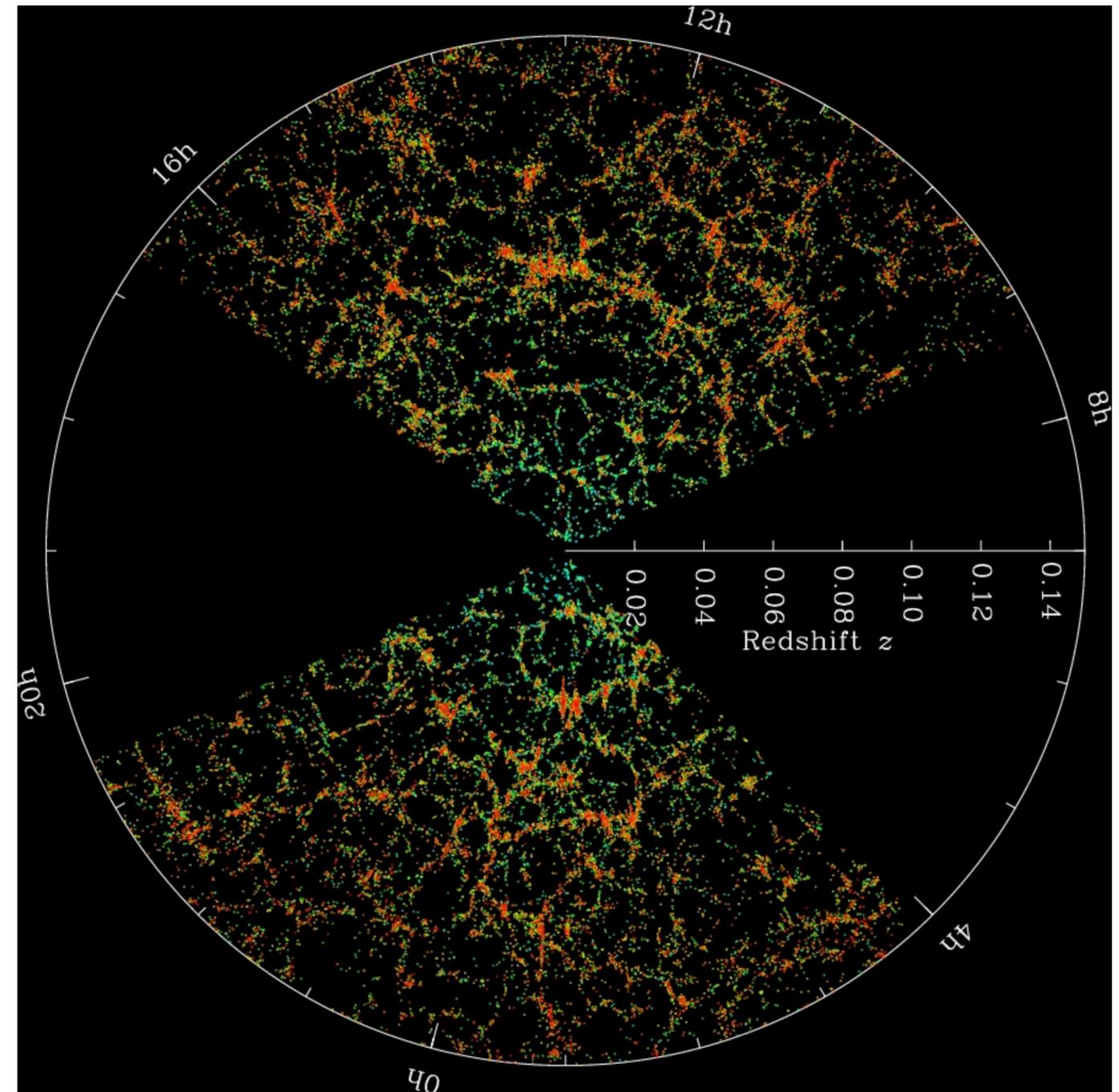


Probing large-scale structures through cross-correlations of the tSZ effect

Emma Ayçoberry (postdoc at CEA Paris-Saclay)

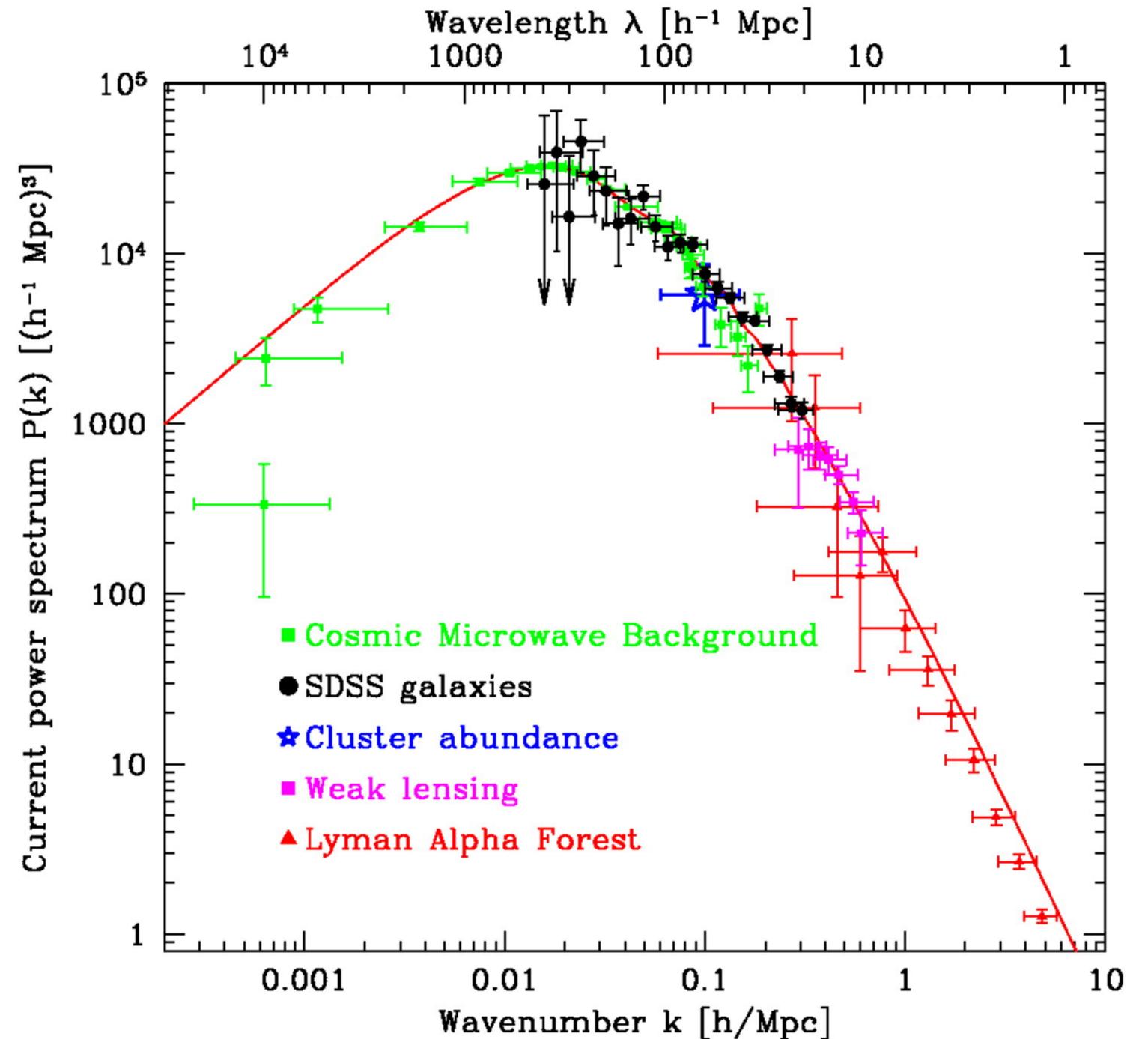
Large-scale structures

- ▶ Measuring the matter distribution through time
- ▶ Gravitational instability & cosmic expansion
- ▶ Probe **matter** through different observables
 - **Galaxy clustering:** biased distribution of matter
 - **Gravitational lensing**
 - **Thermal Sunyaev-Zel'dovich effect**
 - ...



