Title: Combining Spectroscopic and Photometric Surveys with the DMASS sample

Speakers: Sujeong Lee

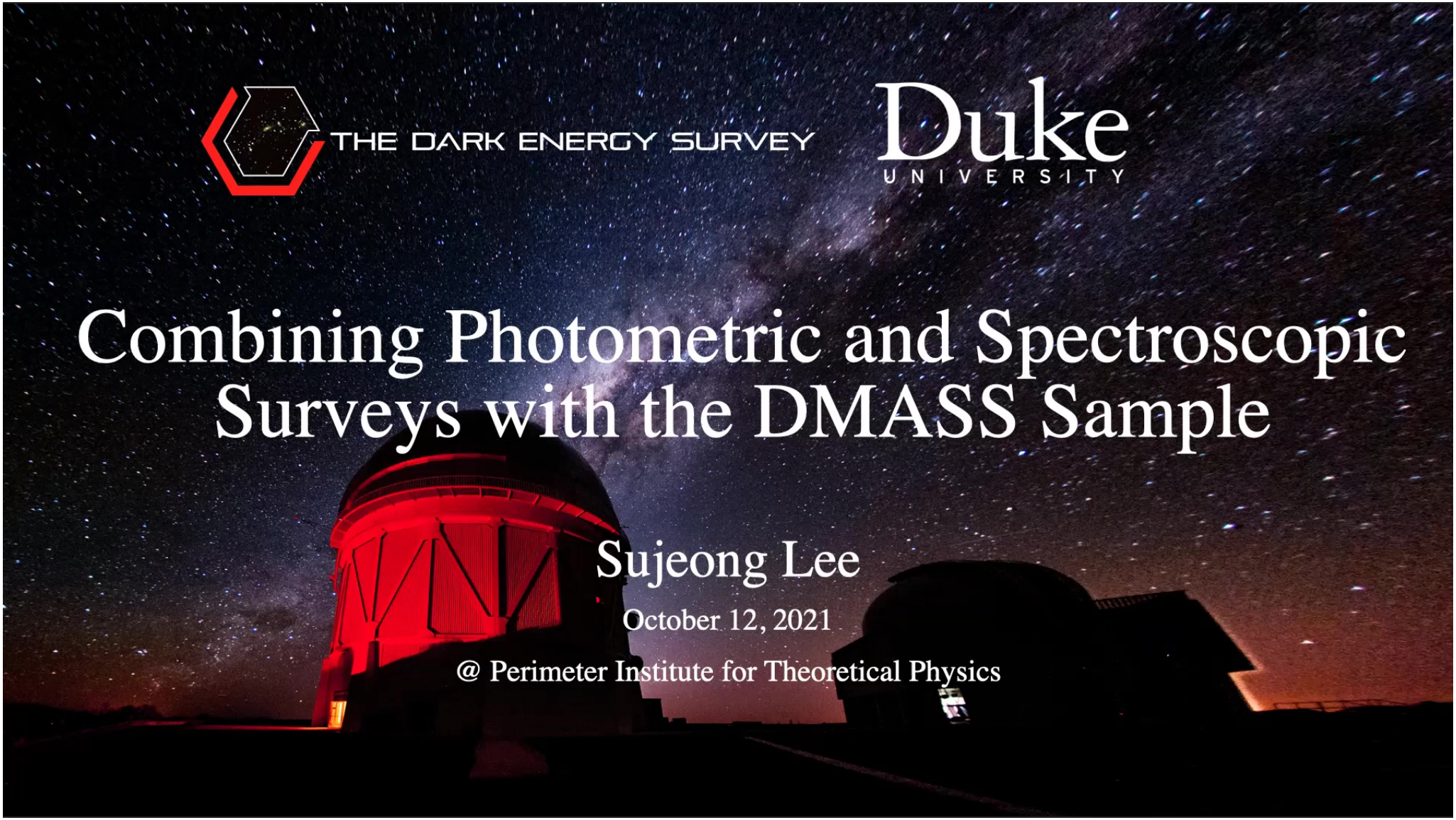
Series: Cosmology & Gravitation

Date: October 12, 2021 - 11:00 AM

URL: https://pirsa.org/21100001

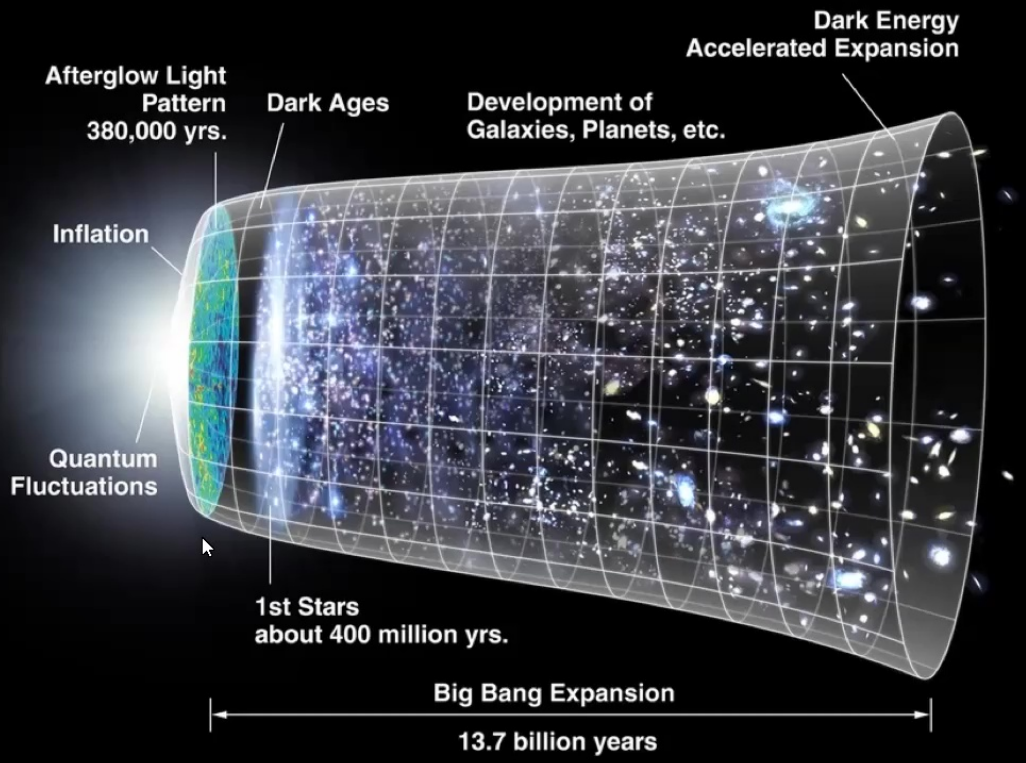
Abstract:

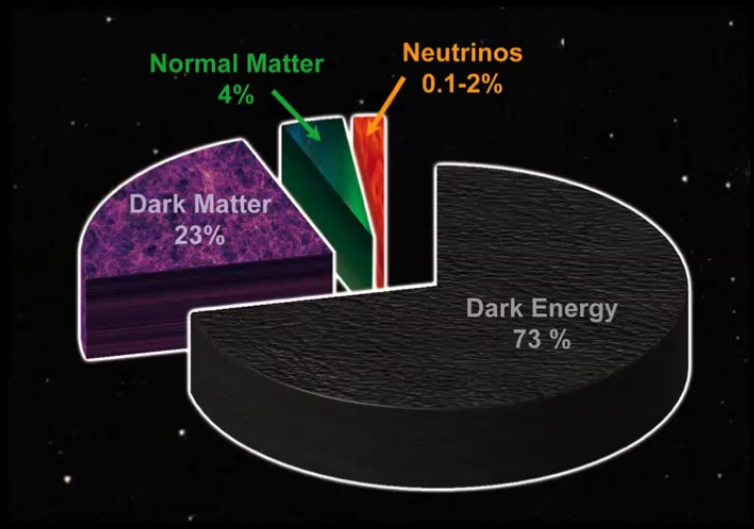
Redshift space distortions and weak gravitational lensing have been used as a powerful combination of growth data to test gravity. In particular, combining these two probes where spectroscopic and photometric surveys overlap, can yield much stronger dark energy and growth constraints than a combination of independent measurements of the two. However, this approach is limited due to a fairly small overlapping area between spectroscopic and photometric surveys. In this talk, I will introduce a new method to optimally combine spectroscopic and photometric surveys, using the DMASS galaxy sample as gravitational lenses. The new approach can extract the full statistical power of photometric surveys beyond the overlapping area. I will illustrate how this approach with DMASS improves cosmological constraints in the frame of modified gravity and will show its application to future surveys having a limited overlap such as DESI and LSST.


THE DARK ENERGY SURVEY
Duke
UNIVERSITY
Combining Photometric and Spectroscopic Surveys with the DMASS Sample
Sujeong Lee
October 12, 2021
@ Perimeter Institute for Theoretical Physics

Contents

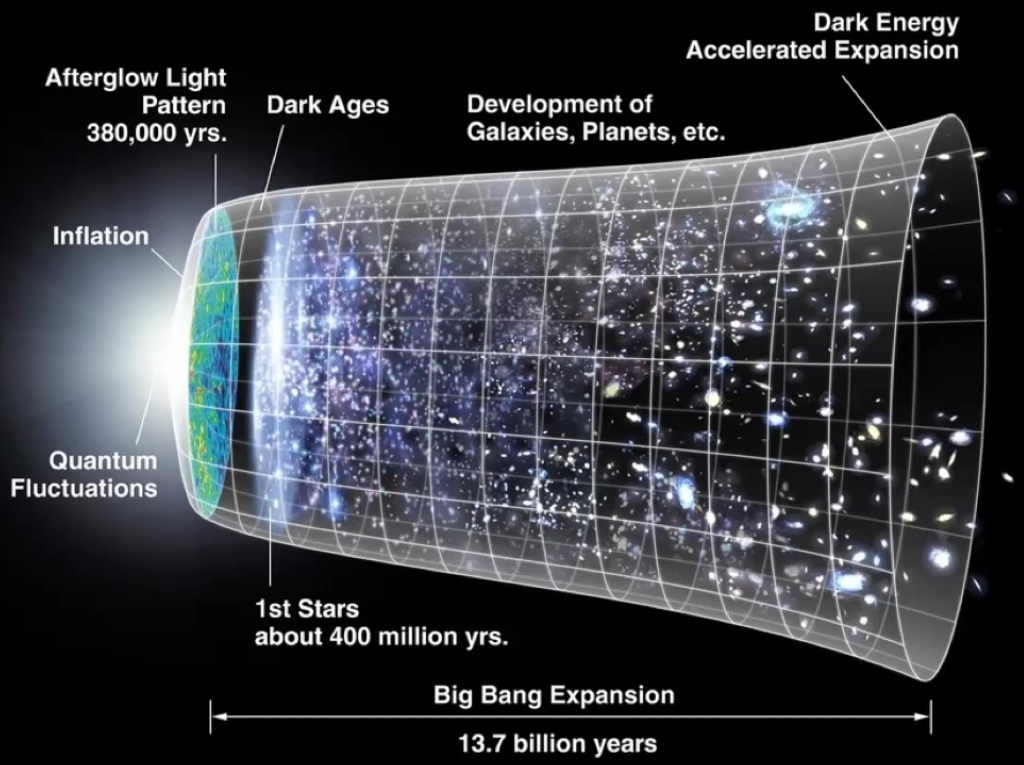
The Universe is Accelerating



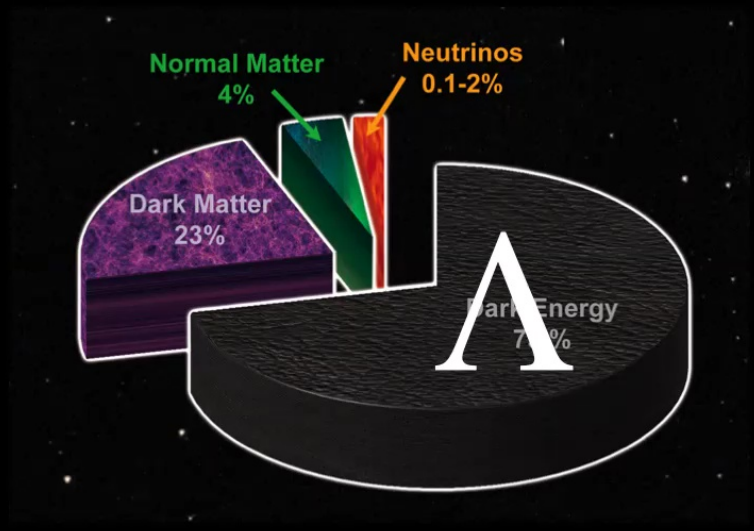


70% of the Unierse today is filled with Dark Energy.
Dark Energy triggers cosmic acceleration.

