Cosmological constraints from weak lensing: present measurements and future challenges

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INPA seminar, LBL

11/20/2015

Outline:

I. Introduction

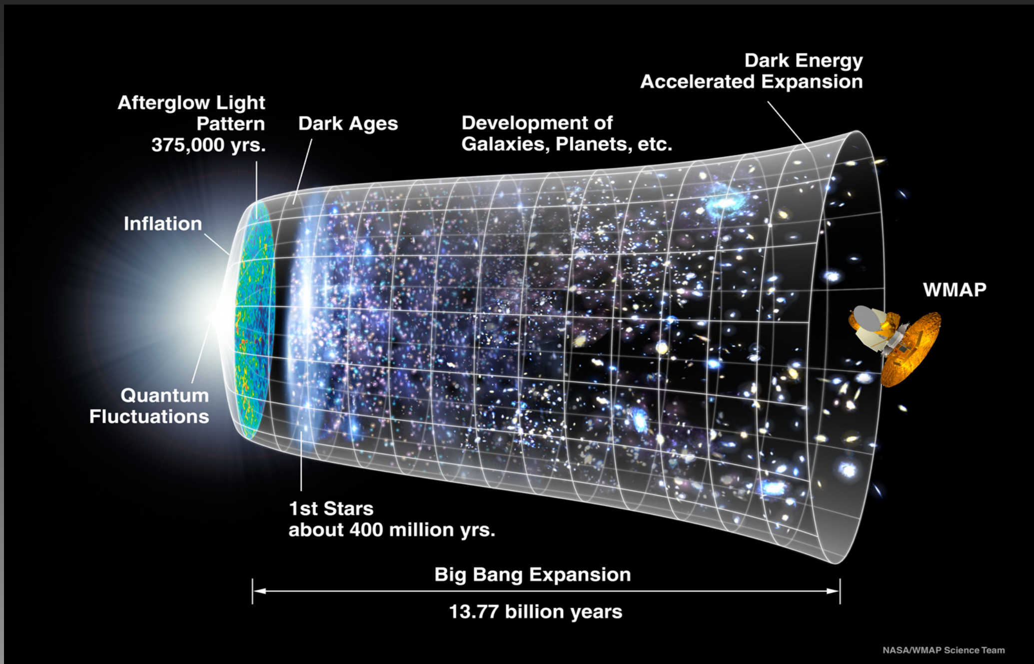
II. Cosmic Shear

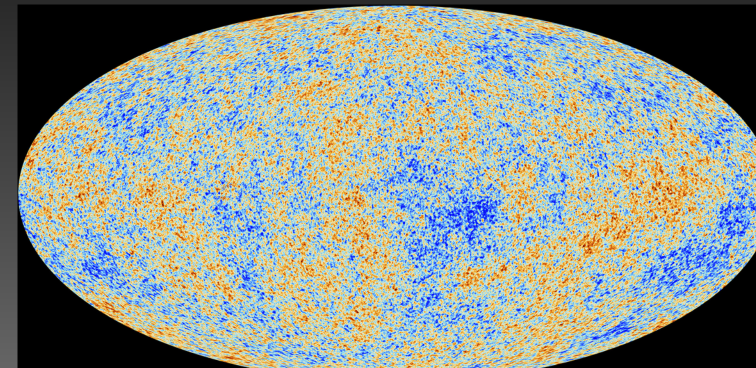
III. Galaxy-Galaxy Lensing

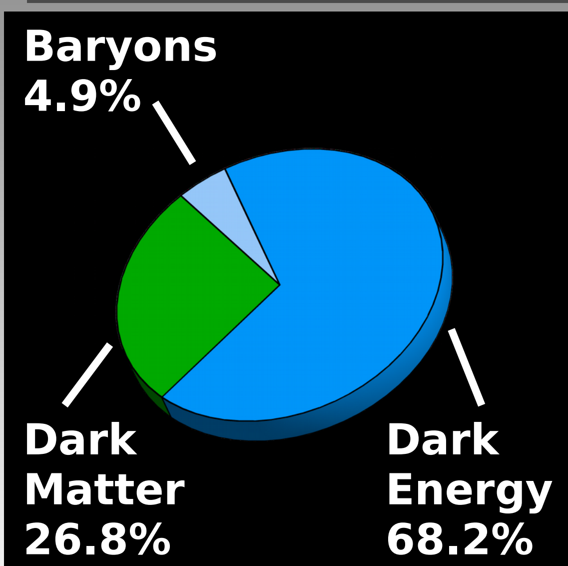
IV. Conclusions

I. Introduction

Cosmological model




ESA & Planck Collaboration



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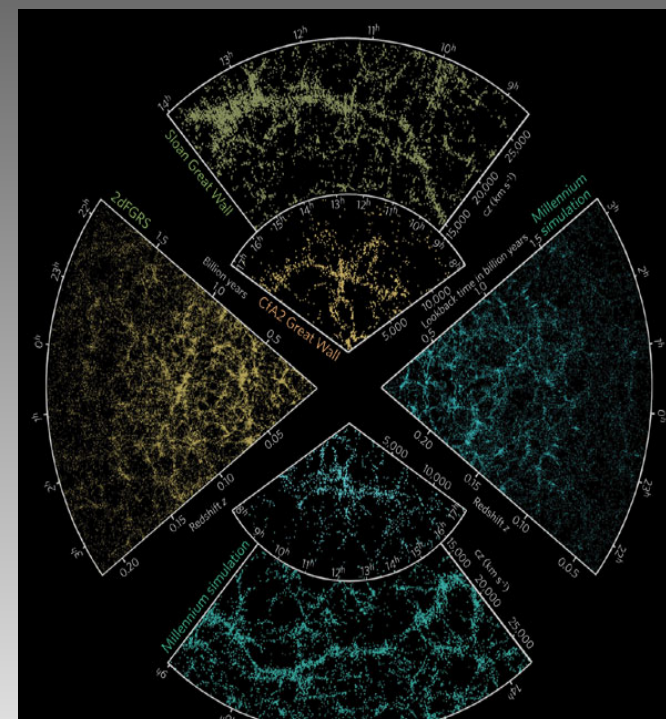
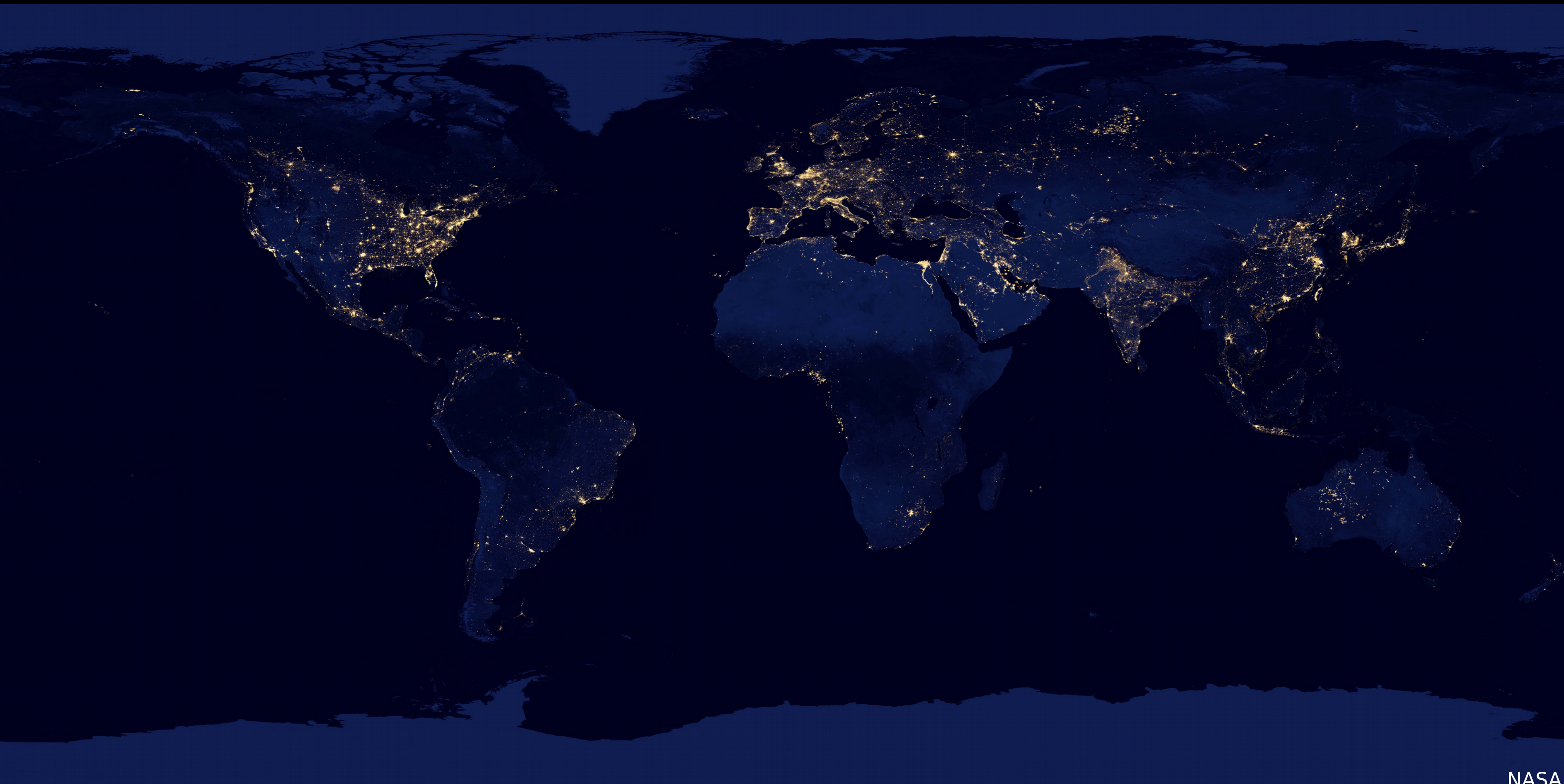
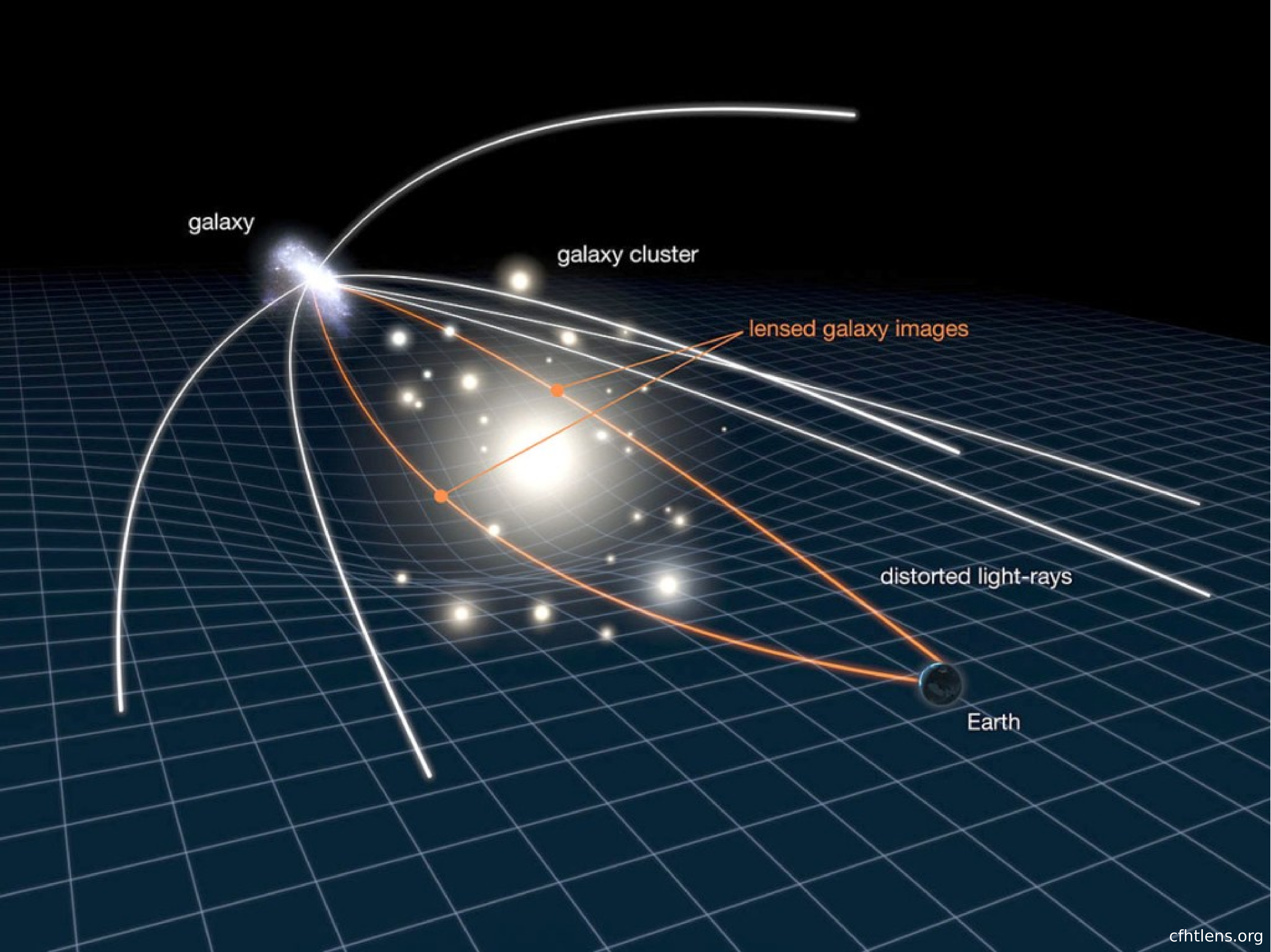