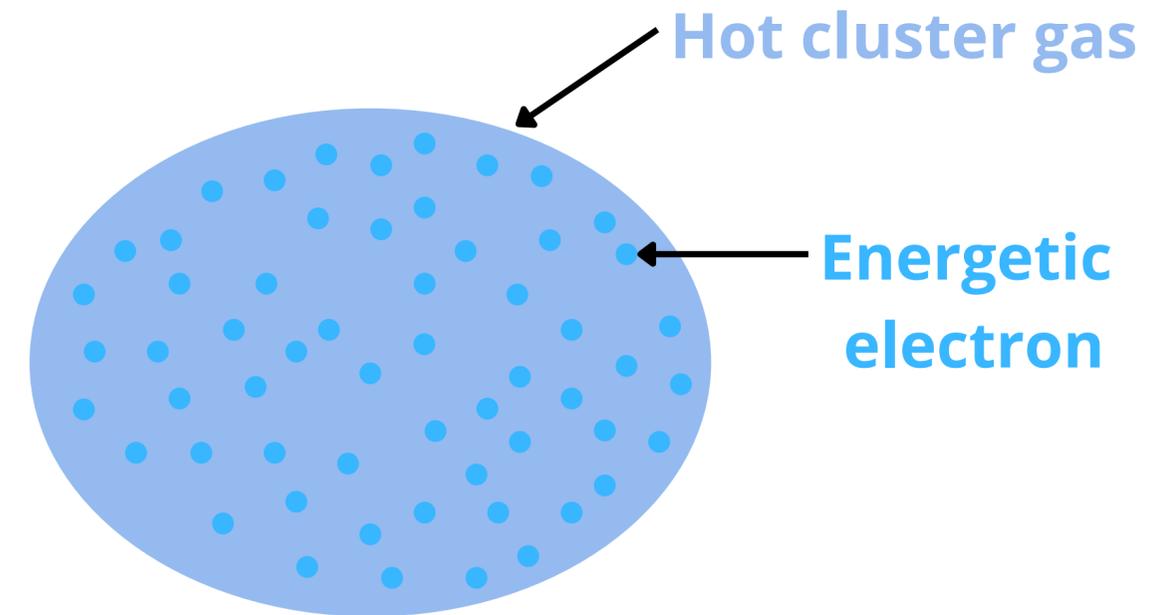
Limitations of the observables

- ▶ Weak lensing & other observables are sensitive to their modeling
- ▶ **Minimise biases & systematics** using different observables
- ▶ **CMB x large scale structures cross-correlation**
 - ▶ tSZ - WL - galaxy clustering correlation
 - ▶ Constrain cosmology and astrophysics



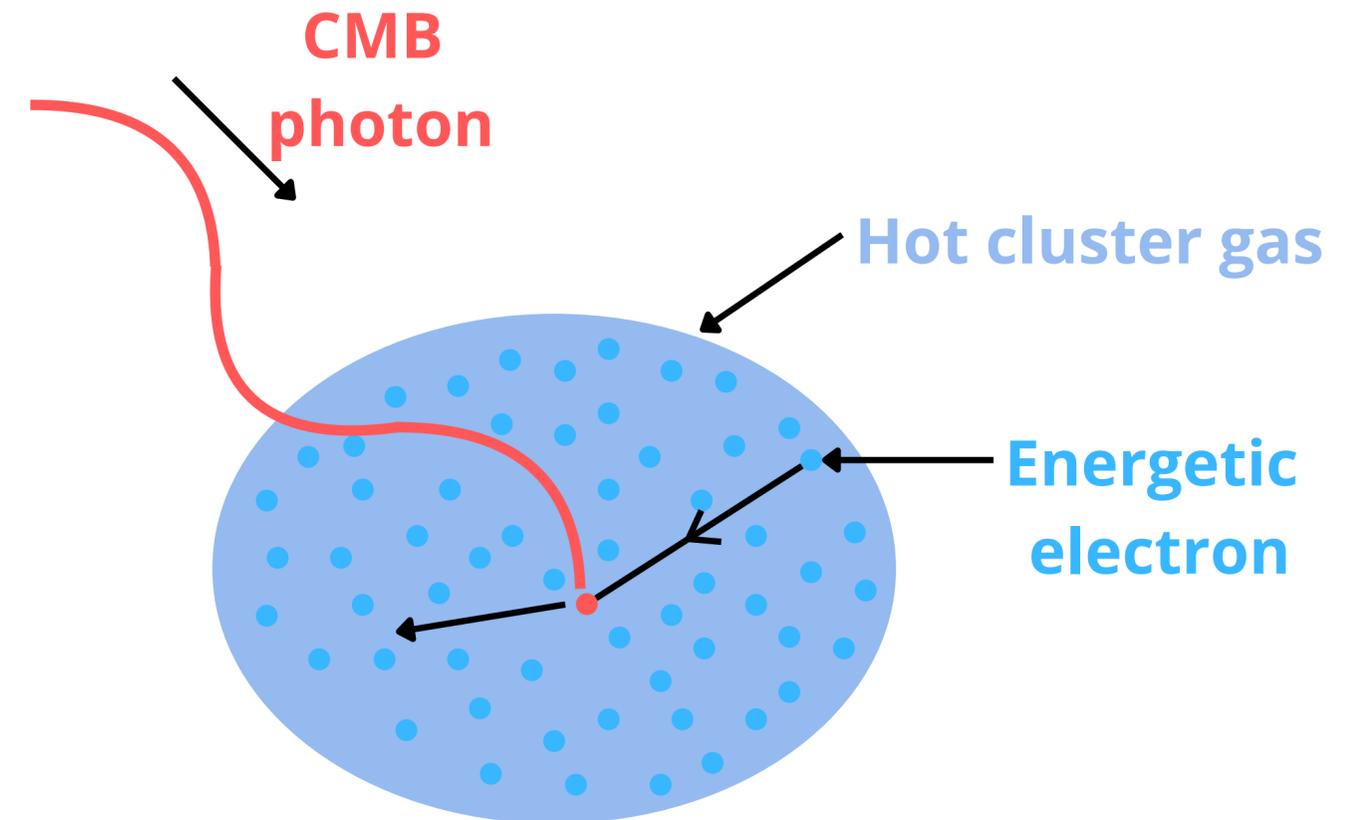
Thermal Sunyaev-Zel'dovich effect

- ▶ Comes from the **thermal electrons**, which reside mostly in **galaxy clusters**



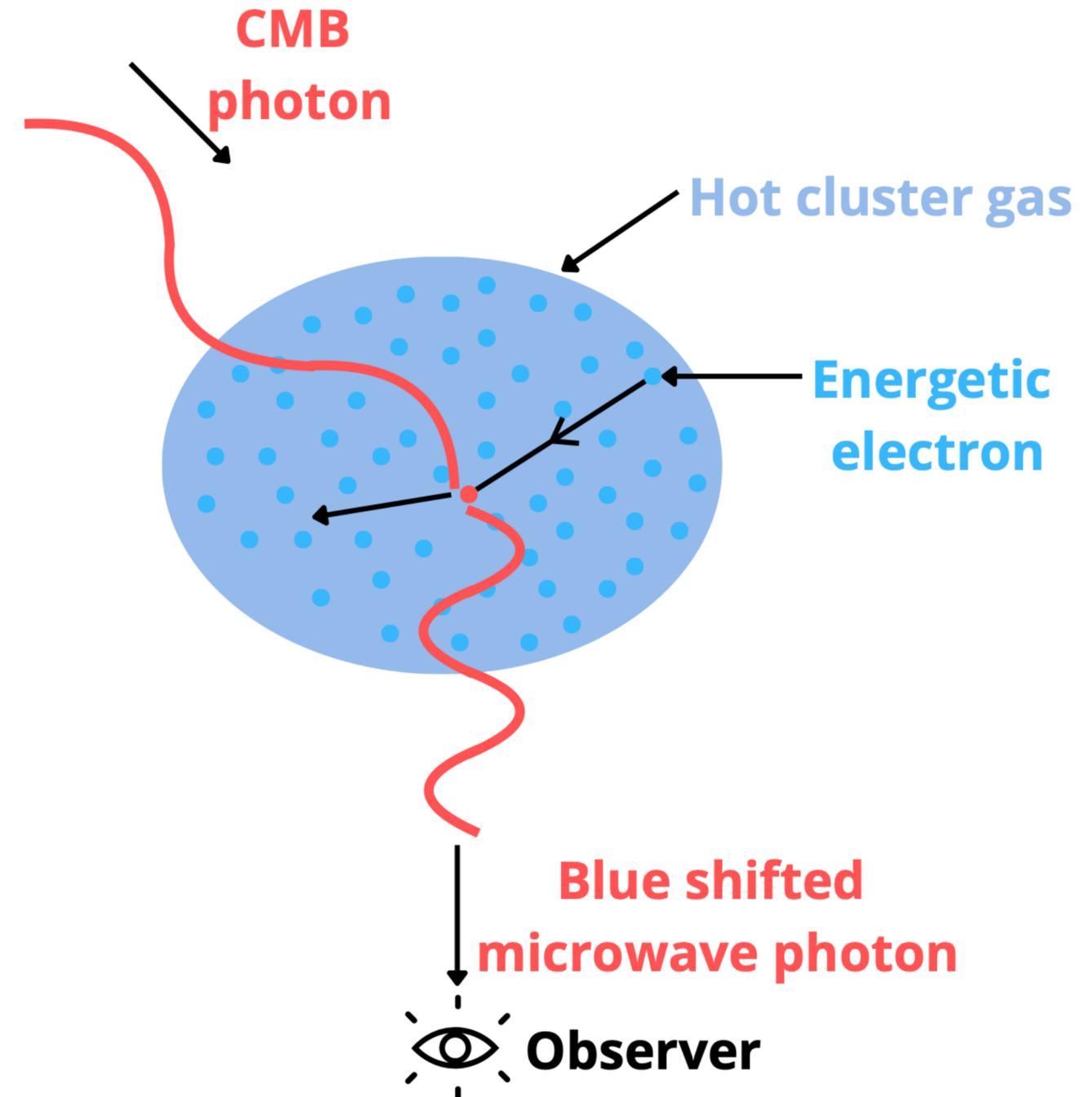
Thermal Sunyaev-Zel'dovich effect

- ▶ Comes from the **thermal electrons**, which reside mostly in **galaxy clusters**
- ▶ Energy is transferred from **hot electrons** to **CMB photons** through **inverse Compton scattering**



