Cross-correlation between 2MASS galaxies and the thermal Sunyaev-Zeldovich effect

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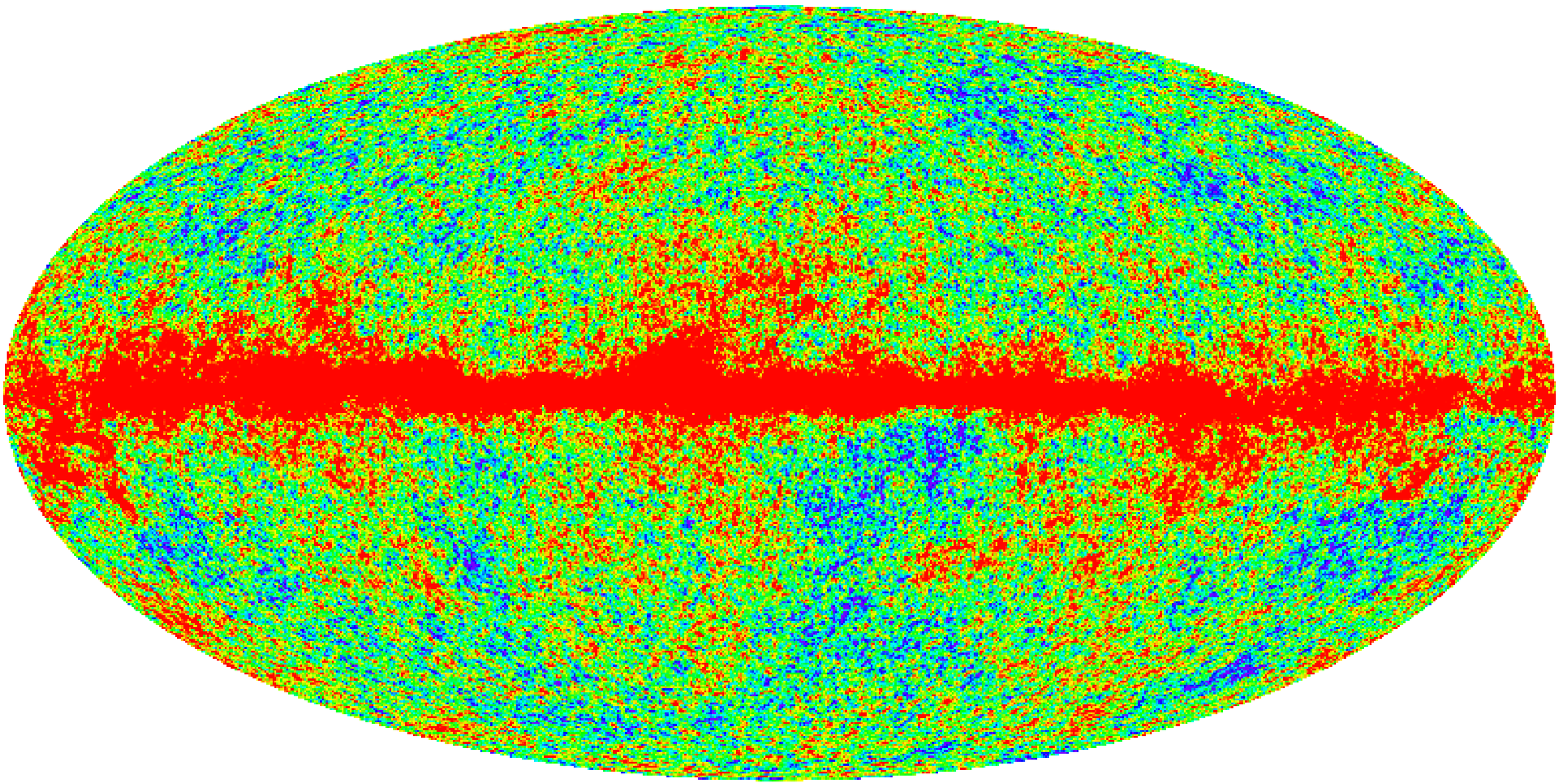
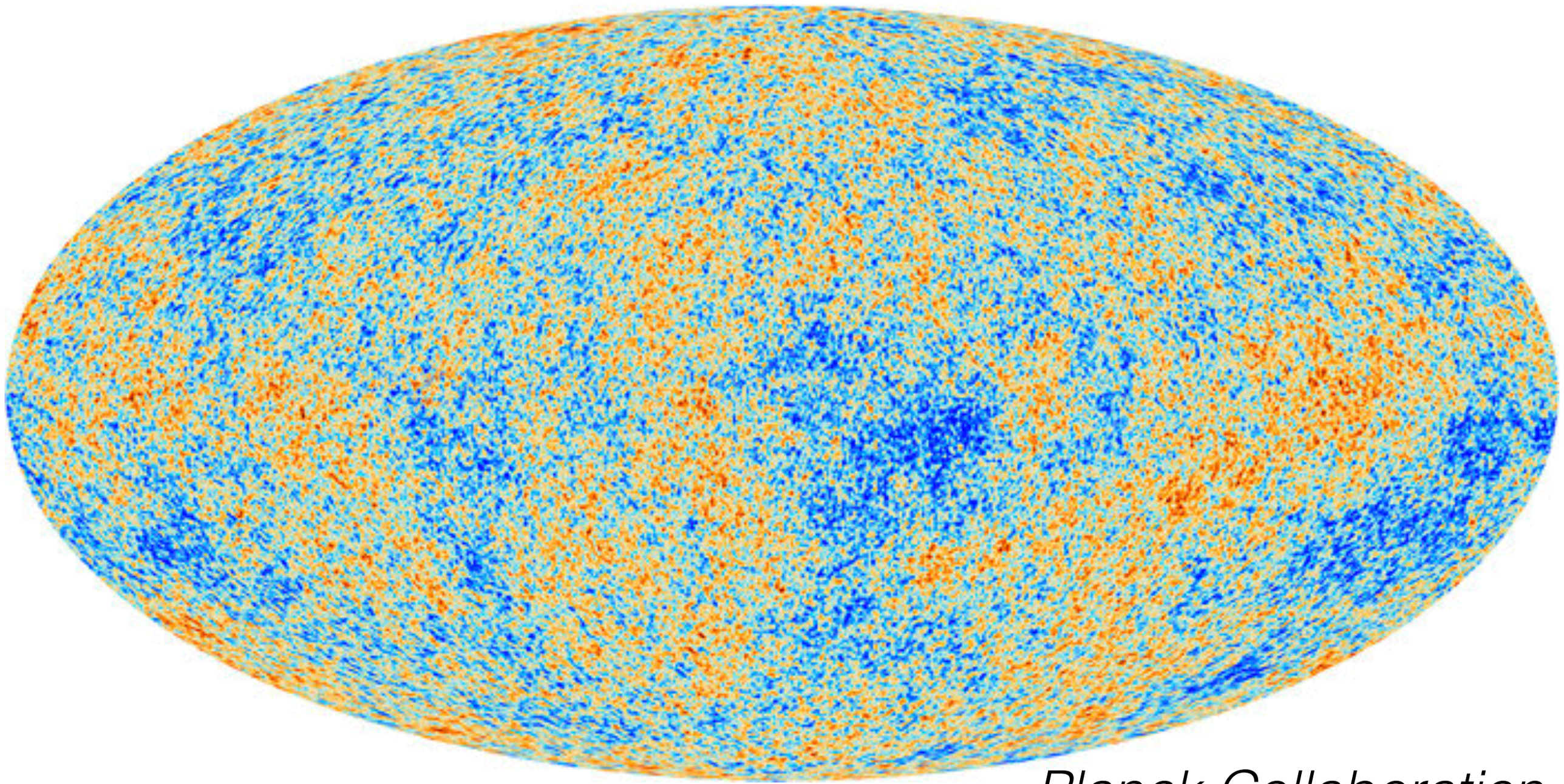
Microwave Data Deliver!



From full-sky temperature maps to…

Full-sky Map of Primordial Fluctuations [z=1090]