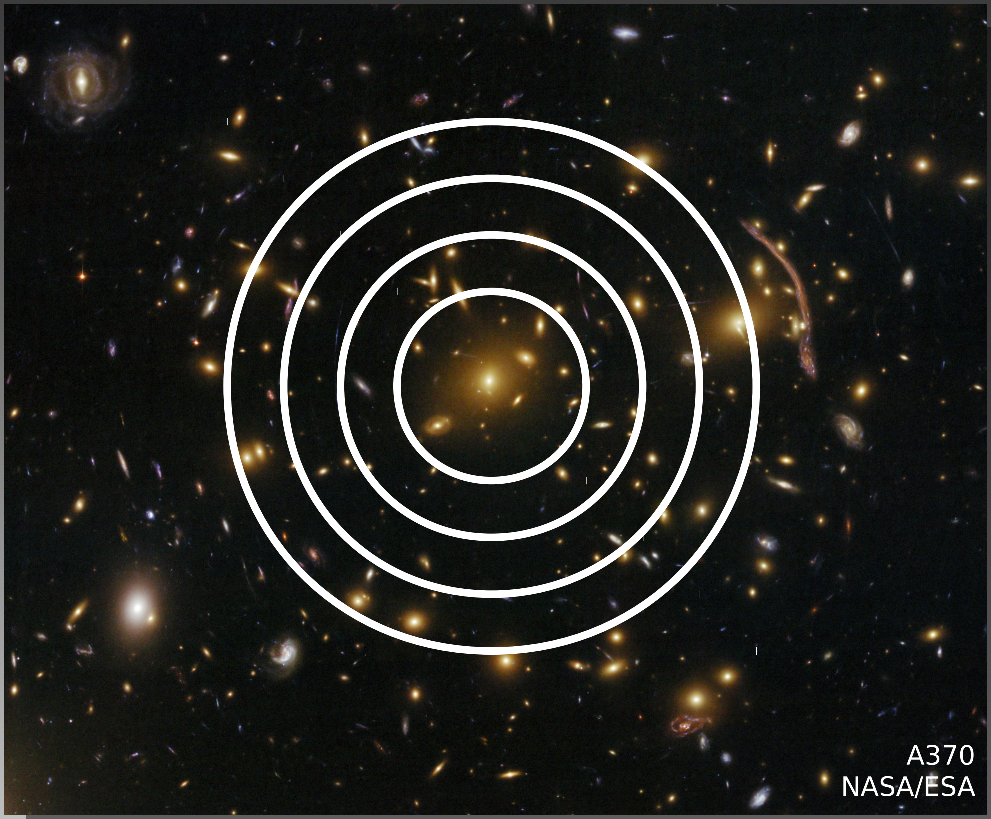
Springel et al. (2006)

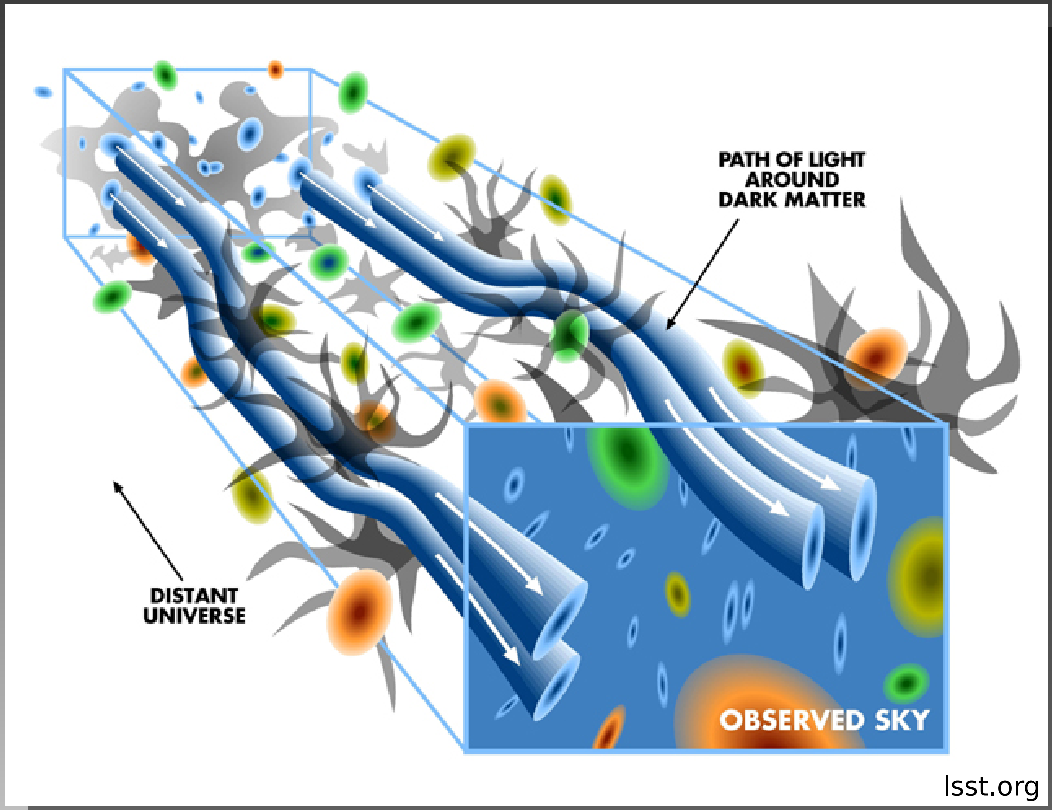

NASA


galaxy
galaxy cluster
lensed galaxy images
distorted light-rays
Earth


A370
NASA/ESA

Two statistics:





shear-position
(a.k.a. galaxy-galaxy lensing)

shear-shear
(a.k.a. cosmic shear)

Weak lensing: Surveys

Area	Survey	Galaxy density	Median redshift	Status
10^2 deg^2	CFHTLenS	17 gals/arcmin^2	$z_m = 0.75$	completed
	RCSLenS	6 gals/arcmin^2	$z_m = 0.60$	
10^3 deg^2	KiDS	9 gals/arcmin^2	$z_m = 0.70$	ongoing
	HSC	20 gals/arcmin^2	$z_m = 1.00$	
	DES	8 gals/arcmin^2	$z_m = 0.65$	
10^4 deg^2	Euclid	30 gals/arcmin^2	$z_m = 0.90$	> 2020
	LSST	31 gals/arcmin^2	$Z_m = 1.00$	

Weak Lensing: Challenges

1) Accurate photometric redshifts

2) Shape noise:

Bridle et al. (2009)

“The bigger (deeper) the survey the smaller the uncertainties!”

3) Blending (!)

II. Cosmic Shear

"A direct measurement of tomographic lensing power spectra from CFHTLenS"

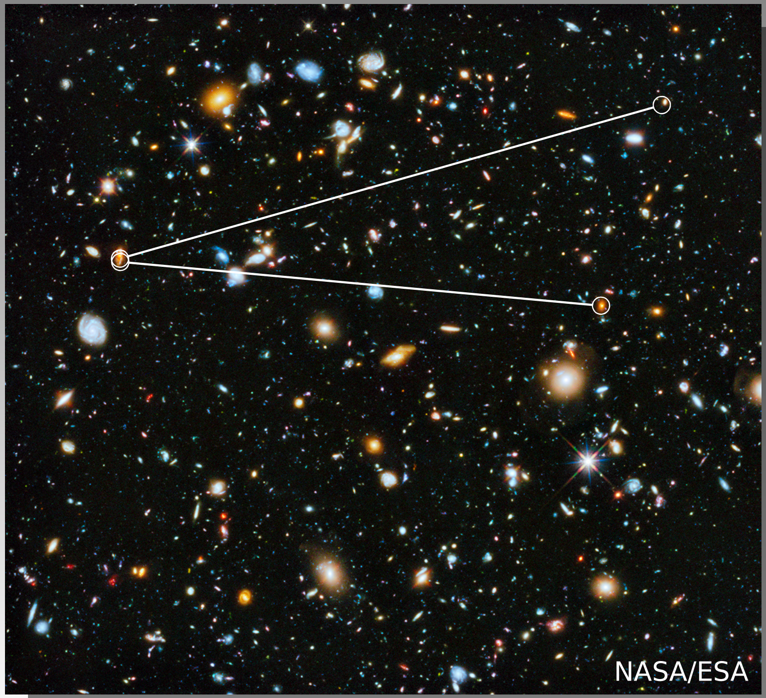
FK, M. Viola, W. Valkenburg, B. Joachimi, H. Hoekstra, K. Kuijken
2015 (in press at MNRAS; arXiv1510.04071)

