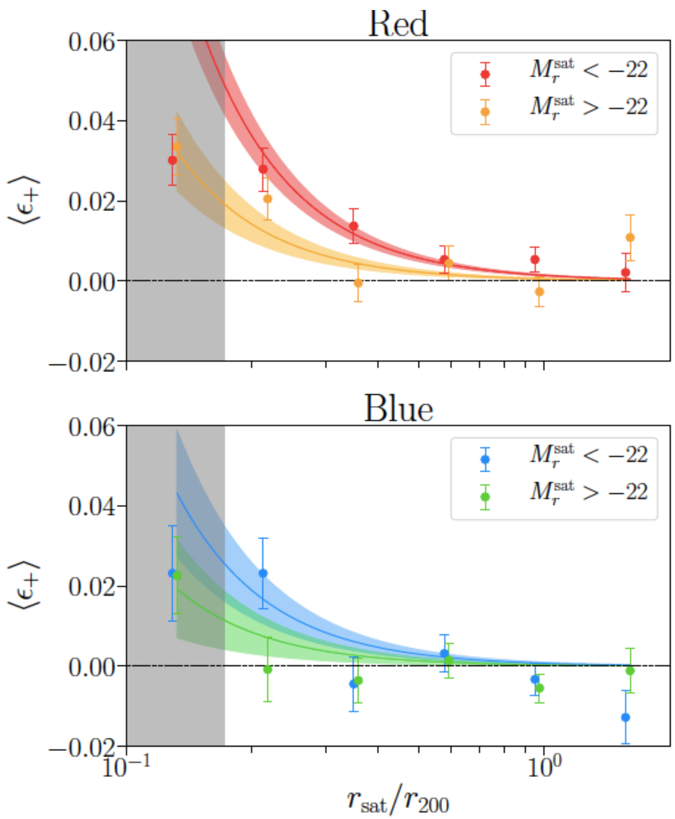
Intrinsic alignments

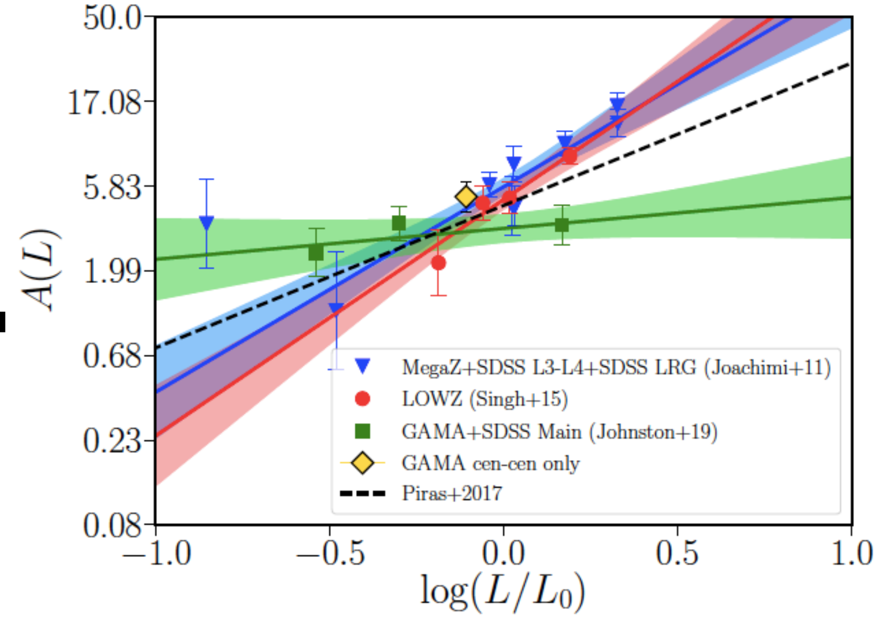
Gravitational lensing introduces *apparent* alignments in the shapes of galaxies, but local tidal effects may align galaxies *intrinsically*.



The amplitude of these *intrinsic alignments* depends on the complex physics of galaxy formation.

