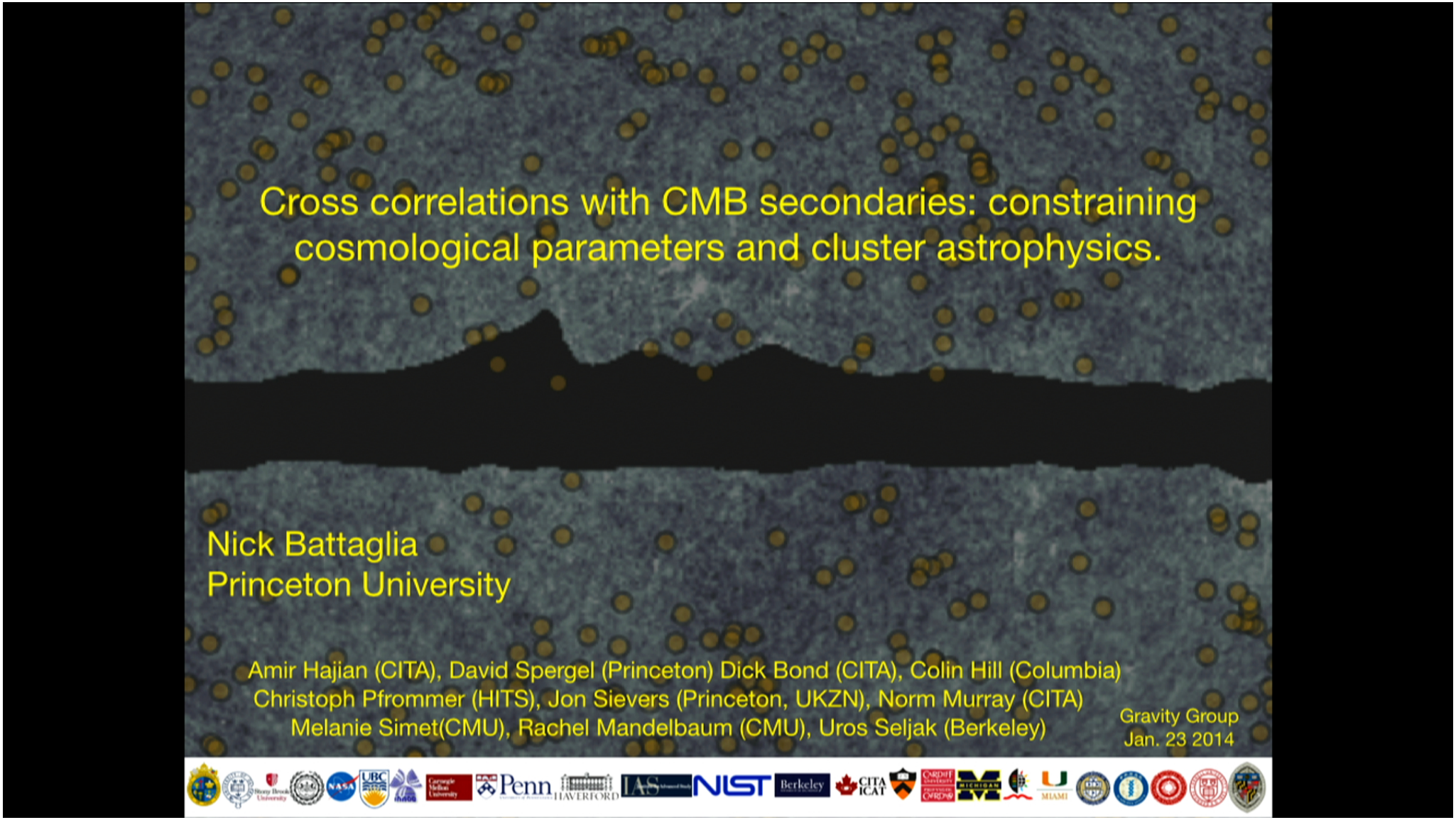
Title: Cross correlations with CMB secondaries: constraining cosmological parameters and cluster astrophysics.

Date: Apr 28, 2015 11:00 AM

URL: http://pirsa.org/15040084

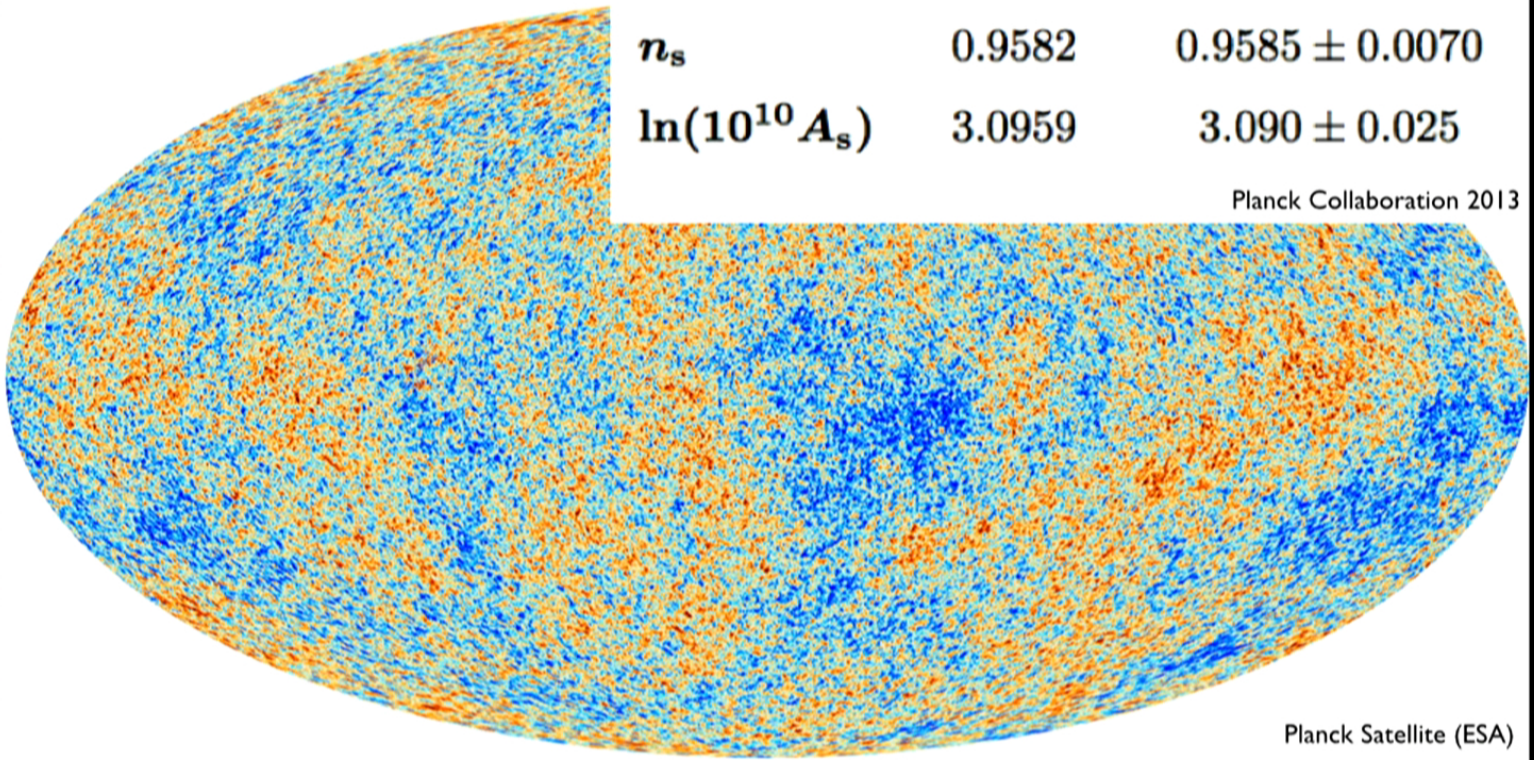
Abstract: High resolution CMB experiments, such as ACT, SPT, and the Planck satellite are making precision measurements of the secondary anisotropies caused by the thermal Sunyaev Zel'dovich (tSZ) effect from galaxy clusters. However, our ability to obtain cosmological information from this tSZ signal is limited by our theoretical understanding of the baryons in clusters and groups. I will discuss how cross correlation methods are providing new windows into the messy â€œGastrophysicsâ€• of the intracluster medium and the potential for these methods to constrain various cosmological parameters.


Cross correlations with CMB secondaries: constraining cosmological parameters and cluster astrophysics.
Nick Battaglia
Princeton University
Amir Hajian (CITA), David Spergel (Princeton) Dick Bond (CITA), Colin Hill (Columbia)
Christoph Pfrommer (HITS), Jon Sievers (Princeton, UKZN), Norm Murray (CITA)
Melanie Simet(CMU), Rachel Mandelbaum (CMU), Uros Seljak (Berkeley)
Gravity Group
Jan. 23 2014

Primary CMB
The foundation of modern cosmology

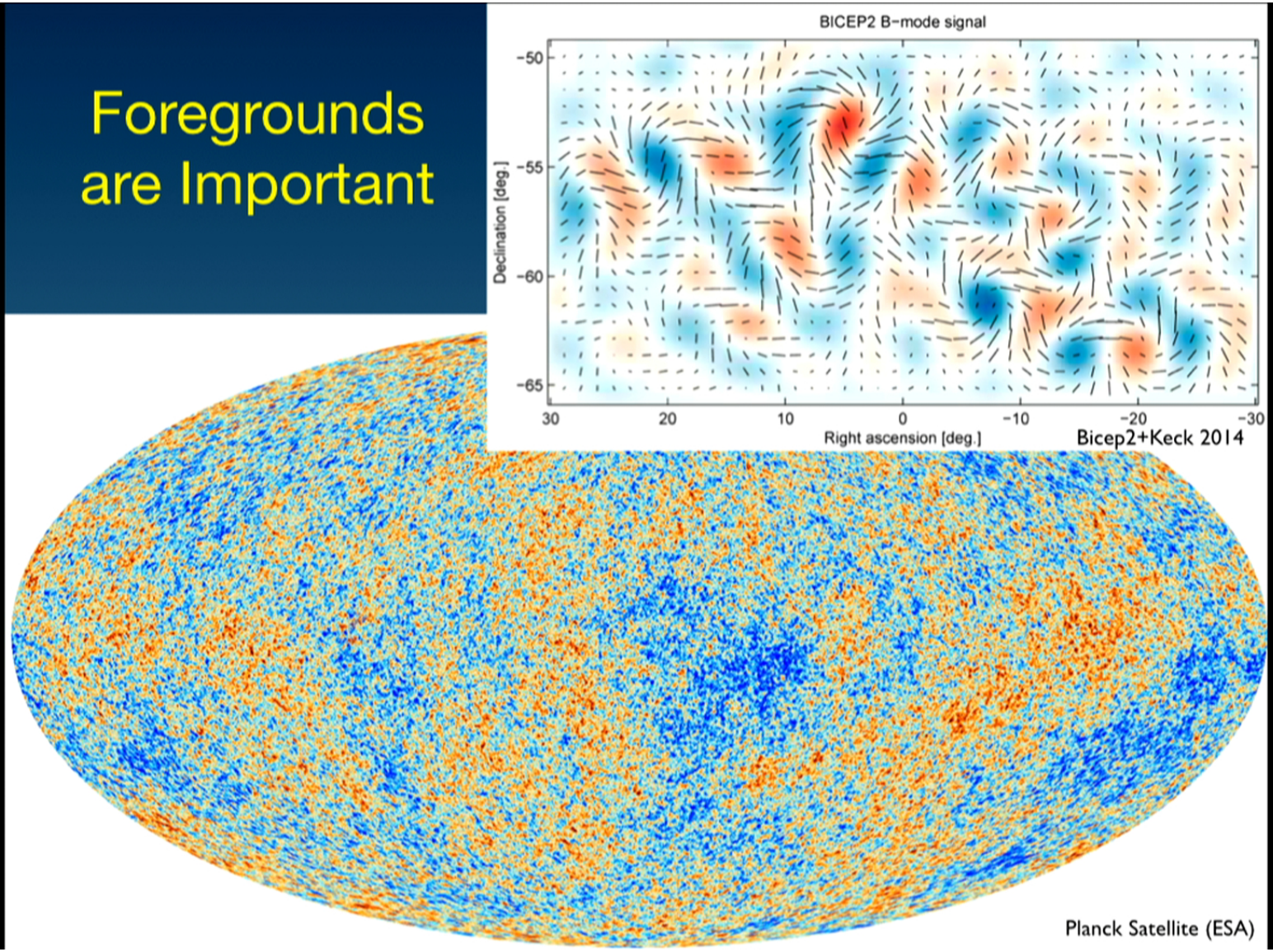
Parameter	Best fit	68% limits
$\Omega_b h^2$	0.022069	0.02207 ± 0.00027
$\Omega_c h^2$	0.12025	0.1198 ± 0.0026
$100\theta_{MC}$	1.04130	1.04132 ± 0.00063
τ	0.0927	$0.091^{+0.013}_{-0.014}$
n_s	0.9582	0.9585 ± 0.0070
$\ln(10^{10} A_s)$	3.0959	3.090 ± 0.025