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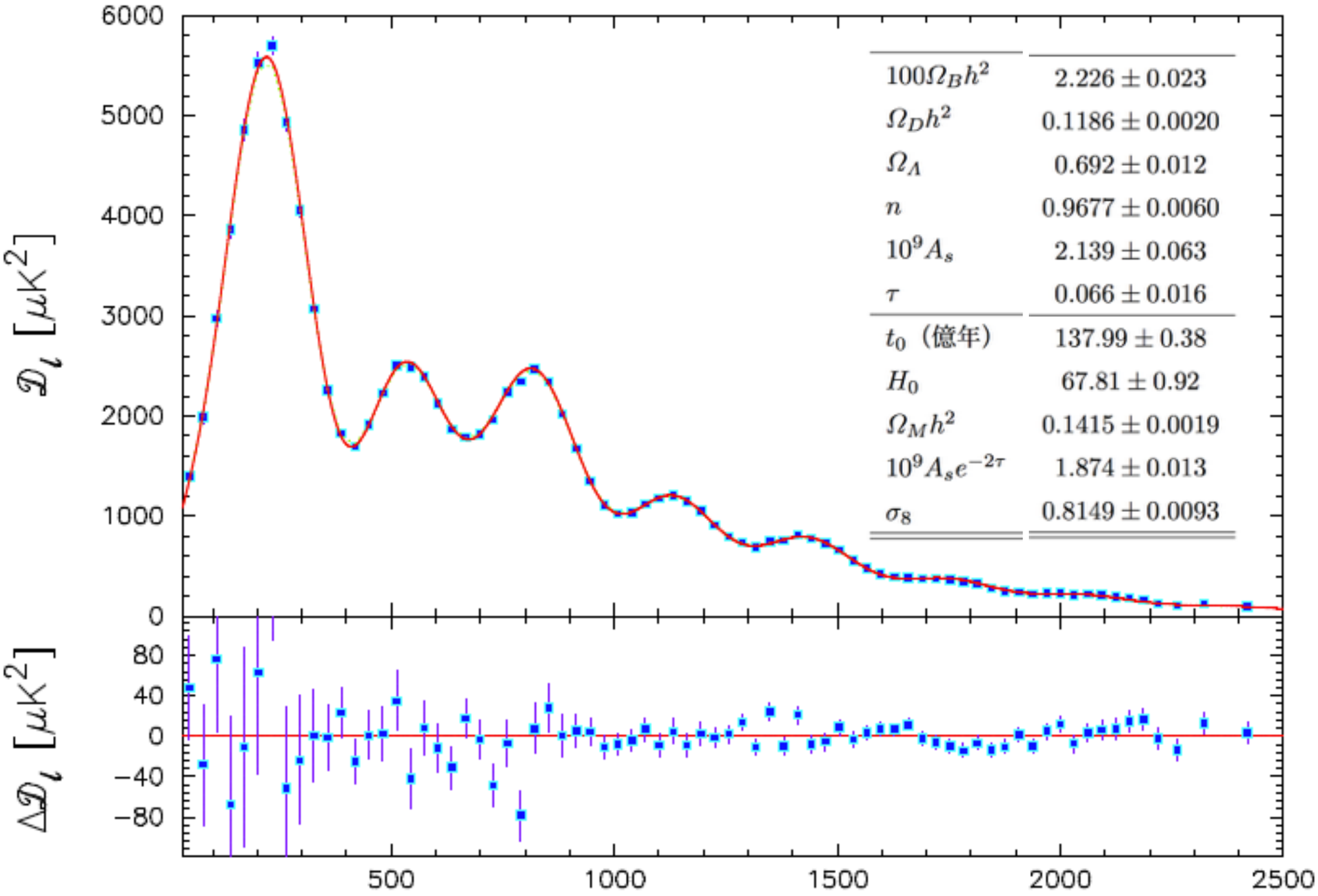
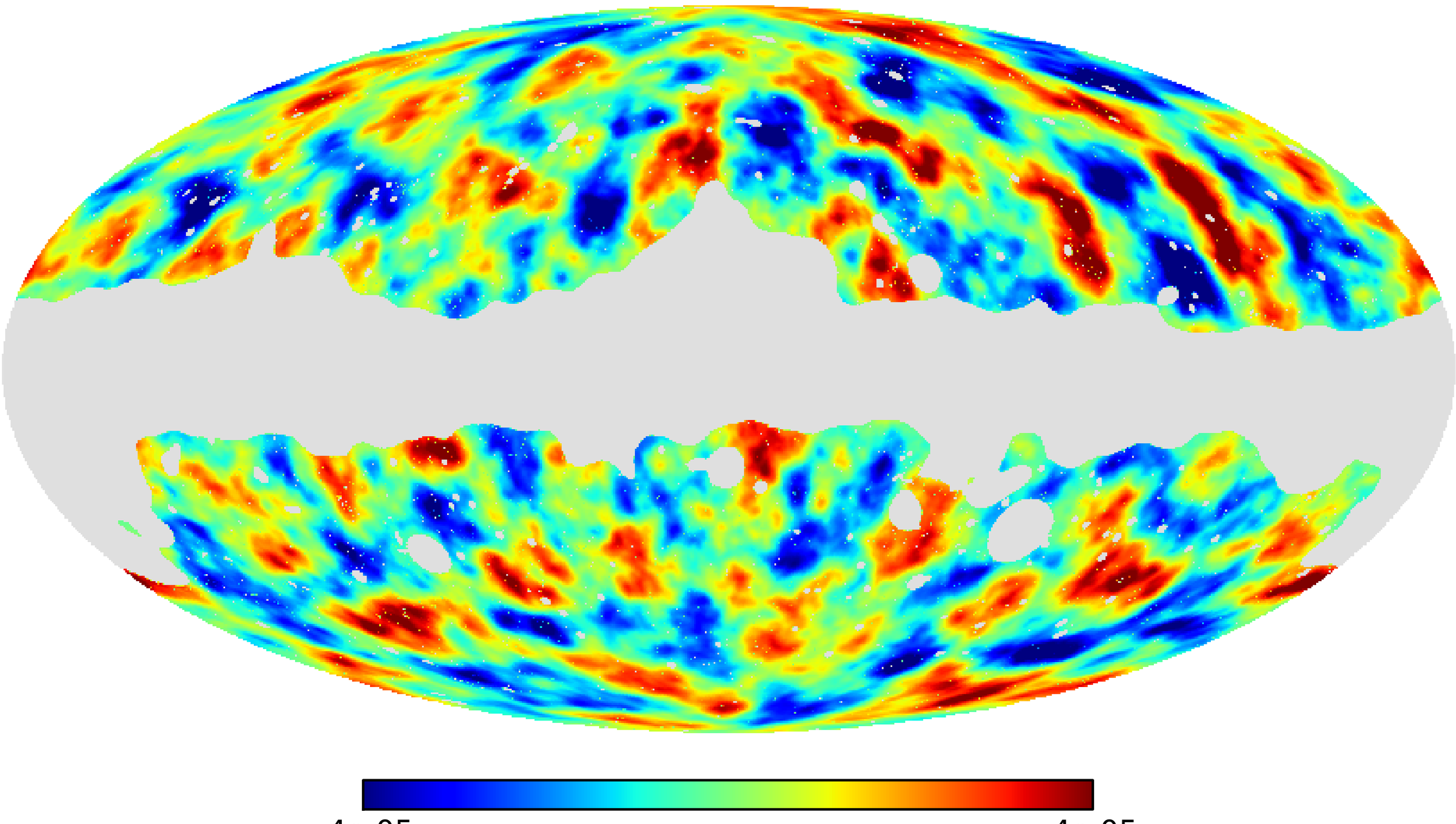
C_l determines LCDM



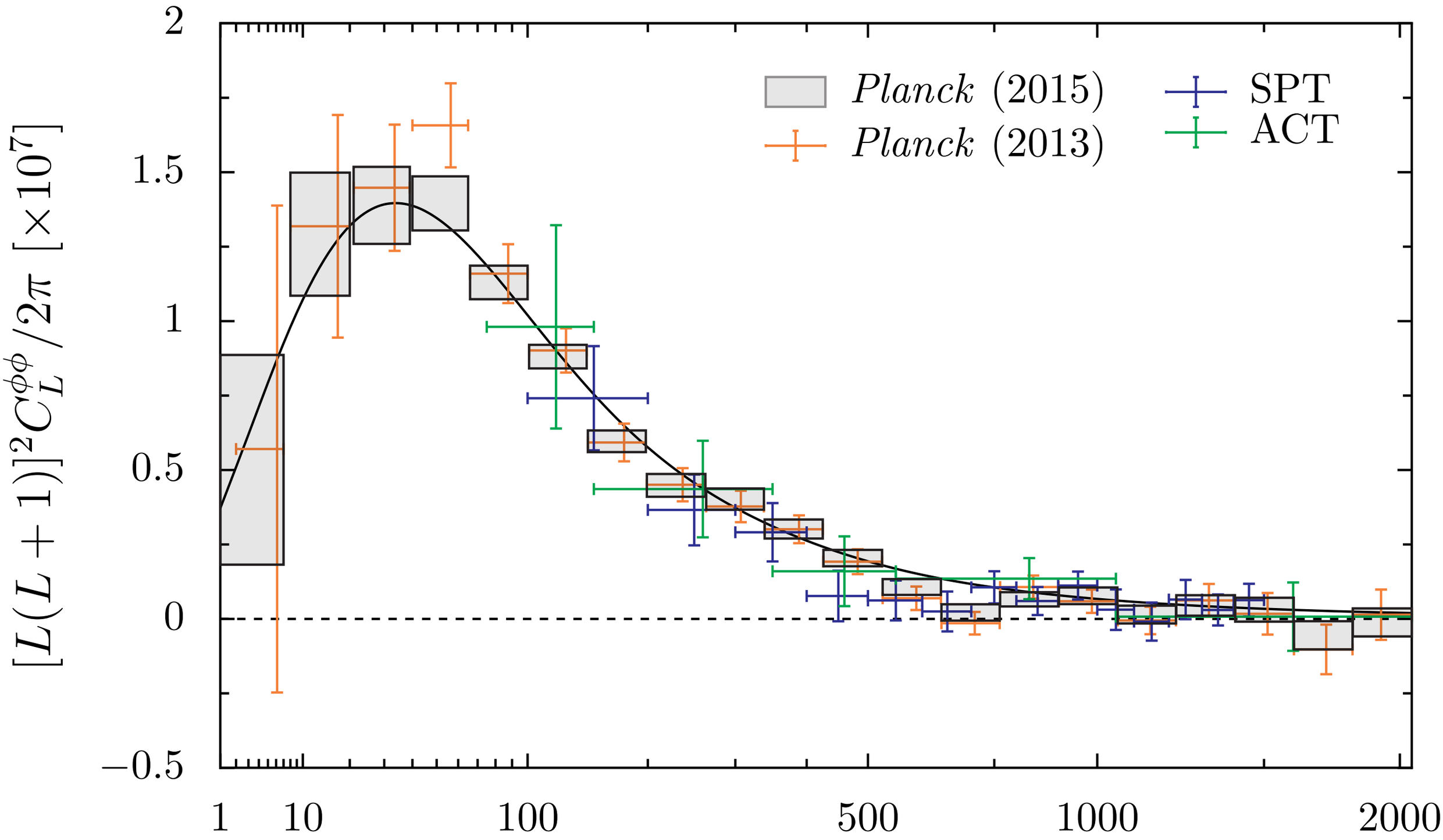
$100\Omega_B h^2$	2.226 ± 0.023
$\Omega_D h^2$	0.1186 ± 0.0020
Ω_A	0.692 ± 0.012
n	0.9677 ± 0.0060
$10^9 A_s$	2.139 ± 0.063
τ	0.066 ± 0.016
t_0（億年）	137.99 ± 0.38
H_0	67.81 ± 0.92
$\Omega_M h^2$	0.1415 ± 0.0019
$10^9 A_s e^{-2\tau}$	1.874 ± 0.013
σ_8	0.8149 ± 0.0093

