Cosmological Constraints from Galaxy-galaxy Lensing and Clustering with the Subaru HSC and SDSS BOSS Data

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Our Team

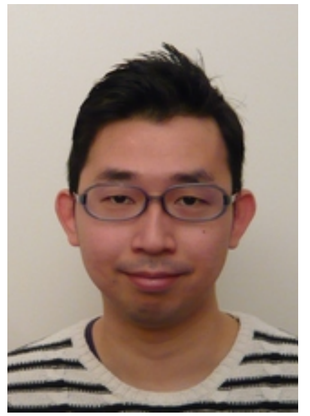
Nishimichi et al. (2019)
Shirasaki et al. (2019)
Miyatake et al. (2021)
Miyatake et al. (in prep.)


S. More


M. Oguri


H. Miyatake


M. Takada

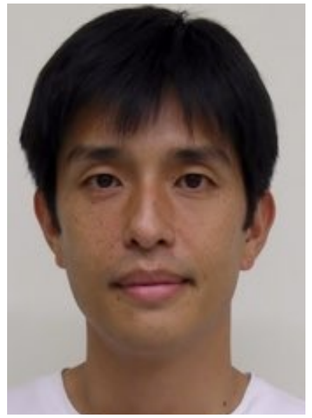

T. Nishimichi

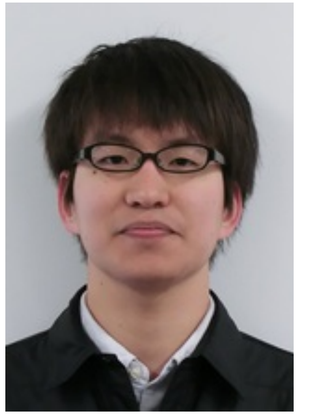

S. Sugiyama


R. Takahashi


K. Osato


M. Shirasaki

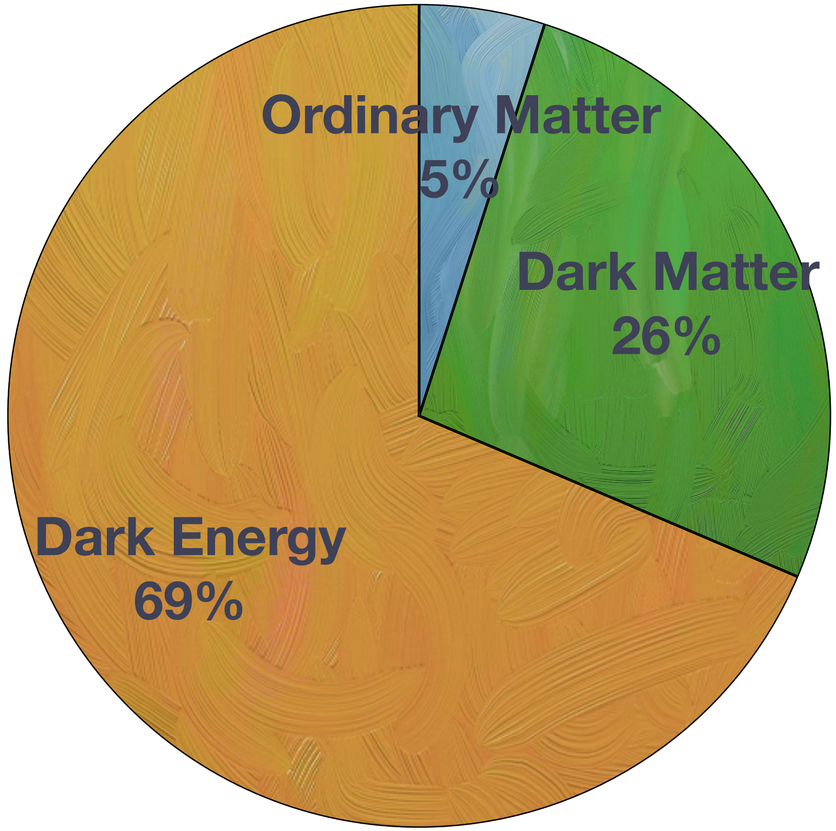

N. Yoshida


R. Murata


Y. Kobayashi

Dark Sector of the Universe

- Dark matter
  - Unknown matter, **invisible**
  - Source of gravity to form a galaxy
- Dark energy
  - Source of **cosmic acceleration**
  - Unknown energy, or **a new force**?
  - **Breakdown of General Relativity**?



