Weak lensing

A look at the dark side of the Universe

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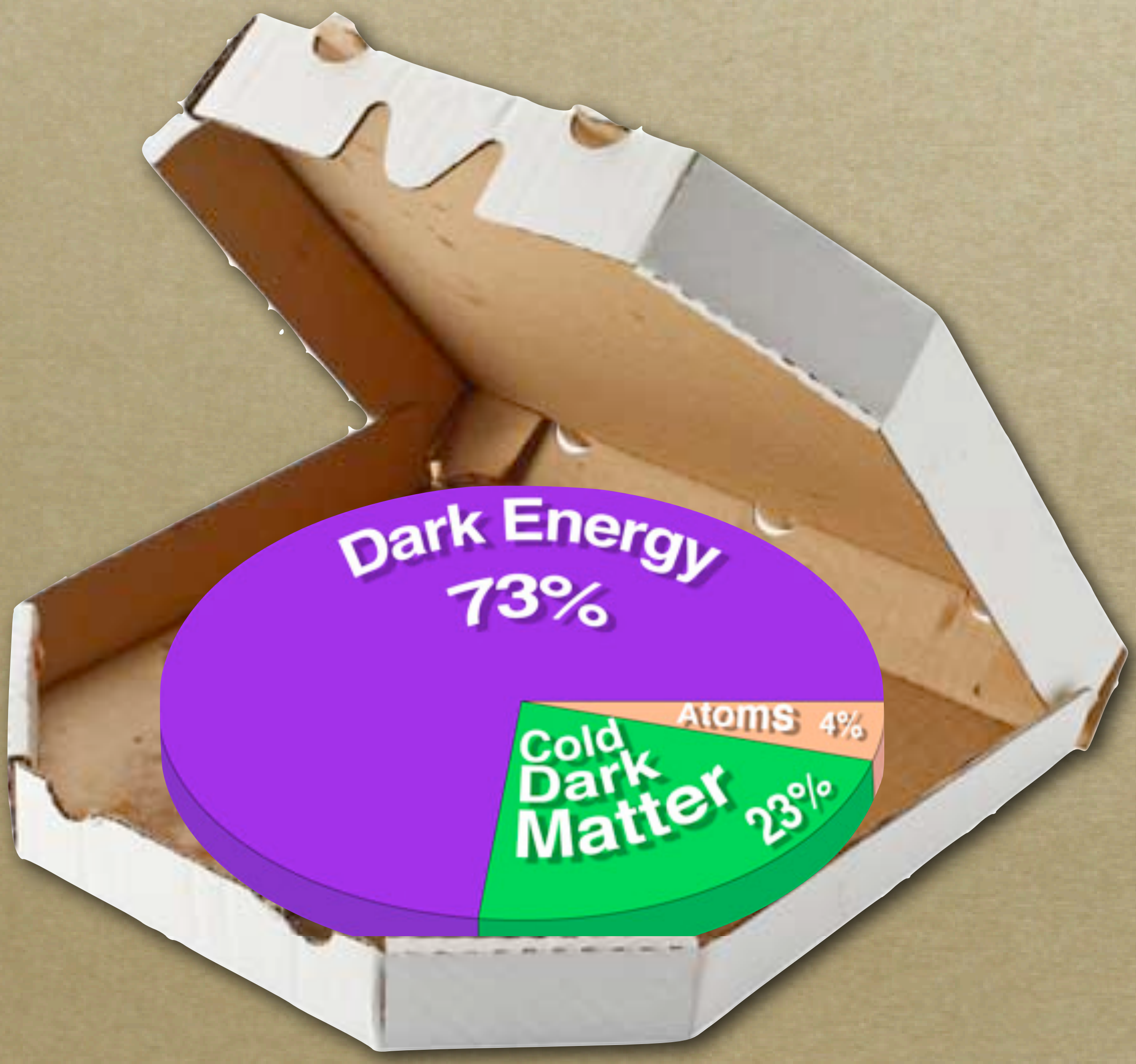
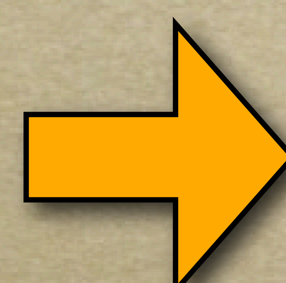
The Dark Universe

We now have a good inventory of the constituents of the Universe, but 96% of the “ingredients” are not described by the standard model of particle physics.





New physics

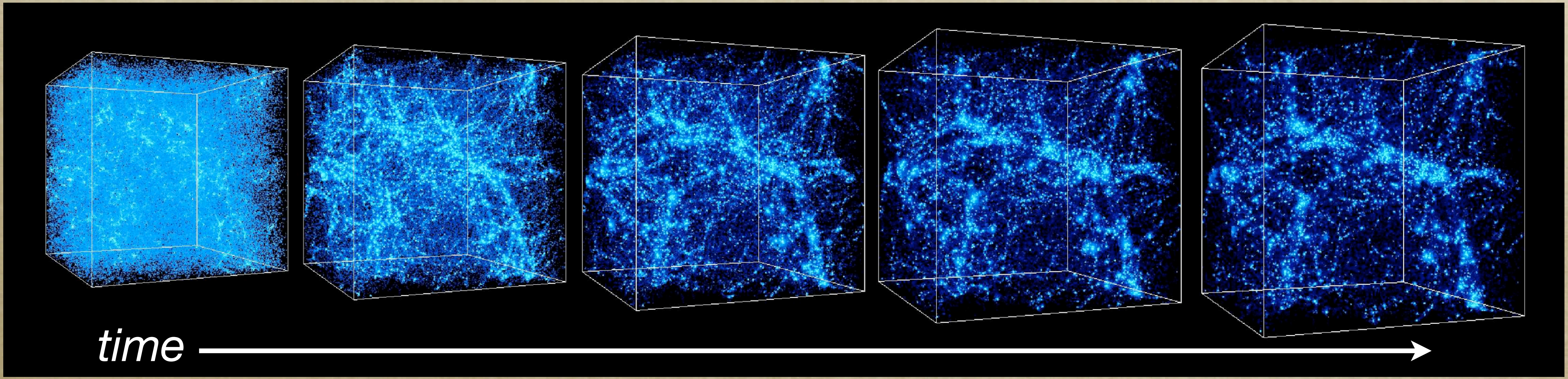
Constant or not?

The hardest thing of all is to find a black cat in a dark room, especially if there is no cat - Confusius

To learn more about dark energy we need to improve observational constraints by more than an order of magnitude!

This is difficult, because the effects of dark energy are subtle and systematic effects (can be) large.

How to study dark energy?

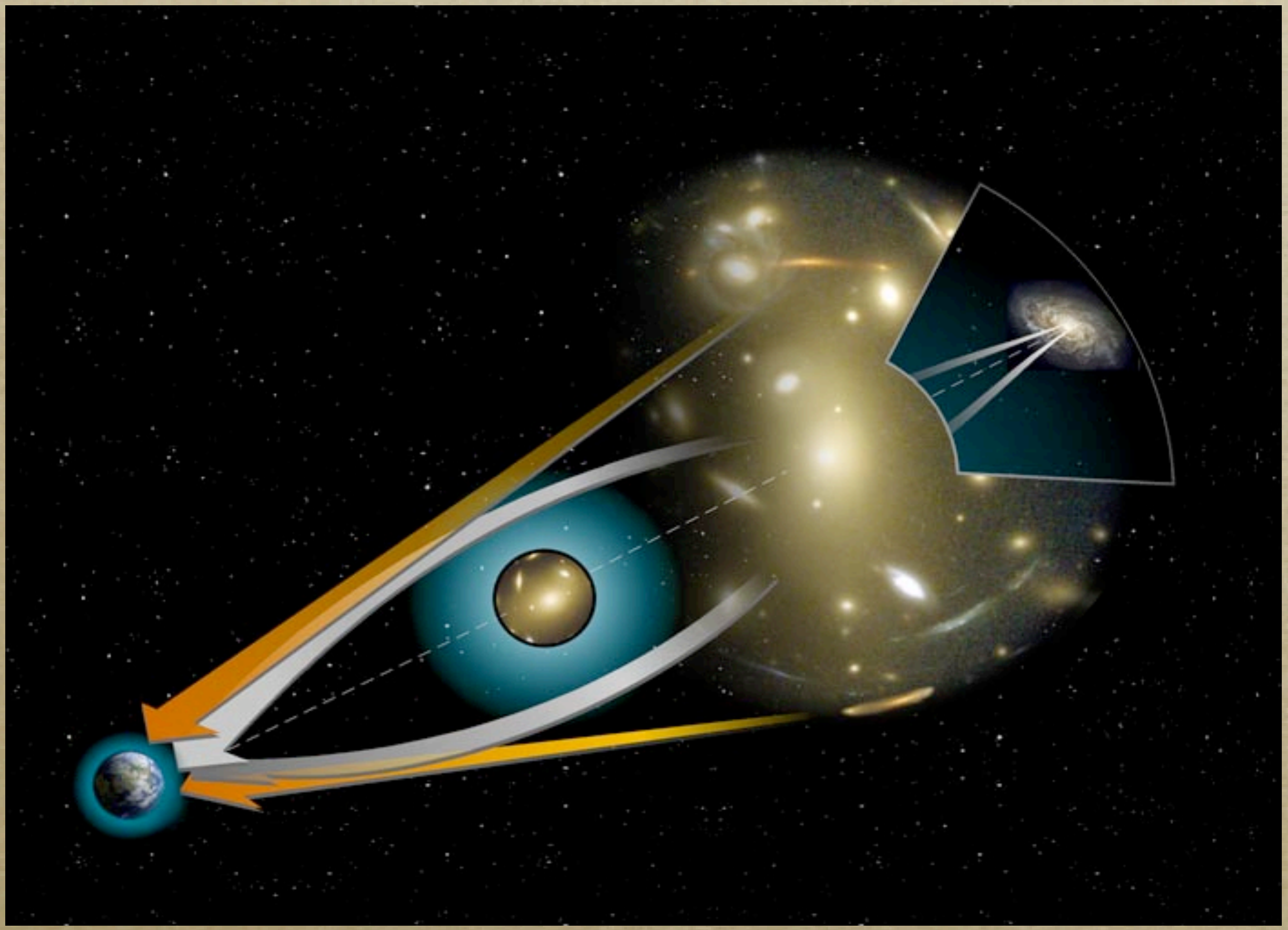


Dark energy changes the expansion history of the Universe and thus modifies the growth of large-scale structures.