Lensing of LSS

Theory:

$$C_{\mu\nu}^{\mathrm{EE}}(\ell) = \frac{9\Omega_{\mathrm{m}}^2 H_0^4}{4c^4} \int_0^{\chi_{\mathrm{H}}} \mathrm{d}\chi \, \frac{g_\mu(\chi) g_\nu(\chi)}{a^2(\chi)} P_\delta\left(k = \frac{\ell}{f_{\mathrm{K}}(\chi)}; \chi\right)$$

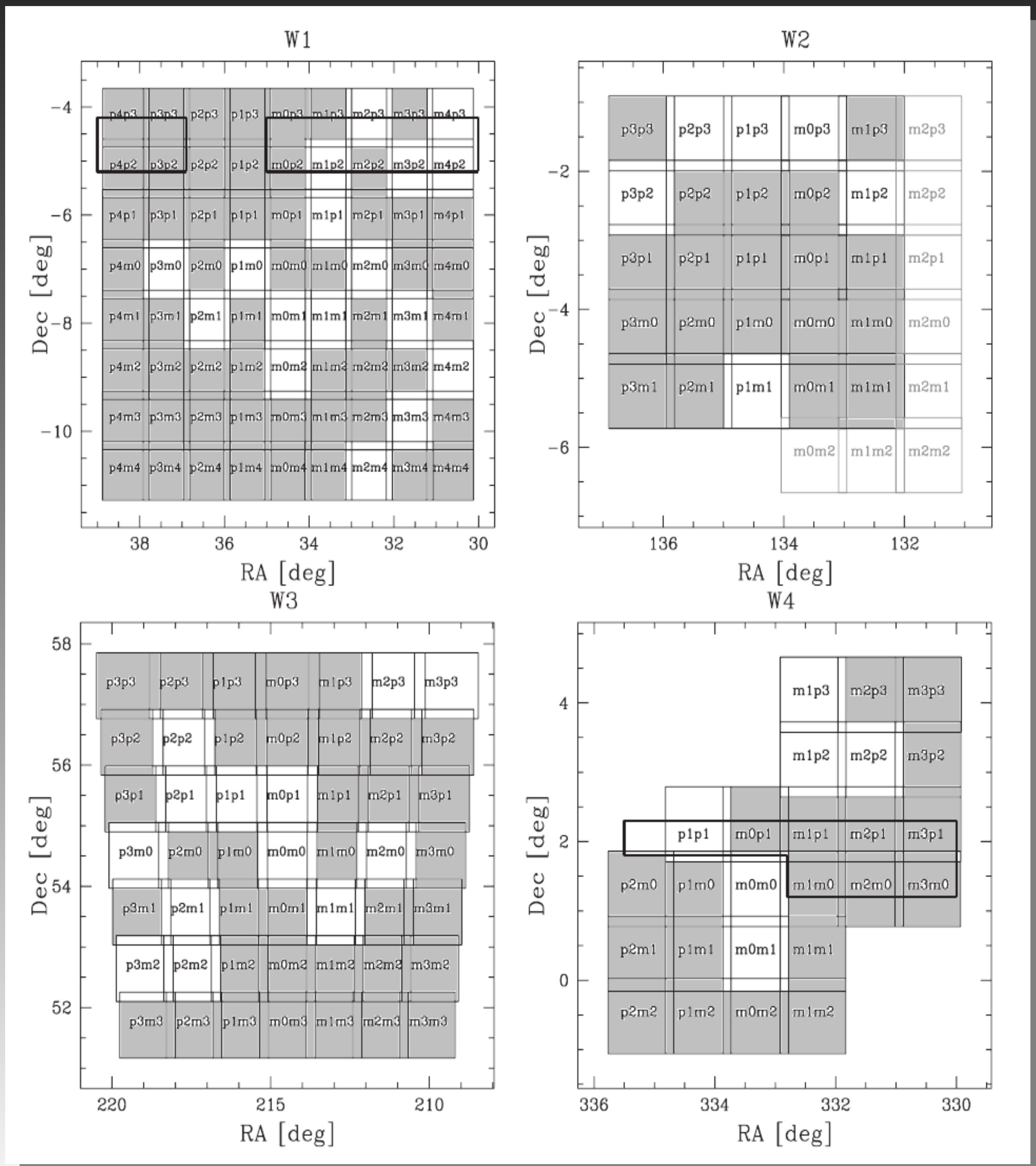
"geometry" "physics"



measurements:

correlation functions $\Longleftrightarrow$ **power spectra**

The CFHTLenS case



Erben et al. (2012)

~154 deg² (~115 deg²)

n_{gal} = 17 gals/arcmin²

two redshift slices:

z_1: $0.50 < z \leq 0.85$
z_2: $0.85 < z \leq 1.30$

minimize intrinsic alignments

!!! PUBLIC data !!!

Goal:

measure cosmic shear **lensing power spectrum:**

- – include low multipoles (large scales)
- – in redshift bins

Why?

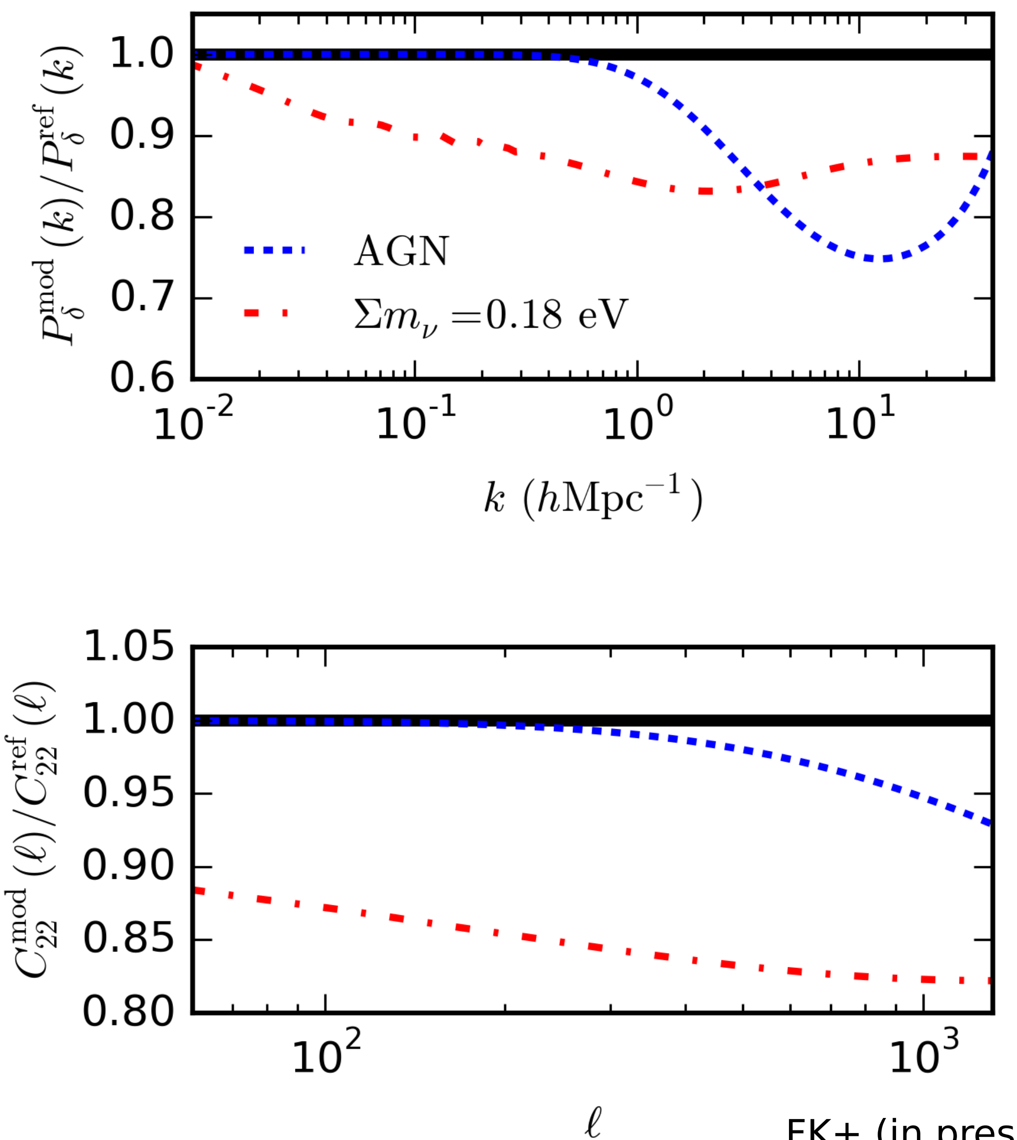
– better handling of scale mixing in multipole space (compared to real space analyses)

– coupling to other cosmological probes (CMB)

– account for scale dependent features:

→ **Neutrinos**, baryon feedback (e.g. Harnois-Déraps et al. 2015)!

Baryons & neutrinos



FK+ (in press)

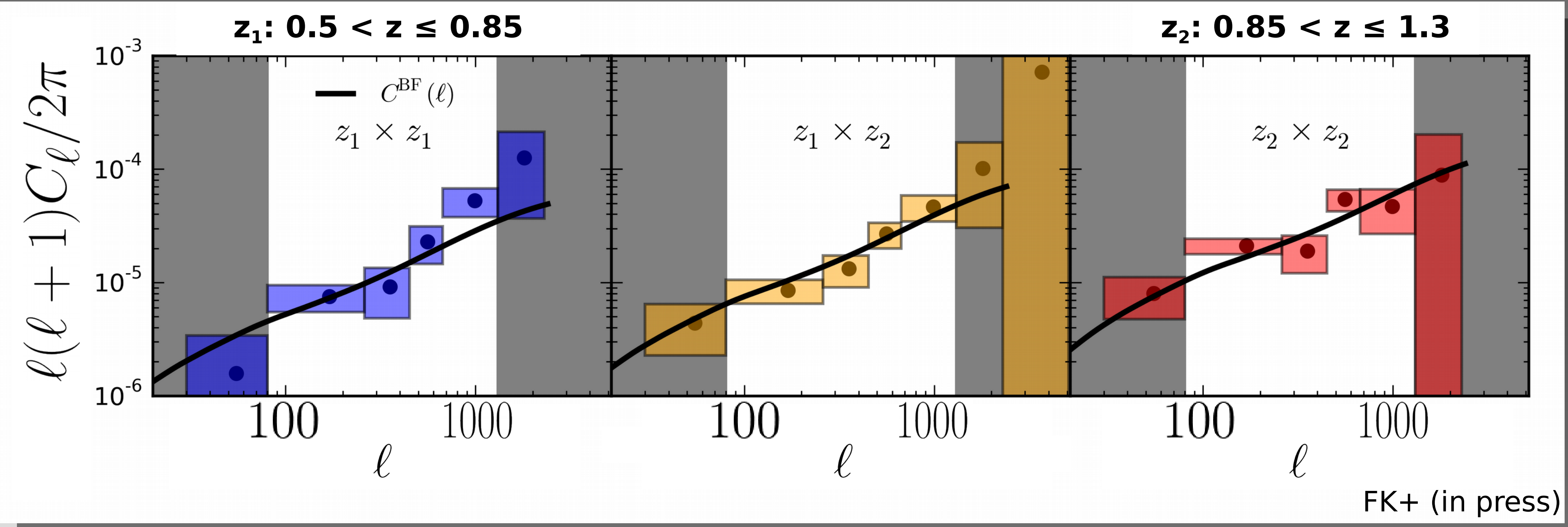
integration over lensing kernel

- AGN feedback from OWLS after Harnois-Déraps et al. (2015)
- 3 degenerate, massive neutrinos with Σm_ν = 0.18 eV

