A search for missing baryons in the cosmic-web

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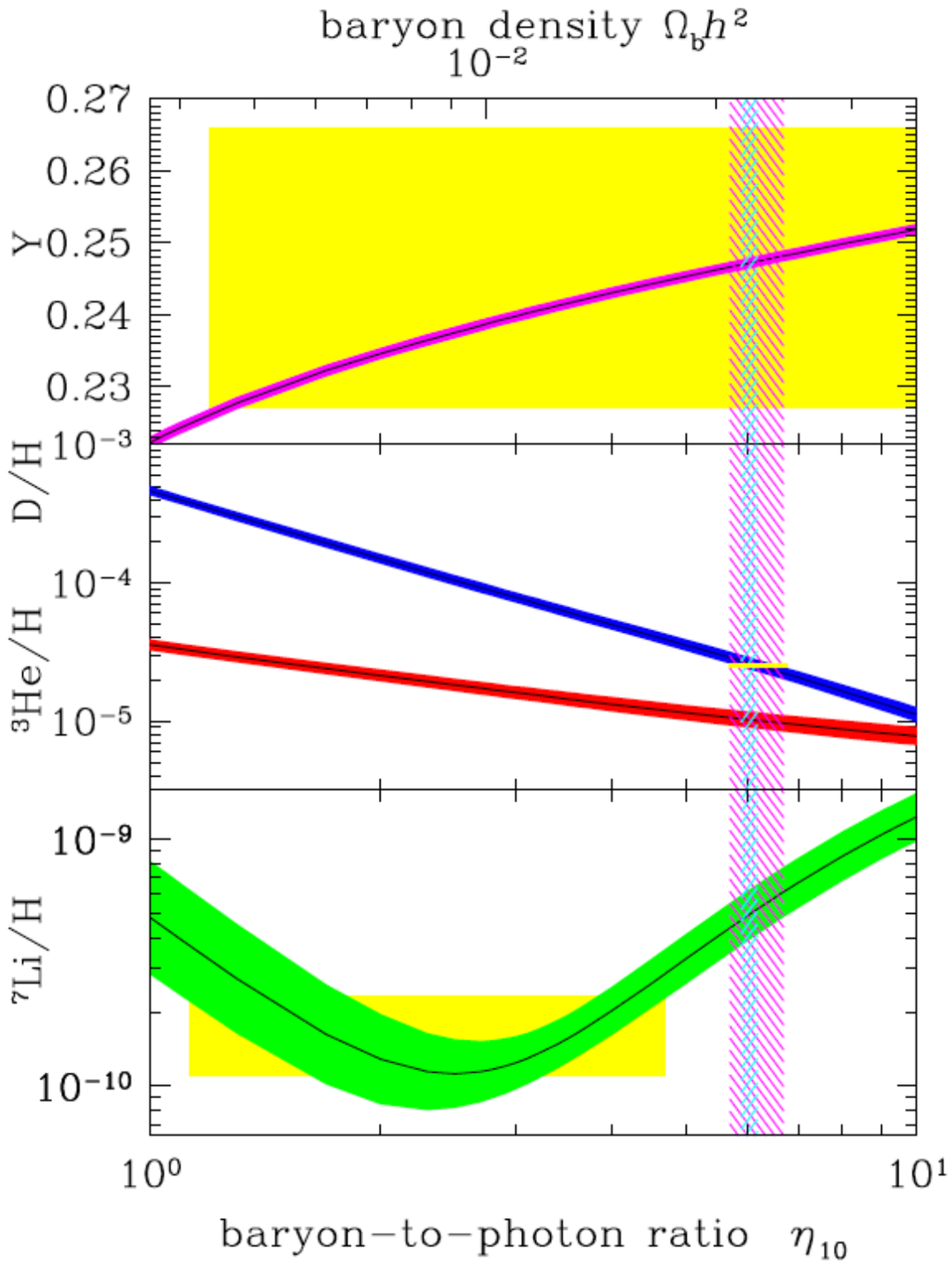
arXiv:1709.10378
Anna de Graaff, YC, Catherine Heymans, John A. Peacock

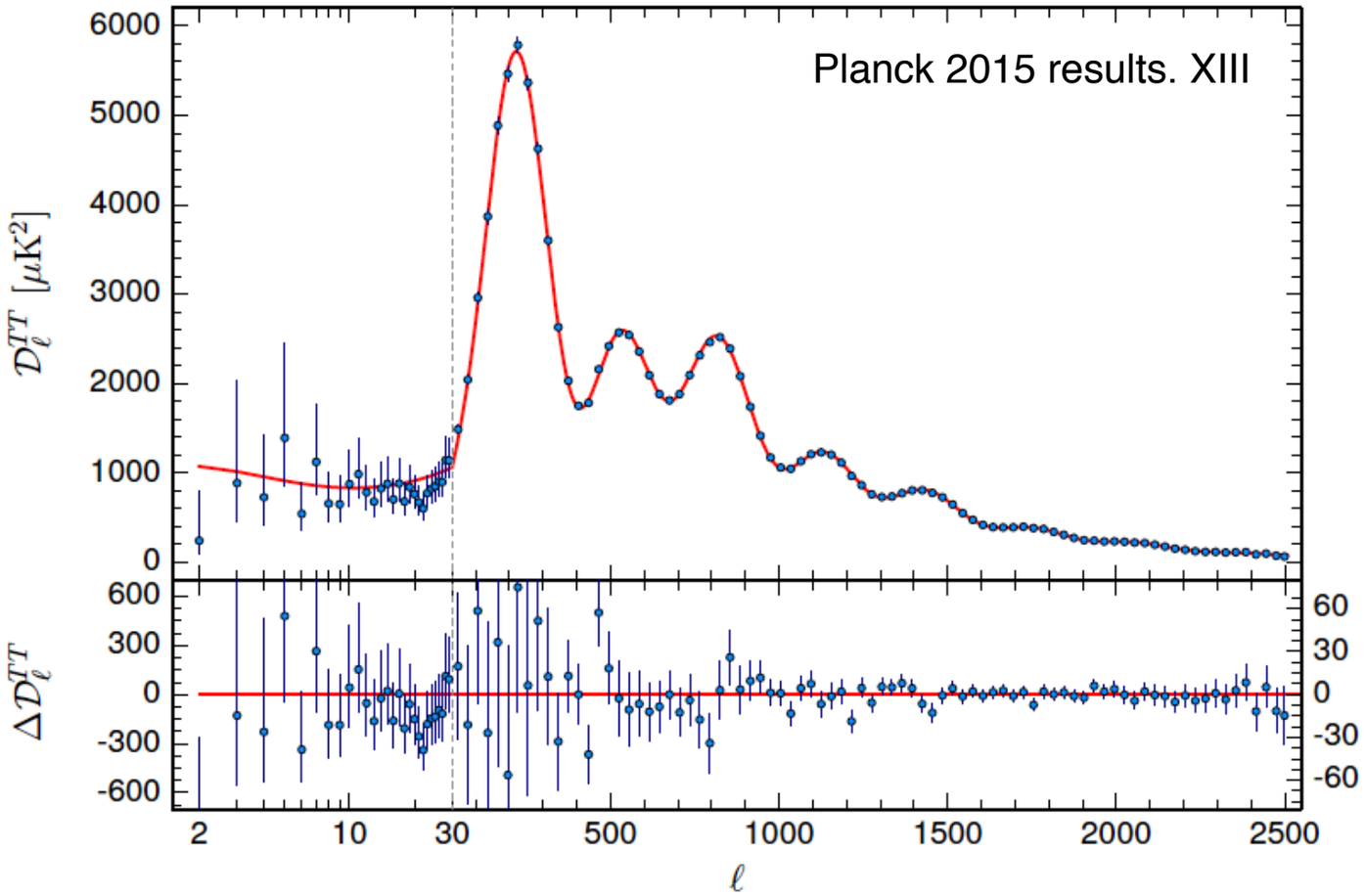
IAU 30, a focus meeting, Warm and Hot Baryonic Matter in the Cosmos, Vienna, 2018.08.30

