Cosmological constraints from galaxy-galaxy lensing and galaxy clustering with HSC-Y1 and BOSS data

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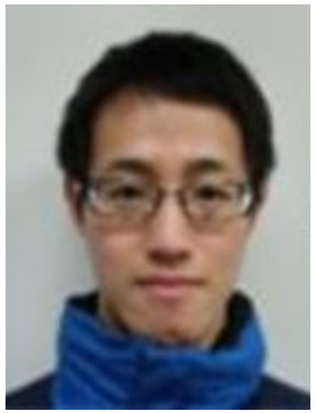
on behalf of HSC collaboration

Credit: NAOJ/HSC Project

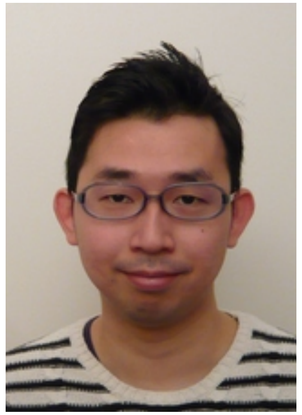
Our Team

Nishimichi et al. (2019)
Shirasaki et al. (2019)
Sugiyama et al. (2020)
Sugiyama et al. (2021)
Miyatake et al. (2020)
Miyatake et al. (2021)


H. Miyatake


S. Sugiyama


M. Takada


T. Nishimichi


M. Shirasaki


Y. Kobayashi


R. Mandelbaum


S. More


M. Oguri

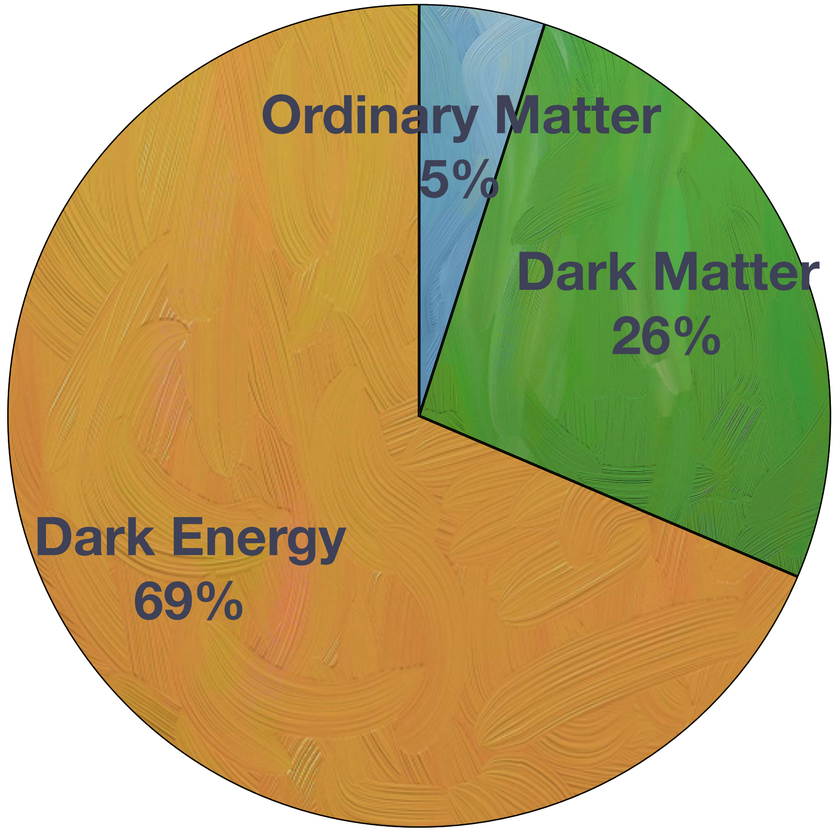

K. Osato


Y. Park


R. Takahashi

Dark Sector of the Universe

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



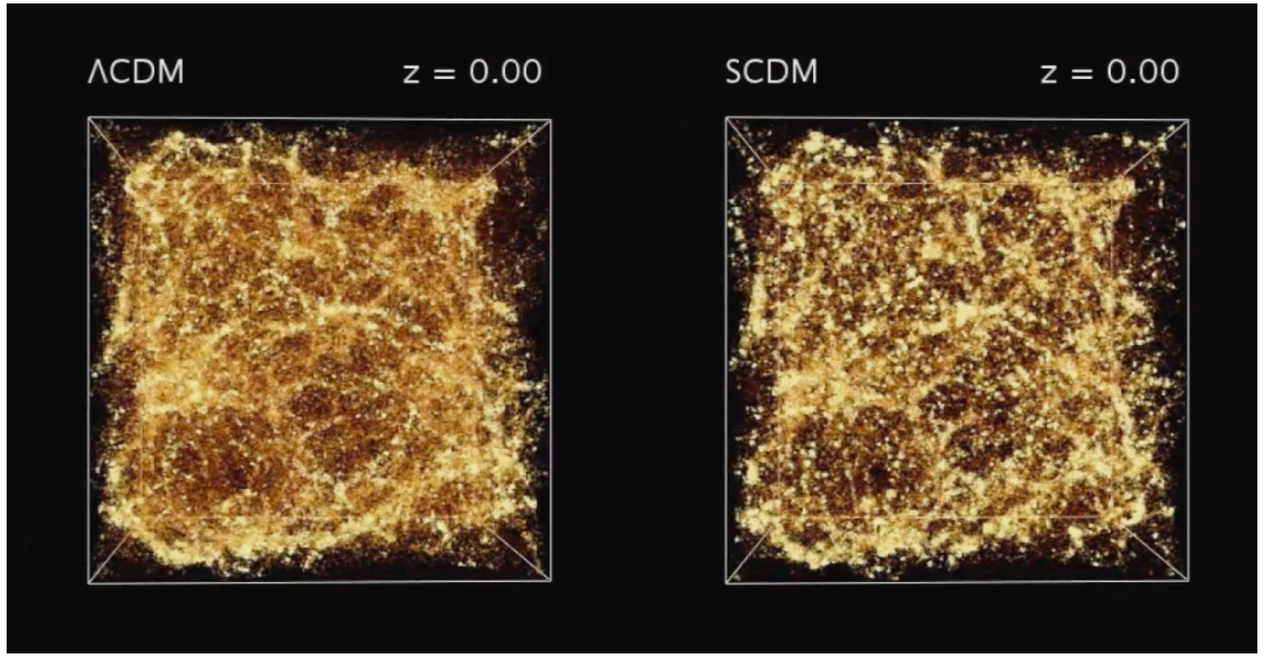
Revealing the origin of cosmic acceleration will be a breakthrough in modern physics and astronomy.