The Universe is Accelerating

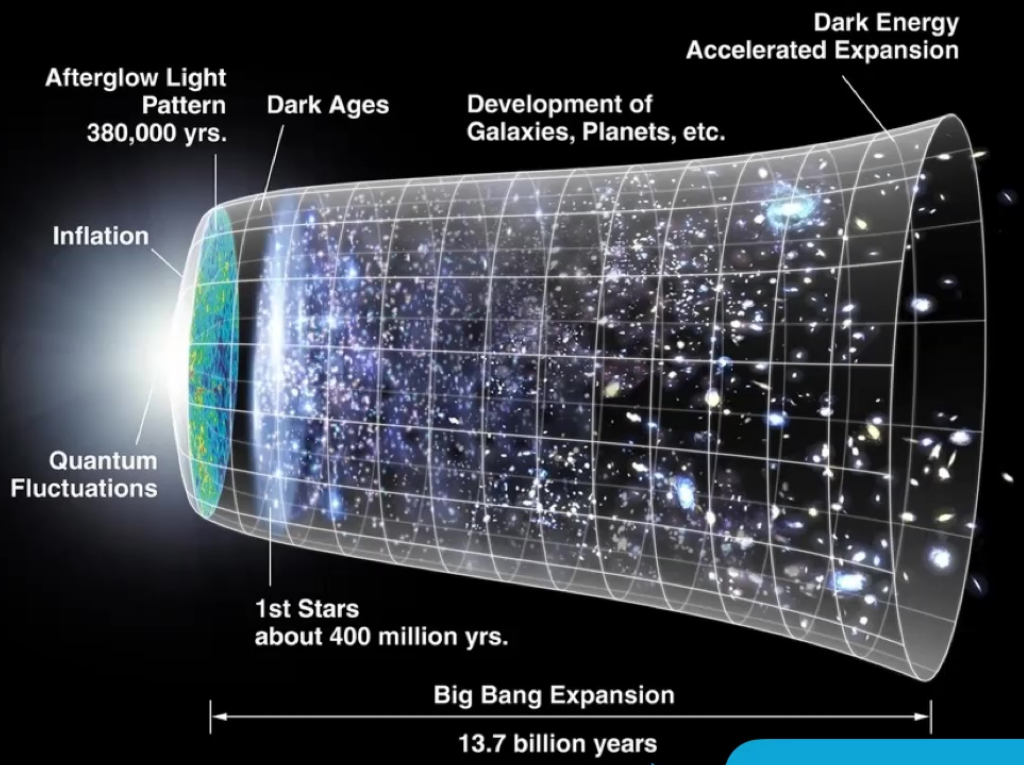


ΛCDM Model

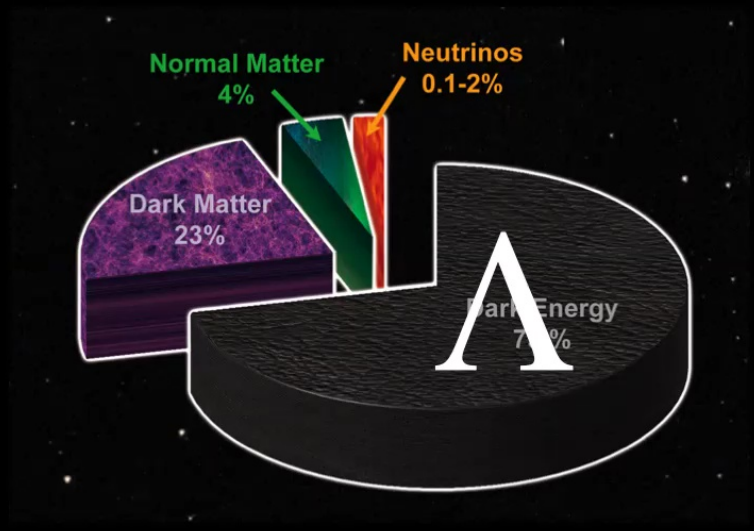


70% of the Unierse today is filled with Dark Energy.
Dark Energy triggers cosmic acceleration.

The Universe is Accelerating



ΛCDM Model



70% of the Unierse today is filled with Dark Energy.
Dark Energy triggers cosmic acceleration.