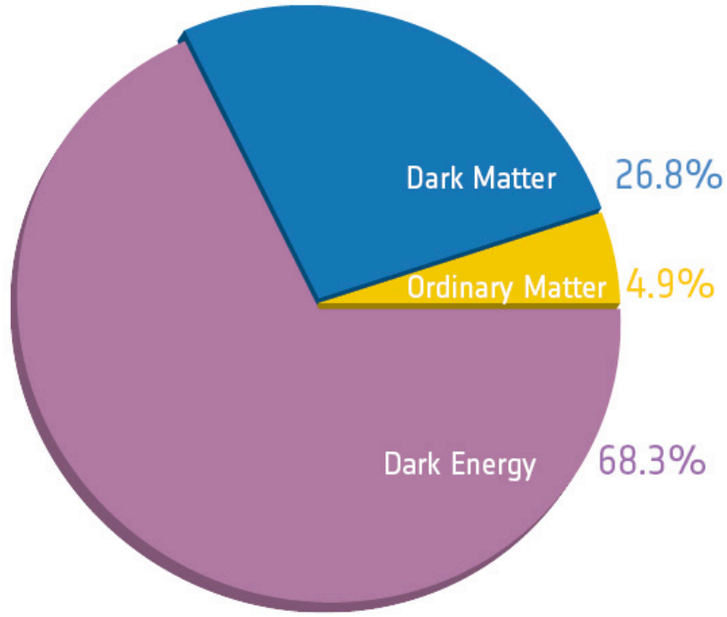
Baryon fraction from BBN



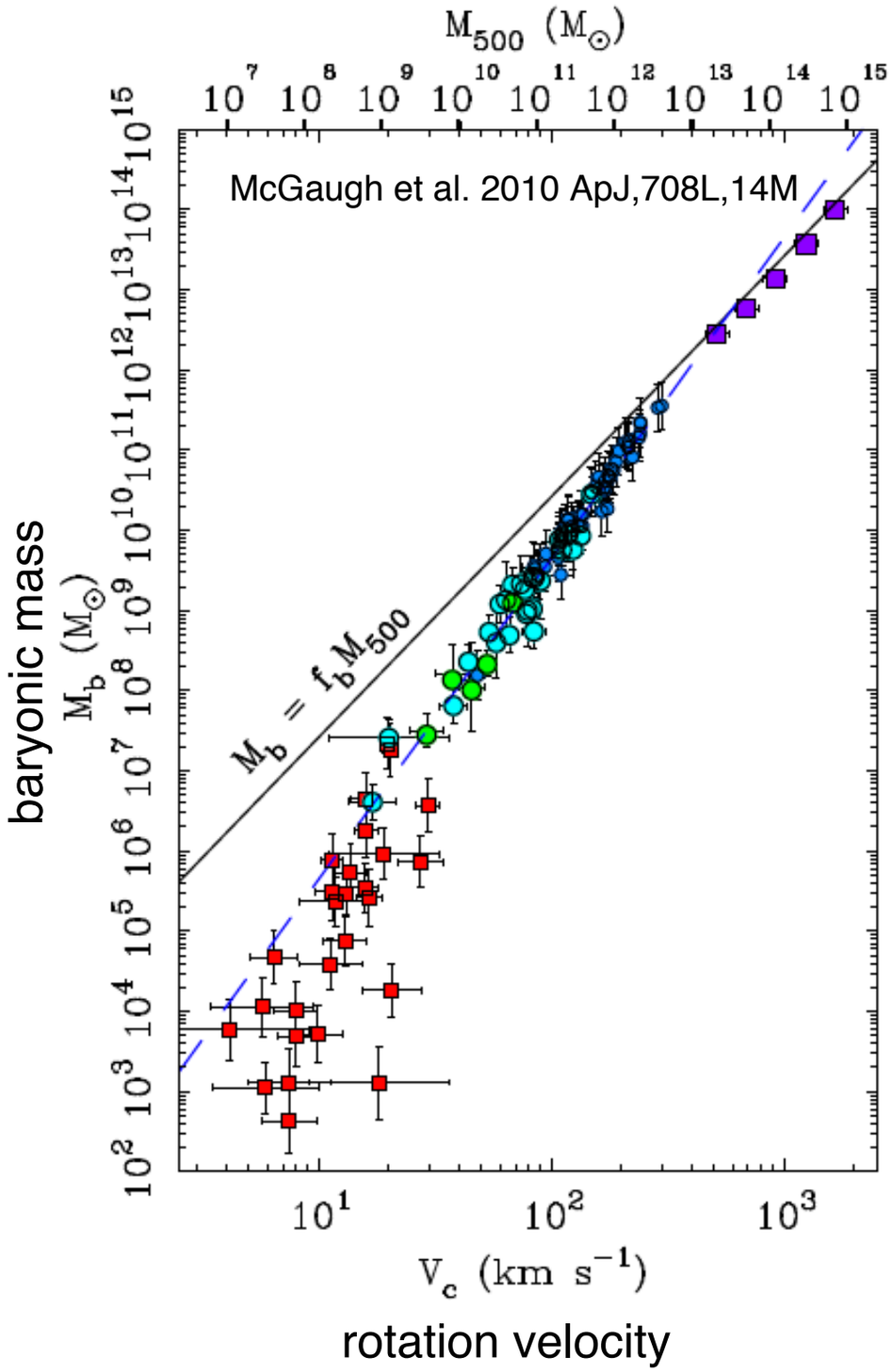
Fields et al. 2014
(arXiv:1412.1408)