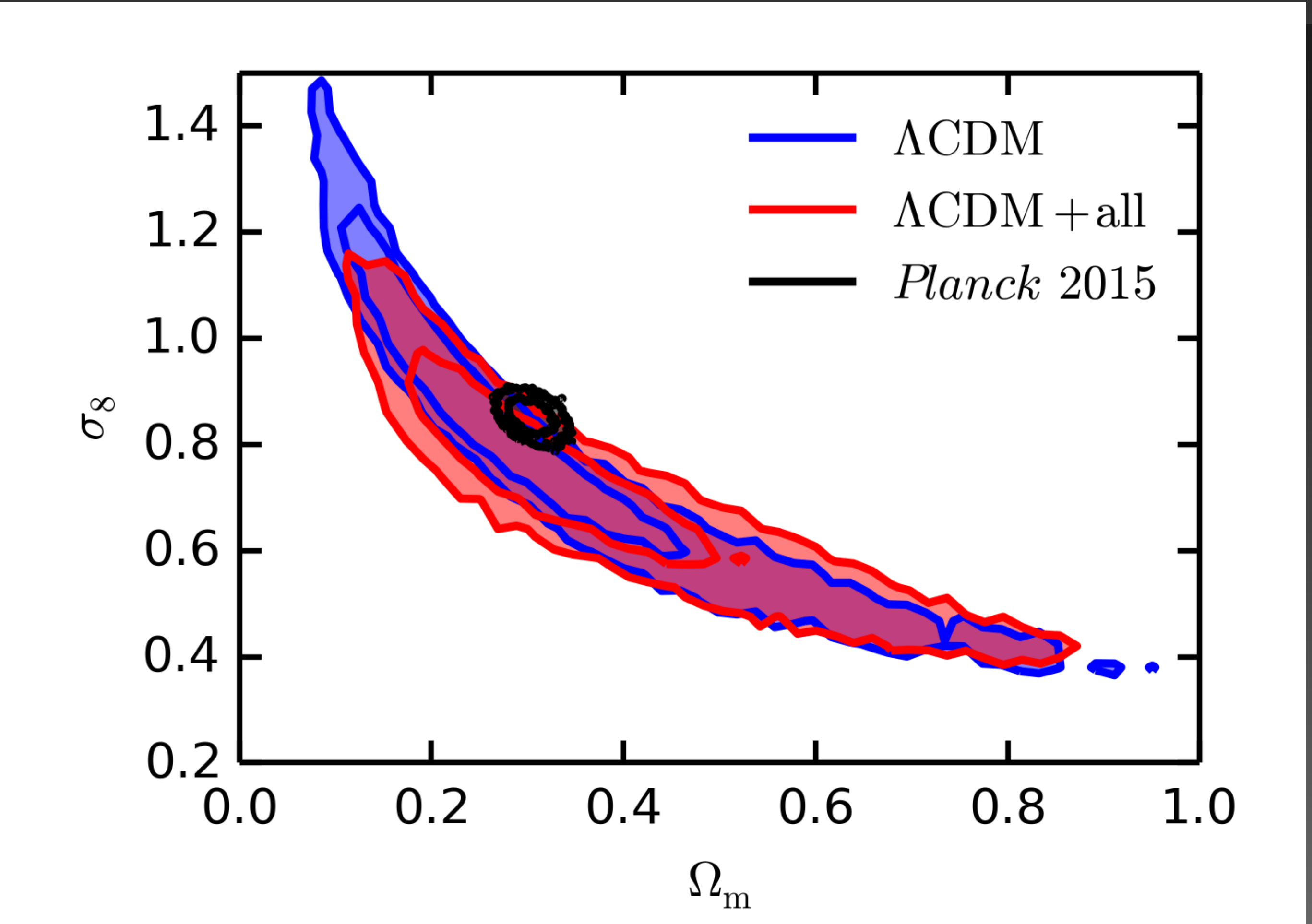
Results: Multipole Space

WL power spectra from CFHTLenS
(W1, W2, W3 & W4 combined with inverse variance weights)

quadratic estimator method (Hu & White 2001)
expanded to include photometric redshift bins

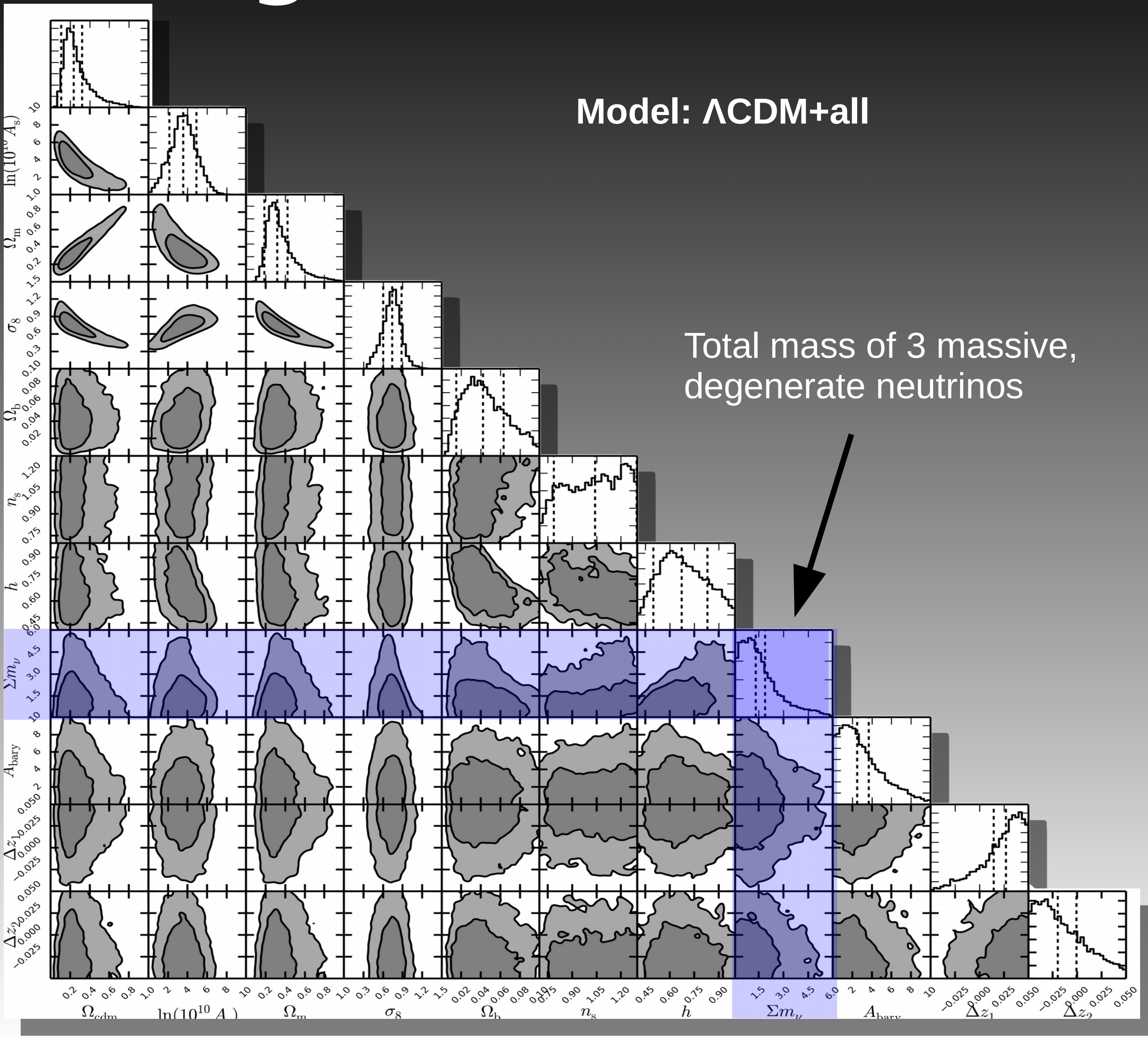


Cosmological inference



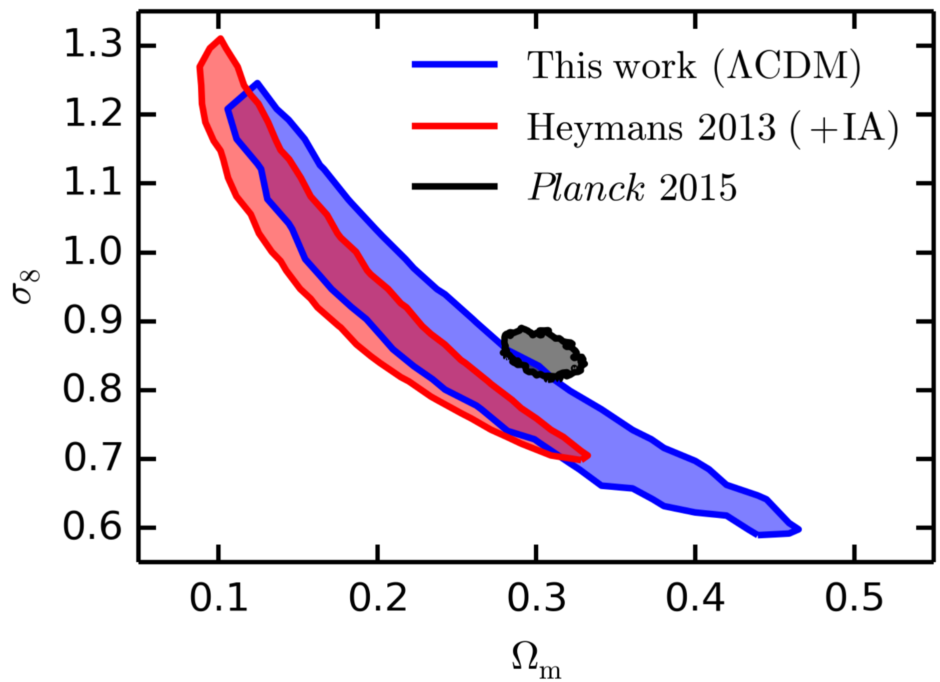
FK+ (in press)

Cosmological inference

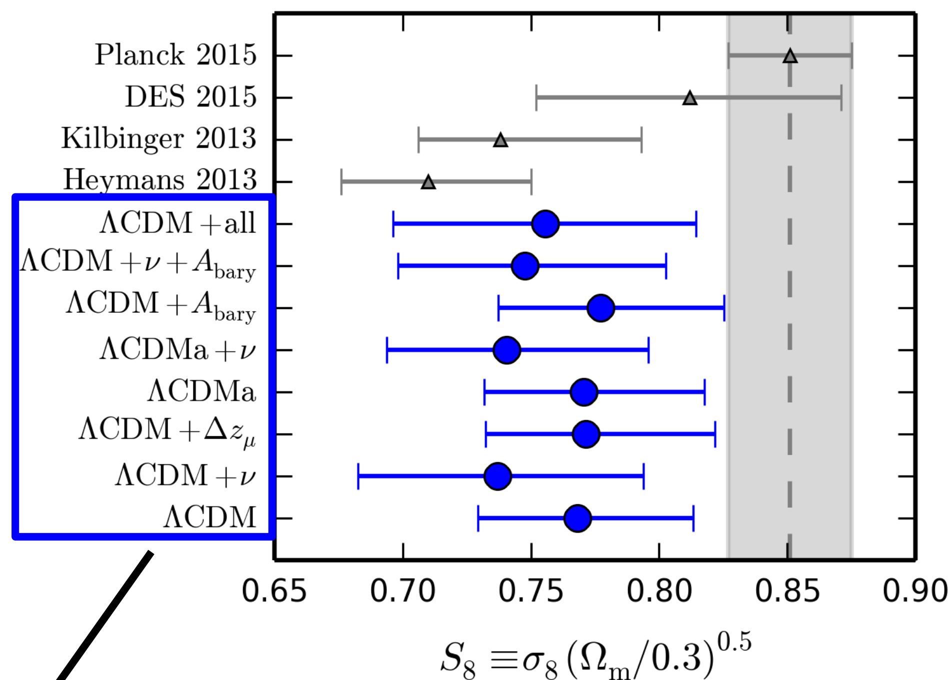


FK+ (in press)

Cosmological inference



FK+ (in press)



FK+ (in press)

Which model describes the data the best?