Planck Collaboration (2020)

Measurement of Cosmic Acceleration

w/ dark energy

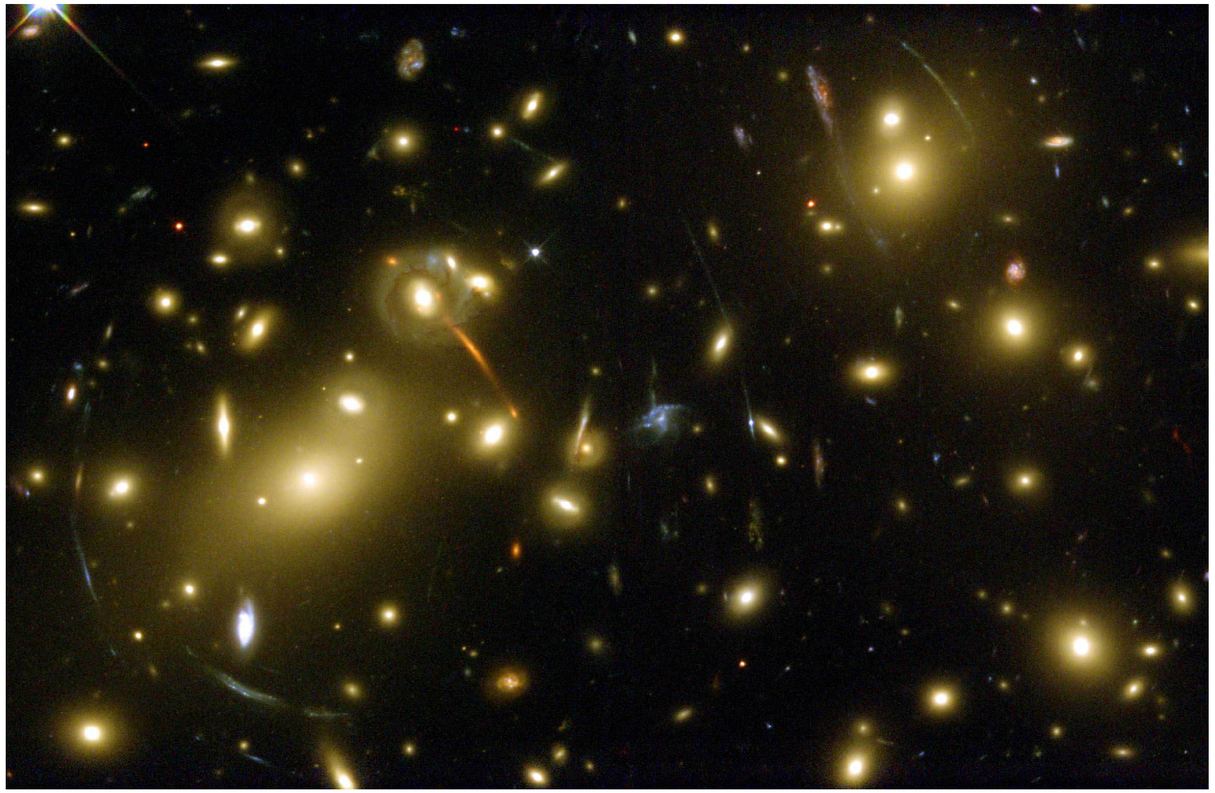
w/o dark energy

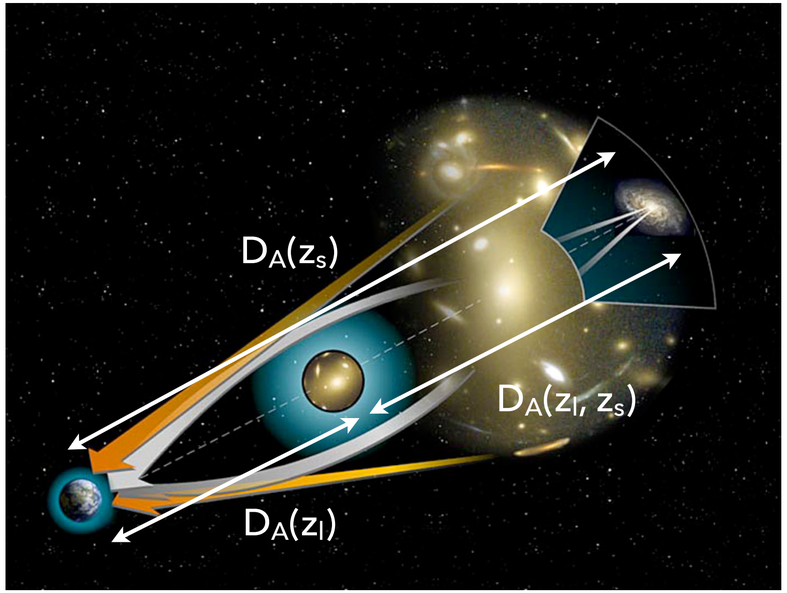


- **Large scale structure (LSS)** of the Universe is a powerful probe of cosmic acceleration.
- Difficulties: most of the matter is dark matter, but they are **invisible**!