Measure the matter power spectrum

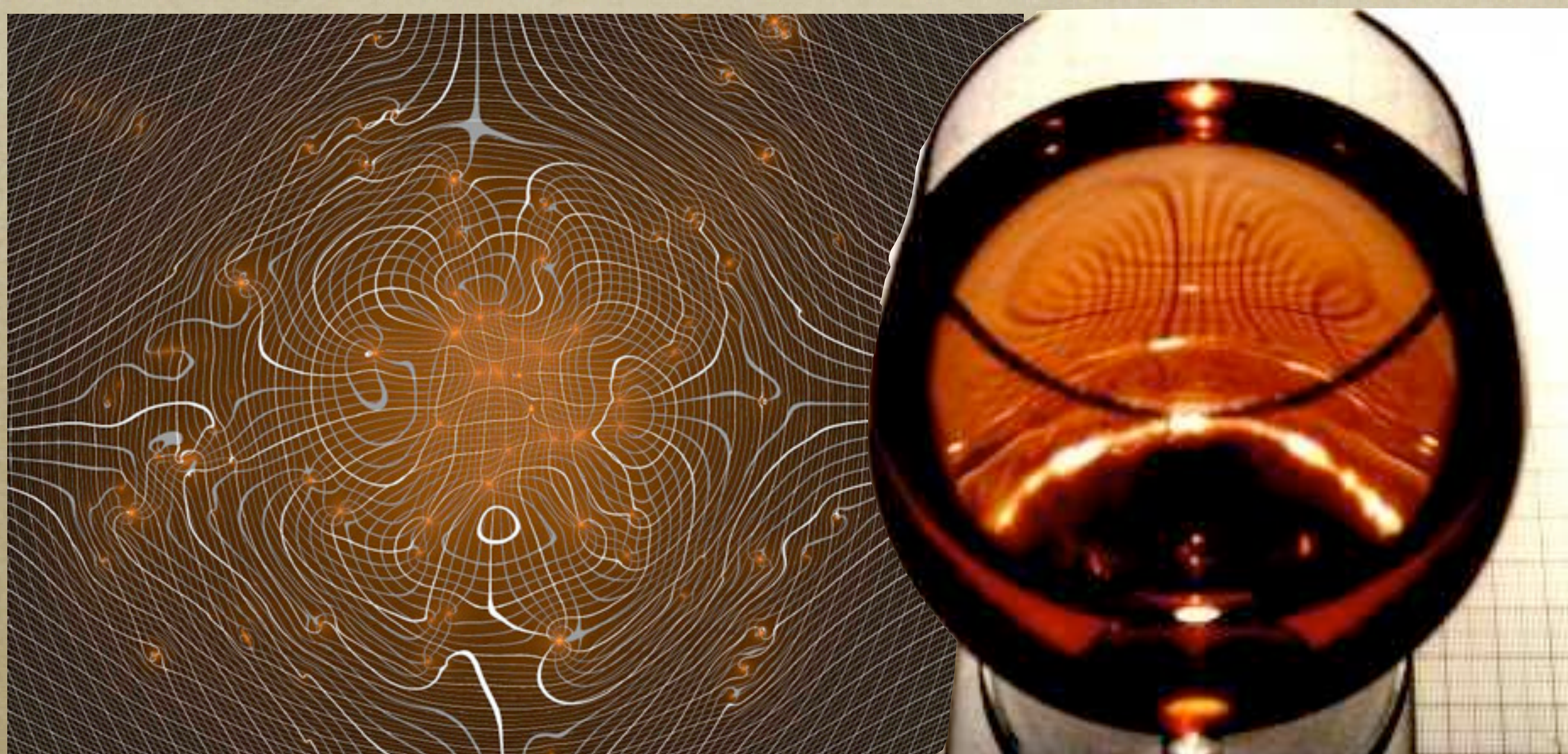
Can we see the matter?

Rays of light are deflected by massive objects in the Universe



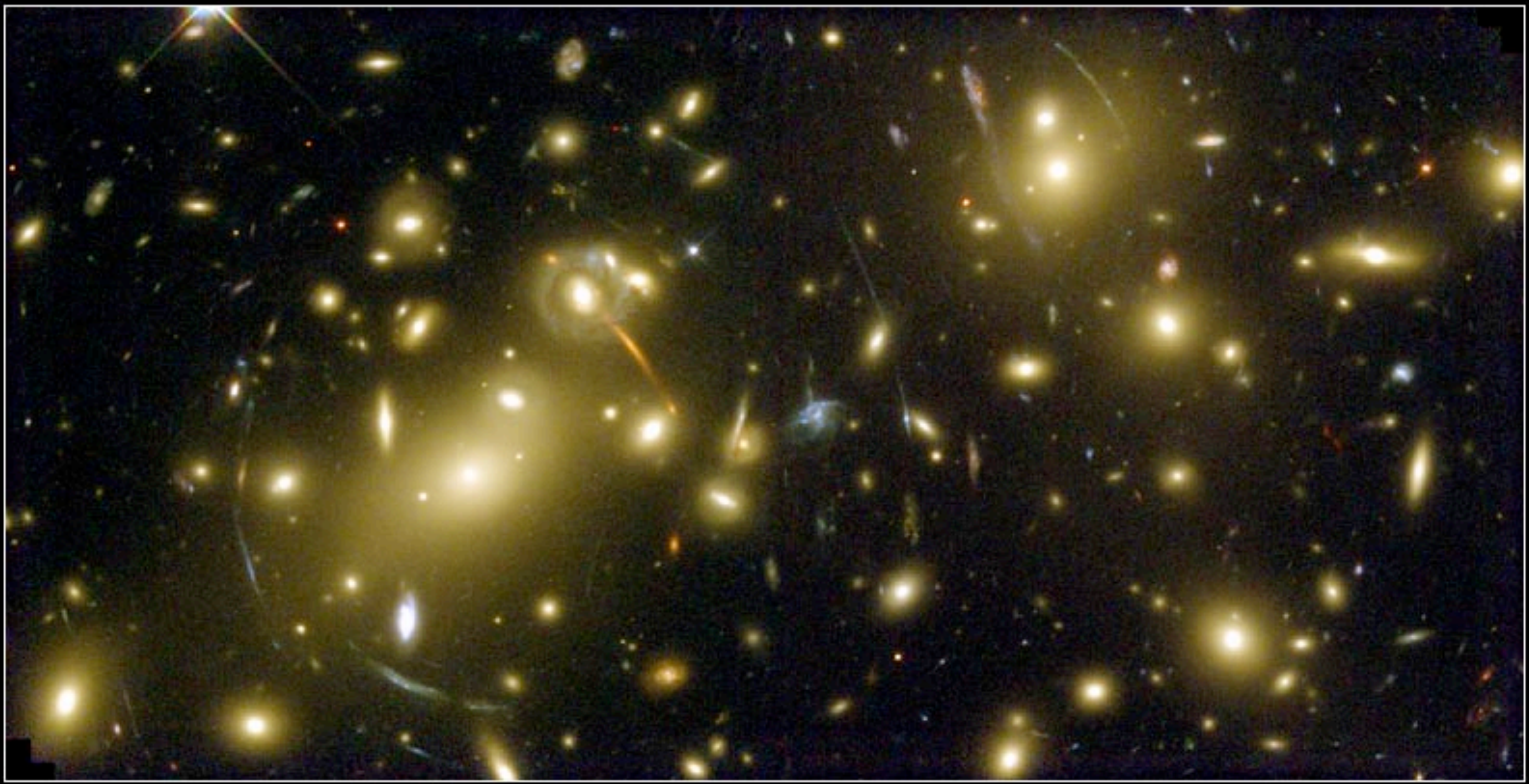
The angle of deflection is a *direct* measure of the mass!