Evidences

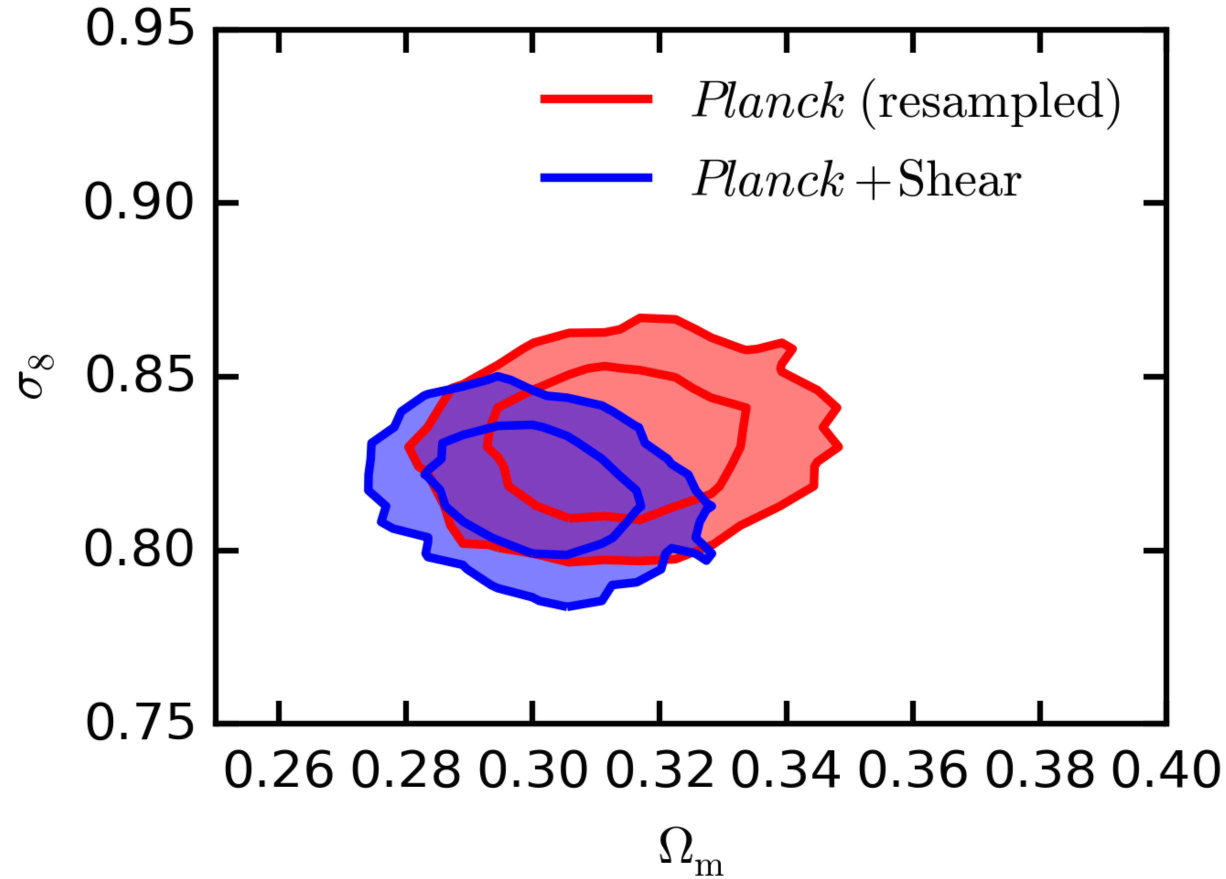
likelihood analysis performed with *Monte Python* (Audren et al. 2012) and *Multinest* (Feroz et al. 2008, 2009, 2013)

Evidences:

Model	$\ln \mathcal{Z}$	$2\ln K$ $(K \equiv \mathcal{Z}_i/\mathcal{Z}_{\Lambda\mathrm{CDM}})$
ΛCDM	-40.96 ± 0.06	0
ΛCDMa	-41.07 ± 0.06	-0.22
$\Lambda\mathrm{CDM} + \nu$	-41.63 ± 0.07	-1.34
$\Lambda\mathrm{CDMa} + \nu$	-41.83 ± 0.07	-1.74
$\Lambda\mathrm{CDM} + A_{\mathrm{bary}}$	-41.66 ± 0.06	-1.40
$\Lambda\mathrm{CDM} + \nu + A_{\mathrm{bary}}$	-42.48 ± 0.07	-3.04
$\Lambda\mathrm{CDM} + \Delta z_{\mu}$	-40.75 ± 0.07	0.42
$\Lambda\mathrm{CDM} + \mathrm{all}$	-42.19 ± 0.07	-2.46

FK+ (in press)

Cosmological inference



FK+ (in press)

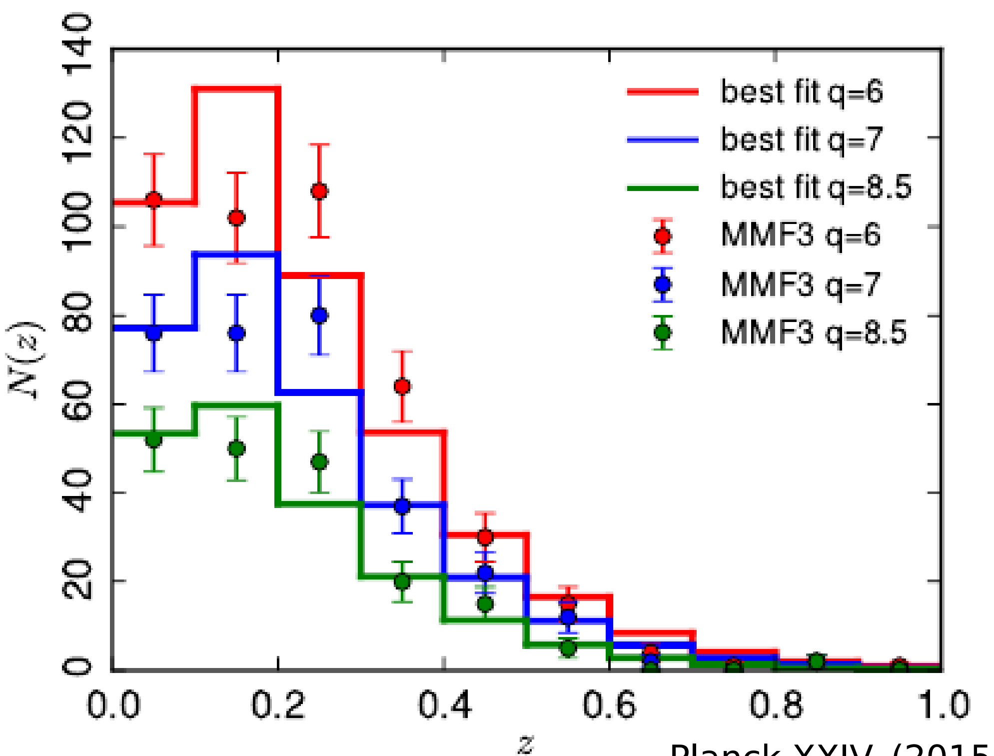
↳ Degeneracy broken: $\boldsymbol{\Omega_m}$ = 0.300 +/- 0.011, $\boldsymbol{\sigma_8}$ = 0.818 +/- 0.013

III. Galaxy-Galaxy Lensing

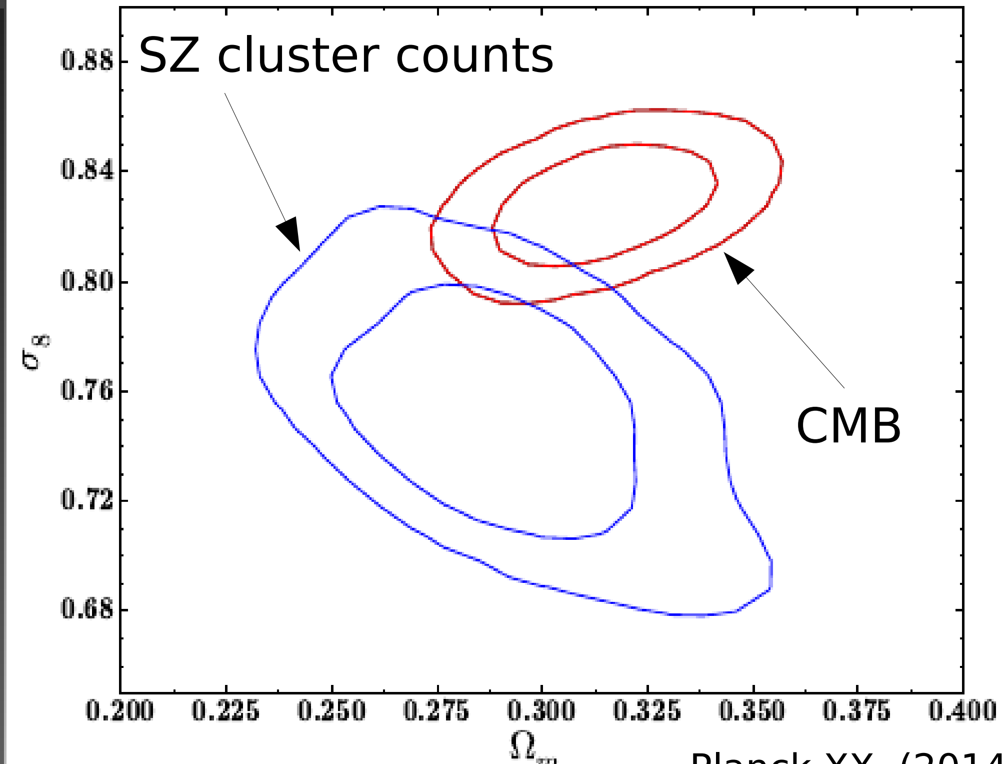
"Statistical uncertainties and systematic errors in weak lensing mass estimates of galaxy clusters"

