The sigma8 tension in light of the cross-correlation between HSC weak lensing and ACT thermal Sunyaev-Zel'dovich effect

Feb 9, 2024

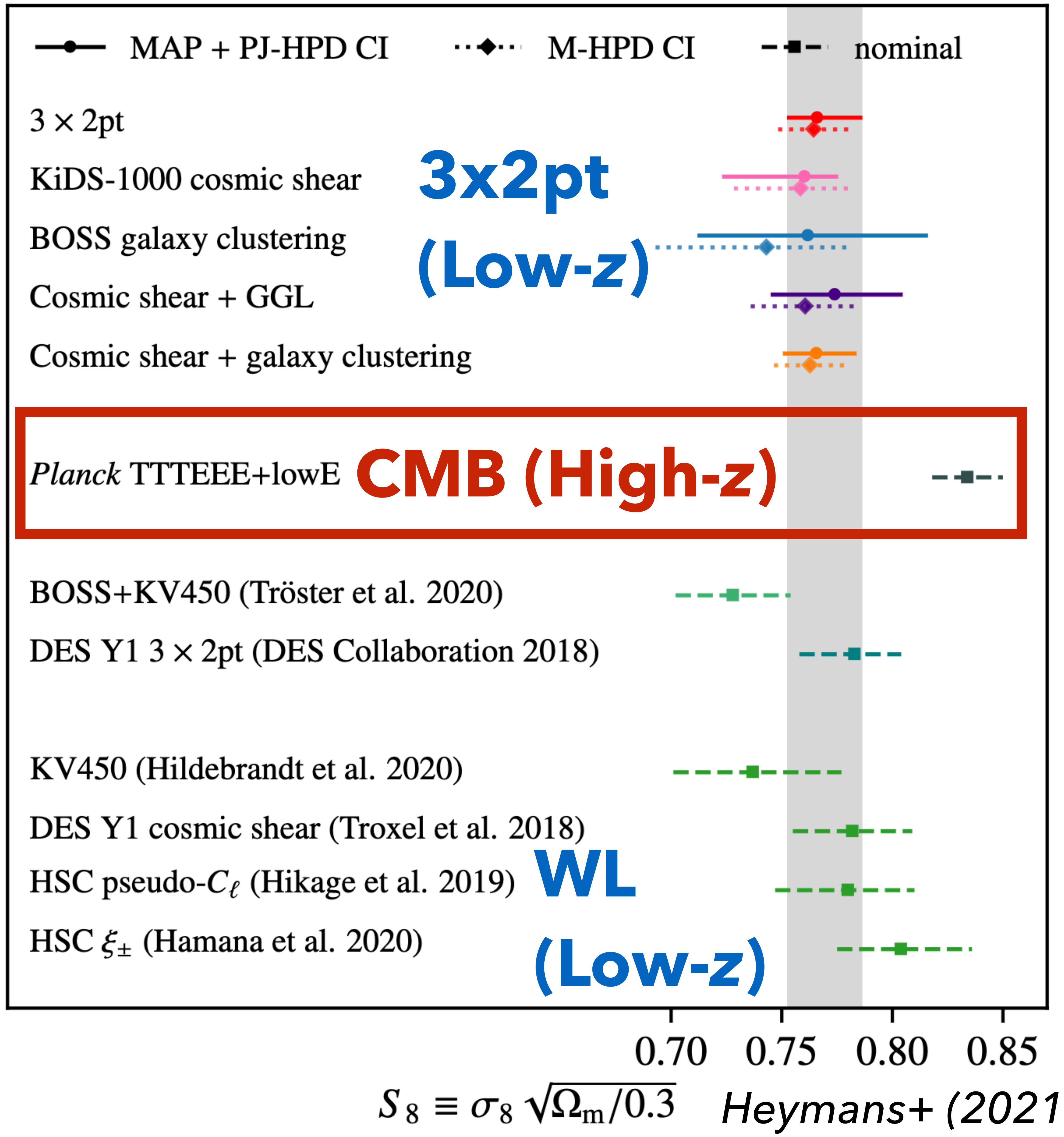
Gravity and Cosmology 2024 @ YITP, Kyoto

Ken Osato (Chiba University)

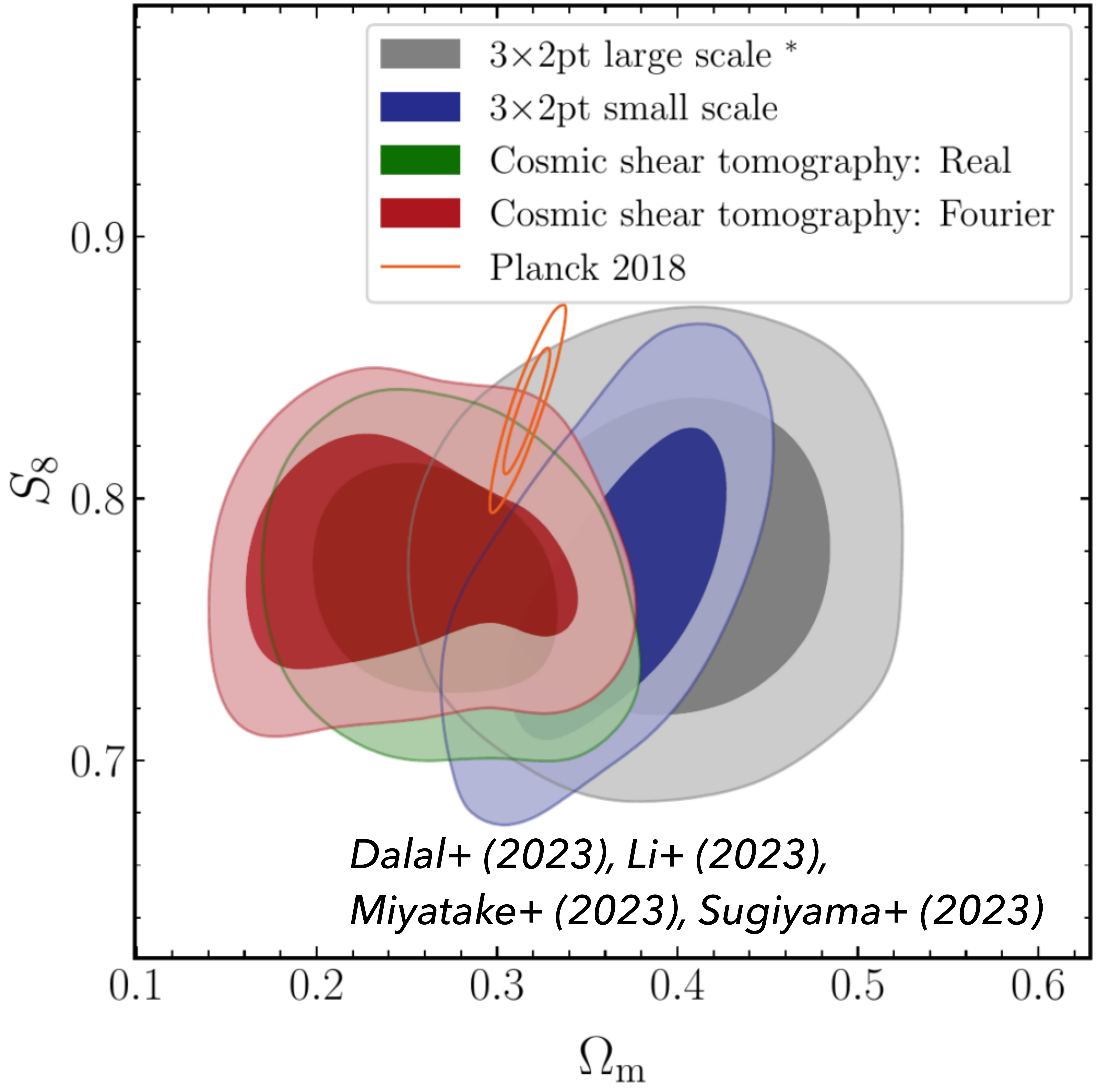
In collaboration with

Masato Shirasaki (NAOJ), Hironao Miyatake (Nagoya), Daisuke Nagai (Yale),
Naoki Yoshida (UTokyo/IPMU), Mathew Madhavacheril (UPenn),
William Coulton (CCA), HSC WL WG & ACT Collaboration