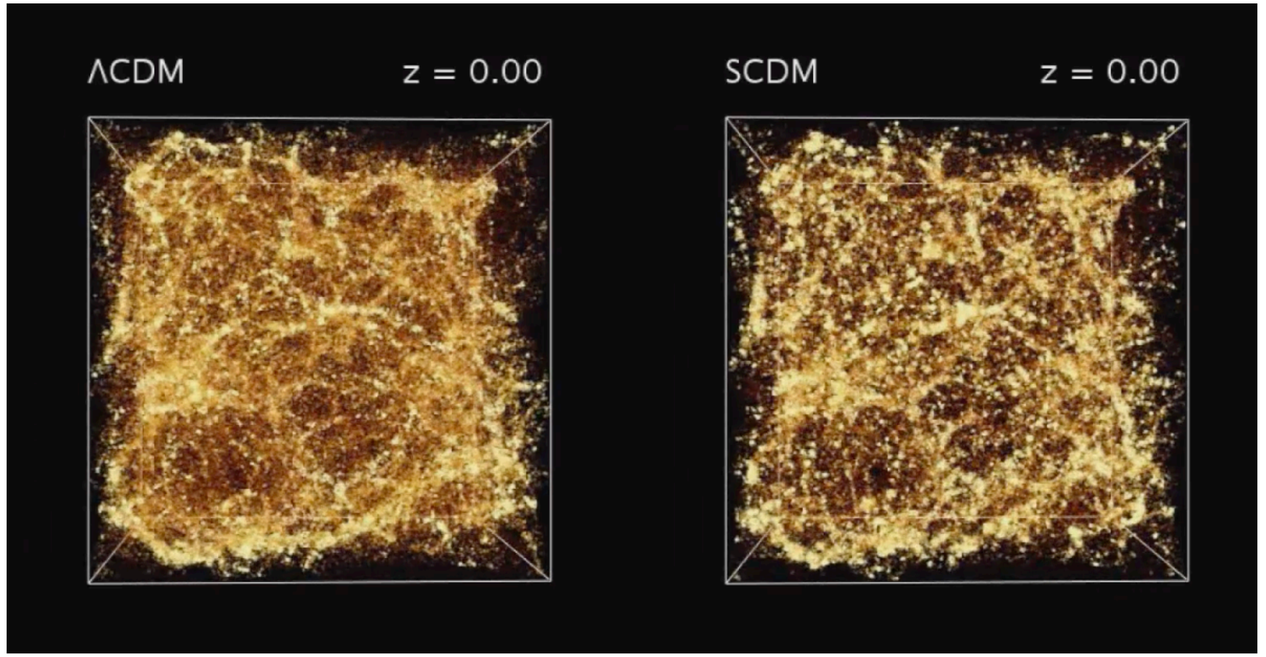
Revealing the origin of cosmic acceleration will be a breakthrough in modern physics and astronomy.

Planck Collaboration (2020)