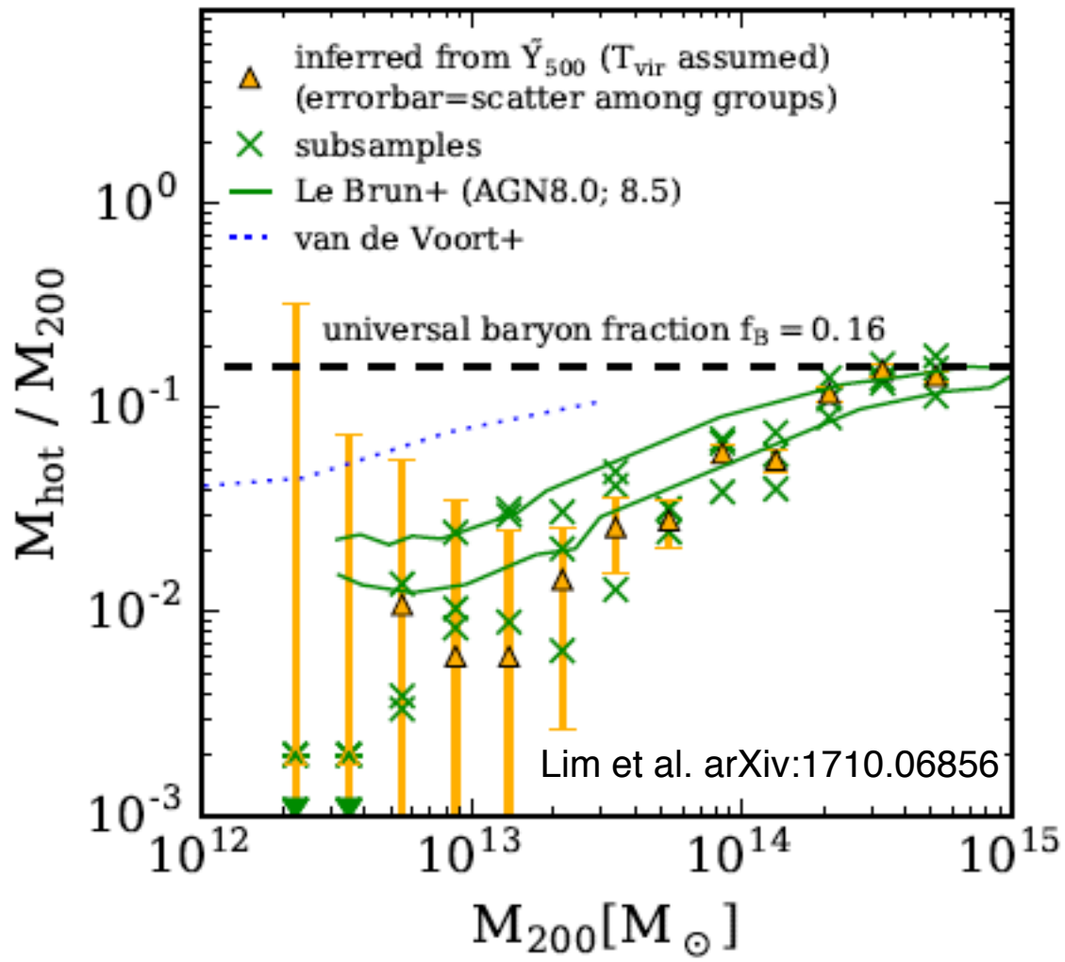
Baryon fraction from the CMB



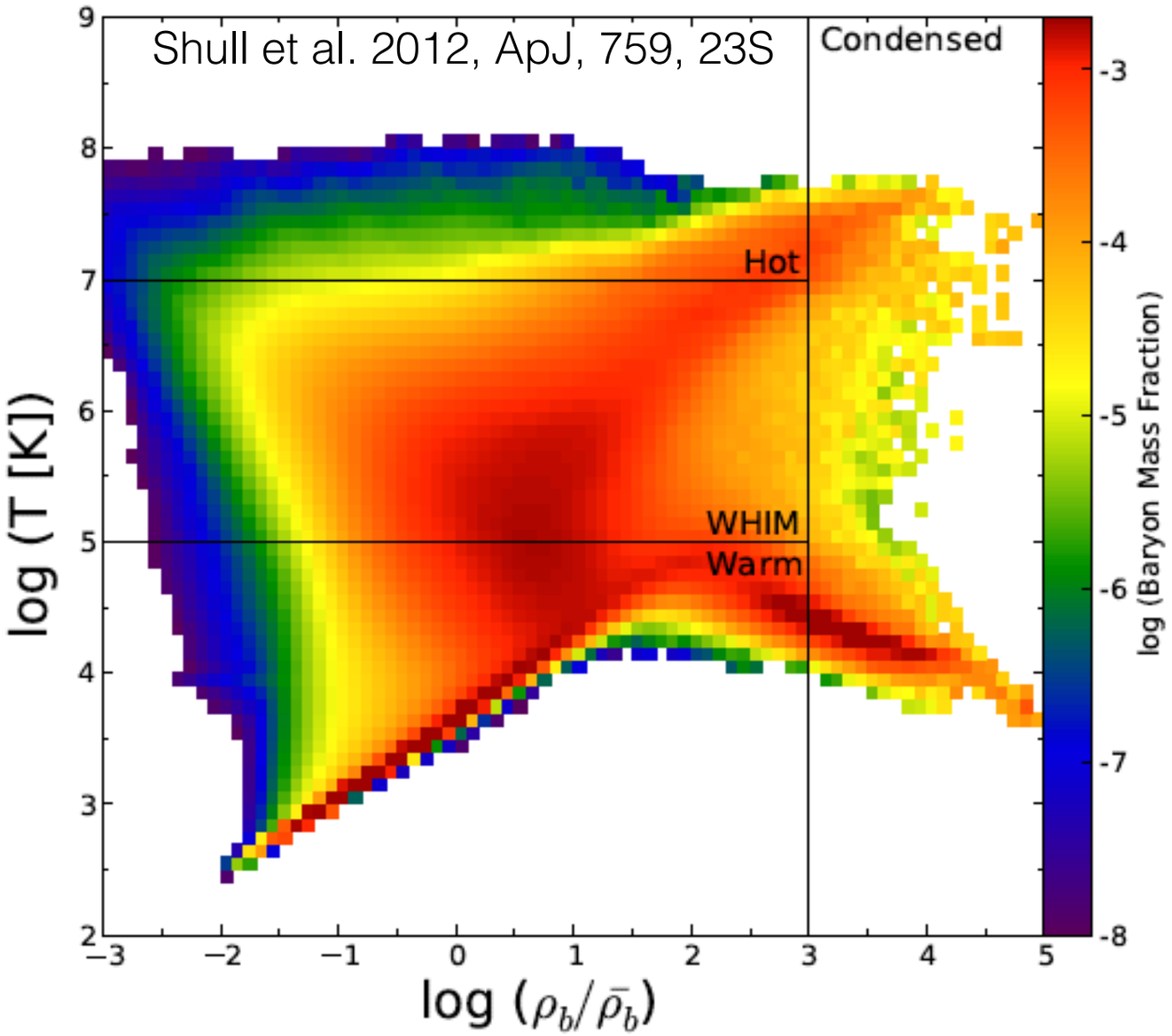


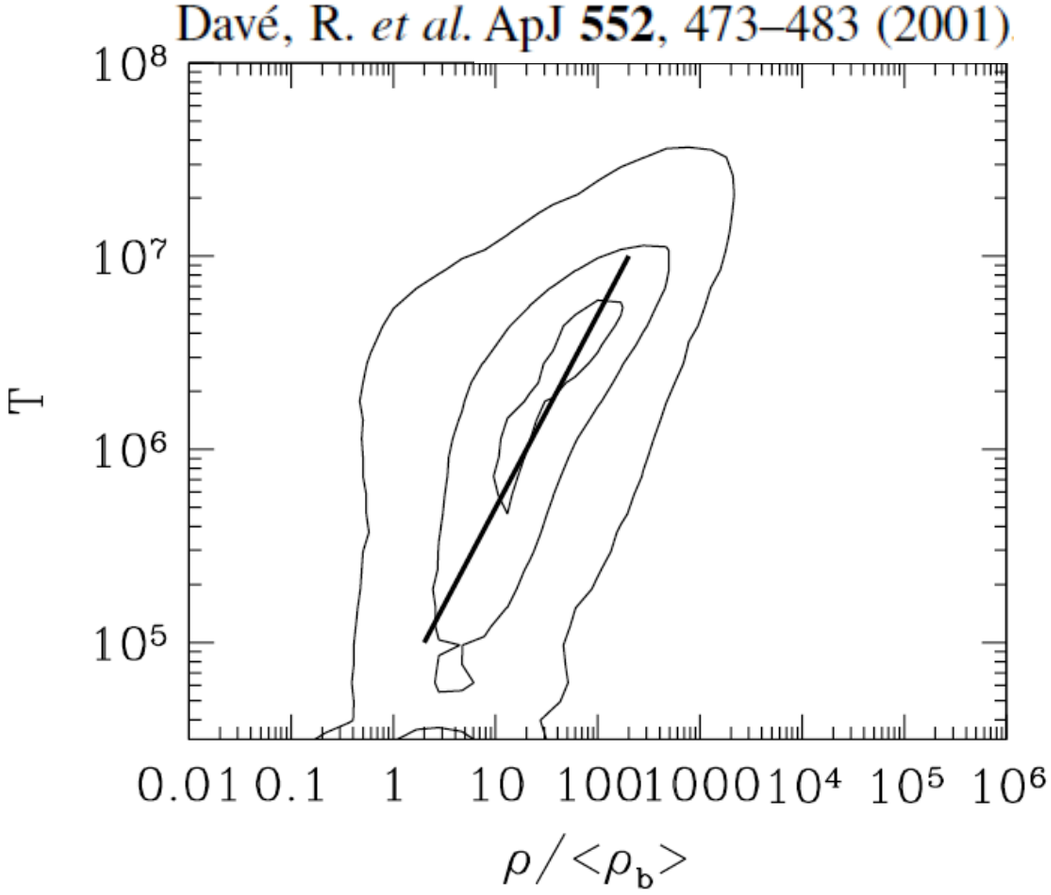
Baryon fraction at late-time Universe

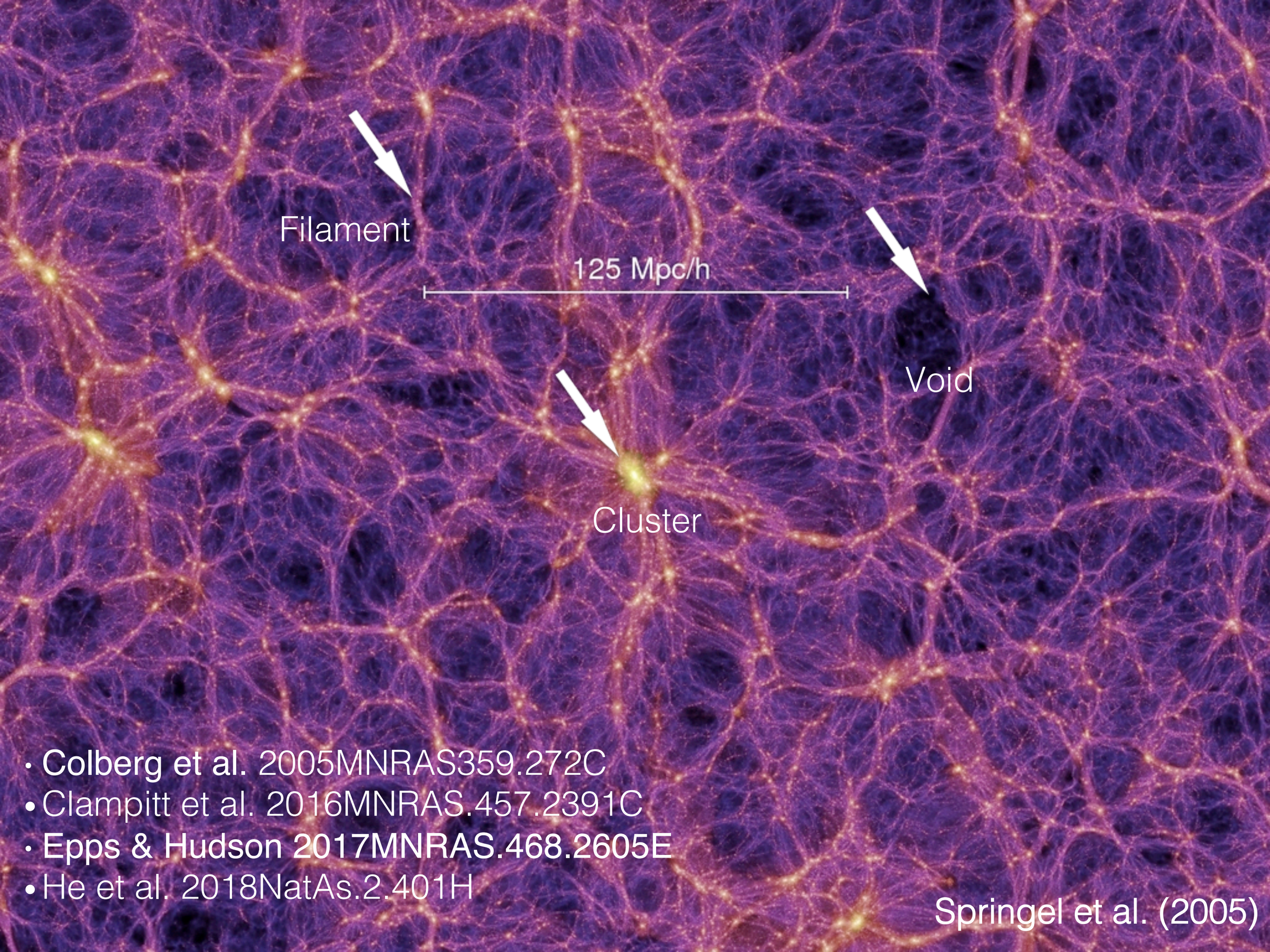




1. Diffuse: T<10^5 K, Lyman alpha absorber
2. Condensed: T<10^5 K, stars and cool gas
3. Hot: T>10^7 K, gas in clusters and groups
4. Warm-Hot: 10^5<T<10^7 K, WHIM







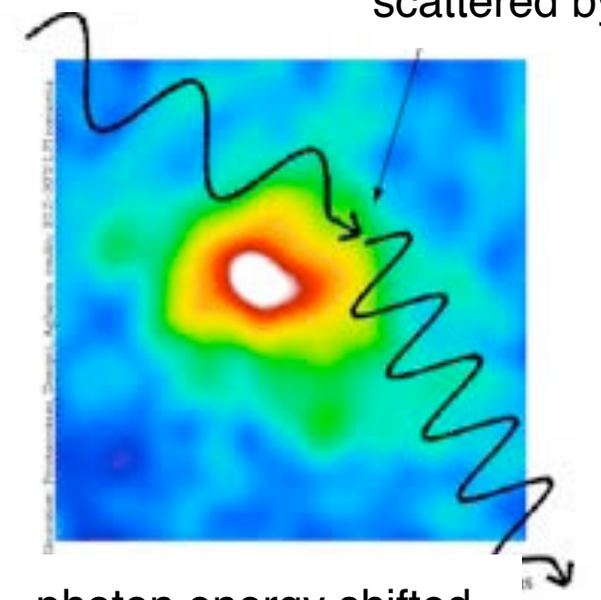
- **Colberg et al.** 2005MNRAS359.272C
- Clampitt et al. 2016MNRAS.457.2391C
- **Epps & Hudson 2017MNRAS.468.2605E**
- He et al. 2018NatAs.2.401H