σ_8 (or S_8) tension

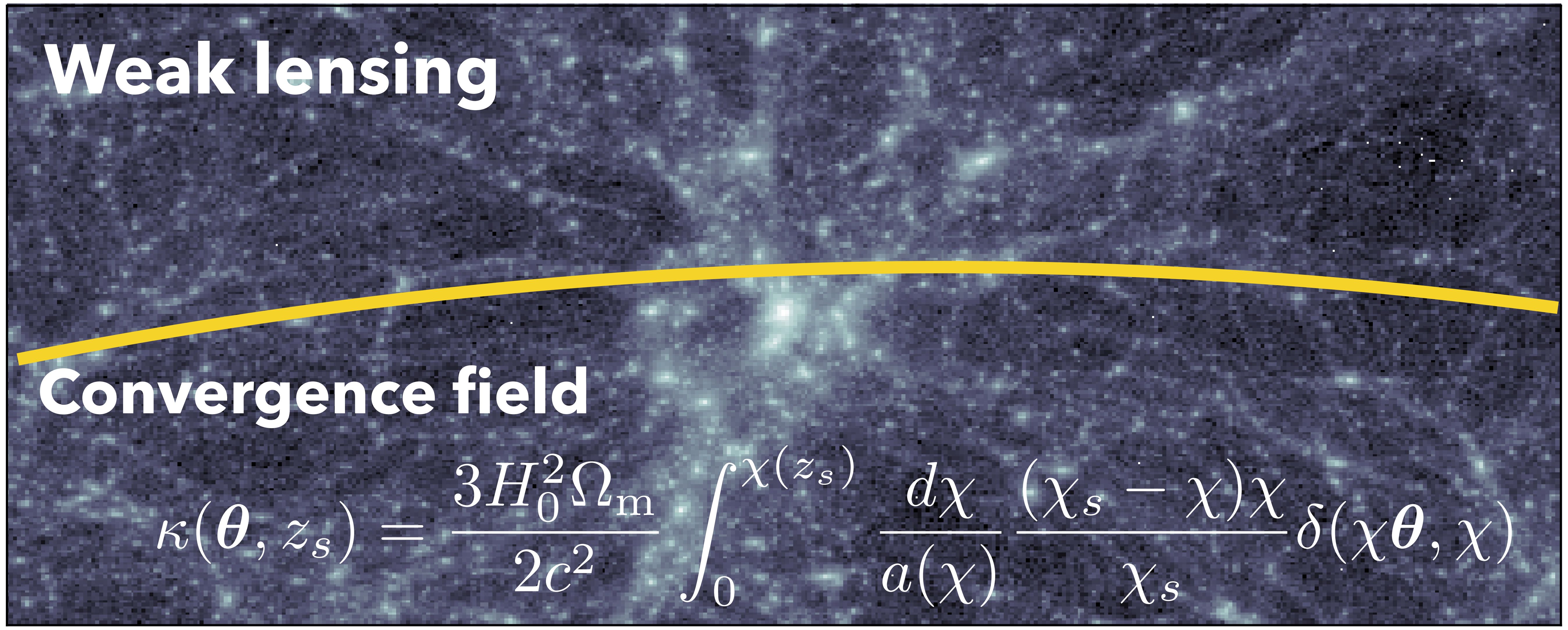


Heymans+ (2021)