Measurement of Cosmic Acceleration

w/ dark energy

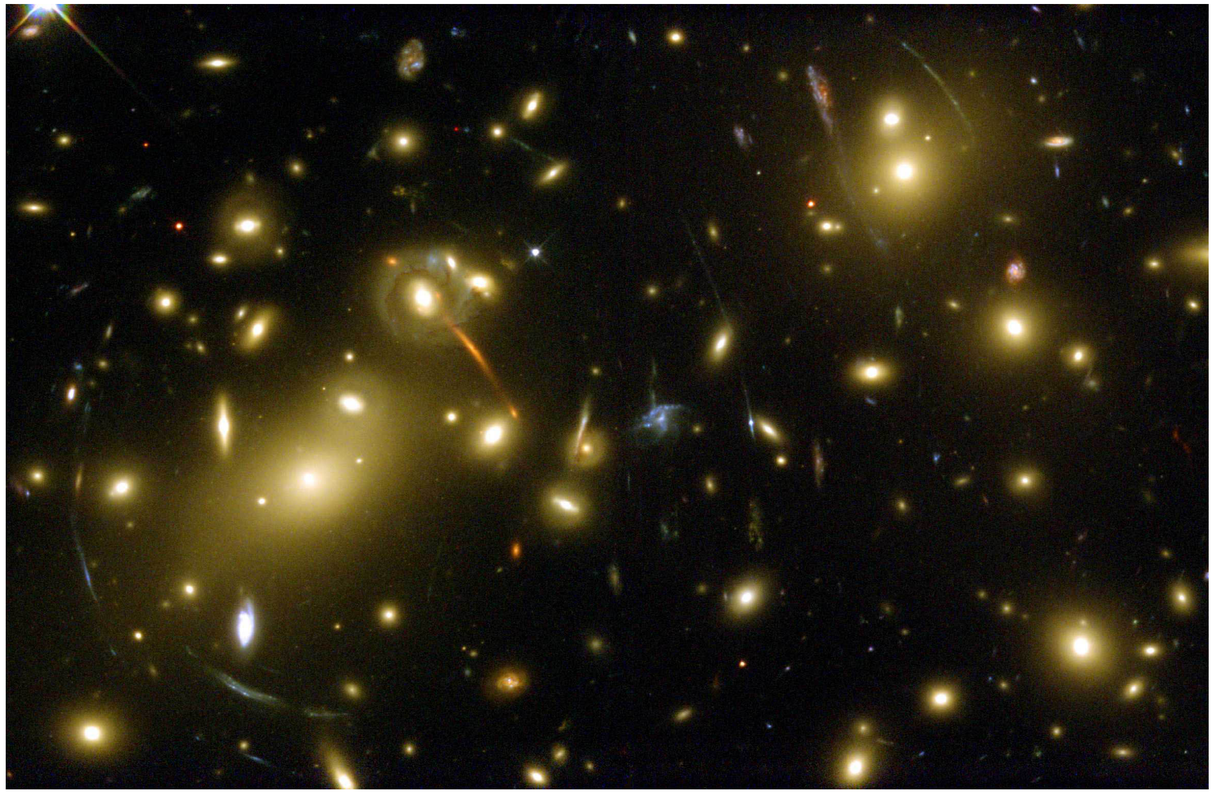
w/o dark energy

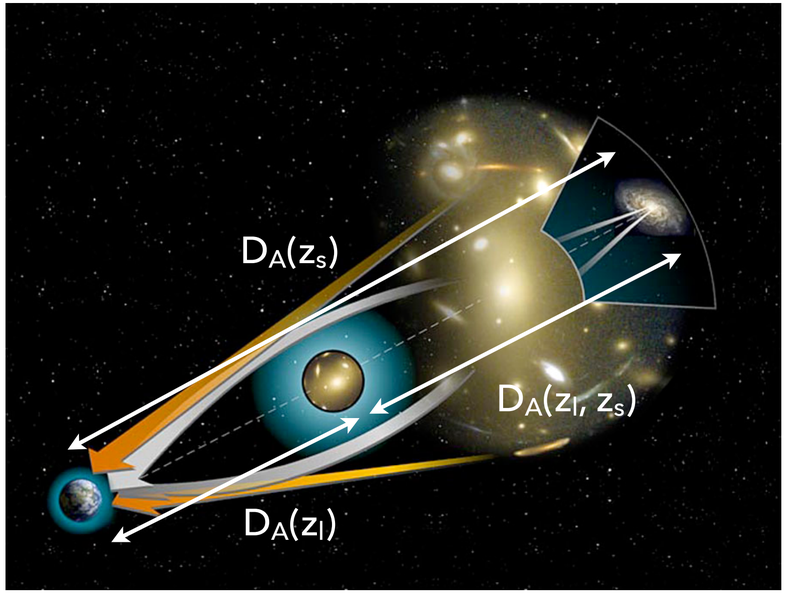


- **Large scale structure (LSS)** of the Universe is a powerful probe of cosmic acceleration.
- Difficulties: most of the matter is dark matter, but they are **invisible**!