Credit: ESA

Weak Gravitational Lensing



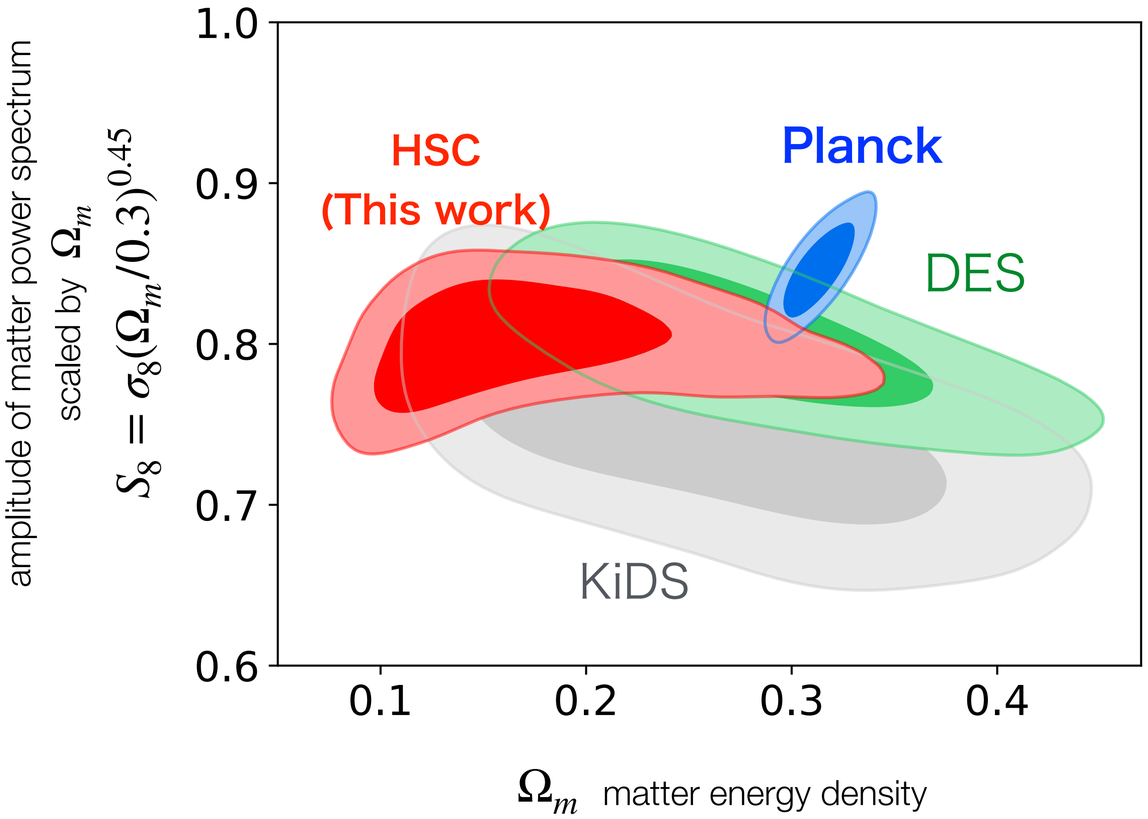


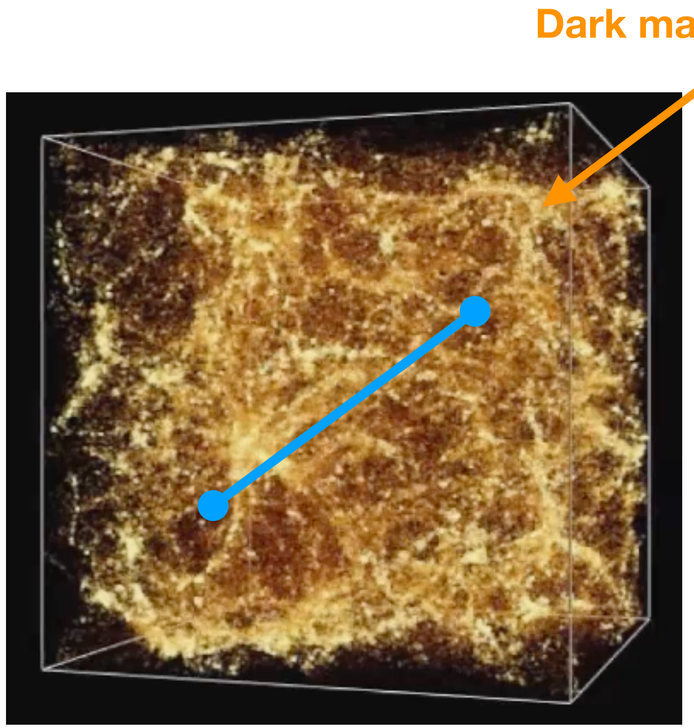
Weak Lensing Shear Density fluctuations in LSS

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

Weak lensing enables us to measure dark matter distributions.

Cosmic Shear: First Cosmology Result from HSC





$$\langle \gamma\gamma \rangle \sim \langle \delta_{\rm m}\delta_{\rm m} \rangle \equiv \xi_{\rm mm}$$

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

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

Galaxy-galaxy Lensing x Galaxy-galaxy Clustering

Galaxy-galaxy clustering

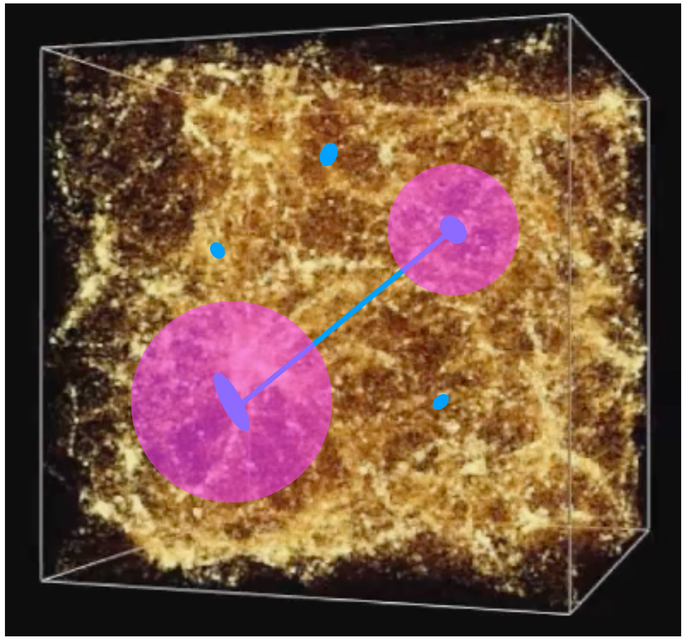
$$\xi_{\rm gg} = \langle \delta_{\rm g} \delta_{\rm g} \rangle \sim b^2 \langle \delta_{\rm m} \delta_{\rm m} \rangle = b^2 \xi_{\rm mm}$$

$\delta_{\rm g} \sim b \delta_{\rm m}$ at large scales

Galaxy-galaxy lensing

$$\xi_{\rm gm} = \langle \delta_{\rm g} \delta_{\rm m} \rangle \sim b \langle \delta_{\rm m} \delta_{\rm m} \rangle = b \xi_{\rm mm}$$