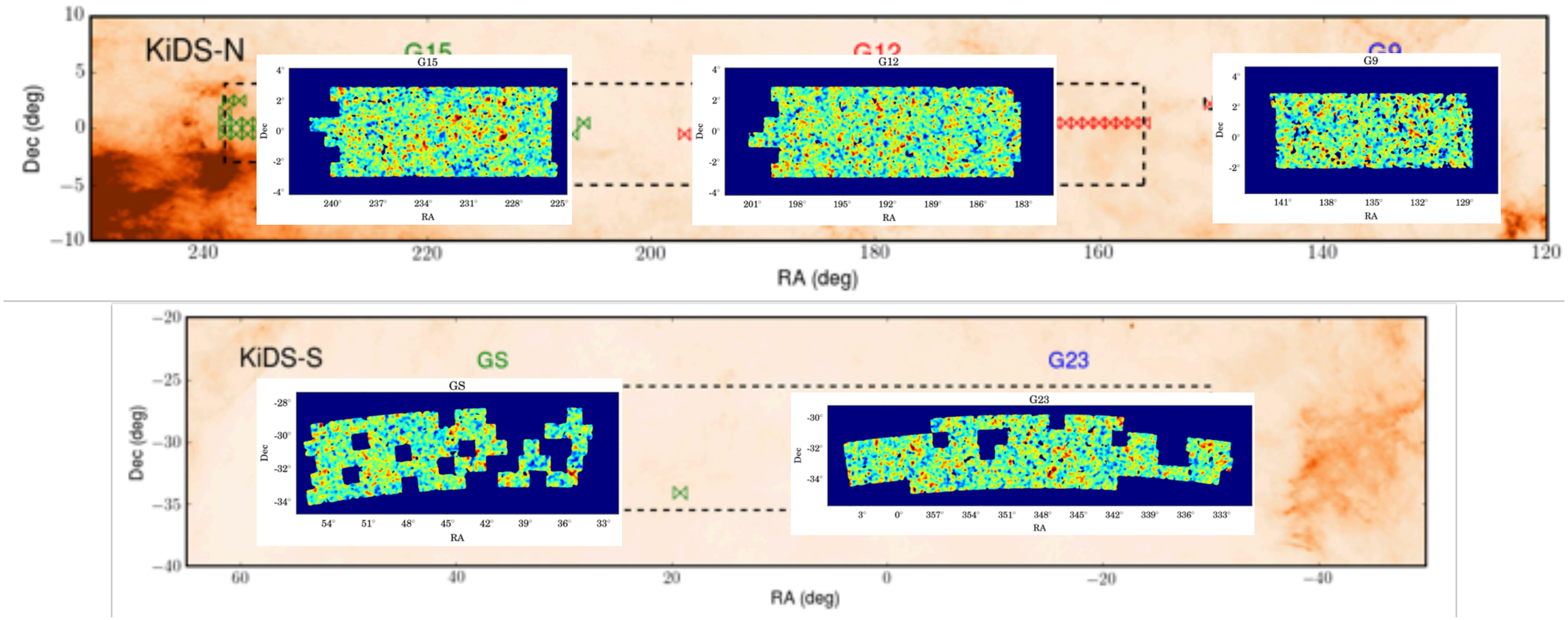
A consistent model of intrinsic alignments





Fortuna et al. (arXiv:2003.02700): halo model approach using observational constraints for blue/red galaxies to predict the alignment signal.

KiDS-450 survey area (DR3)



For the KiDS-450 results (Hildebrandt et al. 2017) we used observations prior to July 2015, which cover ~450 deg^2 with *ugri* data.