Credit: ESA

Weak Gravitational Lensing



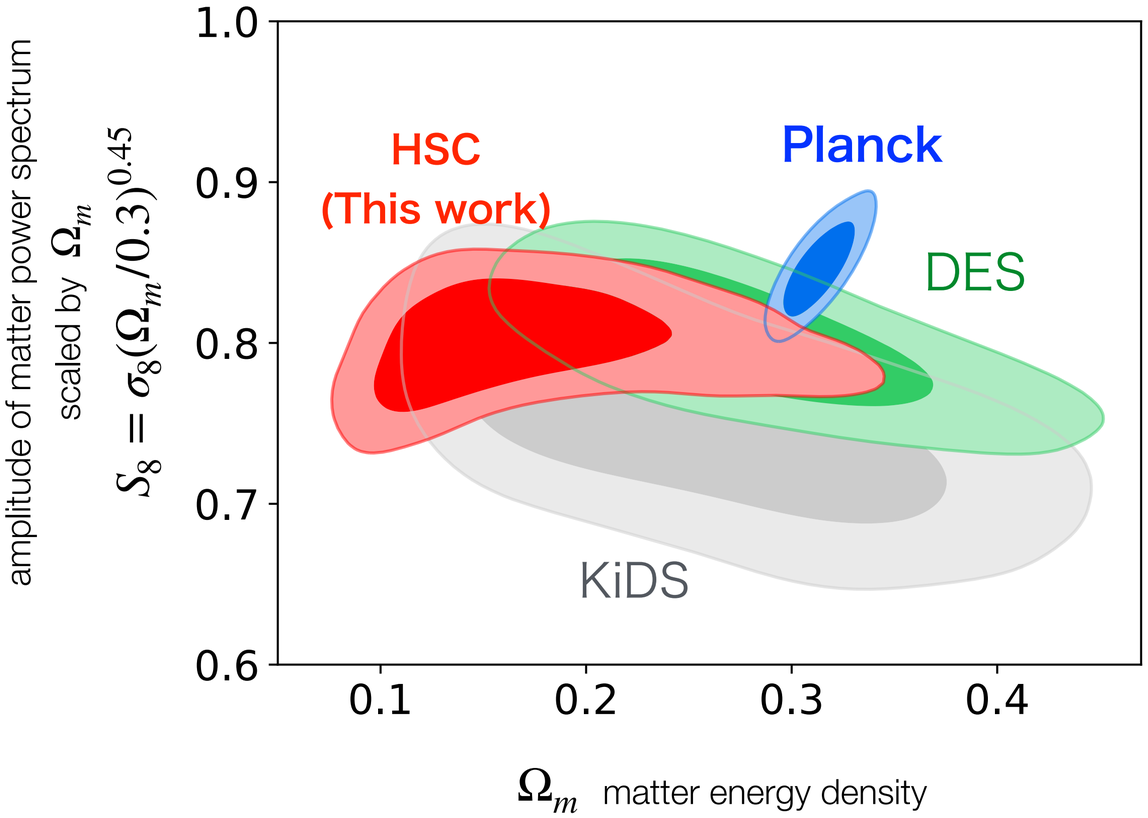


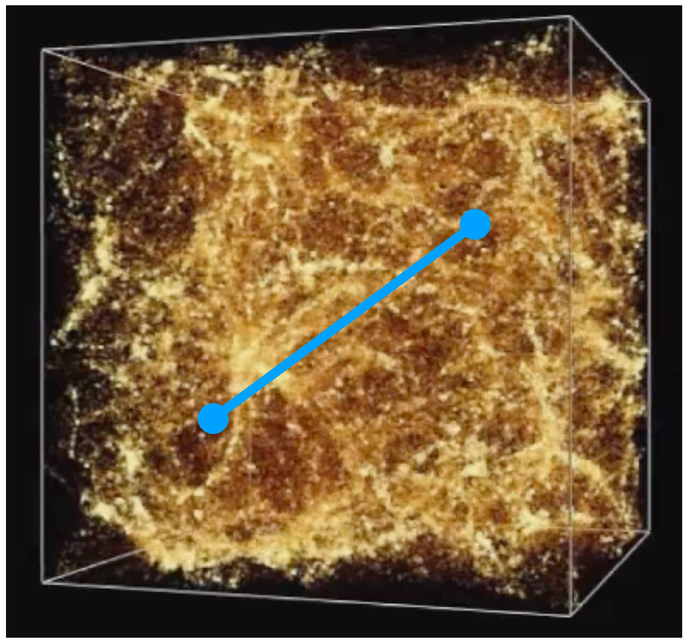
Weak Lensing Shear Density fluctuations in LSS

$$\gamma \propto \frac{D_A(z_l, z_s) D_A(z_l)}{D_A(z_s)} \delta(z_l)$$

Weak lensing (WL) enables us to measure dark matter distributions.

Cosmic Shear: First Cosmology Result from HSC





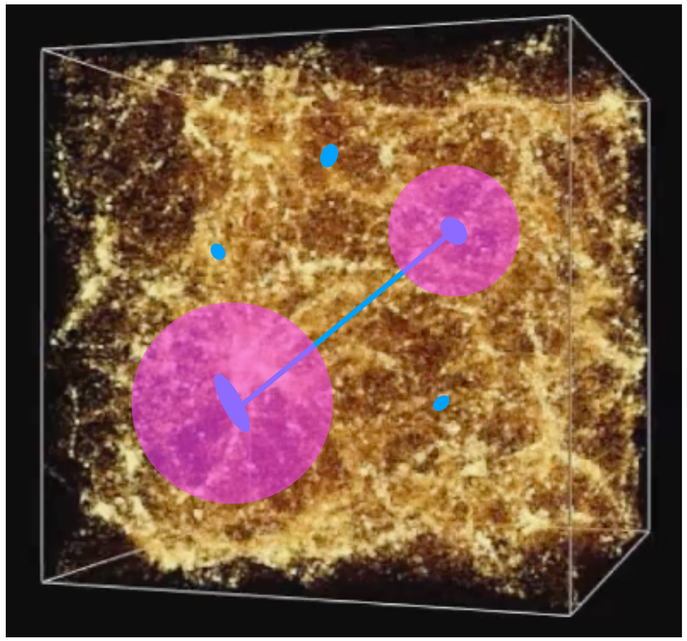
$$\langle \gamma\gamma \rangle \sim \langle \delta_m \delta_m \rangle$$