Gravitational lensing



Inhomogeneities in the mass distribution distort the paths of light rays, resulting in a remapping of the sky. This can lead to spectacular lensing examples…

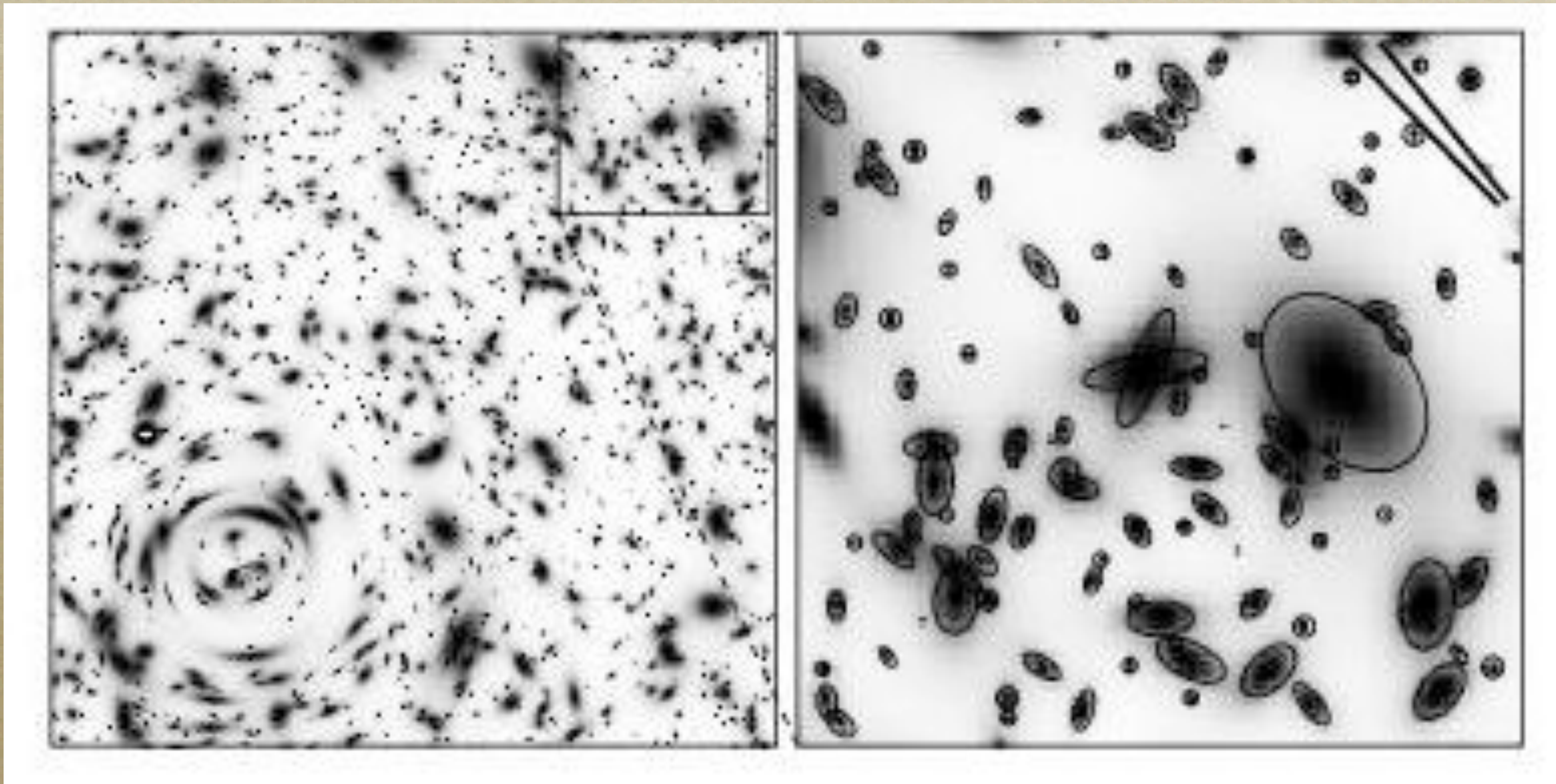
Gravitational lensing



Galaxy Cluster Abell 2218 HST • WFPC2

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

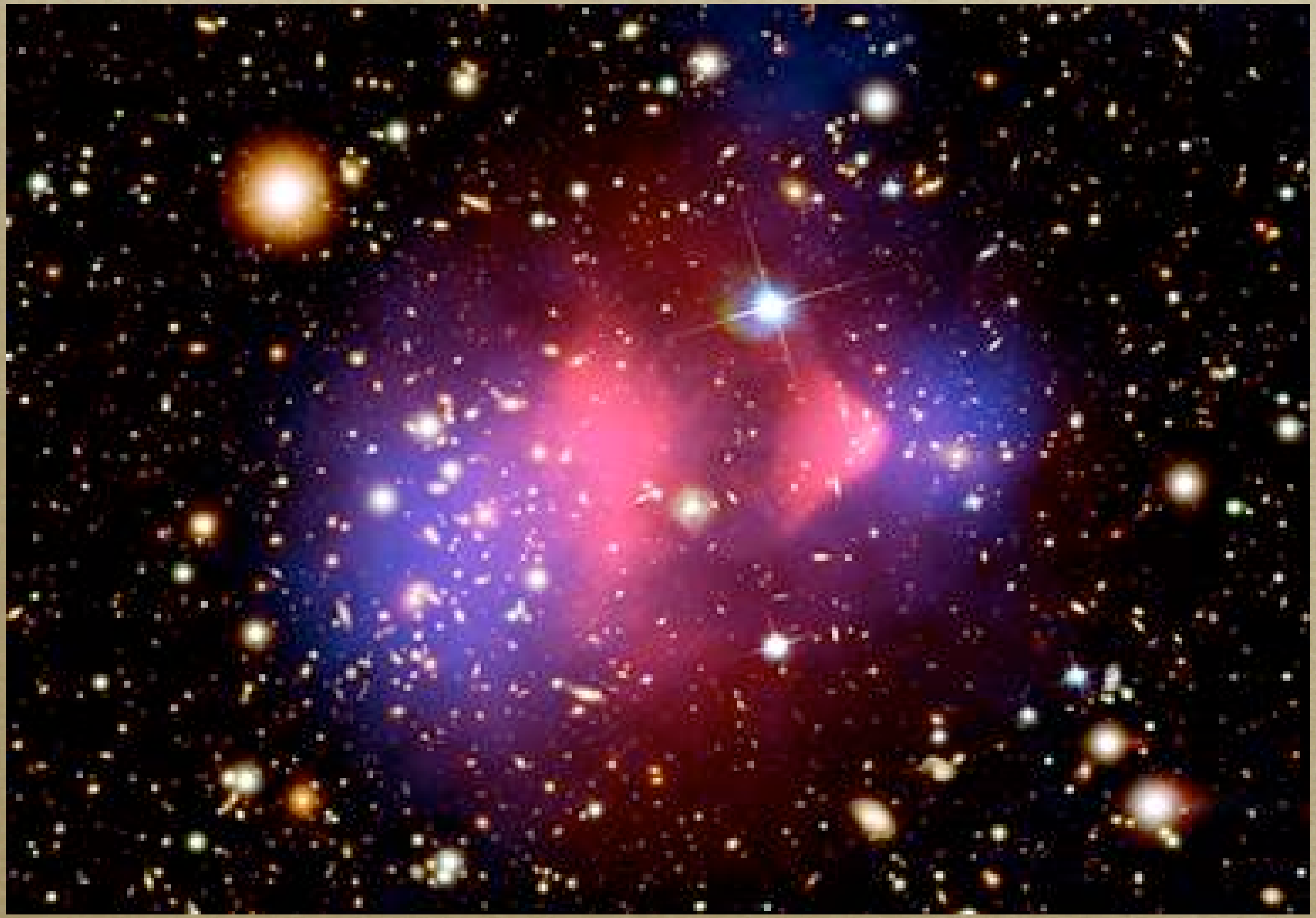
Weak gravitational lensing



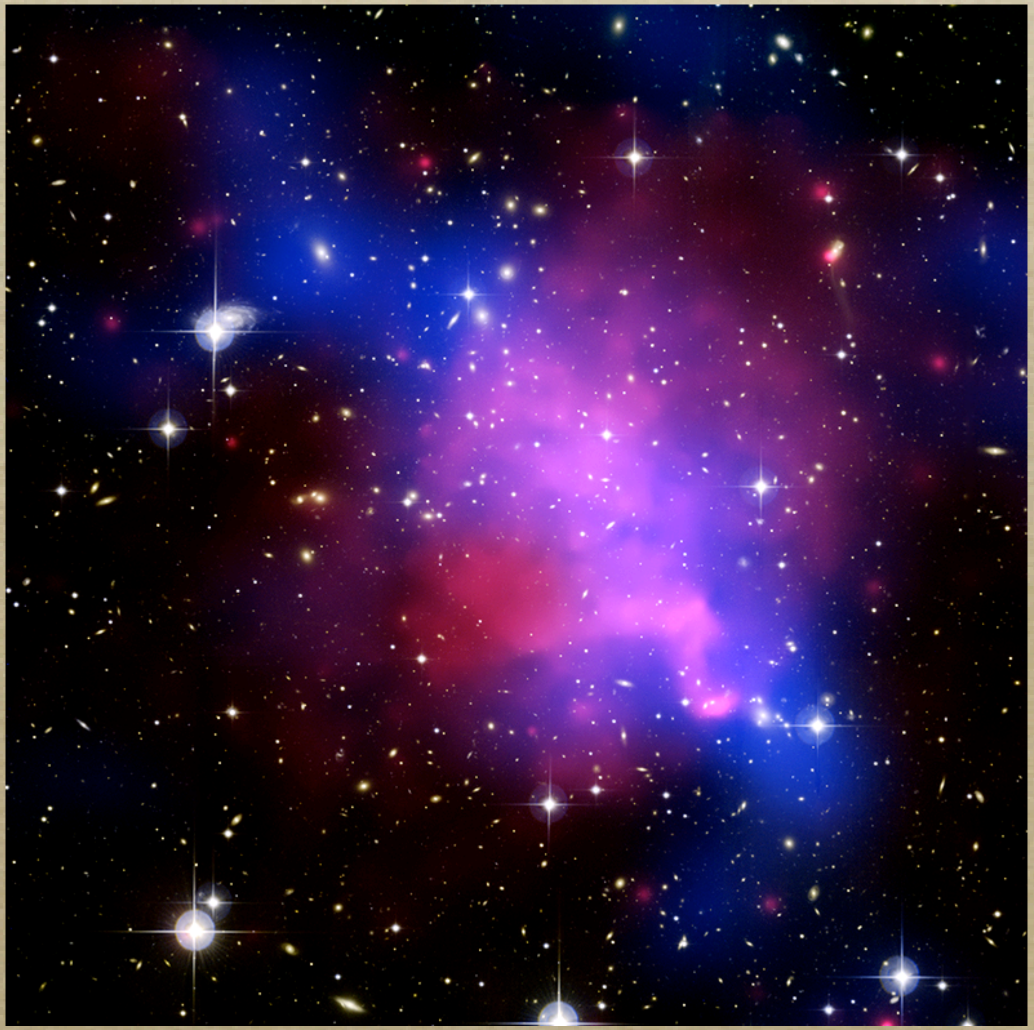
A measurement of the ellipticity of a galaxy provides an unbiased but noisy measurement of the shear.