Springel et al. (2005)

Thermal Sunyaev-Zel'dovich effect

CMB photons

scattered by free electrons



photon energy shifted

(Courtesy of Marian Douspis)

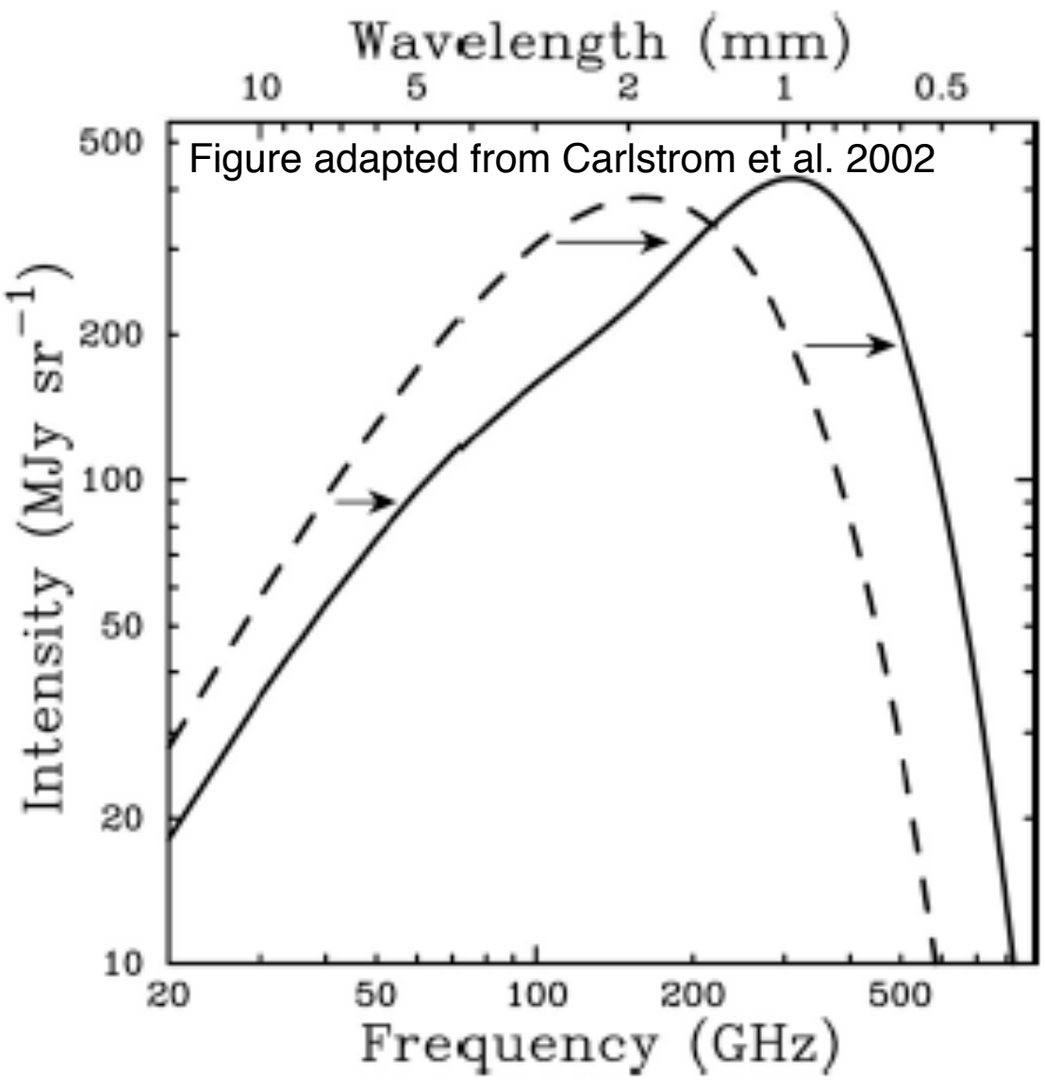


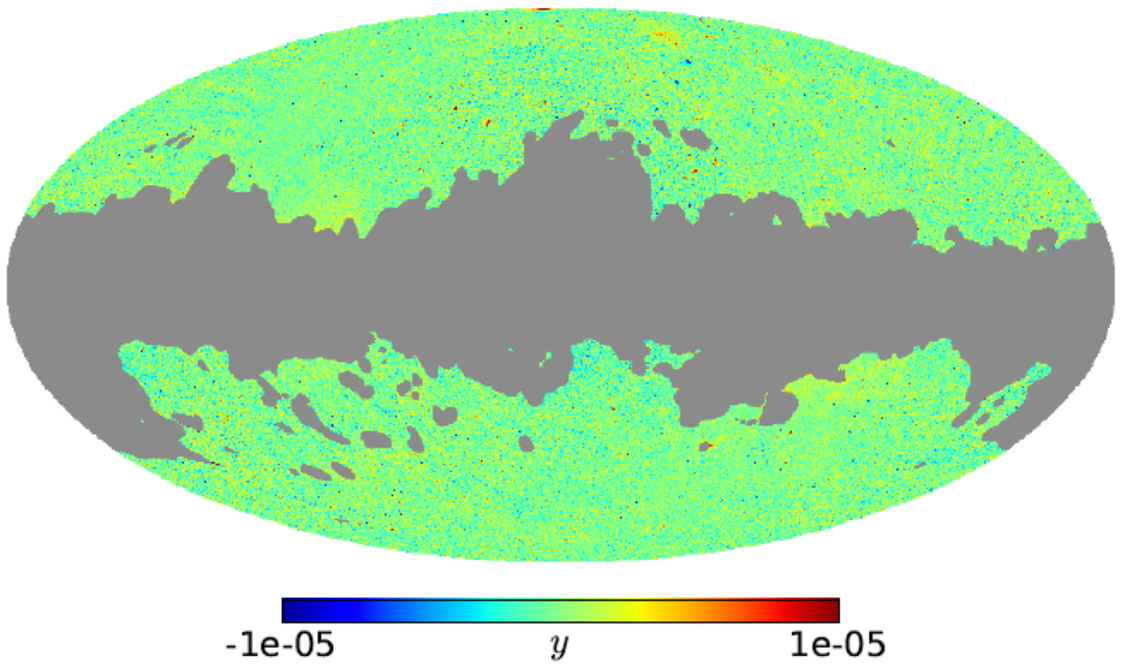
Figure adapted from Carlstrom et al. 2002

$$\frac{\Delta T}{T_{\rm CMB}} = g(\nu)\, y$$

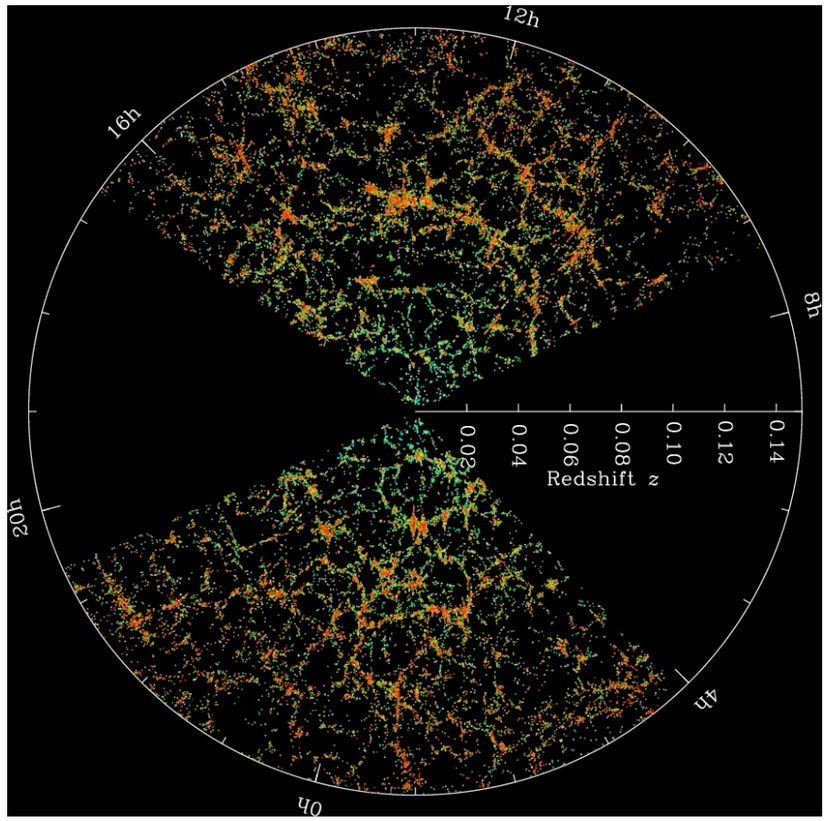
$$y = \int \frac{k_{\rm B} T_{\rm e}}{m_{\rm e} c^2}\, n_{\rm e}\, \sigma_{\rm T}\, {\rm d}\ell \propto n_{\rm e} T_{\rm e}$$

filaments and galaxy pairs

Planck SZ y-map (Planck 2015 results. XXII)