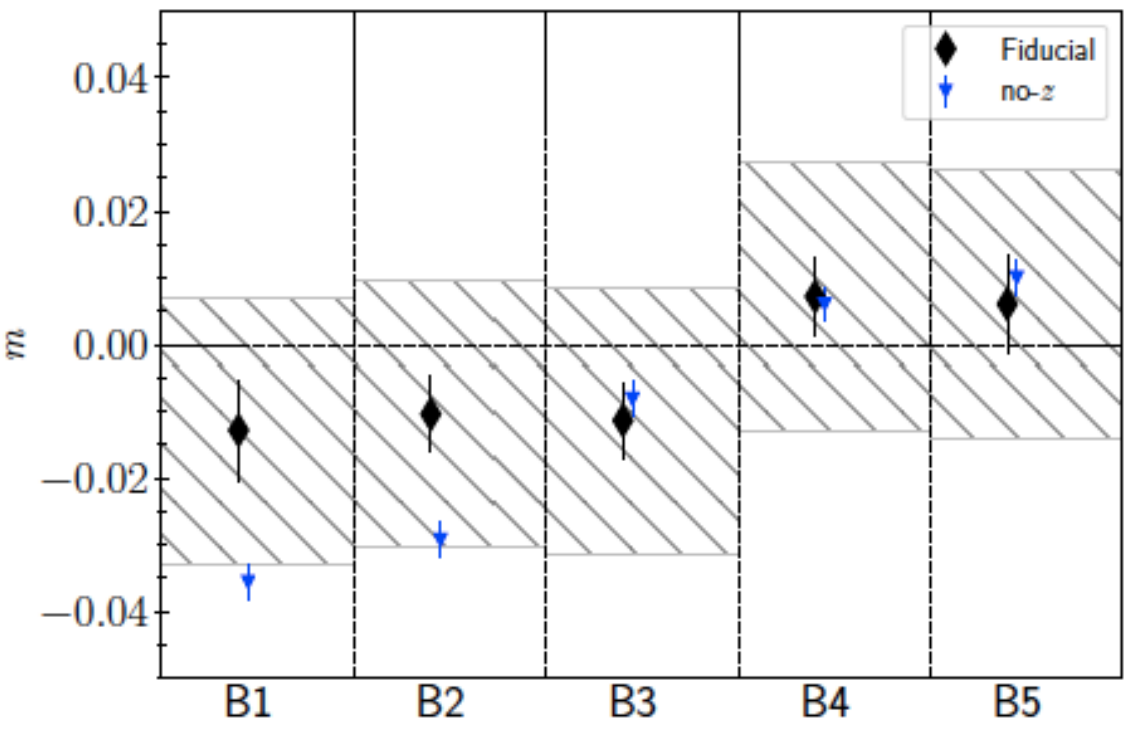
Improvements in the analysis

Hildebrandt et al. (2020) uses the same KiDS data but the analysis has been improved on quite a number of points.

- Inclusion of VIKING (*ZYJHK*) data
- Source sample split into 5 tomographic bins
- Better calibration of the shape measurement algorithm
- Direct calibration of the n(z) using deep spectroscopic surveys
- Improved covariance matrix (accounting for masks)