FK, H. Hoekstra, M. Eriksen 2015 (MNRAS, 453, 3107)

Cluster counts



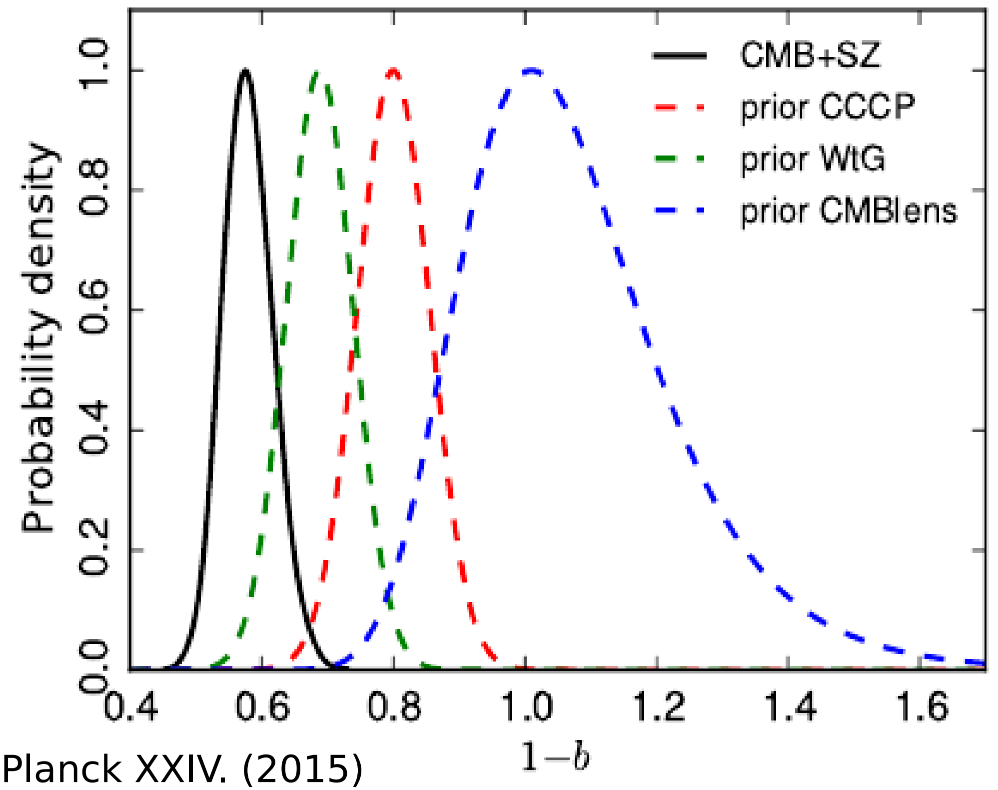
Planck XXIV. (2015)



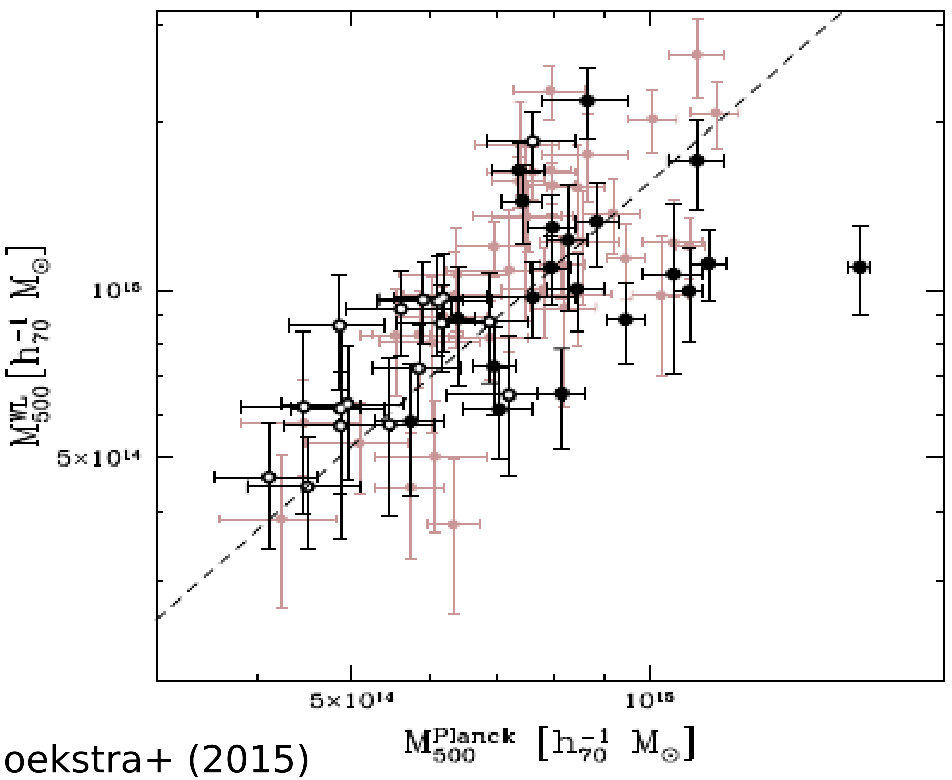
Planck XX. (2014)

Cosmological constraints from the CMB are in tension wrt. the ones derived from SZ-cluster counts.

Mass bias & scaling relations



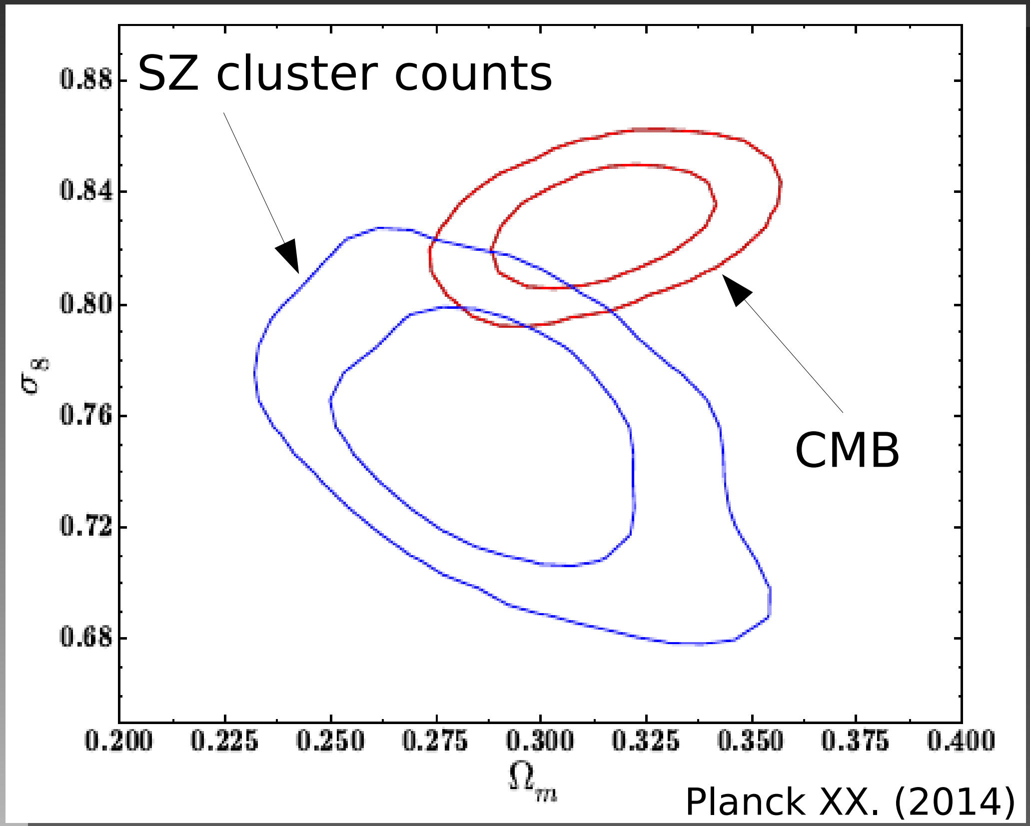
Planck XXIV. (2015)

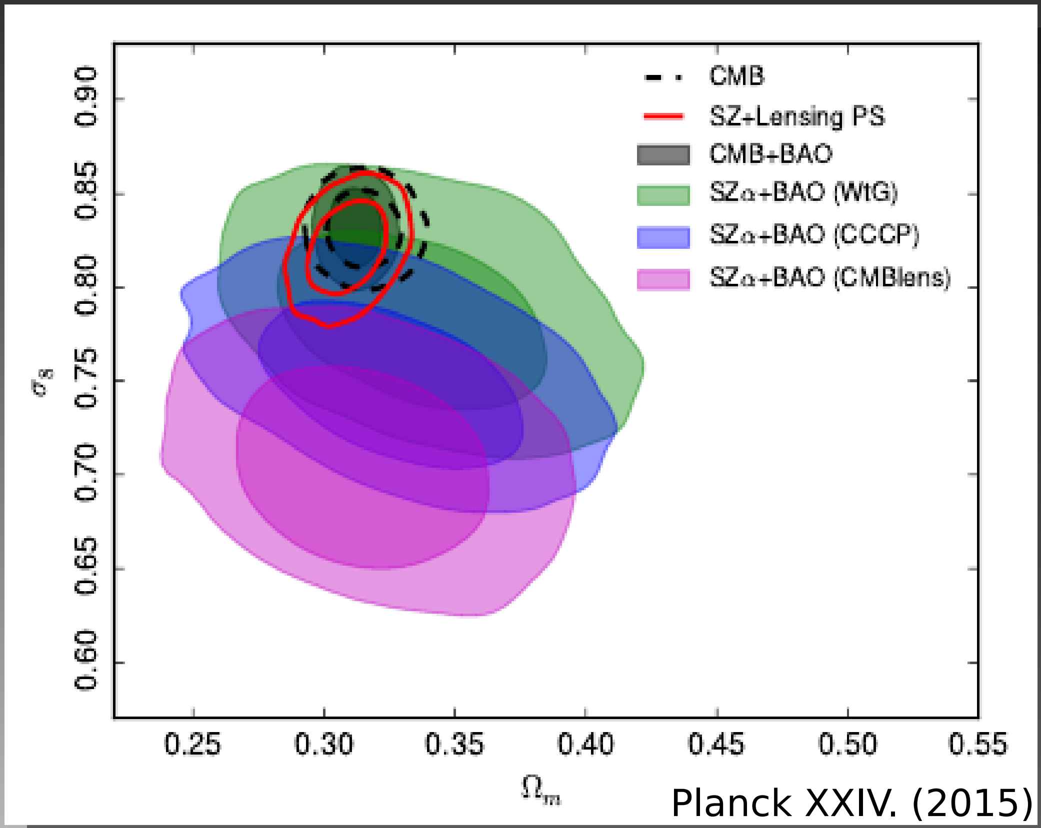


Hoekstra+ (2015)

Weak lensing of clusters can be used to derive tight scaling relations independent of the dynamical state of matter for example.