Thermal Sunyaev-Zel'dovich effect

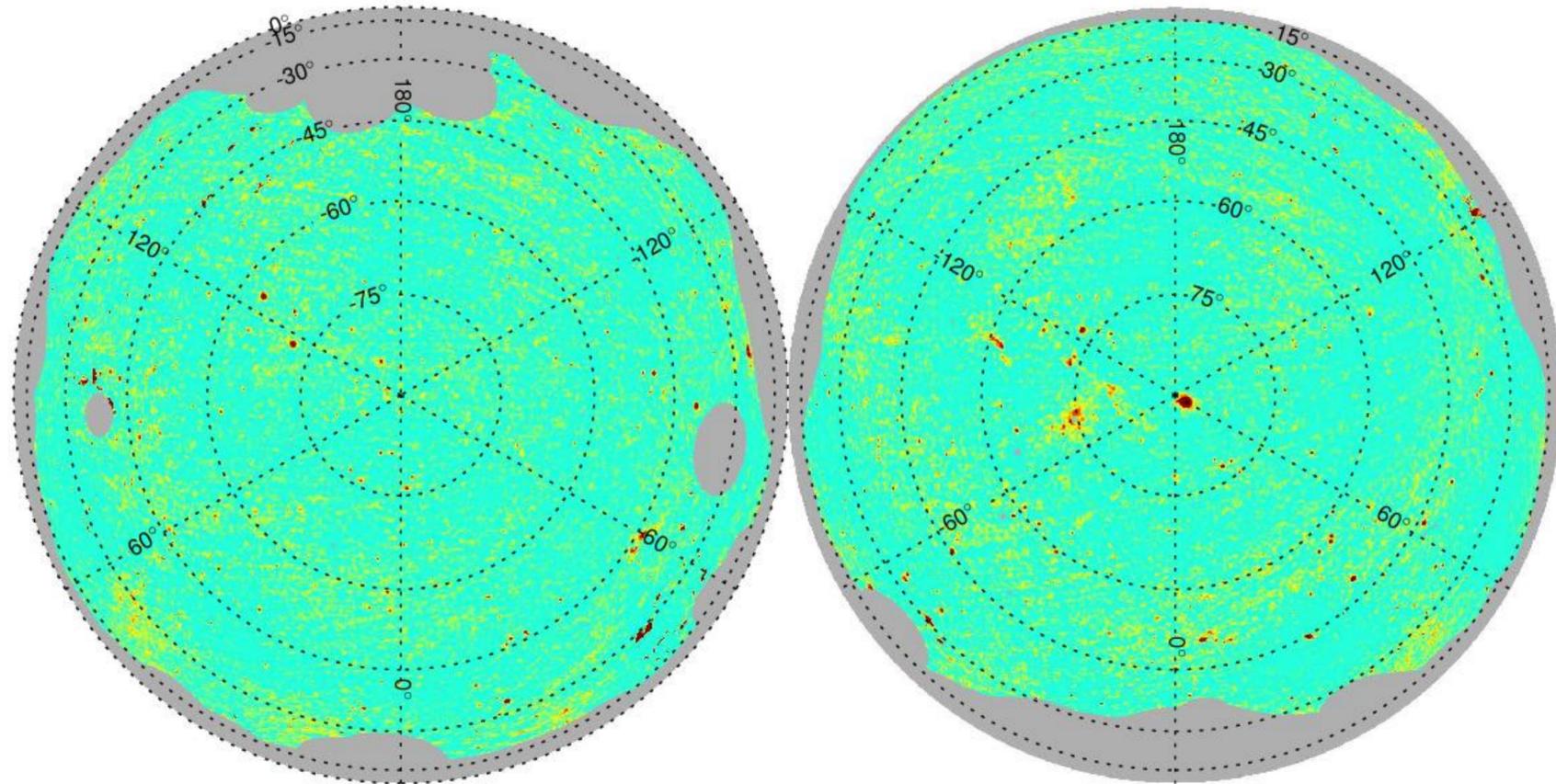
- ▶ Shift in **energy**
- ▶ Information about the late time Universe
- ▶ Dependence: **gas density and temperature**
- ▶ Electron pressure along the line of sight