Planck Collaboration 2013

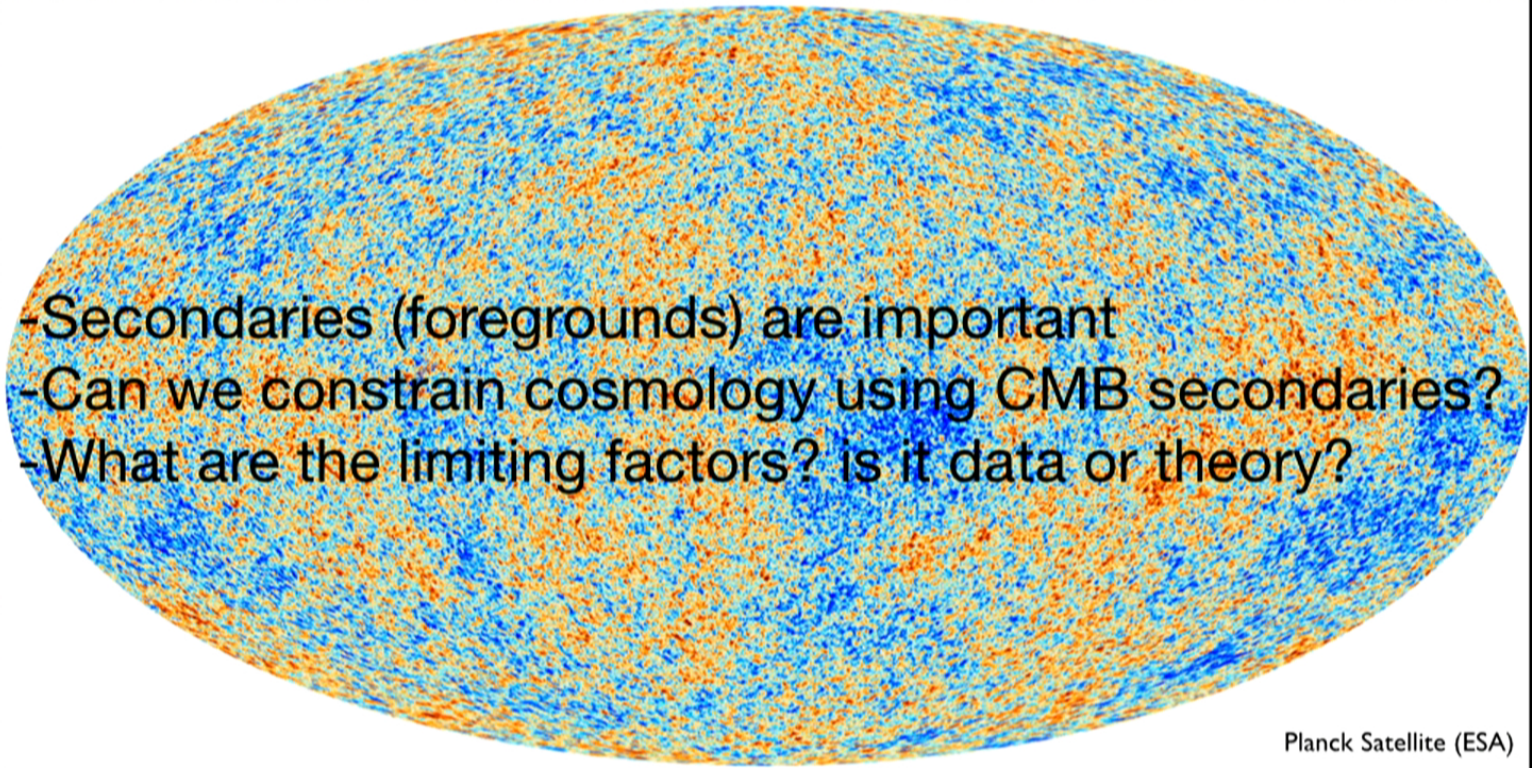


Planck Satellite (ESA)

Foregrounds are Important

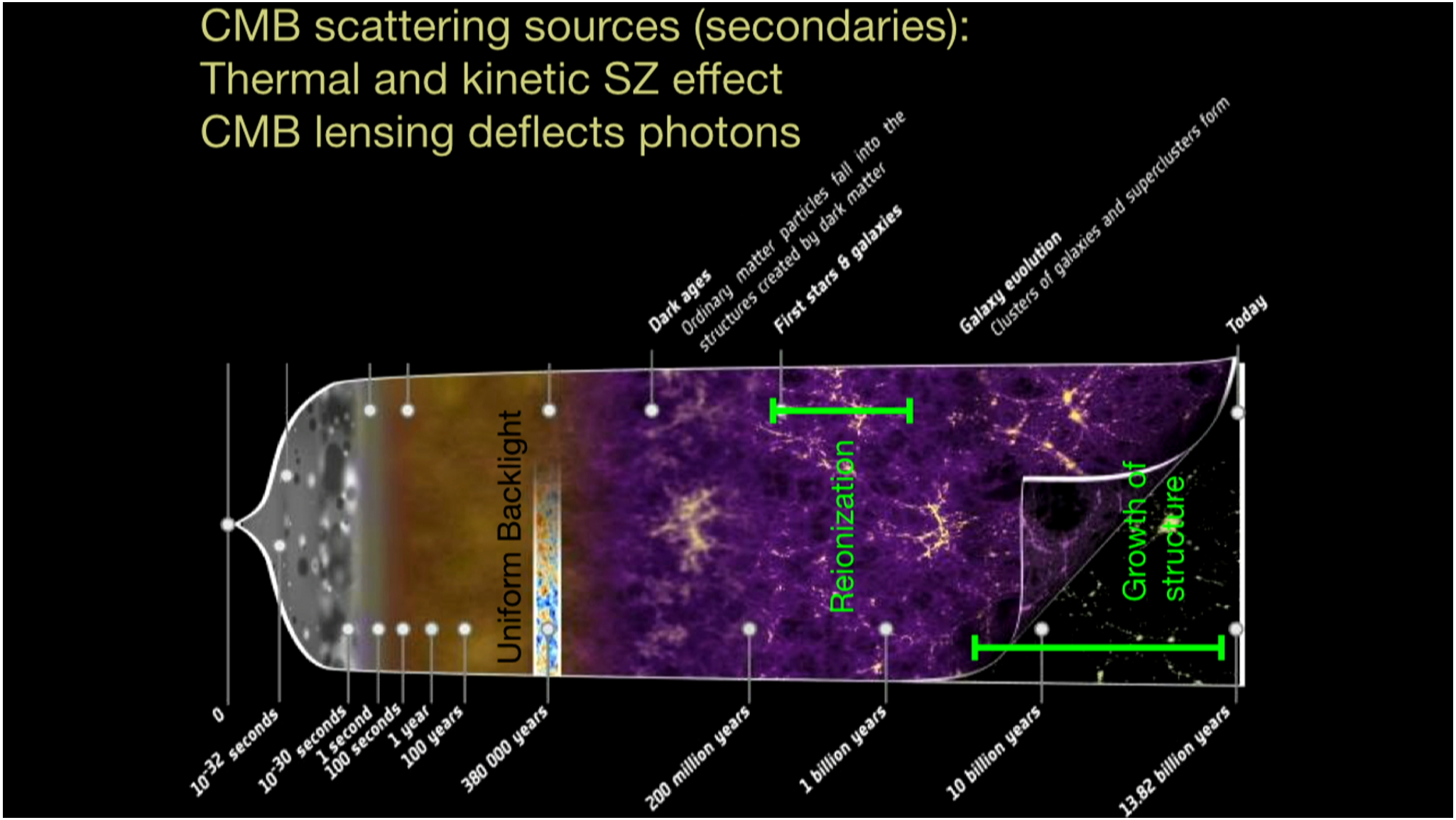


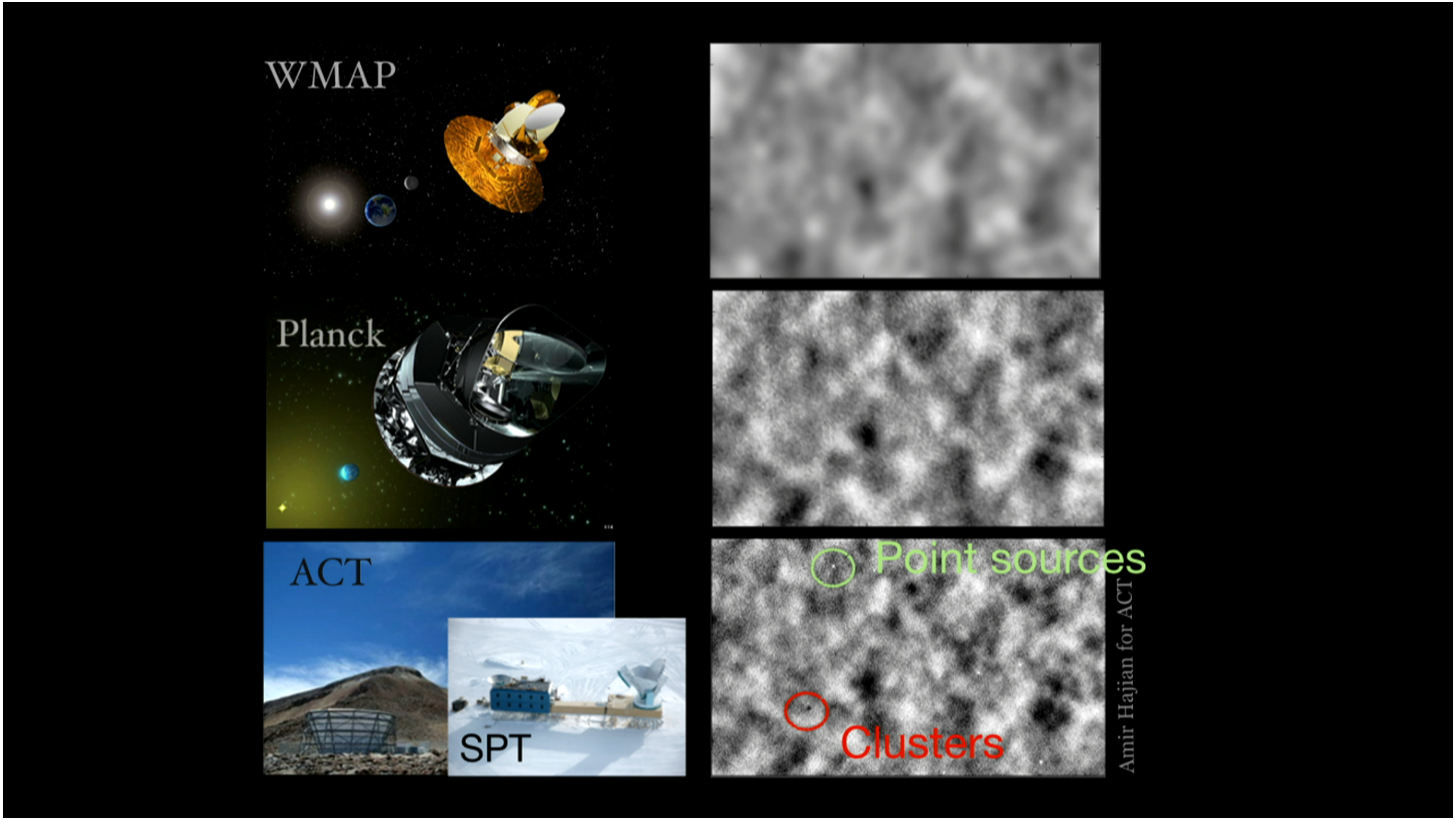
Galatic Synchrotron & Dust
Radio and Dusty point sources
Lensing
SZ sources



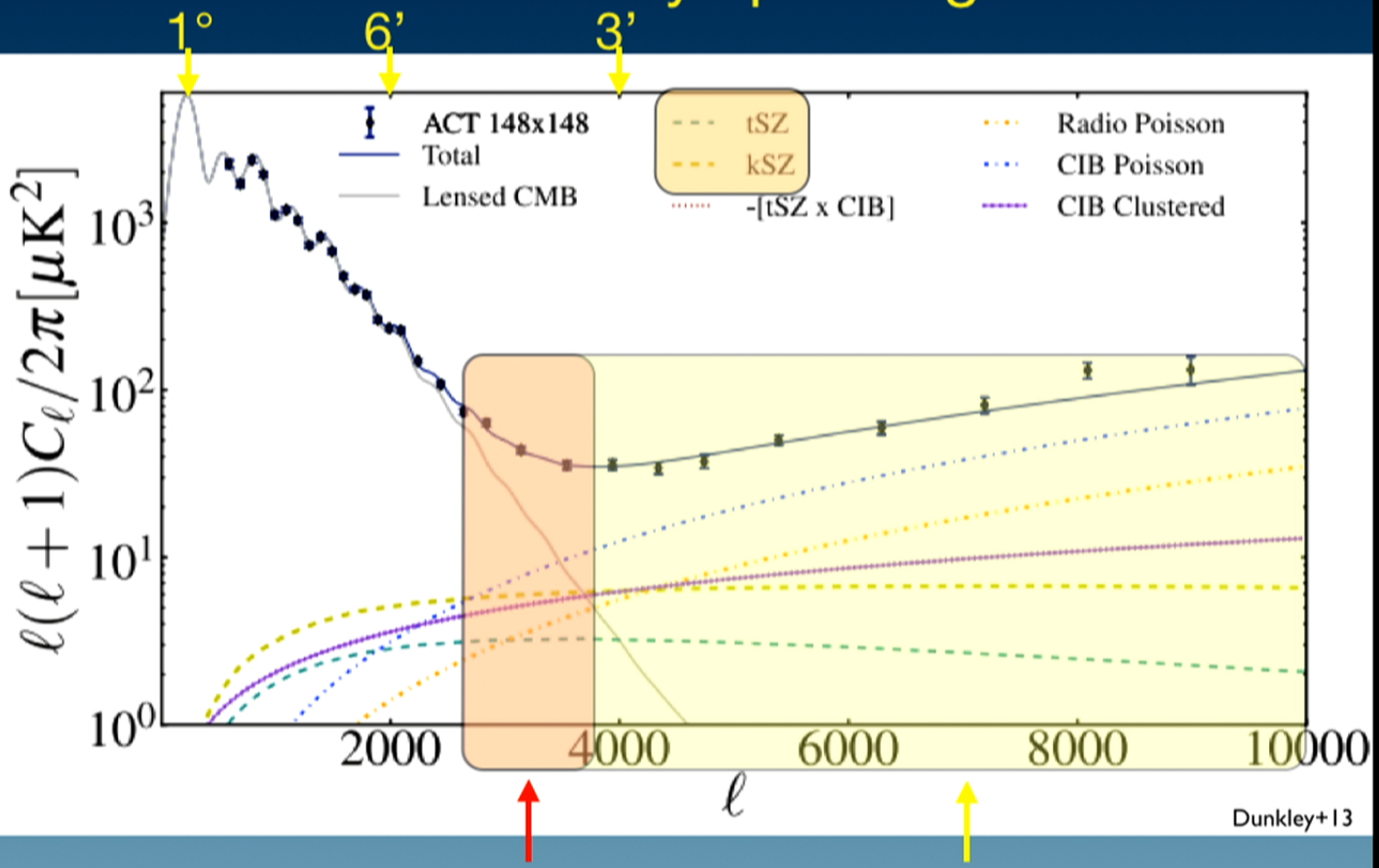
-Secondaries (foregrounds) are important
-Can we constrain cosmology using CMB secondaries?
-What are the limiting factors? is it data or theory?