Alternatives to ΛCDM → wCDM, dynamic dark energy, **New gravity**

Cosmological Probes To Test ΛCDM

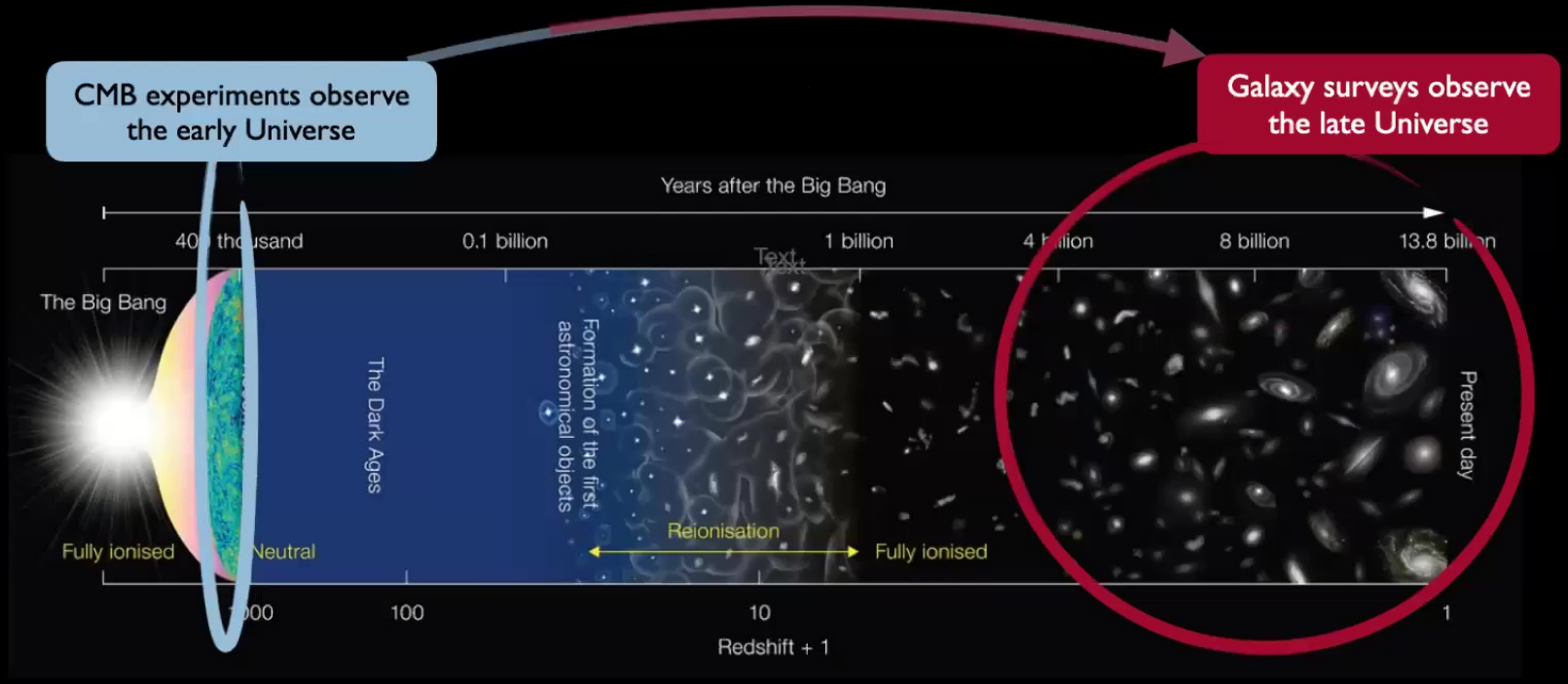


Image credit: NAOJ

Cosmological Probes To Test ΛCDM

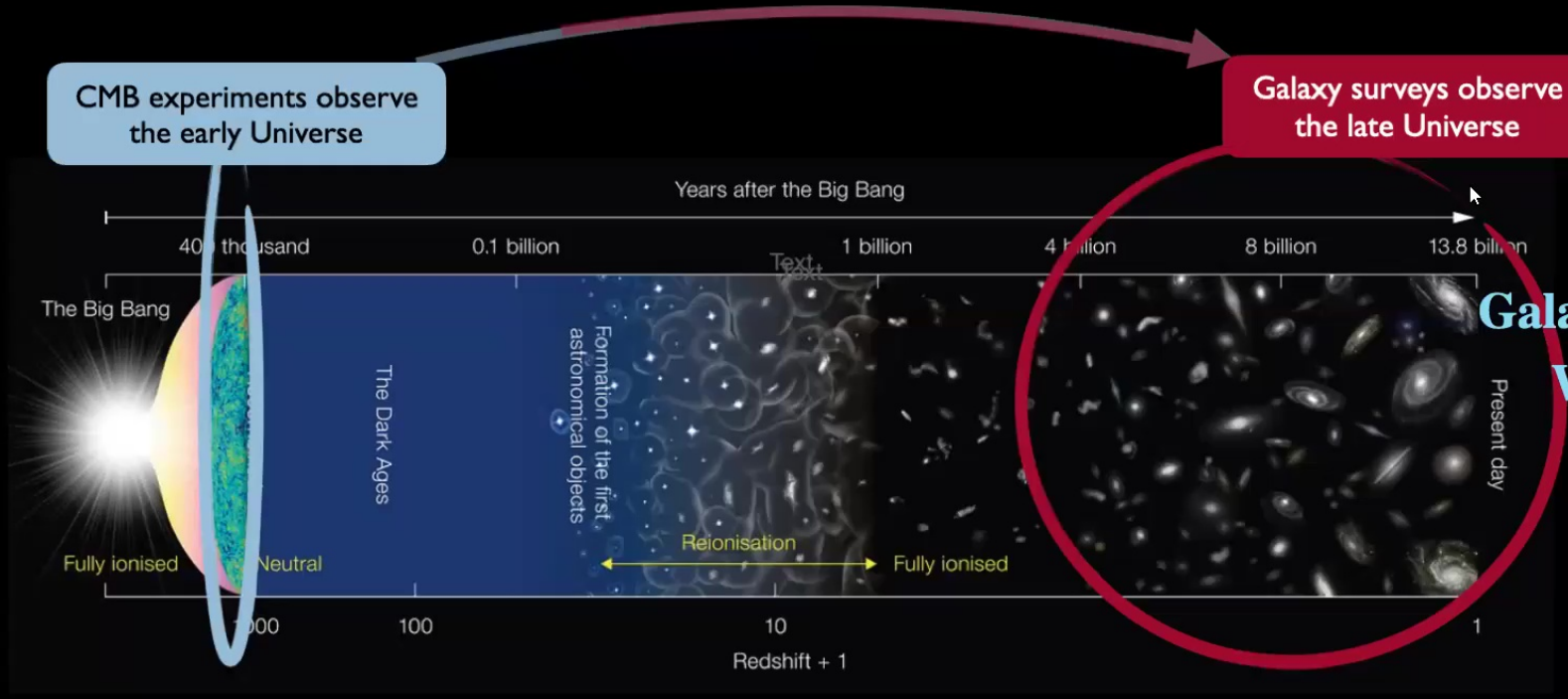


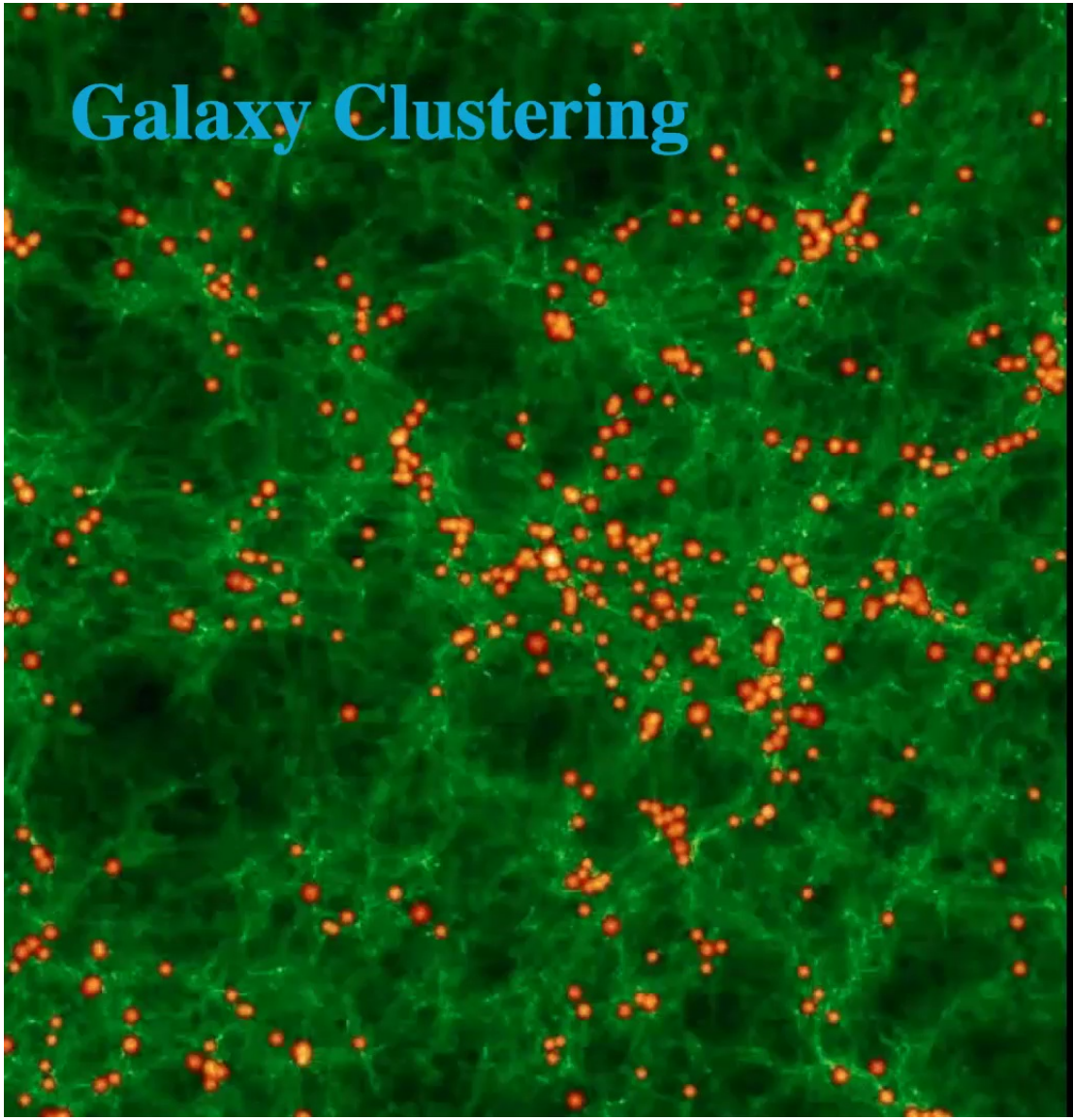
Image credit: NAOJ

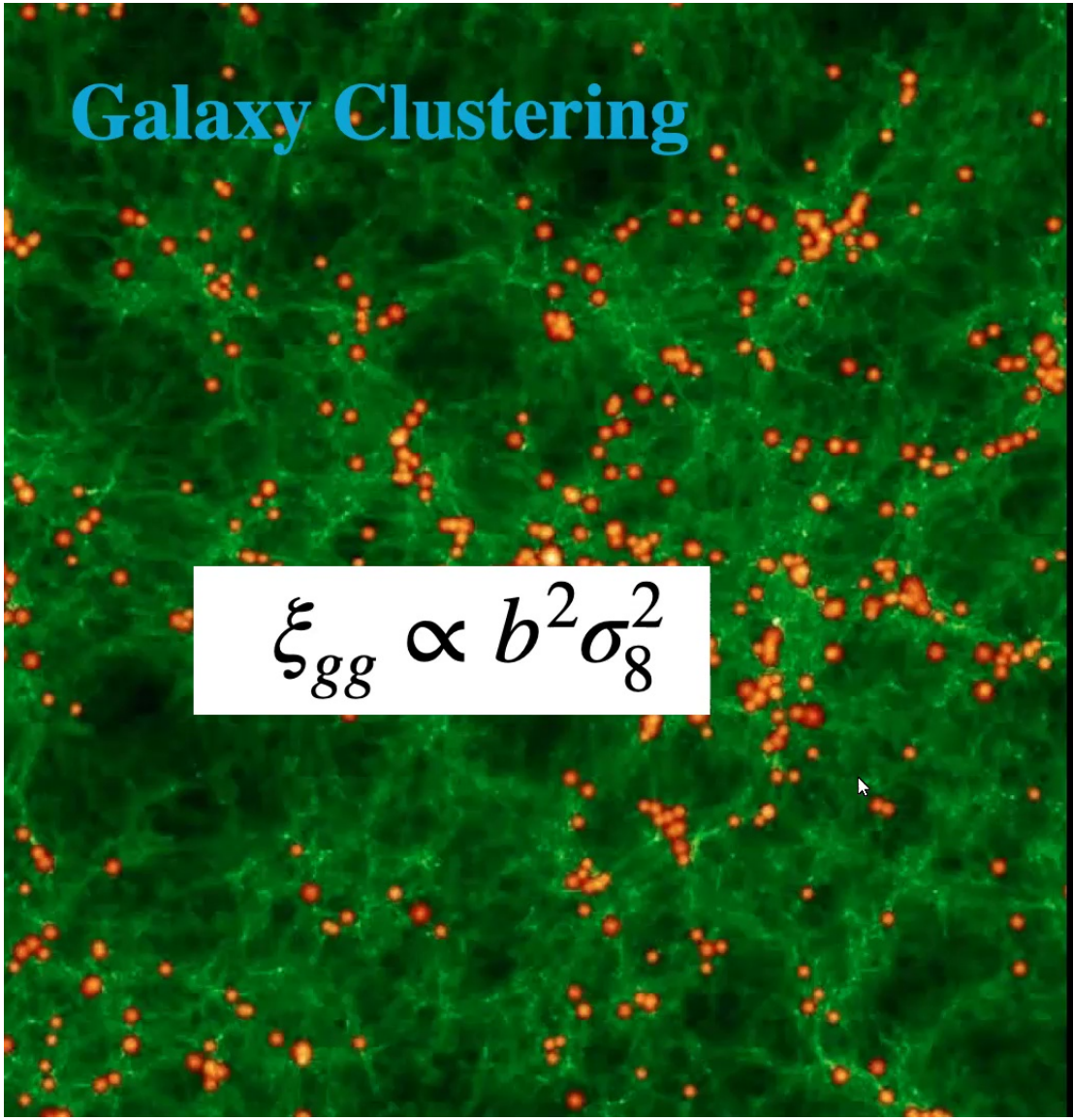
Galaxy clutering

Weak lensing

Clusters

Type 1a SNe


Galaxy Clustering


Galaxy Clustering
$\xi_{gg} \propto b^2\sigma_8^2$

Galaxy Clustering

$$\xi_{gg} \propto b^2 \sigma_8^2$$

Weak Lensing

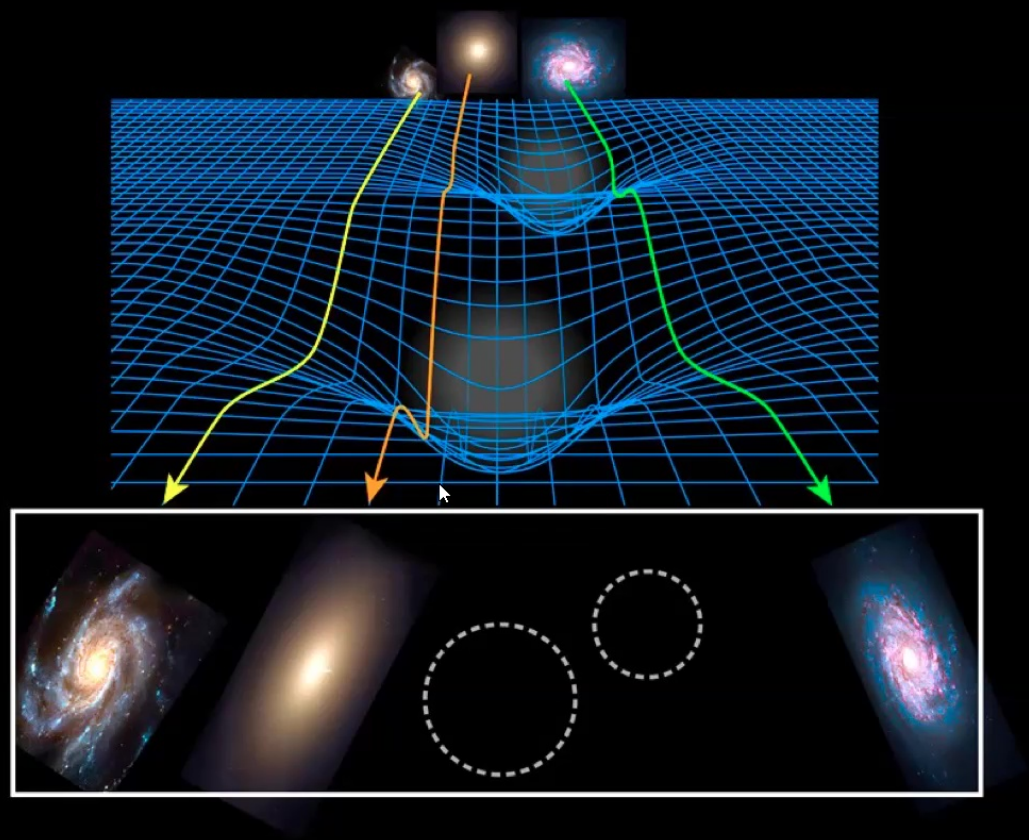
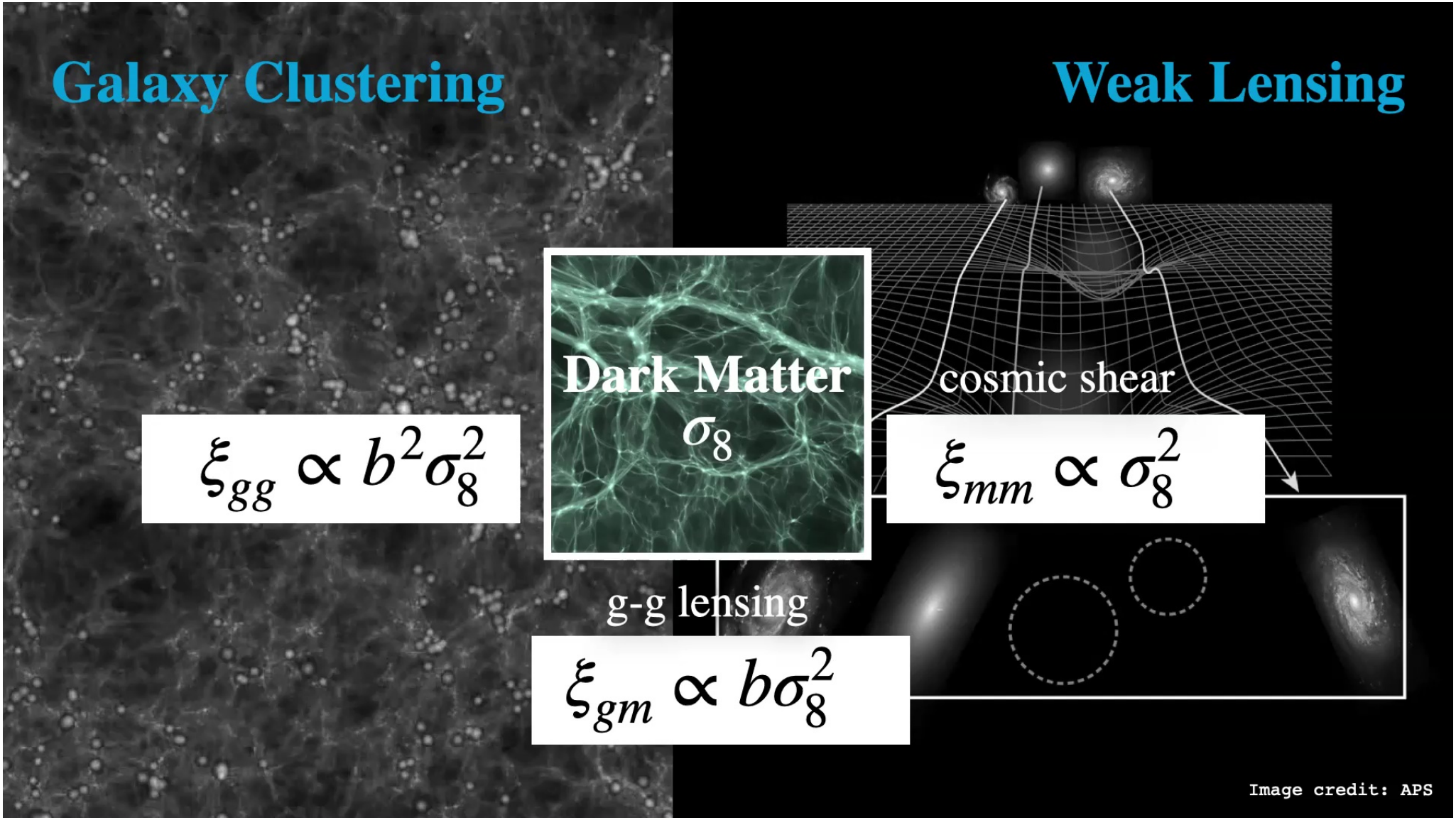
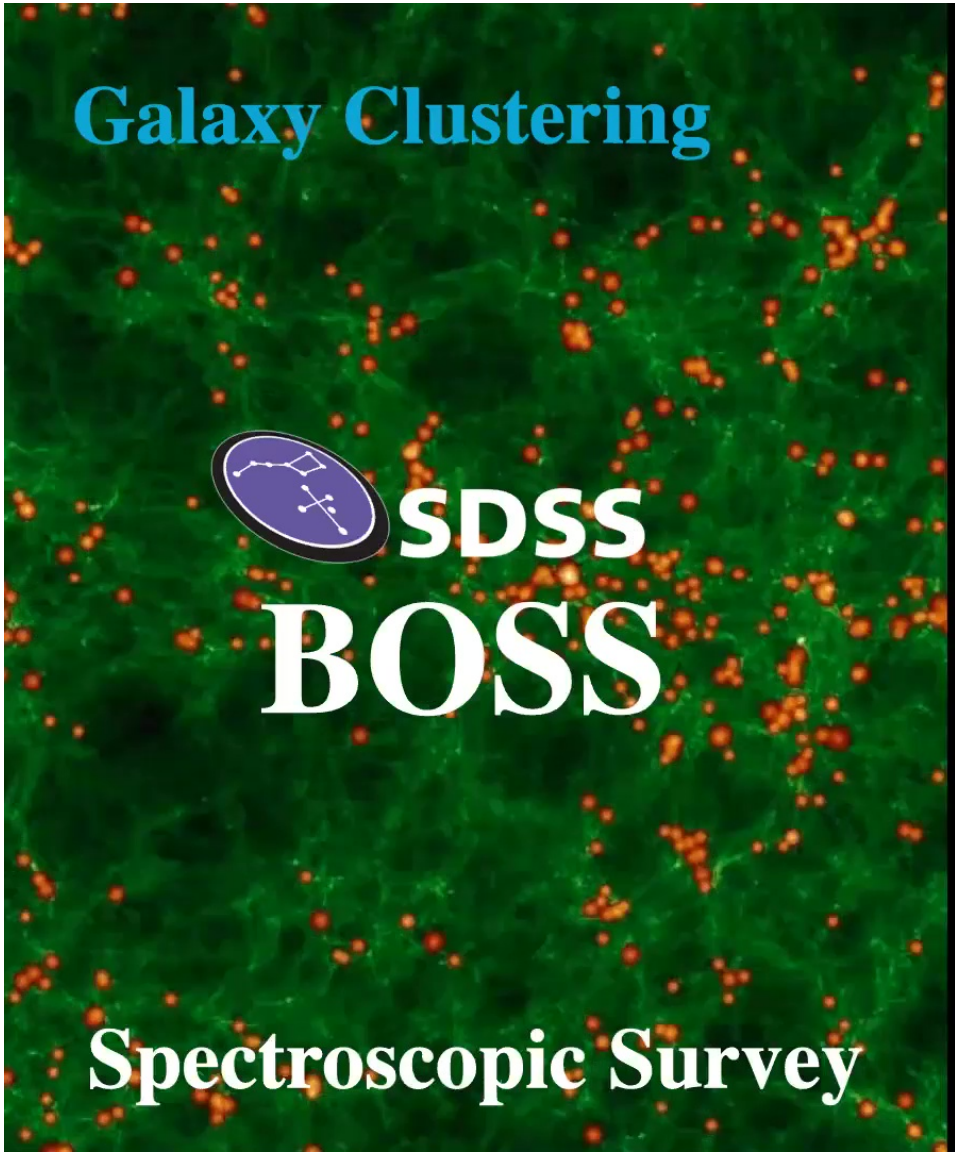
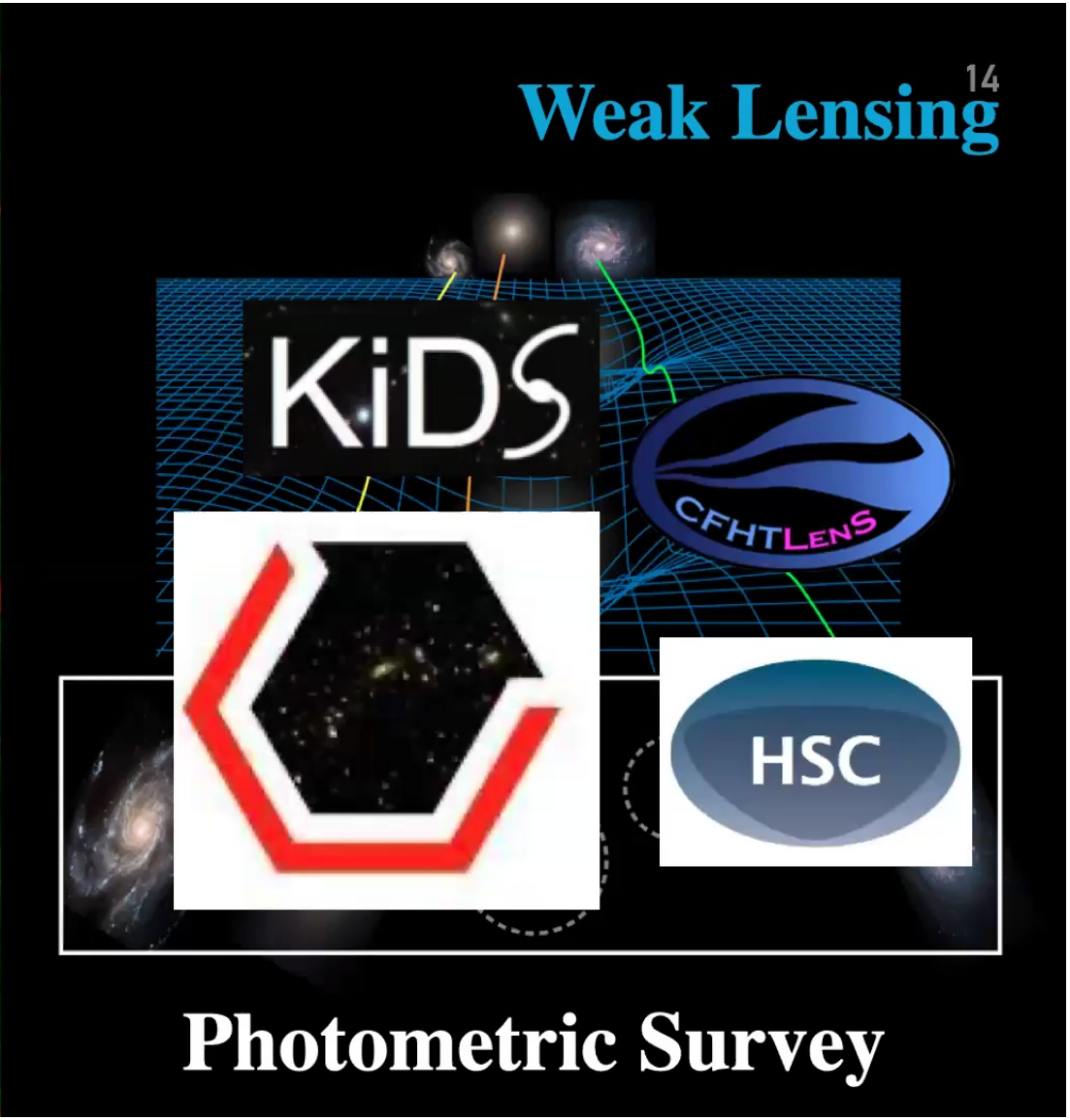