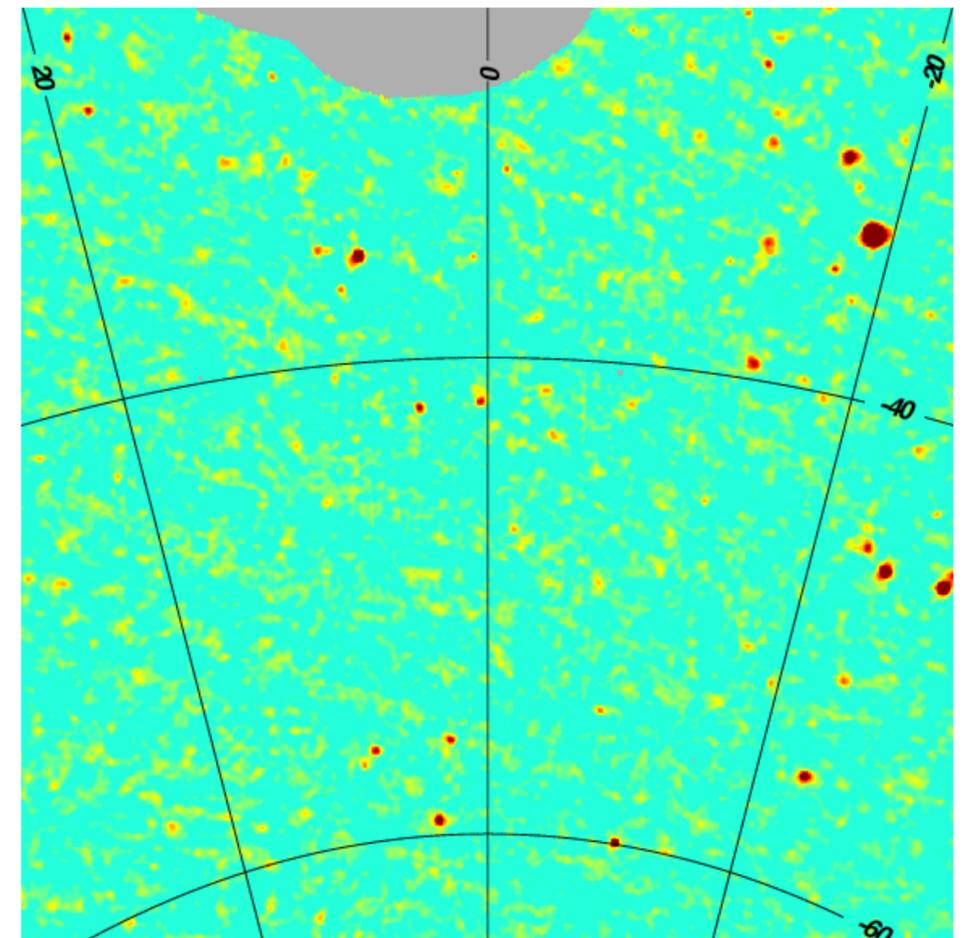
tSZ observation

- ▶ Observation of the **full sky**

MILCA



NLC tSZ map



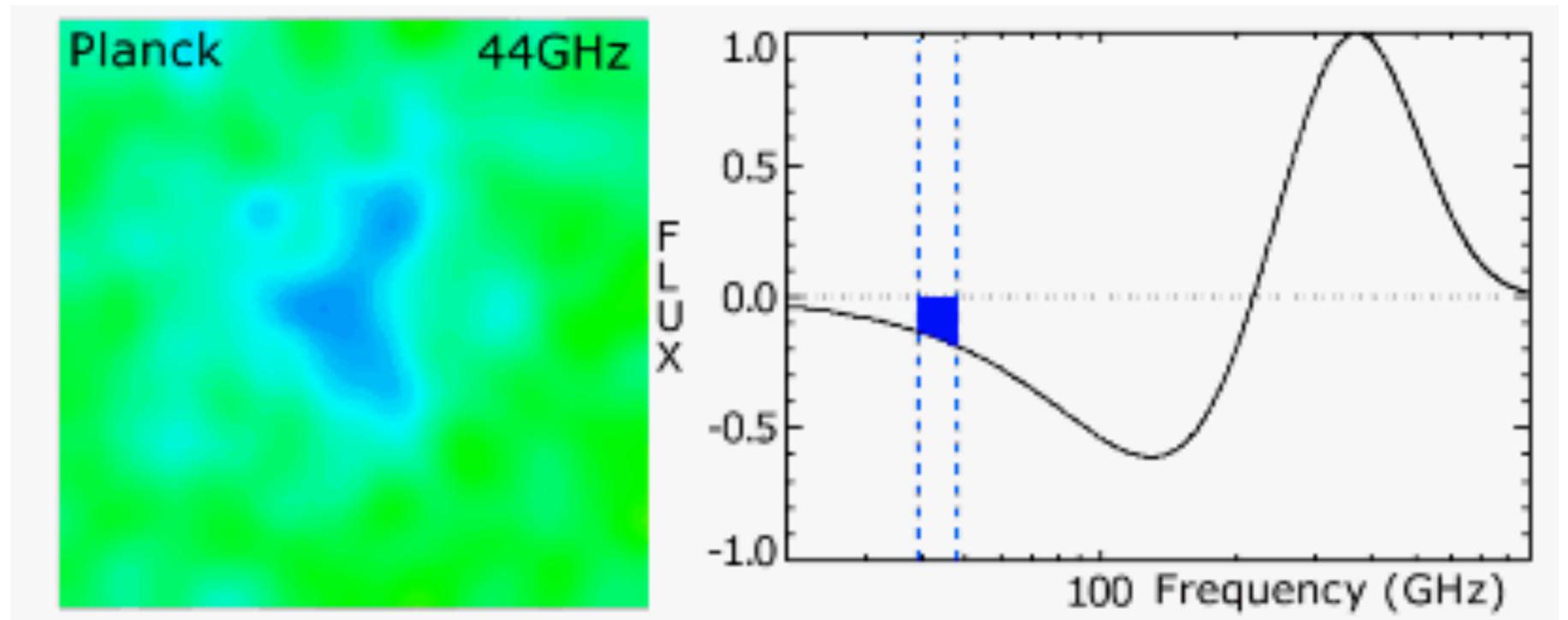
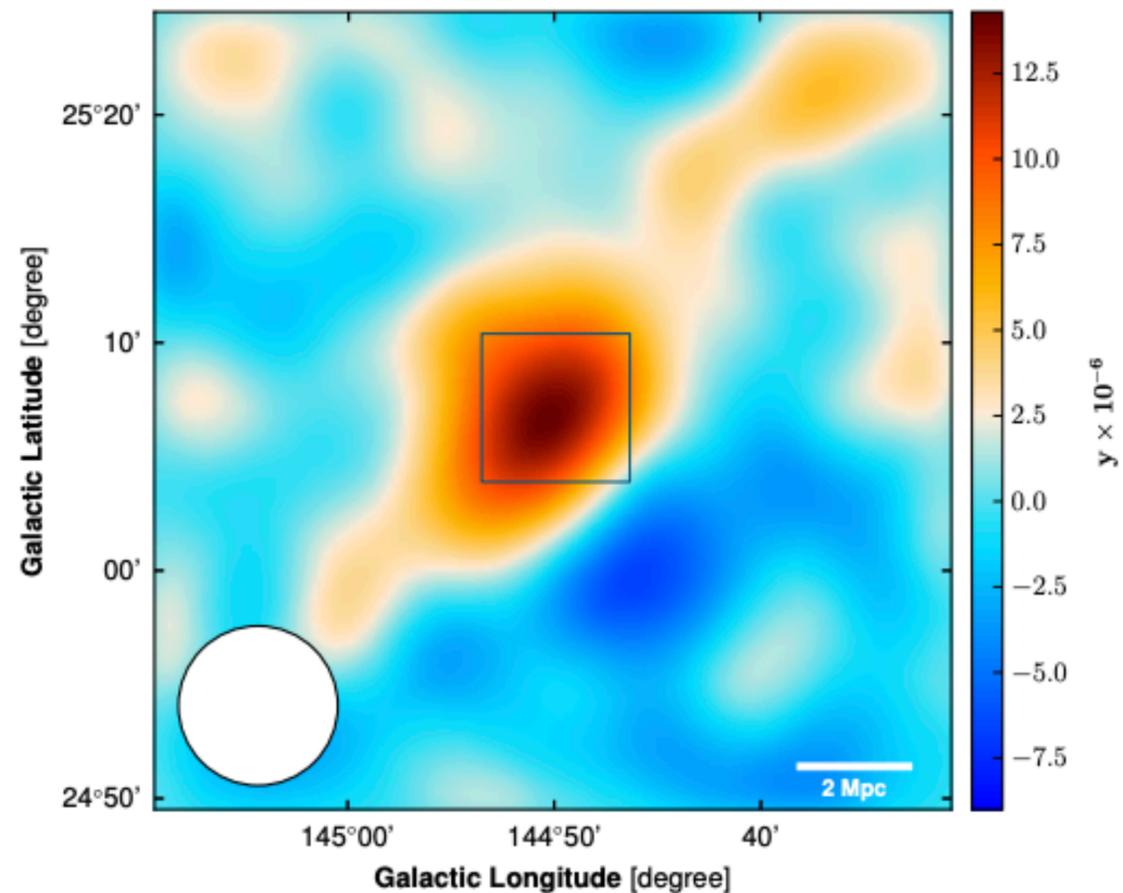
-3.5 $5.0 \mu\text{K}$
(0.0, -45.0) Galactic

-3.5 5.0

μK

Electromagnetic spectrum

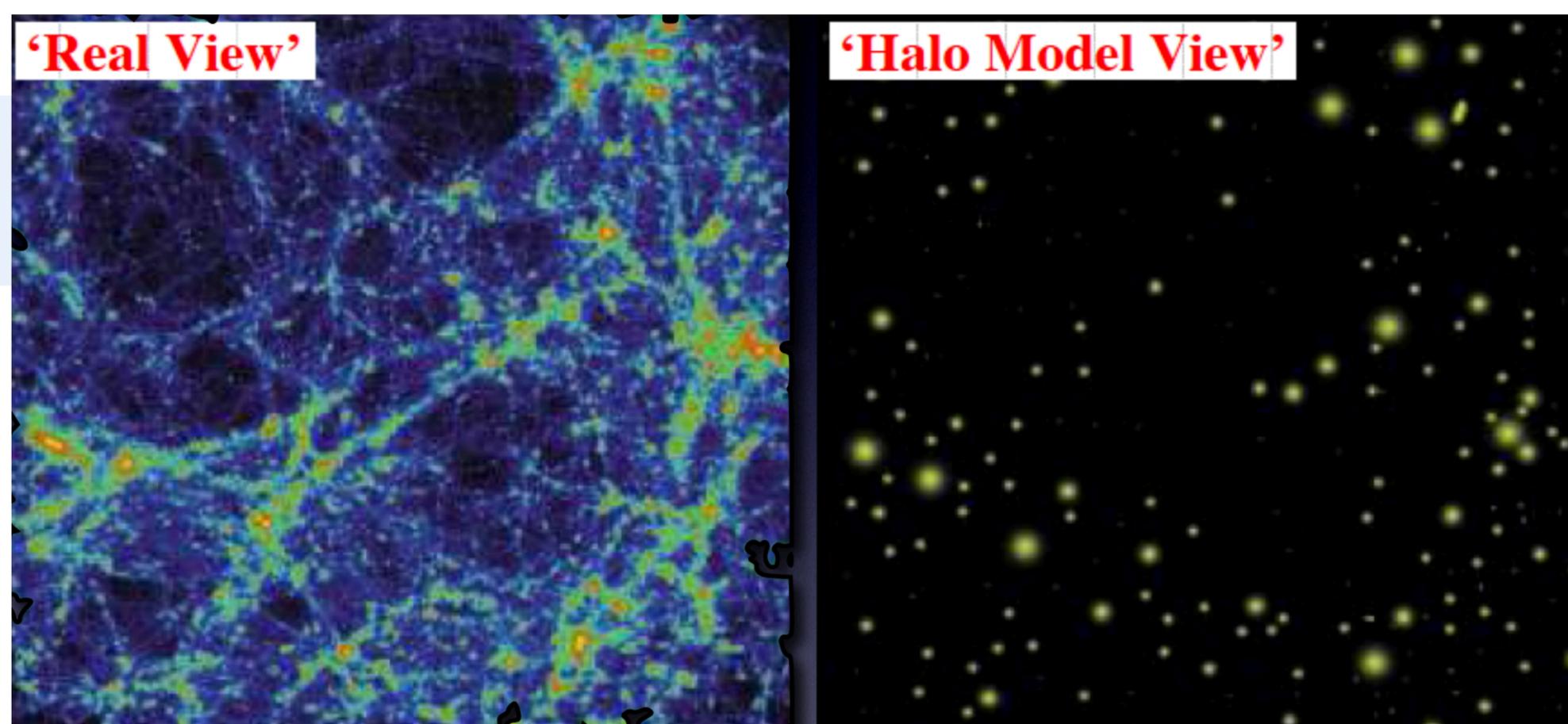
- ▶ Observation of **halos** with, e.g. NIKA-2
 - ▶ Target halos to measure their pressure along the line of sight



ESA/Planck collaboration

Halo model

- ▶ Simplified description of the matter distribution
- ▶ Matter resides in **symmetrical spherical halos**