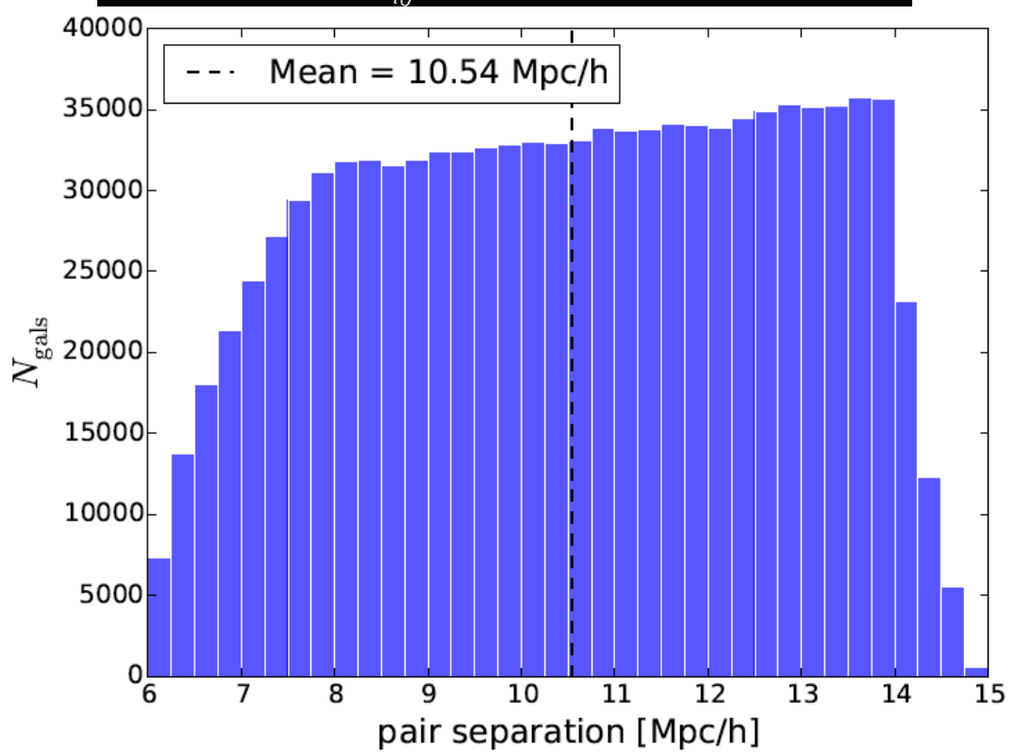
×



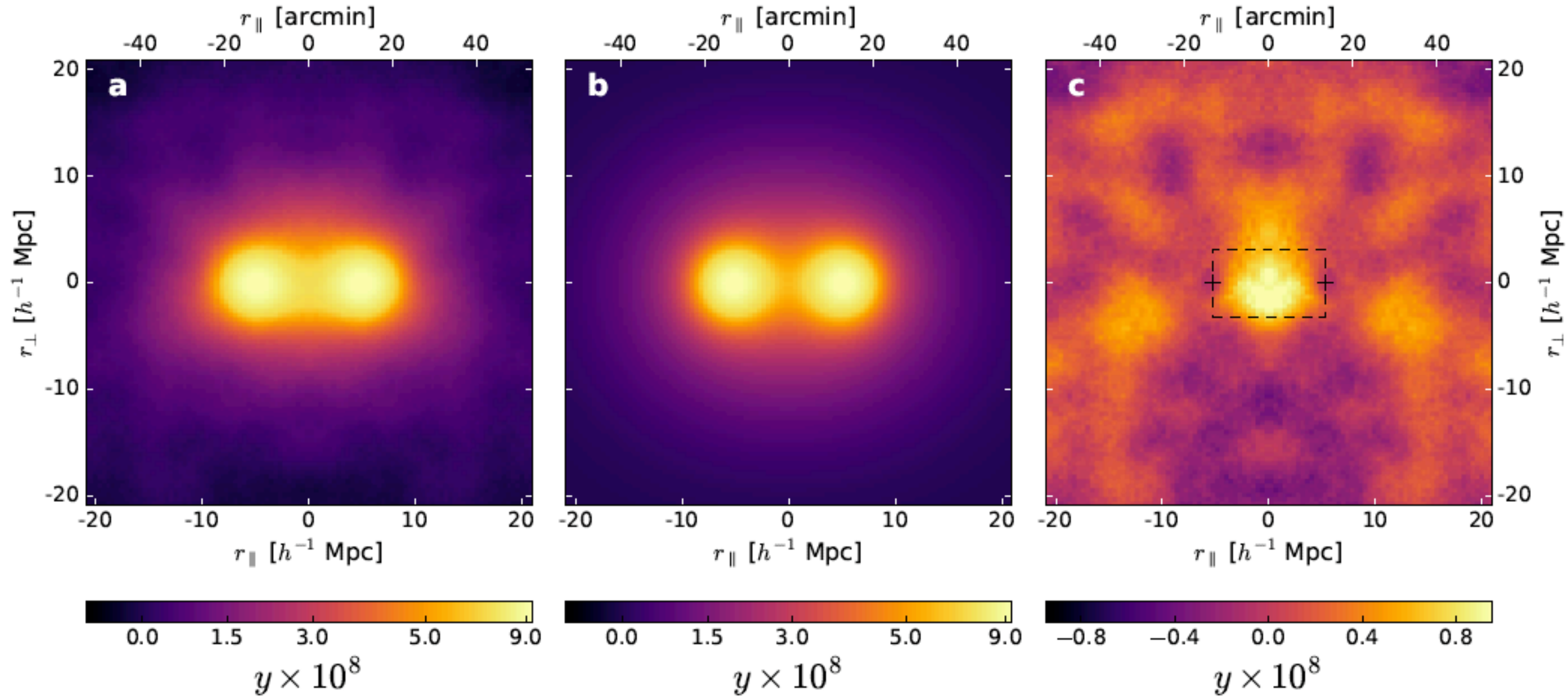
BOSS-CMASS galaxies

1 million pairs with:

- 6 < transverse separation < 15 Mpc/h
- LOS separation < 5 Mpc/h
- 0.4 < z< 0.7



SZ filaments between galaxies

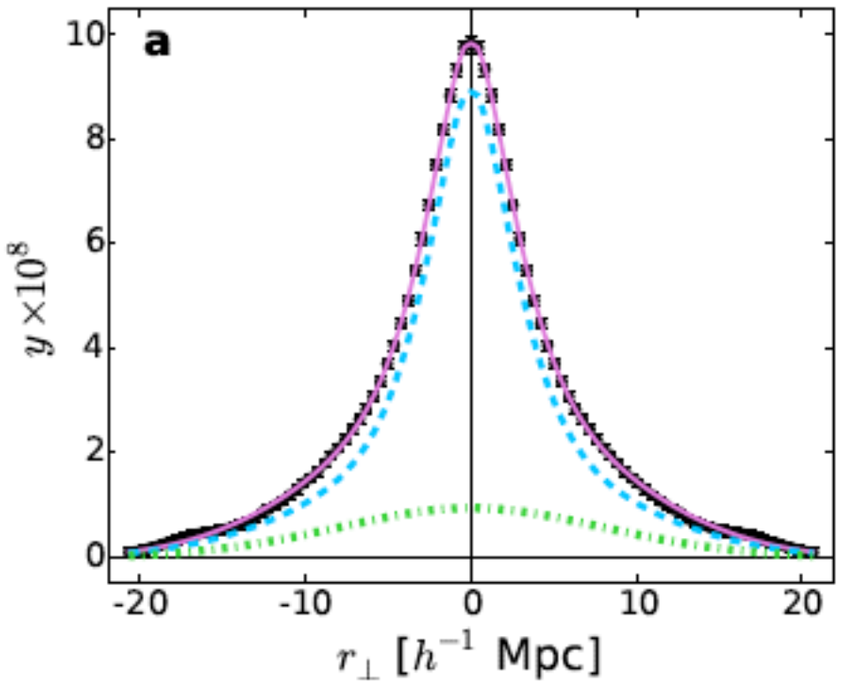


Data - Model = Residual

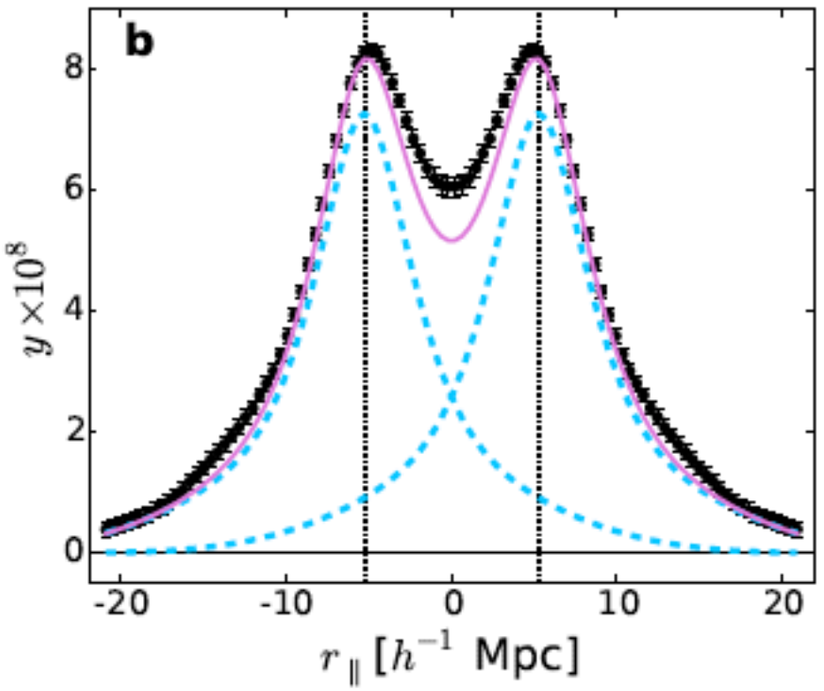
Detected fSZ ilament signal: $y \approx 0.6 \times 10^{-8}$ at the 5.1σ level