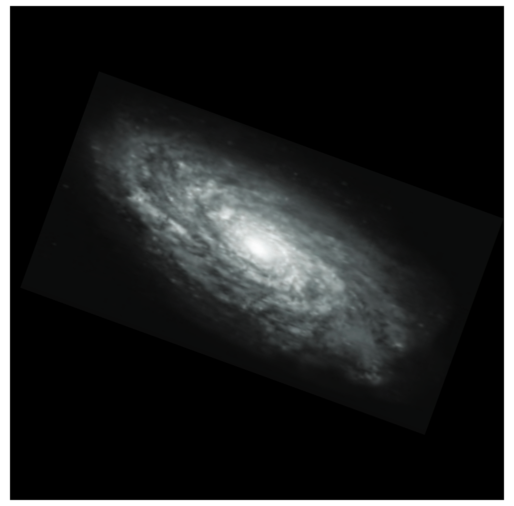


Cross-correlation of WL and tSZ

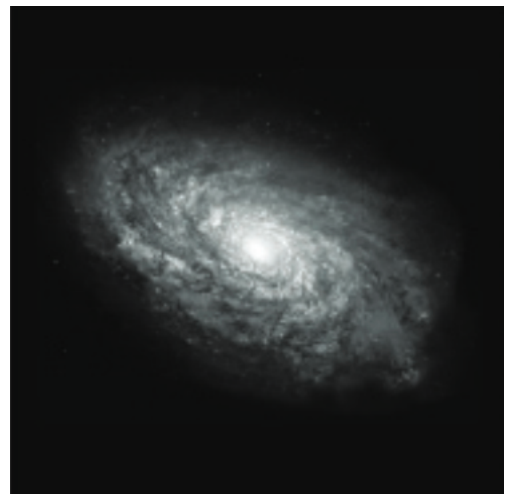
Telescopes



Lensed image

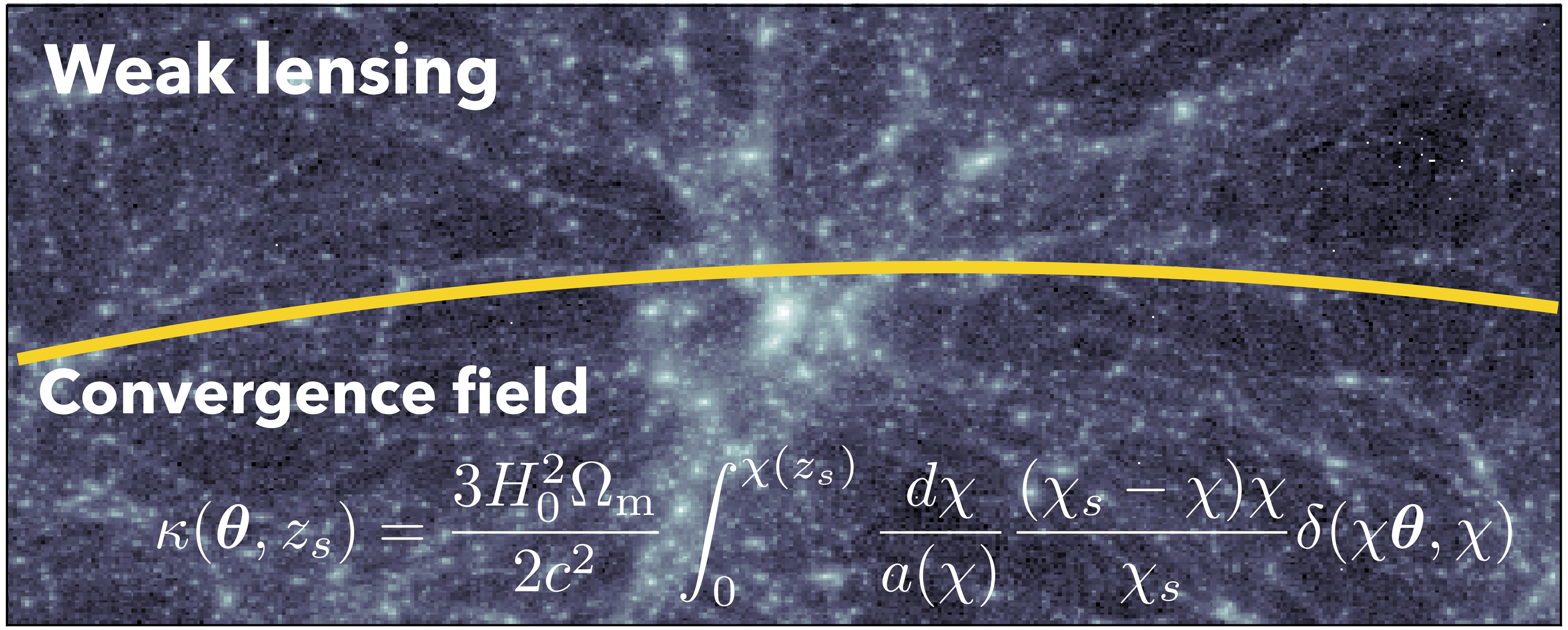


True image

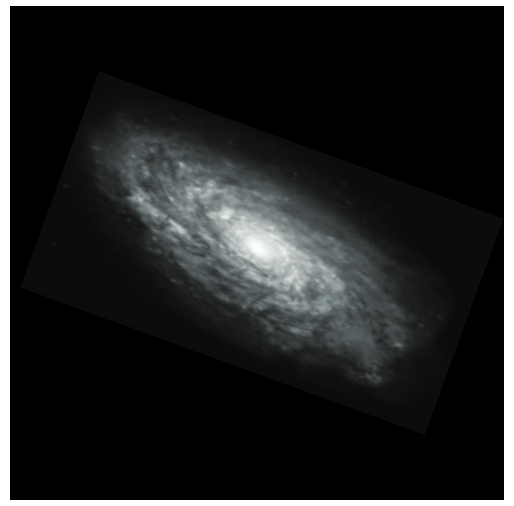


Cross-correlation of WL and tSZ

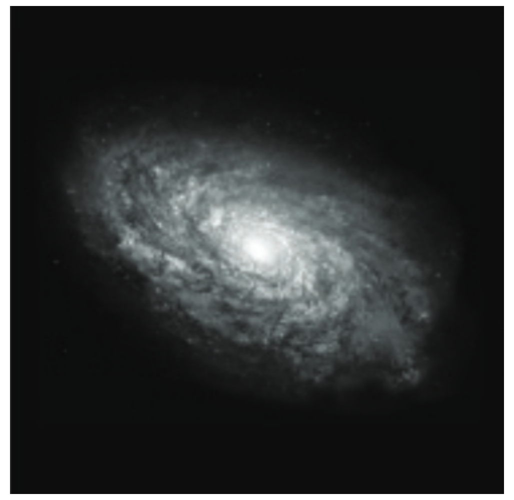
Telescopes

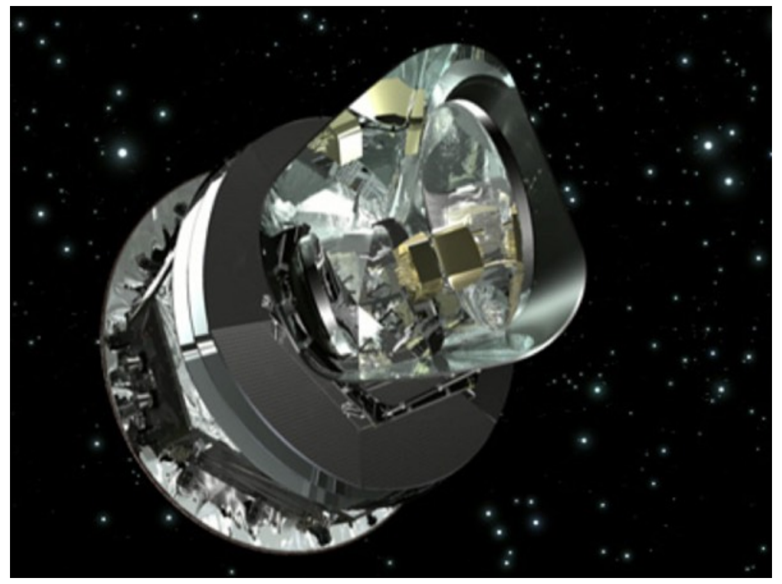


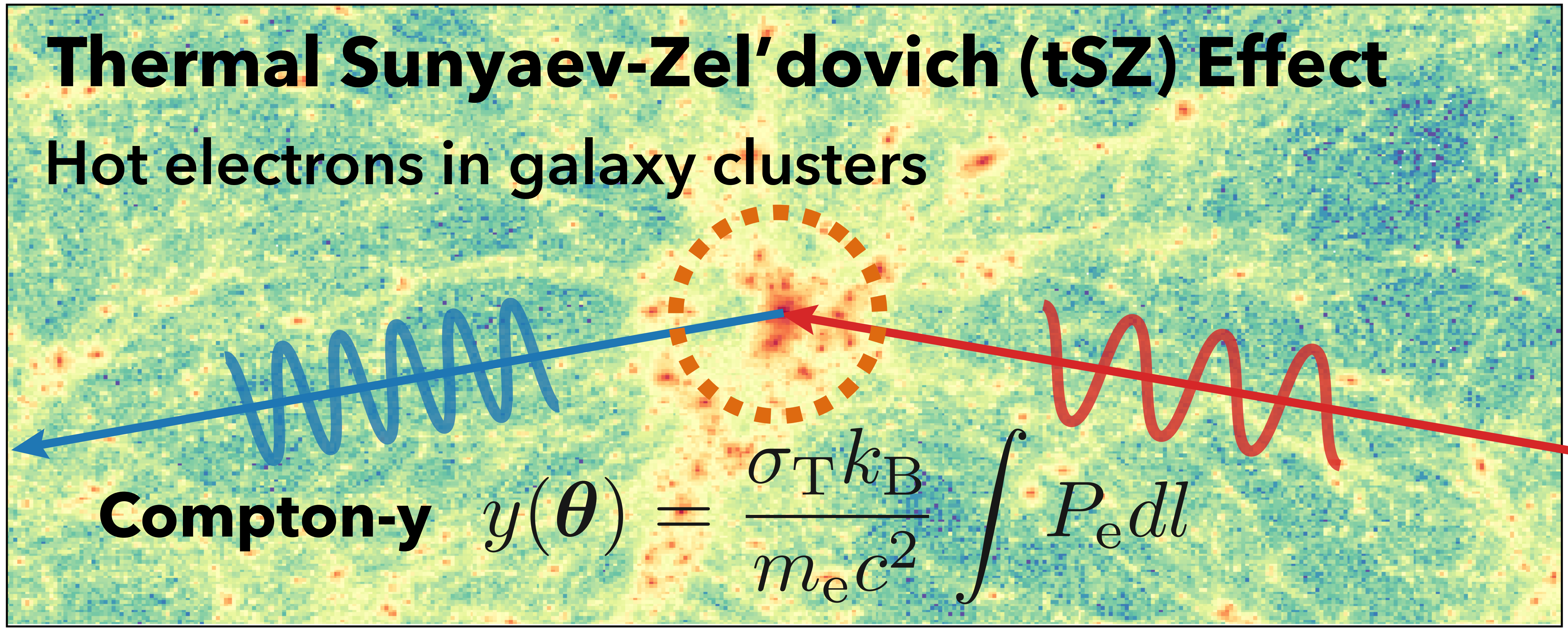
Lensed image

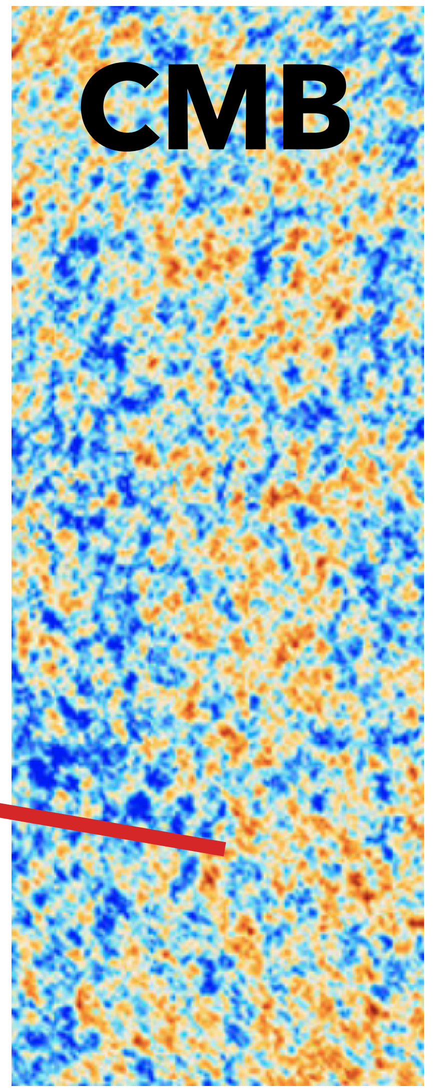


True image









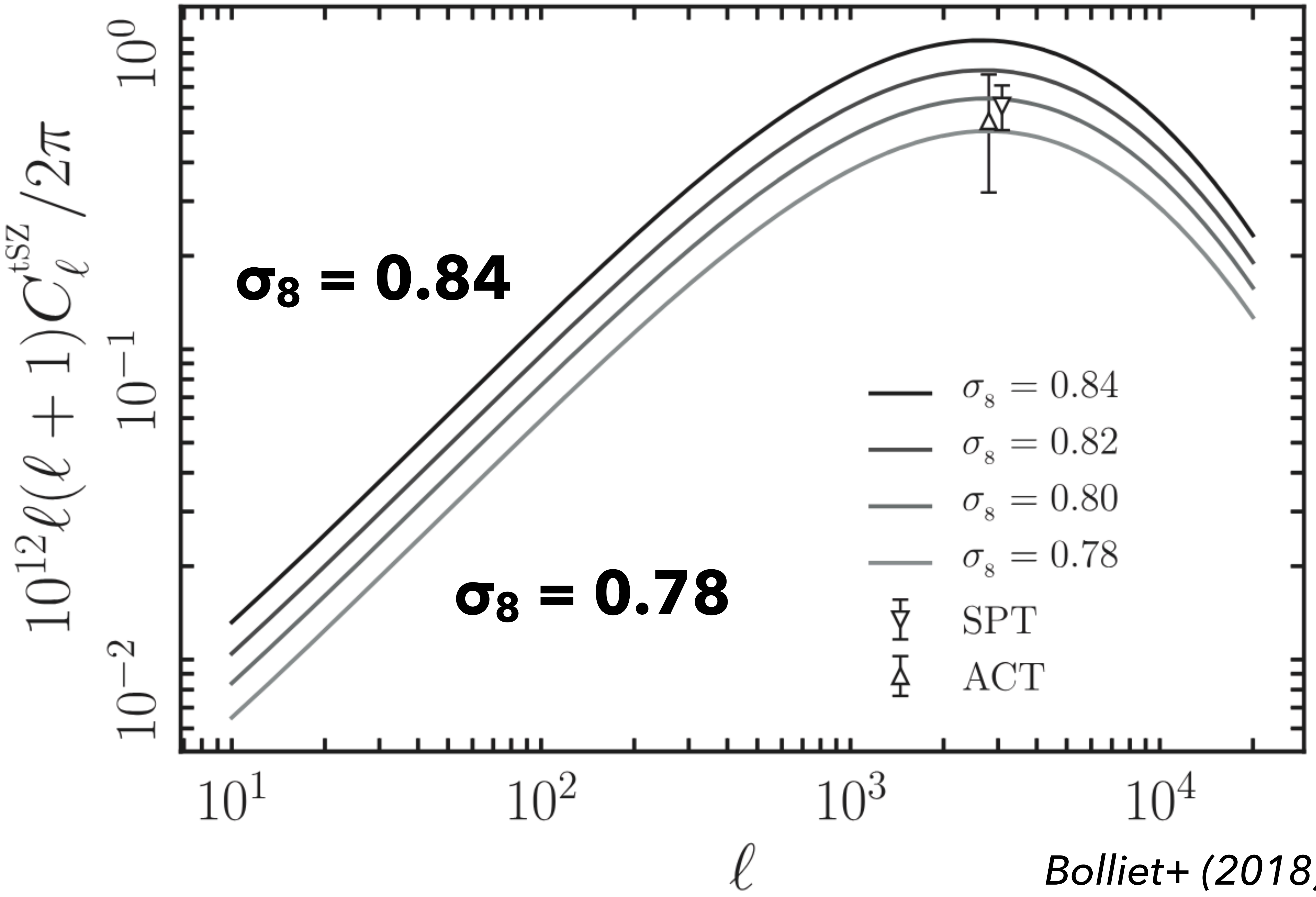
Sensitivity of tSZ Statistics to Matter Fluctuations

✦The power spectrum of tSZ effect is sensitive to σ_8.
(c.f., Komatsu & Seljak, 2002; Shaw+, 2010)