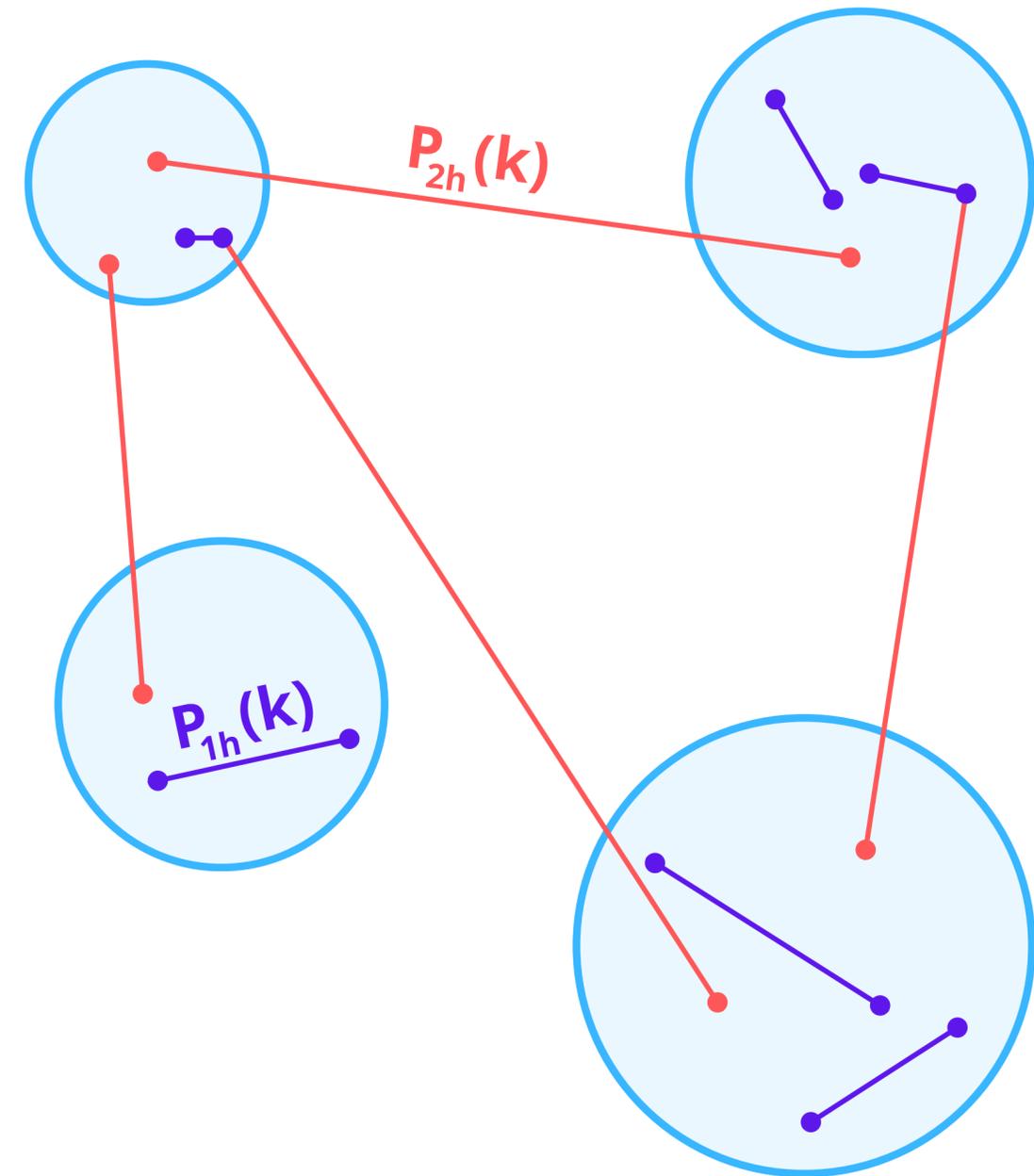
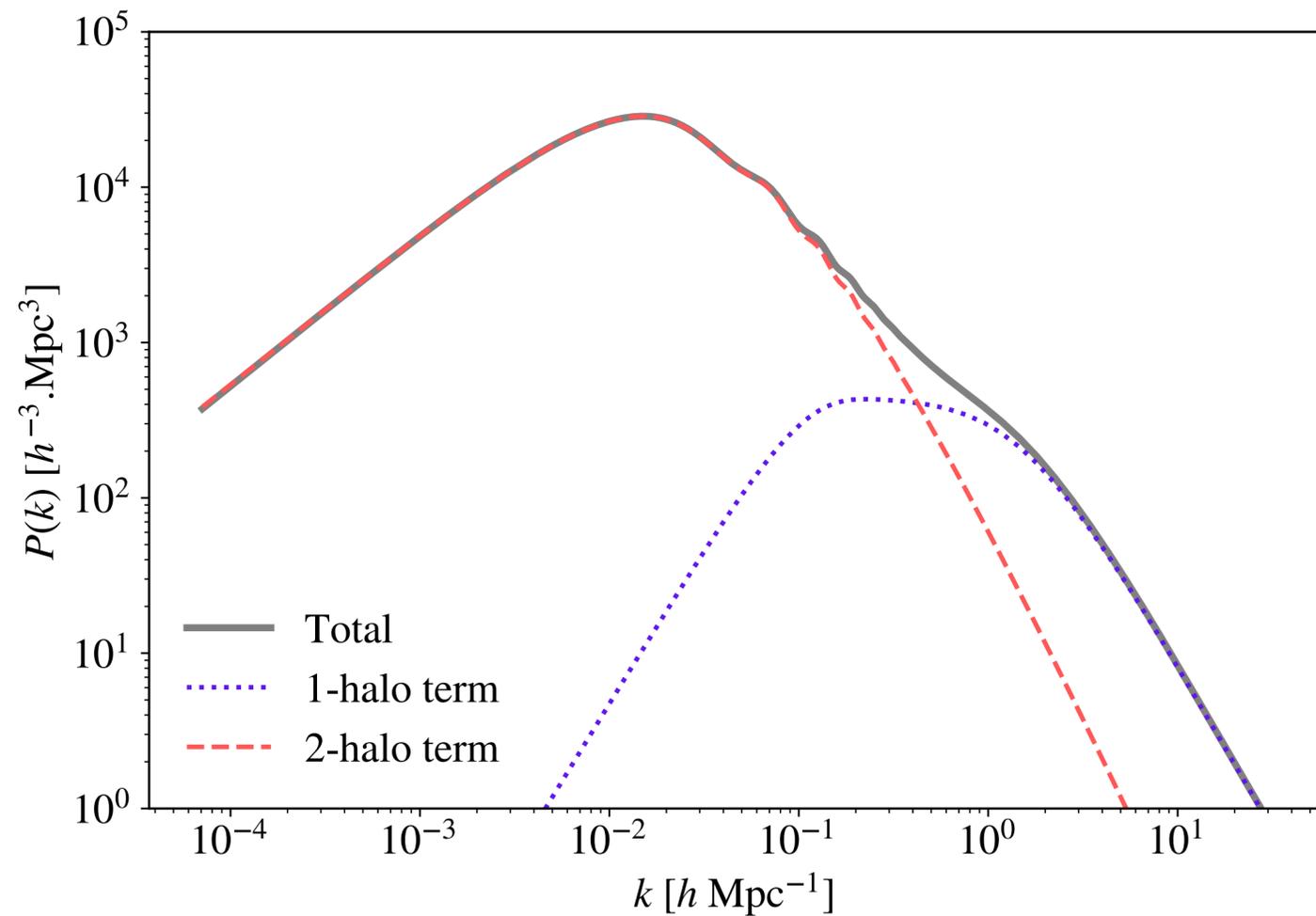


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- ▶ 3 semi-analytic components:
 - **Halo mass function** $n(M)$: distribution of halos in a mass & redshift range
 - **Halo bias function** $b(M)$: how halos cluster relative to matter
 - **Halo profiles**: spherically symmetric and only mass-dependent

Halo model

- ▶ Can estimate the power spectrum
- ▶ Sum of the **one-halo** and **two-halo** term



Power spectrum

$$P(k) = P^{1h}(k) + P^{2h}(k)$$

$$P_{uv}^{1h}(k) = \int_0^\infty W_u(M, k) W_v(M, k) n(M) dM$$

$$P_{uv}^{2h}(k) = P_{lin}(k) \prod_{i=u,v} \left[\int_0^\infty b(M) W_i(M, k) n(M) dM \right]$$

- ▶ $u(r), v(r)$ fields we want to correlate
- ▶ **Fourier transform of the profile**
 - ▶ tSZ: electron pressure profile
 - ▶ Galaxy clustering: HOD
 - ▶ WL: dark matter NFW profile
- ▶ **Halo mass function**
- ▶ **Linear halo bias**
- ▶ **Linear matter power spectrum**

