Constraints on Cosmology and Baryonic Feedback with the Deep Lens Survey (DLS) Using Galaxy-Galaxy and Galaxy-Mass Power Spectra

(arXiv:1807.09195)

Mijin Yoon (Yonsei)

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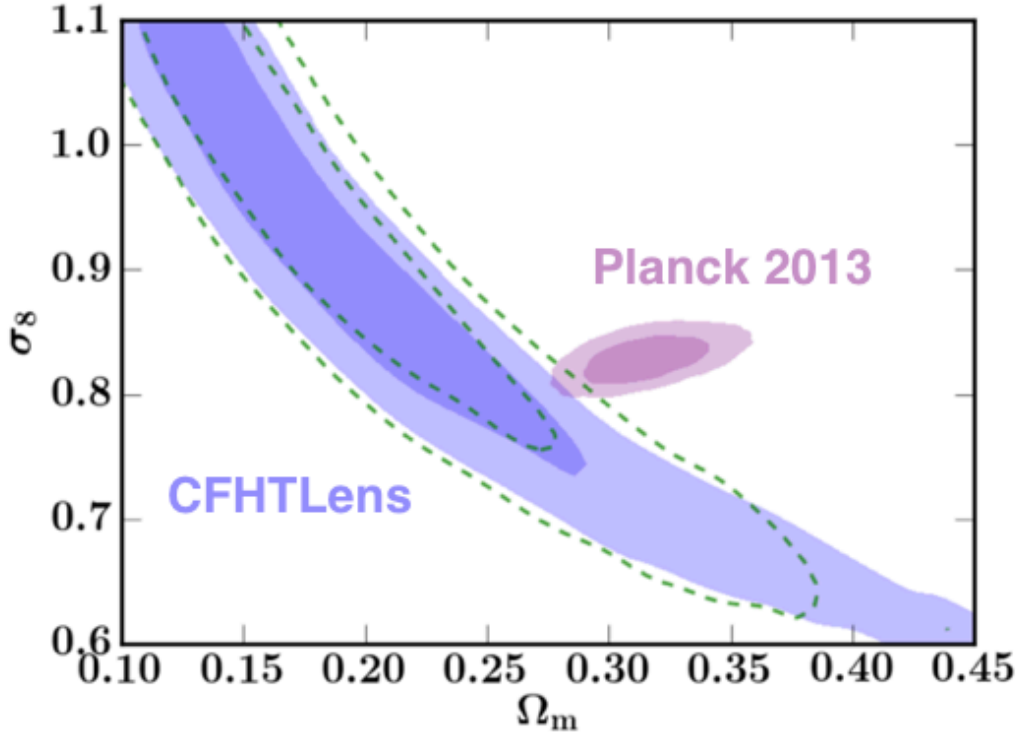
COSMO18

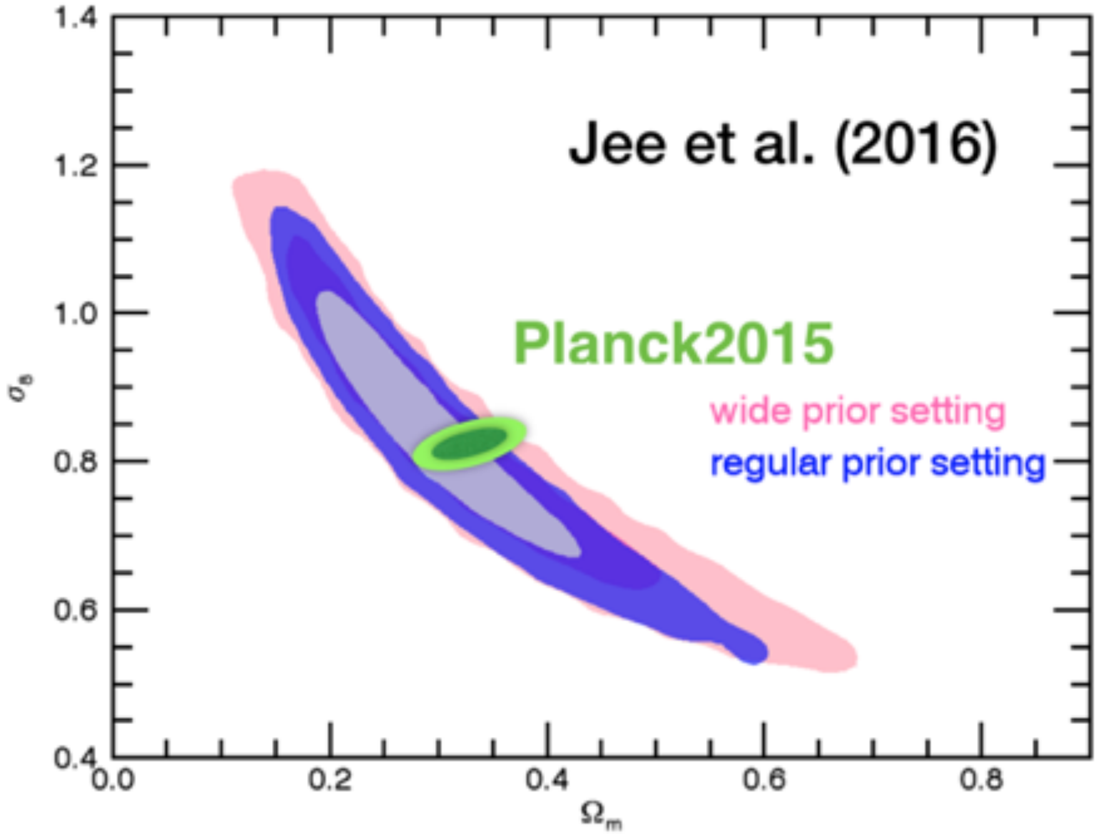
Collaborators: M. James Jee (Yonsei), J. Tony Tyson (UC Davis), Samuel Schmidt (UC Davis), David Wittman (UC Davis), and Ami Choi (Ohio State)

Tension between Planck and weak lensing



- CMB (early universe) and LSS (late time universe) tension may require modification of cosmology model.

Deep Lens Survey cosmic shear



- DLS cosmic shear result (Jee+2016) has no tension with Planck.

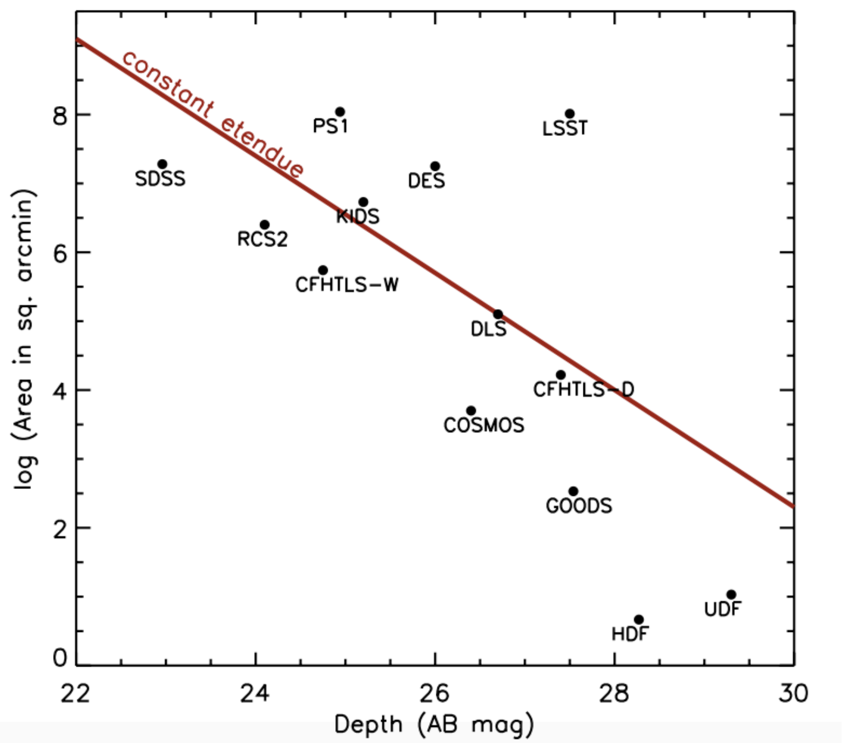
Deep Lens Survey (DLS)

- DLS is a precursor of LSST (as deep as LSST).
- DLS has BVRz' band images, with magnitudes reaching down to 27th.
- DLS has widely separated 5 fields, 4 deg^2 each.
    - F1 & F2 (Mosaic-1 at the NOAO/KPNO 4m Mayall Telescope)
    - F3 - F5 (Mosaic-2 at NOAO/CTIO 4m Blanco Telescope)