Planck Satellite (ESA)


CMB scattering sources (secondaries):
Thermal and kinetic SZ effect
CMB lensing deflects photons
Dark ages
Ordinary matter particles fall into the structures created by dark matter
First stars & galaxies
Galaxy evolution
Clusters of galaxies and superclusters form
Today
Uniform Backlight
Reionization
Growth of structure
0
10-32 seconds
10-30 seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13.82 billion years


WMAP
Planck
ACT
SPT
Point sources
Clusters
Amir Hajian for ACT

Statistically speaking

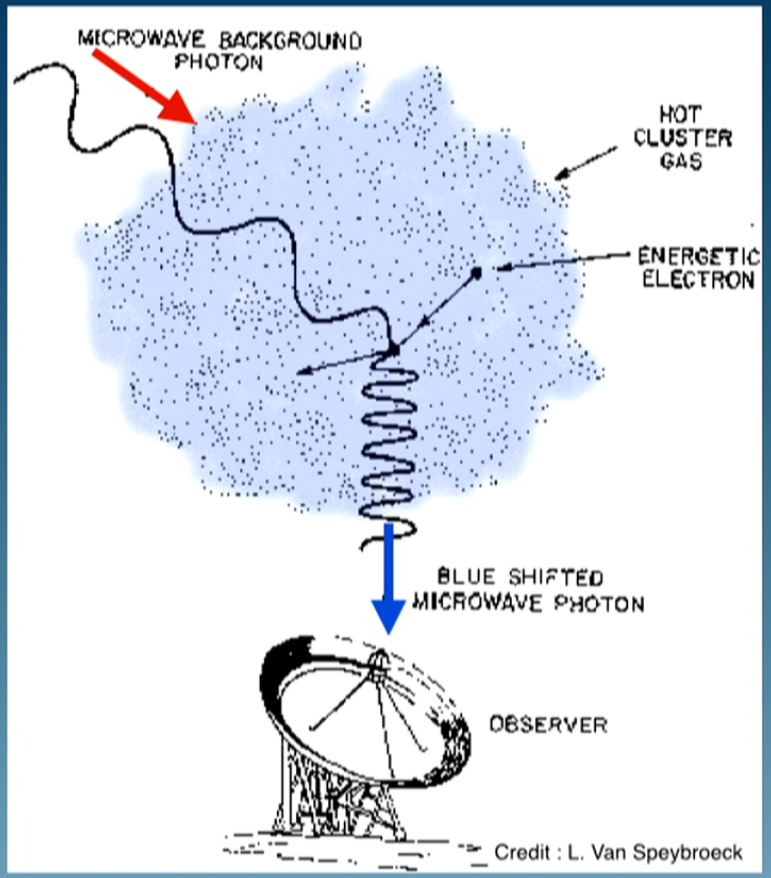


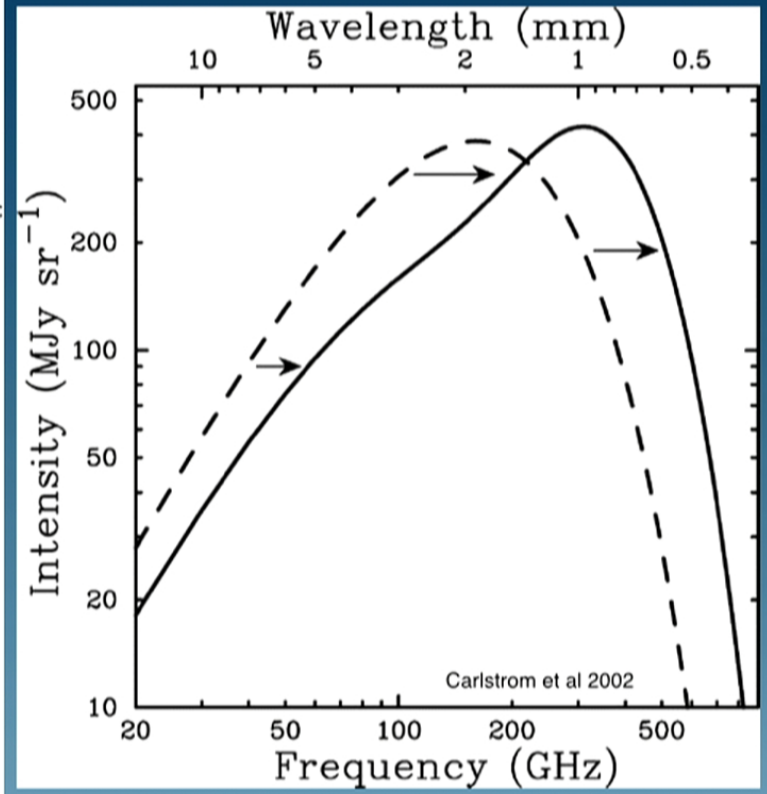
tSZ & kSZ

Other secondaries

Thermal Sunyaev-Zel'dovich Effect

- Inverse Compton scattering of CMB photons





Thermal Sunyaev-Zel'dovich Effect

- Secondary anisotropies in the CMB

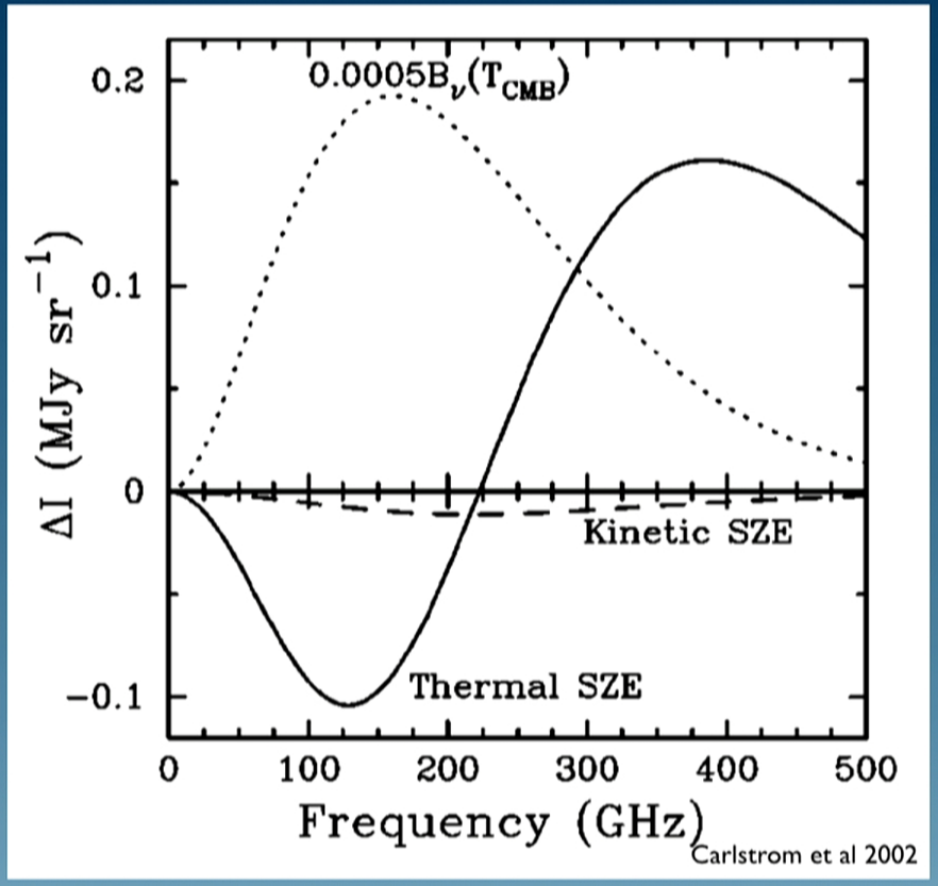
$$\frac{\Delta T}{T_{CMB}} = g_\nu \, y$$

$$y = \frac{k_b \sigma_T}{m_e c^2} \int n_e T_e dl$$

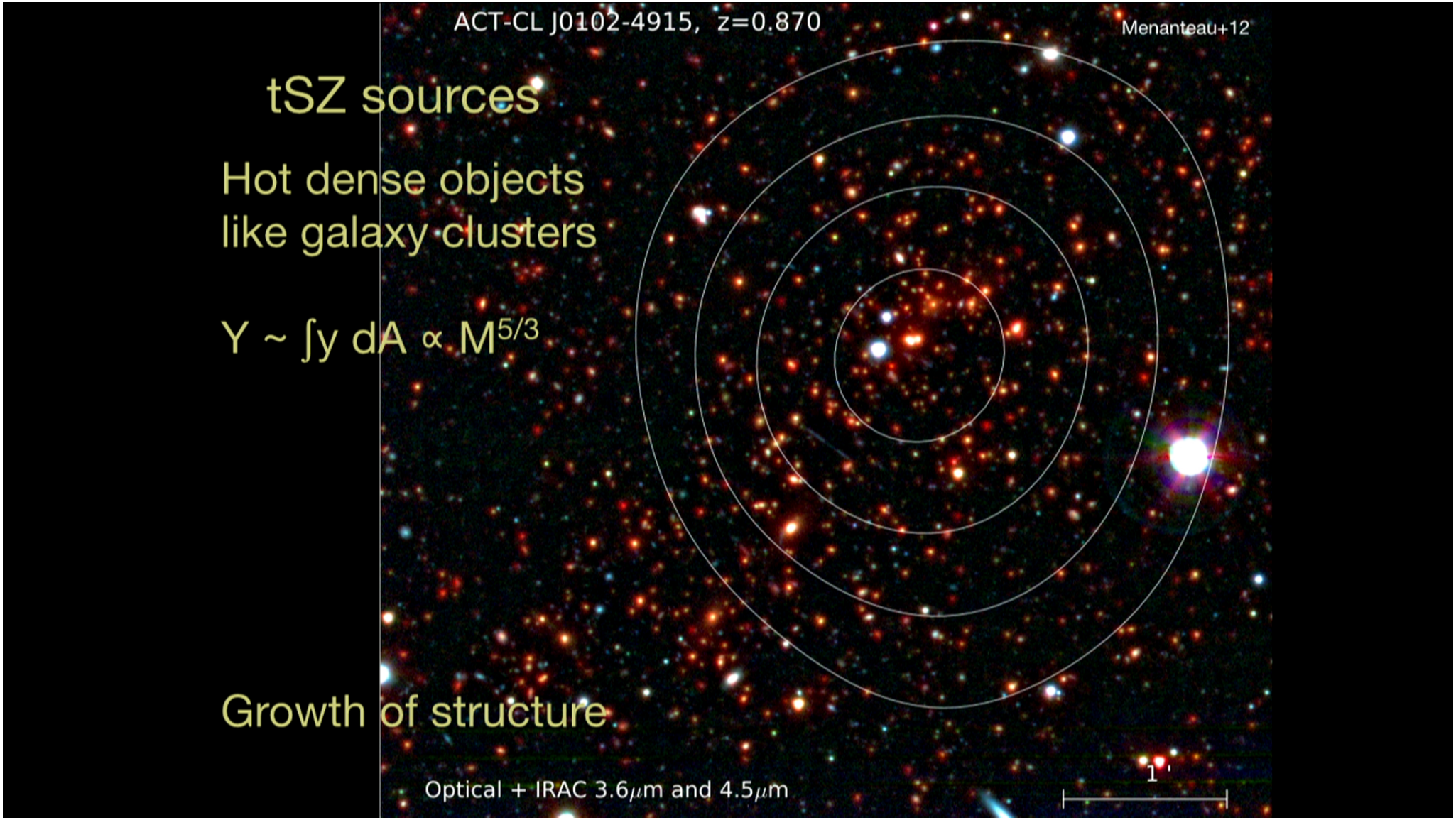
- Integrated pressure

relativistic terms are small and not included

Until the end…

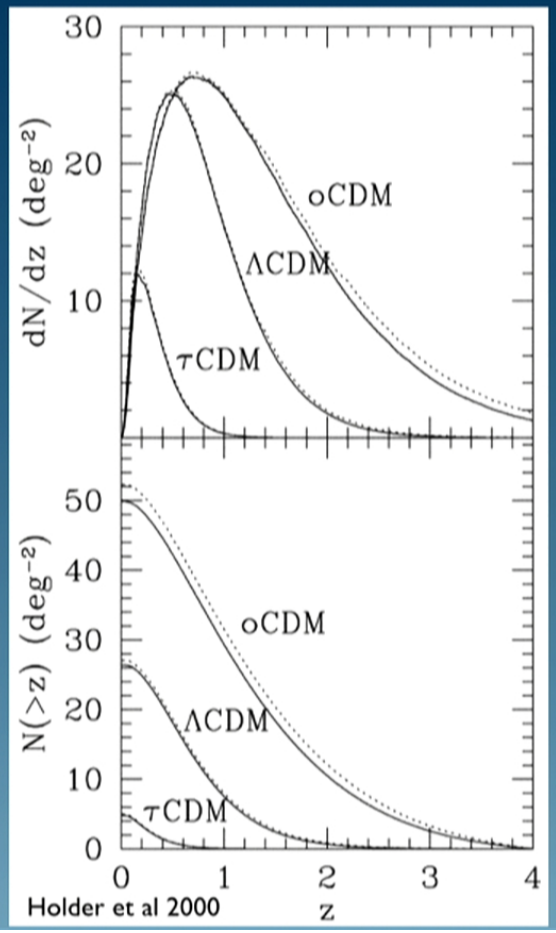


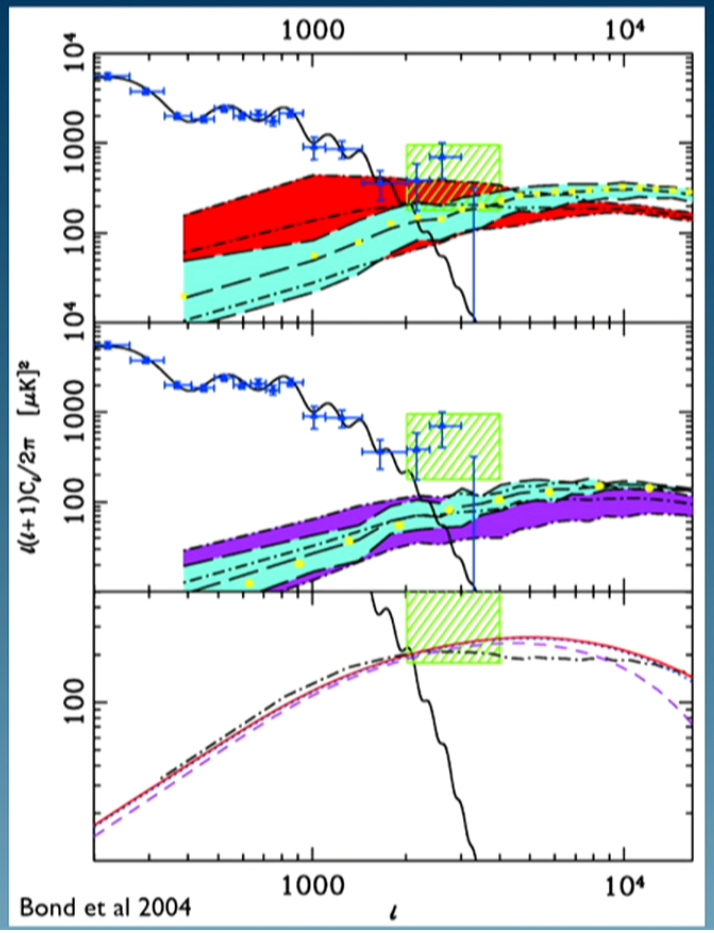
Carlstrom et al 2002


ACT-CL J0102-4915, z=0.870
Menanteau+12
tSZ sources
Hot dense objects
like galaxy clusters
Y ~ ∫y dA ∝ M5/3
Growth of structure
Optical + IRAC 3.6μm and 4.5μm
1'