Angular power spectrum

Fourier transform of tracers distributions (θ_C, θ_P)

$$C_{\ell}^{ij,1h} = \int_{z_{min}}^{z_{max}} dz \frac{d^2V}{dzd\Omega} \int_{M_{min}}^{M_{max}} dM \frac{dn(z, M)}{dM} \tilde{u}_{\ell}^i(z, M) \tilde{u}_{\ell}^j(z, M)$$

$$C_{\ell}^{ij,2h} = \int_{z_{min}}^{z_{max}} dz \frac{d^2V}{dzd\Omega} \left[\int_{M_{min}}^{M_{max}} dM \frac{dn(z, M)}{dM} \tilde{u}_{\ell}^i(z, M) b(z, M) \right] \left[\int_{M_{min}}^{M_{max}} dM \frac{dn(z, M)}{dM} \tilde{u}_{\ell}^j(z, M) b(z, M) \right] P_m^L(z, k)$$

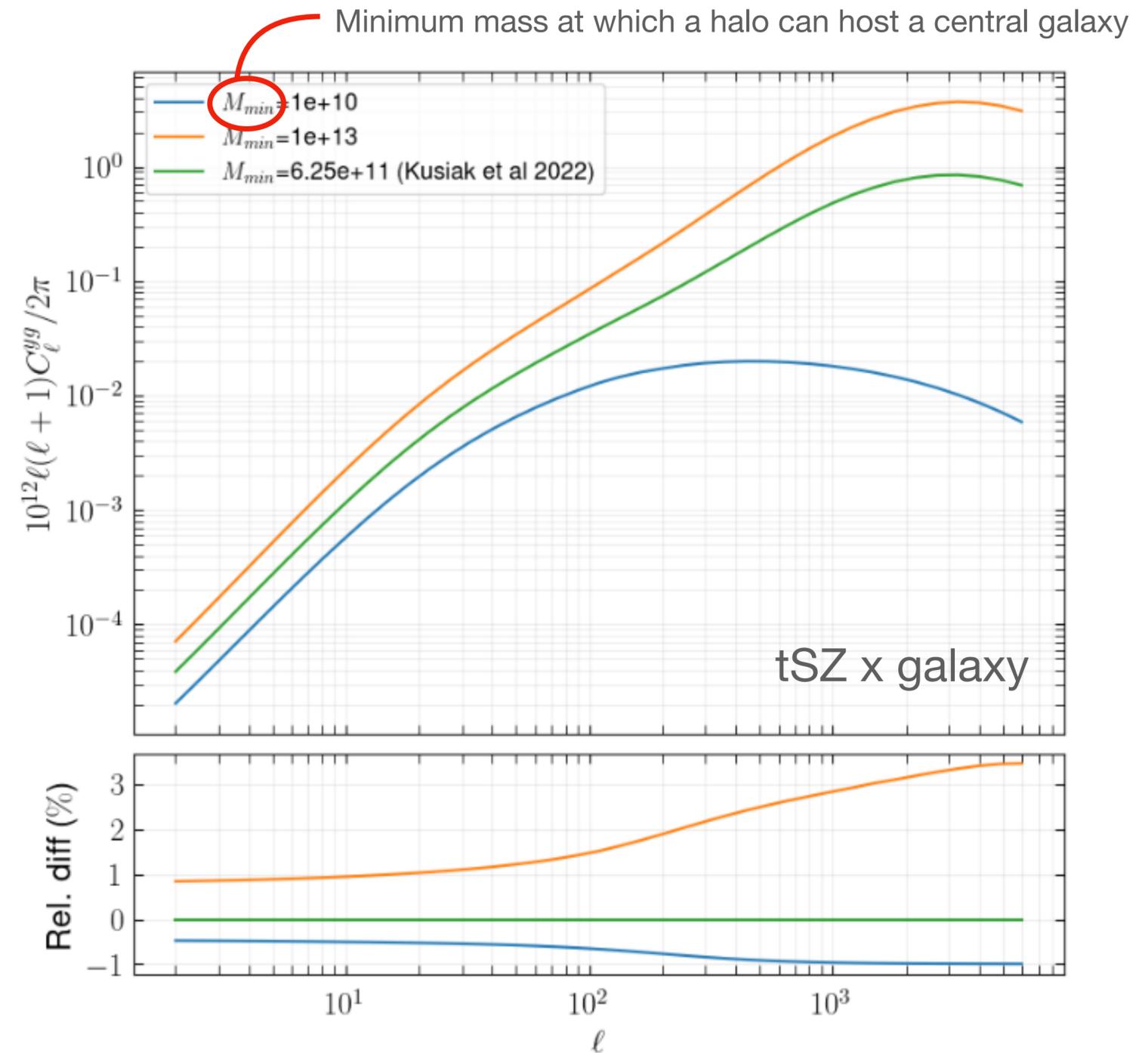
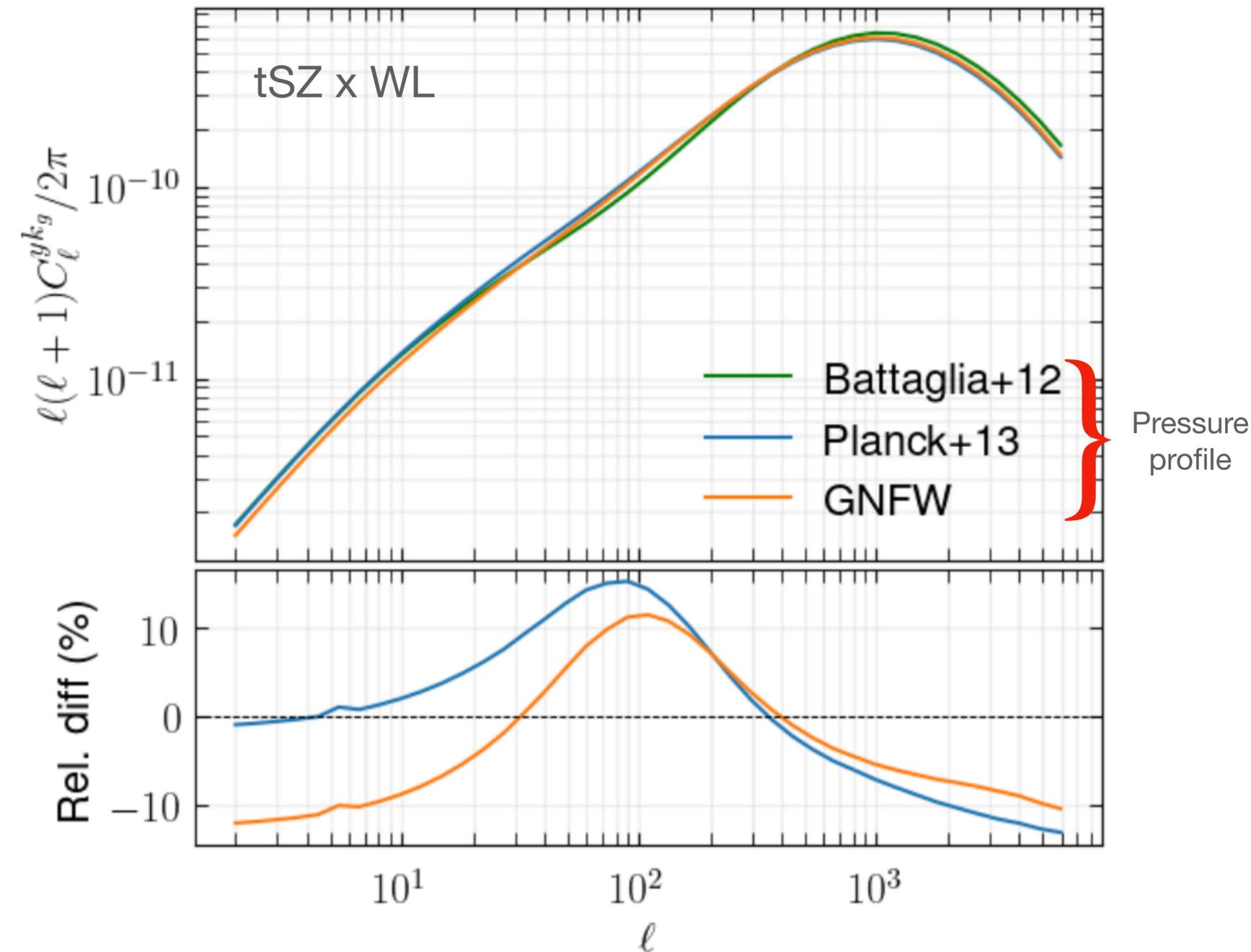
halo mass function (θ_C) :