But degenerate with other cosmological parameters and **mass bias**.

$$C_\ell^{\rm tSZ} \propto \sigma_8^{8.1}\Omega_{\rm m}^{3.2}B^{-3.2}h^{-1.7} \quad \text{for} \quad \ell \lesssim 10^3.$$

$$B \equiv (1-b)^{-1}, \quad \frac{M_{\rm HSE}}{M_{\rm true}} = 1-b$$



Bolliet+ (2018)

In addition to thermal pressure, **turbulence and magnetic fields** support galaxy clusters.
b ~ 0.2 according to hydro simulations.

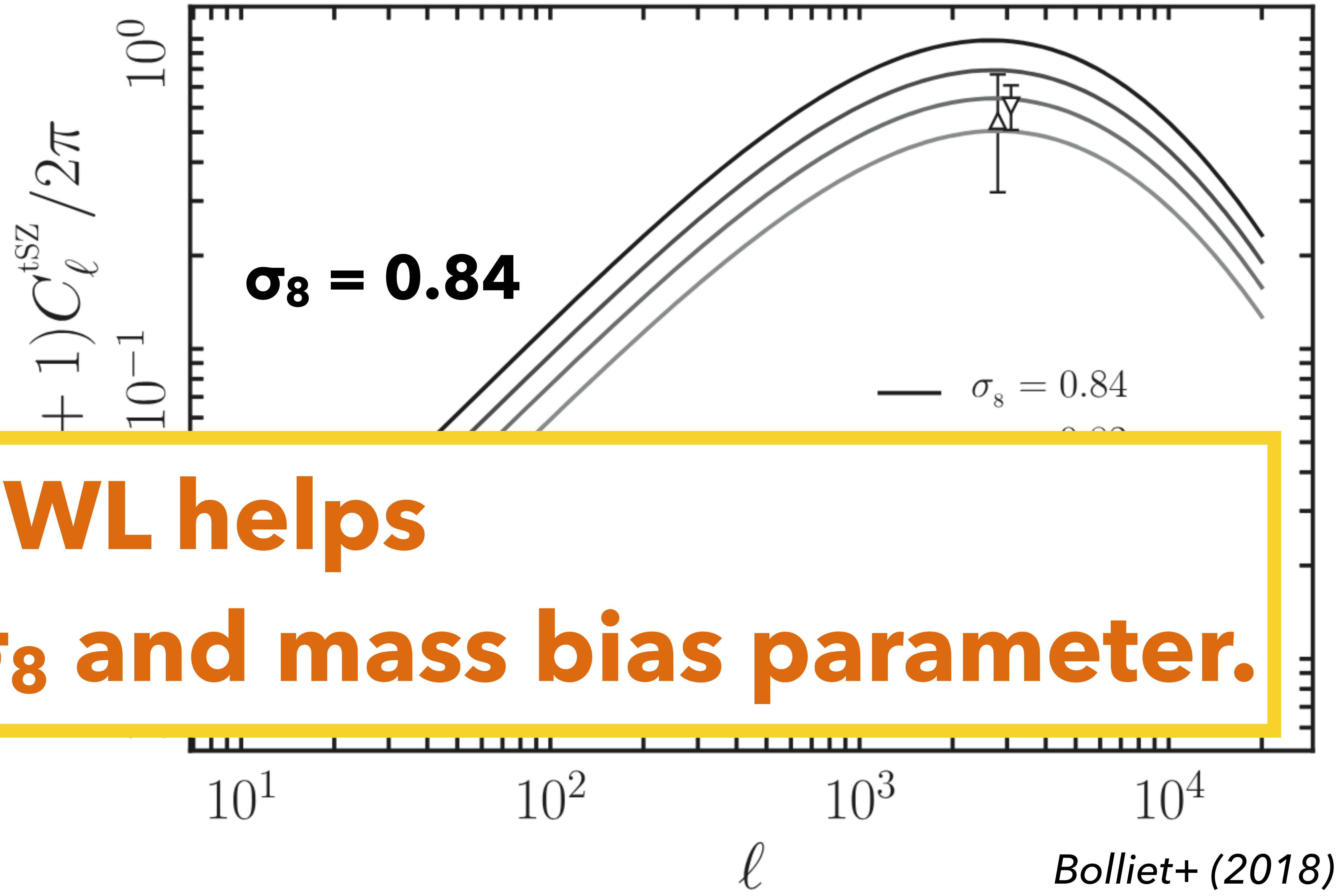
Sensitivity of tSZ Statistics to Matter Fluctuations

✦The power spectrum of tSZ effect is sensitive to σ_8.
(c.f., Komatsu & Seljak, 2002; Shaw+, 2010)

But degenerate with other cosmological pa

Cross-correlation with WL helps break degeneracy of σ_8 and mass bias parameter.