$\xi_{\rm mm}$

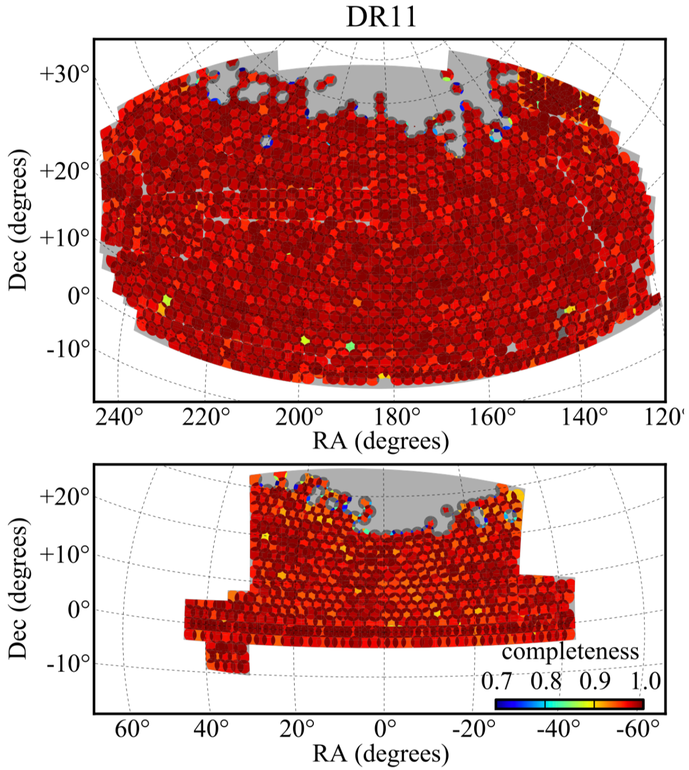


Robust against systematics in lensing measurement (shapes and photo-z) compared to cosmic shear.

HSC x BOSS Measurement

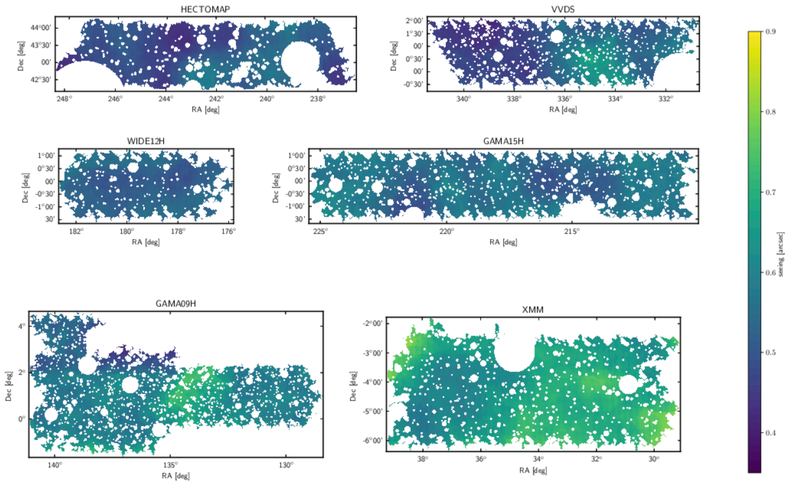
SDSS-III/BOSS spec-z sample

- 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 SSP first-year shape catalog

