Cosmology with HSC cosmic shear analysis

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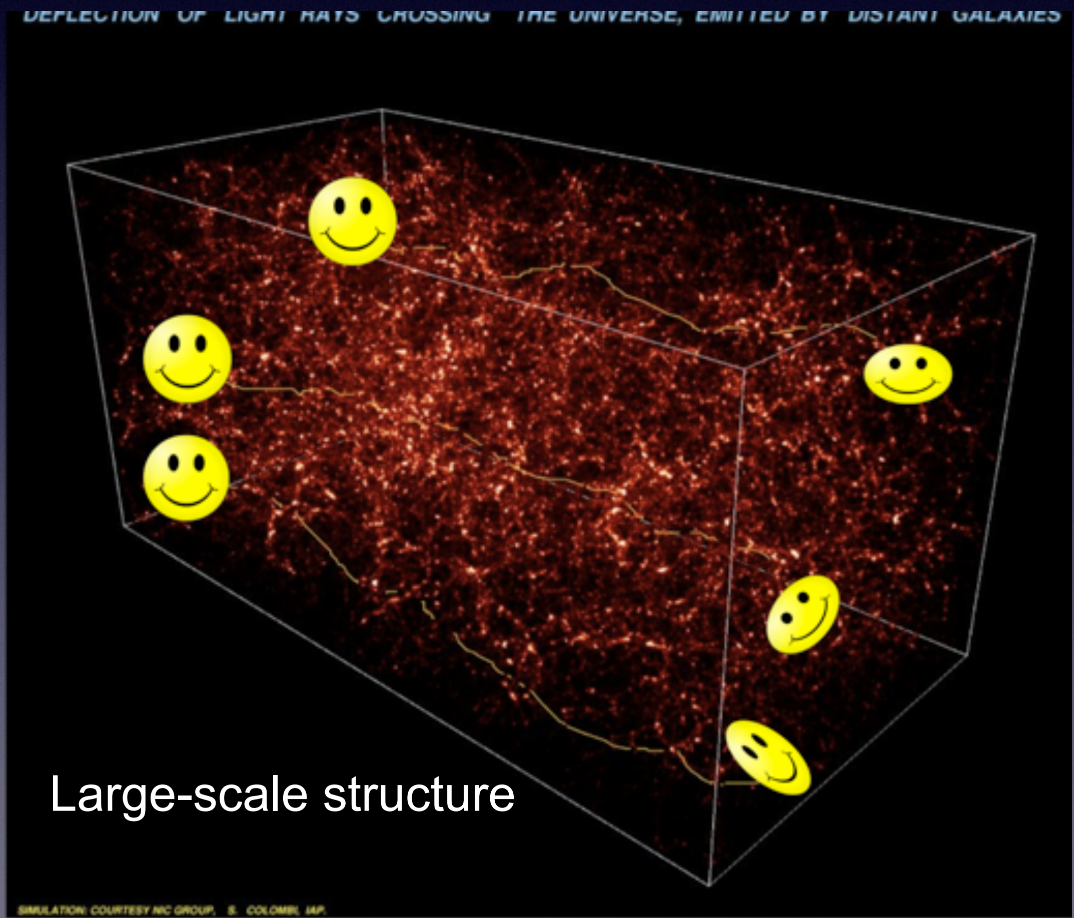
Cosmic shear

Large-scale structure distort the distant galaxy images by the gravitational lensing effect



(c) S. Colombi

Weak distortion in galaxy images are spatially correlated and becomes a **direct probe of matter density field**

Lensing power spectrum

Cosmic shear depends on both the growth of matter density field and the expansion history of the universe

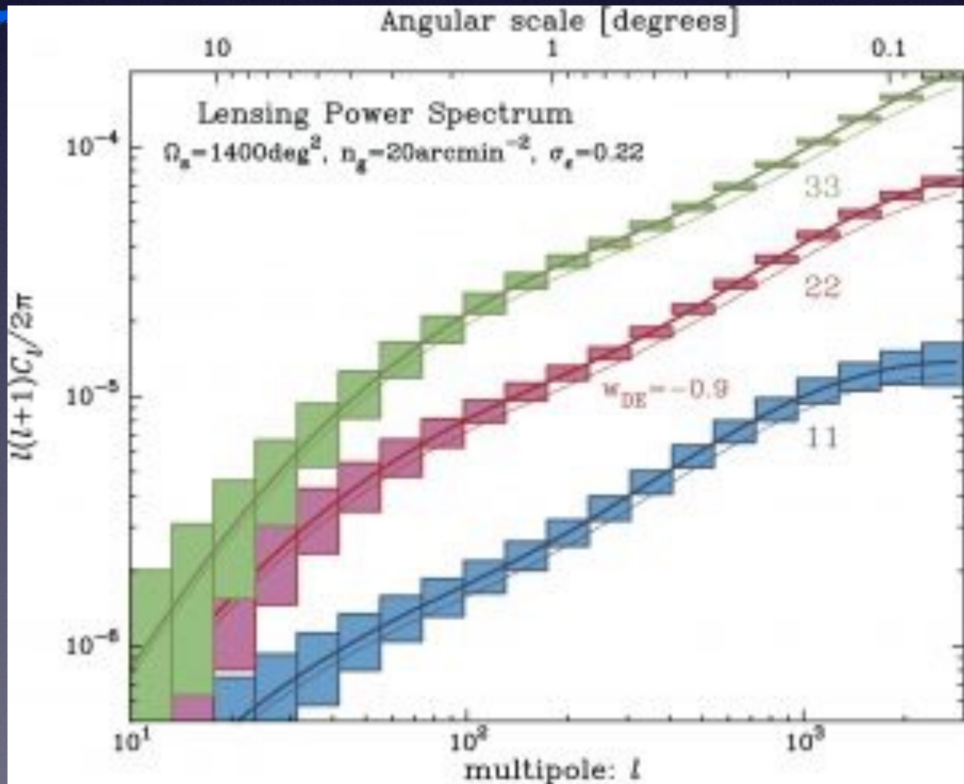
$$\gamma \propto \Omega_{m0} \int_0^{z_s} dz_L \frac{d_s(z_L)d_s(z_s - z_L)}{d_s(z_s)} \delta(z_L)$$