Image credit: APS

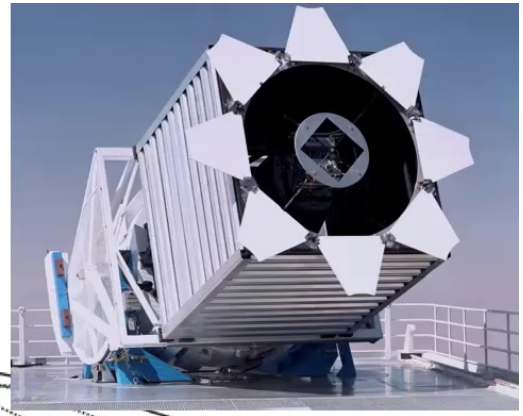

Galaxy Clustering
Weak Lensing
Dark Matter
σ_8
cosmic shear
$\xi_{gg} \propto b^2\sigma_8^2$
$\xi_{mm} \propto \sigma_8^2$
g-g lensing
$\xi_{gm} \propto b\sigma_8^2$
Image credit: APS


Galaxy Clustering
SDSS
BOSS
Spectroscopic Survey

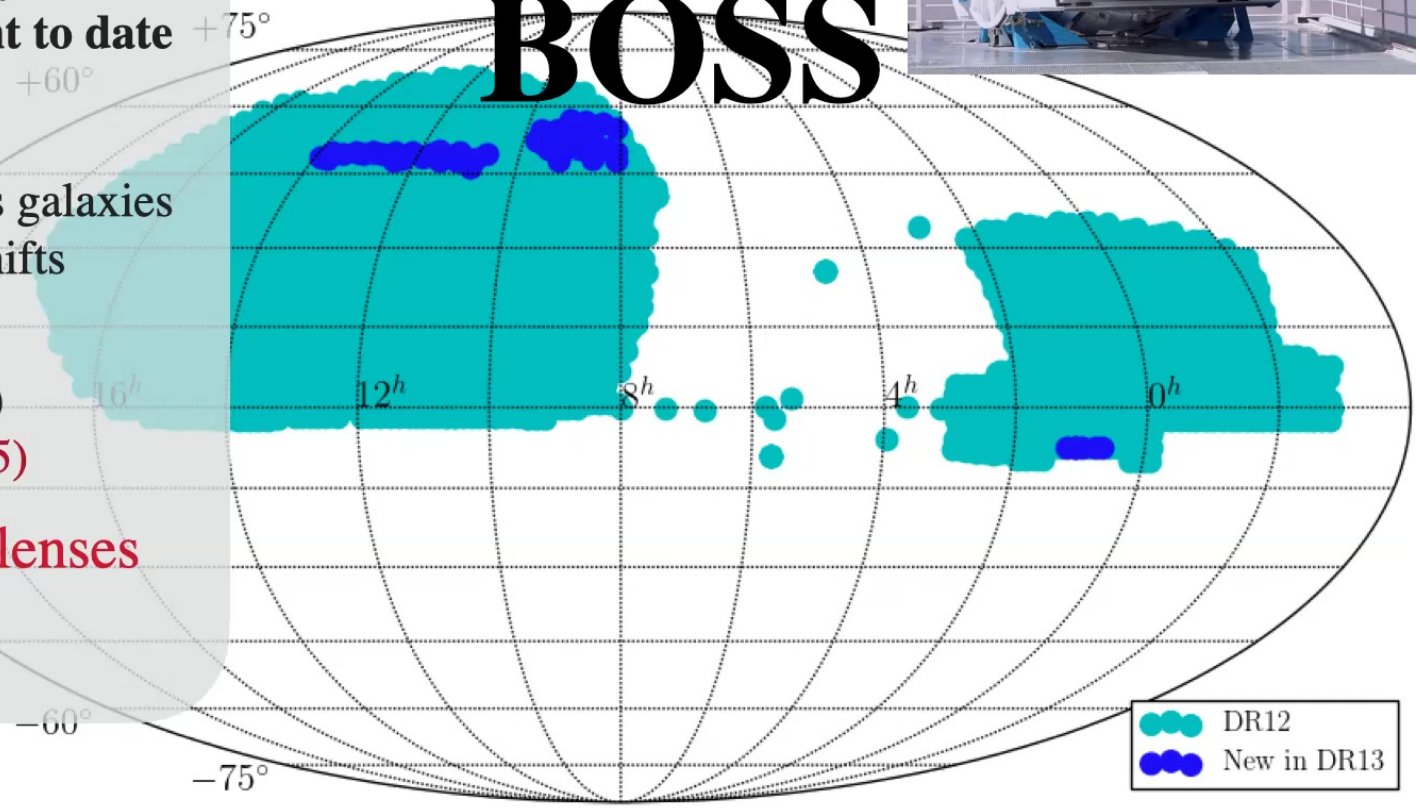

Weak Lensing
KiDS
CFHTLenS
HSC
Photometric Survey

Baryon Oscillation Spectroscopic Survey

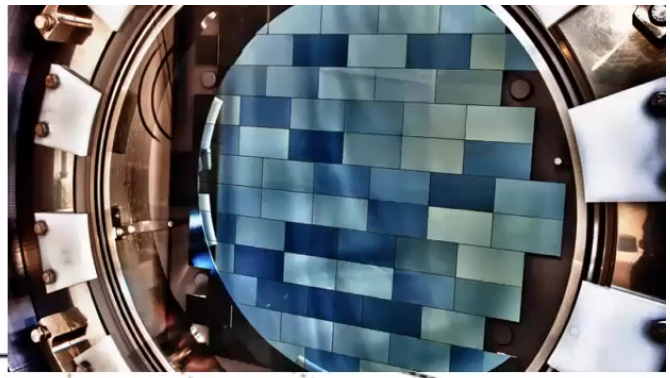
- **The most precise galaxy clustering measurement to date**
- 10,000 deg2
- 1.5 million red luminous galaxies with spectroscopic redshifts
- The galaxy samples :
  LOWZ (0.15 < z < 0.43)
  CMASS (0.43 < z < 0.75)
- Perfect foreground lenses



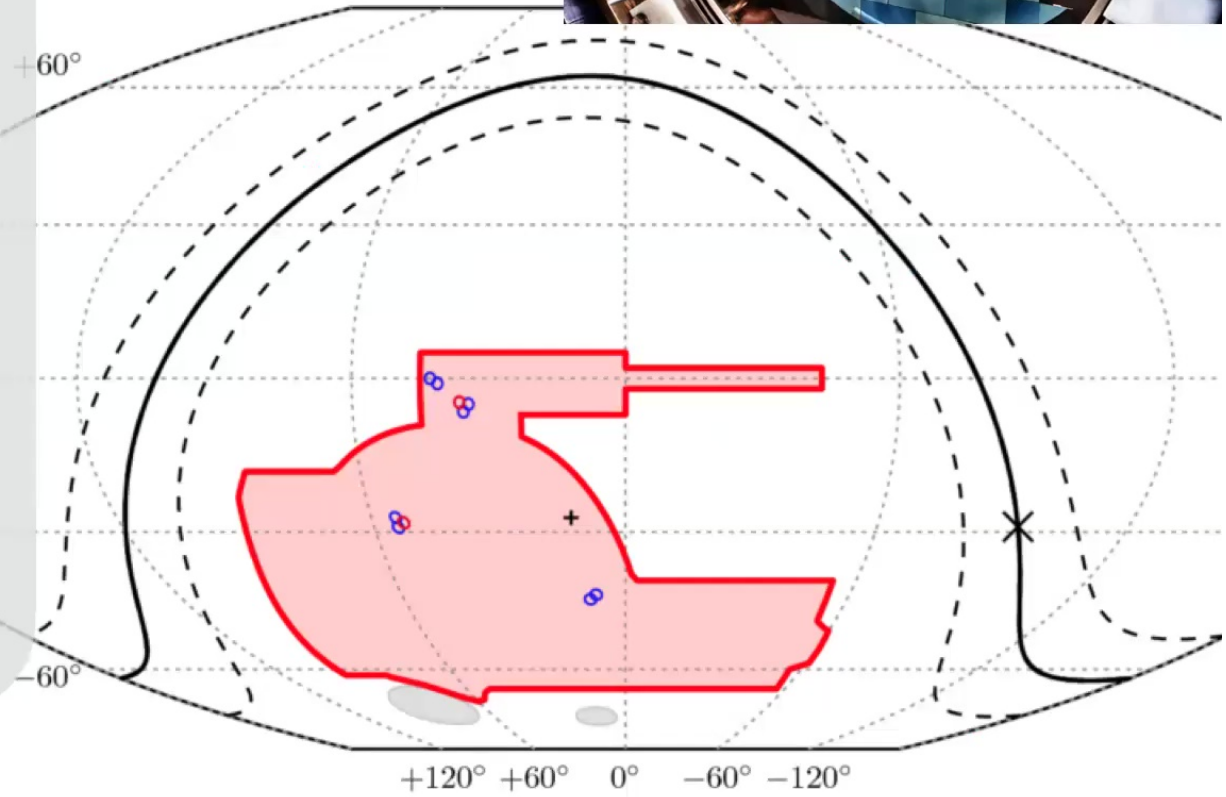
SDSS BOSS



Dark Energy Survey (DES)

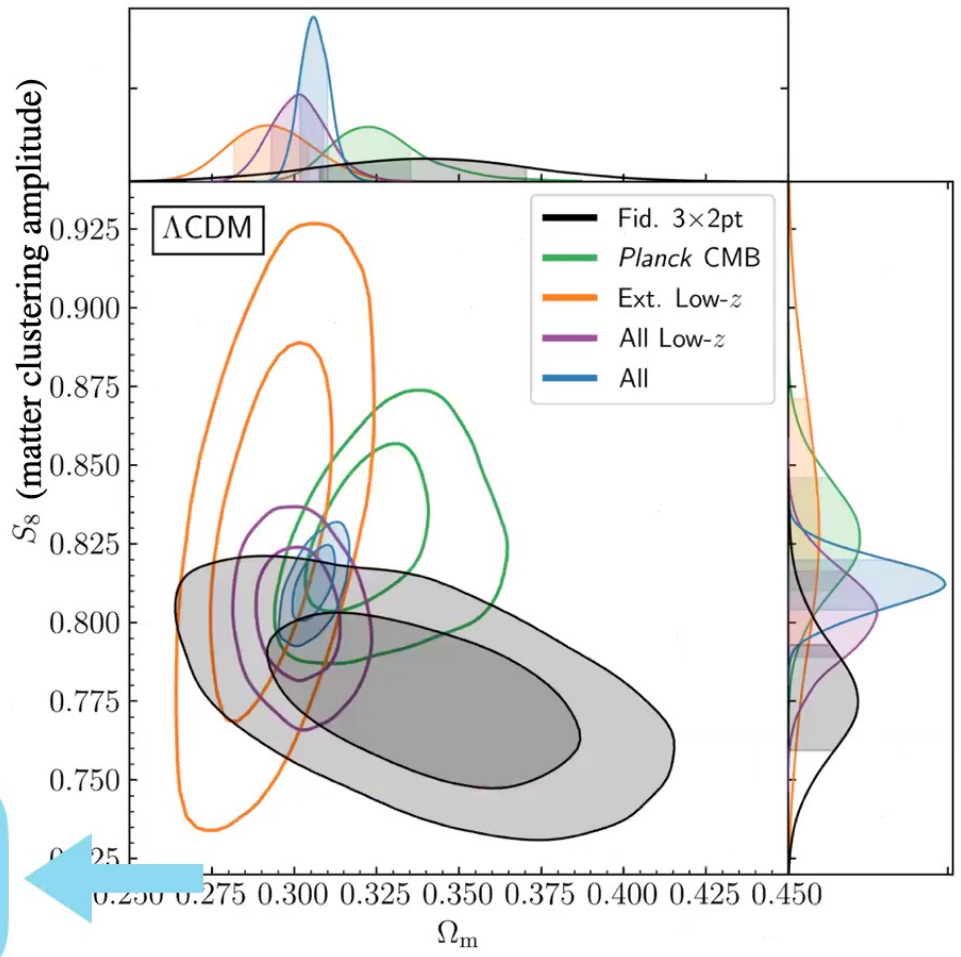


- Optical imaging survey with the Blanco 4m telescope in Chile
- Scan 5000 deg2 in grizY bands
- 300 million galaxies
- Observe very faint galaxies up to 24th i-band magnitude
- Finished all 5.5 years of observing
- Y3 results out (~30 papers), Y6 analysis in progress