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



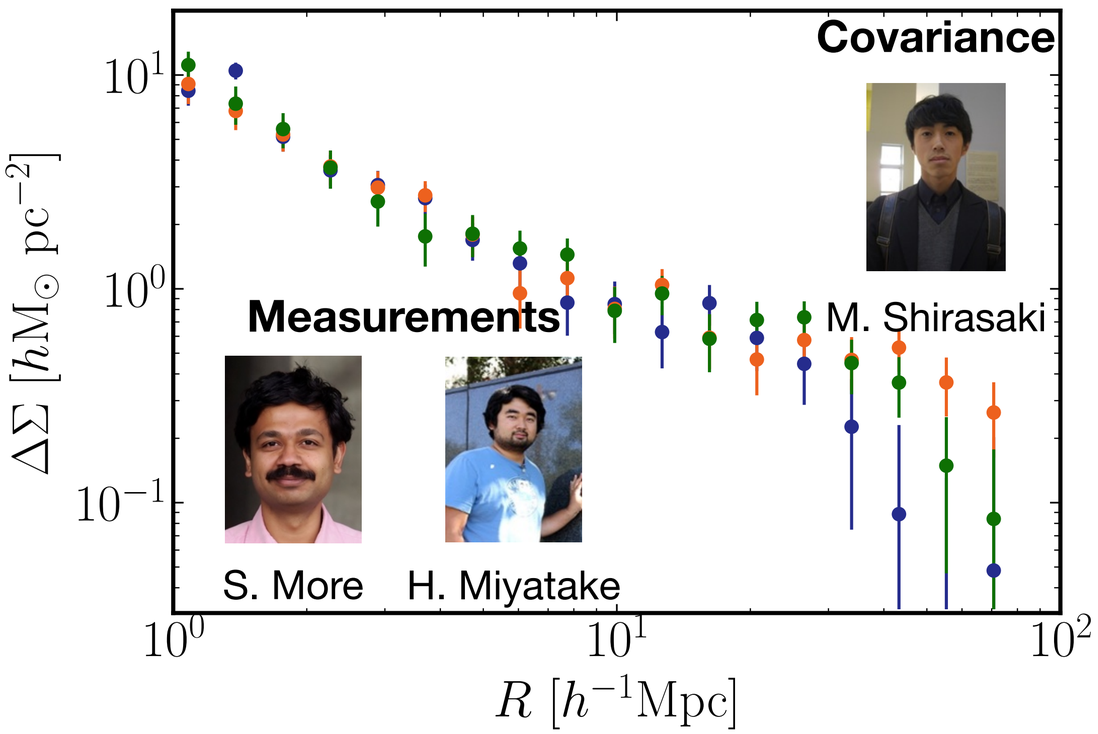
g-g lensing signal

g-g clustering signal

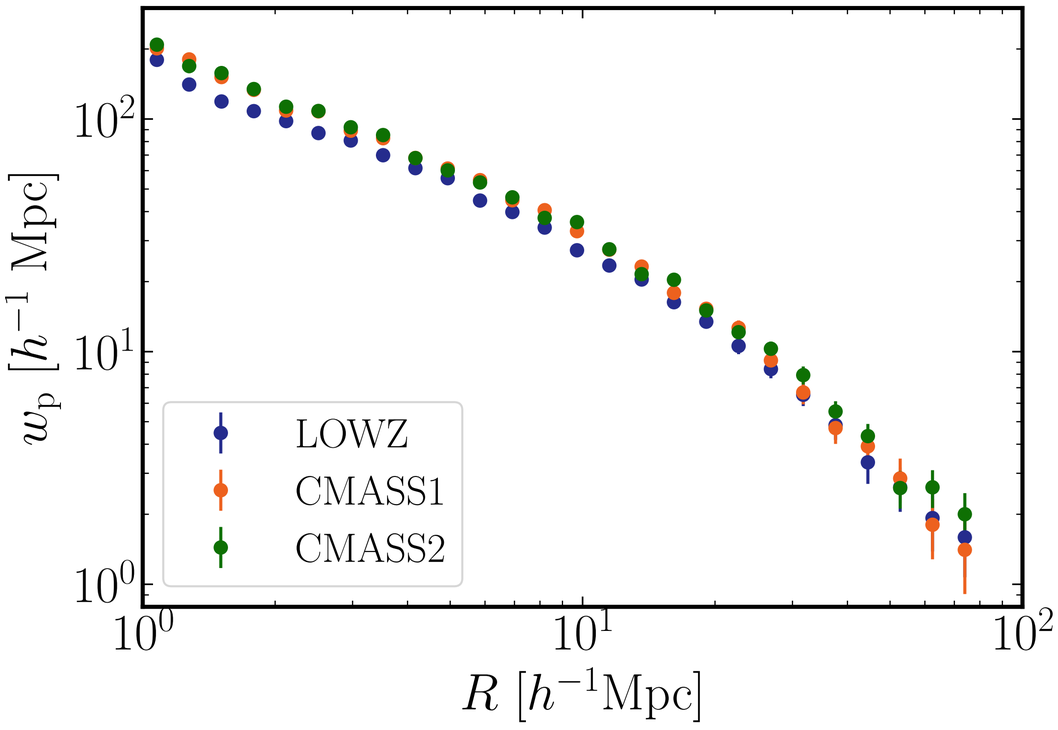
Miyatake et al. (In prep)