"Standard" Measurements

Number counts or power spectrum





Also: higher order meas.

e.g. Wilson+13, Hill+13, Bhattacharya+13 Crawford+13

f_{gas}

e.g. Mantz+10

"Standard" Measurements

Number counts or power spectrum

Also higher order meas.

e.g. Wilson+13, Hill+13, Bhattacharya+13, Crawford+13

f_{gas} e.g. Mantz+10

Cluster counts — Selection function & Mass proxy

$$N = \int_0^{z_{max}} dz \frac{dV}{dz} \int dM \frac{dn(M,z)}{dM}$$

Gastrophysics

tSZ power spectrum $A_{tSZ} \propto \sigma_8^8$

$$C_l = g_\nu^2 \int_0^{z_{max}} dz \frac{dV}{dz} \int dM \frac{dn(M,z)}{dM} \left|\tilde{y}_l(M,z)\right|^2$$

+ Clustering of clusters (Sub-dominant)

Modeling the ICM

Simulations or (Semi)Analytical

e.g. Da Silva et al 2000, Springel 2001, Bond et al 2002, BBPSS 2010 McCarthy et al 2014

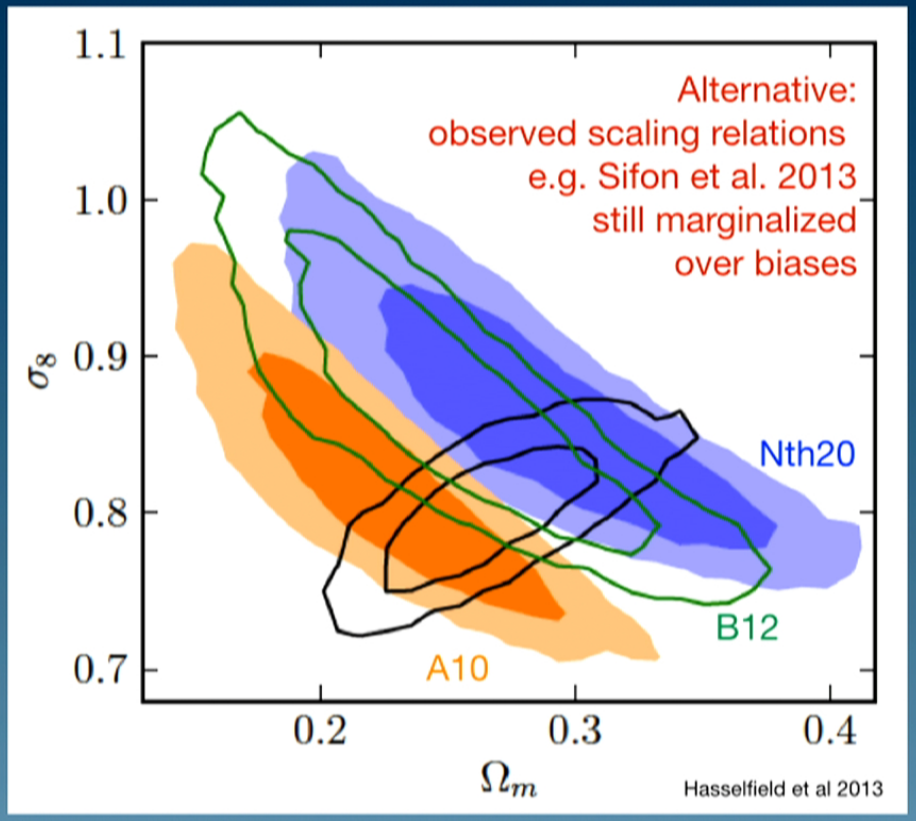
e. g. Komatsu & Seljak 2001, Ostriker et al. 2005, Bode et al 2009(12), Sehgal et al 2010, Shaw et al 2010, Trac et al 2011

Processes that need to be included (Sub-grid)

- Radiative cooling
- Star formation
- Feedback (AGN, stellar)
- Non-thermal pressure support P_{KIN}, CR, P_B …
- Asphericity and sub-structure
- Plasma processes
- etc...

The ICM is complex!

X-roads Cosmology & Astrophysics



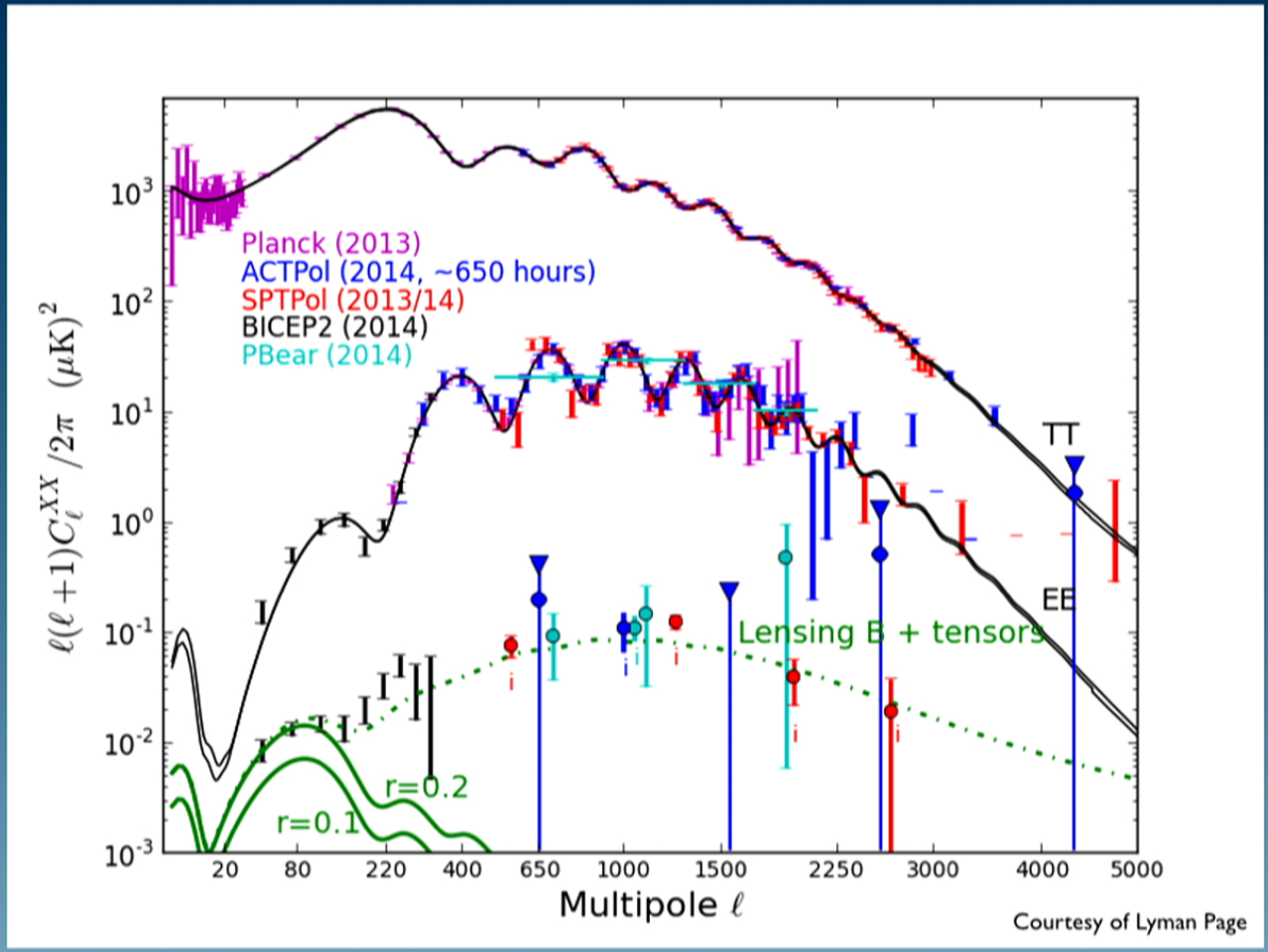
Status of cluster cosmology

Limited by uncertainty in the Y-M relation & Pressure profile

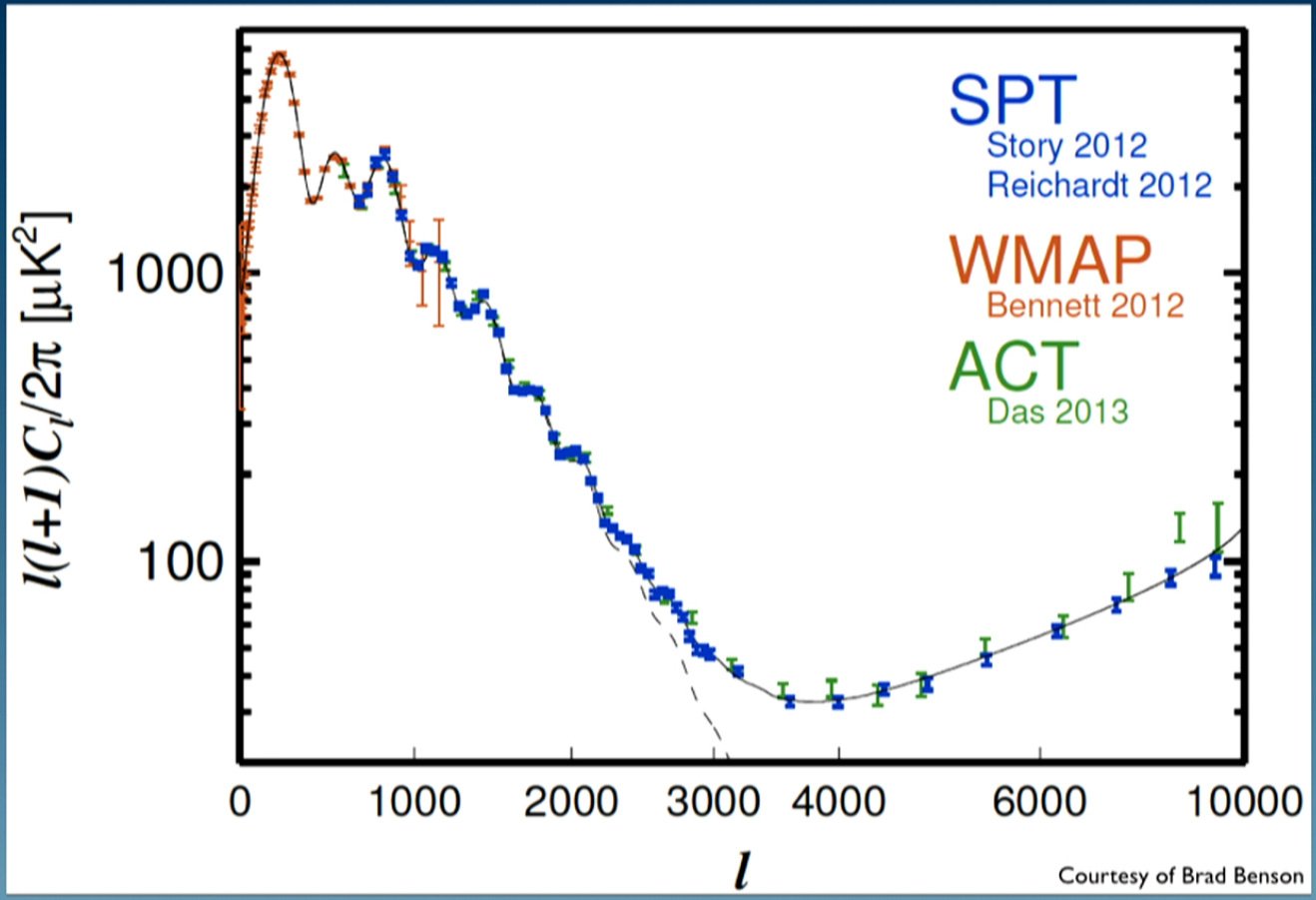
e.g. Benson et al 2013, Hasselfield et al 2013, Rozo et al 2013, & Planck Coll. XX 2013

Simulations are a tool for understanding and quantifying the important gastrophysics, biases, and scatter in surveys