Dark Energy Survey (DES)

- Optical imaging survey with the Blanco 4m telescope in Chile
- Scan 5000 deg2 in grizY bands
- 300 million galaxies
- Observe very faint galaxies up to 24th i-band magnitude
- Finished all 5.5 years of observing
- Y3 results out (~30 papers), Y6 analysis in progress



A factor of 2.1 improvement from DES Y1.
Consistent with Planck in LCDM (0.7-1.5σ)

Spectroscopic and Photometric Surveys

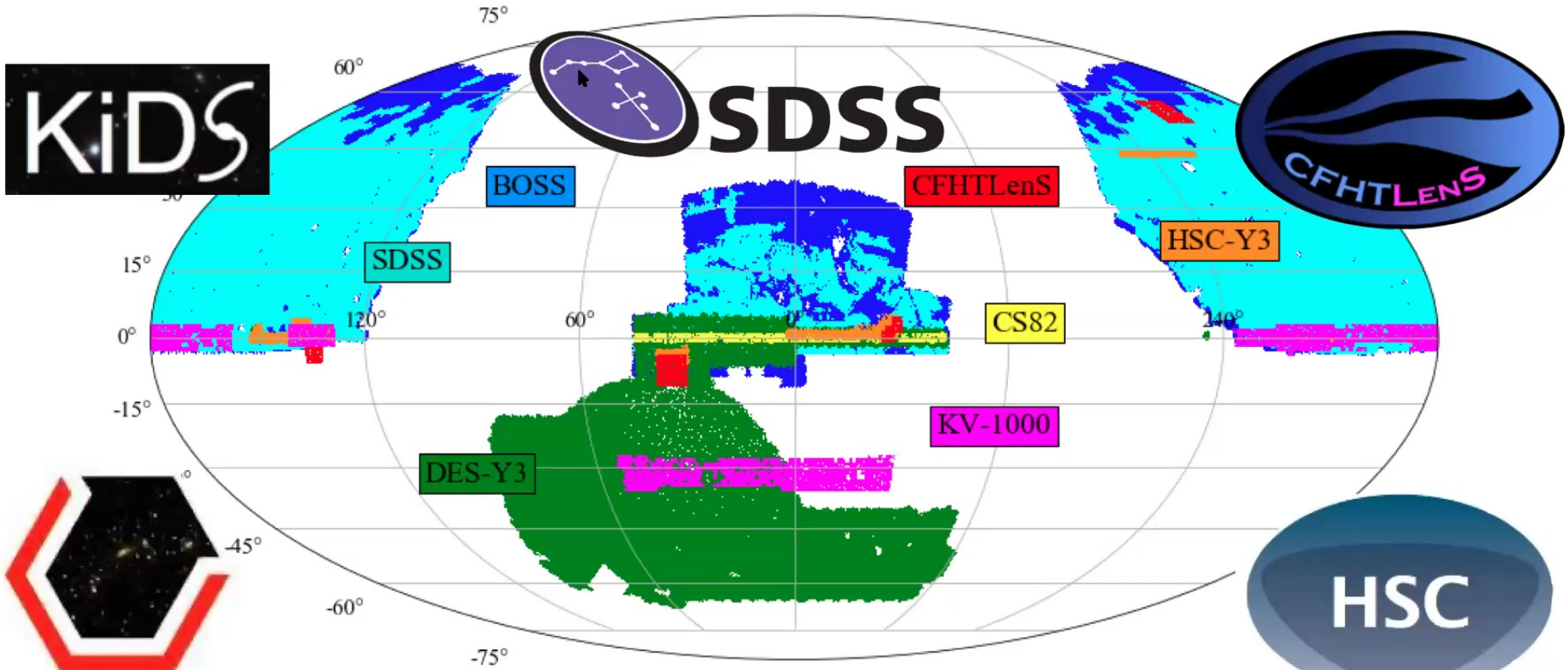


Image credit : Alex Amon

Only a few hundreds deg2 overlap

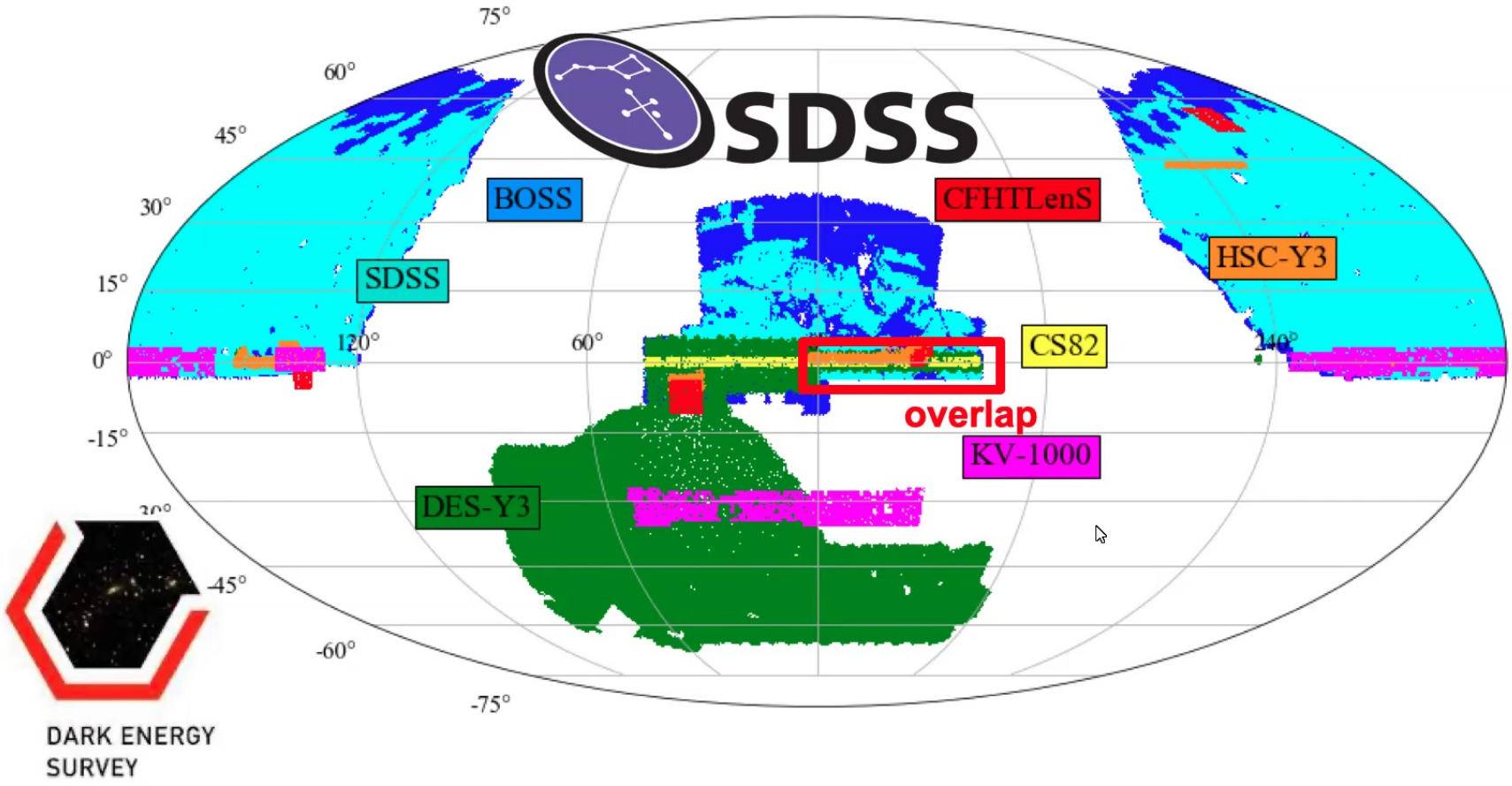
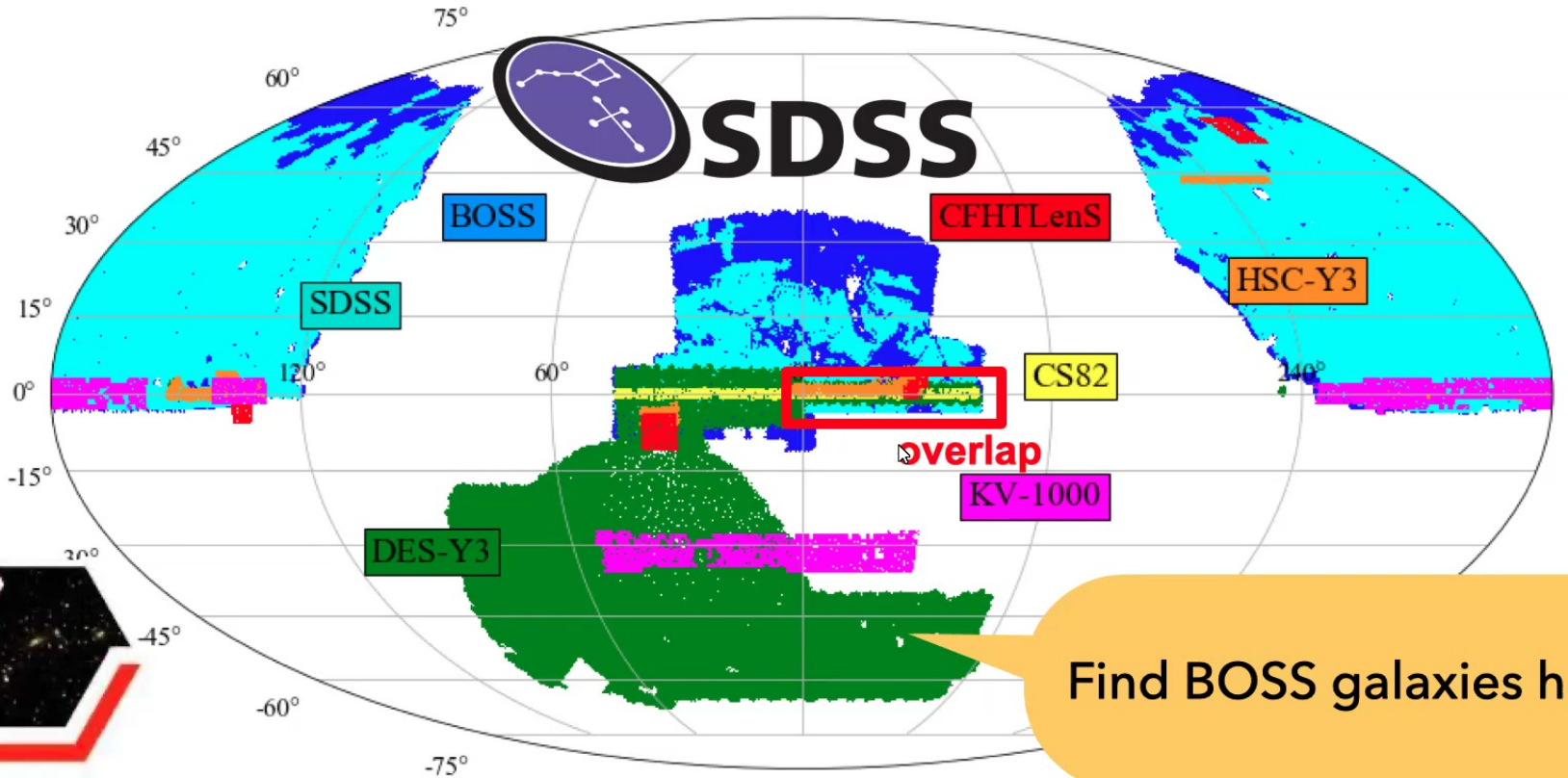


Image credit : Alex Amon

Only a few hundreds deg2 overlap



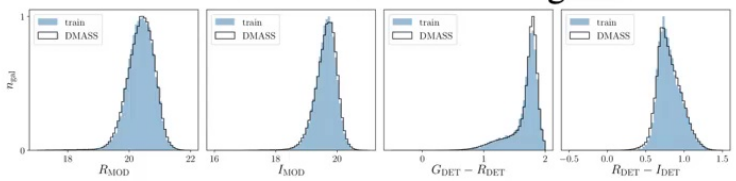
DARK ENERGY SURVEY

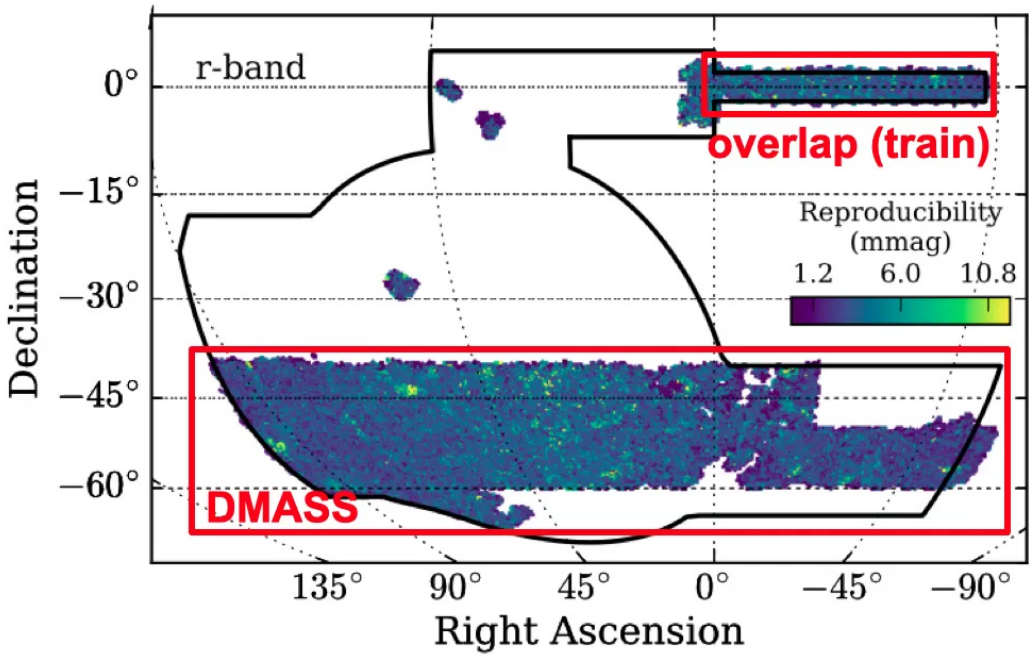
Find BOSS galaxies here!