distance

matter density field

- Lensing (Cosmic shear) power spectrum are sensitive to a combination of cosmological parameters
  $S_8 = \sigma_8 \Omega_m^{\alpha}$ (α~0.5)

Tomographic lensing spectra expected from HSC final data

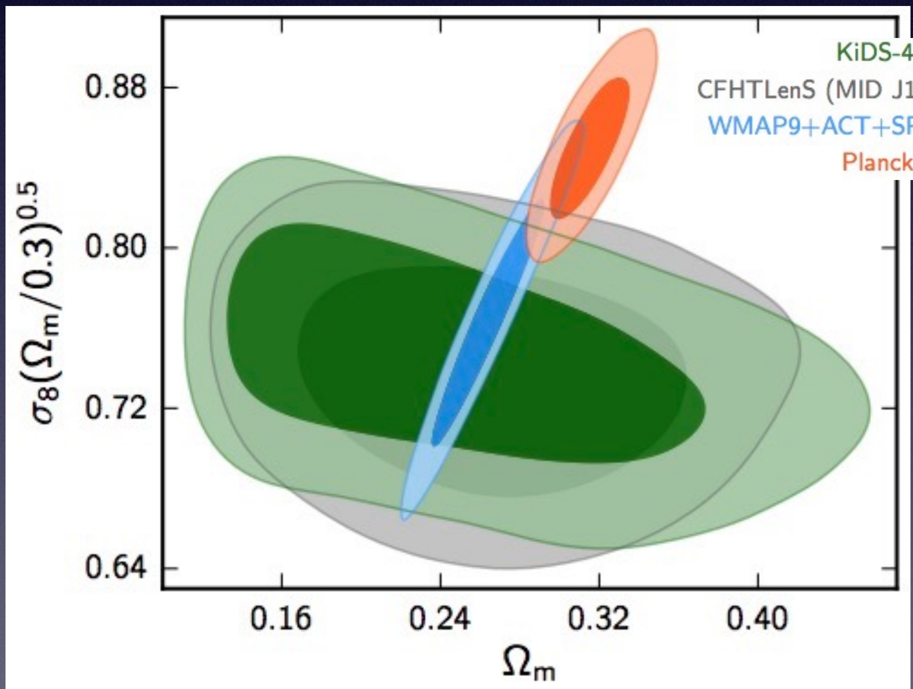


(c) HSC collaboration

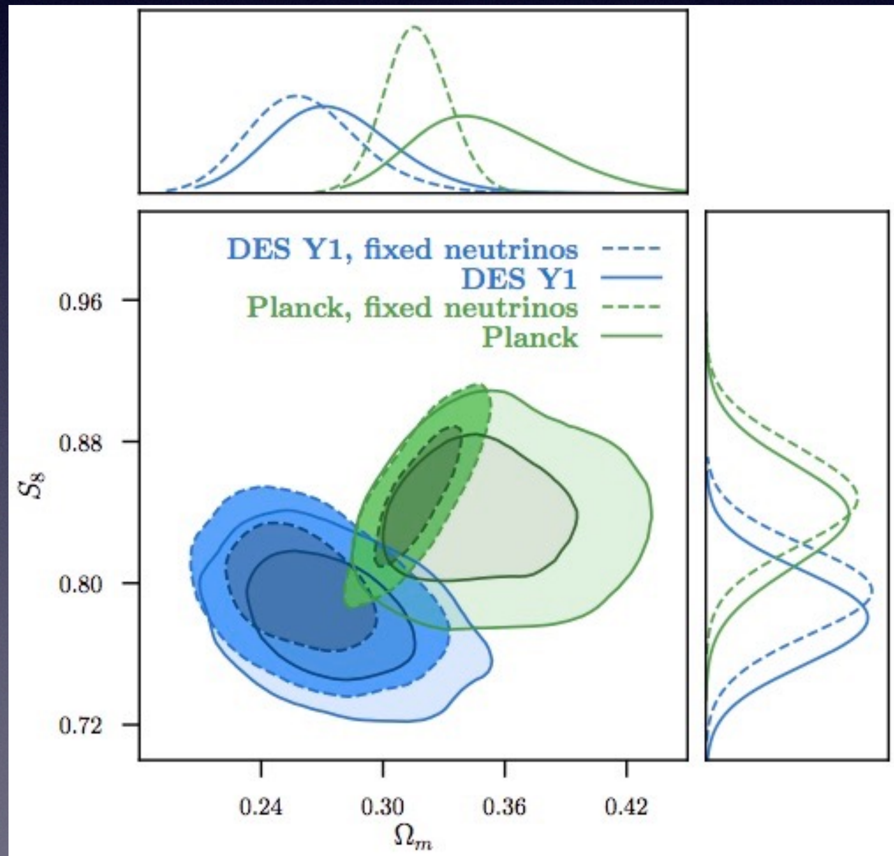