G-g lensing and clustering measurements by HSC-Y1 and BOSS

Galaxy-galaxy lensing

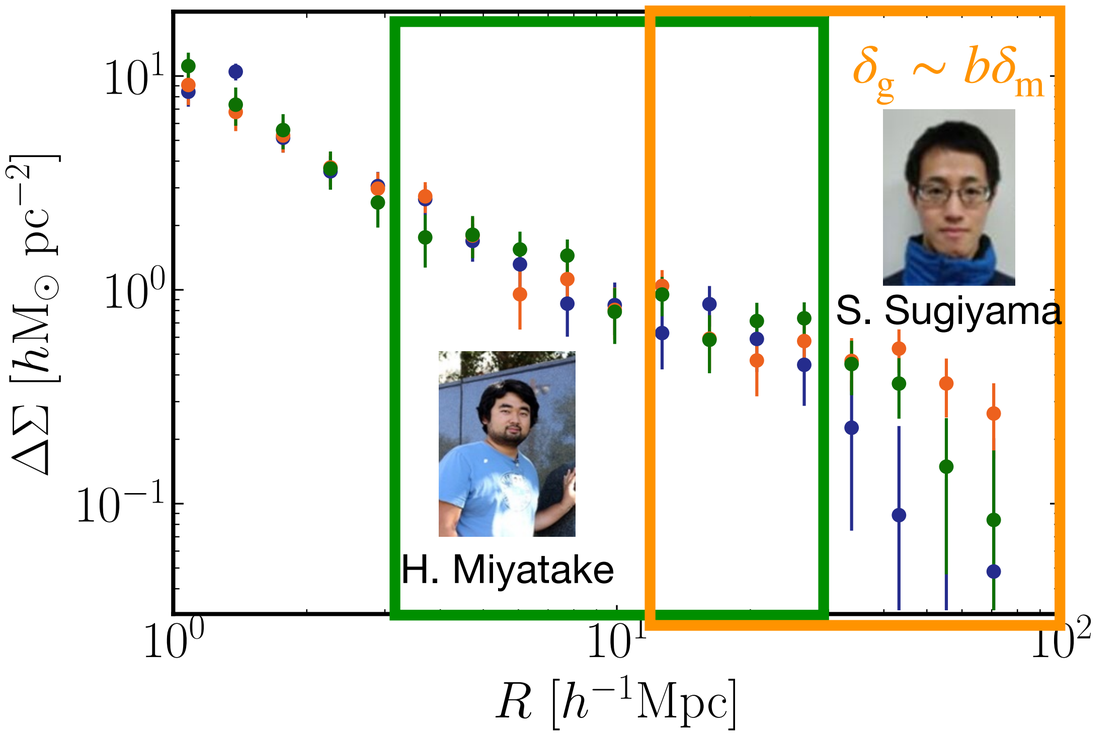


Galaxy-galaxy clustering

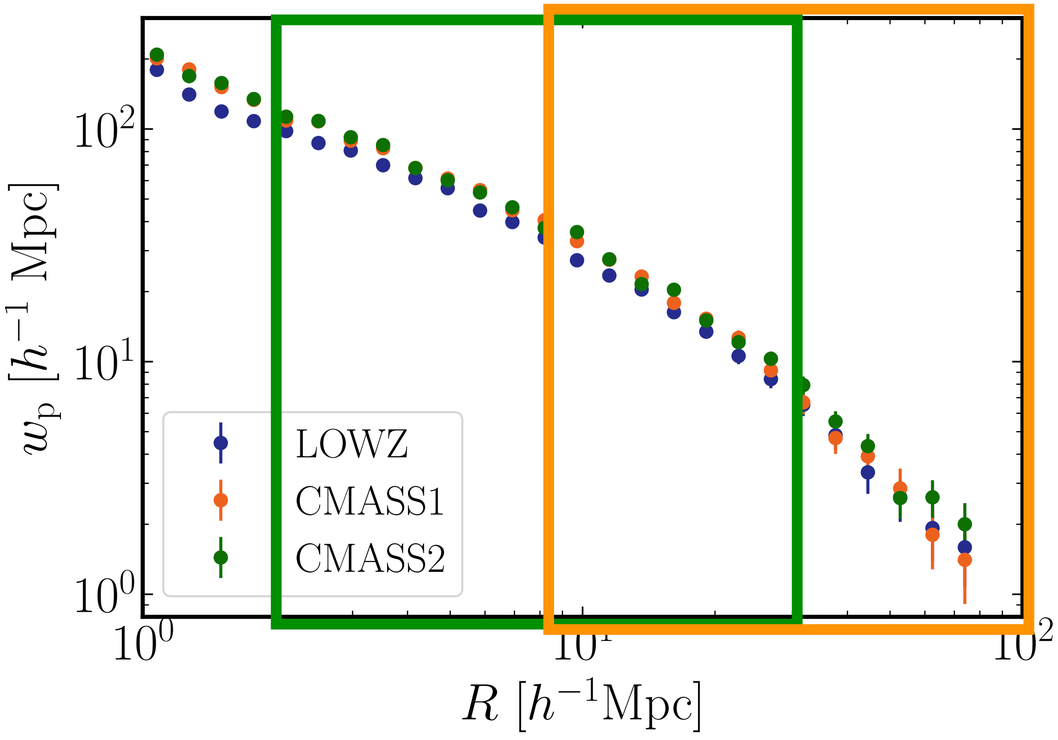


G-g lensing and clustering measurements by HSC-Y1 and BOSS

Galaxy-galaxy lensing



Galaxy-galaxy clustering

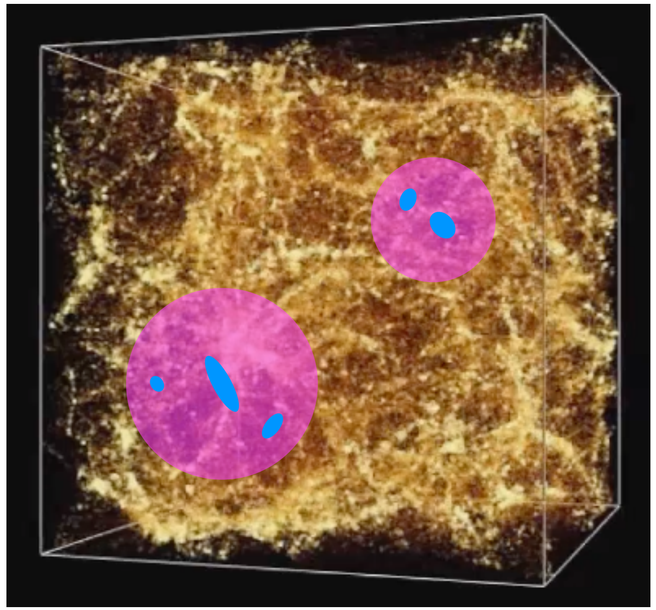


Large scale analysis (Sugiyama et al., 2021): Less modeling systematics, less signal-to-noise

Small scale analysis (Miyatake et al., 2021): Challenges in modeling, more signal-to-noise

Credit: ESA

Modeling small-scale signals



dark matter

dark matter halos

galaxies

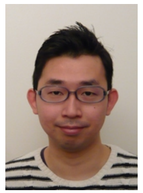
Challenges

- Accurate modeling of non-linear regimes
- Proper treatment of uncertainties in galaxy-halo connection

Cosmo. Params.
$(\sigma_8, \Omega_{\rm m}, \dots)$

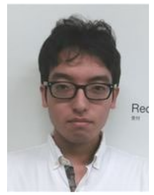
$$\xi_{\rm hh} = \langle \delta_{\rm h} \delta_{\rm h} \rangle$$
$$\xi_{\rm hm} = \langle \delta_{\rm h} \delta_{\rm m} \rangle$$

$$\xi_{\rm gg} = \langle \delta_{\rm g} \delta_{\rm g} \rangle$$
$$\xi_{\rm gm} = \langle \delta_{\rm g} \delta_{\rm m} \rangle$$



T. Nishimichi

H. Miyatake



Y. Kobayashi

Modeling non-linear regimes
Prediction by **AI-accelerated cosmic emulator (Dark Emulator)** achieved a few % accuracy

Nishimichi et al. (2019)

Uncertainties between galaxy-halo connection
Analytical convolution of phenomenological model enables us to marginalize unknown galaxy physics.