$$B \equiv (1-b)^{-1}, \quad \frac{M_{\rm HSE}}{M_{\rm true}} = 1-b$$



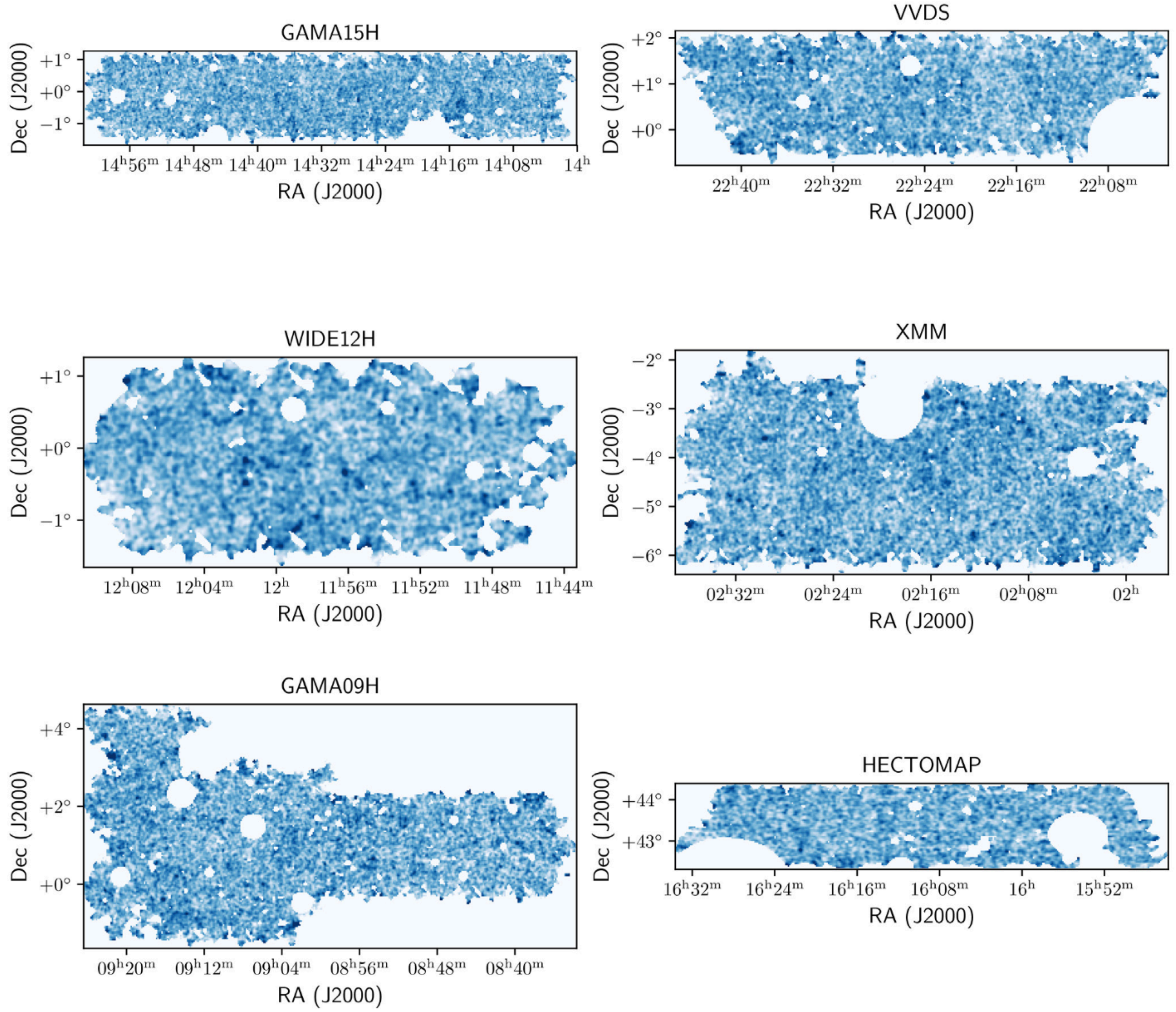
Bolliet+ (2018)

In addition to thermal pressure, turbulence and magnetic fields support galaxy clusters.
b ~ 0.2 according to hydro simulations.

HSC WL Y1 x Planck tSZ

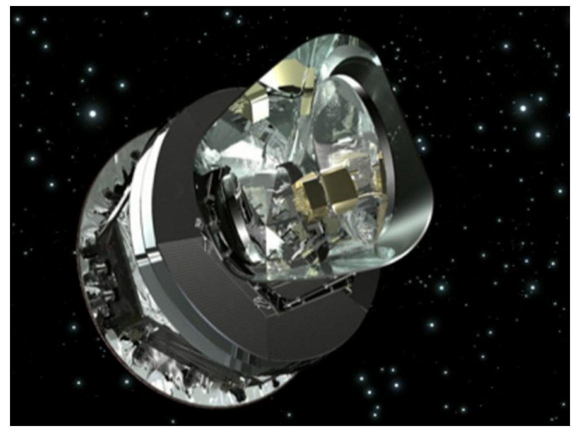
- **HSC WL Y1**

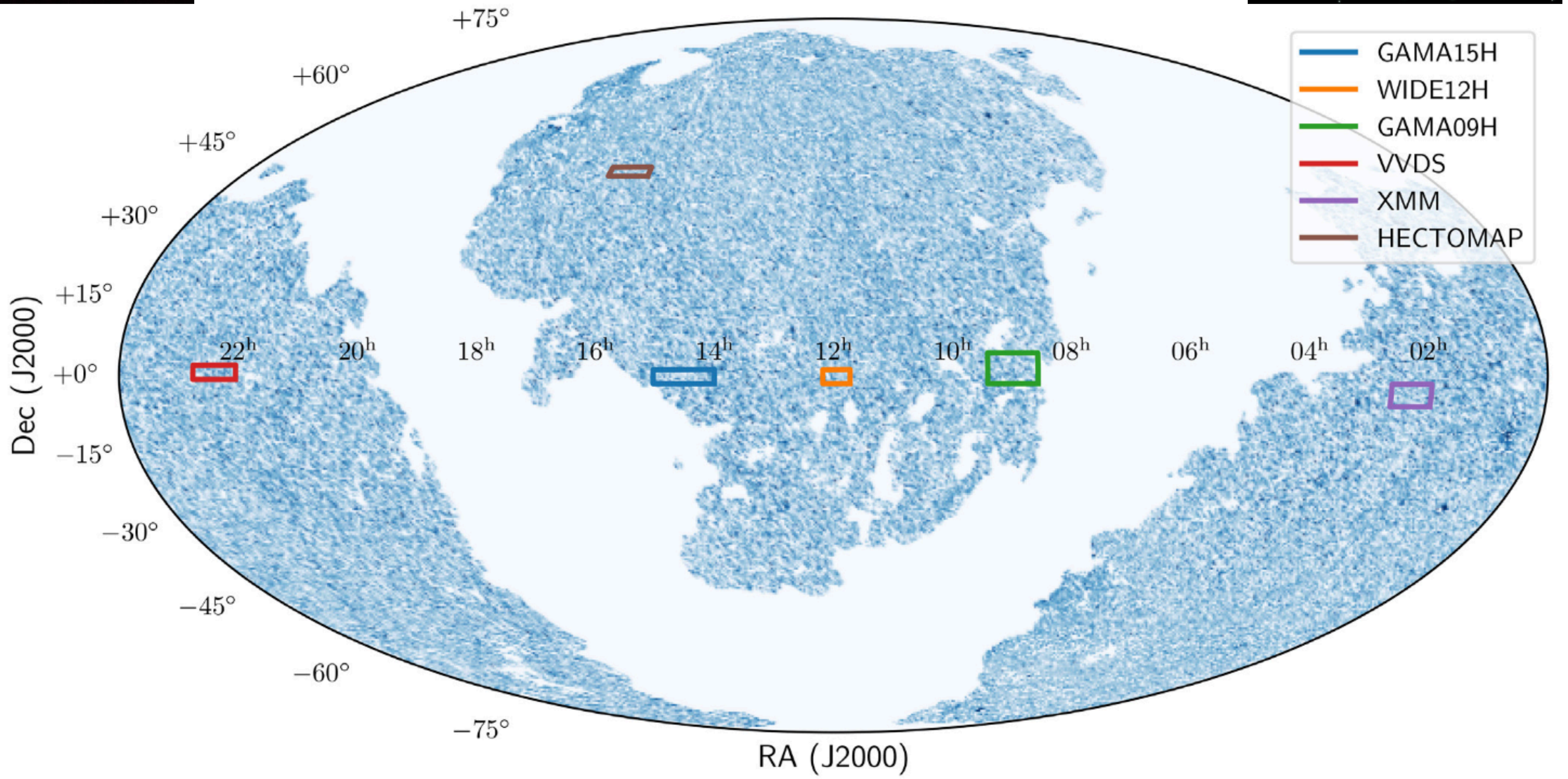
  Wide and deep WL survey which covers 136.9 deg^2 with mean i-band seeing ~ $0''.58$ and source density $n_{\rm eff} = 24.6\,\mathrm{arcmin}^{-2}$.



- **Planck tSZ map**

  Full-sky with MW and point sources masked. The beam size is 10′.