We can see dark matter!

... and it's blue!



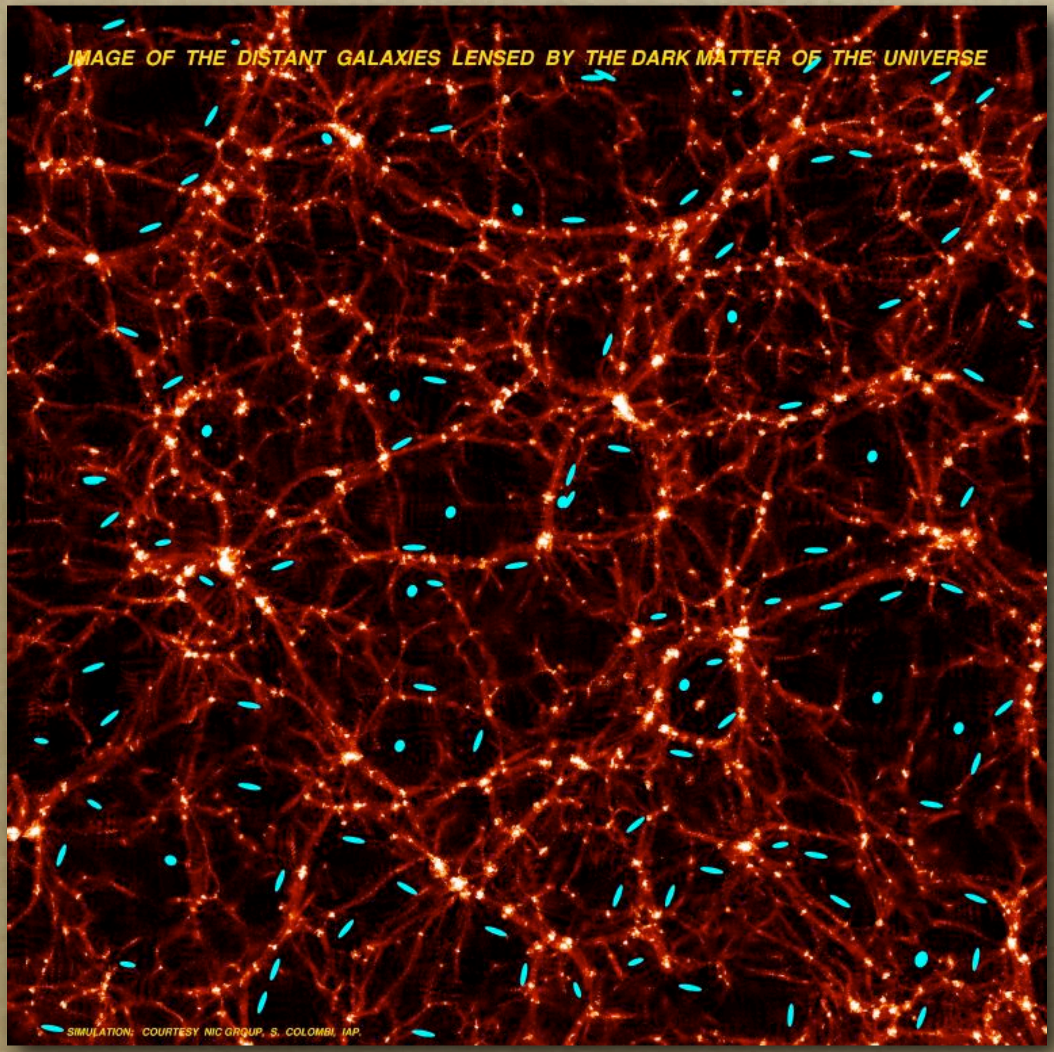
Clowe et al. (2006)

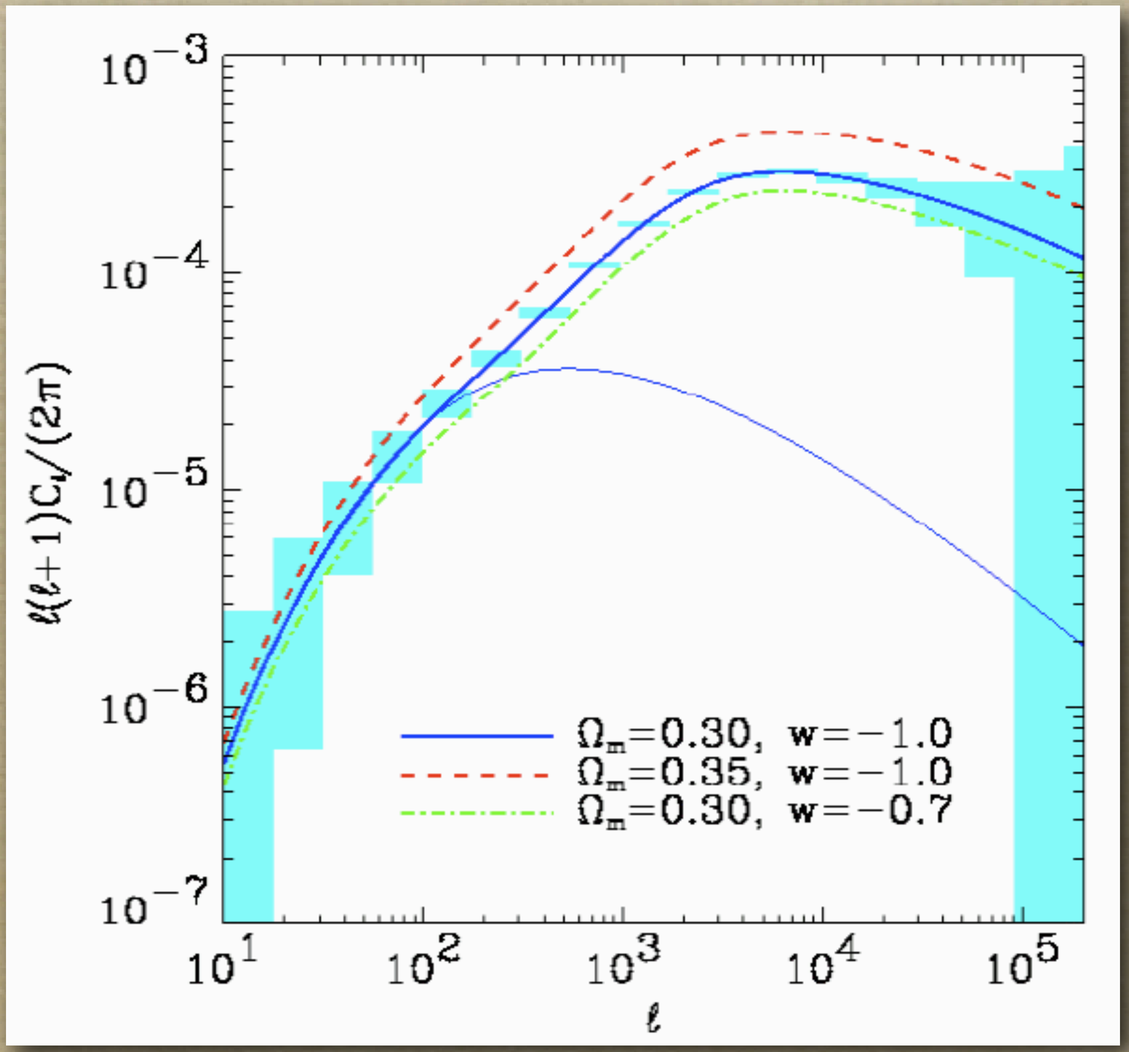


Mahdavi et al. (2008)

Cosmic shear: *mapping the invisible*

Weak lensing by large-scale structure is the most direct way to measure the clustering of matter.





What do we need to do?