Full-sky Map of ALL MATTER

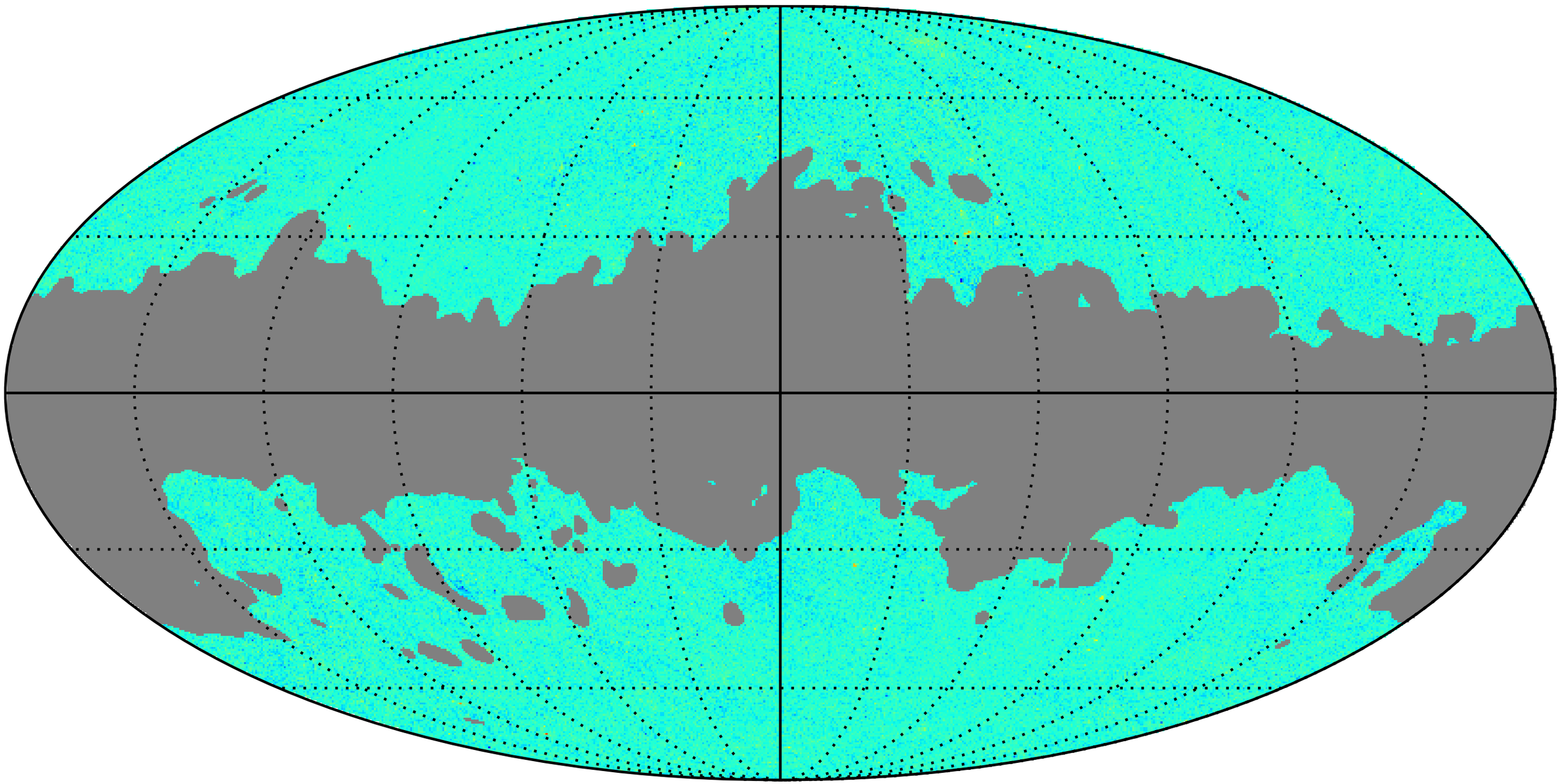
[z~0.5-3]



The Same LCDM fits!



Full-sky Map of ALL HOT GAS [z<1]



The thermal Sunyaev-Zel'dovich (tSZ) Effect

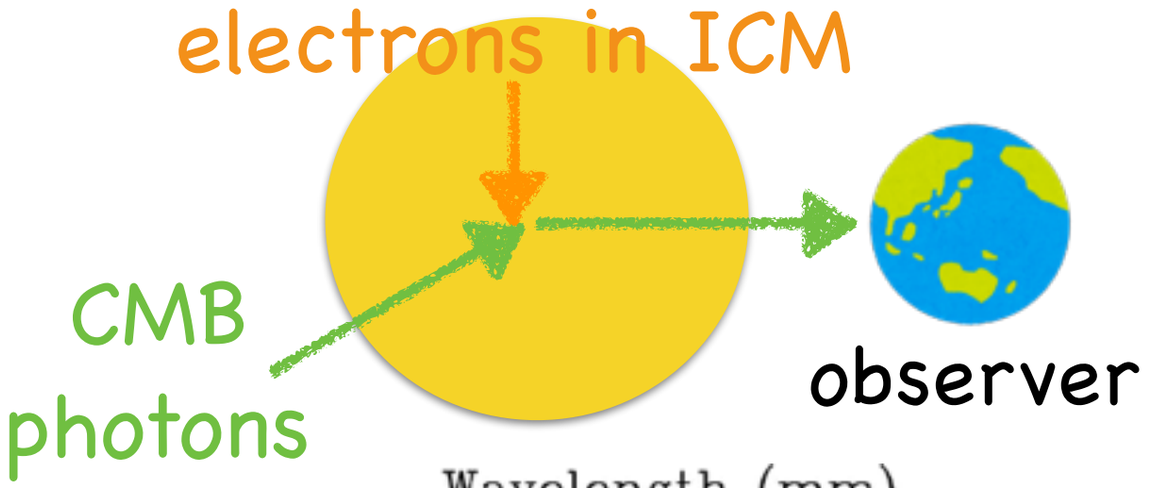
(Sunyaev & Zel'dovich 1972)

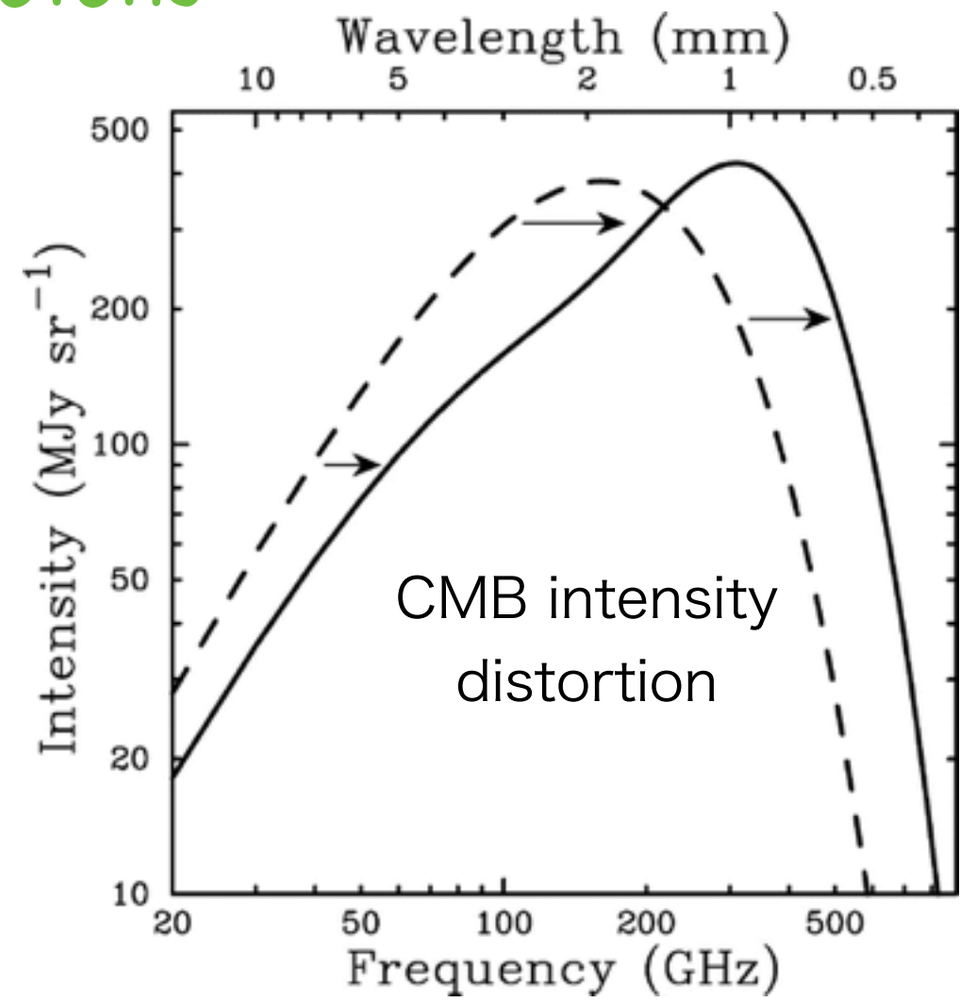
- Cosmic microwave background (CMB) photons are inverse Compton scattered by energetic electrons in ICM