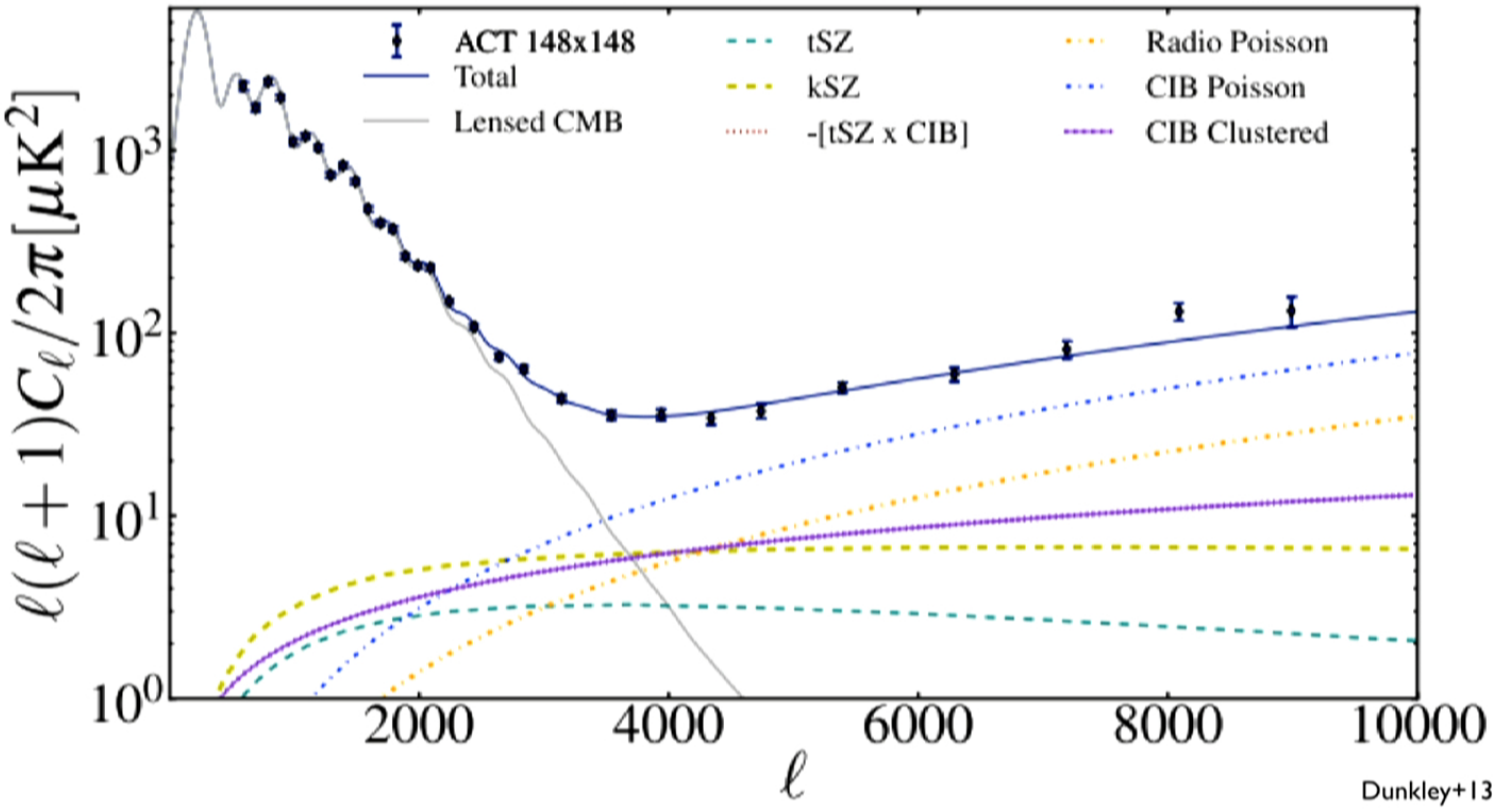
State of primary CMB



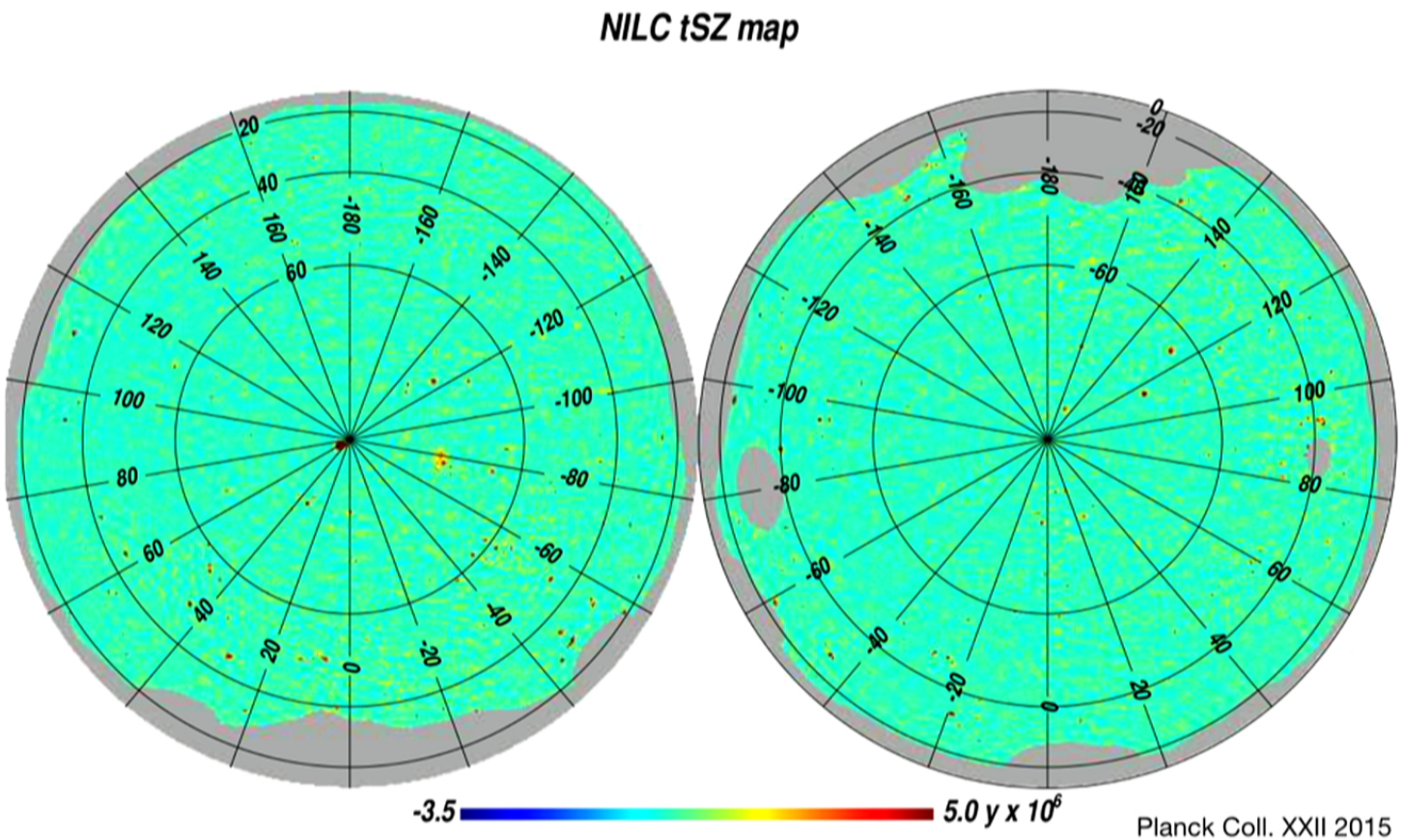
State of tSZ PS



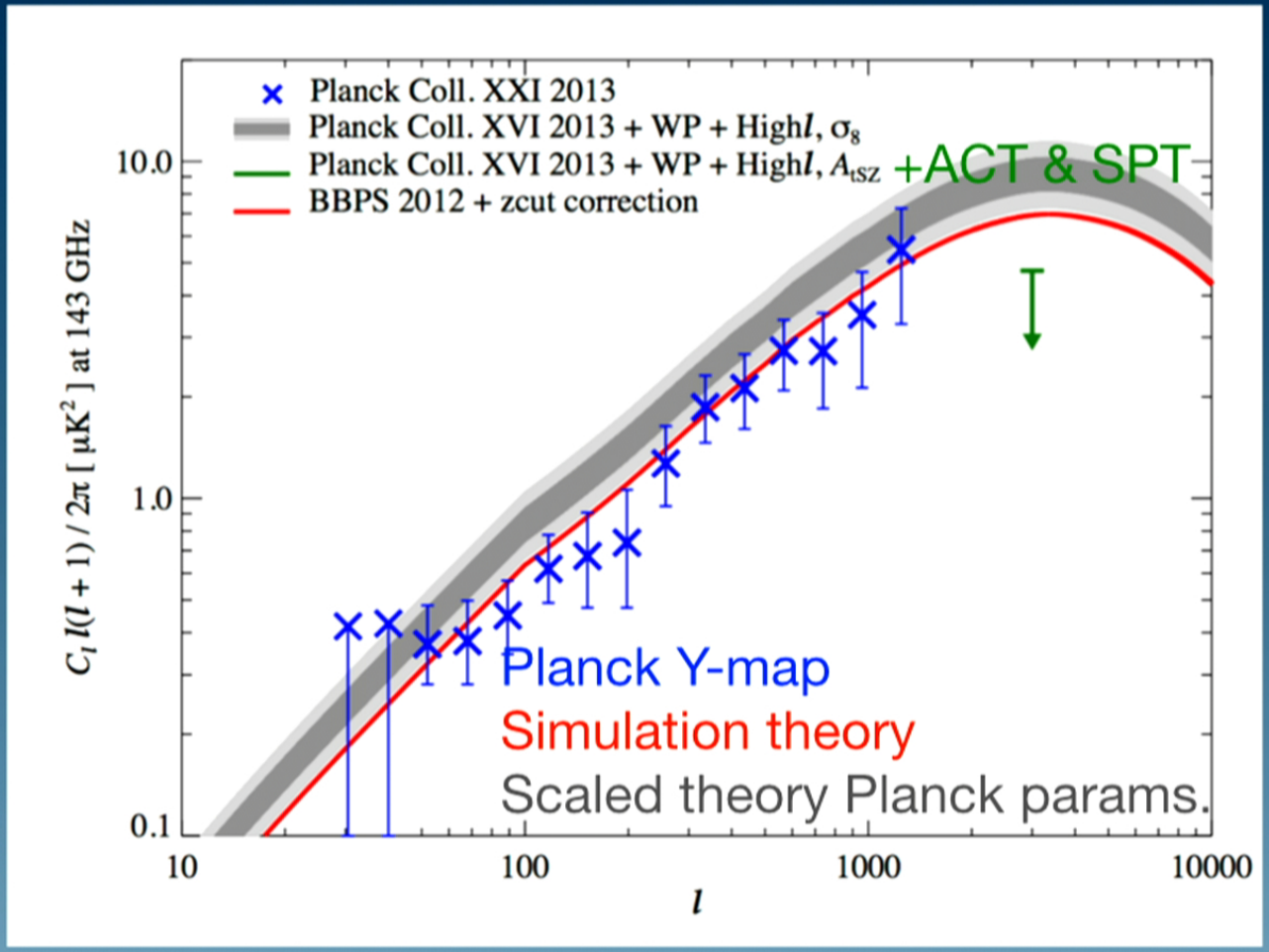
State of tSZ PS



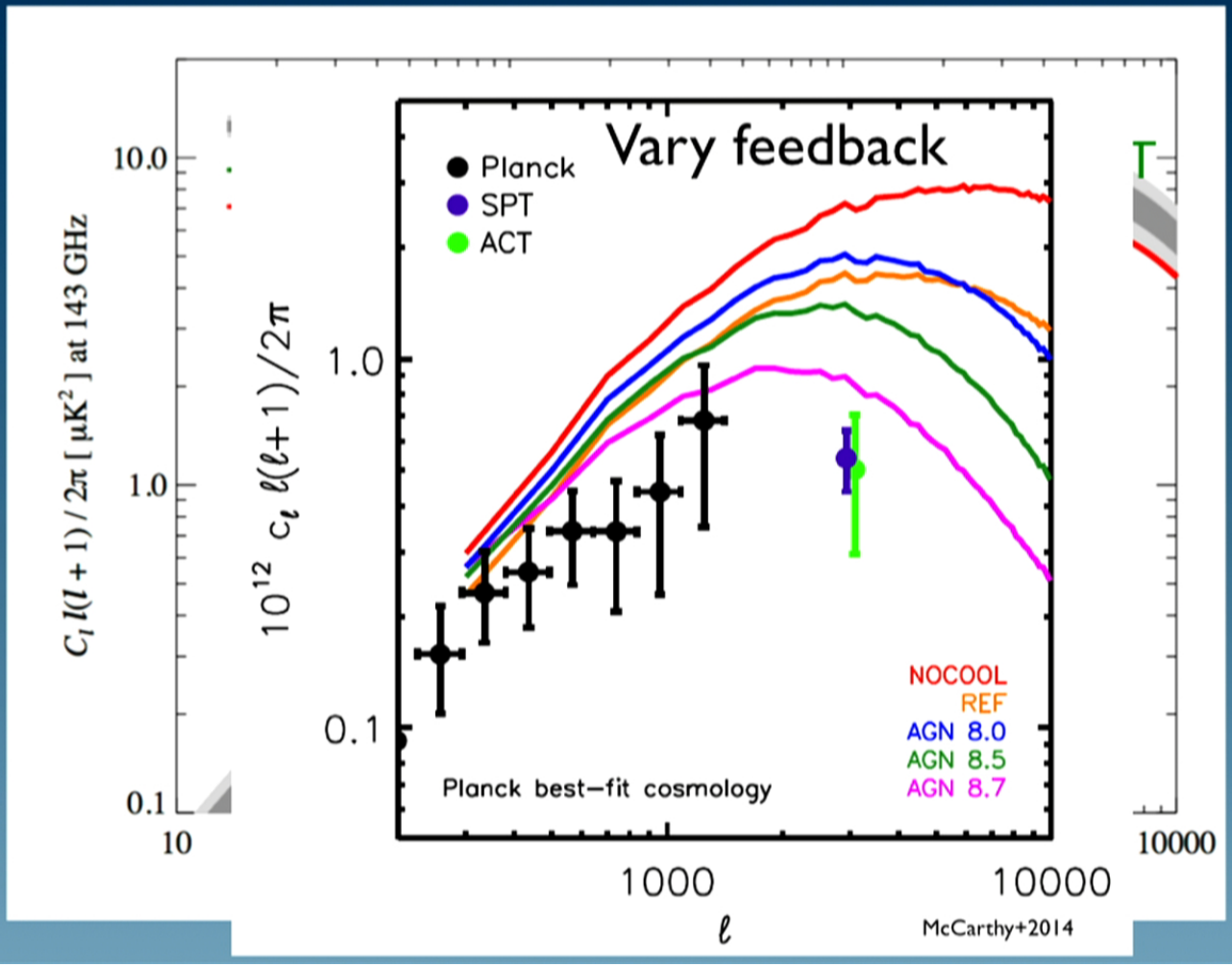
Planck y-map



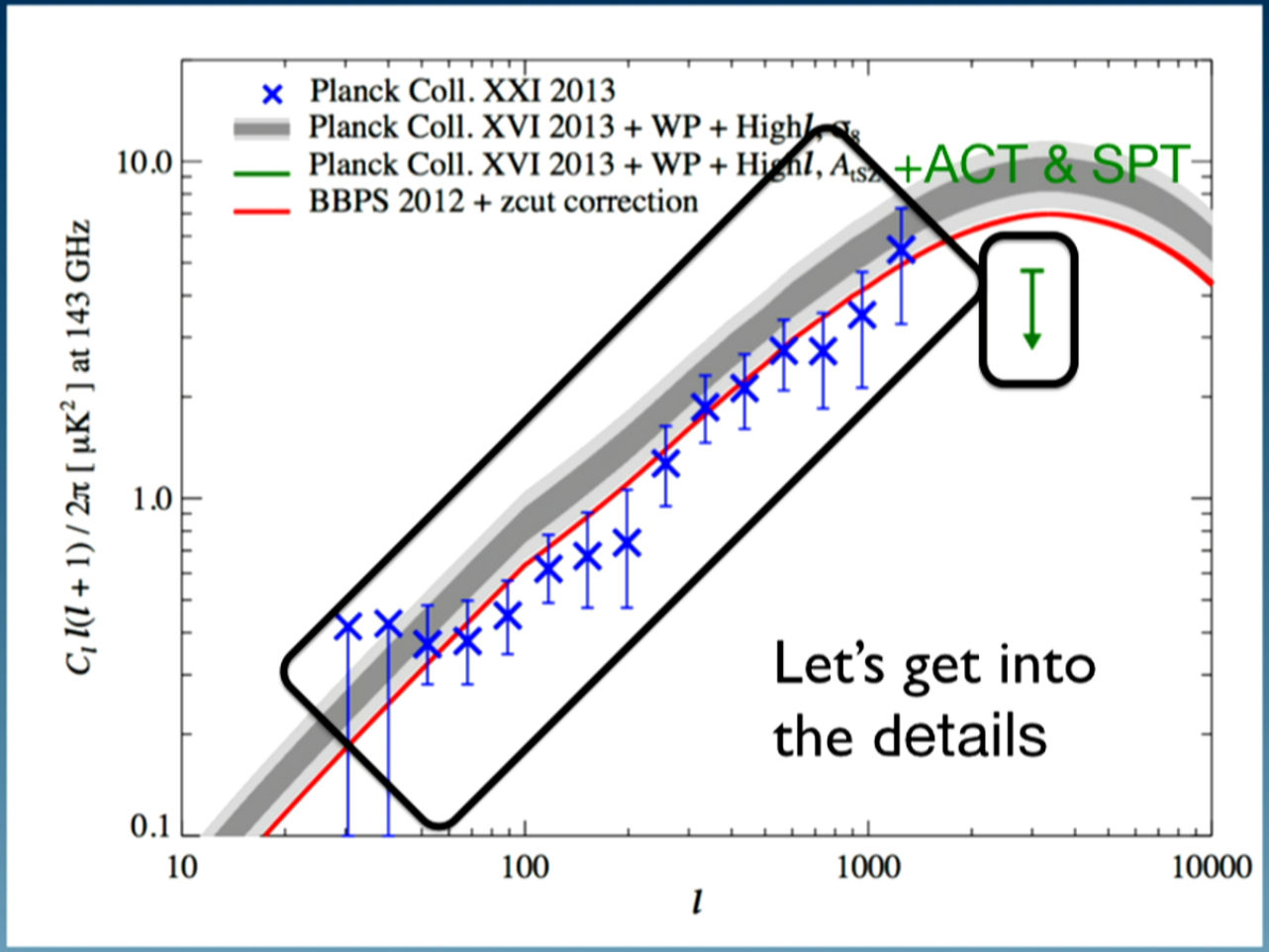
What's going on with CMB secondaries?



What's going on with CMB secondaries?



What's going on with CMB secondaries?



What's going on with CMB secondaries?

Gastrophysics? for tSZ P_{th} profile

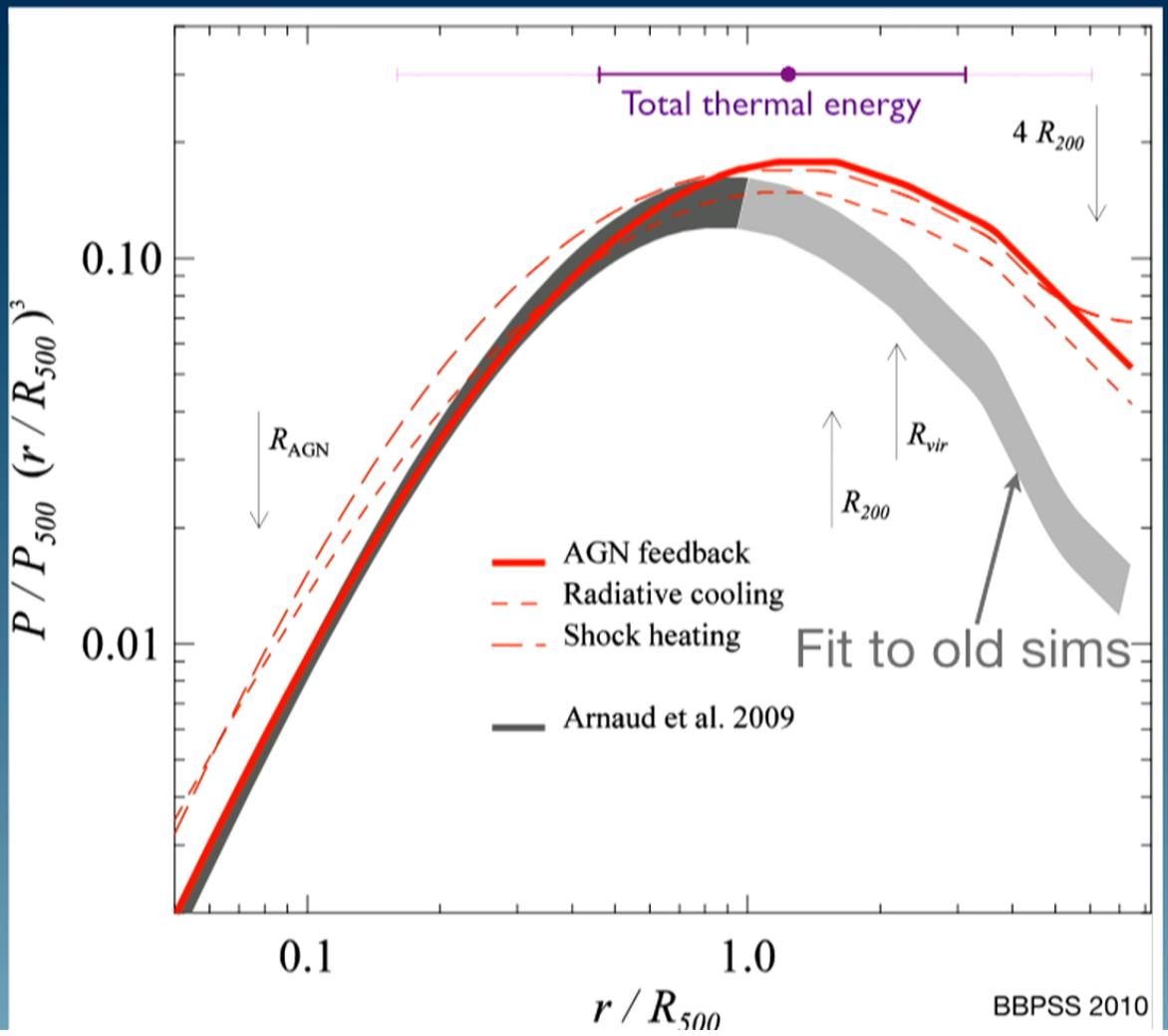
CIB contamination and IR fill in?