Image credit : Alex Amon

The DMASS Galaxy Sample

DES color distribution of BOSS galaxies





- **DMASS = DES-CMASS**
- The sample can replicate various statistical properties of the BOSS high redshift sample, **CMASS** ($0.4 < z < 0.7$)
- The algorithm was trained with the DES colors of CMASS galaxies in the overlapping area
- 11,000 effective galaxies
- covers DES Year 1 area (~1200 deg2)

Lee et al. (2019) arxiv: 1906.01136	DMASS Year 3 Warner et al. (in prep)

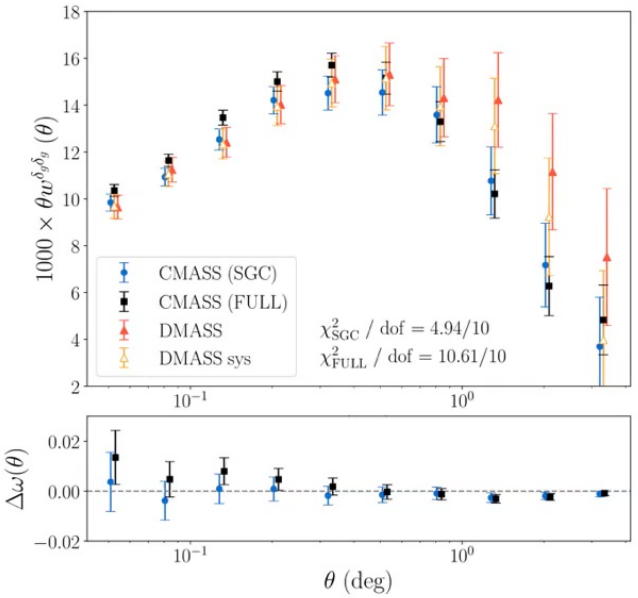
The DMASS Galaxy Sample

How similar DMASS is to CMASS?

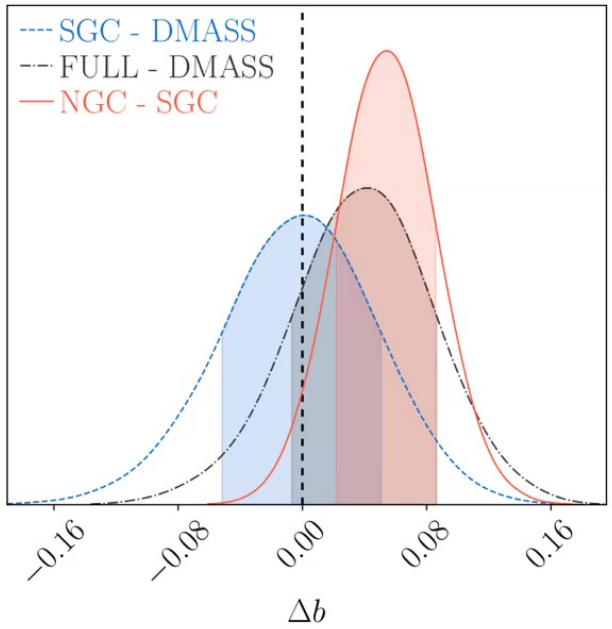
- Color distributions
- Number density
- Redshift distributions
- **Two point function**
- **Galaxy bias**

Lee et al. (2019)
arxiv: 1906.01136

angular correlation function



galaxy bias difference



Only a few hundreds deg2 overlap

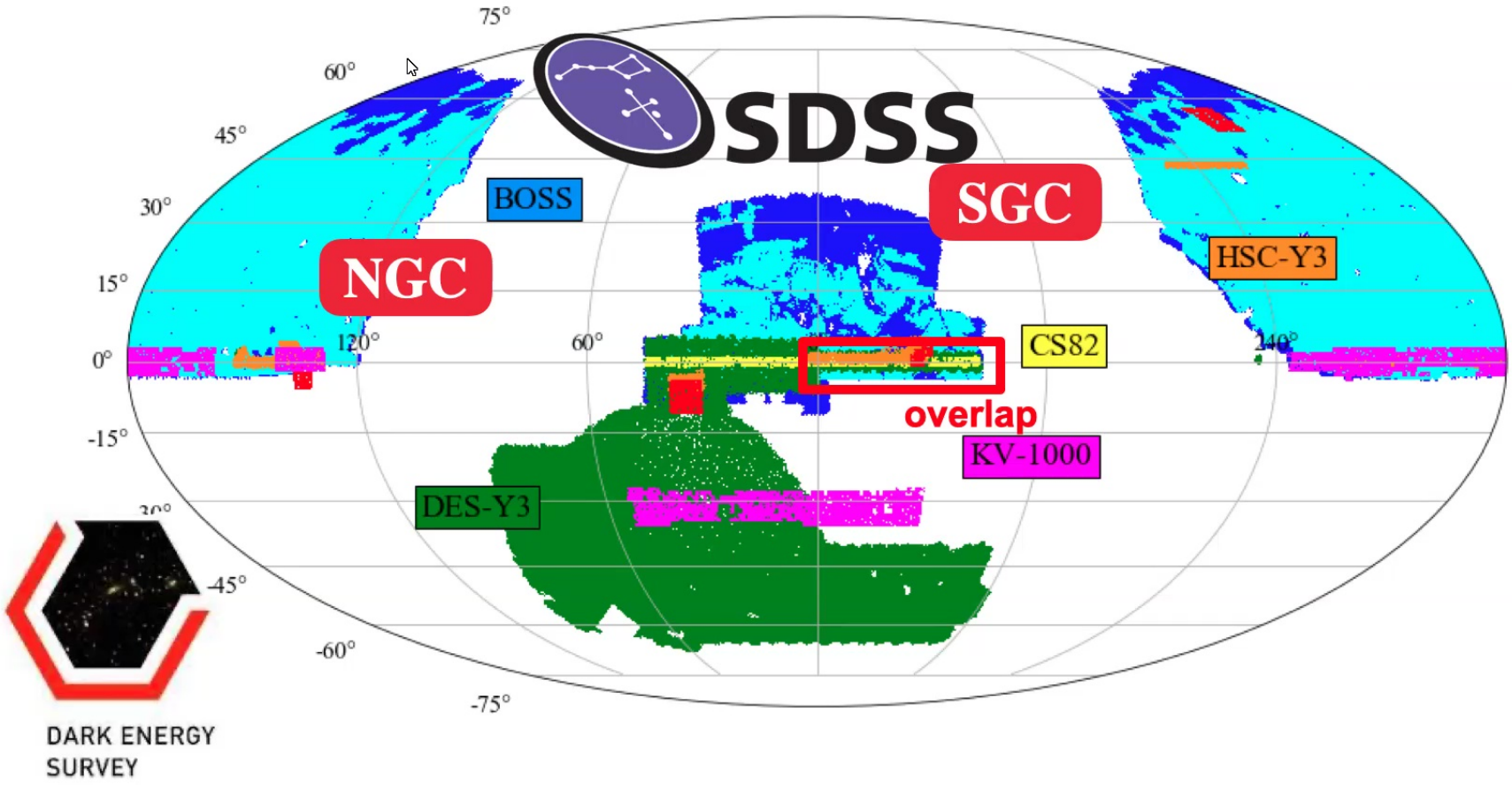


Image credit : Alex Amon

Contents

Galaxy-galaxy lensing measurement

The mean tangential shear

$$\gamma_t(\theta) = \langle \gamma_+(\theta) \rangle$$

$$\gamma_t(\theta) = \frac{1}{2\pi} \int_0^\infty C_{g\kappa}(\ell) J_2(\ell\theta) l \mathrm{d}\ell$$

$$C_{g\kappa}(\ell) = b_g r_{\mathrm{cc}} \int_0^\infty \mathrm{d}\chi \left(\frac{n_g(z(\chi))}{\bar{n}_g} \frac{\mathrm{d}z}{\mathrm{d}\chi} \right) \frac{W_\kappa(\chi)}{\chi^2} P_{\delta\delta}(k, z(\chi))$$

$$= b_\gamma$$

Cross-correlation coefficient in this work

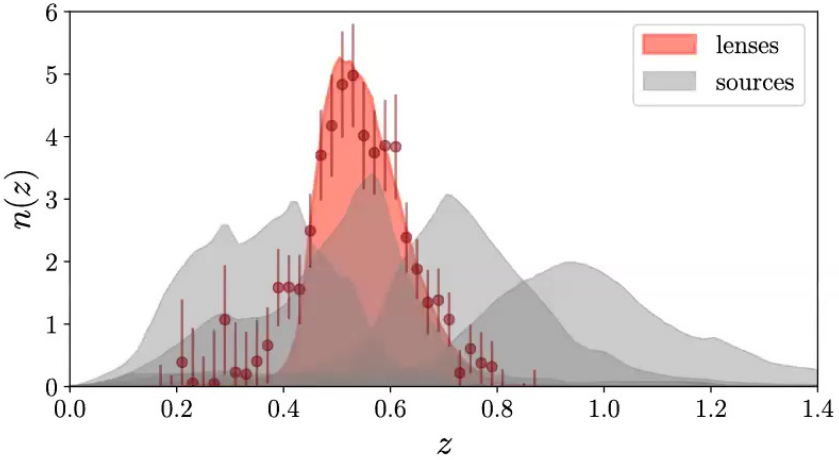
$$r_{\mathrm{cc}} = \frac{b_\gamma}{b_g}$$

b_g : clustering galaxy bias, b_γ : lensing galaxy bias

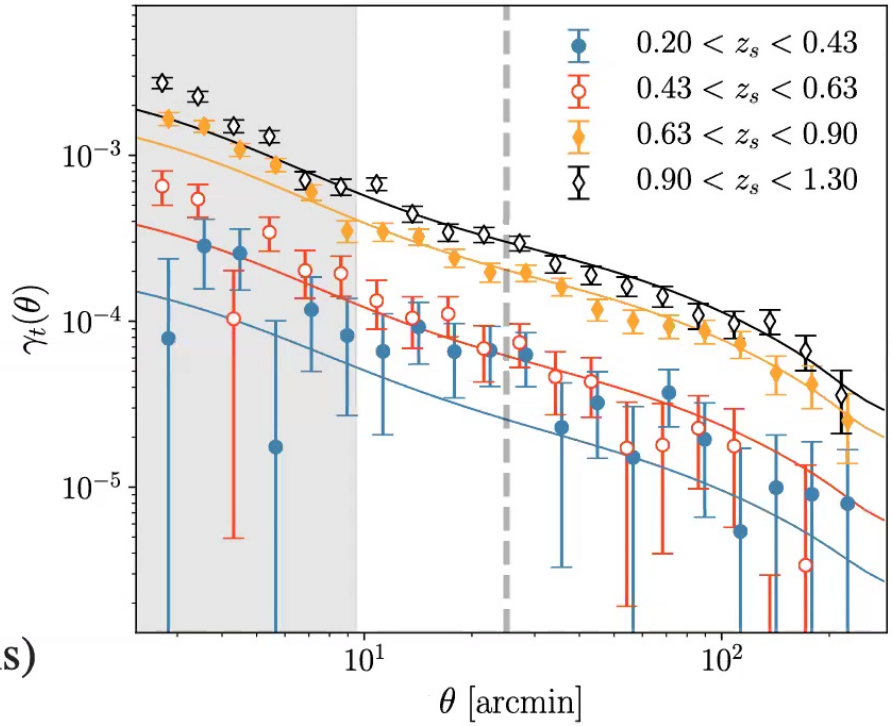
1. The cross-correlation between galaxies and matter within the scales of interest.
2. **A barometer indicating the consistency between the two tracers**

Galaxy-galaxy lensing measurement

redshift distribution



tangential shear measurement



- lens: DMASS (1 lens bin)
- source: DES Y1 shape catalog (4 source bins)

galaxy-galaxy lensing
(Lee et al. 2021)

Constraints on r_{cc}

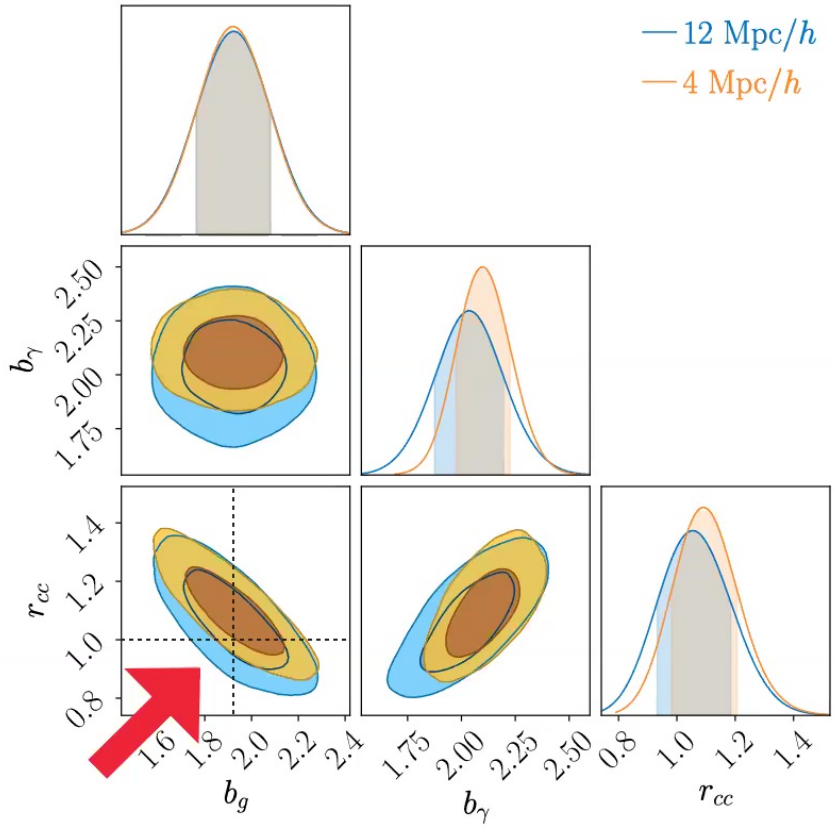
- Performed a joint analysis with Galaxy clustering of BOSS-CMASS

Chuang et al. (2017)

$b\sigma_8(z),\ f(z)\sigma_8(z)$

$H(z),\ D_A(z),\ \Omega_m h^2$

- r_{cc} is derived from the ratio of the two galaxy biases.
- The resulting r_{cc} is consistent with unity for the both scale cuts.