Mayall Telescope at Kitt Peak

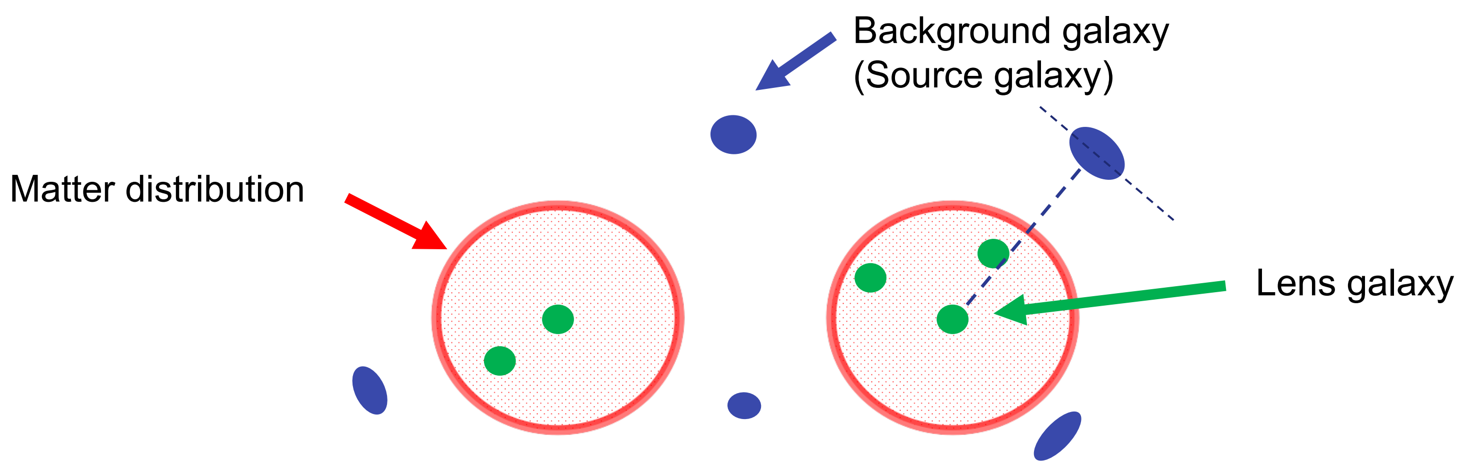
Blanco Telescope at CTIO

Deep Lens Survey (DLS)

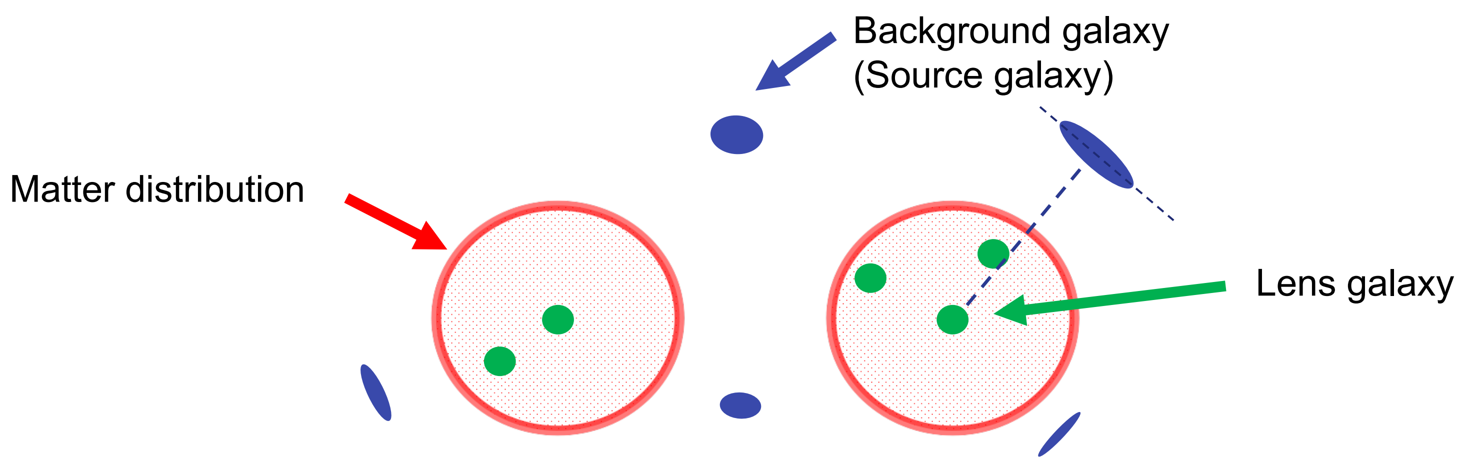


- DLS is dedicated to depth.
  - good for accurate shape measurement.
  - optimal for cosmological studies due to long redshift baseline.

Intro to galaxy-galaxy lensing

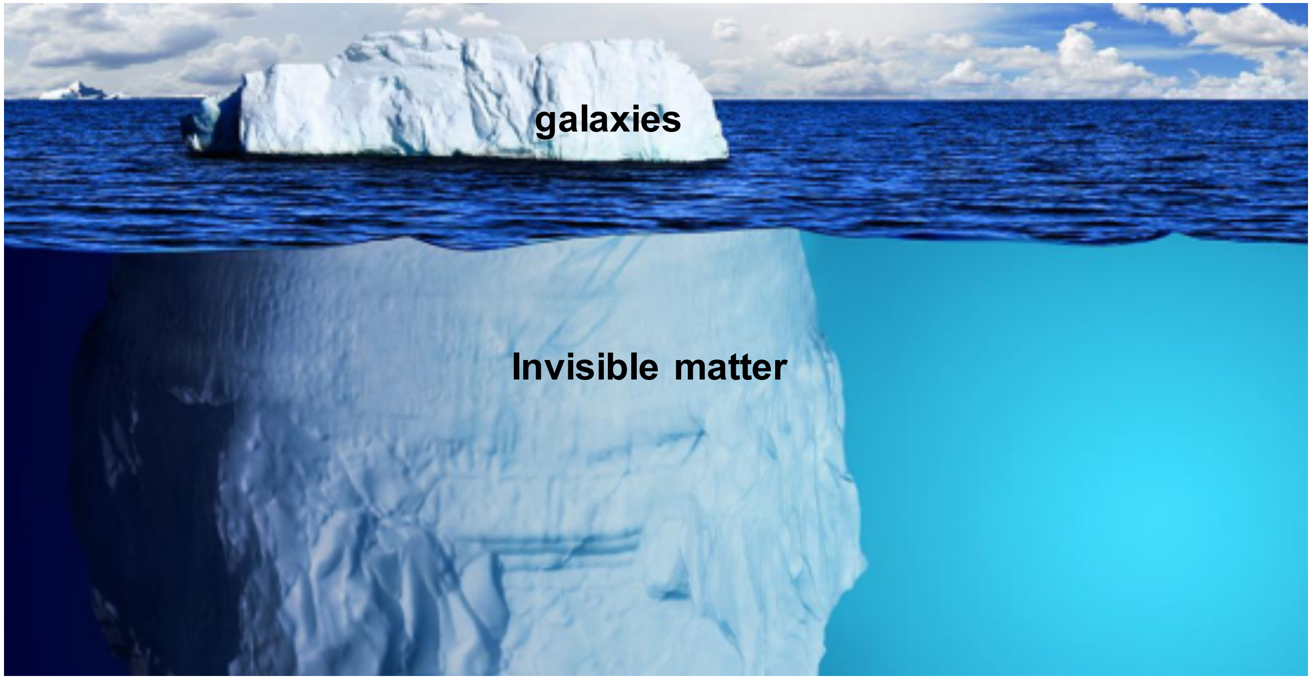


Intro to galaxy-galaxy lensing



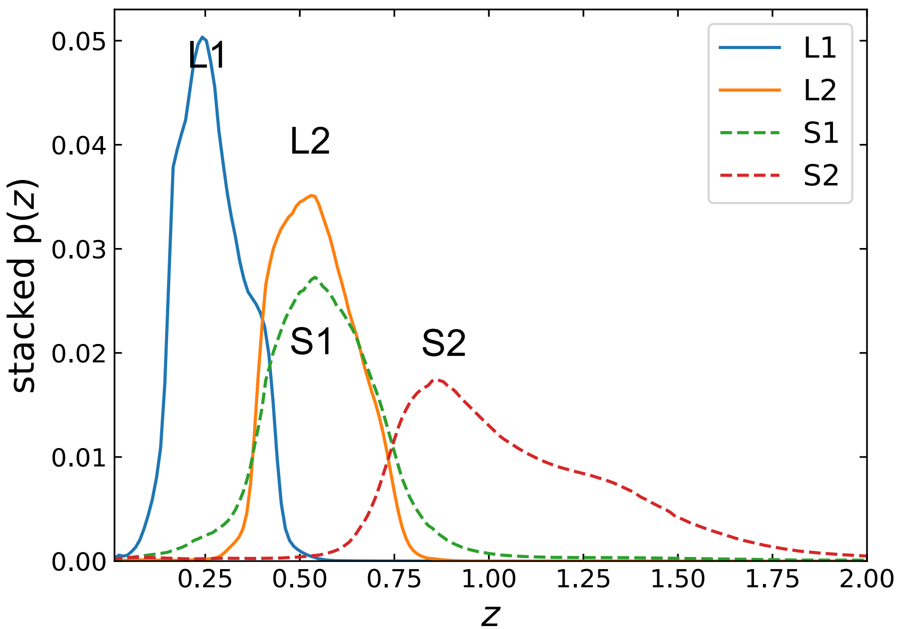
- The images of background galaxies become tangentially distorted by the mass of foreground matter distribution.
- The measured shear informs how matter is distributed around lens galaxies on average.