- Characterized by the Compton-y parameter

$$\frac{\Delta T_{\rm CMB}}{T_{\rm CMB}} = f_\nu(x) \left(\frac{k_B \sigma_T}{m_e c^2} \right) \int n_e(l) T(l) dl$$

Compton-y





(Carlstrom et al. 2002)

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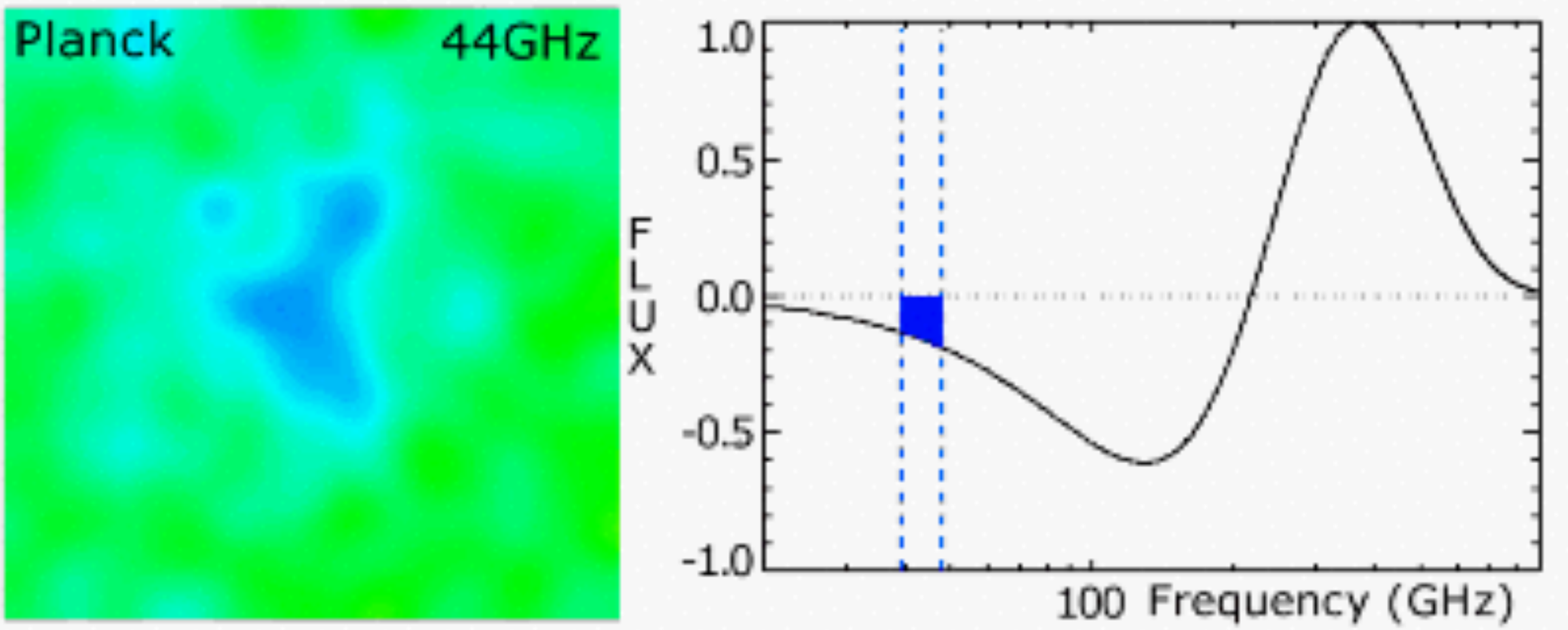
Thermal SZ (tSZ) Effect

- The unique frequency dependence of tSZ: we can make a map of Y_{tSZ}



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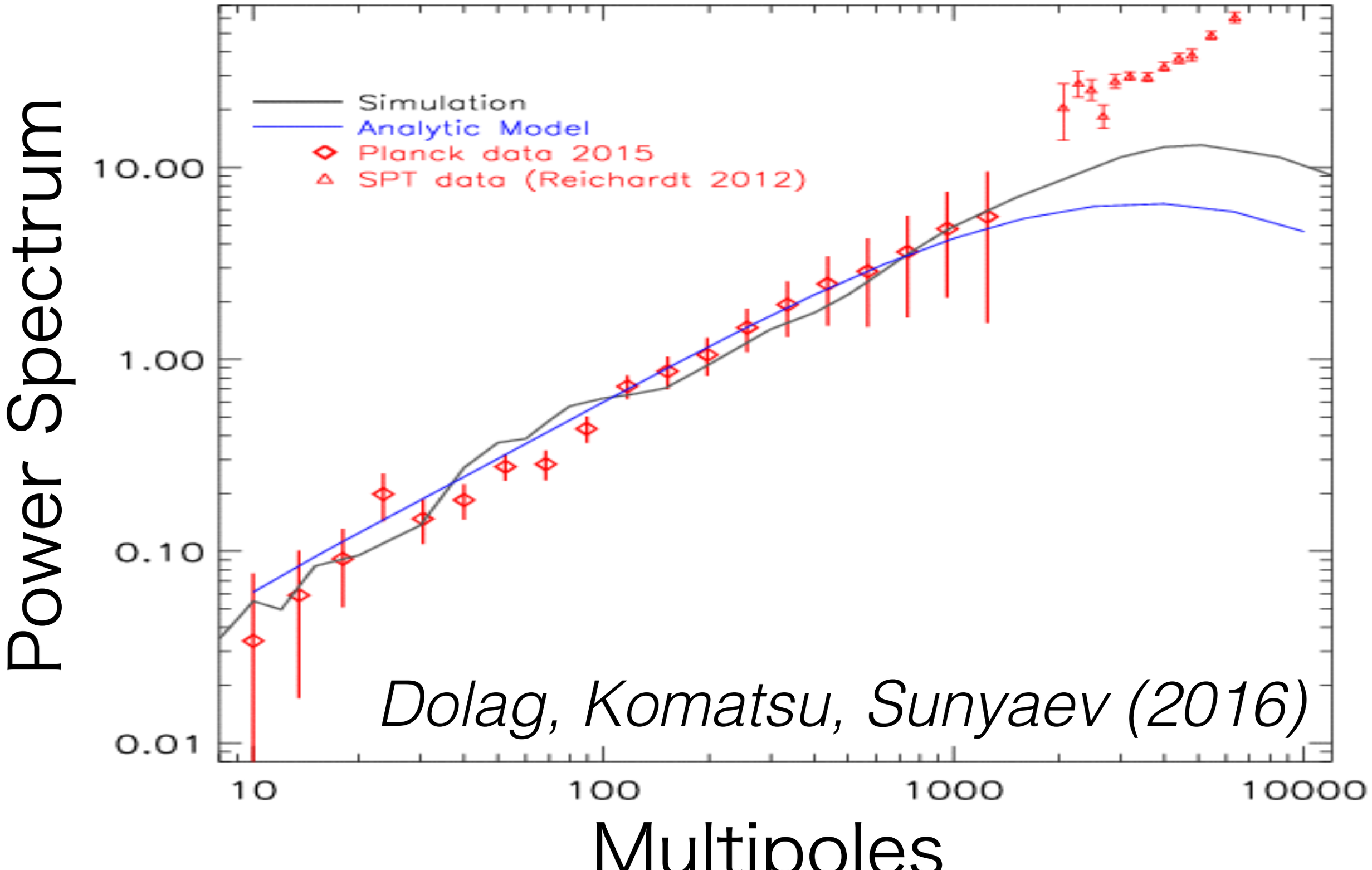