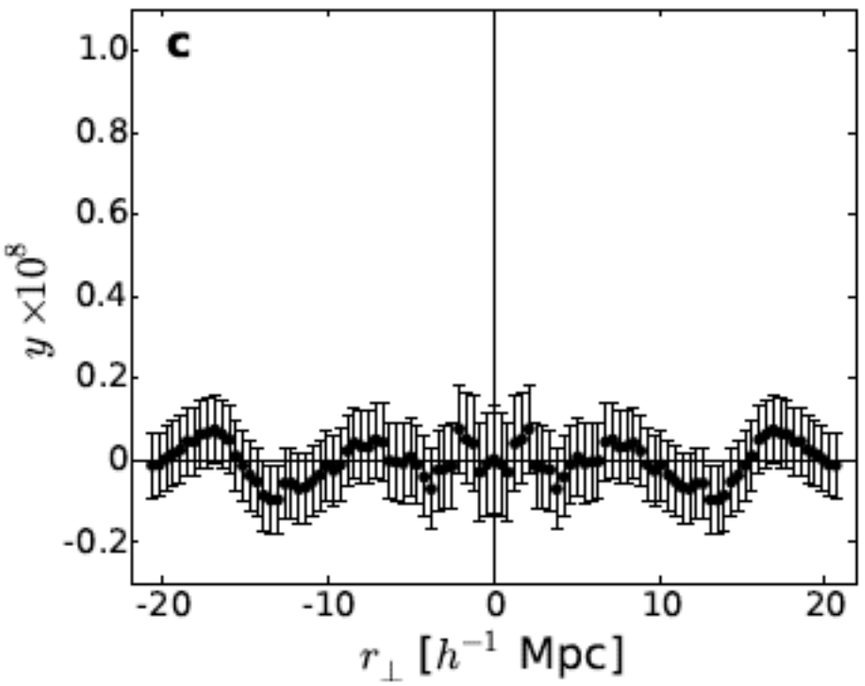
(Significance may change in a later revision)

Vertical profile

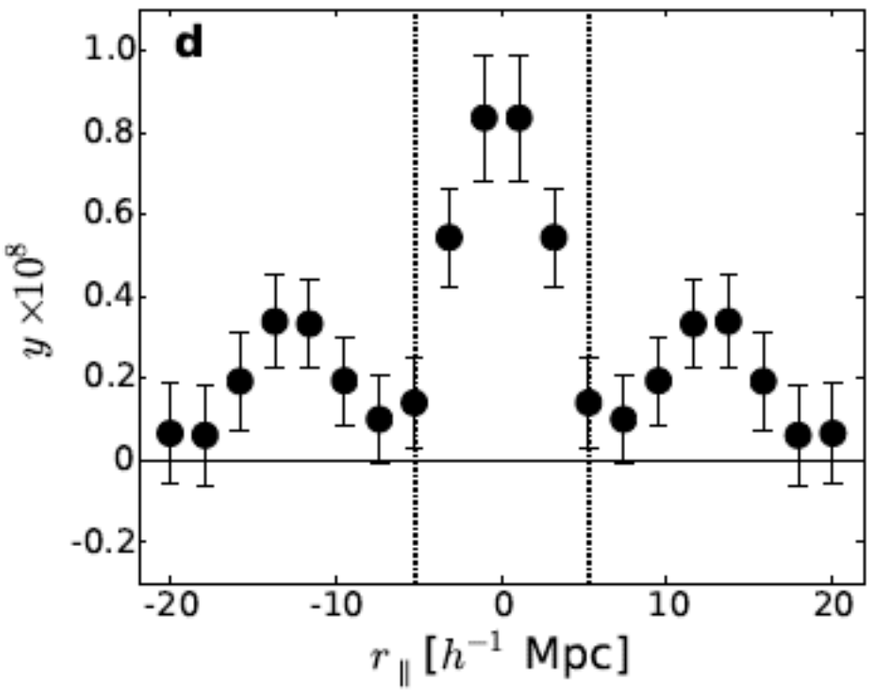


Horizontal profile





Vertical residual



Horizontal residual

Detected SZ filament signal: $y \approx 0.6 \times 10^{-8}$ at the 5.1σ level

(Significance may change in a later revision)

A Search for Warm/Hot Gas Filaments Between Pairs of SDSS Luminous Red Galaxies

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18 September 2017

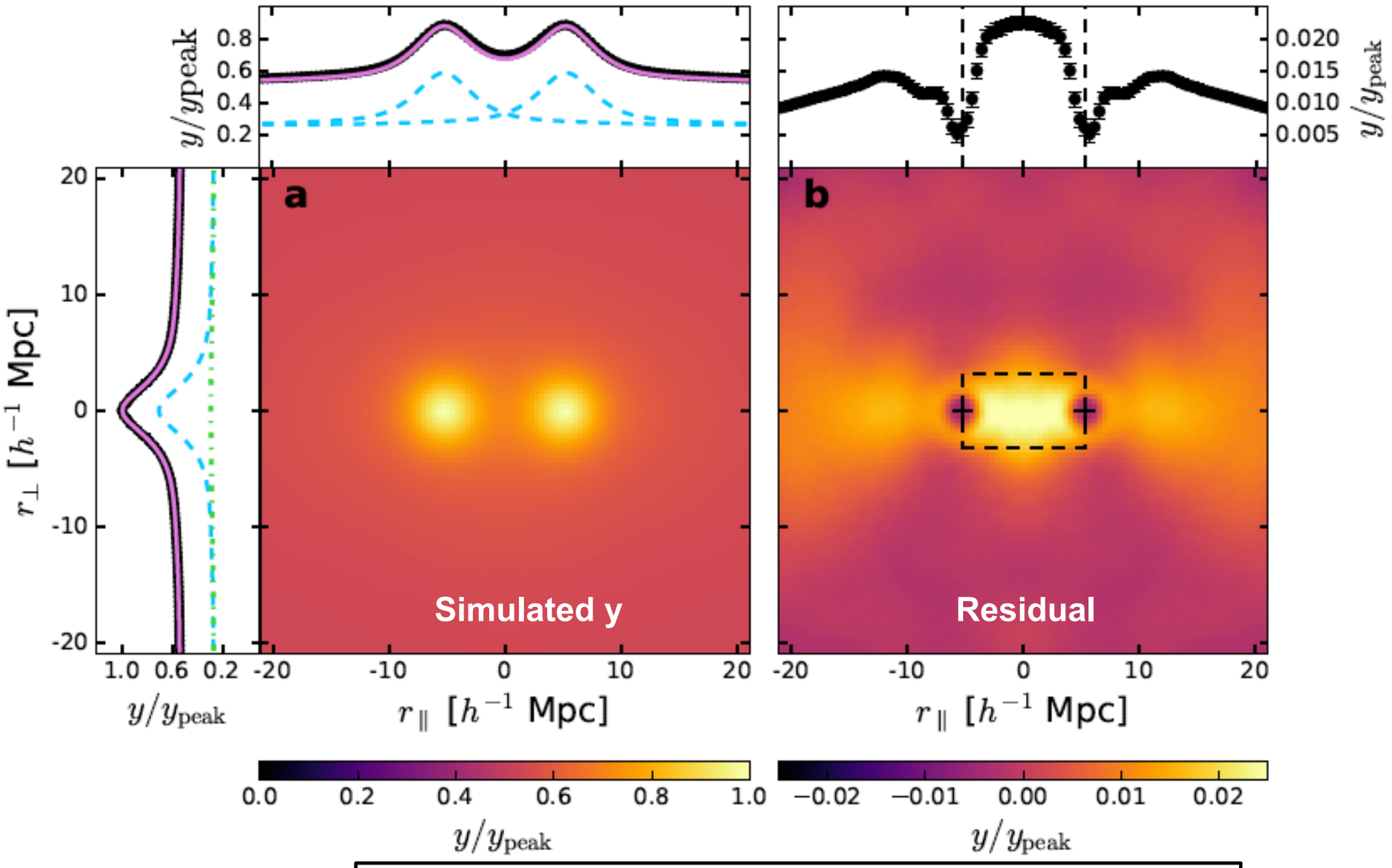
ABSTRACT

We search the *Planck* data for a thermal Sunyaev-Zel'dovich (tSZ) signal due to gas filaments between pairs of Luminous Red Galaxies (LRG's) taken from the Sloan Digital Sky Survey Data Release 12 (SDSS/DR12). We identify ~260,000 LRG pairs in the DR12 catalog that lie within 6–10 h^{-1}Mpc of each other in tangential direction and within 6 h^{-1}Mpc in radial direction. We stack pairs by rotating and scaling the angular positions of each LRG so they lie on a common reference frame, then we subtract a circularly symmetric halo from each member of the pair to search for a residual signal between the pair members. We find a statistically significant (5.3σ) signal between LRG pairs in the stacked data with a magnitude $\Delta y = (1.31 \pm 0.25) \times 10^{-8}$. The uncertainty is estimated from two Monte Carlo null tests which also establish the reliability of our analysis. Assuming a simple, isothermal, cylindrical filament model of electron over-density with a radial density profile proportional to r_c/r (as determined from simulations), where r is the perpendicular distance from the cylinder axis and r_c is the core radius of the density profile, we constrain the product of over-density and filament temperature to be $\delta_c \times (T_e/10^7\ \mathrm{K}) \times (r_c/0.5h^{-1}\ \mathrm{Mpc}) = 2.7 \pm 0.5$. To our knowledge, this is the first detection of filamentary gas at over-densities typical of cosmological large-scale structure. We compare our result to the BAHAMAS suite of cosmological hydrodynamic simulations (McCarthy et al. 2017) and find a slightly lower, but marginally consistent Comptonization excess, $\Delta y = (0.84 \pm 0.24) \times 10^{-8}$.

What does the signal mean?