Tension between Planck and weak lensing

Constraints on $S_8=\sigma_8(\Omega_m/0.3)^{0.5}$ from lensing surveys are smaller than that from Planck

→Observational systematic or hints beyond ΛCDM model ?



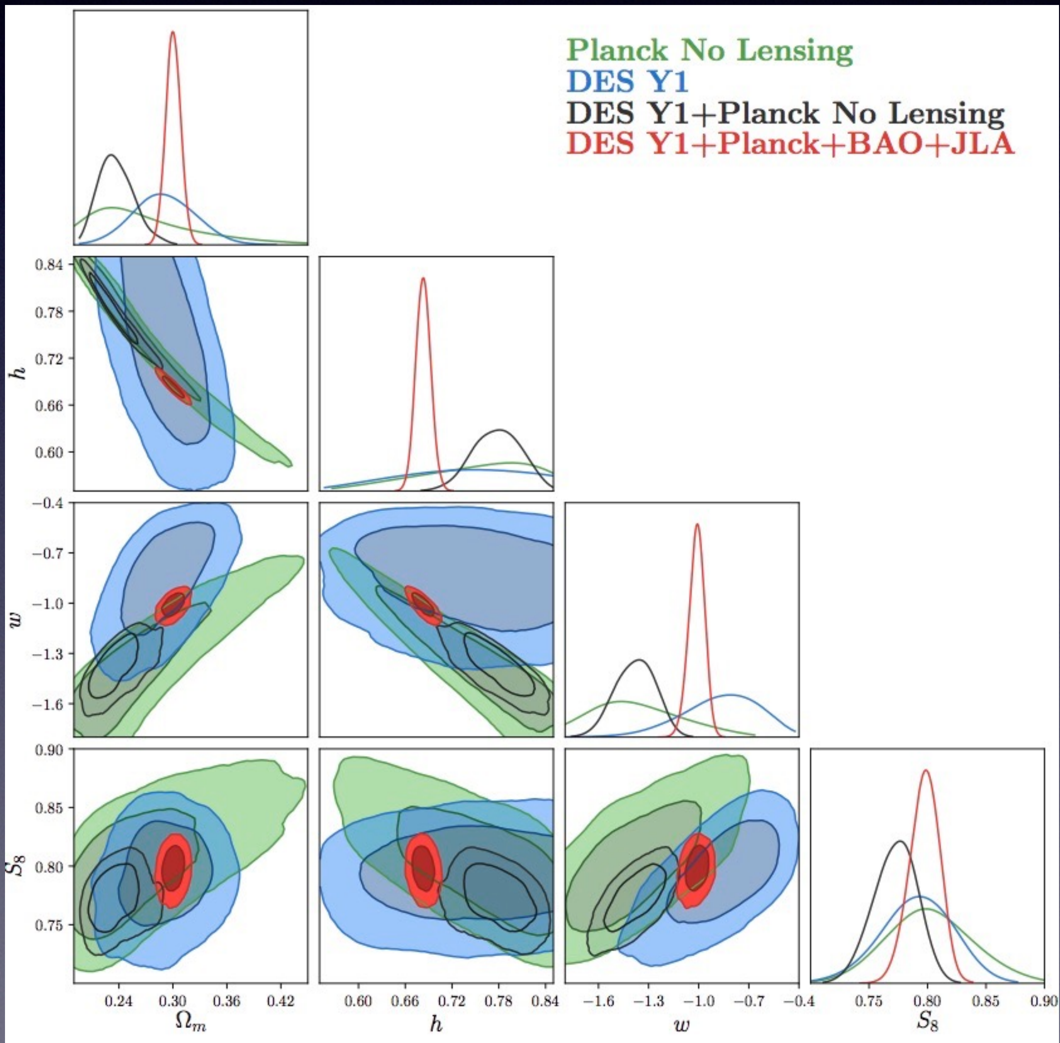
KiDS/CFHTLenS vs Planck



DES vs Planck

DES+Planck: w<-1 !?

wCDM (dark energy EoS parameter ‘w’ is varied)