Hikage et al. (2019): PASJ Excellent Paper Award 2020

Hikage et al. (2019)
Hamana et al. (2020)

Galaxy-galaxy Lensing x Galaxy-galaxy Clustering

- Amplitude of galaxy-galaxy clustering $\xi_{gg} = \langle \delta_g \delta_g \rangle$ contains cosmological information.
- Galaxies are **biased tracers** of underlying dark matter.
- This bias can be calibrated by measuring dark matter distribution around galaxies using **weak lensing** $\xi_{gm} = \langle \delta_g \delta_m \rangle$.
- Robust against systematics in lensing measurement (shapes and photo-z) compared to cosmic shear.



Challenges: building a robust theoretical model
- Uncertainties in galaxy physics
- Dark matter halos → Non-linear regime

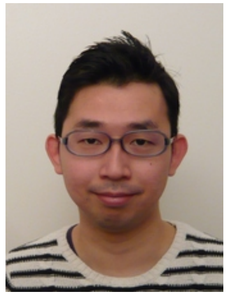
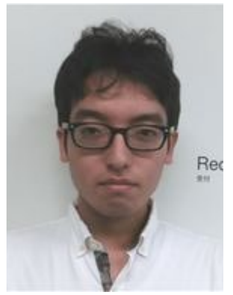
Clustering
$\xi_{gg} = \langle \delta_g \delta_g \rangle$

Lensing
$\xi_{gm} = \langle \delta_g \delta_m \rangle$

→ $\xi_{hh} = \langle \delta_h \delta_h \rangle$, $\xi_{hm} = \langle \delta_h \delta_m \rangle$ →

Cosmo. Params.
(Ω_m, σ_8)

Dark Emulator: Modeling accurate ξ_{hh} and ξ_{hm}

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Lensing
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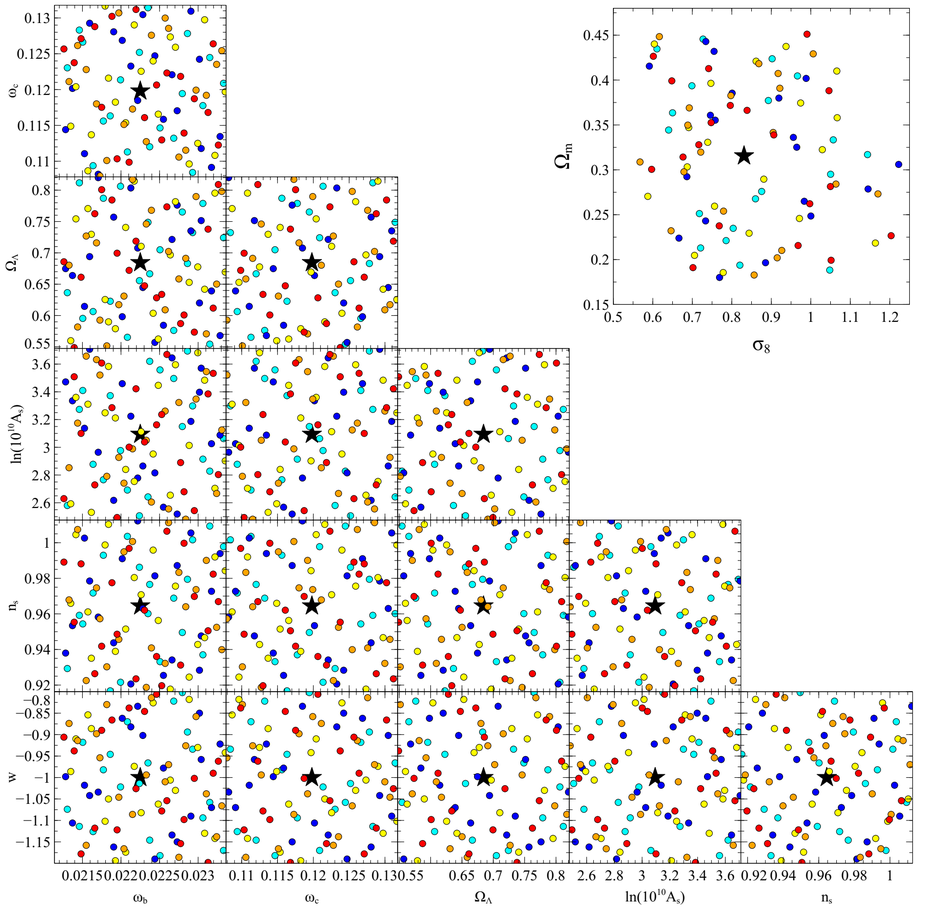
$\xi_{hm} = \langle \delta_h \delta_m \rangle$