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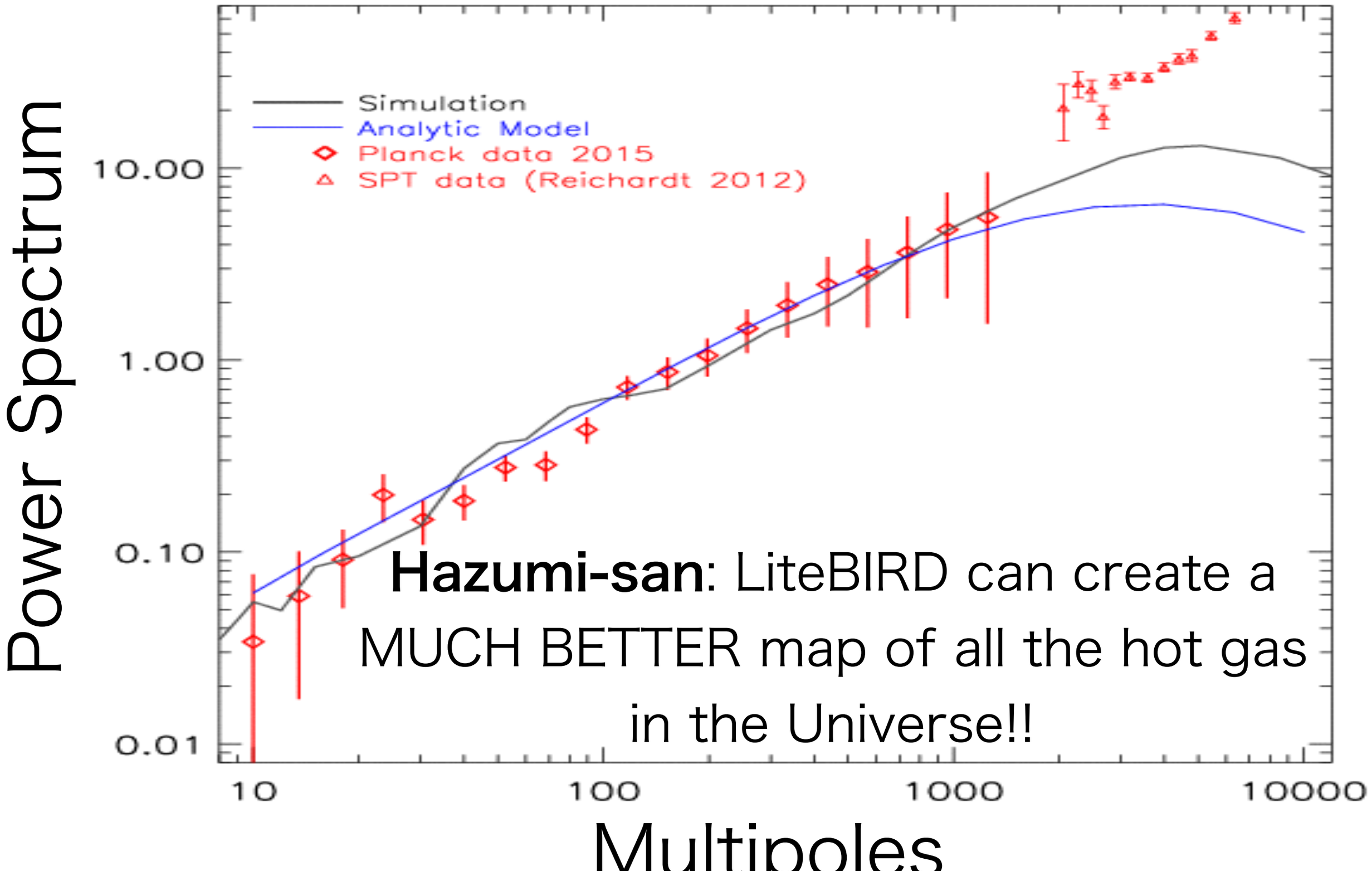


Hazumi-san: LiteBIRD can create a MUCH BETTER map of all the hot gas in the Universe!!

Then What?

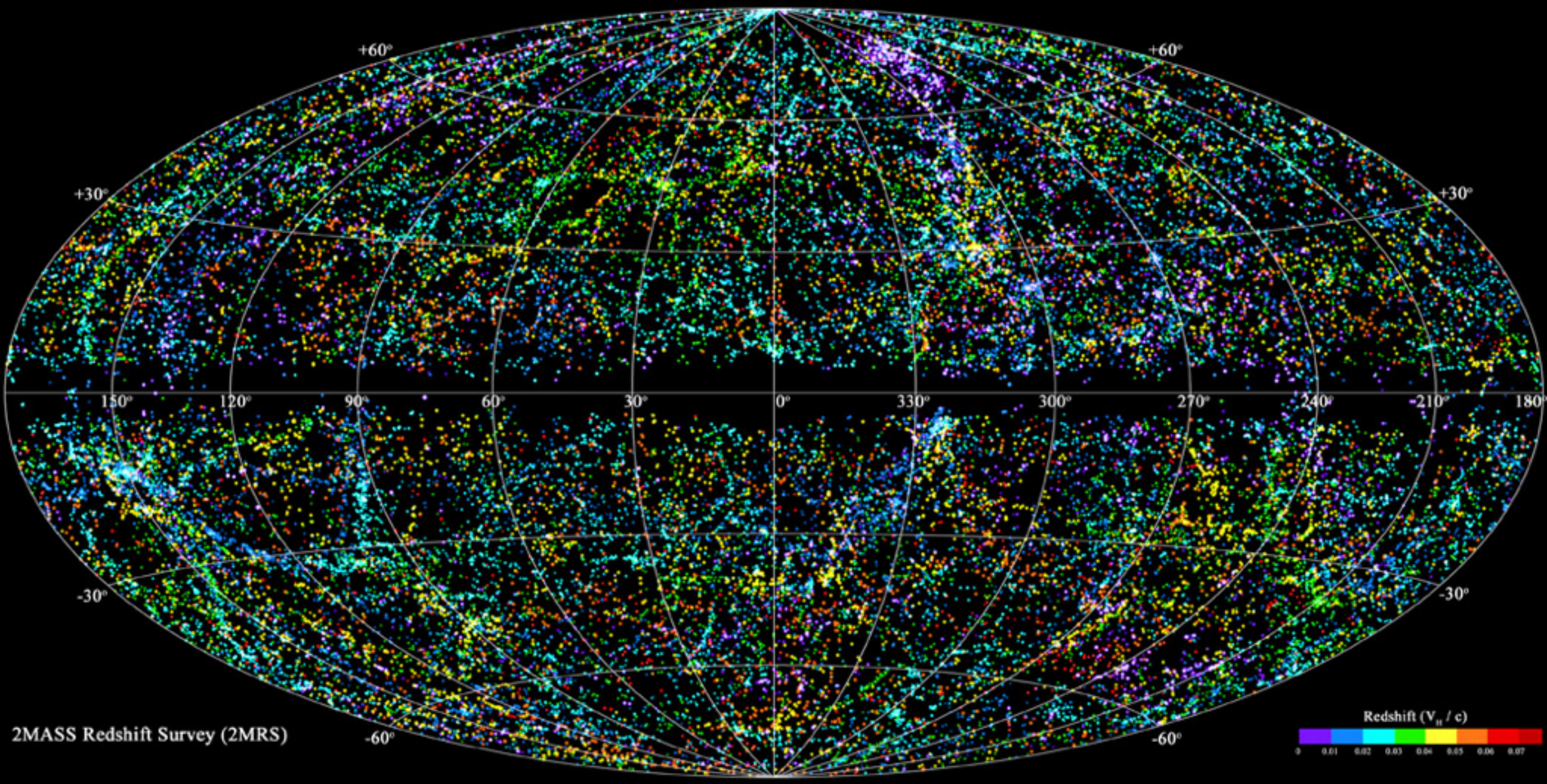
Then What?

Tomography to get

three-dimensional distribution of gas

=> Cross-correlation

This work: tSZ-2MASS cross correlation



- Go to **local universe**!
  - median z~0.03 (~0.3 for CMB lensing, ~0.1 for SDSS)

New Research Direction

- Looking deeper into our local neighborhood!
  - “Cosmology in our backyard”

2MASS redshift survey (2MRS)

(Huchra et al. 2012)