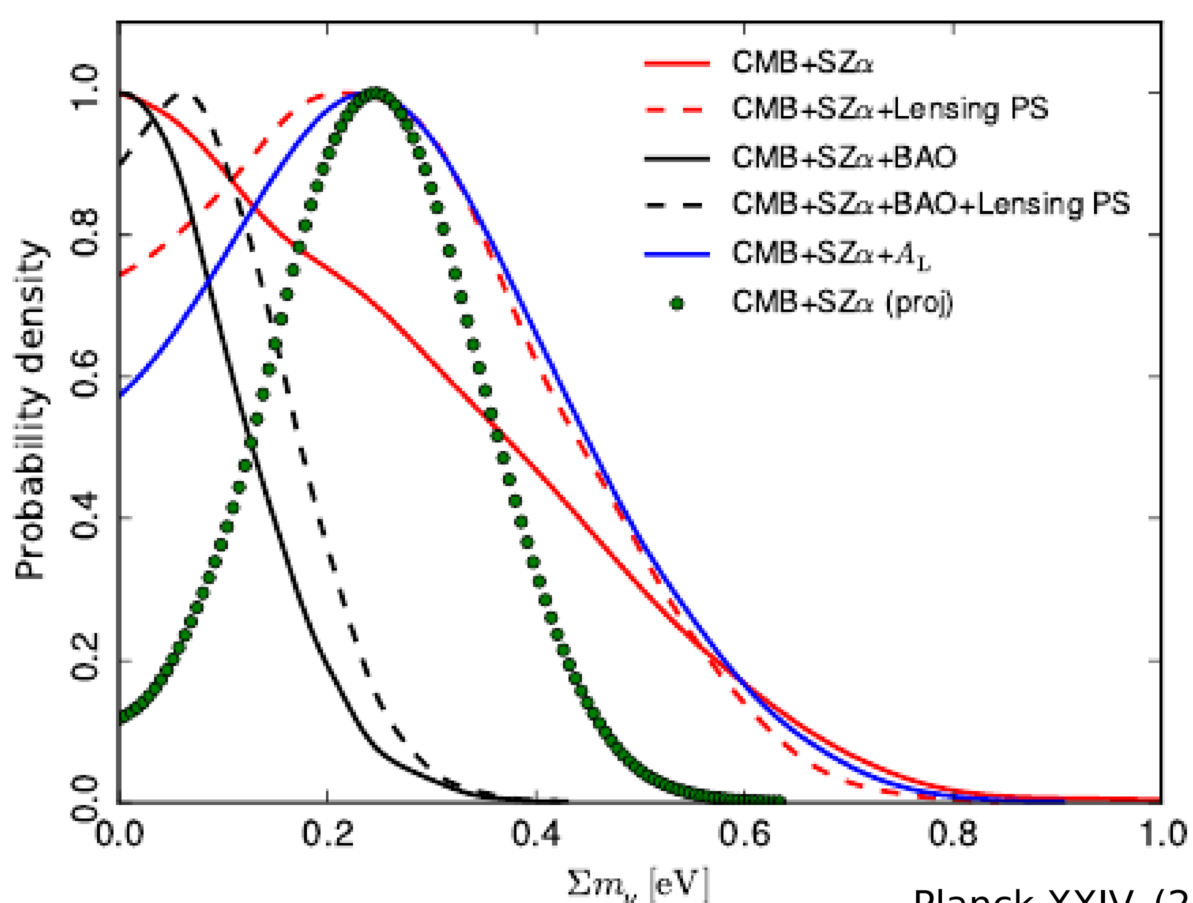
Cluster counts revised





Scaling relations gauged with weak lensing masses alleviate the tension...

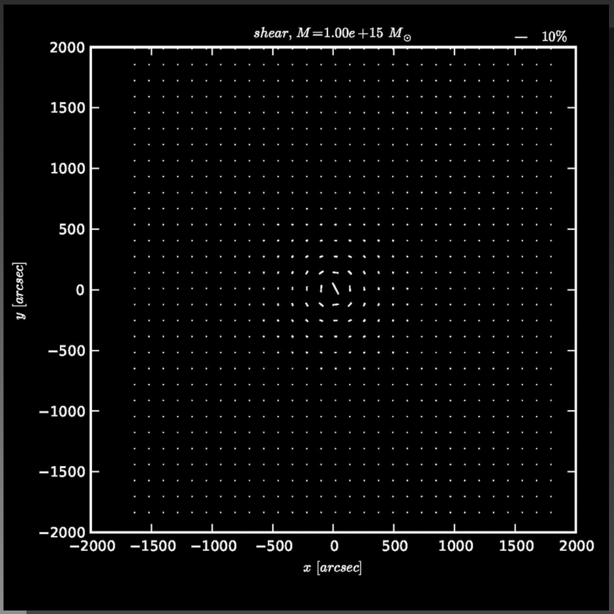
The possibilities

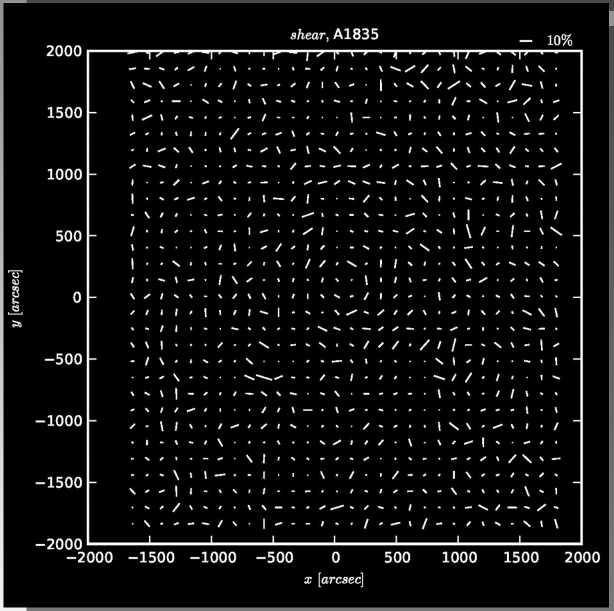


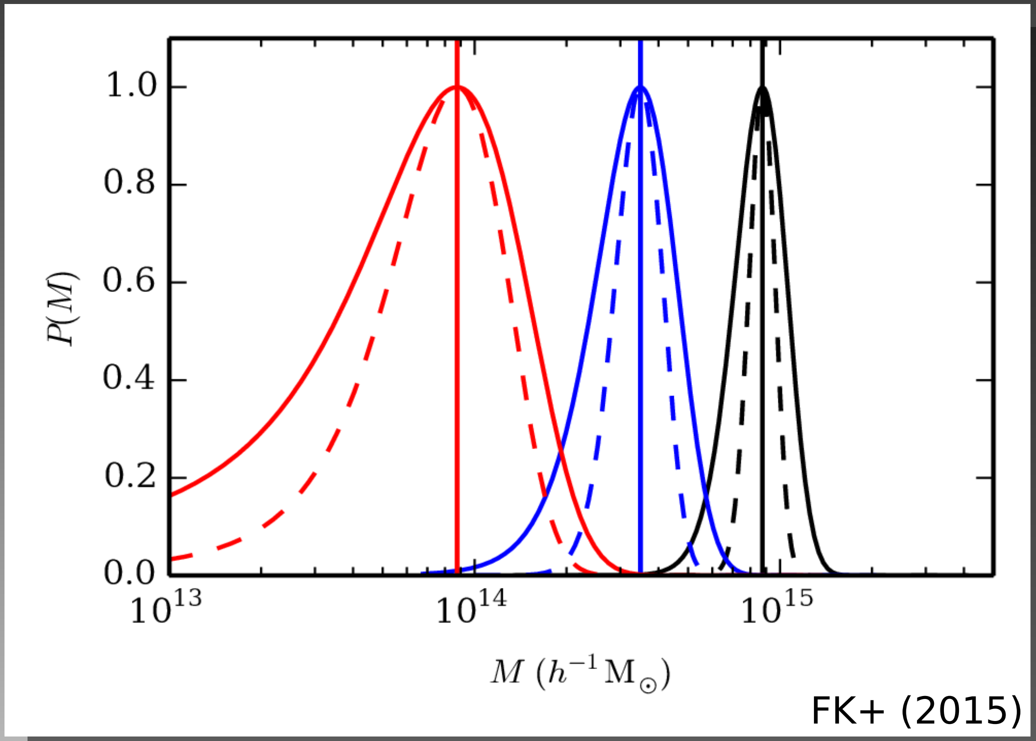
Planck XXIV. (2015)

If the uncertainty on the mass bias can be reduced to 1%, tight constraints on the total mass of neutrinos are possible.