Galaxy-galaxy lensing + galaxy clustering



- Galaxy Clustering + Galaxy-galaxy lensing-> Cosmological parameter constraints
- Because galaxy-galaxy lensing utilizes info of matter distribution around galaxies, it gives almost independent constraint from cosmic shear.

Lens & source selection



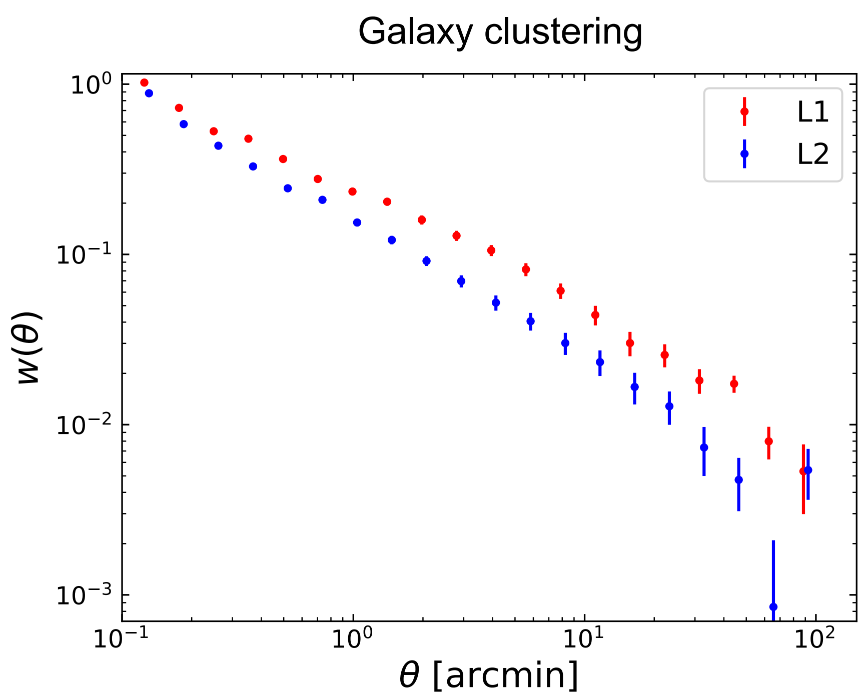
- The stacked p(z) curves (the sum of p(z)s of the individual galaxy in each bin) are used to estimate the model power spectrum.
- We measure galaxy clustering from the lens bins. (L1, L2)
- We measure lensing signal from the lens-source bin pairs (L1S1, L1S2, L2S2)

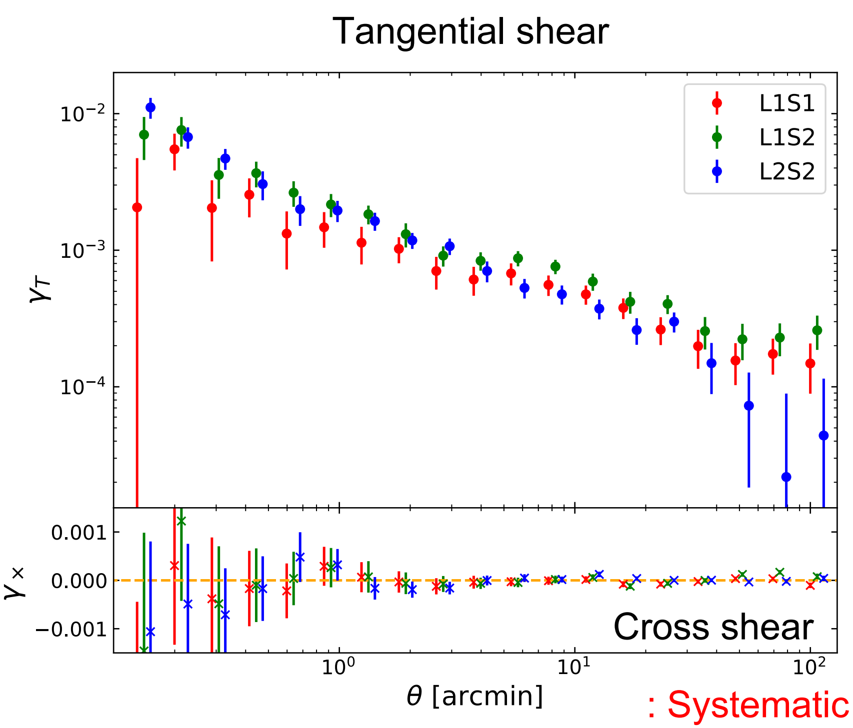
redshift (z_b^-, z_b^+) — R band mag (m_R^-, m_R^+)

bins		z_b^-	z_b^+	$\langle z \rangle$	m_R^-	m_R^+	# of gal
Lens	L1	0.15	0.4	0.270	18	21	57,802
	L2	0.4	0.75	0.542	18	22	98,267
Source	S1	0.4	0.75	0.642	21	24.5	418,932
	S2	0.75	1.5	1.088	21	24.5	450,353

~ 1 million galaxies

Clustering and shear measurements



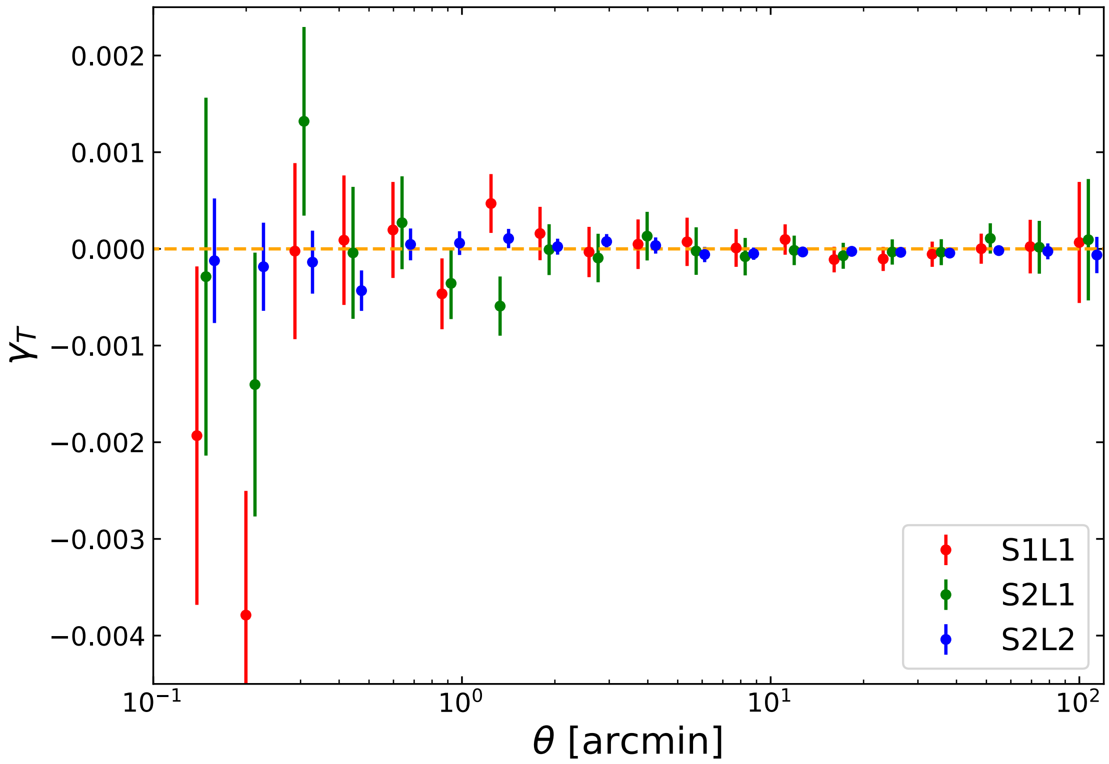


: Systematic test 1

- Clustering of galaxies for L1 and L2 (2-point correlation) was measured using LS estimator.
- Tangential shear for L1S1, L1S2, and L2S2 was measured.
- The errors were estimated using simulations based on log-normal distributions (FLASK).
- Cross shear measurements are consistent with zero which validates the fidelity of our lensing signal.