- ~43,500 galaxies with spectroscopic redshifts over the full sky

- redshift distribution peaks at z ~ 0.03

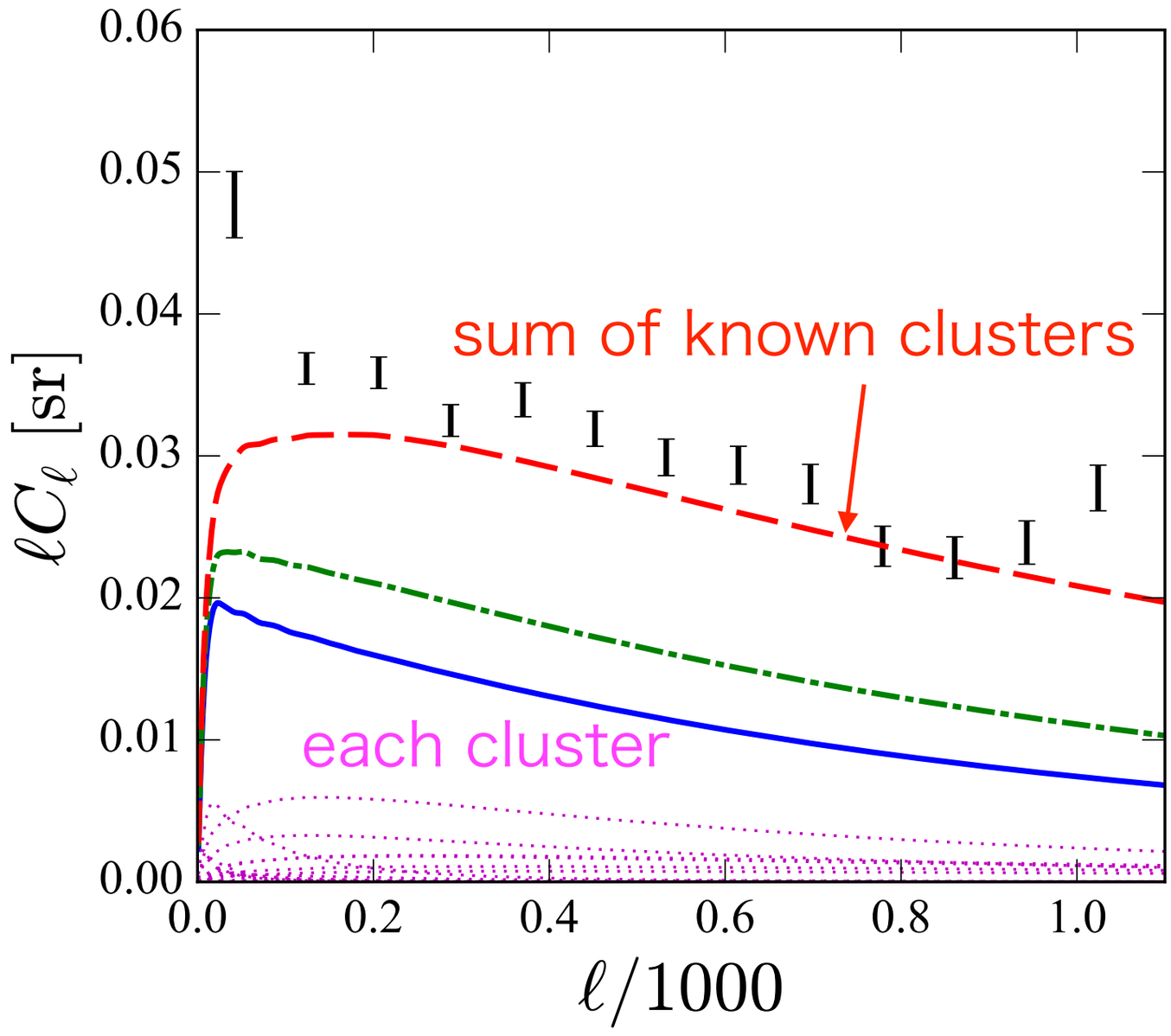
2MASS redshift survey (2MRS)

(Huchra et al. 2012)

- What can we learn?
  - **Structure formation in our local neighborhood**
    — How do local galaxies trace gas?
- Provide great constraint on “the local universe simulation” (e.g. Dolag, Komatsu & Sunyaev 2016; Nuza, Dolag & Saro 2010)
  - constraint of the velocity field of local galaxies
    => kinetic SZ!

2MRS auto-power spectrum

- Surprisingly, significantly detected even at large multipoles
  - despite ~1 galaxy/deg^2
- It is almost completely explained by the contributions from known groups and clusters
  - good for tracing SZ!



(Ando et al. in prep.)

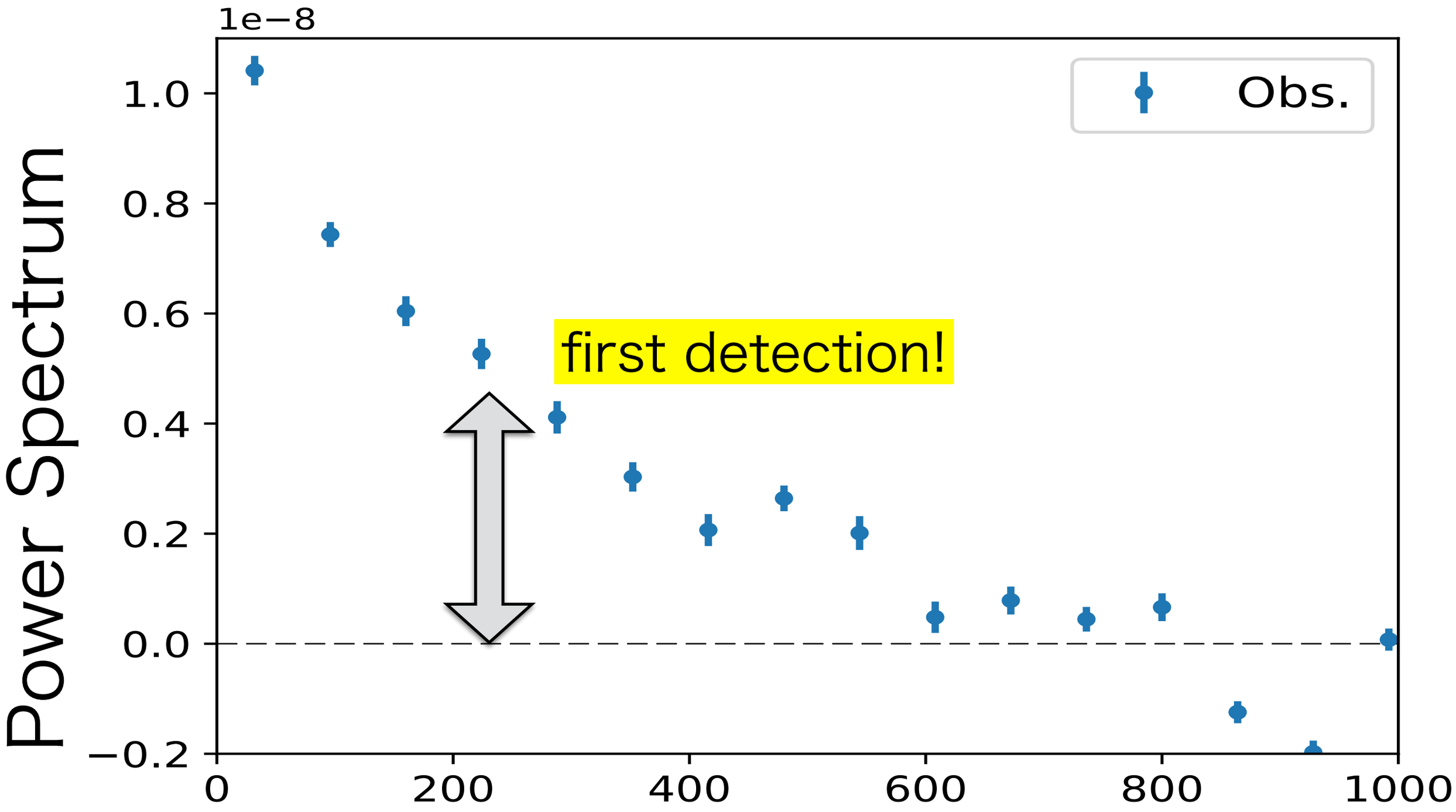
tSZ-2MRS cross-power spectrum

- Calculate the cross correlation between Compton-Y map and 2MRS galaxy density map using the code *anafast* (Gorski et al. 2005)

- Error estimation

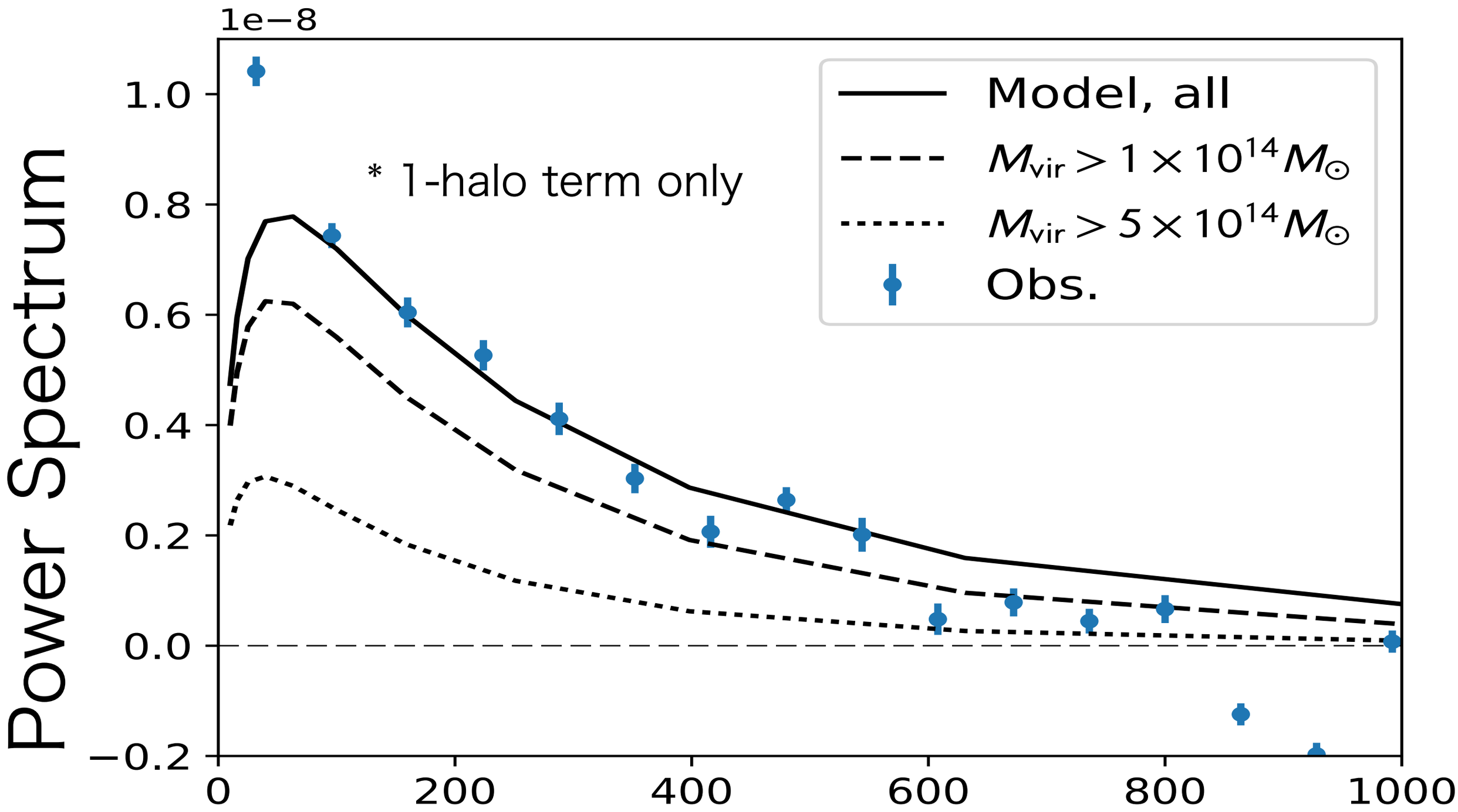
  - generate 100 mock random galaxy catalog and utilize the variance of the tSZ-random catalog cross power spectrum as the statistical error