DES + Planck constraints

$w = -1.34^{+0.08}_{-0.15}$

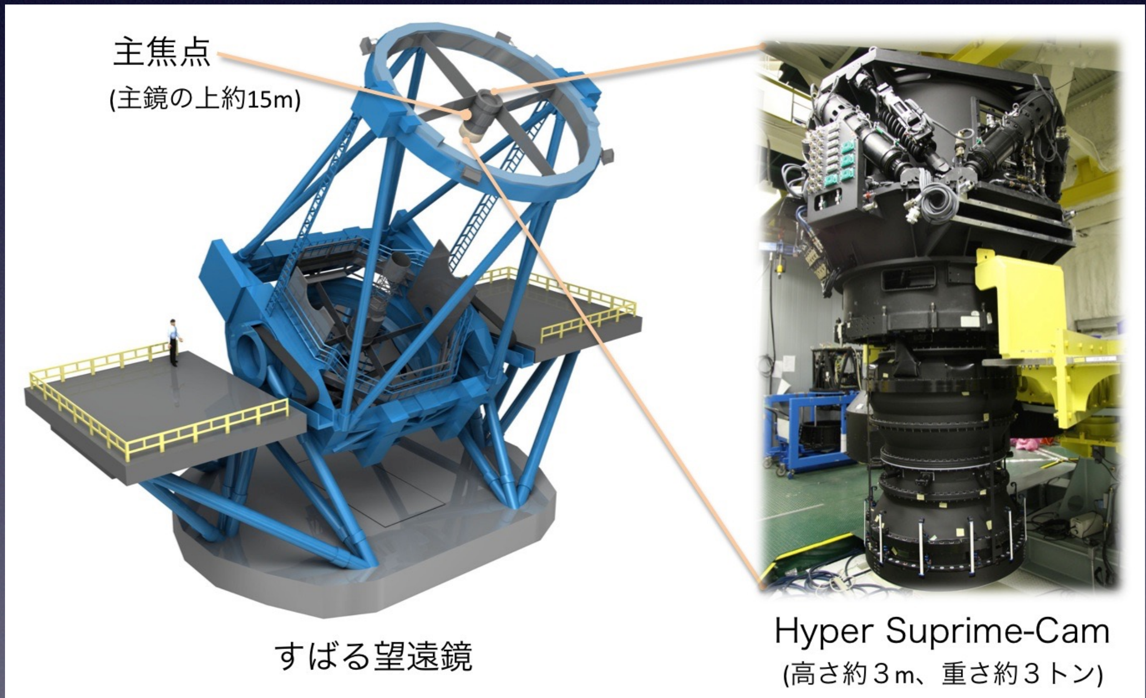
→ Will the universe end in Big Rip ?

Adding BAO & JLA (SNe),

$w = -1.00^{+0.04}_{-0.05}$

Hyper-Suprime Cam
Subaru Strategic Program

Hyper-Suprim Cam: 1.5 deg diameter camera on 8.2m telescope



(c) NAOJ

- 300 nights (2014–2019)
- 3 layers (Wide, Deep, UltraDeep)
- grizY band + NB filters
- seeing: 0.6-0.7 arcsec
- Japan, ASIAA, Princeton

- Wide survey
  - Weak lensing
  - 1400 sq. deg.
  - i<26.4
  - n_g~25 gal^2/sq. arcmin