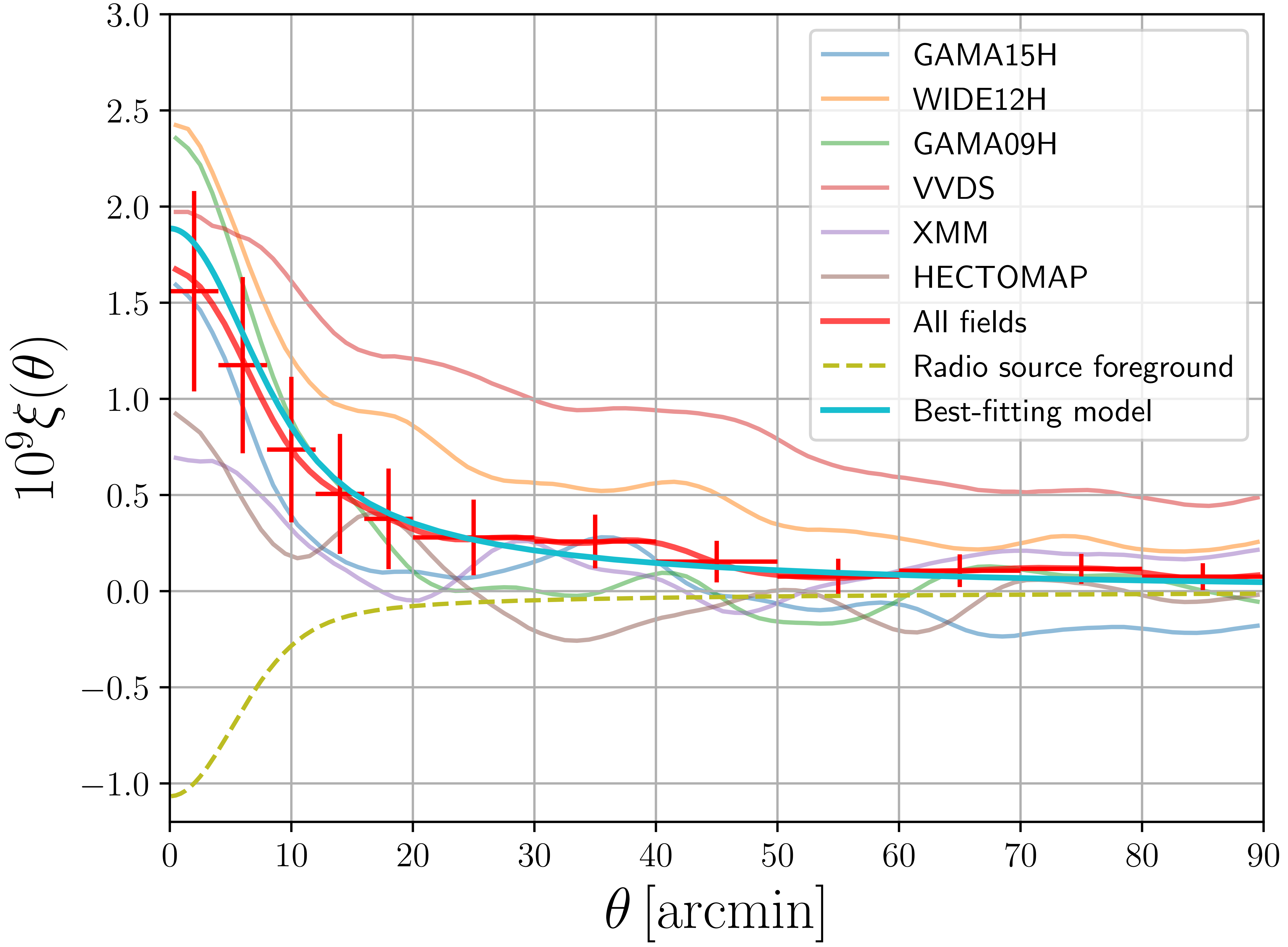




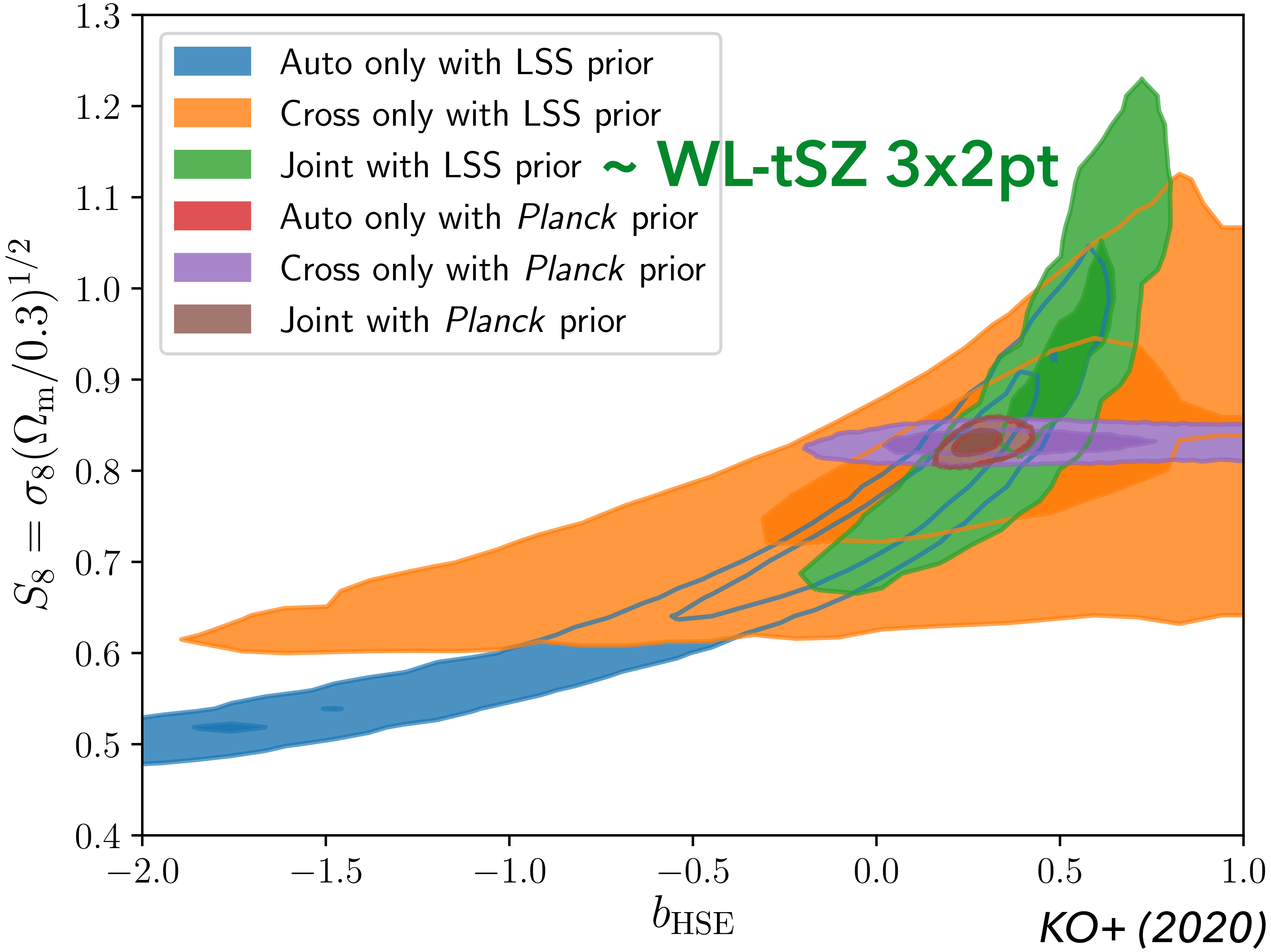
KO+ (2020)