tSZ-2MRS cross power spectrum



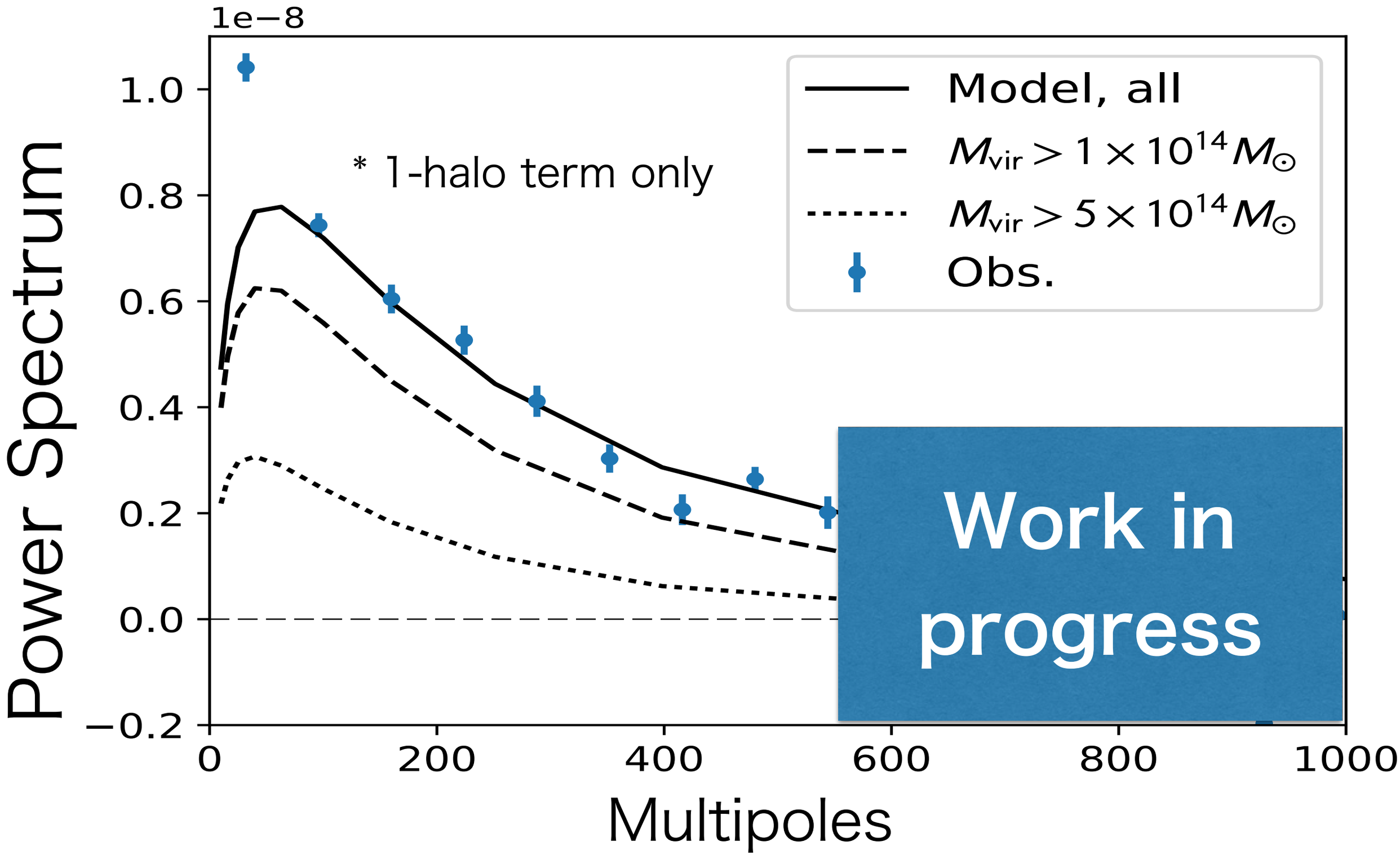
- detected at S/N >10!

tSZ-2MRS cross power spectrum



- model well reproduce observation at l < 600

tSZ-2MRS cross power spectrum



- model well reproduce observation at l < 600

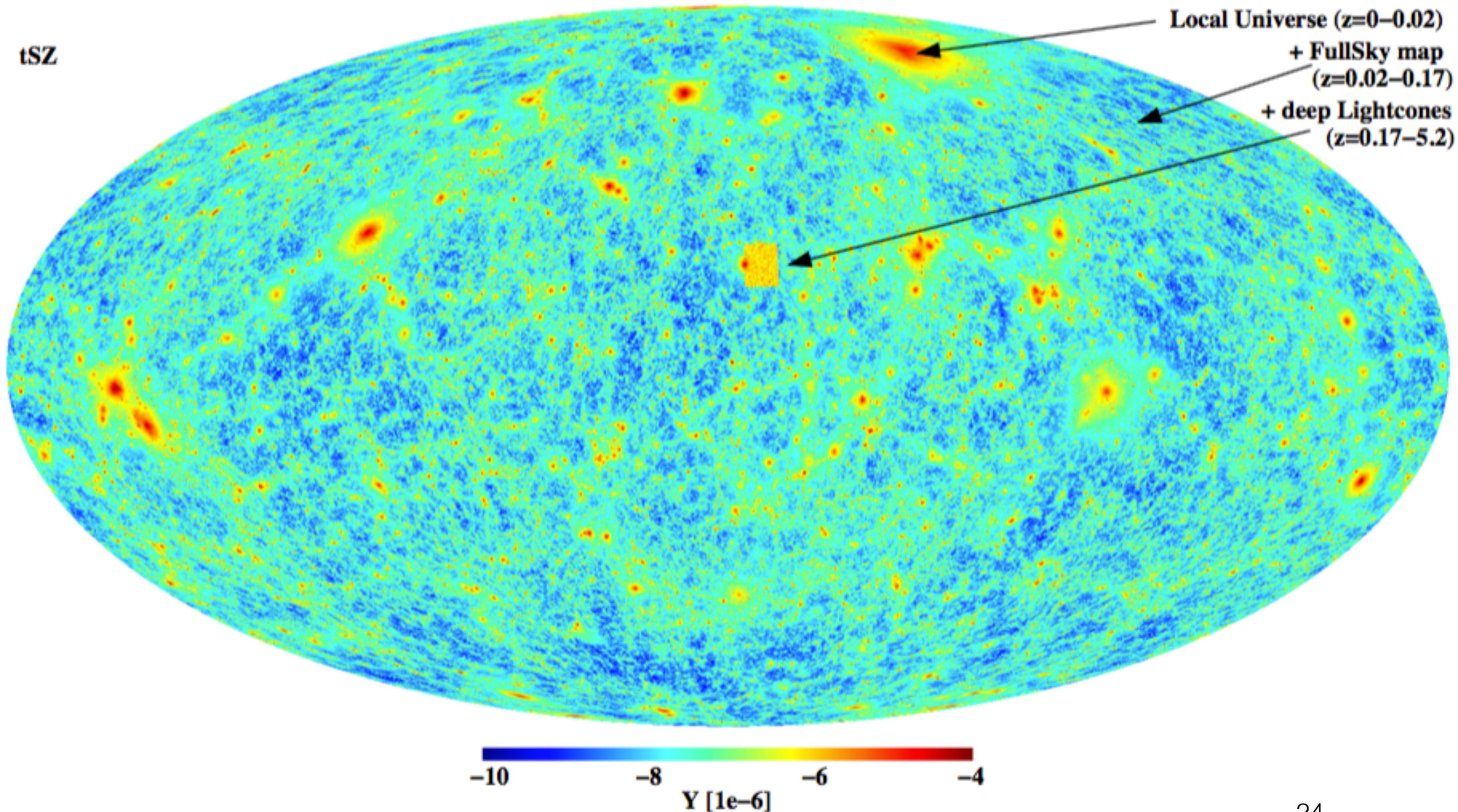
Summary

- Microwave background data deliver three gold mines: primordial fluctuations, all mass in the Universe, and **all hot gas in the Universe**!