Cosmo. Params.
(Ω_m, σ_8)

- Run N-body simulations under 101 sets of cosmological parameters.
  $\overrightarrow{C} = (\omega_b, \omega_c, \Omega_\Lambda, A_s, n_s, w)$
- Measure correlation functions, $\xi_{hh}(x; \overrightarrow{C})$ and $\xi_{hm}(x; \overrightarrow{C})$.
- Interpolate correlation functions across the cosmological parameter sets using a Gaussian process.
- Achieved an accuracy better than 2%.



Nishimichi et al. (2019)

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Marginalize Uncertainties in Galaxy Physics

Modeling Galaxy-halo Connection

Clustering

$\xi_{gg} = \langle \delta_g \delta_g \rangle$ $\xi_{hh} = \langle \delta_h \delta_h \rangle$

Lensing

$\xi_{gm} = \langle \delta_g \delta_m \rangle$ $\xi_{hm} = \langle \delta_h \delta_m \rangle$

Cosmo. Params.

(Ω_m, σ_8)

Use **analytical** Halo Occupation Distribution (HOD) model and **marginalize** galaxy physics uncertainties

Cosmology Challenge

Galaxy Properties with Variants
- Different galaxy-halo connection
- Baryonic Effects
- Assembly Bias
- Incompleteness