Systematic test 2

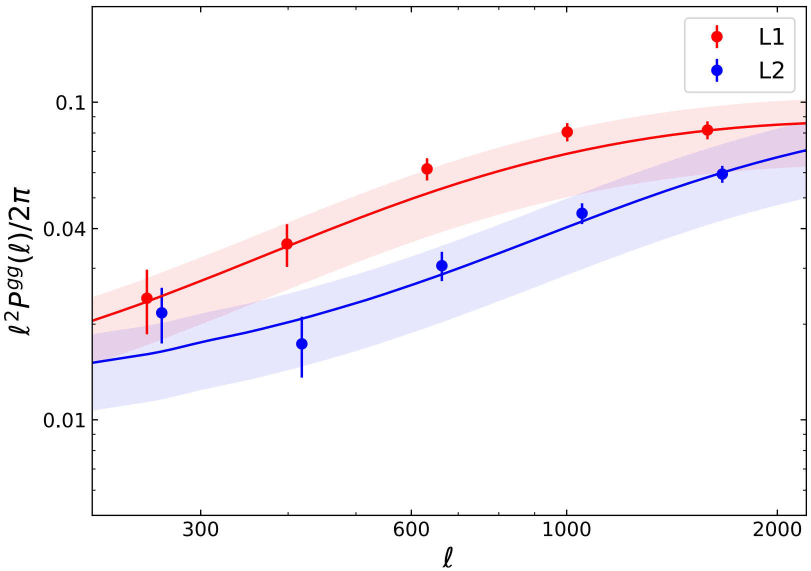
Lens-source flip test



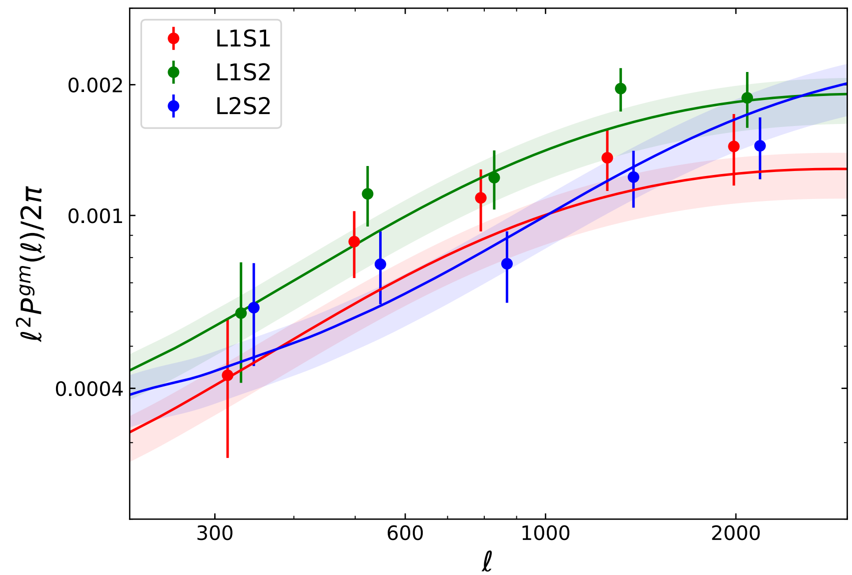
- Lens-source flip test is used to check the residual systematics mainly in photo-z estimations.

Galaxy-galaxy and galaxy-mass power spectra

Galaxy clustering:
$w(\theta) \rightarrow P^{gg}(\ell)$



Tangential shear:
$\gamma_T(\theta) \rightarrow P^{gm}(\ell)$



- We transform the real space measurements to Fourier space to estimate the model parameters.
- The lines are the best-fit model achieved after running nested sampling algorithm. *(multinest)*
- The shaded regions are 1-σ ranges of galaxy biases.
- The measurements and the best-fit models agree very well.

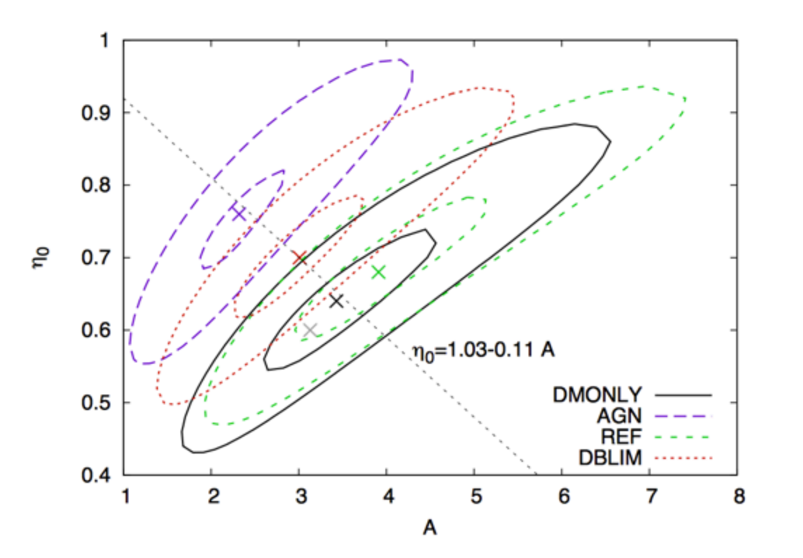
Priors for nested sampling

1. Nuisance parameters
   - Photo-z shifts for each bin
   - Multiplicative errors for shape meas
2. Cosmological parameters
   - Flat LCDM
   - The sum of neutrino masses
3. Astrophysical parameters
   - Galaxy bias for lens bins
   - Baryonic feedback parameter

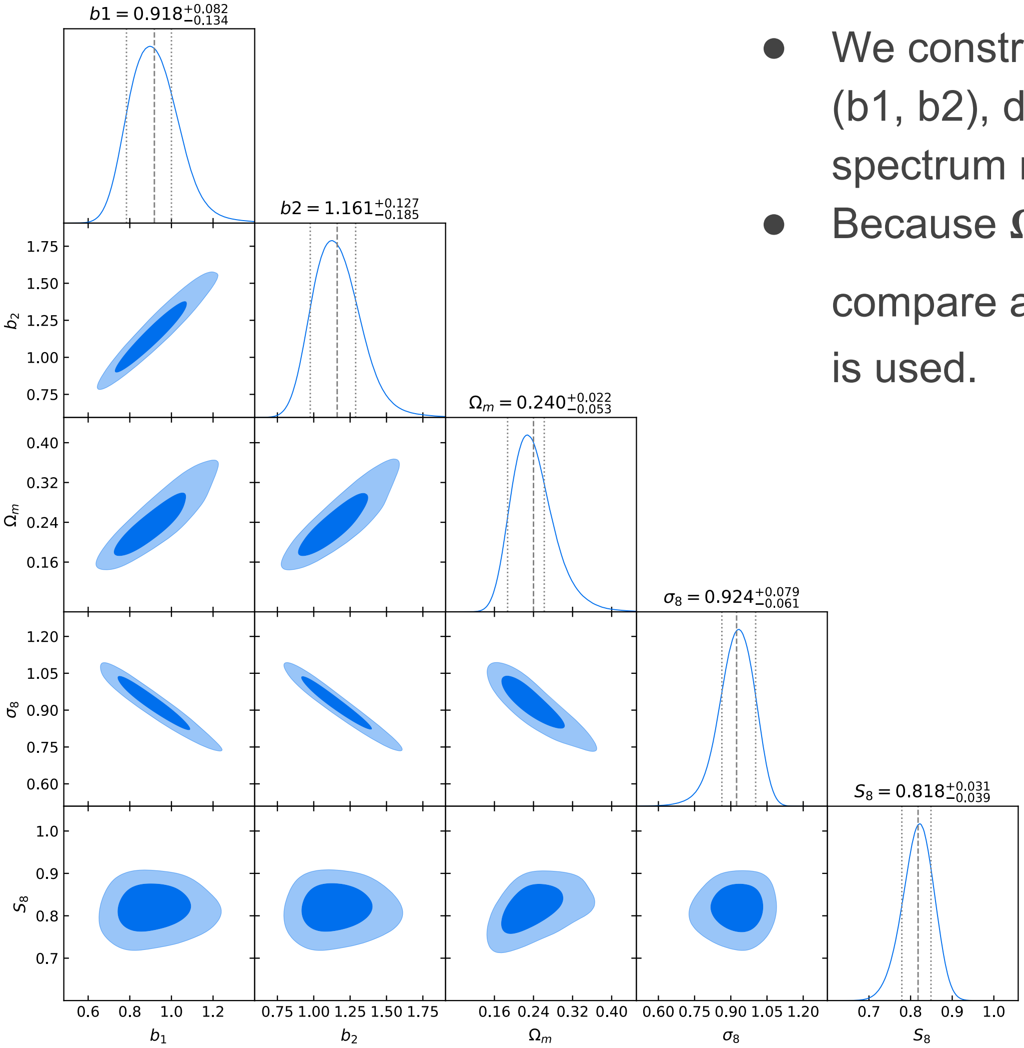
- Baryonic feedback effects in haloes can be parameterized with two parameters (Mead et al. 2015):