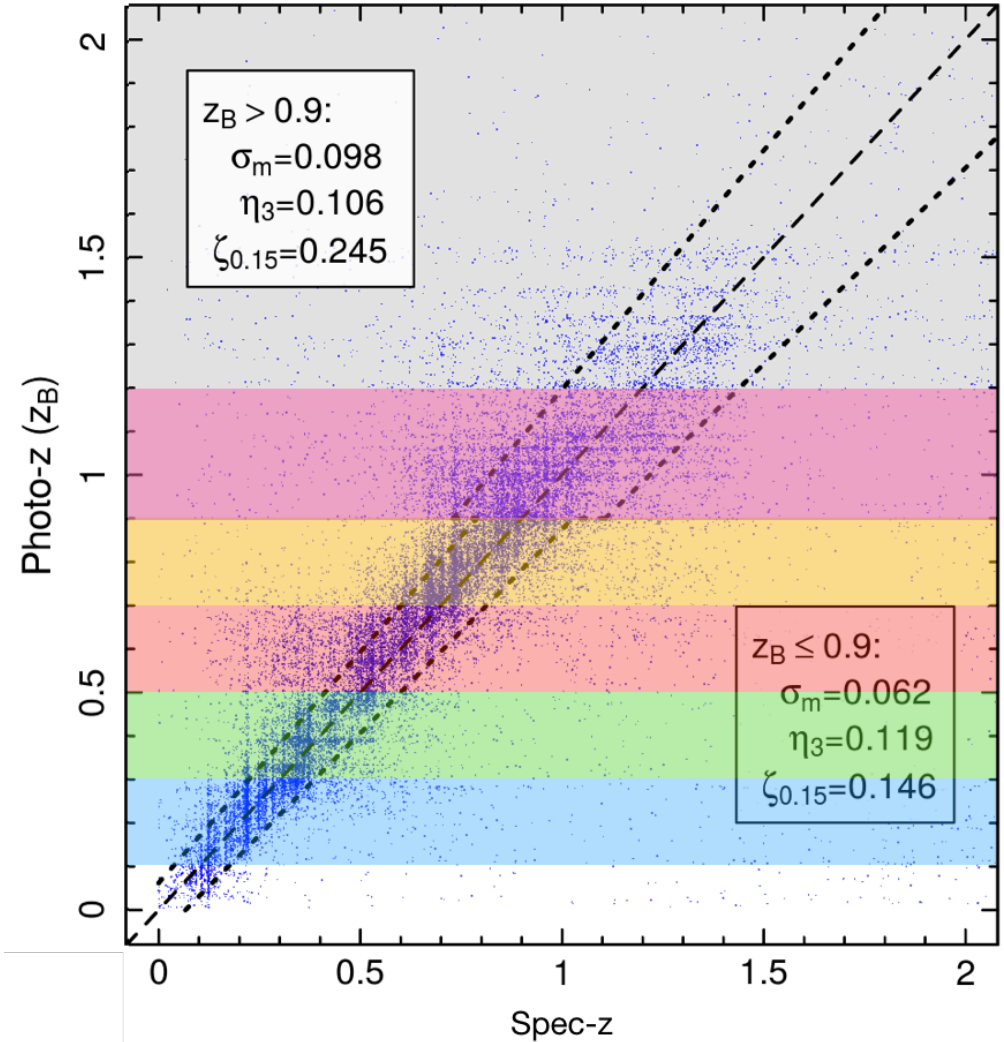
Improvements in the analysis

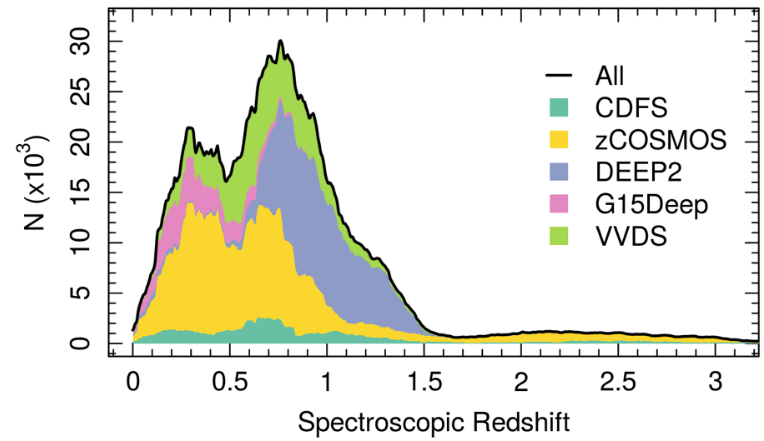
Kannawadi et al. (2019): The improved image simulations are able to faithfully reproduce actual KiDS observations of COSMOS. Further improvements require multi-band image simulations.



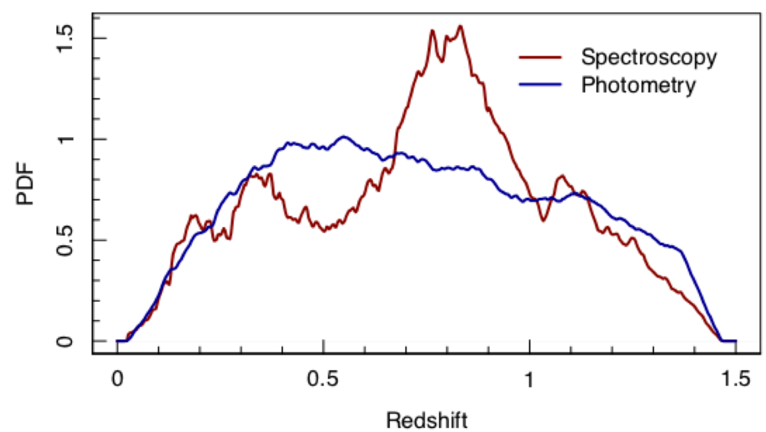
Improvements in redshift calibration

Wright et al. (2018)