SDSS

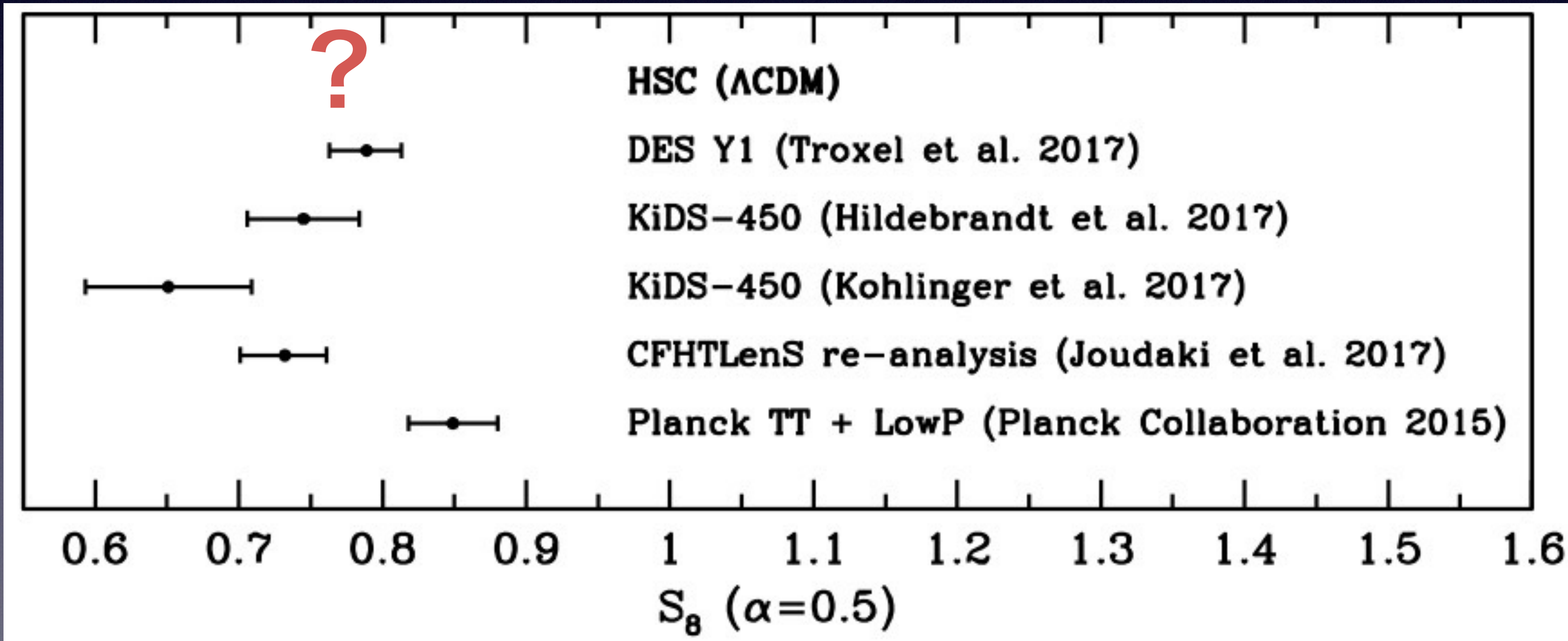
(c) プリンストン

HSC

(c) HSC-SSP, 国立天文台

Main goal of cosmic shear analysis

Deep imaging and high image quality of HSC surveys enables us to do cosmic shear analysis with higher-z galaxies and lower shape noise



Blind analysis

- To avoid human bias, we are doing the blinding analysis
- We prepare for three catalog with different shear multiplicative bias (one catalog is true, while other catalogs are fake)
- The analysis team doesn't know which catalog is true.
- We also blind the central values of cosmological parameters of blind catalogs during the analysis
- We are still in the phase of blind analysis, so we cannot tell the true value of S_8

Properties of HSC Y1 shear catalog

4-bin tomography

bin number	z range	$z_{\rm med}$	$N_{\rm g}$	$n_{\rm g}$ [arcmin^{-2}]	$n_{\rm g,eff}$ [arcmin^{-2}]
1	0.3 – 0.6	0.446	2842635	5.9	5.4
2	0.6 – 0.9	0.724	2848777	5.9	5.3
3	0.9 – 1.2	1.010	2103995	4.3	3.8
4	1.2 – 1.5	1.300	1185335	2.4	2.0
All	0.3 – 1.5	0.809	8980742	18.5	16.5

Comparison with other lensing surveys

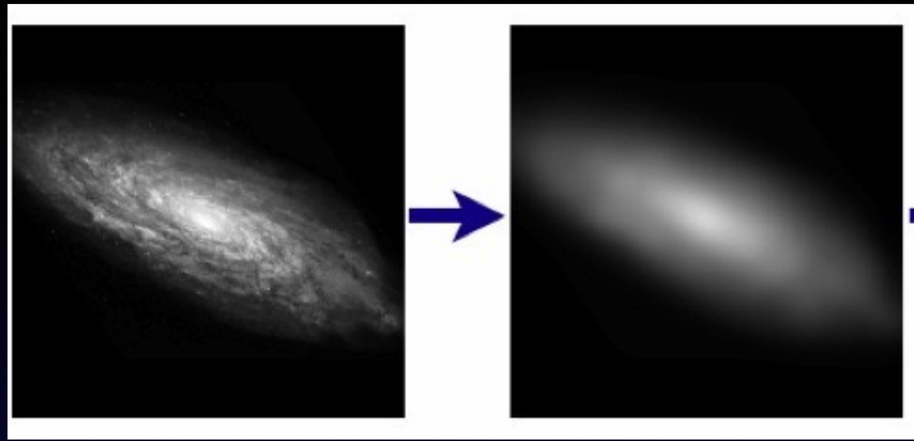
survey catalog	area [deg^2]	No. of galaxies	$n_{\rm g,eff}$ [arcmin^{-2}]	z range	tomography
KiDS-450	450	14.6M	6.85	0.1 – 0.9	4 bins
DES Y1	1321	26M	5.07	0.2 – 1.3	4 bins
HSC Y1	137	9.0M	16.5	0.3 – 1.5	4 bins