A: minimum halo concentration
η_0: halo bloating parameter

$$\eta_0 = 1.03 - 0.11A\ .$$

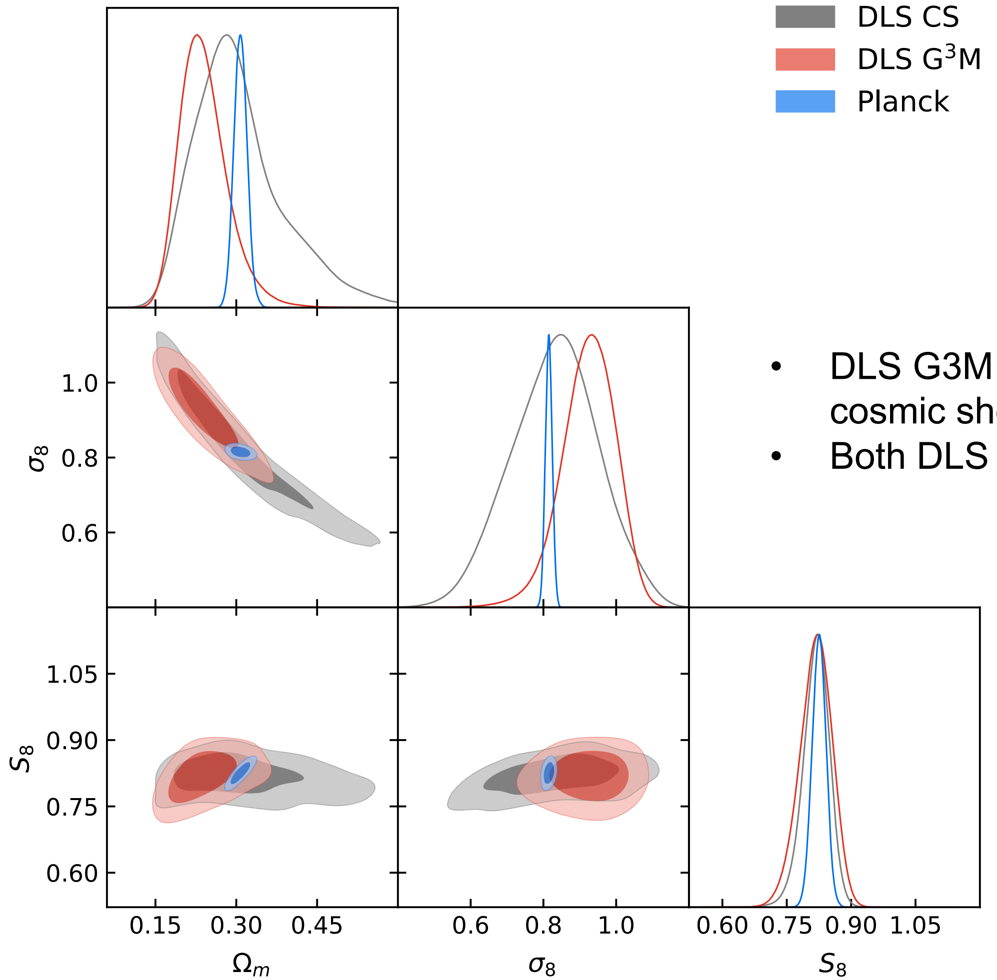


Constrained results from DLS G^{3}M



- We constrained galaxy biases for two lens bins (b1, b2), density parameter ($\boldsymbol{\Omega_m}$), and power spectrum normalization parameter ($\boldsymbol{\sigma_8}$).
- Because $\boldsymbol{\Omega_m}$ and $\boldsymbol{\sigma_8}$ are highly correlated, to compare among different surveys, $\boldsymbol{S_8 \equiv \sigma_8 (\frac{\Omega_m}{0.3})^{0.5}}$ is used.

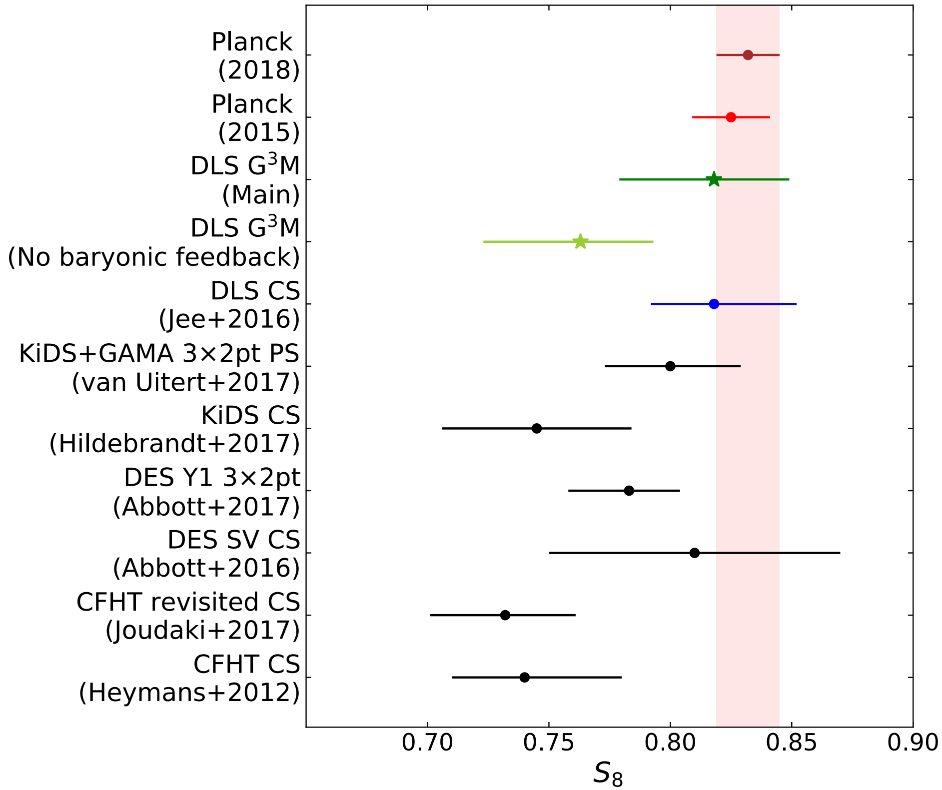
DLS constraints with Planck2015



- DLS G3M results are consistent with the previous DLS cosmic shear results (Jee+ 2016).
- Both DLS constraints also agree with Planck2015 constraint.

Data	S_8
DLS G^3M (Current Study)	$0.818^{+0.031}_{-0.039}$
DLS CS	$0.818^{+0.034}_{-0.026}$
Planck2015	$0.825^{+0.016}_{-0.016}$

Constraints from DLS and various surveys



- DLS has no tension with Planck. Inclusion of baryonic effect shifts S_8 value ~0.05.
- The existing tension for other surveys may be reduced by using the model with baryonic feedback.

Baryonic feedback parameter constraint

- We were able to constrain baryonic feedback parameter: $A_{baryon} = 1.03^{+0.42}_{-0.44}$ and more tightly when combined with Planck: $A_{baryon} = 1.07^{+0.29}_{-0.37}$.

- Based on Bayes factor, the model with baryonic feedback is preferred moderately ($\log BF \sim 3$) using DLS and preferred strongly ($\log BF \sim 11$) when combined with Planck.

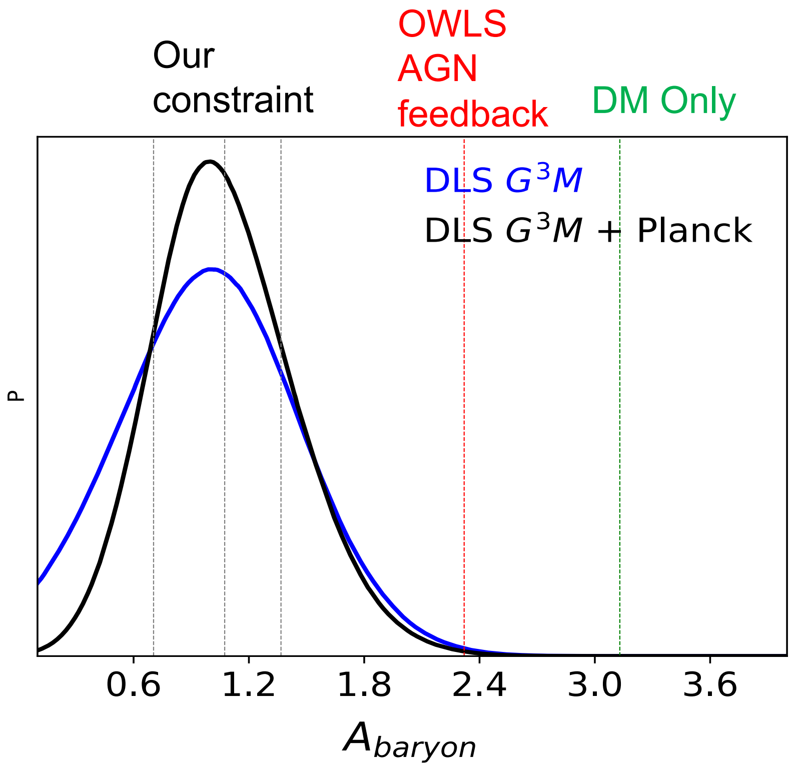
$$BF \equiv \frac{P(M1|D)}{P(M2|D)}$$

$P(M1|D)$ ← Feedback model

$P(M2|D)$ ← DM-only model

- The constrained value hints on a probability of stronger AGN feedback than OWLS simulations.

- In the future, by understanding cosmology we will be able to understand astrophysics better.



Summary

- The weak lensing analysis of galaxy-galaxy lensing + galaxy clustering with the DLS is consistent with the previous the DLS cosmic shear result and with Planck.

- We first achieved a reliable constraint on baryonic feedback parameter using weak lensing analysis.
  - The constrained value implies that the actual baryonic feedback may be stronger than the current OWLS recipe.
- Bayesian evidence shows that the model with the baryonic feedback is preferred.