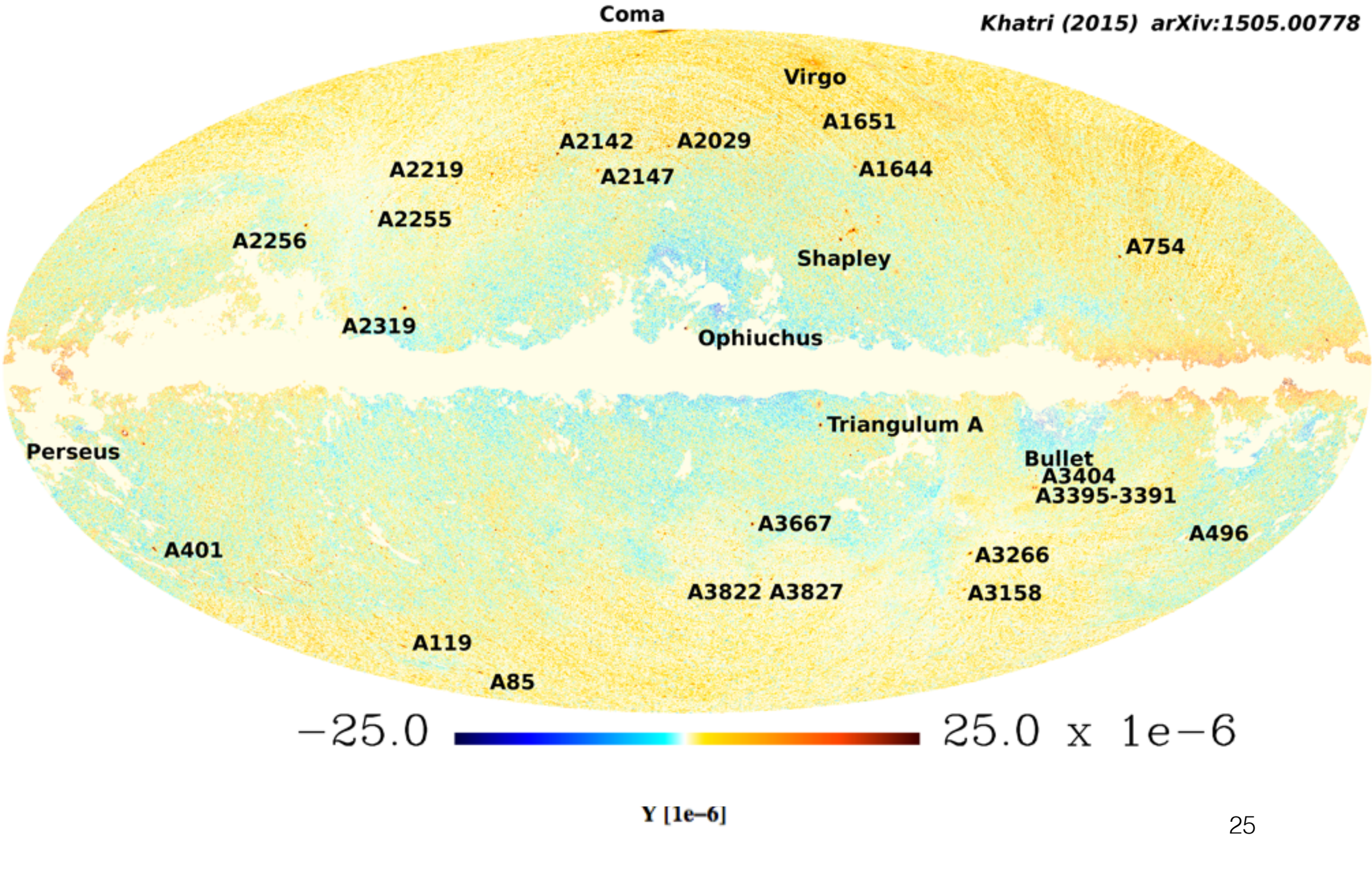
- First measurement of the tSZ x 2MASS power
  - signal detected! (interpretation in progress)
  - will provide good constraint on the local universe cosmology, and beyond…

“The local universe simulation”

Dolag, Komatsu, Sunyaev (2016)



“The local universe simulation” reproduces the observed structures pretty well



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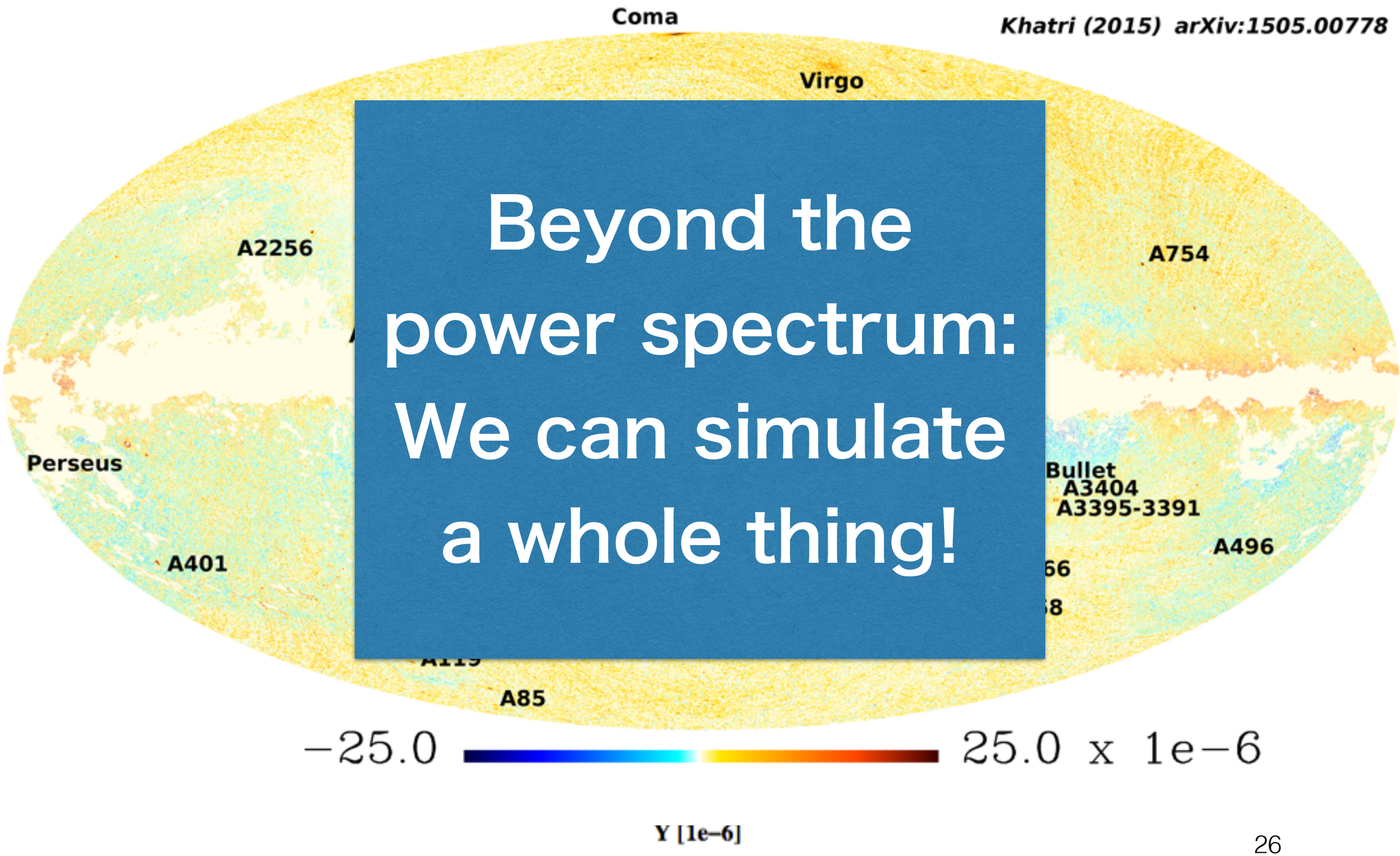

Beyond the power spectrum: We can simulate a whole thing!

Appendix

parameters and model formulation

Cosmological parameters (Planck TT+lowP+lensing)

$$\Omega_m = 0.308,\ h = 0.6781,\ \Omega_b h^2 = 0.02226,\ \Omega_{\rm de} = 1.0 - \Omega_m,\ w = -1.0$$

HOD parameters (MCMC fitting to 2MRS auto)

$$r_{g,max}/r_{200} = 6.992,\ r_{s,g}/r_s = 0.6193,\ \log_{10} M_0 = 11.83,\ \log_{10} M_1 = 11.98,\ \alpha = 0.8533$$

Theoretical models

$$C_l^{gg} = \int dz \frac{dV}{dz d\Omega} \int dM \frac{dn}{dM} \left\{ \frac{W_g(z)}{\chi^2} \right\}^2 P_g\left(\frac{l}{\chi}, z\right)$$

$$C_l^{yy} = \int dz \frac{dV}{dz d\Omega} \int dM \frac{dn}{dM} |\tilde{y}_l(M, z)|^2$$

$$C_l^{gy} = \int dz \frac{dV}{dz d\Omega} \int dM \frac{dn}{dM} \left\{ \frac{W_g(z)}{\chi^2} \right\} \sqrt{P_g\left(\frac{l}{\chi}, z\right)} |\tilde{y}_l(M, z)|$$

data analisys

- SZ
  - 30% mask + point source mask
  - first half と last half の cross correlation を取る
- 2MRS
  - 2MRS_deltag_nside512.fits (by Aurélien)
  - shot noise: random map を生成して見積もった
- SZ x 2MRS
  - 2MRS と同じ Ngal で random map を100個作る
  - SZ x random map の cross を計算, それらの variance を error とする
- mask deconvolution
  - MASTER algorithm