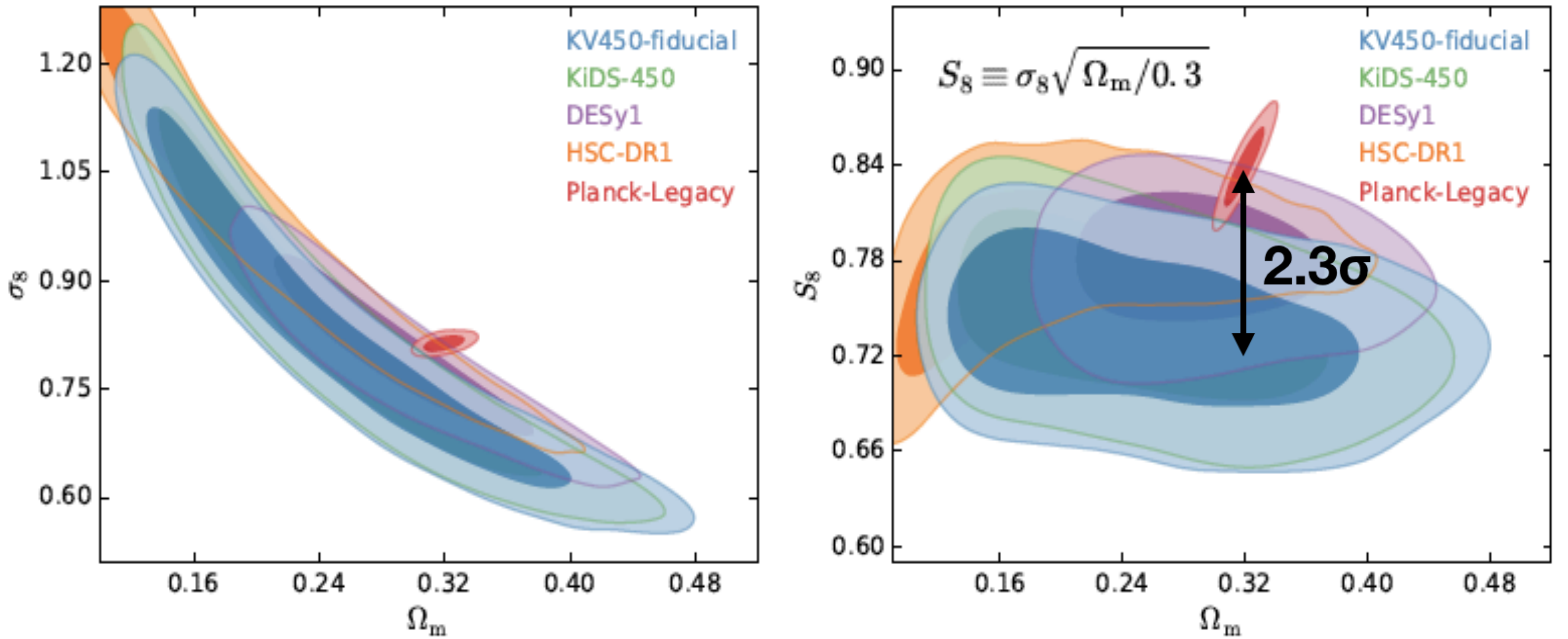




Reweighting

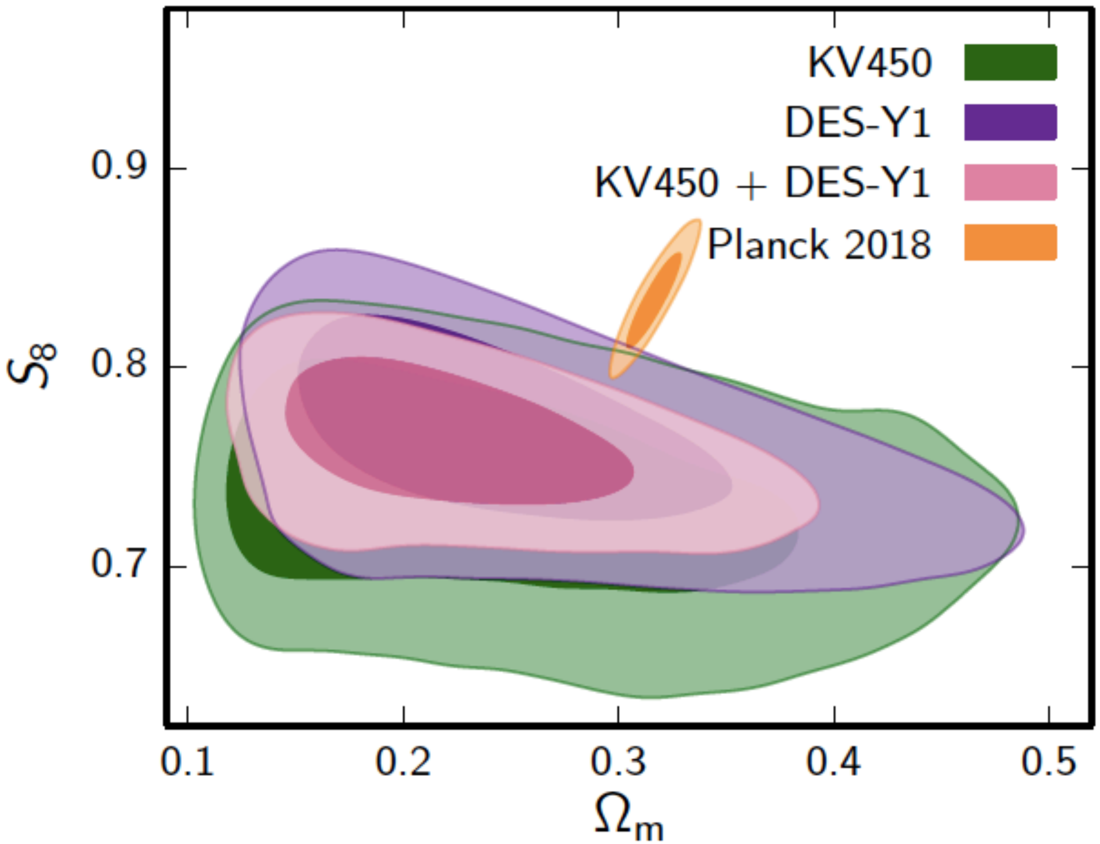


KV450: cosmological parameters



Hildebrandt et al. (2020): the results have barely changed… The calibration of the source redshift distribution remains important.

KV450 + DES Y1



Joudaki et al. (2019): a consistent analysis of KV450 and DES Y1 data shows excellent agreement between the two lensing surveys.