We only need to measure:

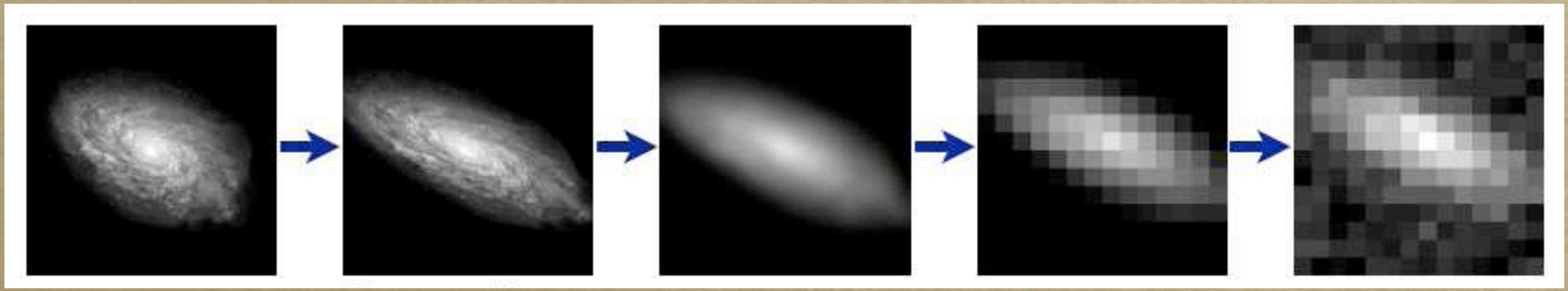
- shapes
- redshifts

The background (or source) galaxies are typically very faint and spectroscopic redshifts cannot be obtained. Even determining photometric redshifts can be difficult.

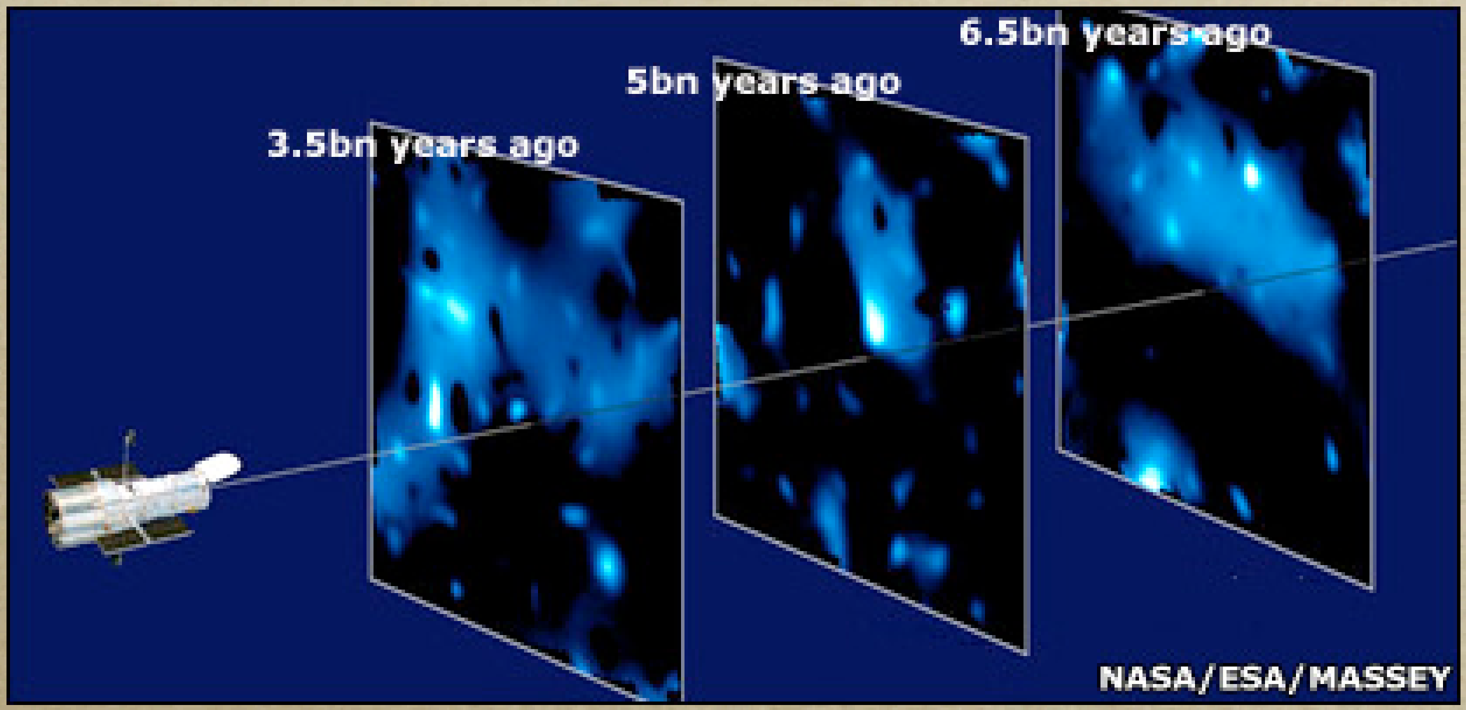
What do we need to do?

It is relatively easy to create simulated data to test the measurement techniques.

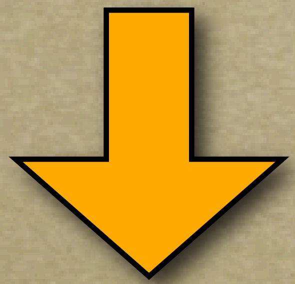
The Shear TEsting Programme is an international collaboration to provide a means to benchmark the various methods. This has evolved into a challenge to involve computer scientists: the GREAT08 and GREAT10 challenges, with more to come!