New physics?

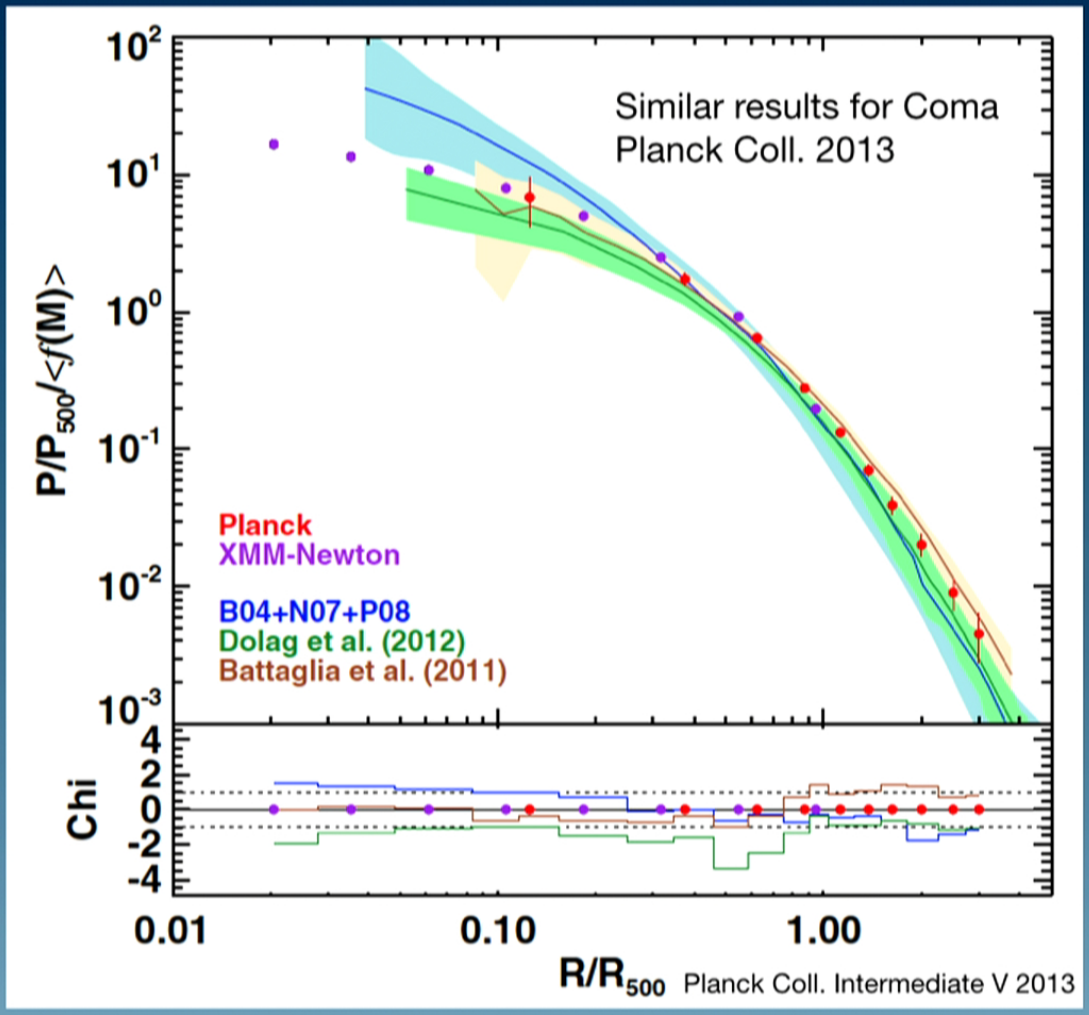
Mass function?

Simulated observables
Compare to recent observations of other statistical cluster properties

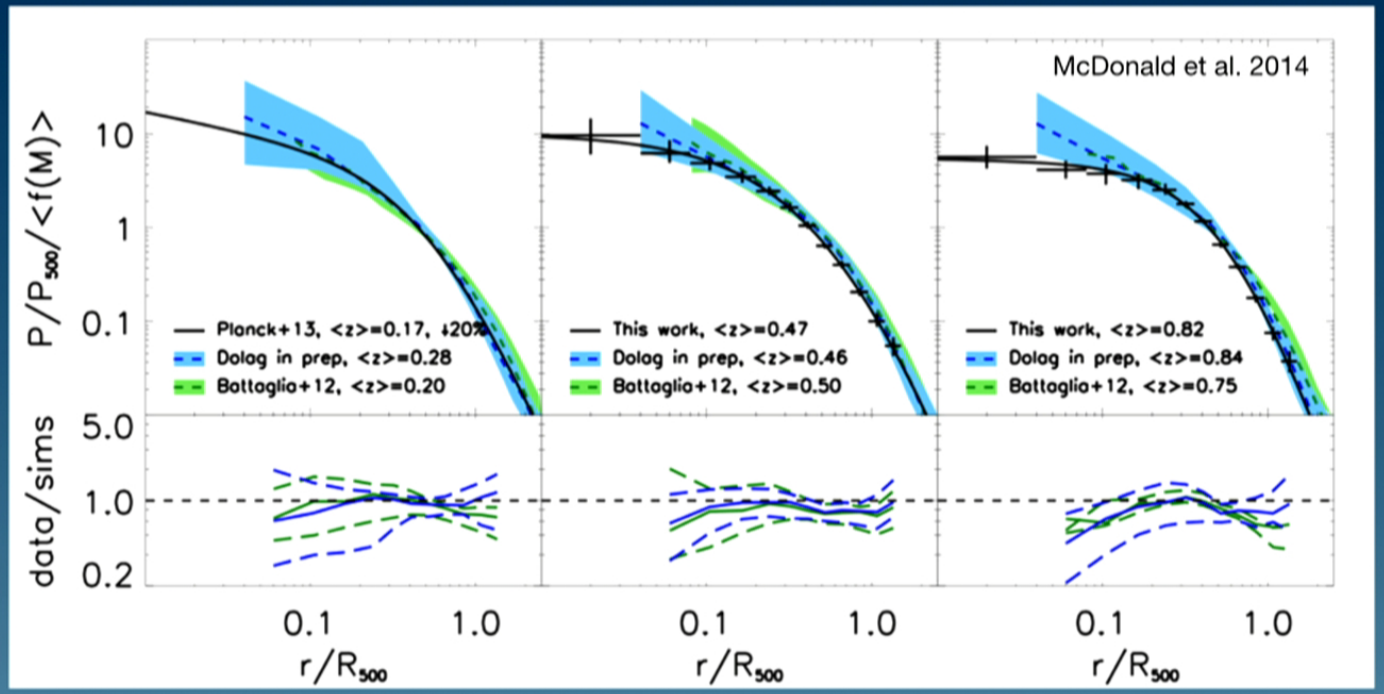
Simulation P_{th} Profile



Planck P_{th} Profile

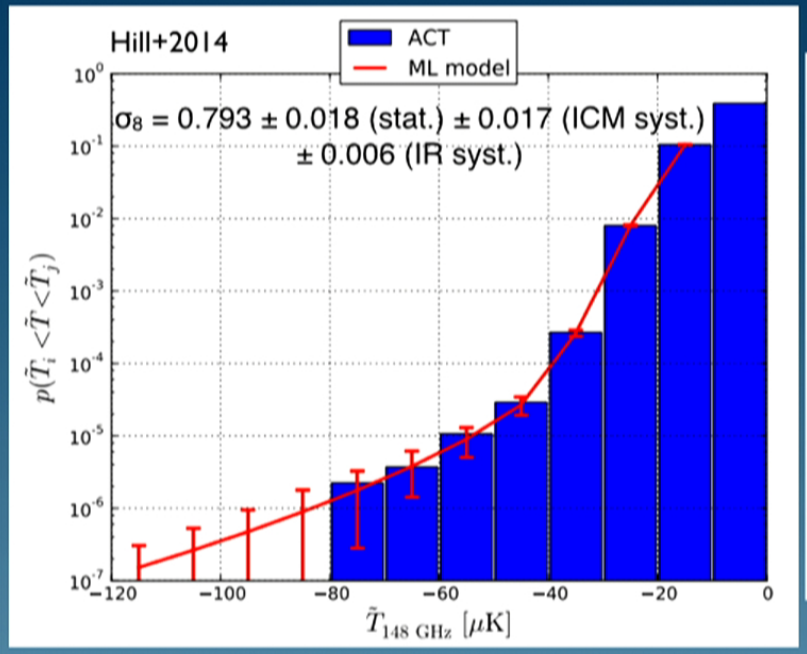


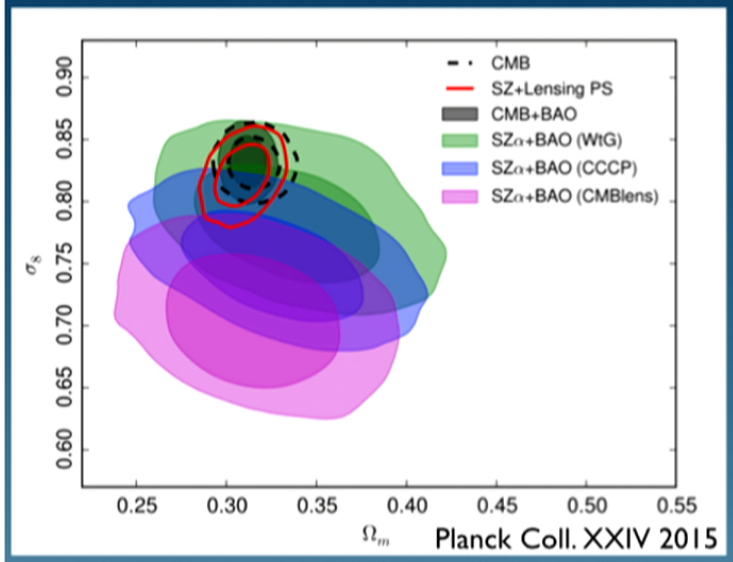
SPT X-ray P_{th} Profile z > 0.3



- Simulations do well to match the observed pressure profile at higher redshifts also
- We understand (can model) the total thermal energy in massive clusters out to high redshift