- We will combine all the DLS weak lensing data (cosmic shear + galaxy-galaxy lensing + galaxy clustering) to constrain cosmological parameters as well as astrophysical parameters more tightly.

Thank you.

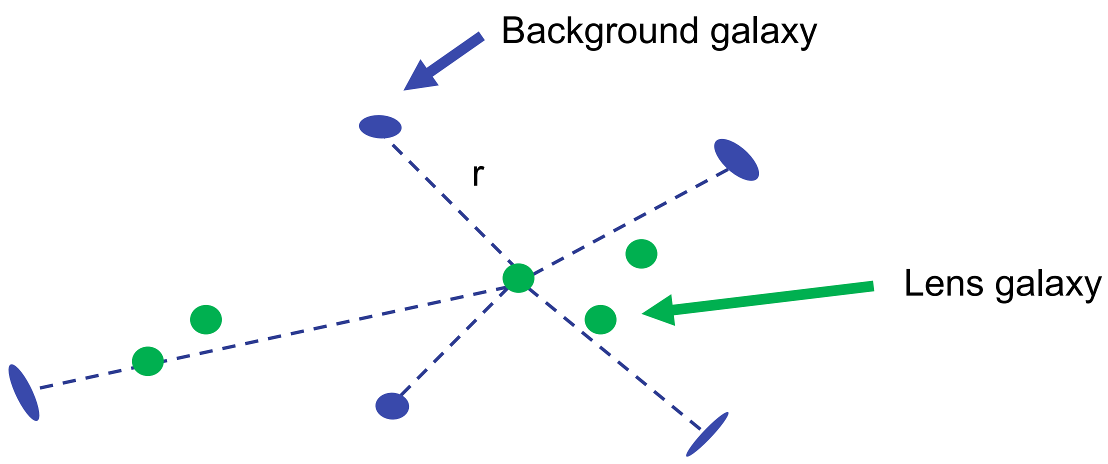
Supplementary slides

Priors for parameter estimations

- A_{baryon} parameterizes the amplitude baryonic feedback in halo model. For DM only model, A_{baryon} = 3.13 and for AGN feedback A_{baryon} = 2.32 (based on OWLS simulations, Mead+2015).

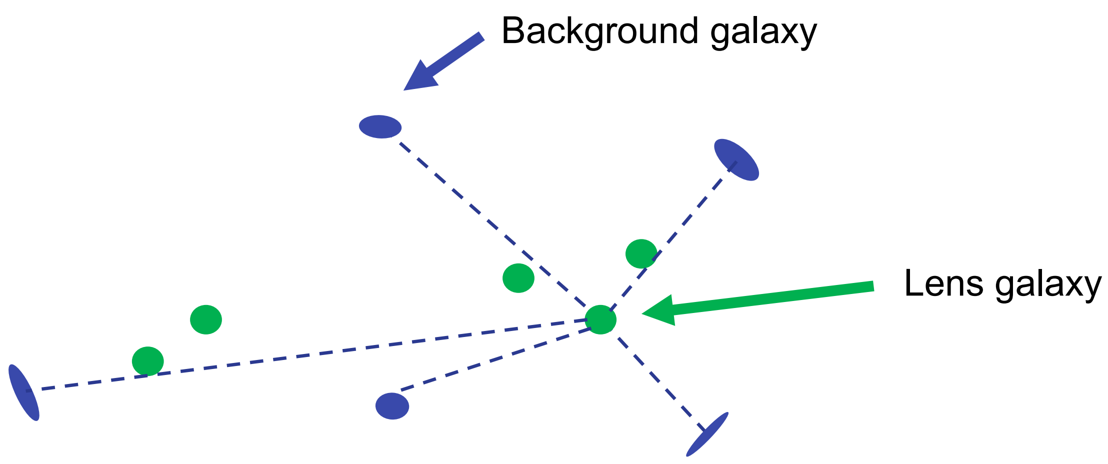
parameters	prior range	
Nuisance parameters		
photo-z shift in L1, L2, S1, S2 (σ_{zi}), $\mathcal{N}(0,0.02)$	-0.04	0.04
multiplicative shear error (m_γ)	-0.02	0.02
Astrophysical parameters		
galaxy bias in L1 & L2 (b_i)	0.1	2.5
baryon amplitude (A_{baryon})	2.0	4.0
Cosmological parameters		
matter density (Ω_m)	0.06	1.0
baryon density (Ω_b)	0.03	0.06
hubble parameter (h)	0.55	0.85
power spectrum normalization (σ_8)	0.1	1.5
spectral index (n_s)	0.9	1.04
sum of neutrino masses ($\Sigma_\nu m_\nu$/eV)	0.06	0.9

Intro to galaxy-galaxy lensing



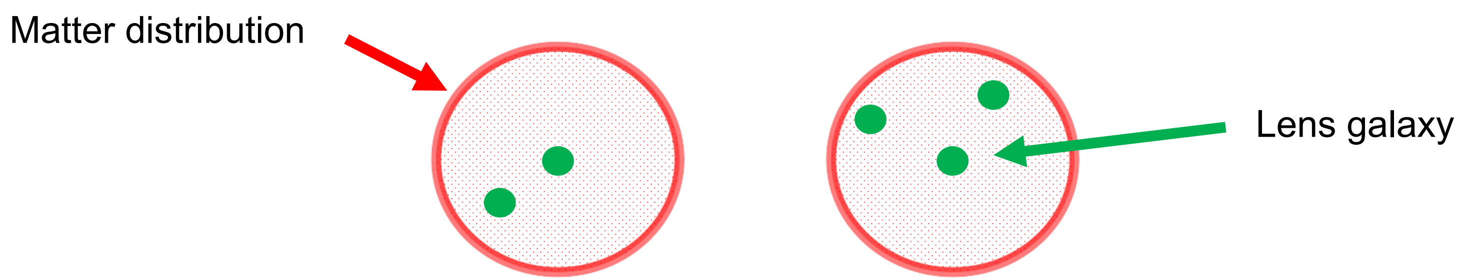
- The images of background galaxies get distorted by the mass of foreground matter distribution.

Intro to galaxy-galaxy lensing



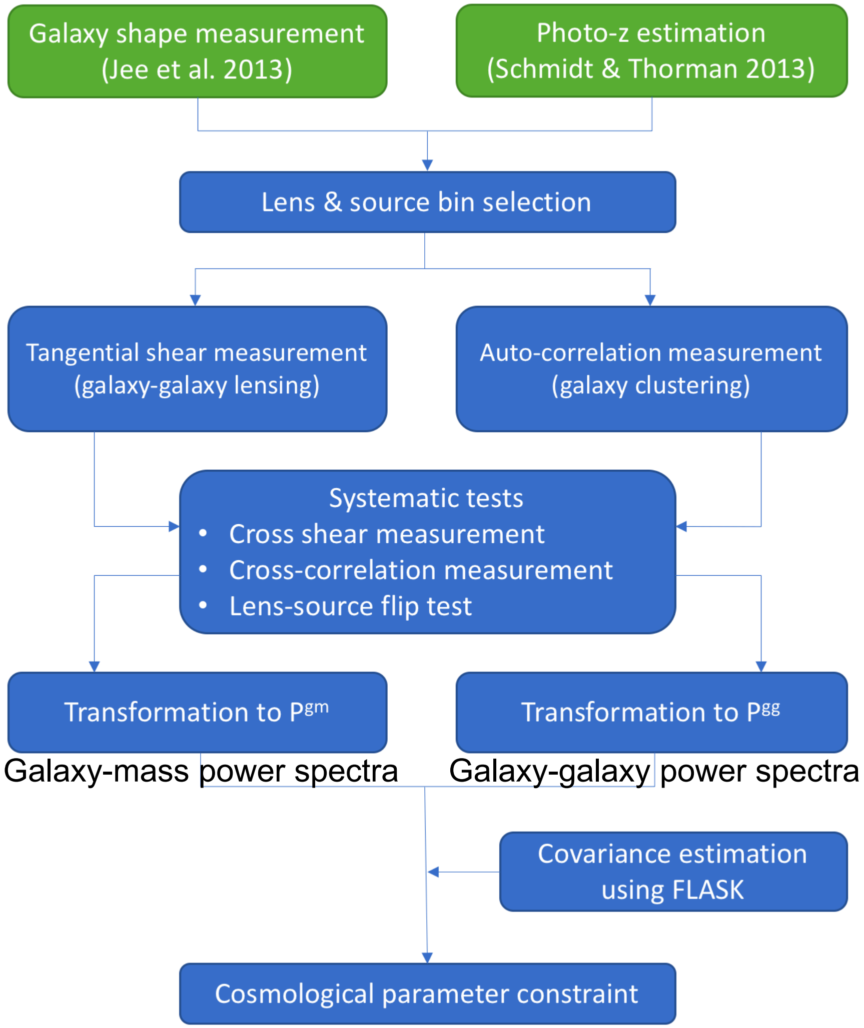
- The images of background galaxies get distorted by the mass of foreground matter distribution.
- The signal needs to be stacked up for all the pairs of lens and source galaxies as a function of distance between the lens and the source.