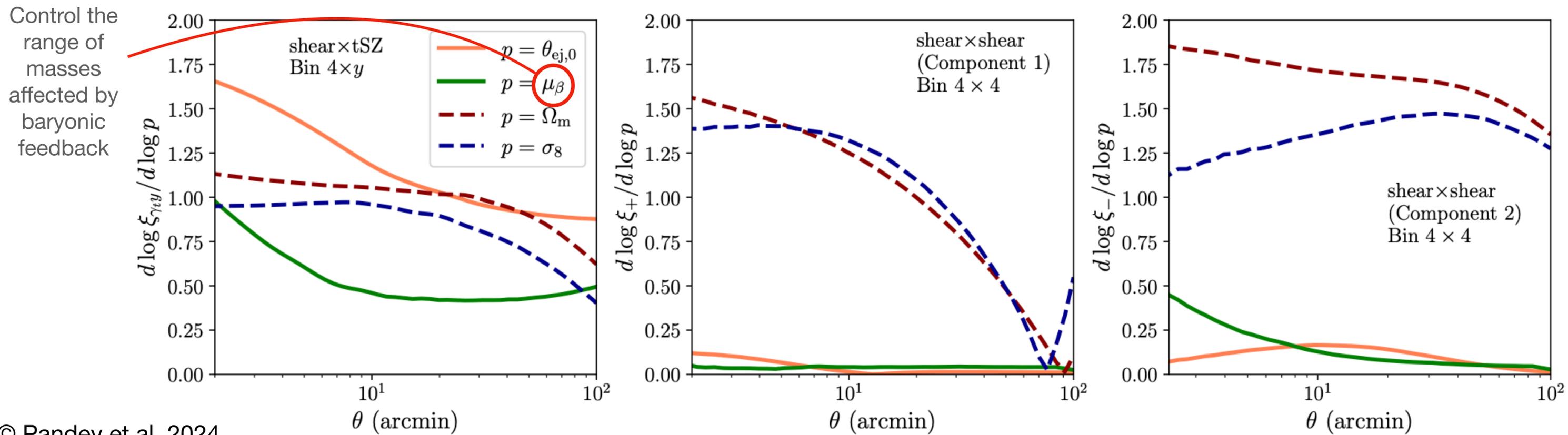
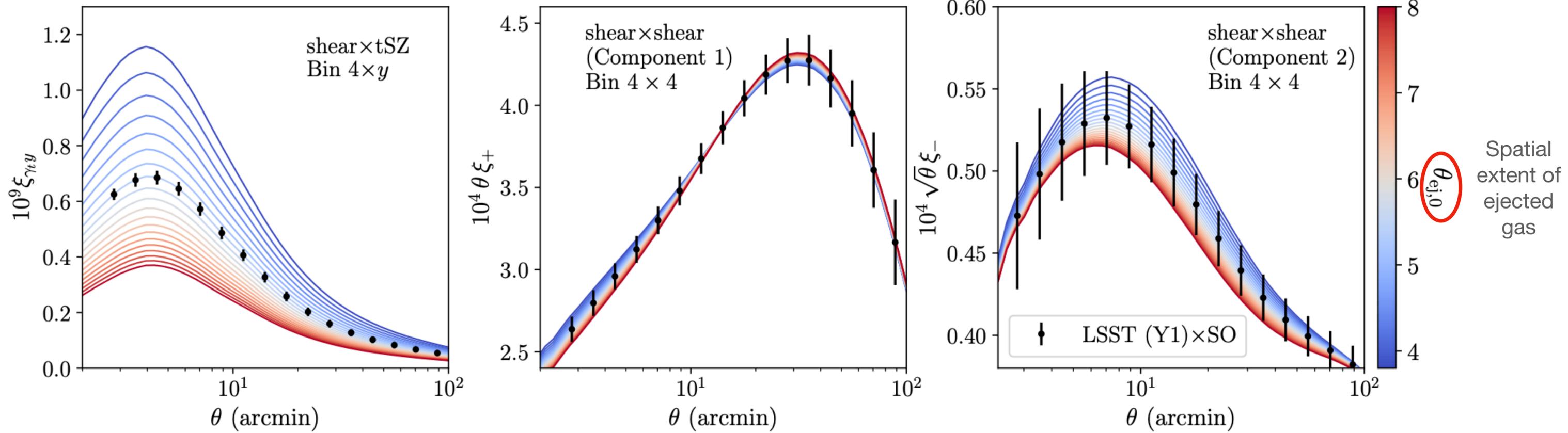
halo bias (θ_C) : $\delta_h = b(z, M)\delta_m$

linear matter power spectrum (θ_C)

- ▶ Parameter to **sample**: **cosmology** ($\Omega_m, w_0, w_a, \dots$), **astrophysics** (HOD & pressure profile)
- ▶ **Choices**: halo mass function, pressure profile
- ▶ Existing codes: **HMx** (Mead+20), **class_sz** (Bolliet+23,24), **godmax** (Pandey+24)

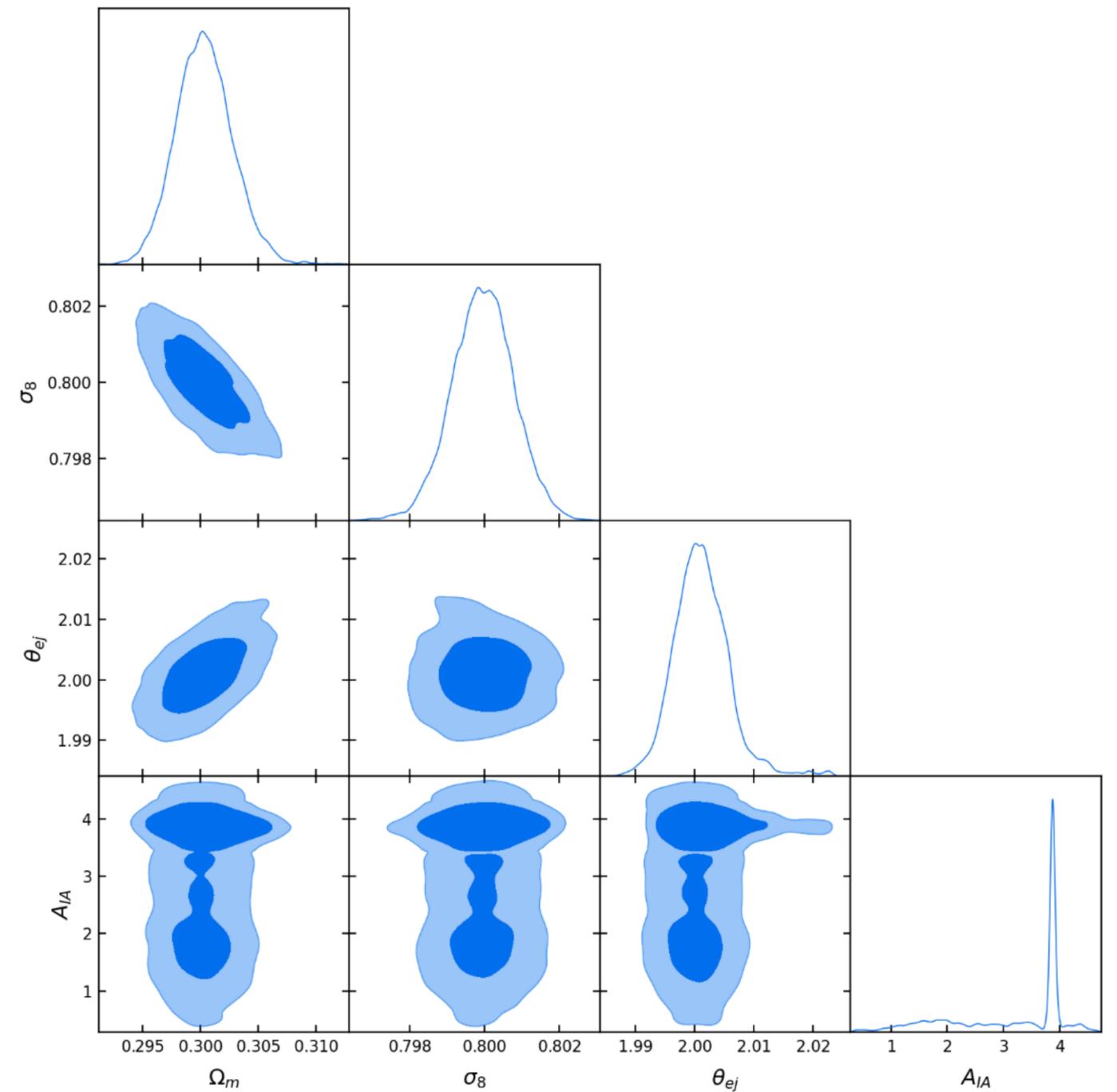
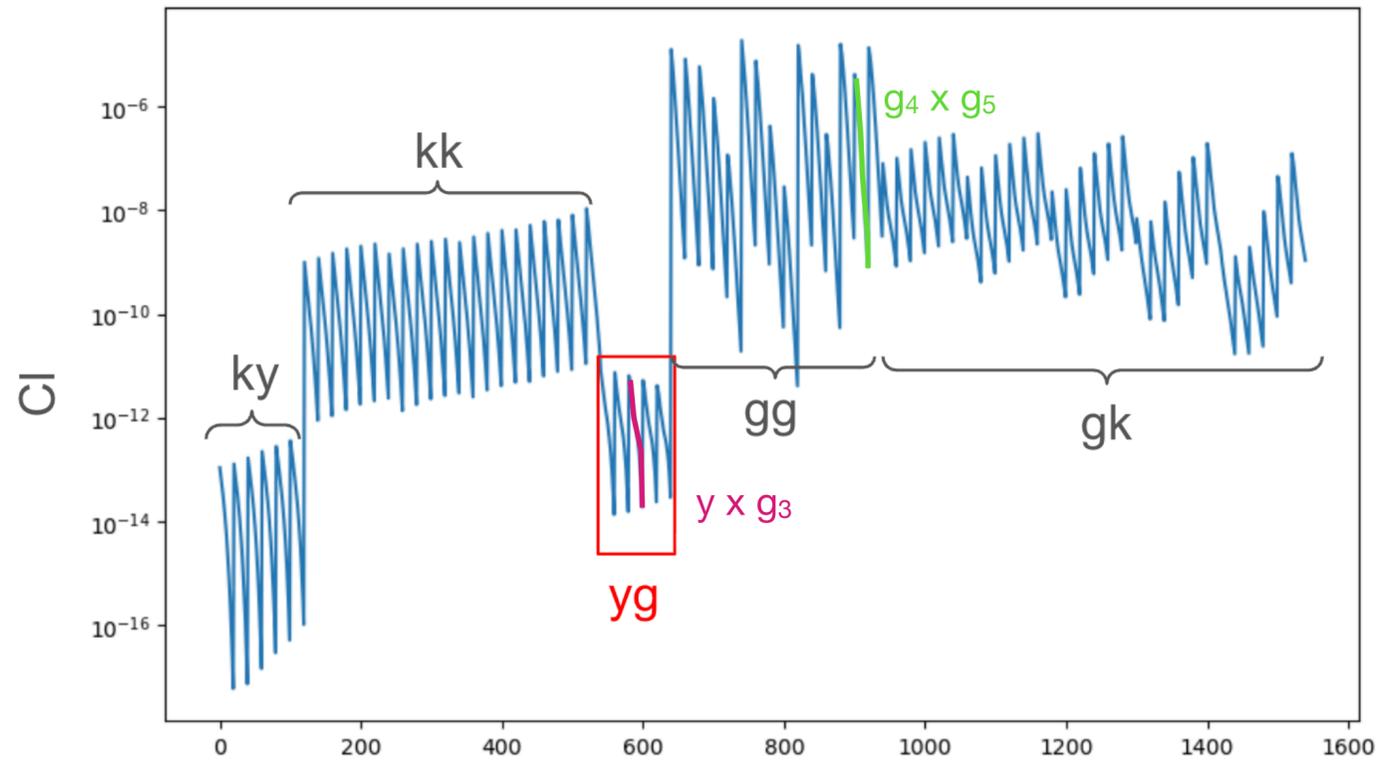
Impact of different parameters