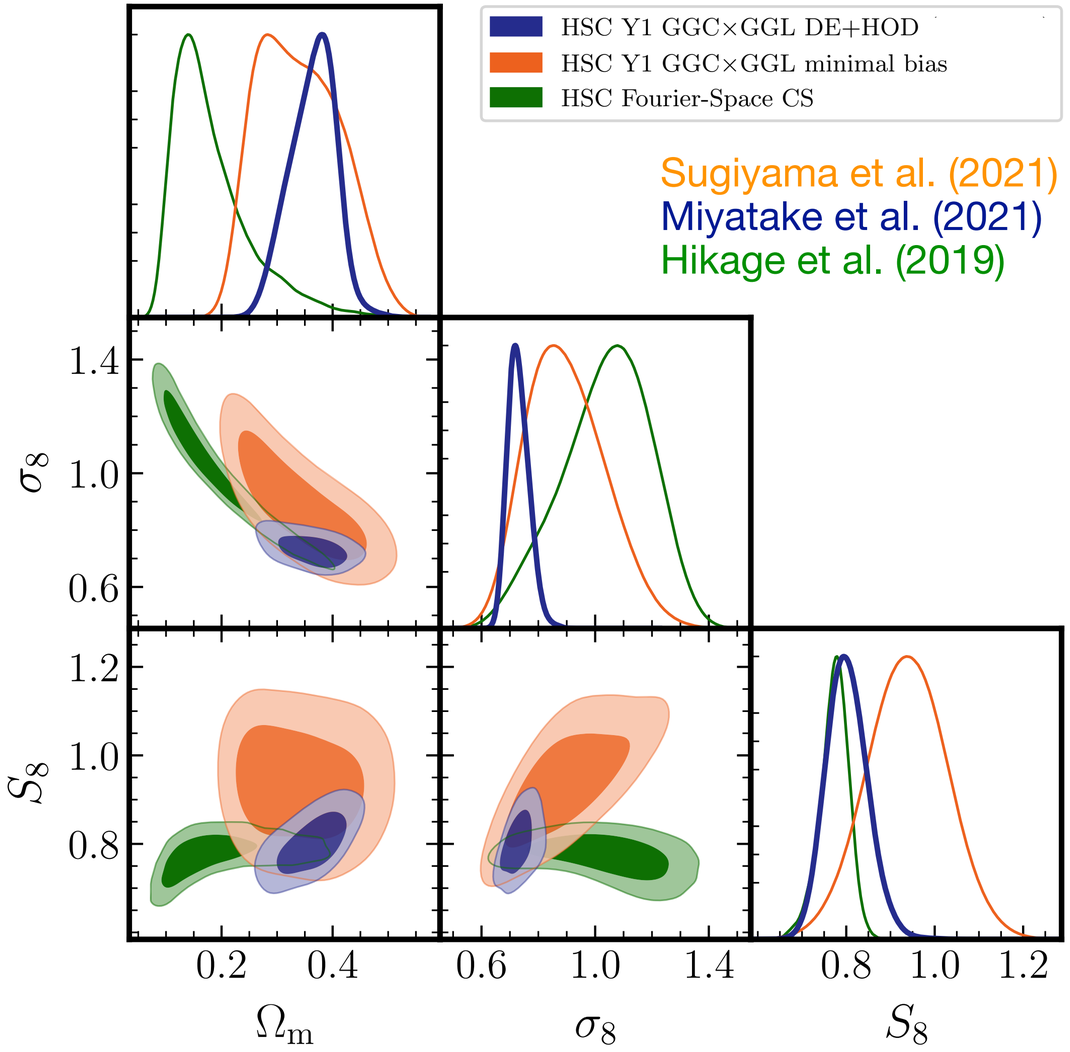
Miyatake et al. (2020)

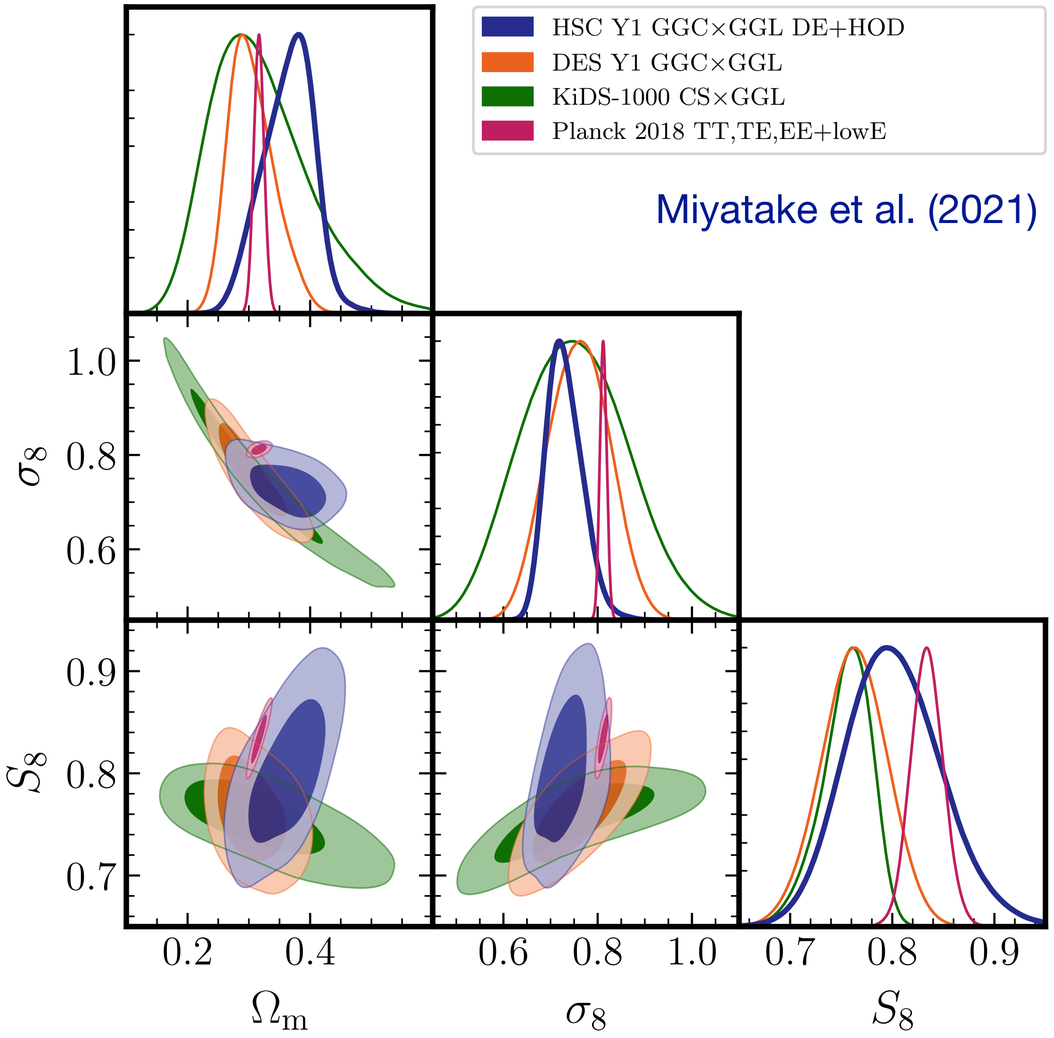
This work is supported by JST AIP Acceleration Research Grant Number JP20317829, Japan.