Intro to galaxy-galaxy lensing



Eventually, the measured shear informs how matter is distributed around lens galaxies on average.

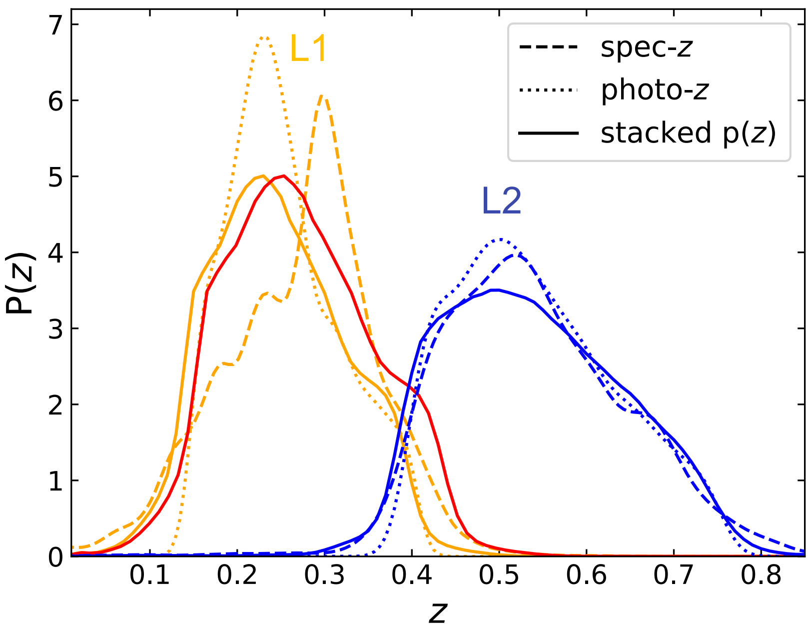
Workflow of data analysis

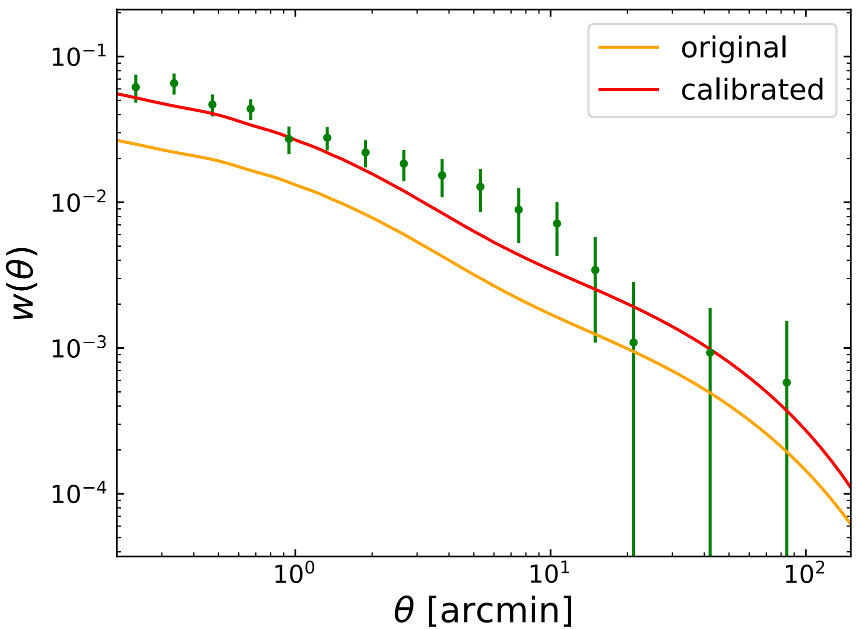


- DLS galaxy shapes were calibrated using image simulations (Jee+2013).
- DLS galaxy shape measurement pipeline was validated through a public challenge, “Great3” (Mandelbaum+2015).
- DLS photo-z (redshift) estimation was estimated by Schmidt & Thorman (2013) using BPZ method with spec-z samples, PRIMUS and SHELS.
- We call “Galaxy-Mass power spectra + Galaxy-Galaxy power spectra” = “G^3M”

Systematic test 3

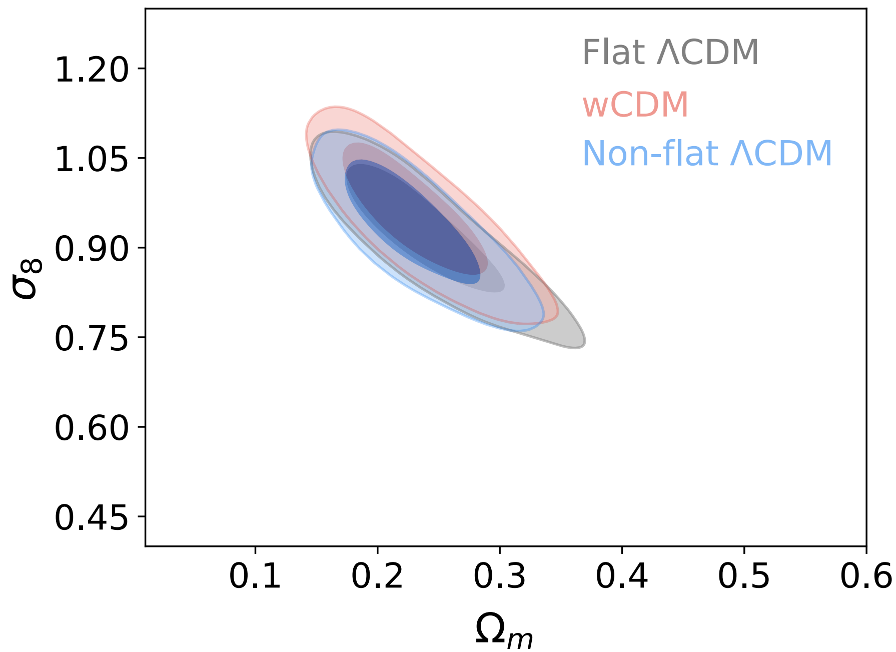
Photo-z calibration and cross-correlation measurement





- The stacked photo-z curves are calibrated by matching with spec-z samples (PRIMUS and SHELS).
- We found 10% photo-z shift for L1 was required, but calibration of L2 was not necessary.
- The cross-correlation measurement between L1 and L2 reconfirms the photo-z calibration was relevant to agree with the theoretical prediction.

1-parameter extensions to flat ΛCDM



Model	Ω_m	σ_8	S_8
Flat ΛCDM	$0.240^{+0.022}_{-0.053}$	$0.924^{+0.079}_{-0.061}$	$0.818^{+0.031}_{-0.039}$
wCDM	$0.232^{+0.030}_{-0.045}$	$0.957^{+0.074}_{-0.066}$	$0.833^{+0.044}_{-0.040}$
Non-flat ΛCDM	$0.230^{+0.023}_{-0.043}$	$0.936^{+0.067}_{-0.059}$	$0.812^{+0.051}_{-0.033}$

$-1.5 < w < -0.5$

$-0.2 < \mathbf{\Omega}_k < 0.2$

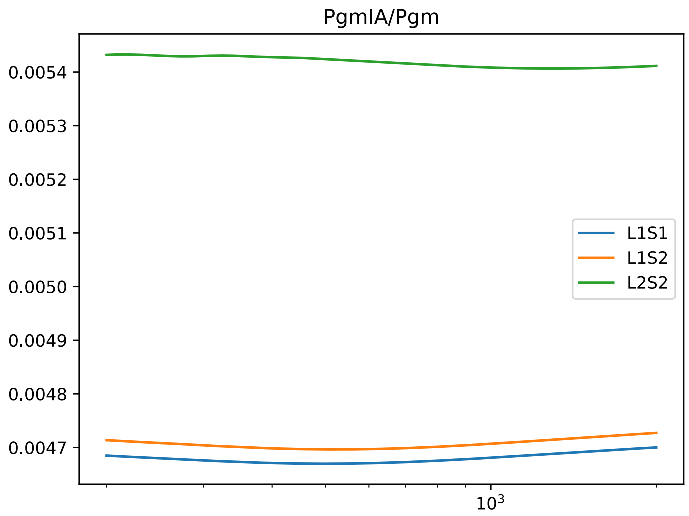
The constraints are not too much dependent on the cosmological model.