KV450 → KiDS-1000

The current results are interesting, but the statistical uncertainties need to be reduced before we can draw firm conclusions.

- We are improving constraints by improving the calibration of the tomographic redshift bins.
- We have started the analysis of 1000 deg^2 of data observed thus far.

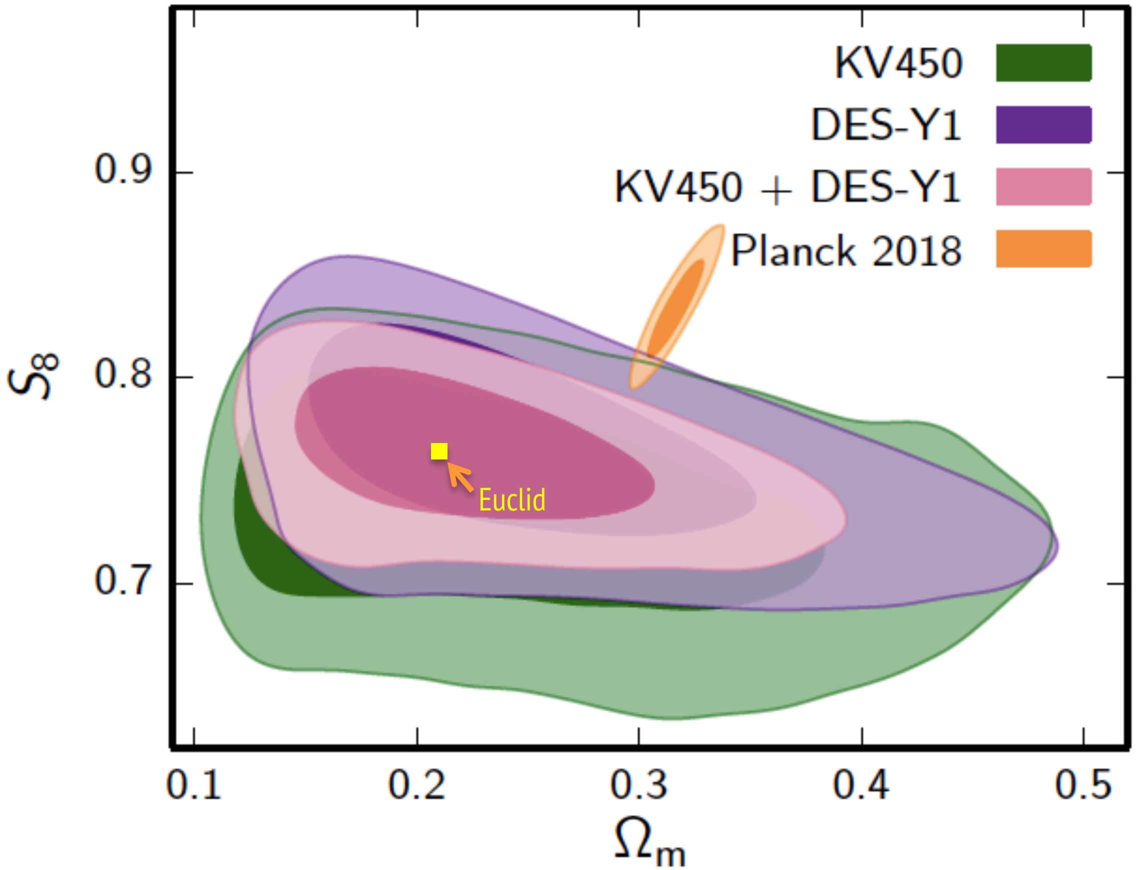
The combination of these should reduce uncertainties by about a factor 2.