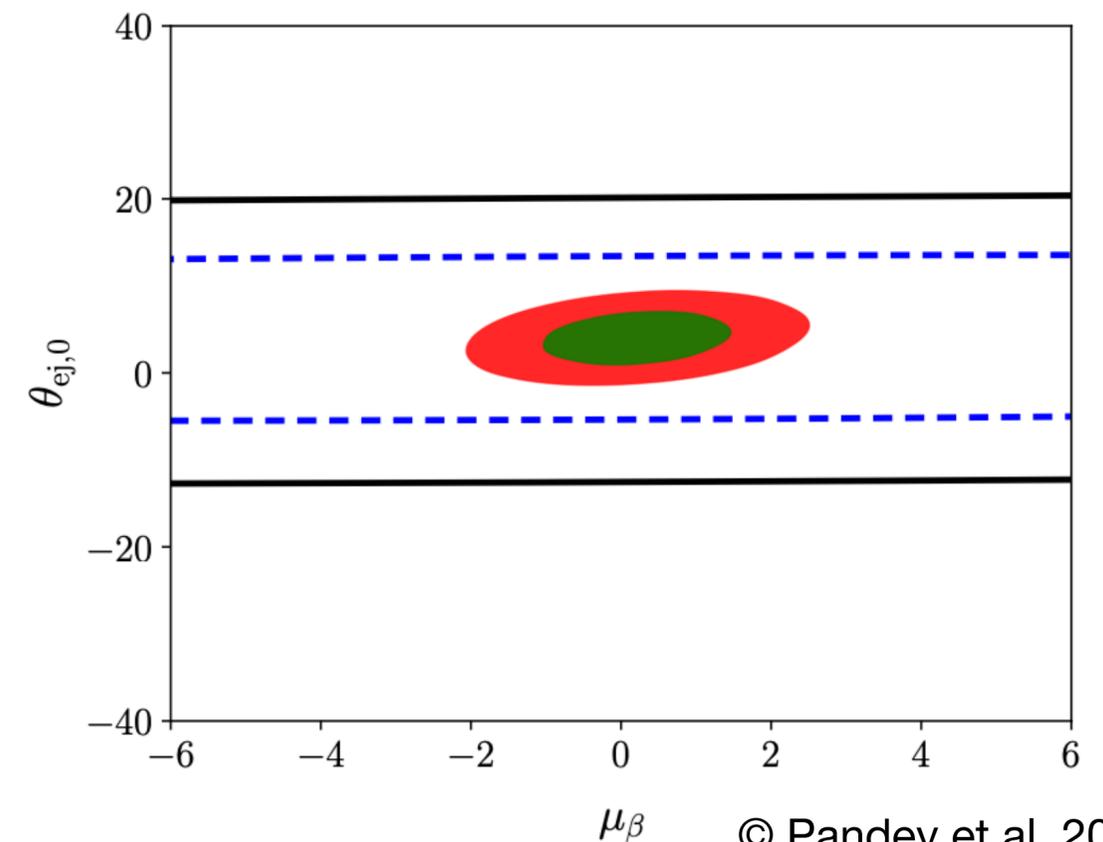
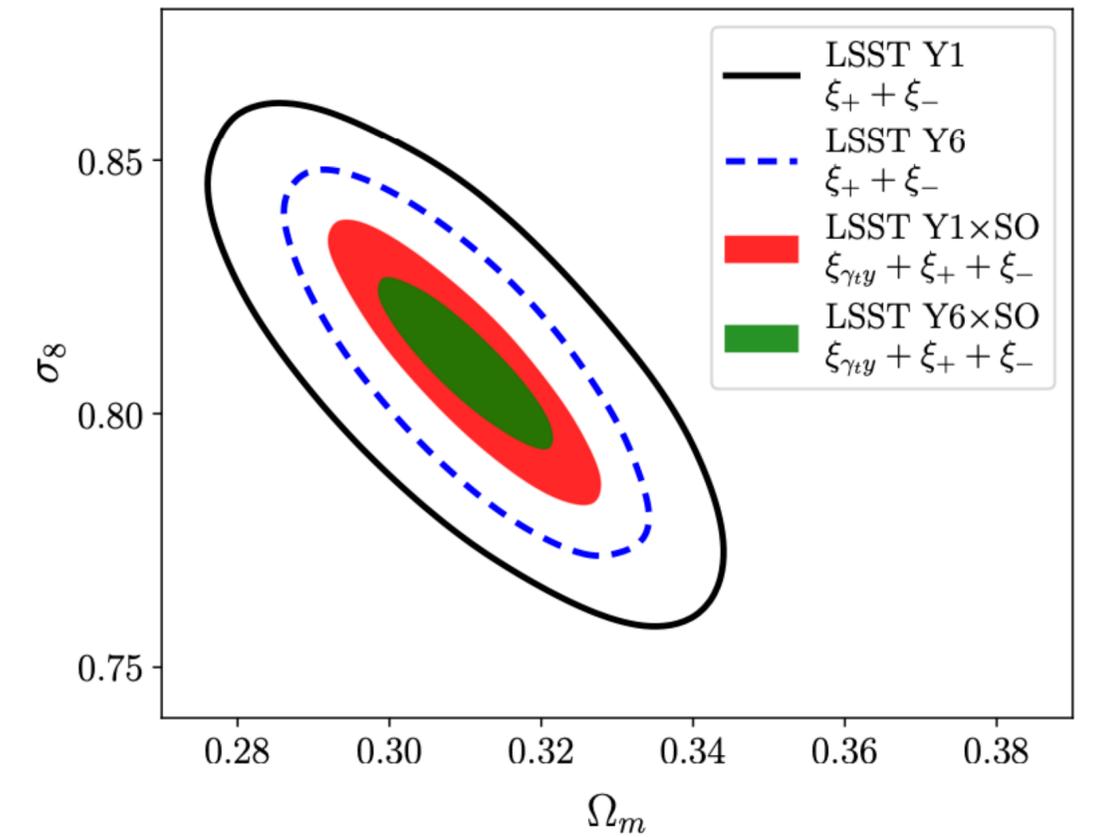
Inference with godmax

- ▶ tSZ x galaxy clustering
- ▶ Mock data from godmax
- ▶ Sampling with NUTS



Conclusions

- ▶ Increase the constraining power with cross-correlation
- ▶ **tSZ** can help to break the **cosmological - astrophysical** degeneracies
- ▶ CMBx with Euclid data



Postdoc projects

- ▶ **Forward model** to estimate the **shear** in Euclid-like images with 
 - ▶ See Ezequiel's talk tomorrow
- ▶ Join the ARGOS consortium to work on the **image reconstruction & calibration** pipeline
- ▶ Join the  to work on the tSZ effect and **cross-correlation**
- ▶ Suite of hydrodynamical **simulations** with a $w_0 - w_a$ **CDM**