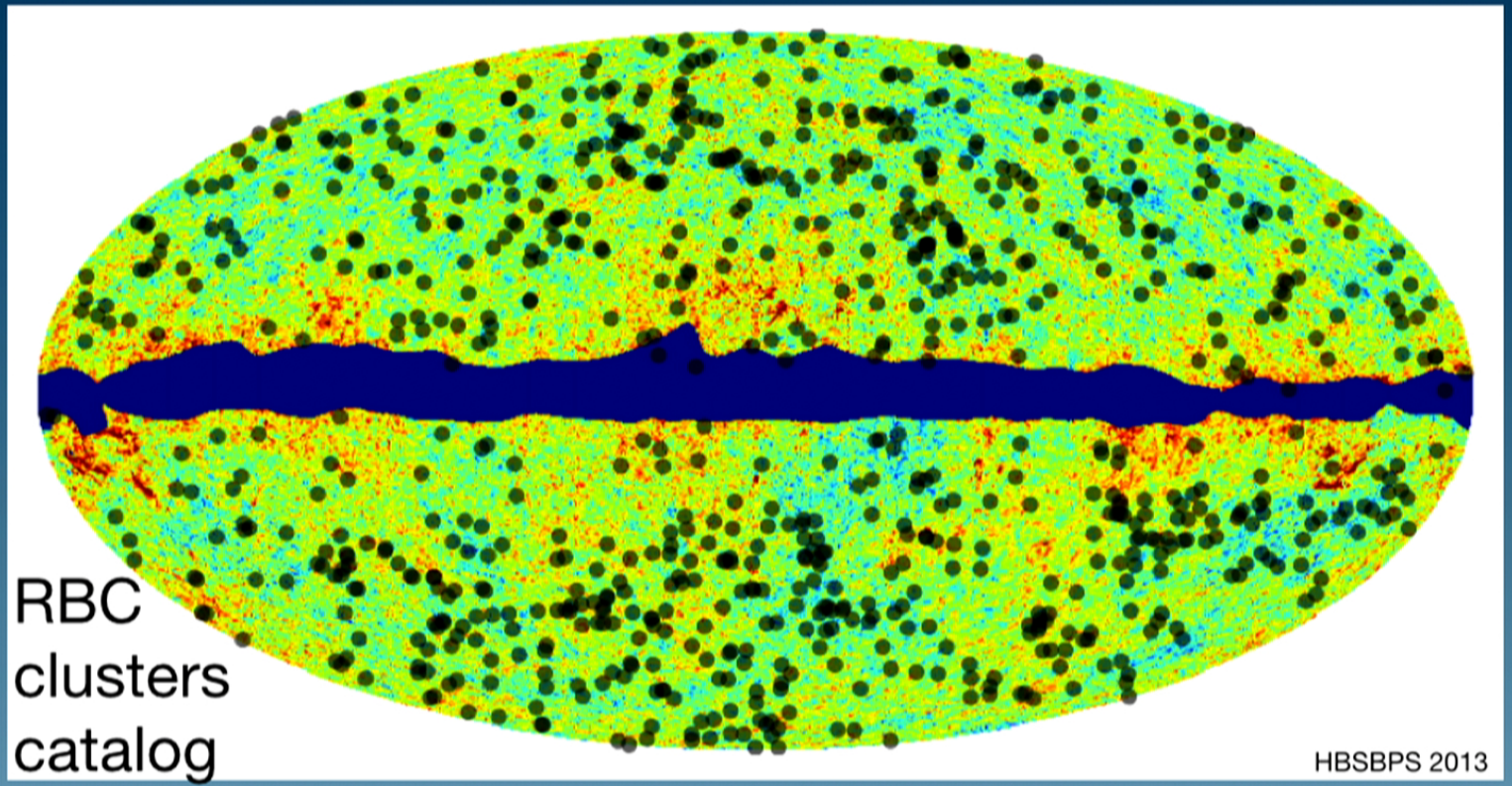
It's not just the power spectrum





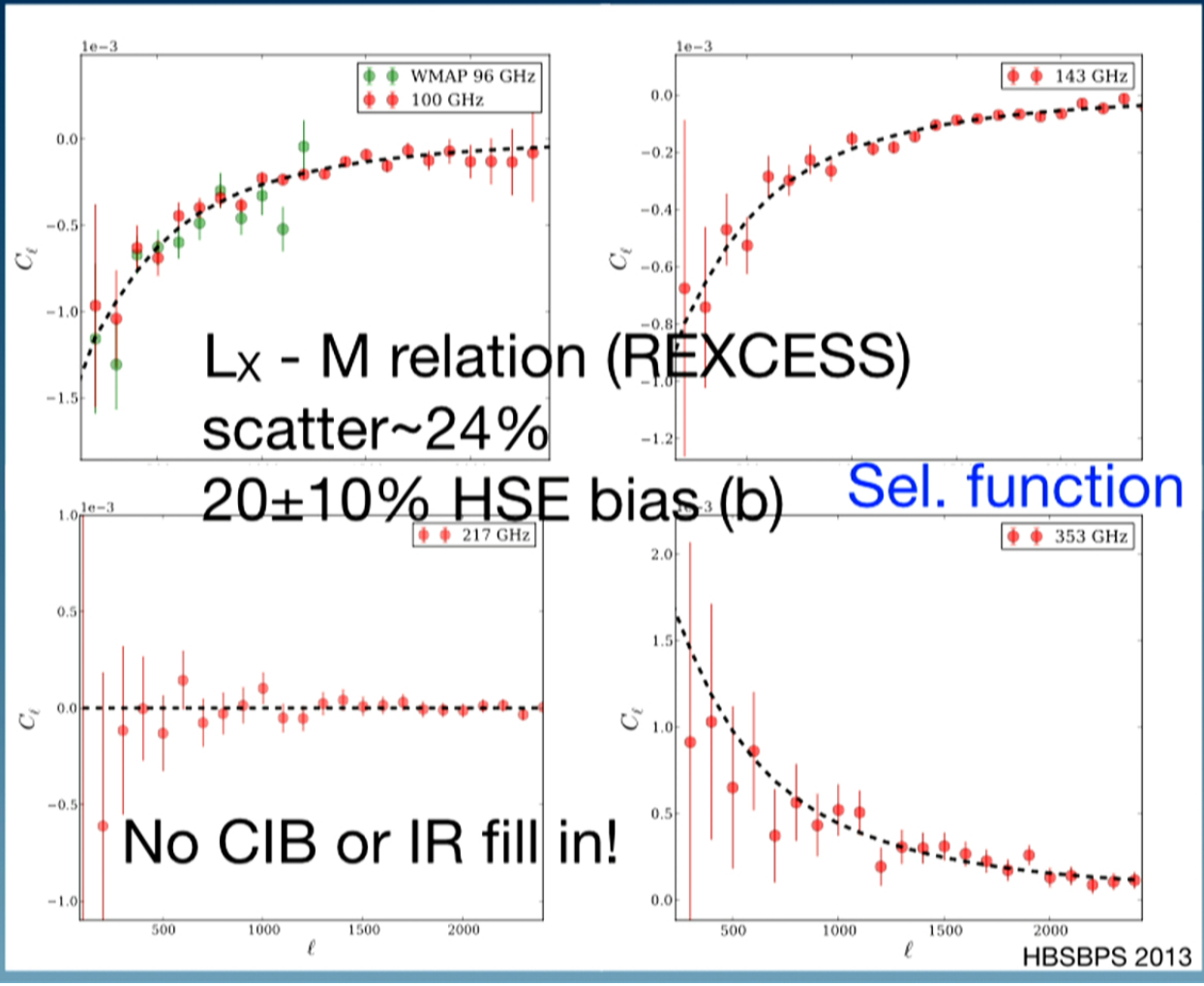
most other low redshift growth of structure constraints are in mild tension with CMB

Cross Correlation with X-ray clusters



Used the raw Planck at 100-857 GHz
Also used the WMAP9 94 GHz

Cross spectra

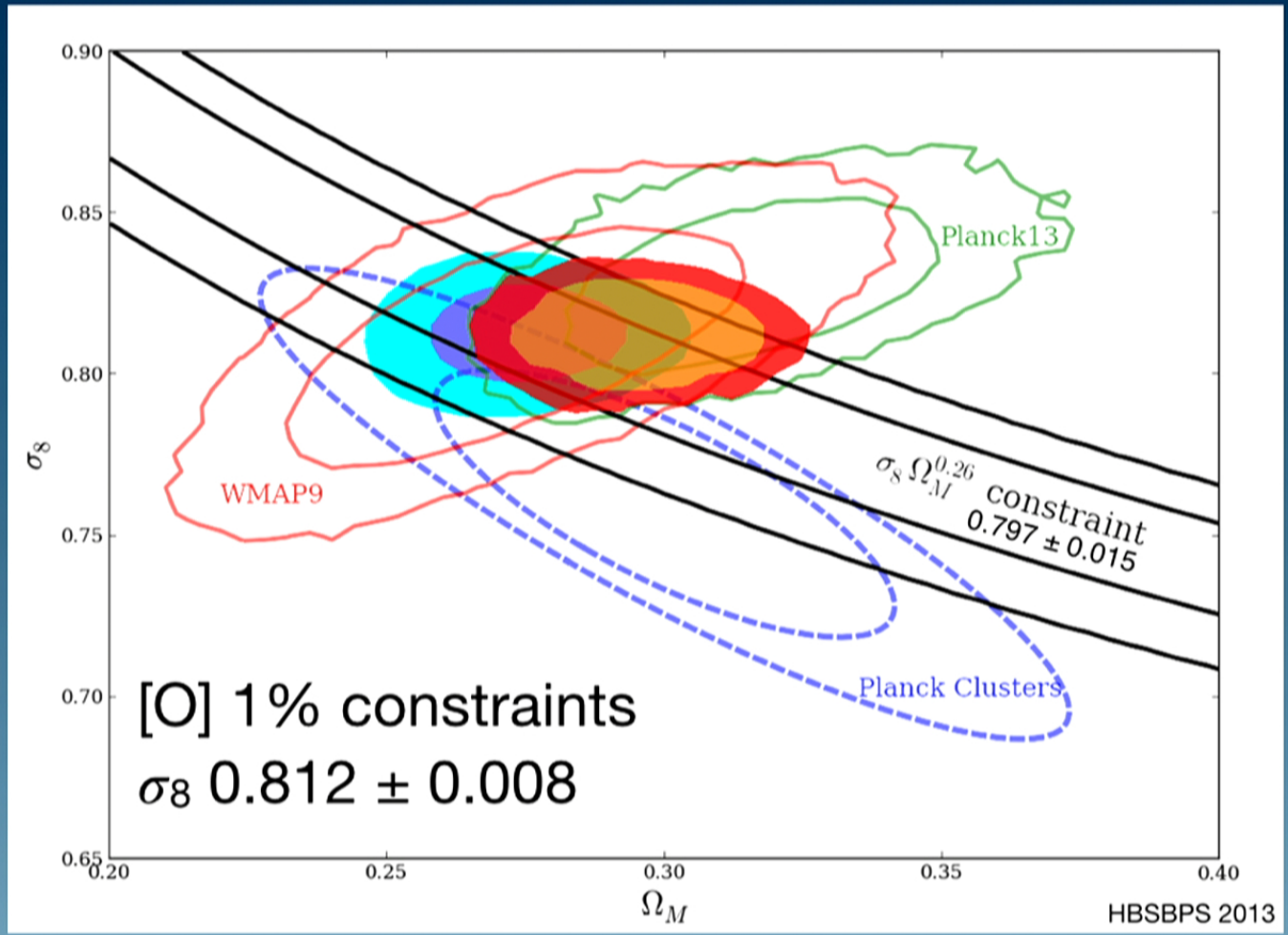


L_X - M relation (REXCESS)
scatter~24%
20±10% HSE bias (b)