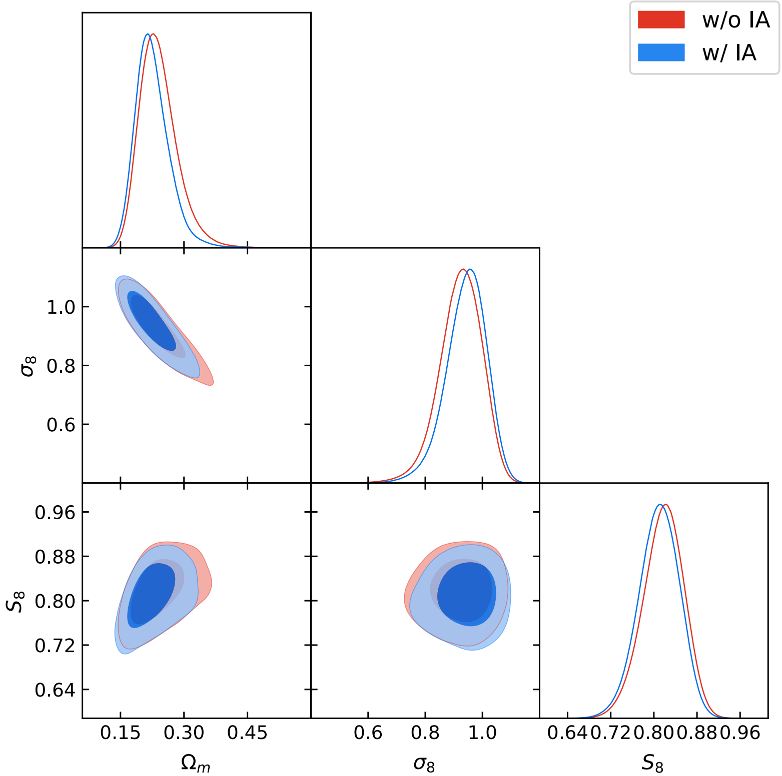
Intrinsic alignment in galaxy-galaxy lensing

- The impact on the power spectra is ~ 0.5% at most when A_IA = 1.
- This is because we do not have overlapping photo-z between lens and source populations.

- A simple intrinsic alignment model (Catelan+2001, Hirata&Seljak 2004)

$$P_{\delta I}(z) = -A\ C_1\ \rho_c \frac{\Omega_m}{D(z)} P_\delta(z)$$





pycamb

- Baryonic effects can be parameterized by two parameters (A baryon and etha0).

$$c(M,z) = A\frac{1+z_\mathrm{f}}{1+z} \ ,$$

$$W(k,M) \rightarrow W(\nu^\eta k, M)$$

$$\eta = \eta_0 - 0.3\,\sigma_8(z) \ .$$

We use power spectra from the OverWhelmingly Large Simulations (OWLS; Schaye et al. 2010; spectra from van Daalen et al. 2011) of a dark-matter (DMONLY) model; a model that has prescriptions for gas cooling, heating, star formation and evolution, chemical enrichment and supernovae feedback (REF); a model that is similar to REF but with the addition of active galactic nuclei (AGN) feedback (called AGN); and a model similar to REF but which additionally has a top-heavy stellar initial mass function and extra supernova energy in wind velocity (DBLIM–called DBLIMFV1618 in van Daalen et al. 2011). It was shown in van Daalen et al. (2011) that the difference in power between the DMONLY and AGN models is particularly large.

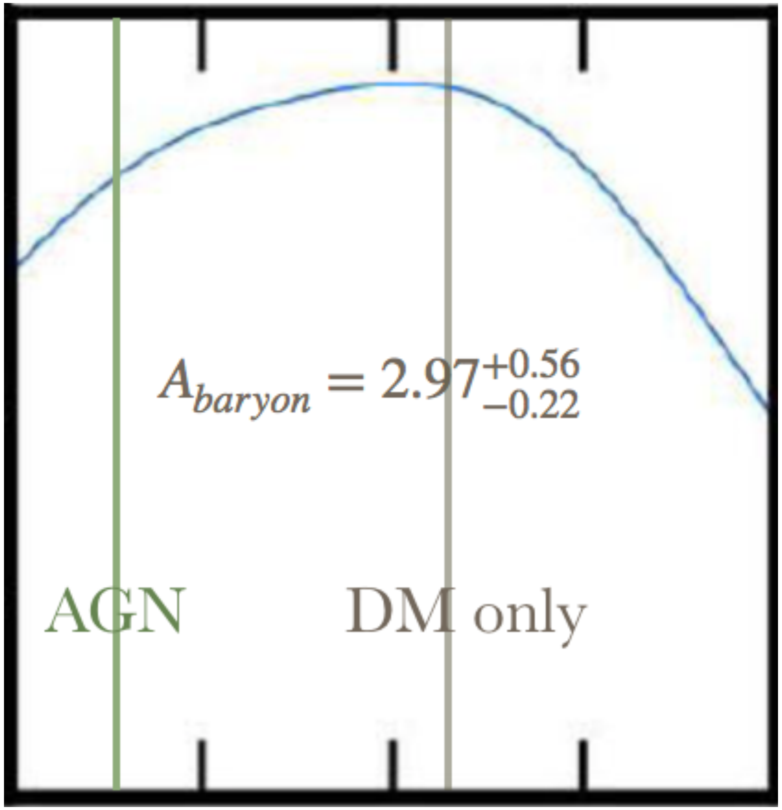
Table 4. Parameter combinations of η_0 and A that best fit OWLS data from $z = 0$ to 1 via the halo-model approach described in the text. These parameters are those at the centres of the ellipses in Fig. 6. The OWLS simulations can be matched at the 5 per cent level over the redshift range. That the values of η_0 and A differ in the case of 'all COSMIC EMU simulations' compared to DMONLY is because a slightly improved fit is possible in the case of dealing with a specific cosmology, which in the case of OWLS is the slightly outdated *WMAP* 3 ($\Omega_\mathrm{m} = 0.238$, $\Omega_\mathrm{b} = 0.0418$, $\sigma_8 = 0.74$, $n_\mathrm{s} = 0.951$, $h = 0.73$).

Model	η_0	A
All COSMIC EMU simulations	0.60	3.13
DMONLY (*WMAP* 3 from OWLS)	0.64	3.43
AGN	0.76	2.32
REF	0.68	3.91
DBLIM	0.70	3.01

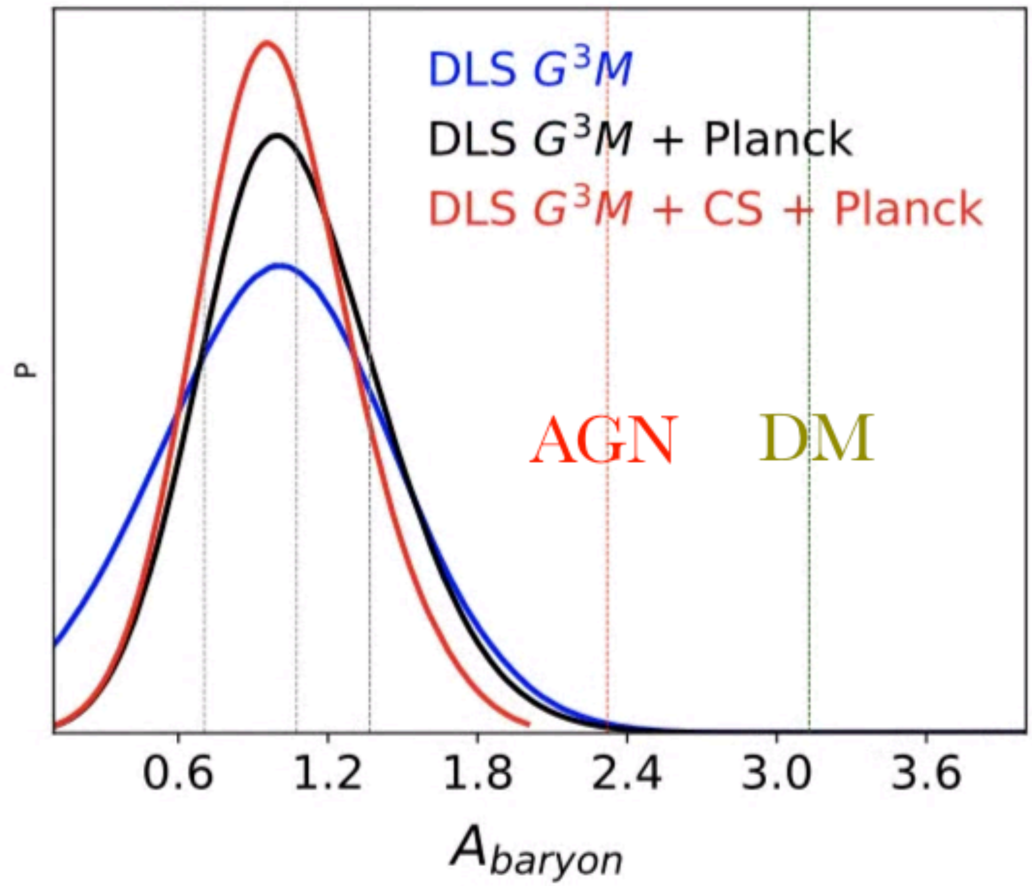
Previous Attempts

Authors	Survey	Method	Results
Hildebrandt et al. (2017)	KiDS	Cosmic Shear	No constraints
Joudaki et al. (2018)	KiDS+ 2dFLenS	Cosmic Shear + GGL + GG	Upper bound
van Uitert et al. (2018)	KiDS+ GAMA	Cosmic Shear+GGL+ GG	Loose constraint

van Uitert et al. (2018)



DLS + Planck


DLS G^3M
DLS G^3M + Planck
DLS G^3M + CS + Planck
AGN
DM
P
0.6
1.2
1.8
2.4
3.0
3.6
A_{baryon}