Weak lensing tomography

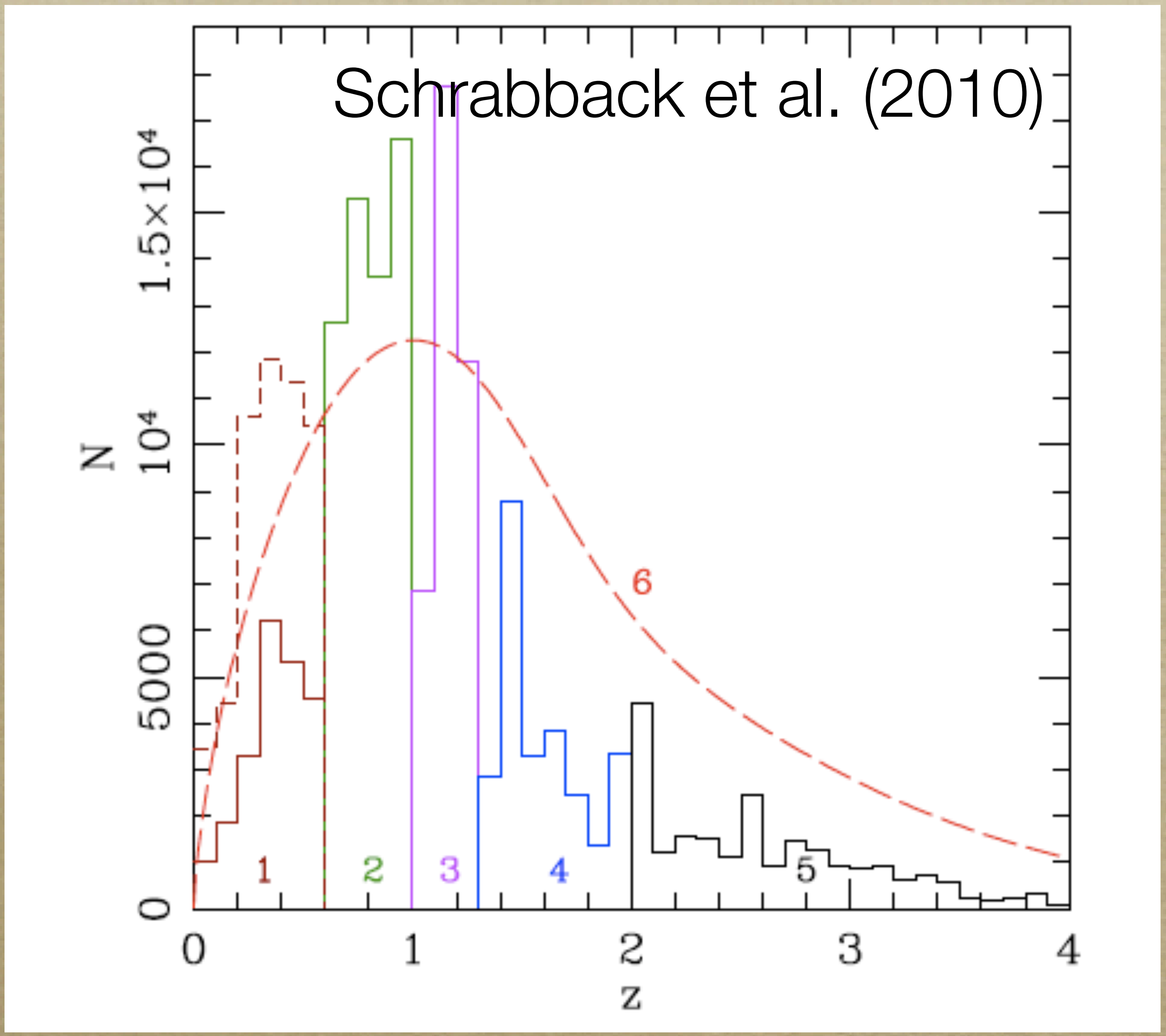


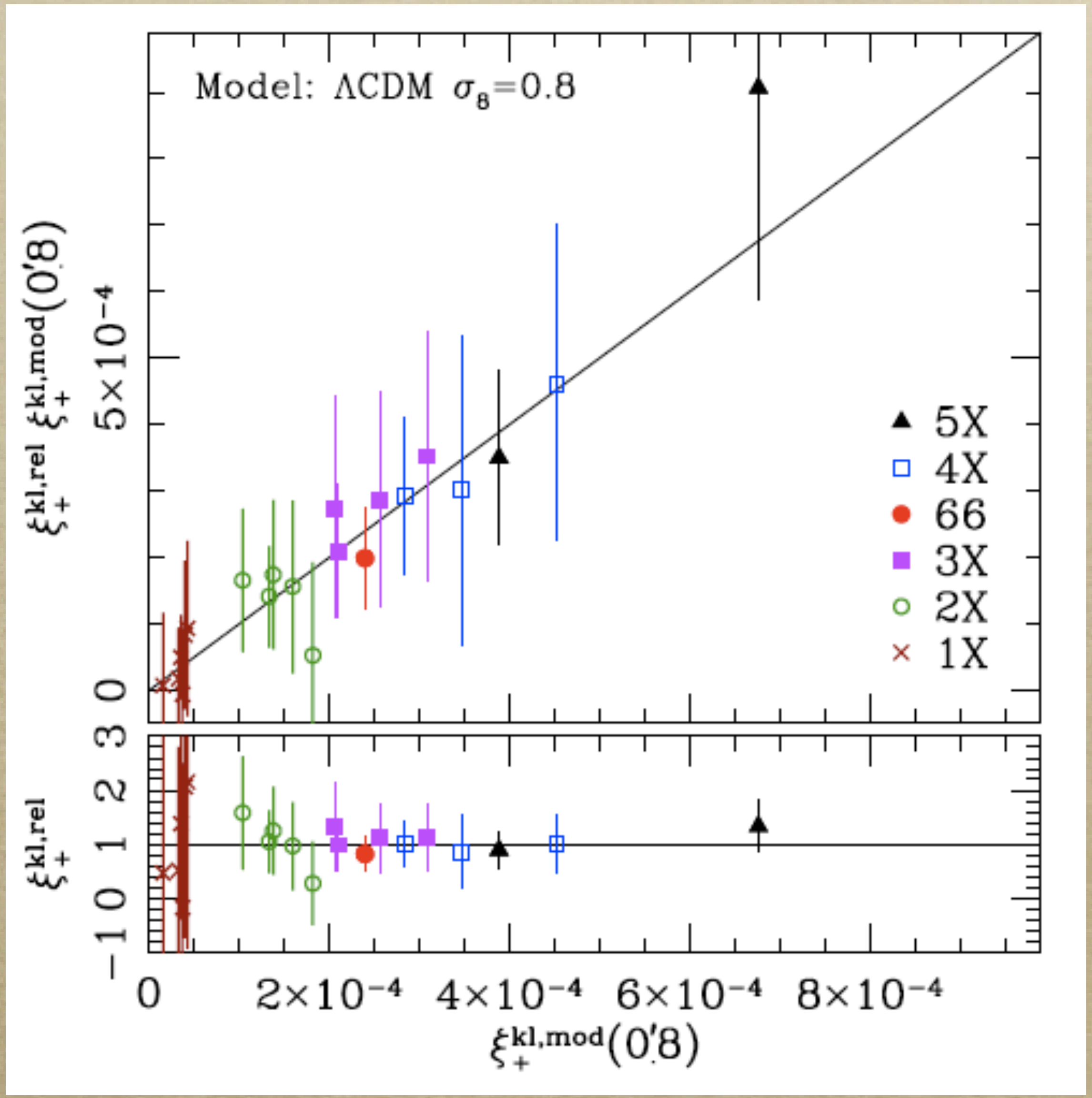
Source redshifts allow us to study the growth of structure



- Constraints on dark energy properties
- Test of gravity on cosmological scales

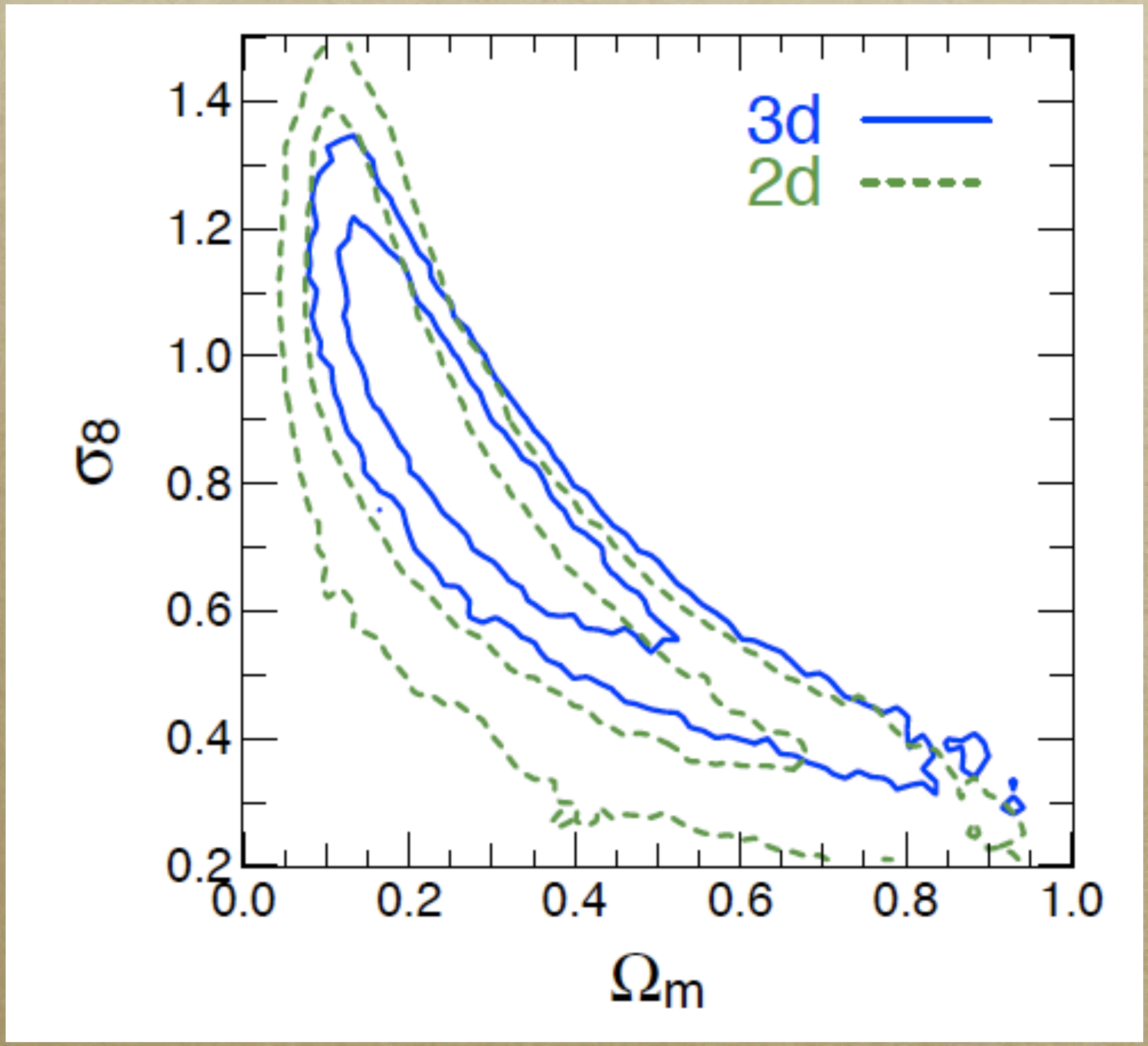
Can tomography been done?