HSC WL Y1 x Planck tSZ

• Cross-correlation function



• Constraints on S_8 and mass bias



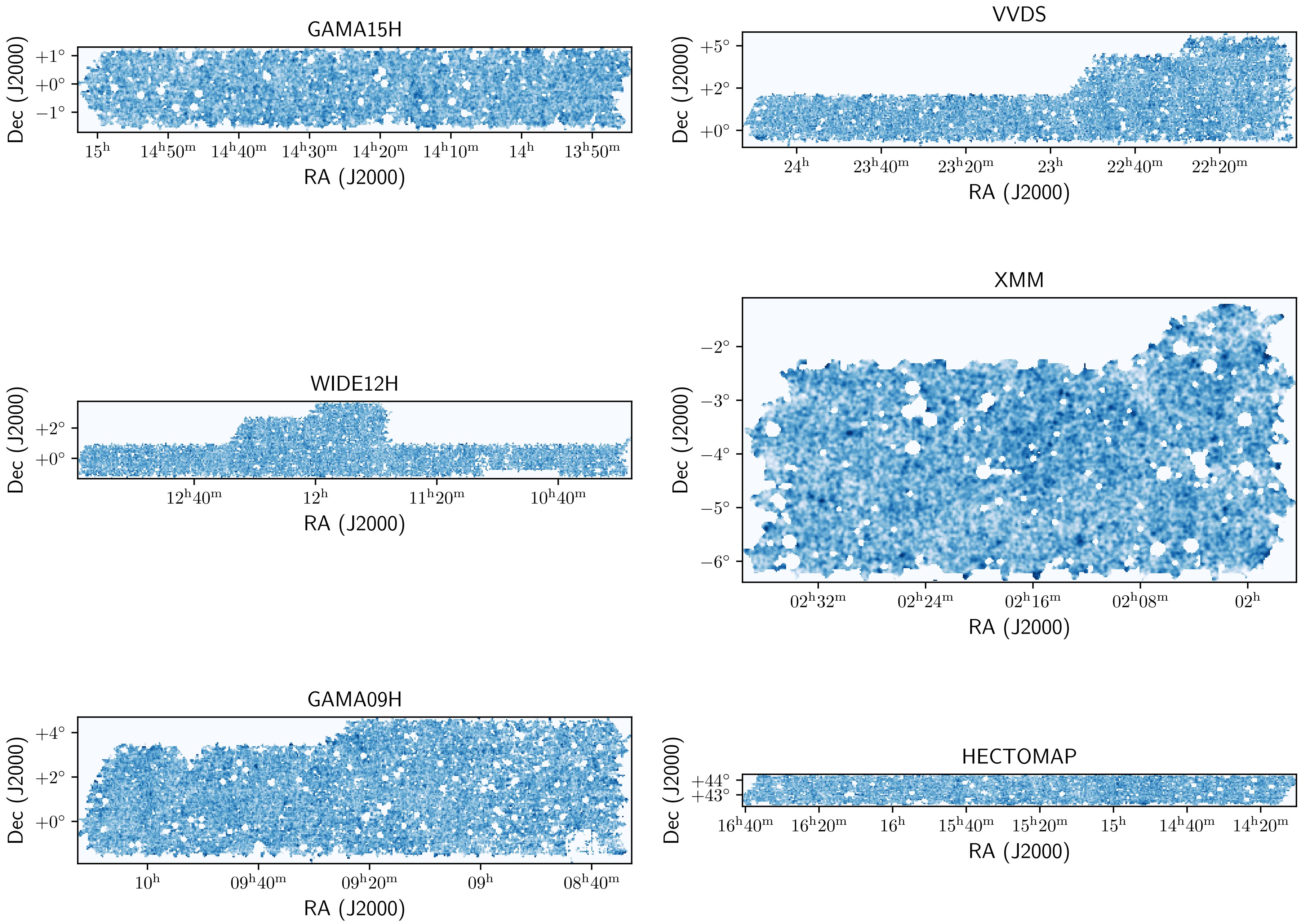
KO+ (2020)

➡ **More areas** with **higher angular resolution** are required to tightly constrain S_8.

HSC Y3 and ACT DR6

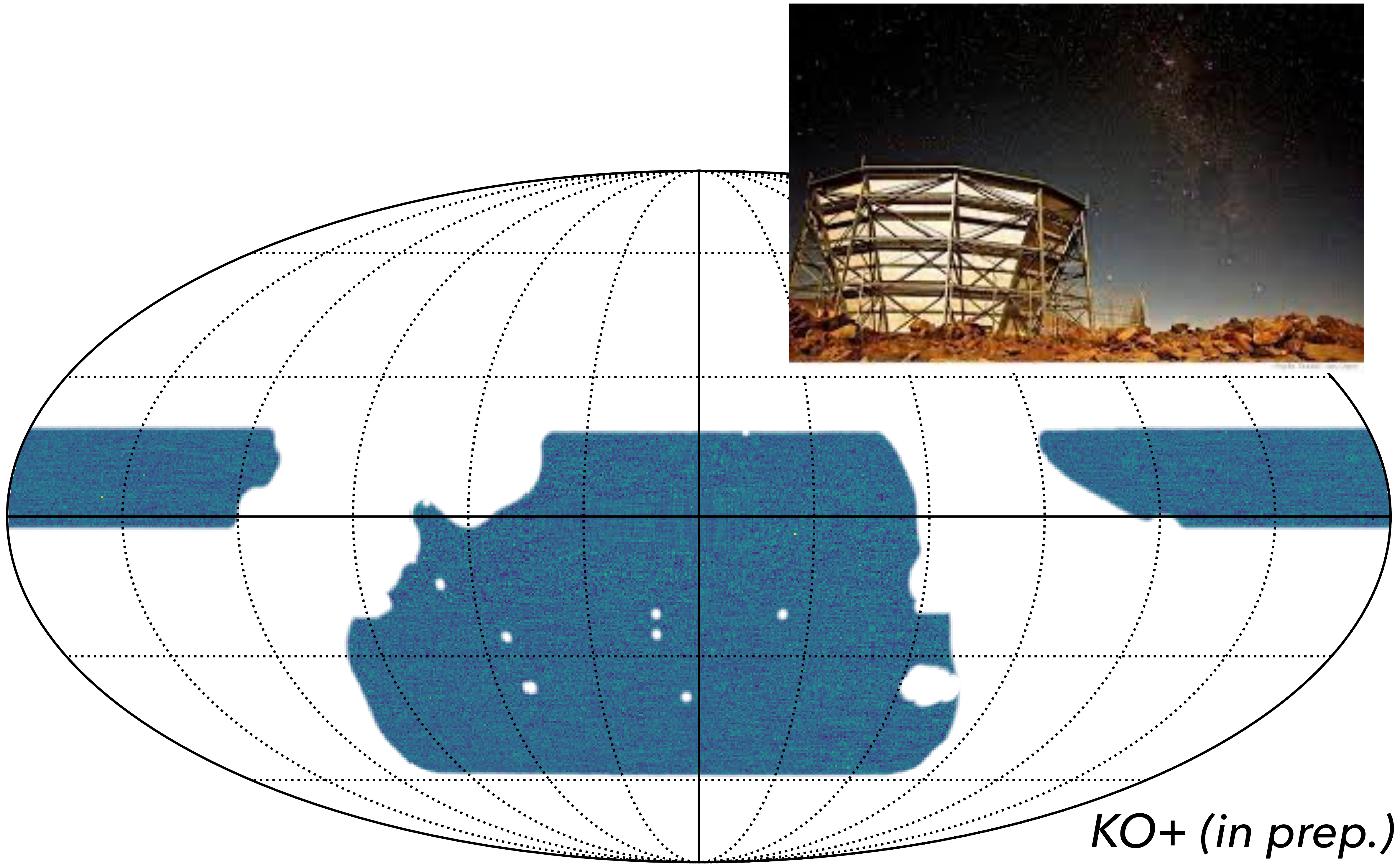
✦HSC WL Y3 *(Li+, 2022)*

The observed area is extended to >**450 deg²**.
The mean seeing is 0.59′ and
source density is $19.9\,\mathrm{arcmin}^{-2}$.



✦ACT DR6 Compton-y *(Coulton+, 2023)*

The beam size is 1.6′ (FWHM) (c.f., 10′ for *Planck*).
The coverage is **>12,000 deg²** and overlapped with HSC footprints. The overlapping area is **3x larger** than HSC Y1 and Planck.



KO+ (in prep.)