Analysis Procedure

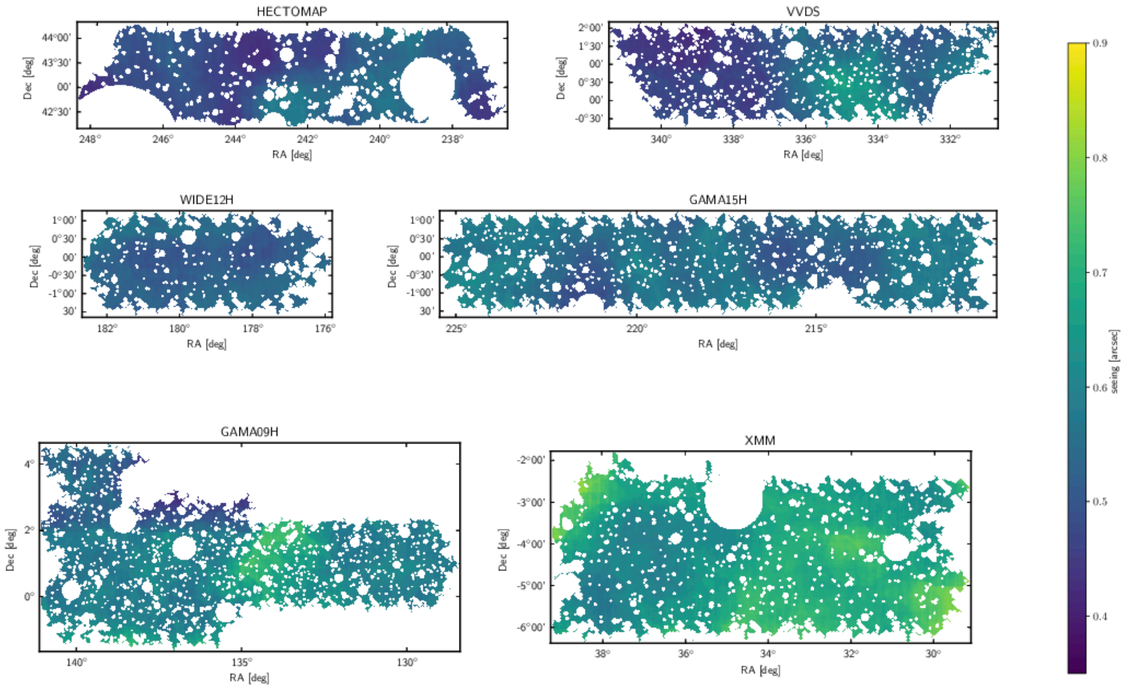
- Tests with mock catalogs
  - Both large-scale and small-scale models are tested against mock catalogs with variants in galaxy properties. We confirmed the cosmological parameters are safely recovered (Sugiyama et al., 2020; Miyatake et al., 2020).
- Blind analysis
  - To avoid confirmation bias, we blinded lensing signal and cosmological constraints. We unblinded the results after systematic uncertainty checks are done.
- Systematic uncertainty checks
  - We checked the robustness of cosmological constraints against theoretical and observational systematic uncertainties.

Results

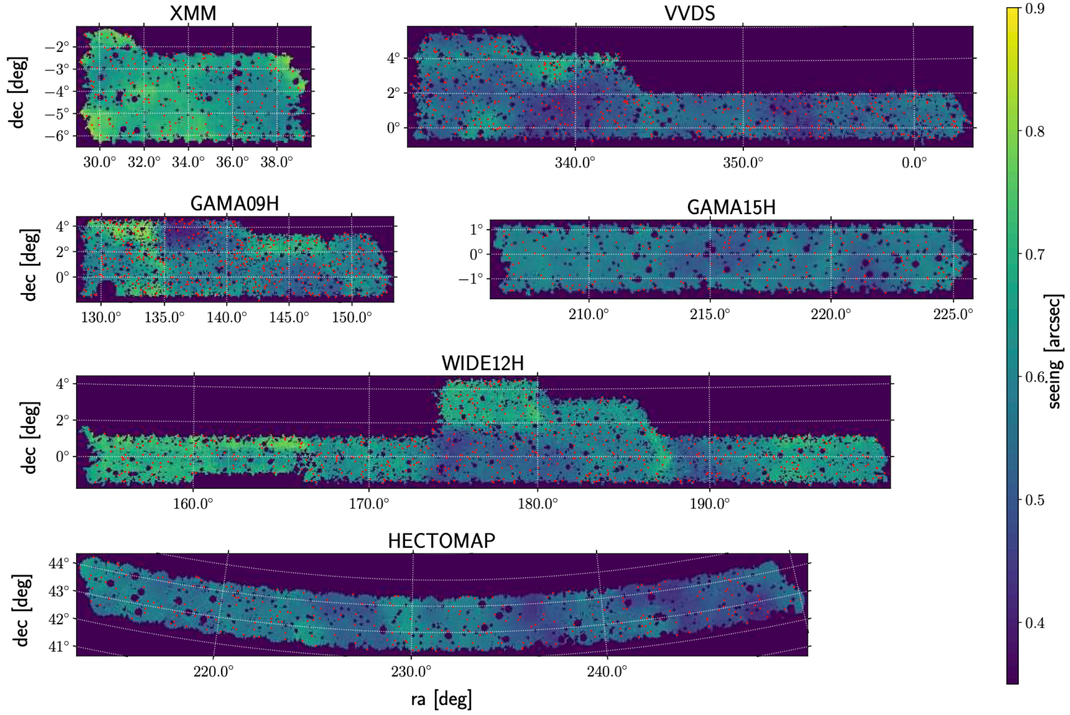

HSC Y1 GGC×GGL DE+HOD
HSC Y1 GGC×GGL minimal bias
HSC Fourier-Space CS
Sugiyama et al. (2021)
Miyatake et al. (2021)
Hikage et al. (2019)
σ_8
S_8
Ω_m
σ_8
S_8


HSC Y1 GGC×GGL DE+HOD
DES Y1 GGC×GGL
KiDS-1000 CS×GGL
Planck 2018 TT,TE,EE+lowE
Miyatake et al. (2021)
σ_8
S_8
Ω_m
σ_8
S_8

Towards HSC Y-3 analyses



Mandelbaum, HM, et al. (2018)



Li, HM, et al. (2021)

We have built shear catalog with 3x area of Y1 data.

Summary

- The combination of galaxy-galaxy lensing and clustering measurements is one of the powerful cosmological probes.
- We measured galaxy-galaxy lensing and clustering signals using the HSC-Y1 and BOSS data.
- We performed large-scale and small-scale analysis.
  - For the small-scale analysis, we used dark emulator for accurate modeling and non-linear regime and marginalized uncertain galaxy physics.
- We obtained cosmological constraints consistent within HSC and with other weak lensing surveys.
- We are now analyzing the HSC-Y3 data (~450 deg^2).