3 times higher number density

Systematics in cosmic shear analysis

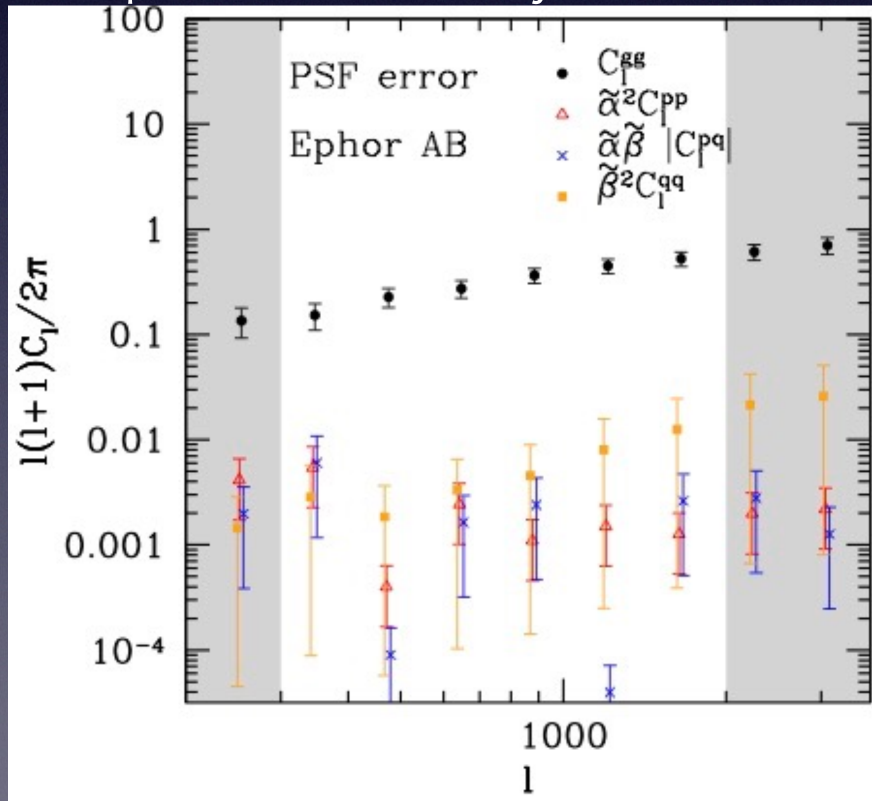
- shape measurement error due to imperfect PSF modeling
- photo-z error
- Intrinsic alignment
- Baryonic effect (SN, AGN feedback)

1. shape measurement bias due to PSF model error



- Observed galaxy images are convolved with point spread function (PSF) caused by atmosphere and telescope optics
- Shape errors & biases are estimated from the image simulations using HST COSMOS galaxy sample (see Mandelbaum et al. 2018)
- The residual PSF model error and the deconvolution errors of the PSF model ('PSF leakage') are less than ~5% of cosmic shear signals.