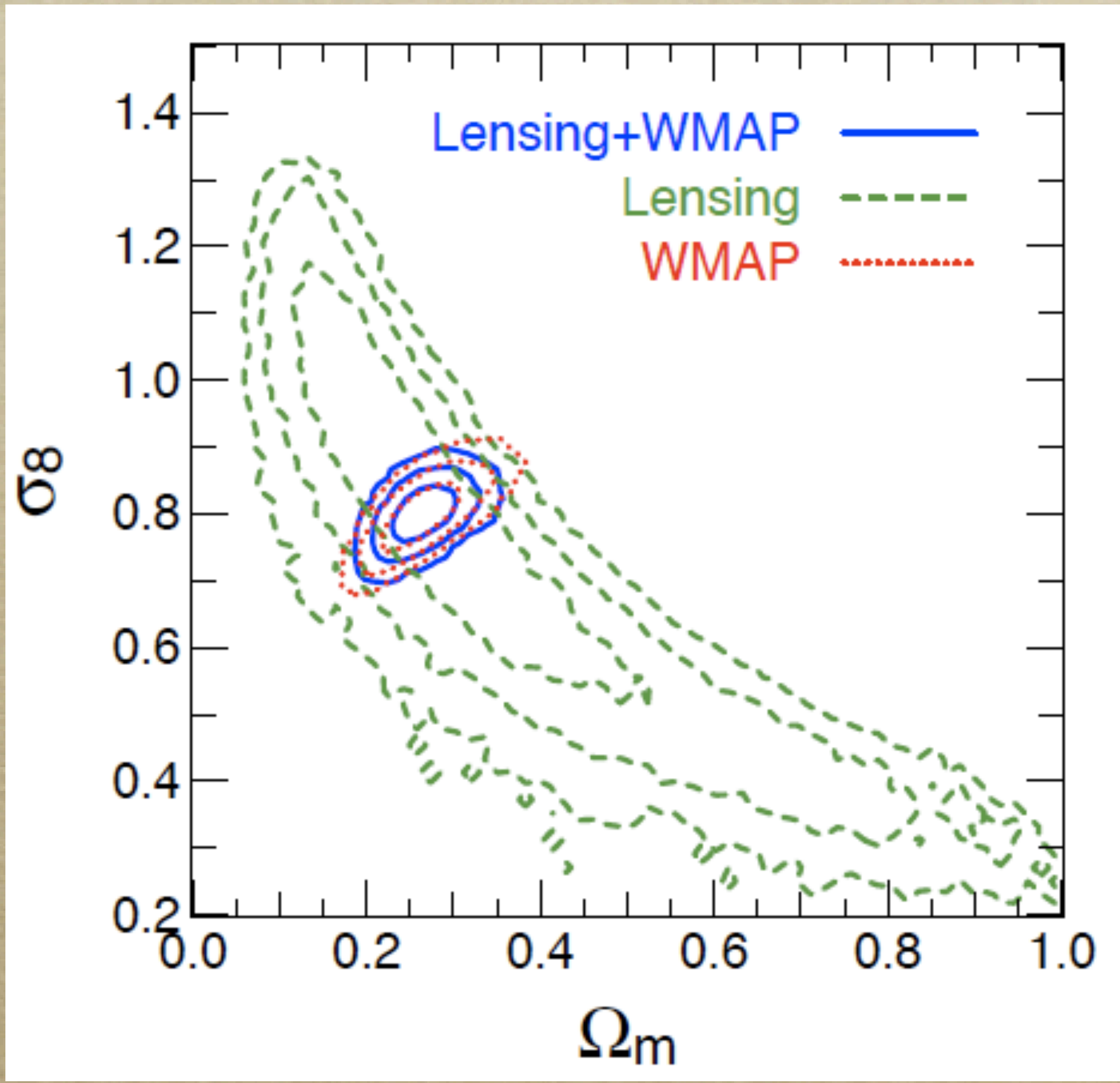




Redshift dependence as expected in ΛCDM...

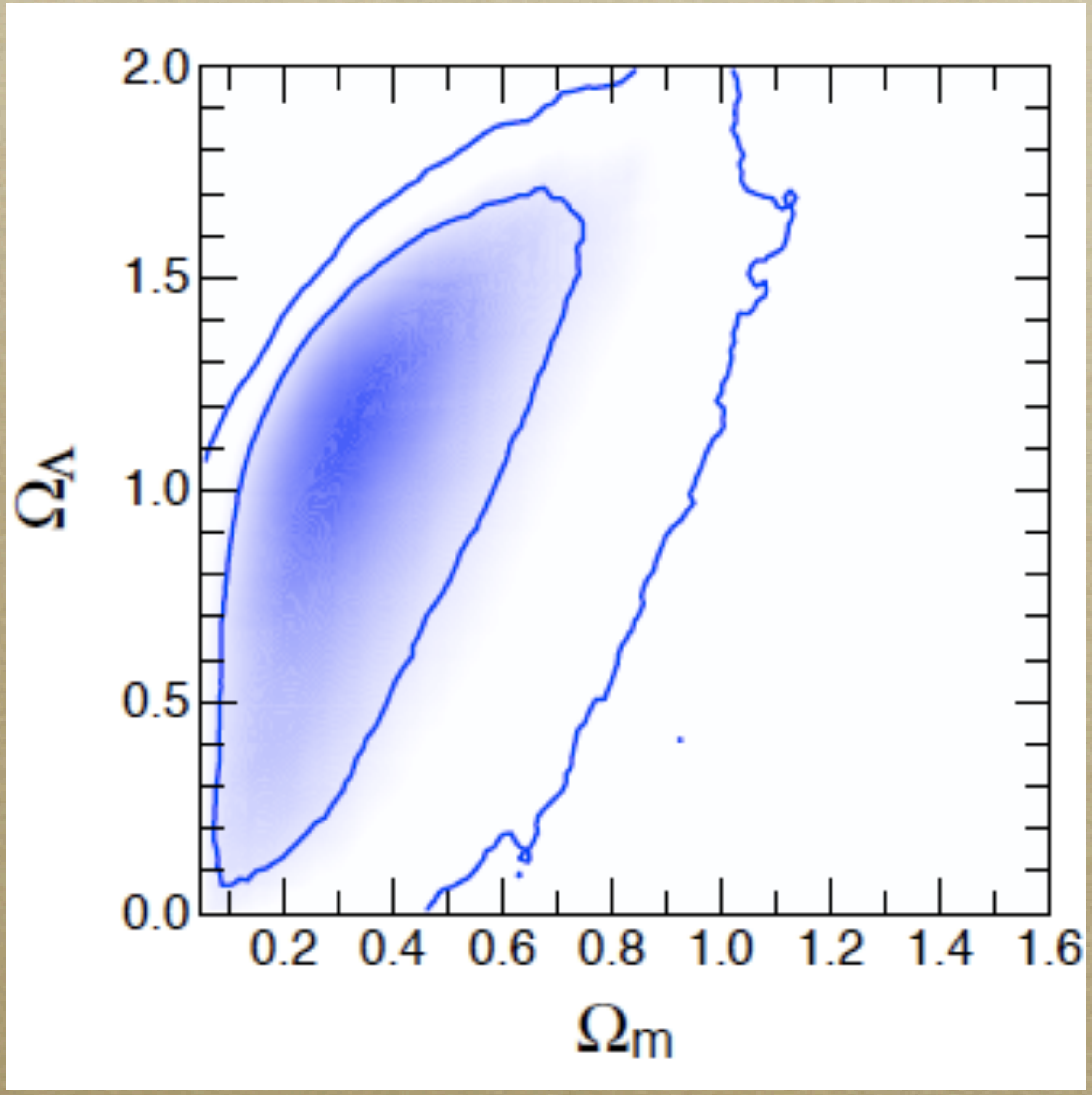
Tomography works!

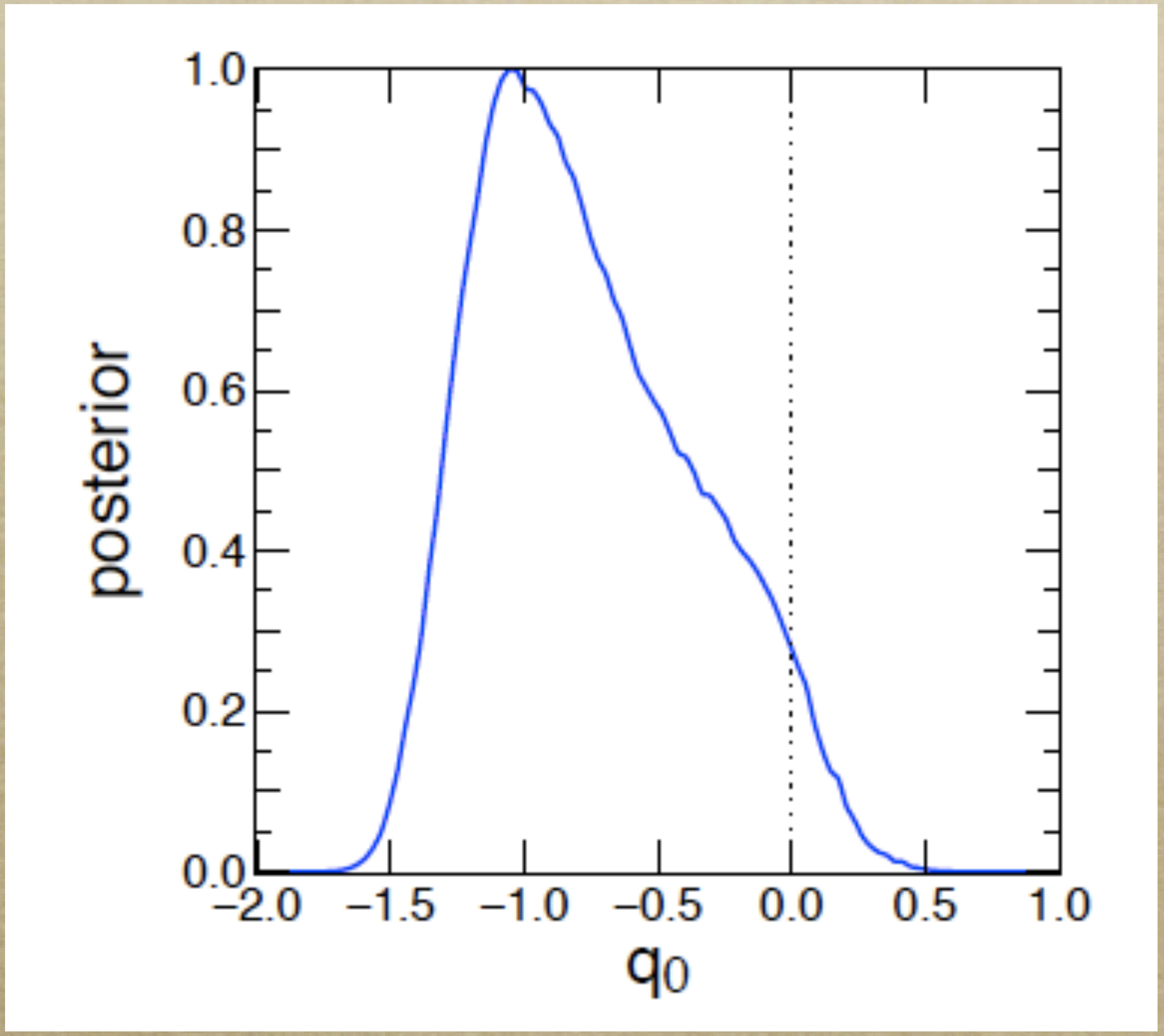




Schrabback et al. (2010)

Evidence for dark energy





From COSMOS weak lensing analysis only.