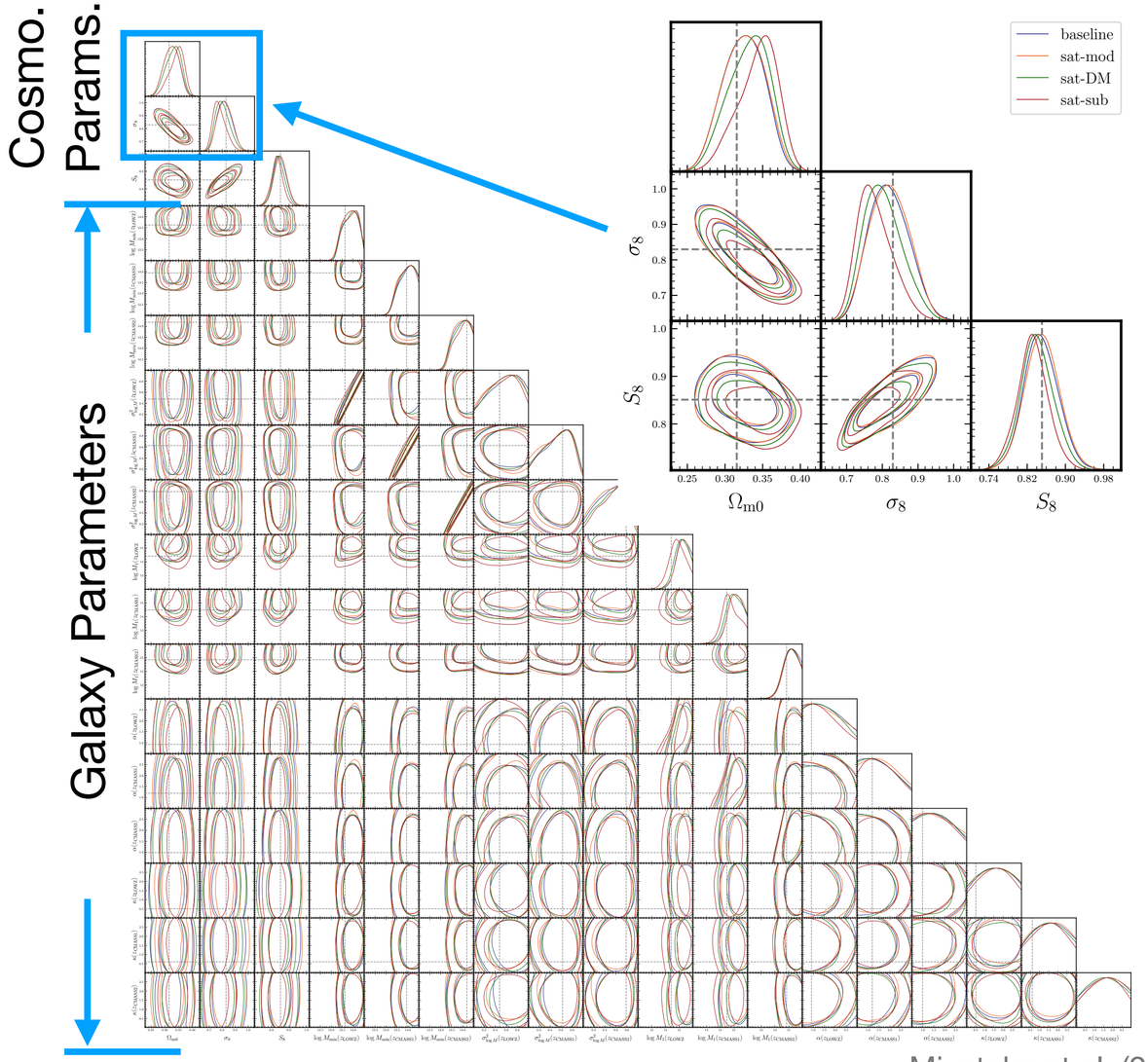
Mock Signals

Fit

Model + Y1 Covariance

Input Cosmo. Params

Output Cosmo. Params



Miyatake et al. (2021)

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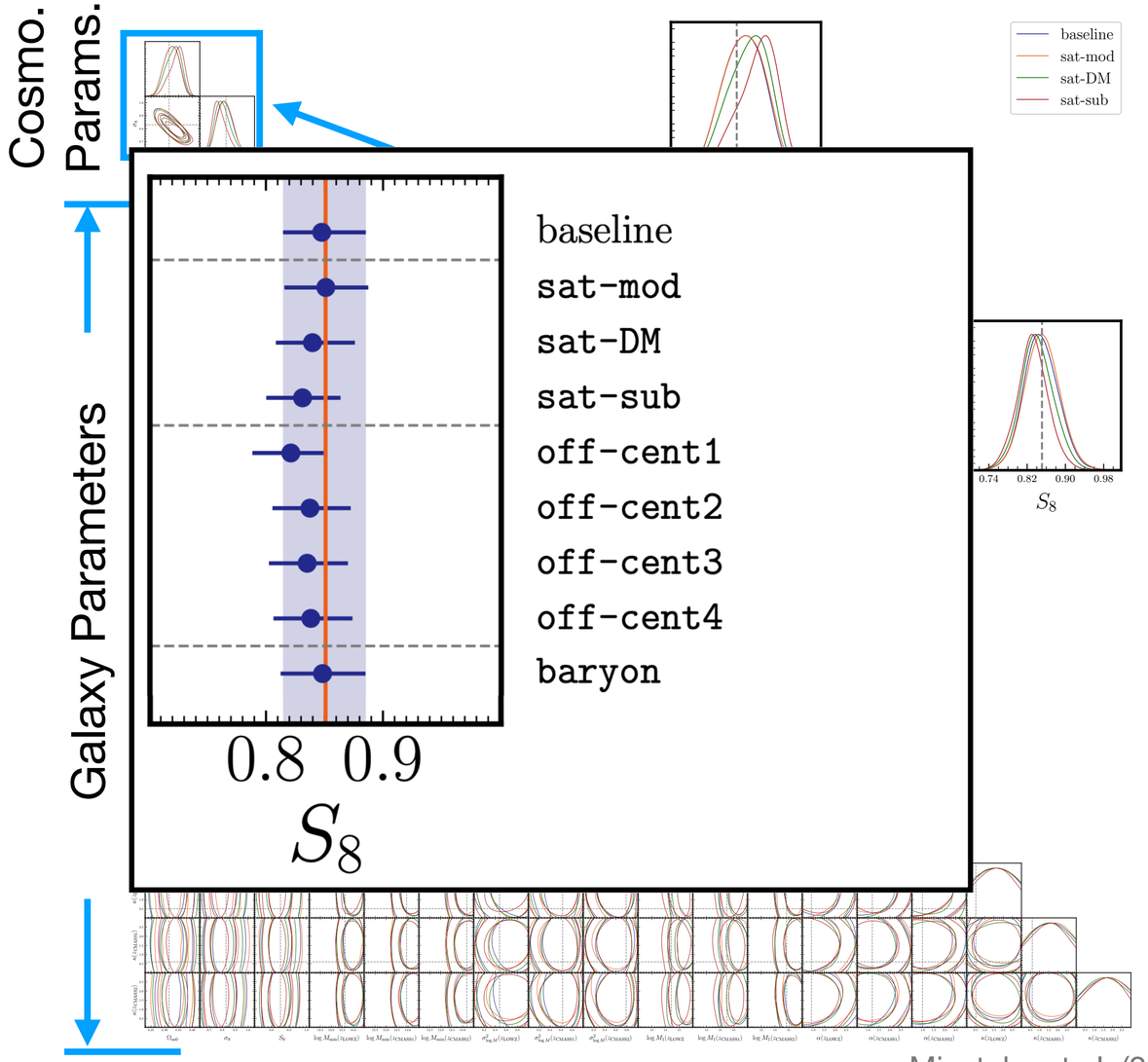
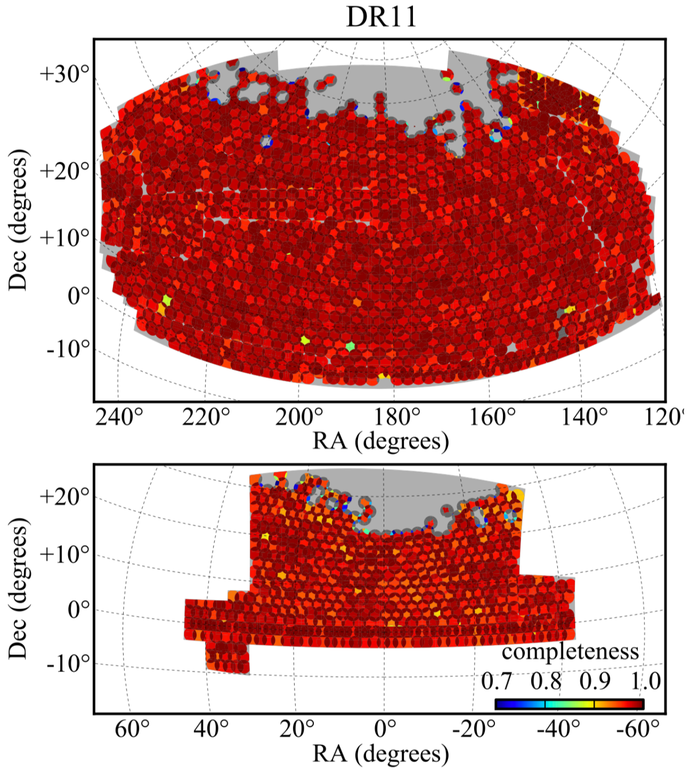