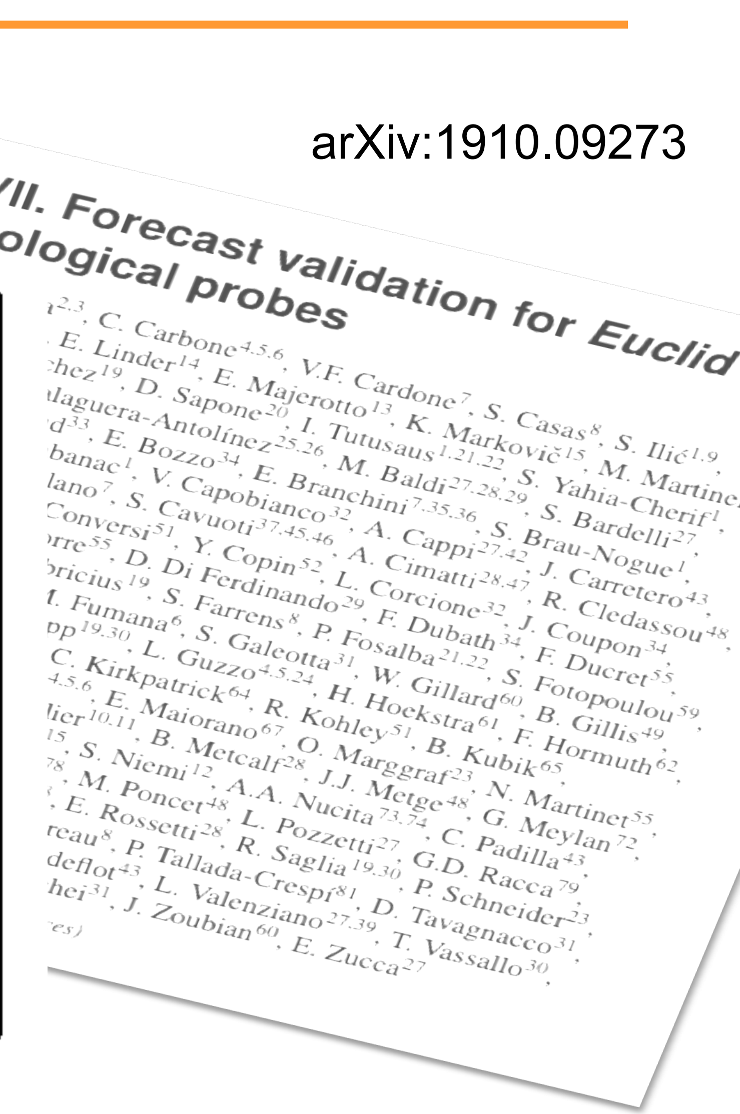
… and we can add complementary constraints!

What is next?

Forecasts for Euclid

arXiv:1910.09273





Conclusions

Weak gravitational lensing studies are yielding excellent results.

Still very much a work in progress as better measurements lead to new insights. To achieve the full potential of the next surveys a number of issues remain...

The data analysis and interpretation is complex: success relies on improving our understanding of observational and astrophysical biases.

…but no show-stopper has been found!