Cosmic shear as noise

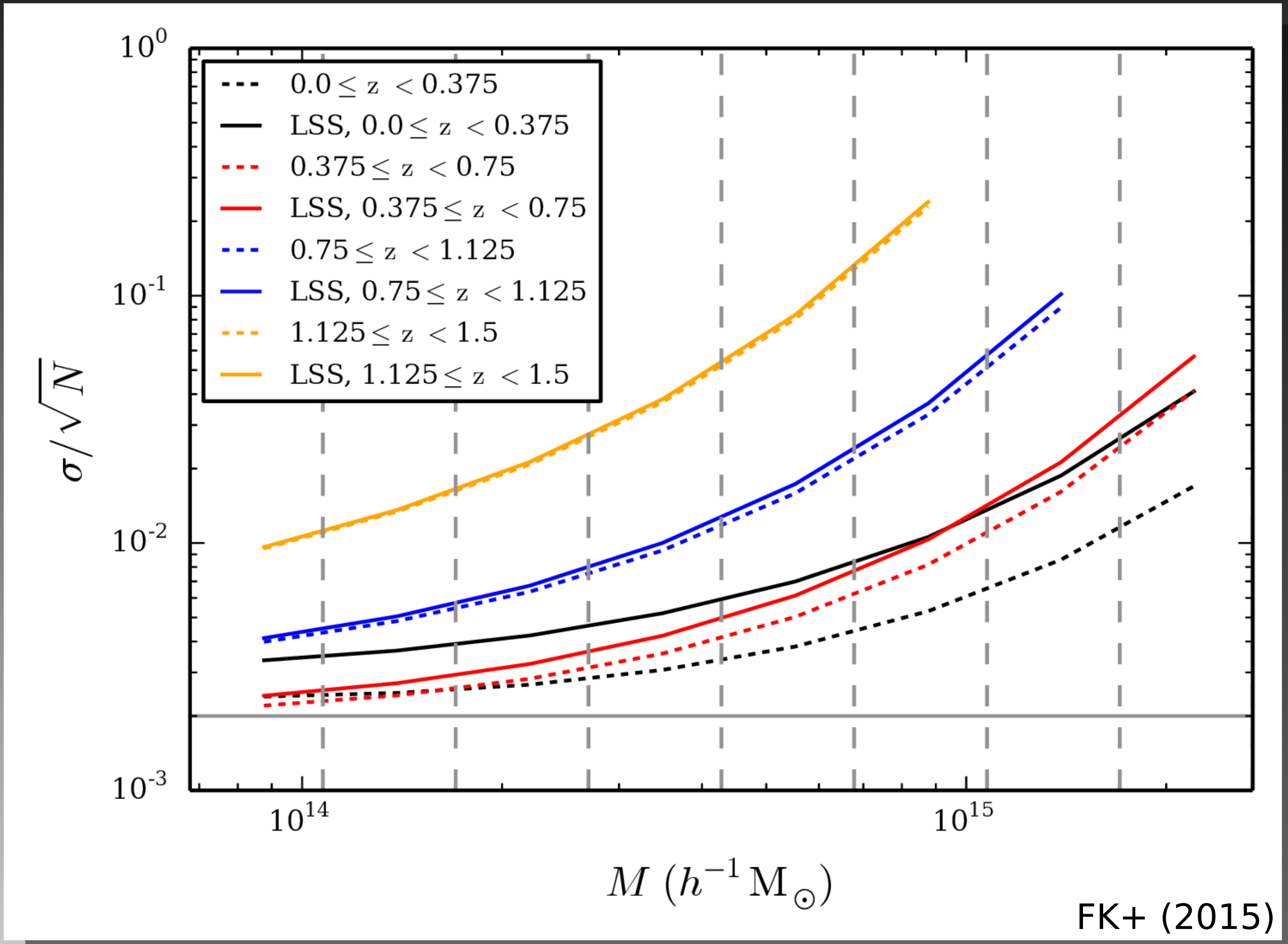






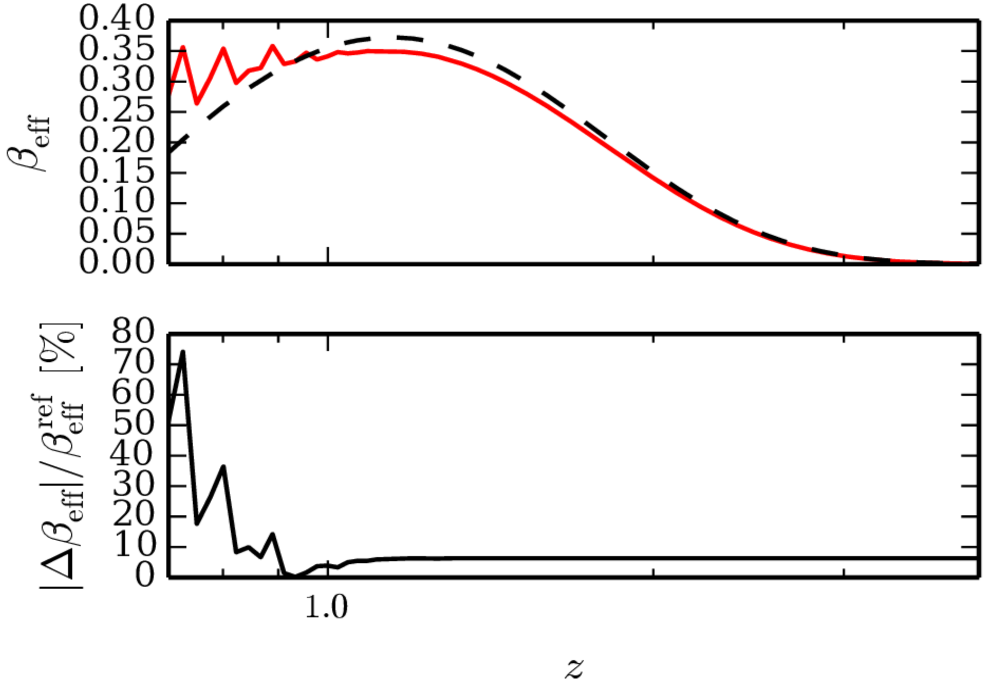
Cosmic noise must be taken into account for deriving realistic uncertainties.

Statistical uncertainties

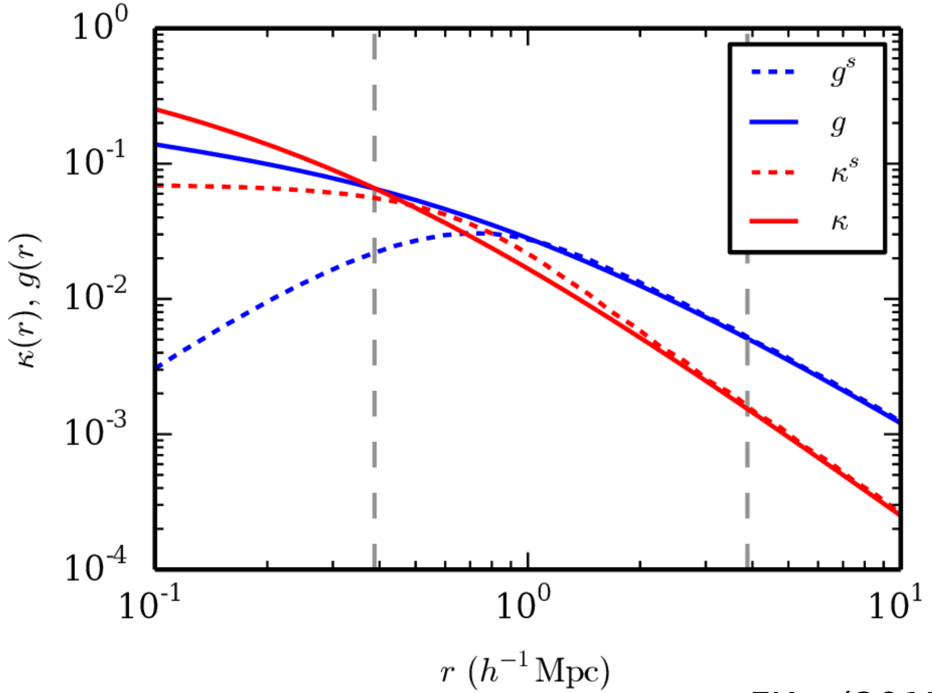


A *Euclid* cluster survey will yield very precise mass measurements of galaxy clusters.

Systematic errors



FK+ (2015)

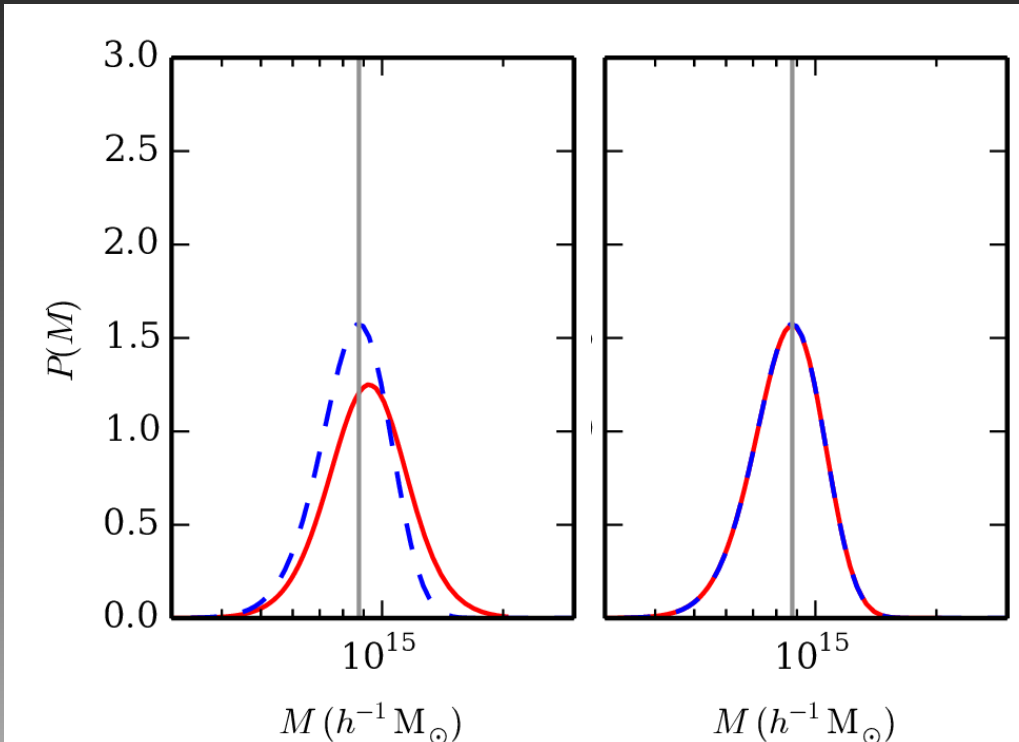


FK+ (2015)

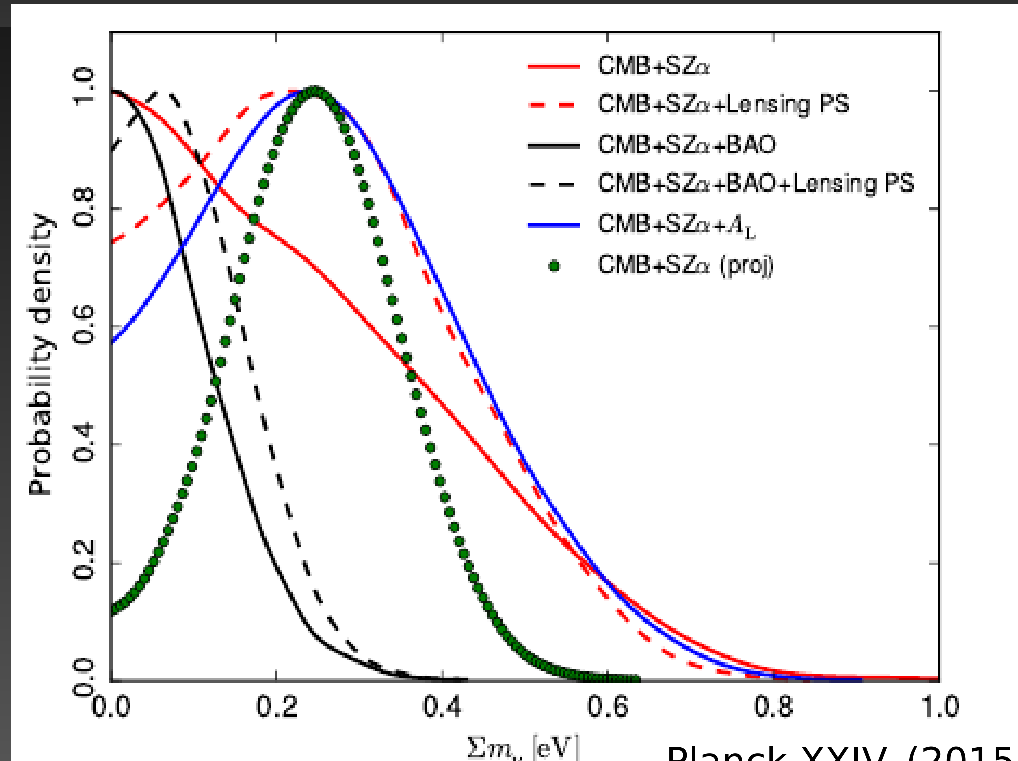
cluster member scattering (due to photo-z errors)

miscentring

Miscentring



FK+ (2015)



Planck XXIV. (2015)

***Euclid* and *eROSITA* promise to become a powerful tool for constraining the total neutrino mass.**

IV. Conclusions

A direct extraction of the lensing power spectrum is the "cleanest" way to compare data with theory.

The power spectrum results show overall consistency with previous results based on correlation-functions.

Future weak lensing galaxy cluster surveys will provide unprecedented statistical power, however, this requires to account also for (tiny) systematic errors.

↳ **If these are accounted for, cluster surveys are a powerful, complementary approach for testing ΛCDM extensions.**