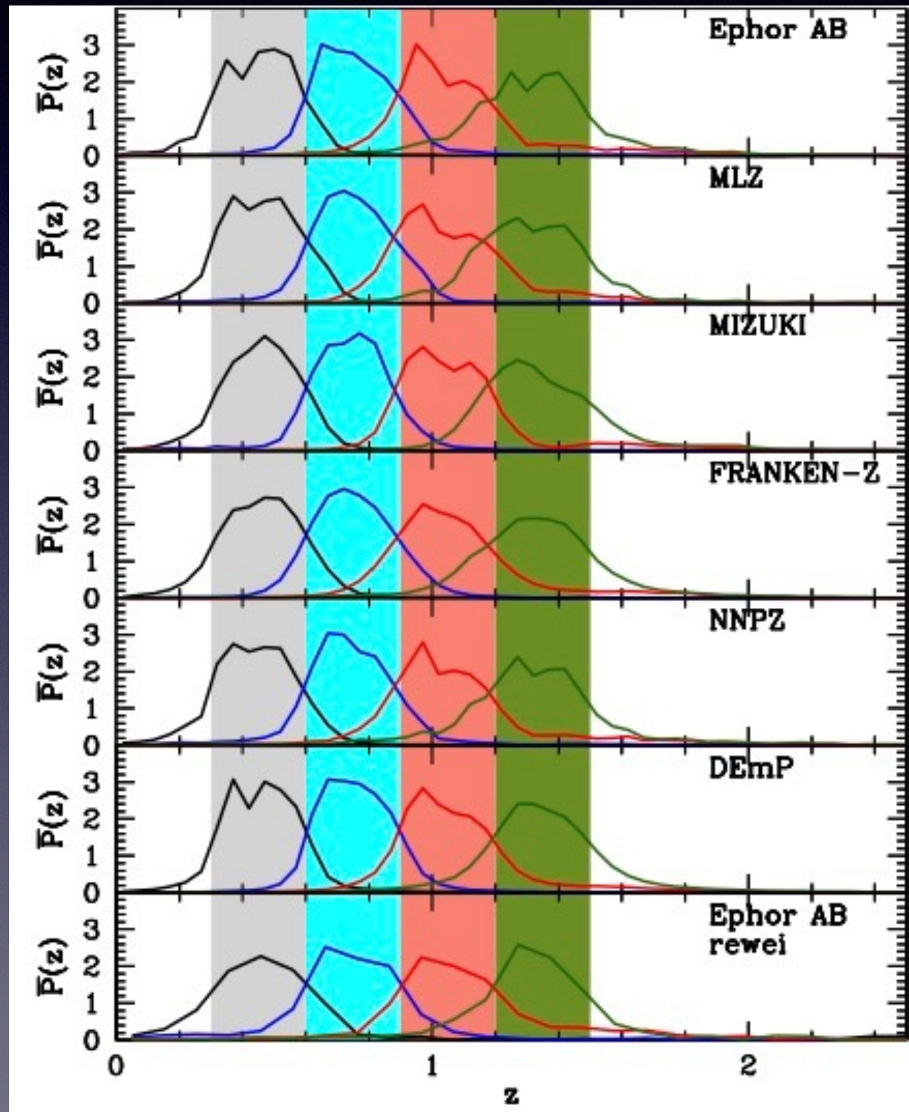
amplitude is arbitrary normalized



2. Photo-z error

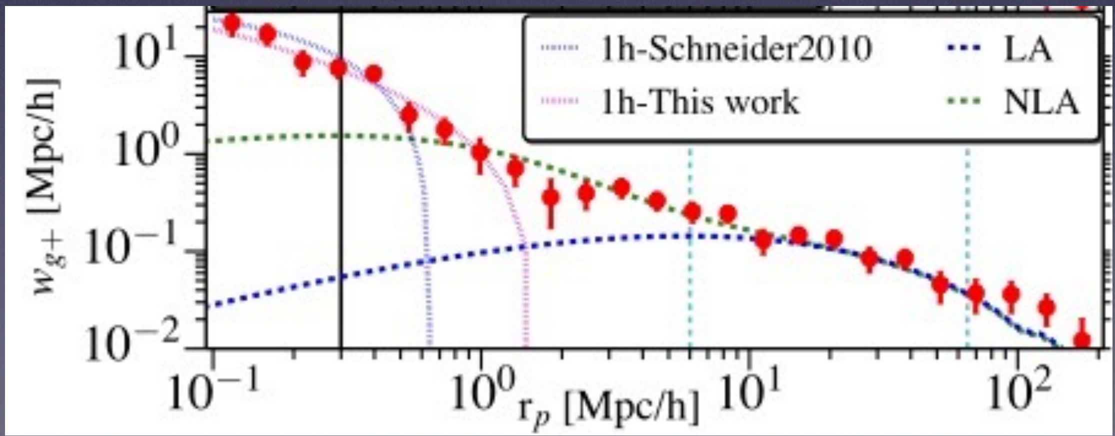
- HSC photo-z team estimate redshift probability distribution p(z) with various methods (e.g., template fitting, machine learning based on NN or SOM)
- Their methods are trained/tested with different set of spec-z, COSMOS samples (see Tanaka et al. 2017)
- The differences of p(z) among different methods are taken into account in our cosmic shear analysis

stacked p(z) in 4 tomographic bin

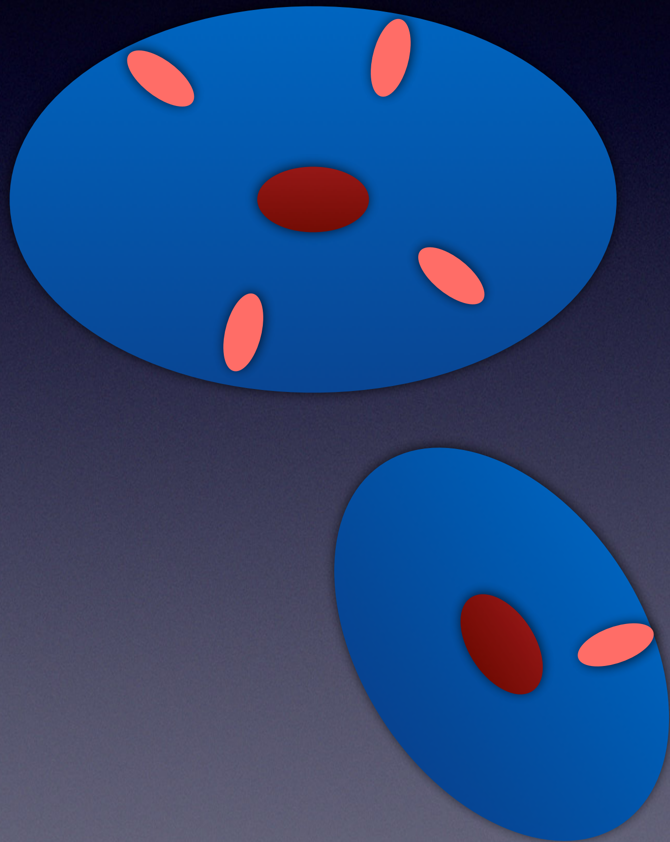


3. Intrinsic alignment (IA)

- Galaxies are intrinsically aligned by the tidal field, which generates additional correlations between galaxy shapes
- We take into account the IA effect using the nonlinear alignment (NLA) model, which well fit the measured IA signal upto ~1Mpc