Miyatake et al. (2021)

HSC x BOSS Measurement

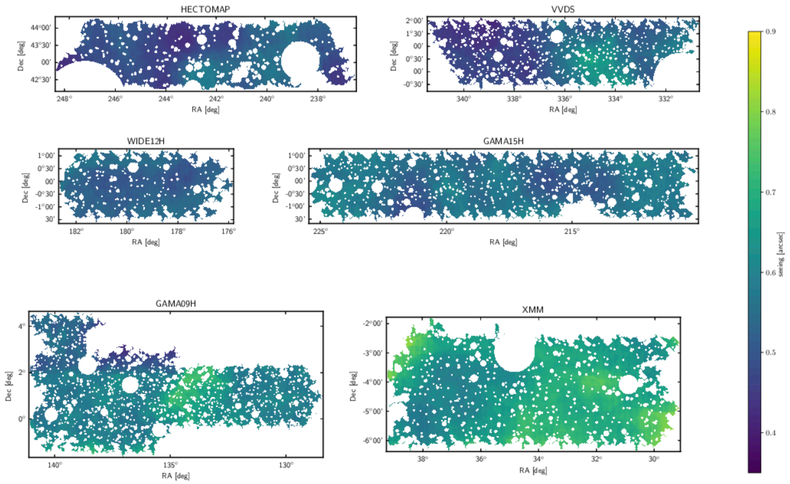
SDSS-III/BOSS spec-z sample

- Area ~ 8300 deg^2
- z = [0.15, 0.35], [0.47, 0.55], [0.55, 0.70]
- Luminosity cut is applied to obtain volume-limited sample.



HSC first-year shape catalog

- Area ~ 137 deg^2 in total
- <z>~1.0.
- Galaxy shapes are blinded.



g-g lensing signal

g-g clustering signal

Miyatake et al. (In prep)

Summary

- Combination of galaxy-galaxy lensing and clustering is a powerful probe of cosmology.
- We have built a robust model with
  - Dark Emulator for halo statistics
  - Analytical HOD to marginalize uncertainties in galaxy physics.
- We are currently analyzing BOSS and HSC first-year data.
  - Systematic tests are almost done for blinded analysis
  - Unblinding is close!
- The next shape catalog (~450 deg^2) is awaiting us!