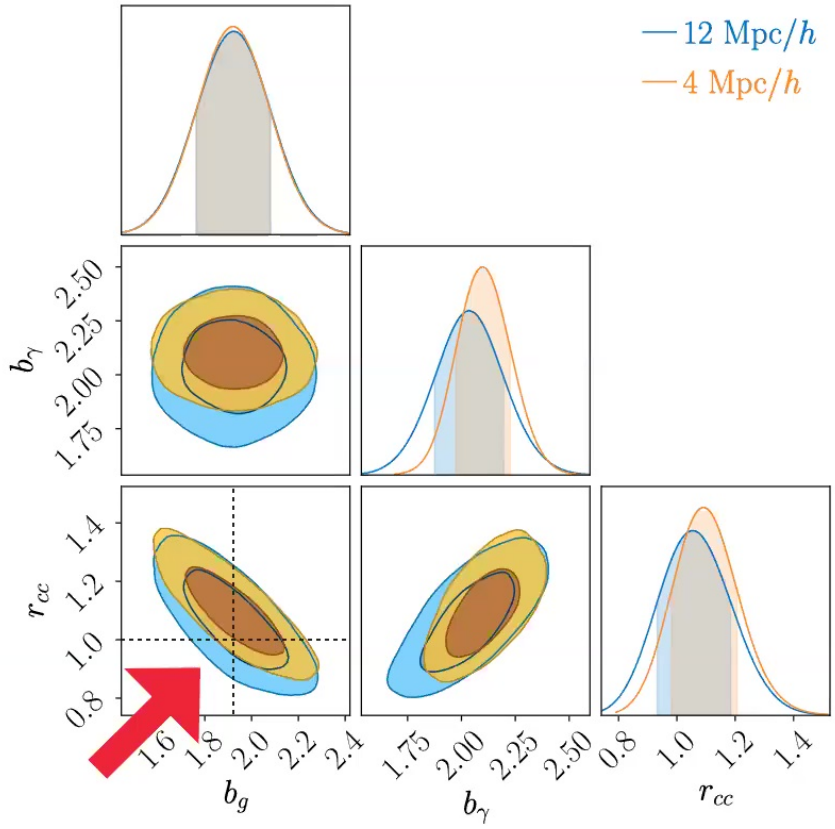
Constraints on r_{cc}

- Performed a joint analysis with Galaxy clustering of BOSS-CMASS

Chuang et al. (2017)

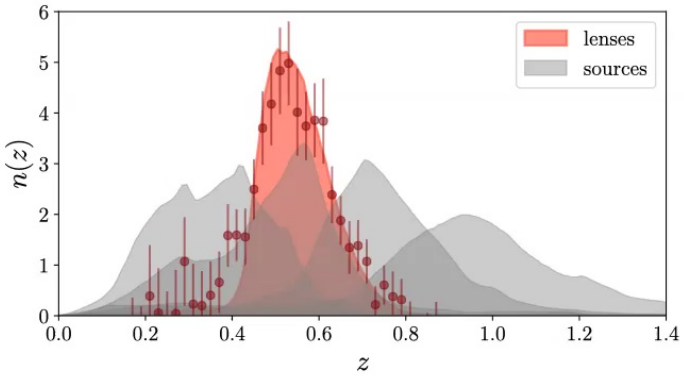
$$b\sigma_8(z),\ f(z)\sigma_8(z)$$
$$H(z),\ D_A(z),\ \Omega_m h^2$$

- r_{cc} is derived from the ratio of the two galaxy biases.
- The resulting r_{cc} is consistent with unity for the both scale cuts.

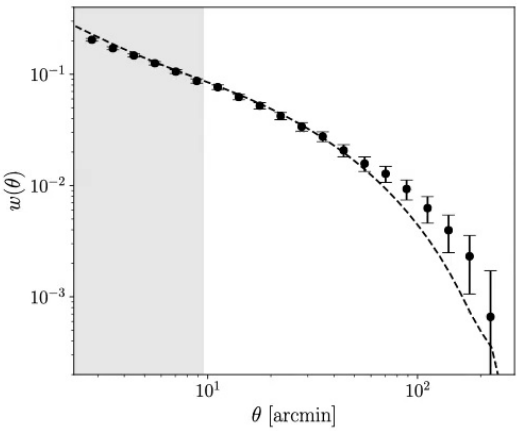


Measurements with DMASS

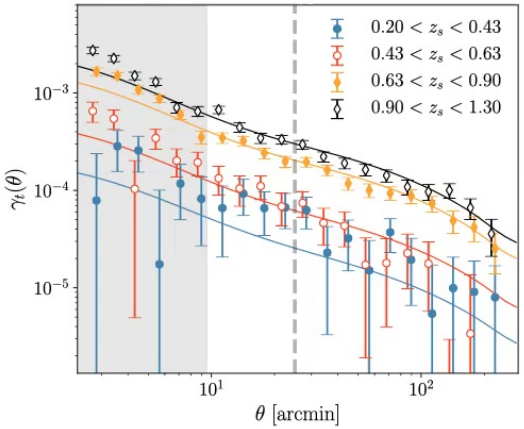
"DMASS 3x2pt"



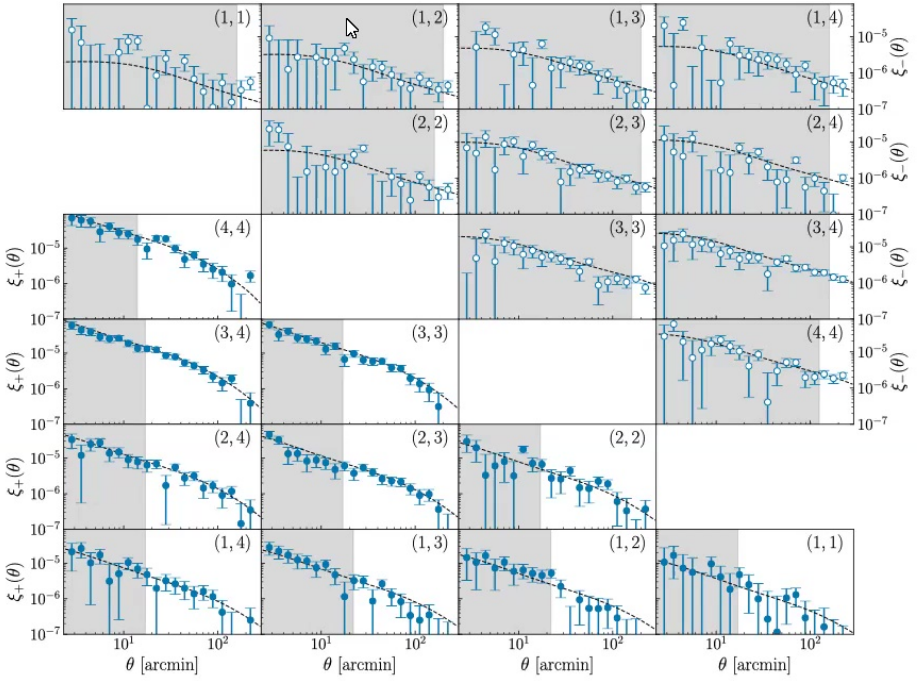
angular galaxy clustering
(Lee et al. 2019)



galaxy-galaxy lensing
Lee et al. (2021)



DES Y1 cosmic shear
Troxel et al. 2018



Modified Gravity (MG) Parametrization

- Phenomenological Approach

Controls modifications to the structure growth

$$k^2\Psi = -4\pi G a^2 (1+\mu(a))\rho\delta$$

$$k^2(\Psi+\Phi) = -8\pi G a^2 (1+\Sigma(a))\rho\delta$$

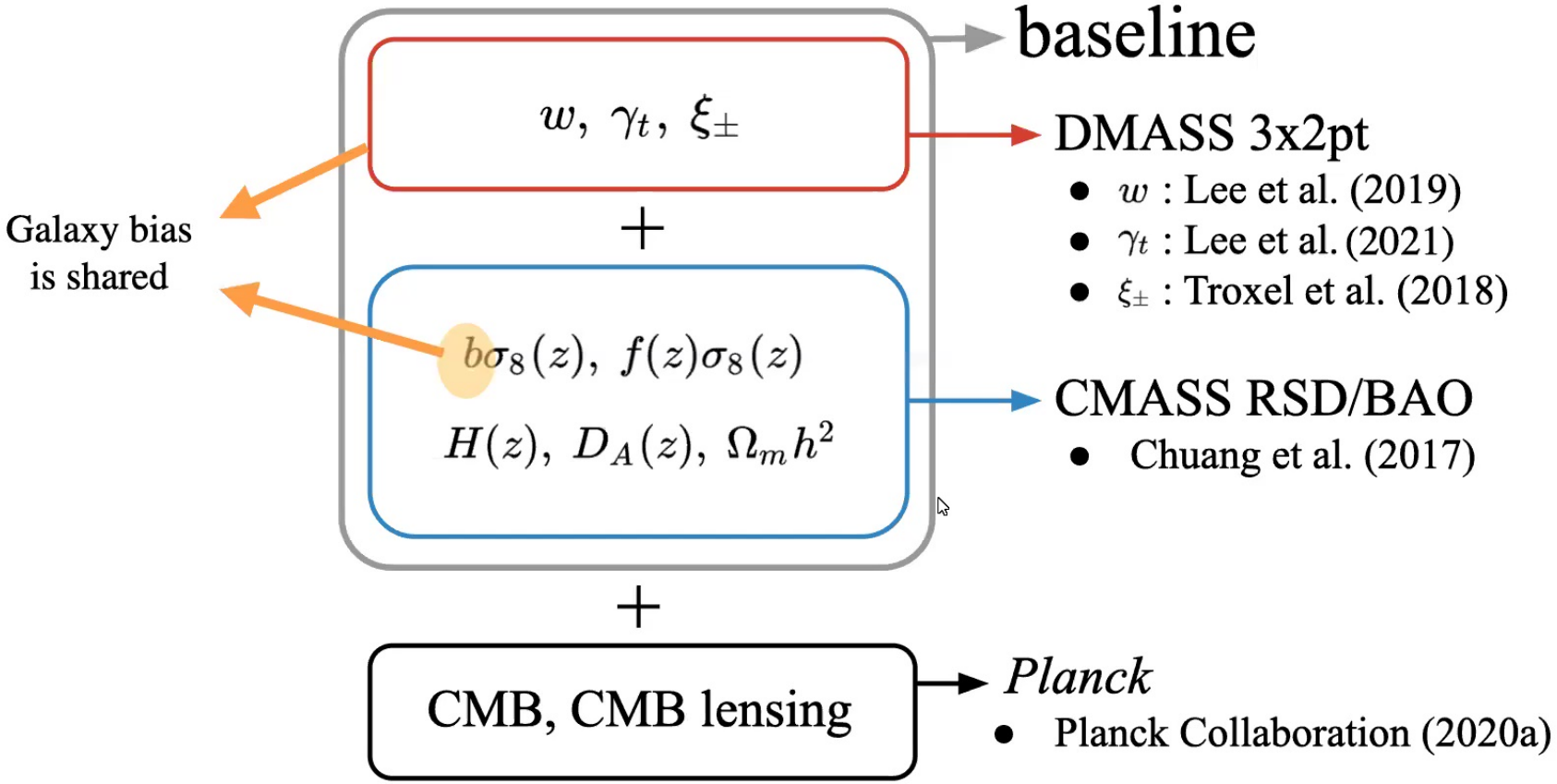
Indicates modifications to the lensing of light

$$\mu(a) = \mu_0 \frac{\Omega_\Lambda(a)}{\Omega_{\Lambda,0}}$$

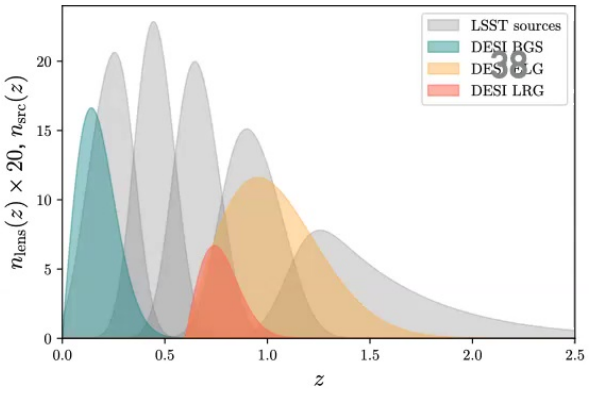
$$\Sigma(a) = \Sigma_0 \frac{\Omega_\Lambda(a)}{\Omega_{\Lambda,0}}$$