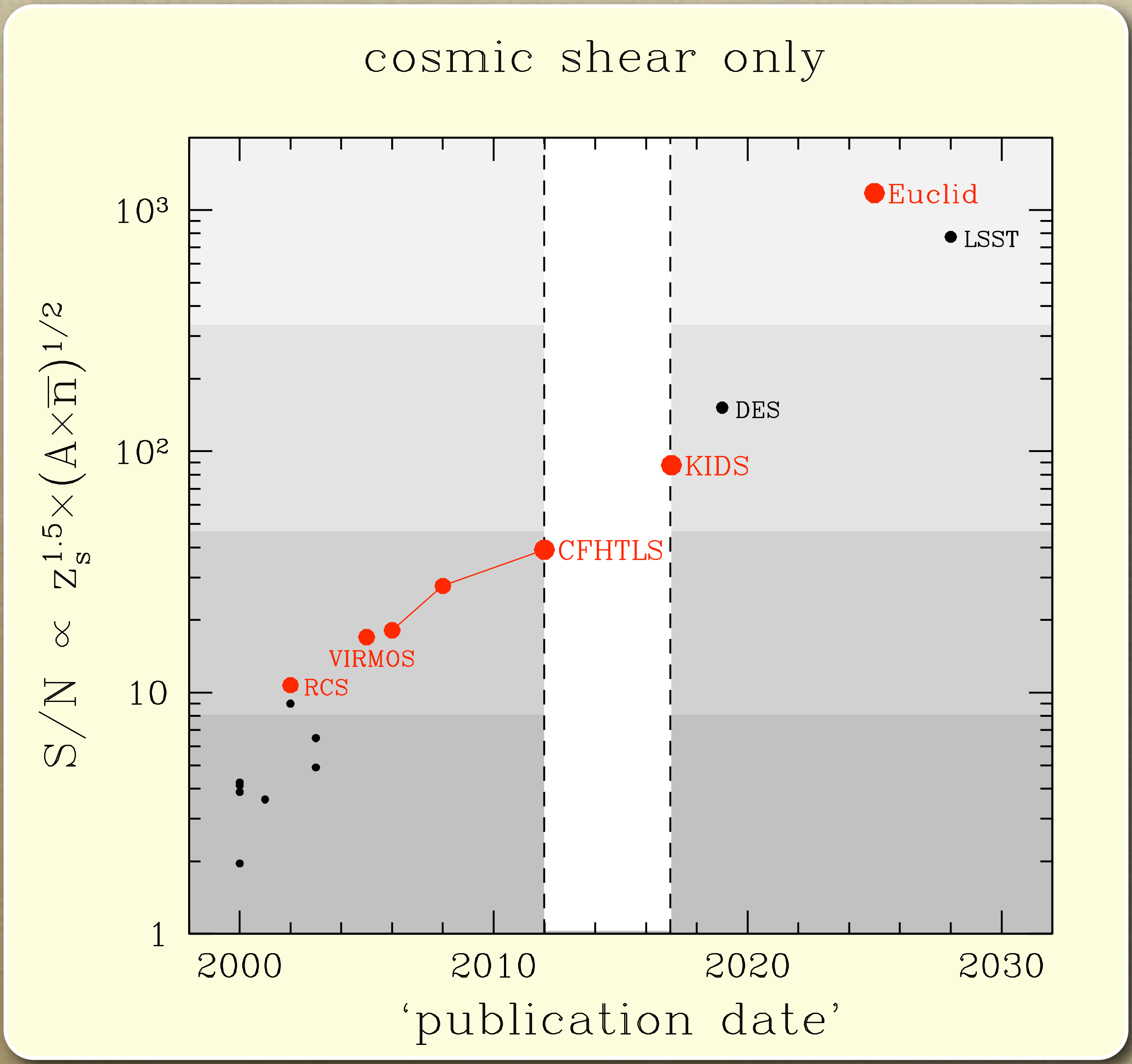
Precision cosmology

To distinguish between dark energy models we need surveys that are more than an order of magnitude larger than current ones.

But for *accurate* cosmology we also need:

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

Cosmic shear surveys



Dark energy physics

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Dark energy constraints

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Measurement

↑

Detection

Kilo Degree Survey

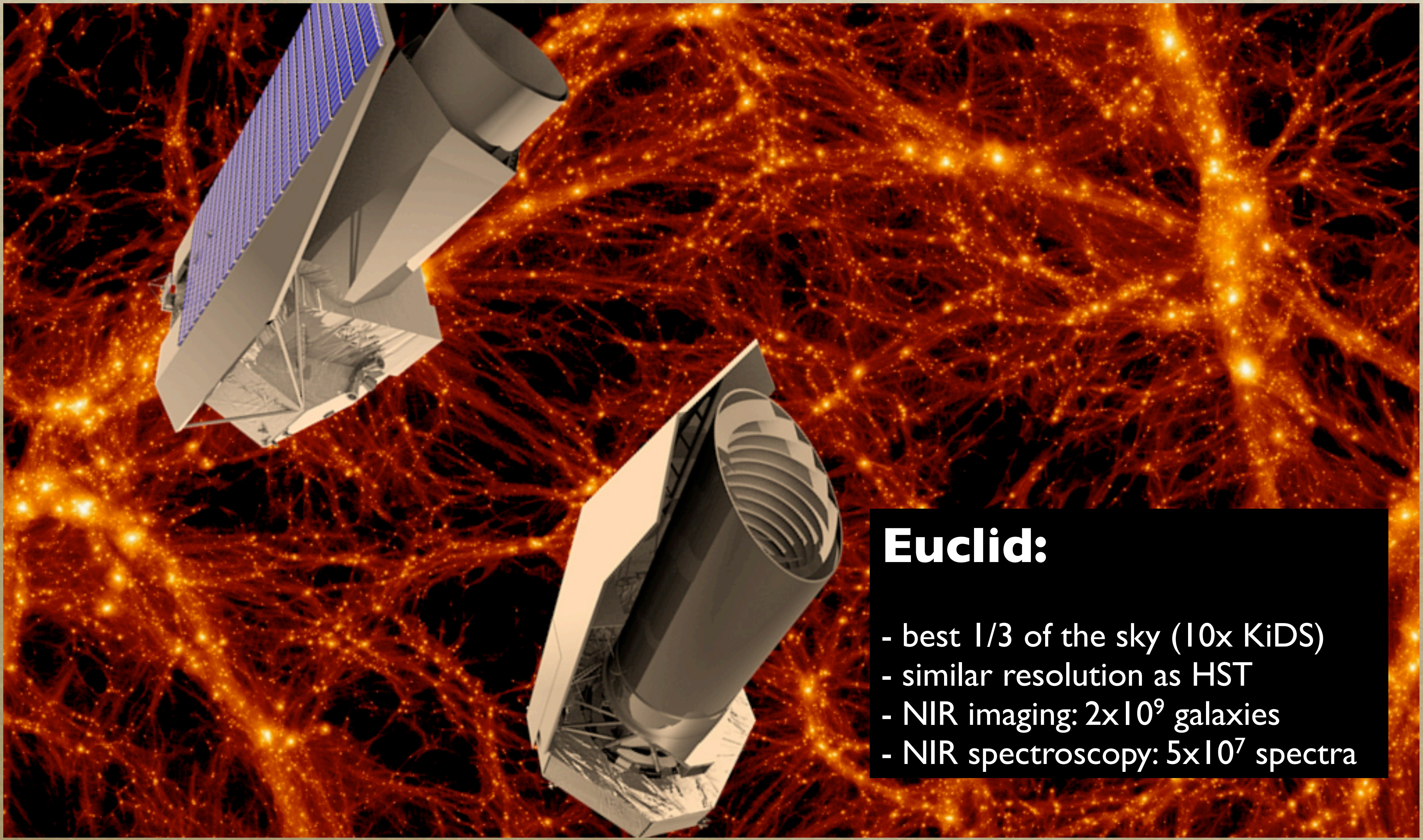
The KiDS is the first cosmic shear survey that can provide dark energy constraints *without* the need of priors from other probes!

survey area: 1500 deg^2
filter coverage: ugri ZYJHK

~10% error in *w*

(~3% with Planck data)

The next 15 years!



Euclid:

- best 1/3 of the sky (10x KiDS)
- similar resolution as HST
- NIR imaging: $2x10^9$ galaxies
- NIR spectroscopy: $5x10^7$ spectra

Conclusions

Weak lensing is rapidly developing into one of the leading probes to study dark energy.

Ongoing ground-based surveys are starting to provide some of the most *accurate* constraints on the dark energy equation-of-state.

Euclid provides a giant step forward in observational cosmology, testing all critical aspects of the current ΛCDM paradigm.

Euclid: the cosmology machine

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	FoM
Euclid Primary	0.010	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	4020
Current	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**