- I. Diffuse gas or lump structure
- II. CIB contamination
- III. Density-temperature degeneration

I. Diffuse gas or lumpy structure?



Ingredients for simulation
1. DM halo from N-body simulation; 2. Y-M relation
3. Number of galaxies per halo: HOD

II. CIB contamination

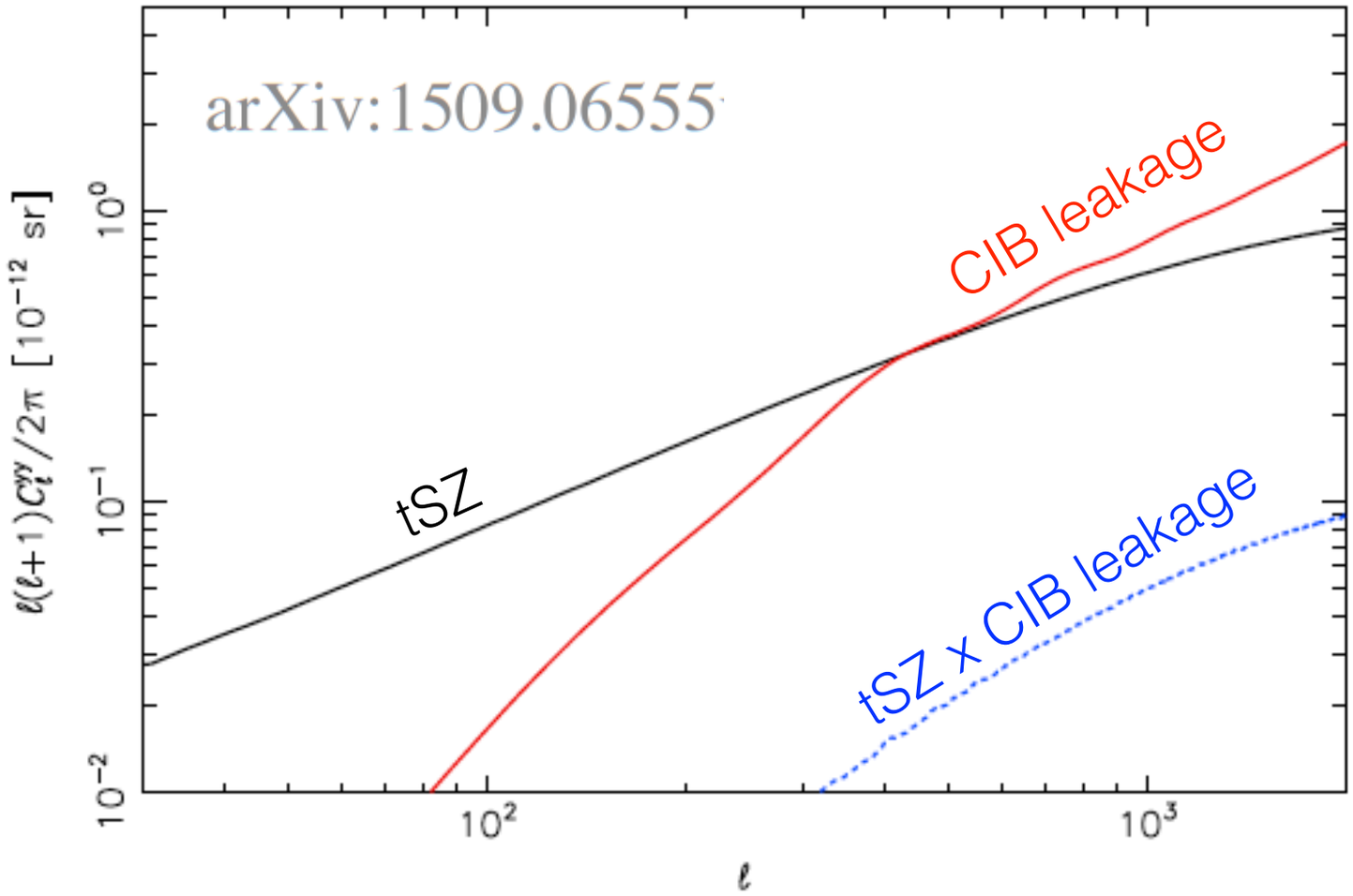
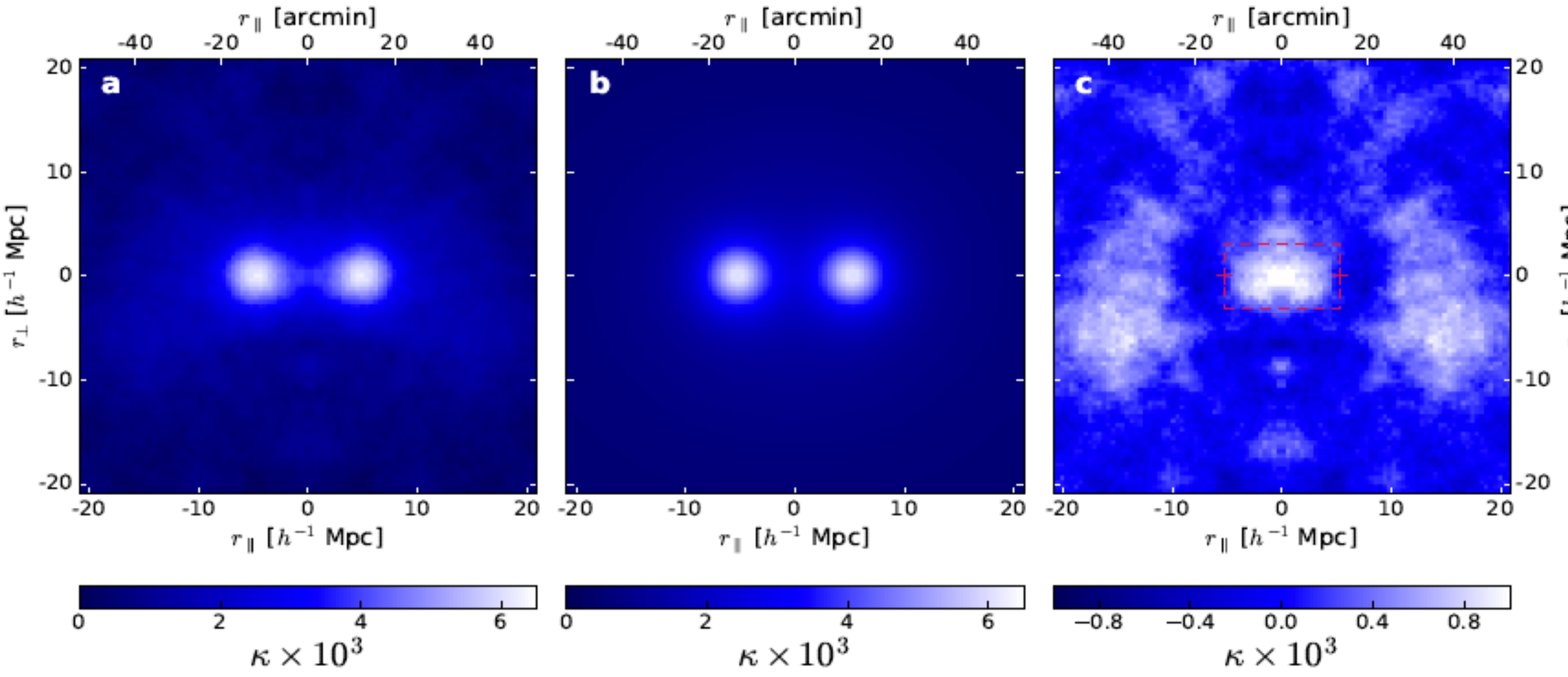


Figure 14. Expected contribution to the tSZ power spectrum for the true tSZ signal (black curve), for CIB leakage (red curve), and for tSZ-CIB leakage contribution (blue curve). The dotted line indicates a negative power spectrum.