Cross-Power Spectrum of HSC Y3 WL and ACT DR6

✦**Cross-power spectrum of ACT DR6 Compton-y and HSC shear E-mode**

The pseudo-C_l power spectra are estimated with NaMaster (Alonso+; 2019) algorithm. Covariance matrix is estimated from all-sky *N*-body simulation mocks *(Takahashi+, 2017).*

Shirasaki+, 2019 for HSC mock shapes; KO & Nagai, 2023 for SZ mocks

Full galaxy sample

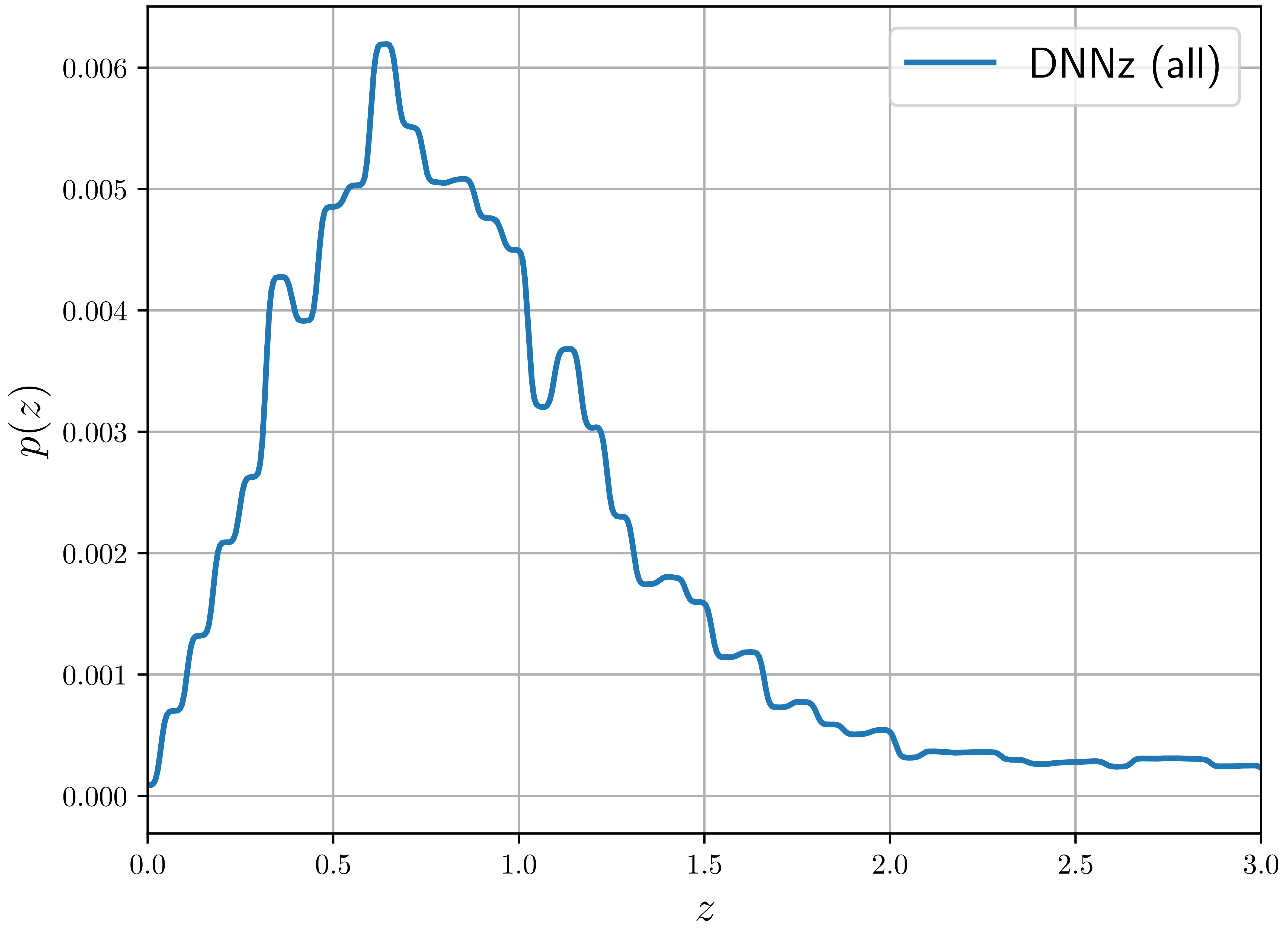
Blinded

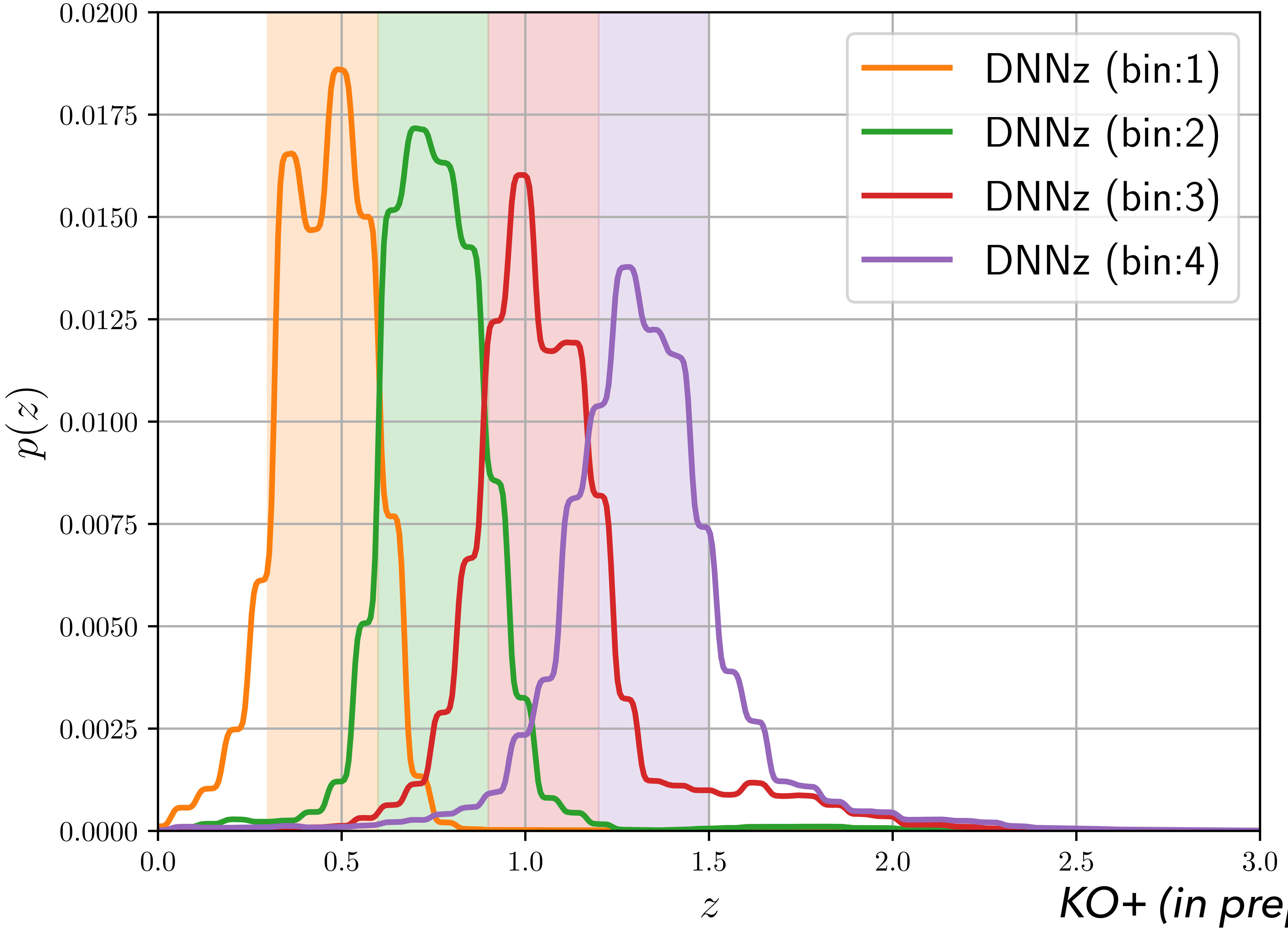
KO+ (in prep.)

Tomographic analysis

- **Tomography:**
  Divide source galaxies based on photo-z to probe the structures at different epochs.

$z_{\text{best}}^{\text{DNNz}} \in (0.3, 0.6], (0.6, 0.9], (0.9, 1.2], (1.2, 1.5]$





KO+ (in prep.)

Tomographic Cross-Power Spectra

z = [0.3, 0.6)

z = [0.6, 0.9)

Blinded

z = [0.9, 1.2)

z = [1.2, 1.5)

KO+ (in prep.)

Summary

- Weak lensing and the thermal Sunyaev-Zel'dovich effect are the sensitive probe into the matter fluctuation, i.e. σ_8.

- Cross-correlation is a powerful statistic with high S/N significance provides additional information useful for breaking degeneracy.

- The cross-correlation of HSC Y1 and Planck can put constraints on S_8 and mass bias parameter. However, the significance is not strong enough to break the parameter degeneracy.

- The large overlapping area and higher resolution of ACT will tighten the constraint on S_8 and mass bias parameter. The cross-correlation of HSC Y3 WL and ACT DR6 will provide more insights into S_8 tension.