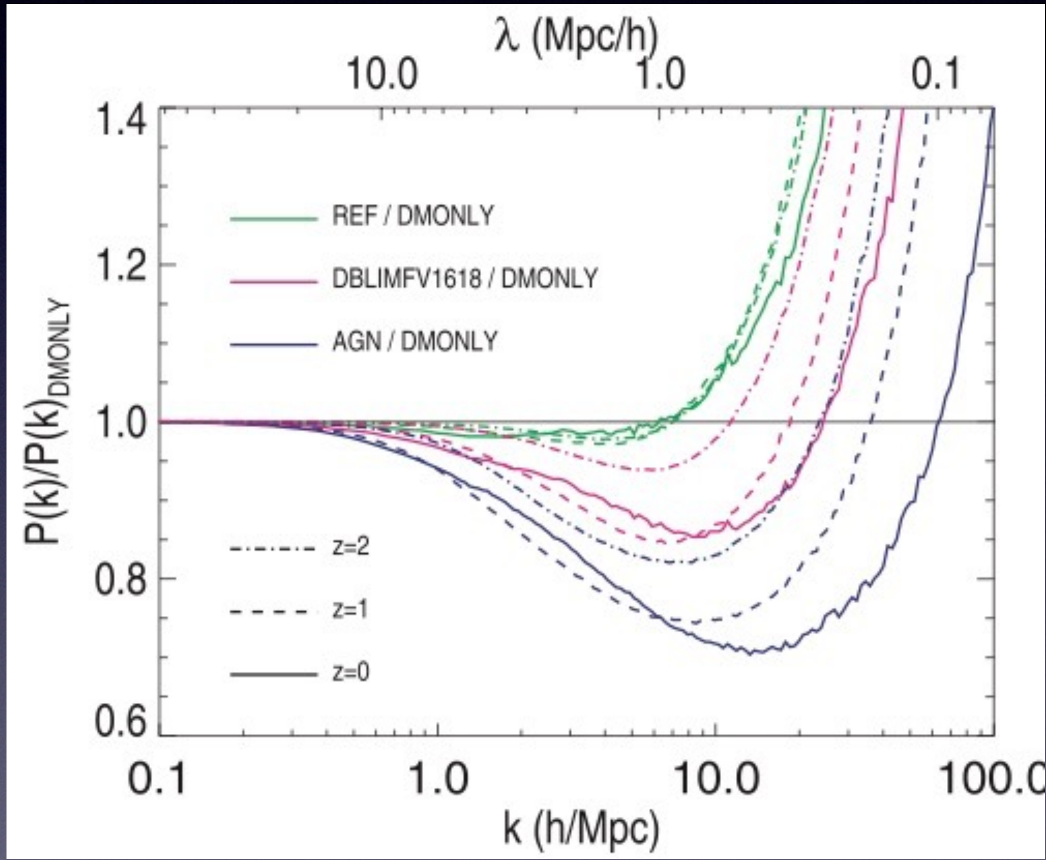


Singh & Mandelbaum 2014



4. Baryon physics

- Simulations suggest that SN & AGN feedback affect the matter clustering on small scales (< ~1Mpc)
- In the cosmic shear analysis, we focus on the scale that the baryonic effect is insignificant
- We also test the baryon effect by introducing additional baryon feedback parameter



Semboloni et al. 2011

Parameters & Priors for MCMC analysis

Parameter	symbols	prior
physical cold dark matter density	$\Omega_c h^2$	flat [0.01,0.99]
physical baryon density	$\Omega_b h^2$	flat [0.019,0.026]
$100 \times$ approx. θ_s	$100\theta_*$	flat [0.5,10]
scalar amplitude on $k = 0.05\mathrm{Mpc}^{-1}$	$\ln(10^{10} A_s)$	flat [1,10]
scalar spectral index	n_s	flat [0.87,1.07]
optical depth	τ	*flat [0.01,0.2]*
neutrino mass	$\sum m_\nu$ [eV]	fixed (0)†, fixed (0.06) or flat [0,1.2]
Hubble parameter	h	[0.4,1]
dark energy EoS parameter	w	fixed $(-1)^\dagger$ or flat $[-2,-0.333]$
amplitude of the intrinsic alignment	A_{IA}	flat $[-6,6]$
redshift dependence of the intrinsic alignment	η_{eff}	flat $[-6,6]$
baryonic feedback amplitude	B	fixed $(3.13)^\dagger$ or flat [2,4]
PSF leakage	$\tilde{\alpha}$	Gauss (0.055,0.017)
residual PSF model error	$\tilde{\beta}$	Gauss $(-1.17,0.71)$
uncertainty of multiplicative bias m	$100\Delta m$	Gauss (0,1)
photo-z shift in bin 1	$100\Delta z_1$	Gauss (0.78,2.52)
photo-z shift in bin 2	$100\Delta z_2$	Gauss $(-1.10,0.92)$
photo-z shift in bin 3	$100\Delta z_3$	Gauss (0.25,1.25)
photo-z shift in bin 4	$100\Delta z_4$	Gauss (0.95,2.29)

Fiducial setup: 5 cosmological parameters and 9 nuisance parameters
(2 for IA, 3 for shape error, 4 for photo-z)

Summary

- Unique property of HSC survey combining the depth and image quality enable us to measure cosmic shear precisely
- Cosmic shear measurement from HSC 1yr data can give 3~5% constraint on $S_8 = \sigma_8 (\Omega_m/0.3)^{\alpha}$ (α~0.5) , which are comparable to other lensing surveys such as DES, KiDS
- We find that our constraint on S_8 is robust against various systematics
- The blinding phase is nearly finishing. We are looking forward to seeing whether the tension with Planck would be still left or not.