***Planck* 2015 results. XXIII. The thermal Sunyaev-Zeldovich effect–cosmic infrared background correlation**

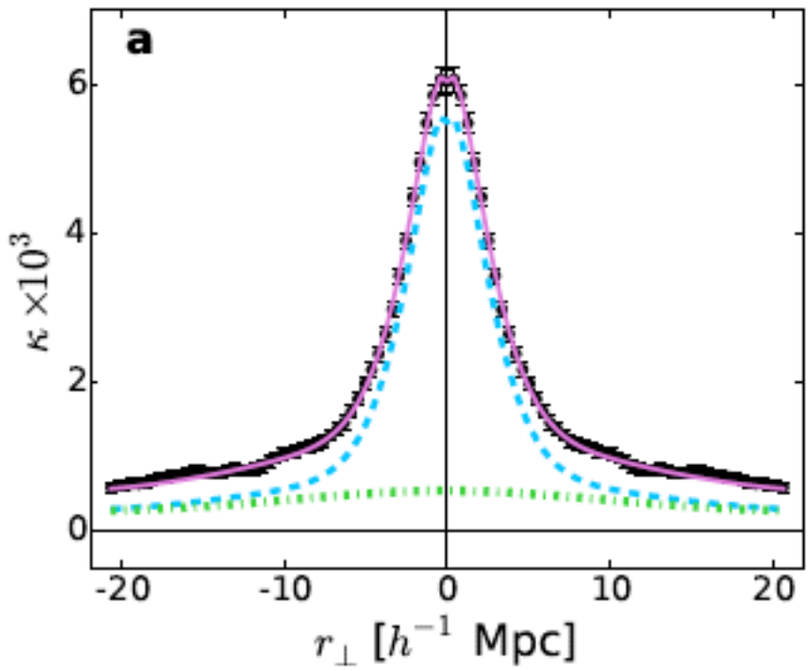
III. Breaking degeneracy with lensing

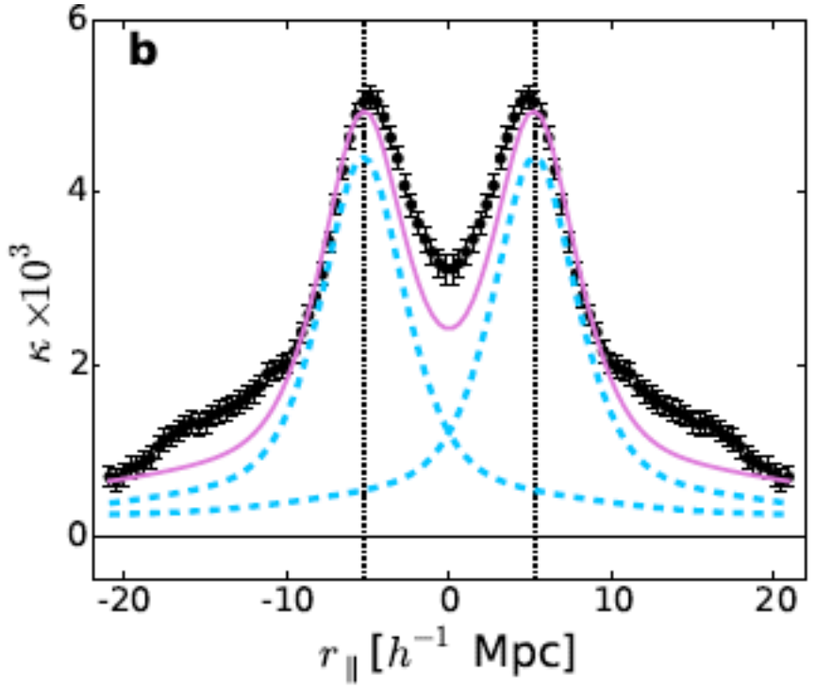


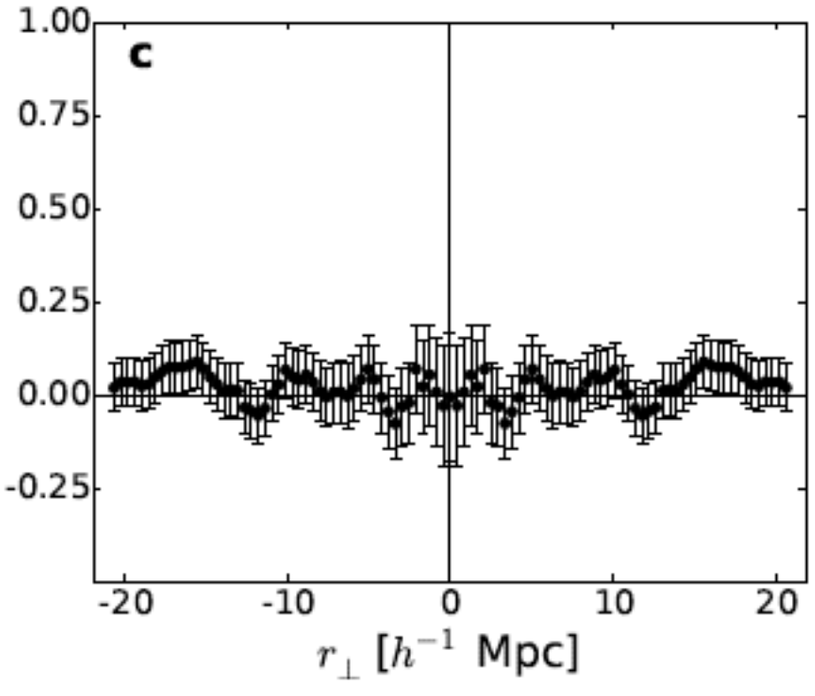
Data - Model = Residual

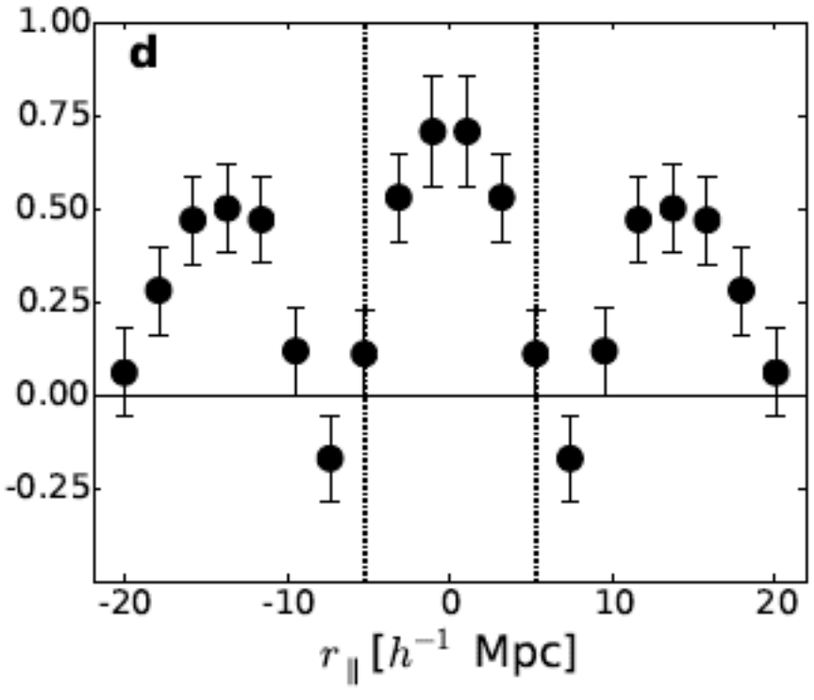
Estimated matter density for the filament: $5.6 \pm 1.6 \times \bar{\rho}(z)$

(Errorbars may change in a later revision)







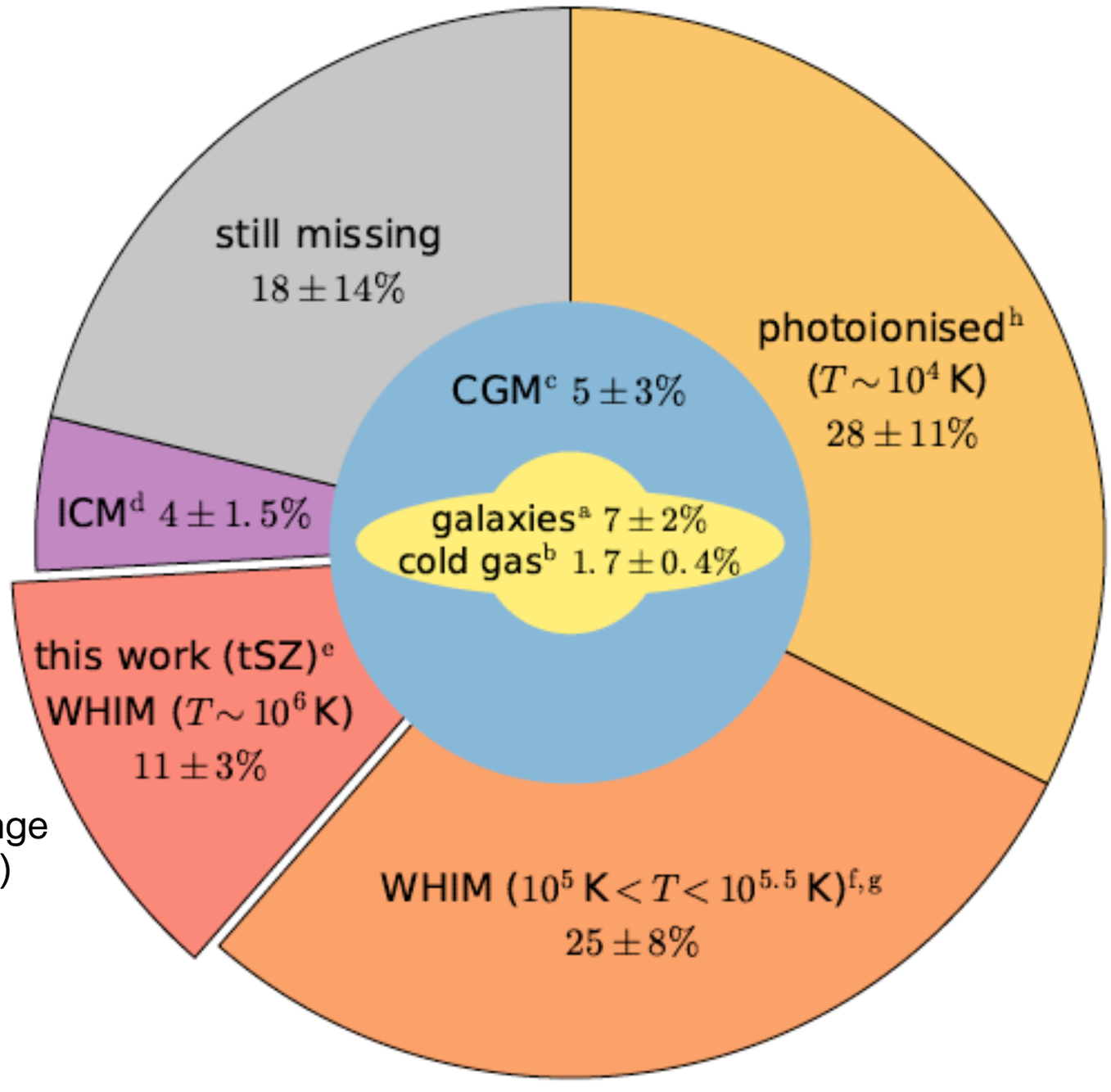


Estimated matter density for the filament: $5.6 \pm 1.6 \times \bar{\rho}(z)$

Gas temperature: $T_{\rm e} = 2.6 \pm 0.8 \times 10^6 {\rm K}$

Account for 11% of baryons

Where are the barvons



(Errorbar may change in a later revision)

See also Nicastro et al. 2018

Summary

- Detection of SZ and lensing signal between galaxies
- Lumpy haloes may contribute up to 20%
- CIB contribution is negligible
- Filament gas temperature is ~10^6 K
- Approximately 11% of baryons found