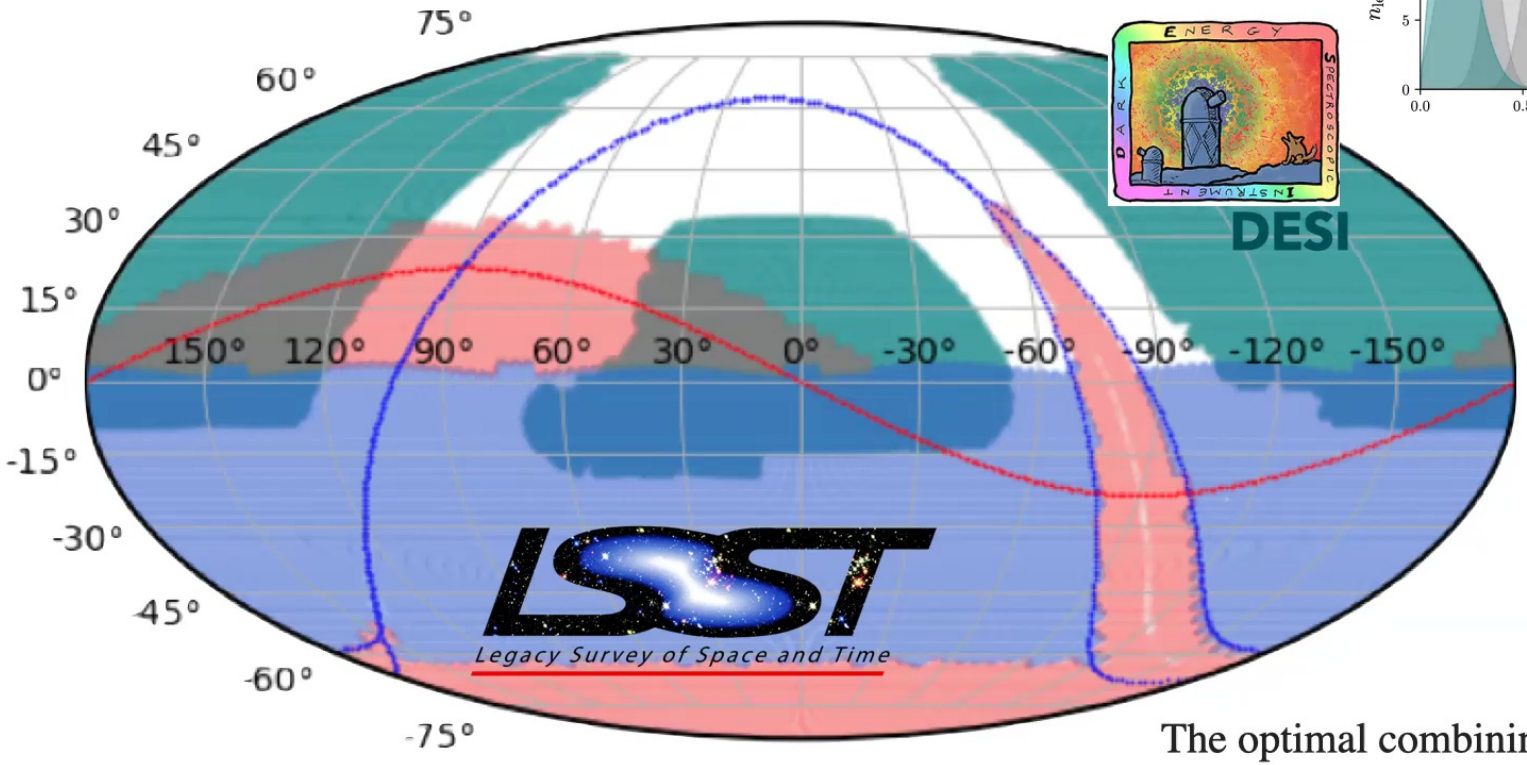
$$(\Sigma_0 = 0, \mu_0 = 0)$$

Data Sets


baseline
$w,\ \gamma_t,\ \xi_\pm$
DMASS 3x2pt
w : Lee et al. (2019)
γ_t : Lee et al. (2021)
$\xi_\pm$: Troxel et al. (2018)
Galaxy bias
is shared
+
$b\sigma_8(z),\ f(z)\sigma_8(z)$
$H(z),\ D_A(z),\ \Omega_m h^2$
CMASS RSD/BAO
Chuang et al. (2017)
+
CMB, CMB lensing
Planck
Planck Collaboration (2020a)

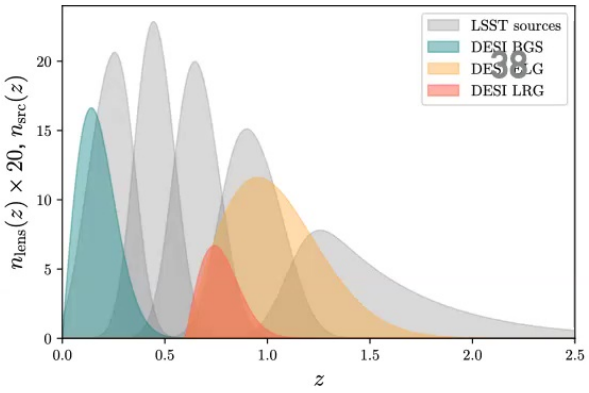
Extension to the LSST-DESI Surveys

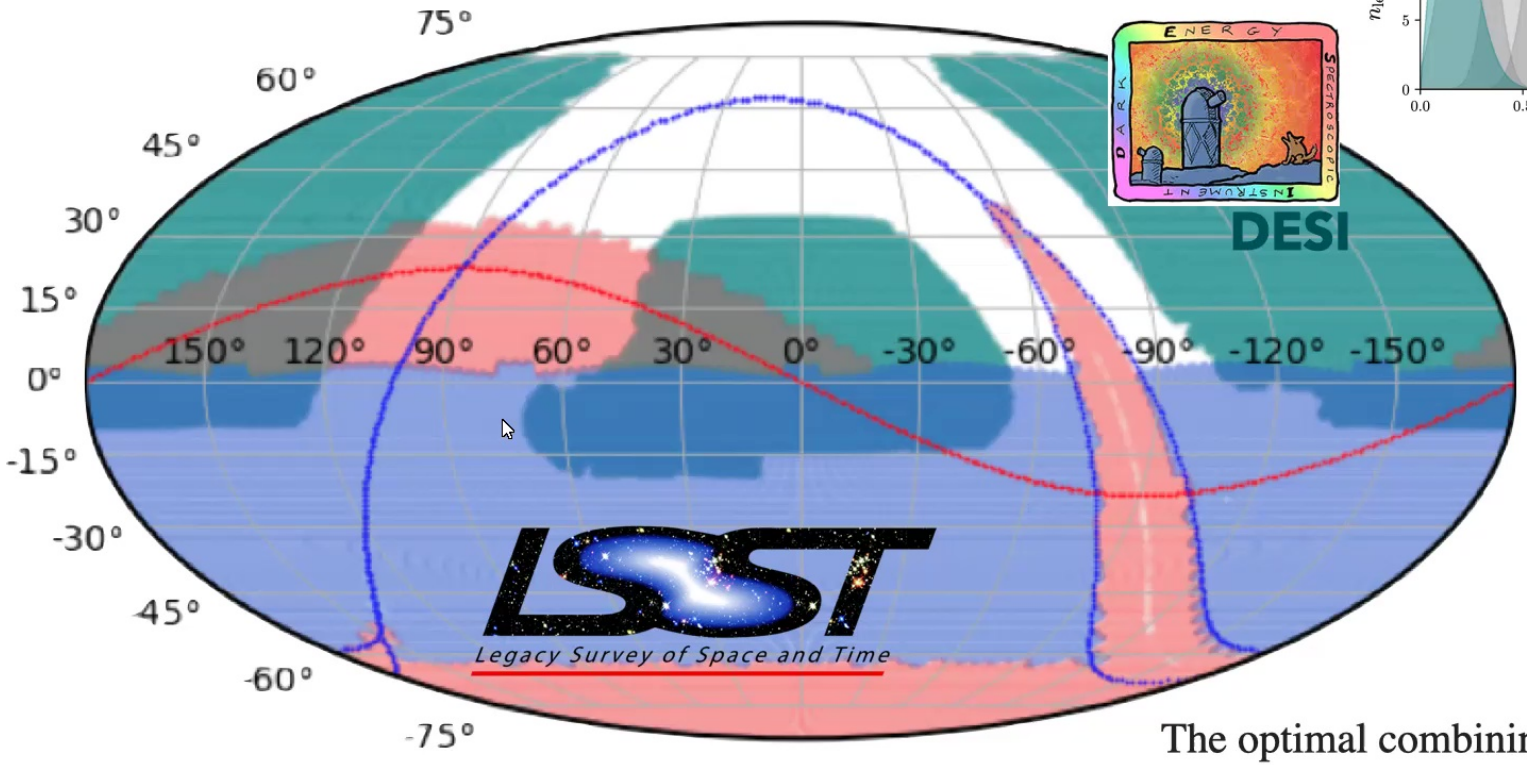




The optimal combining method in this work can be applied to future surveys having a limited overlap, such as DESI and LSST

Extension to the LSST-DESI Surveys





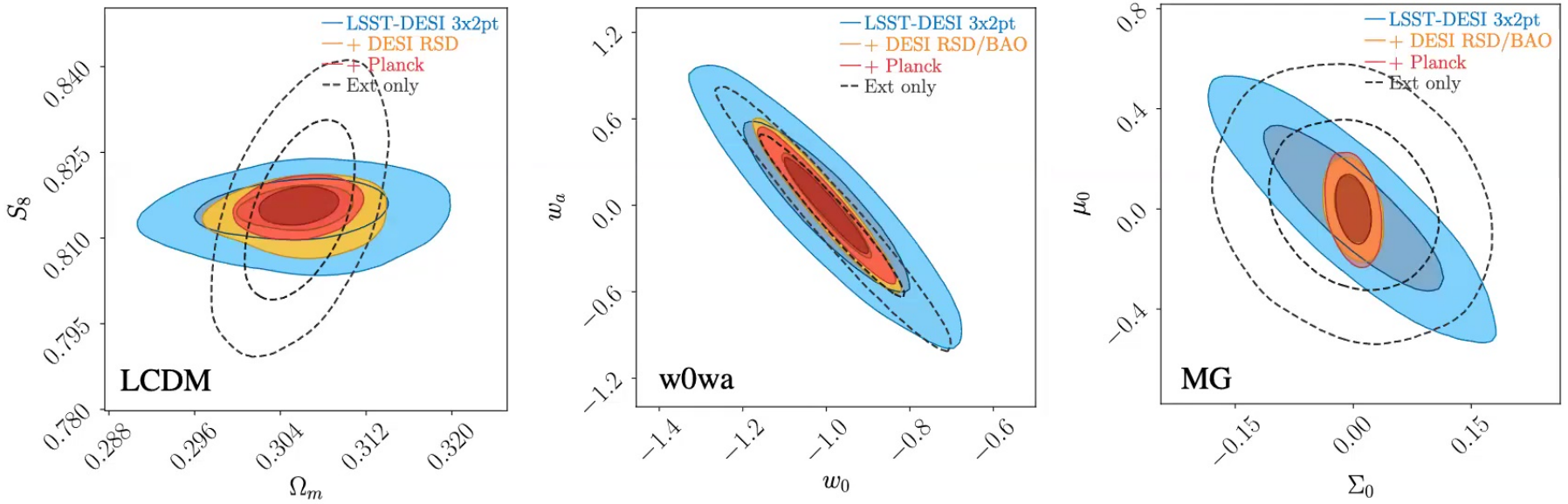
DESI

The optimal combining method in this work can be applied to future surveys having a limited overlap, such as DESI and LSST

Extension to the LSST-DESI Surveys

LSST-DESI 3x2pt + DESI BAO/RSD + Planck

Galaxy bias parameters in 3x2pt and BAO/RSD are shared!

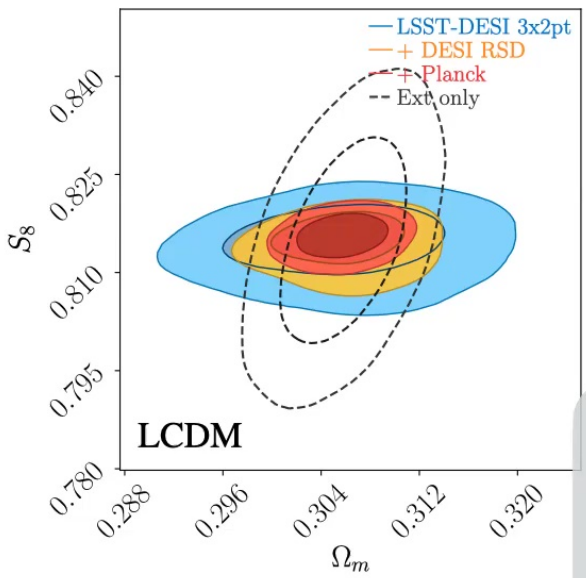


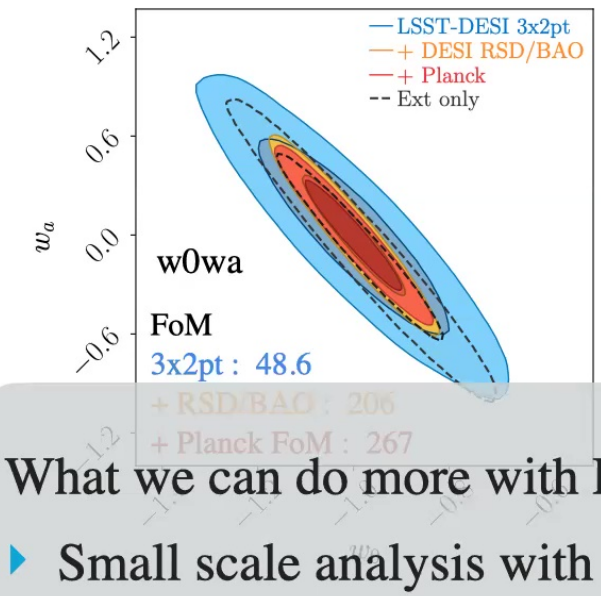
These are preliminary yet

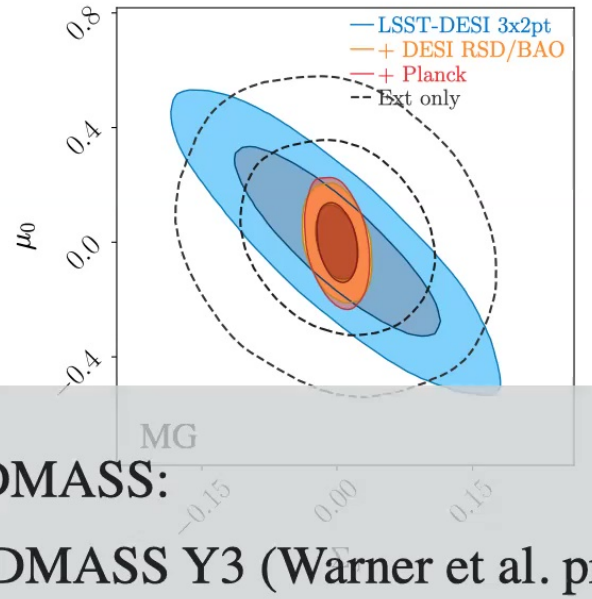
Extension to the LSST-DESI Surveys

LSST-DESI 3x2pt + DESI BAO/RSD + Planck

Galaxy bias parameters in 3x2pt and BAO/RSD are shared!







These are preliminary results

What we can do more with DMASS:

- Small scale analysis with DMASS Y3 (Warner et al. prep)
- DES-eBOSS (Lee et al. prep)

Summary and Take Away

- A color-based algorithm such as the DMASS algorithm can select spec-like galaxies in the photometric survey beyond the overlapping area, and can extract the full statistical power of the photometric survey
- Using DMASS with CMASS and sharing galaxy bias yields better results than using other lenses with an independent galaxy bias parameter (DMASS improves MG constraints by 29% for μ_0 and 21% for Σ_0 than redMaGiC).
- DESI and LSST are the perfect candidates for this combining method
- There are more rooms to improve. Stay tuned!