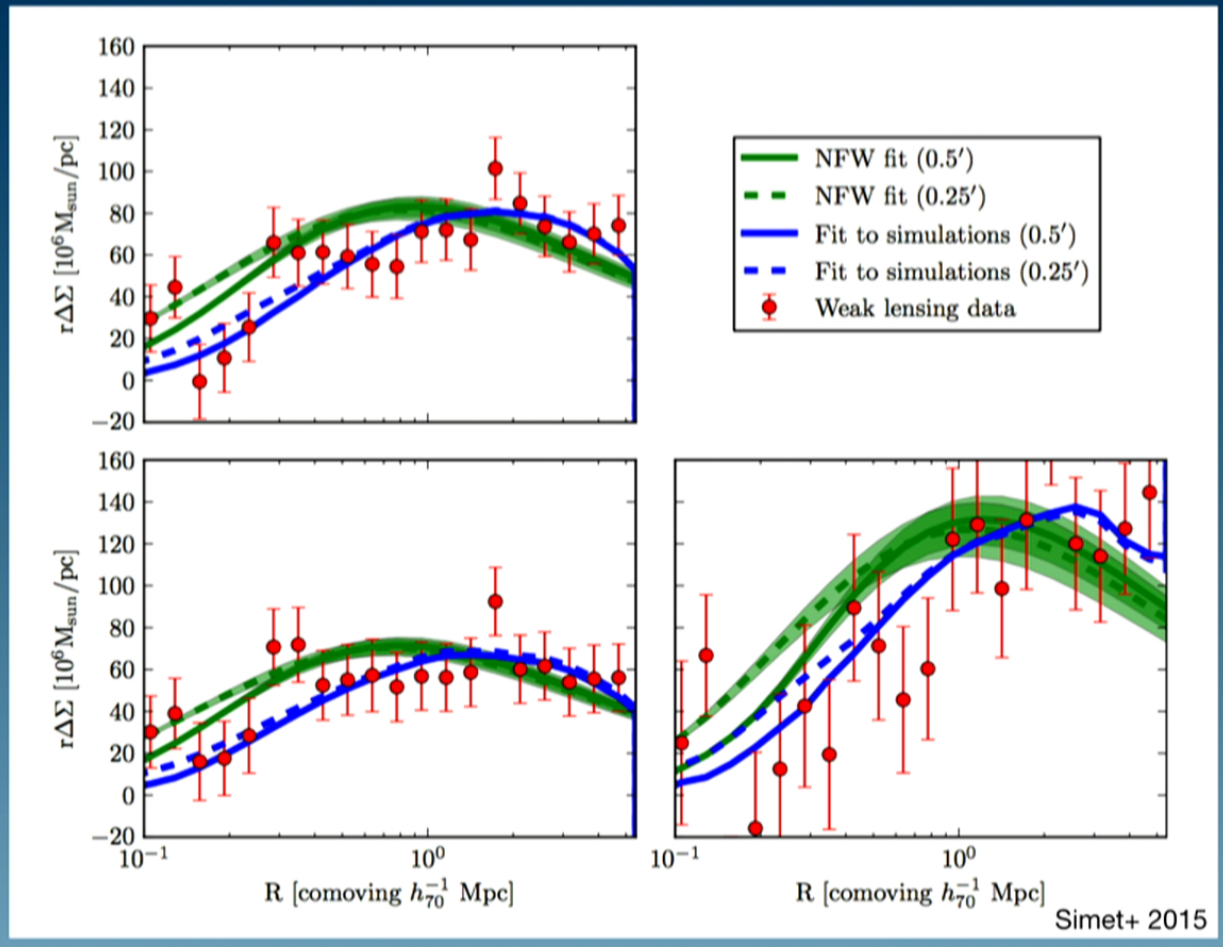
Sel. function

No CIB or IR fill in!

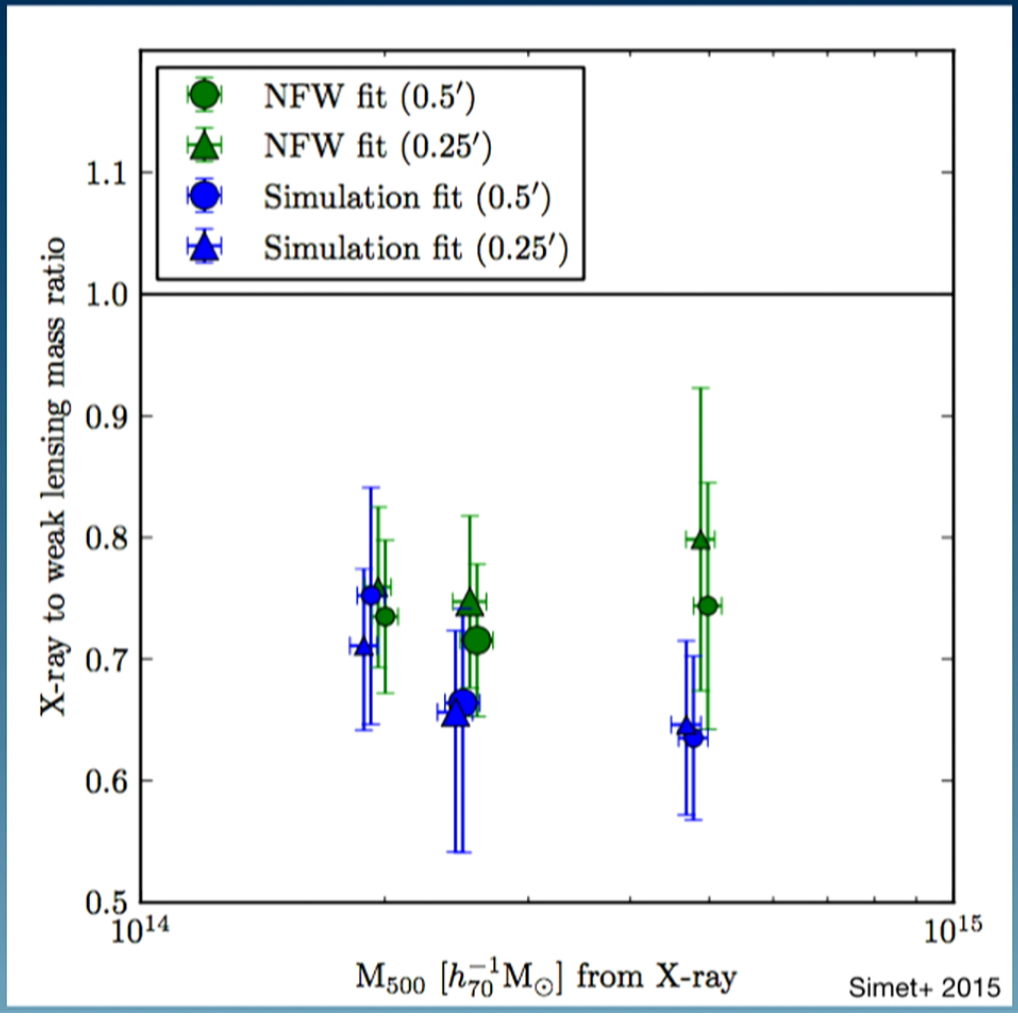
Cross spectra constraints



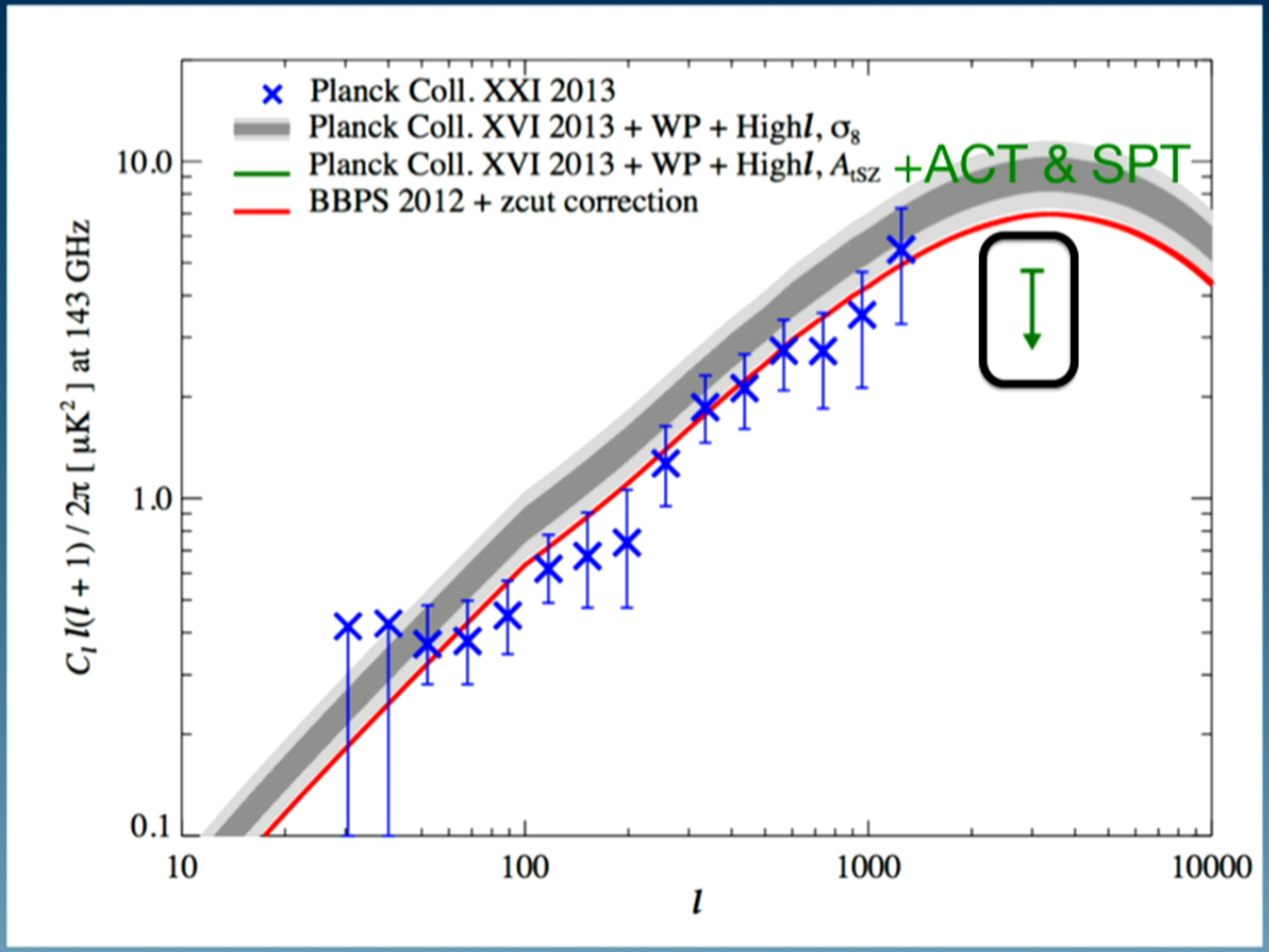
RBC weak lensing mass calibration



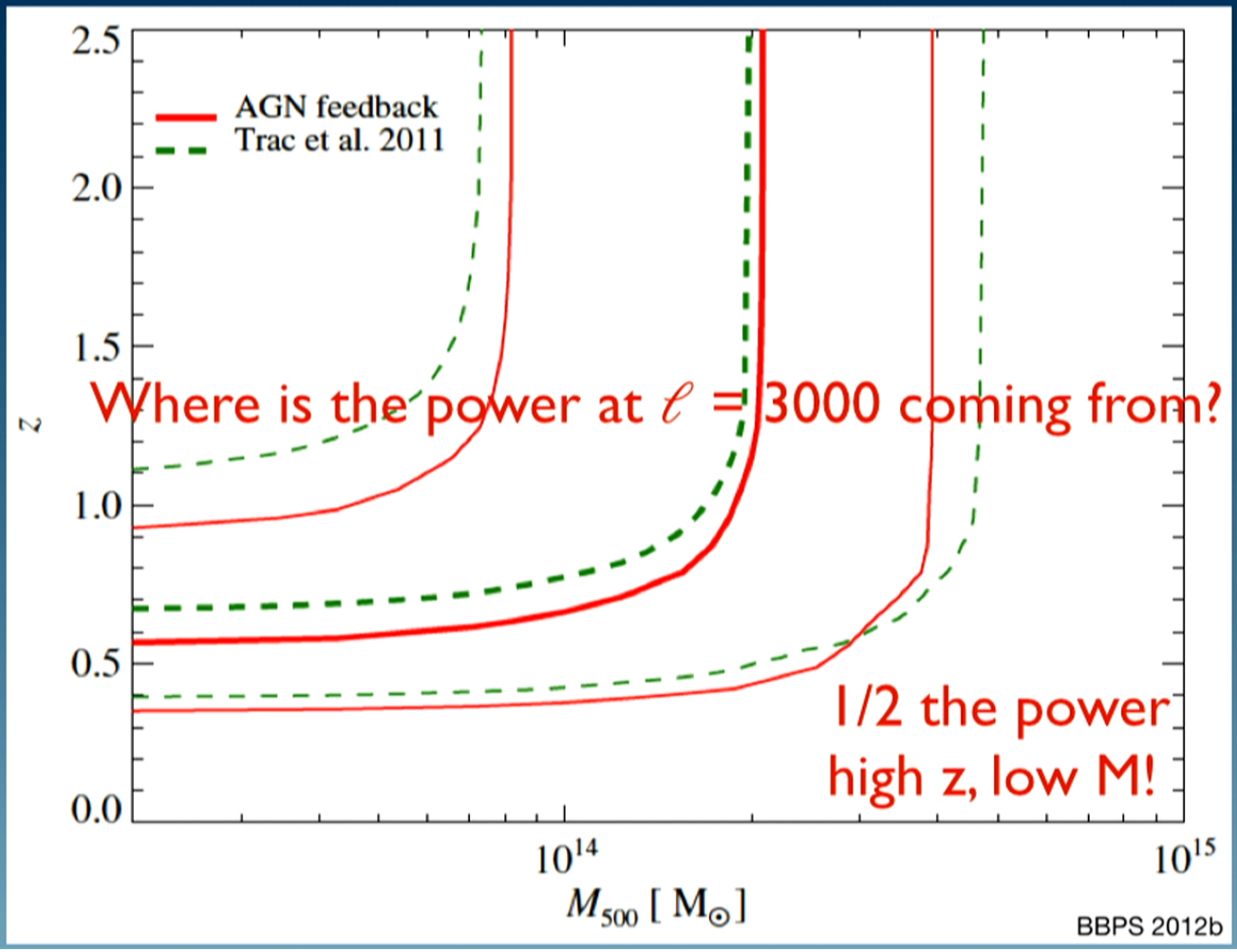
RBC weak lensing mass calibration



Discrepancy at ℓ = 3000?



$C_\ell(M,z)$


AGN feedback
Trac et al. 2011
Where is the power at $\ell = 3000$ coming from?
1/2 the power
high z, low M!
z
M_{500} [$M_\odot$]
BBPS 2012b

Cross correlate with lensing

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Detection of thermal SZ-CMB lensing cross-correlation in Planck nominal mission data

J. Colin Hill and David N. Spergel

PHYSICAL REVIEW D **89,** 023508 (2014)

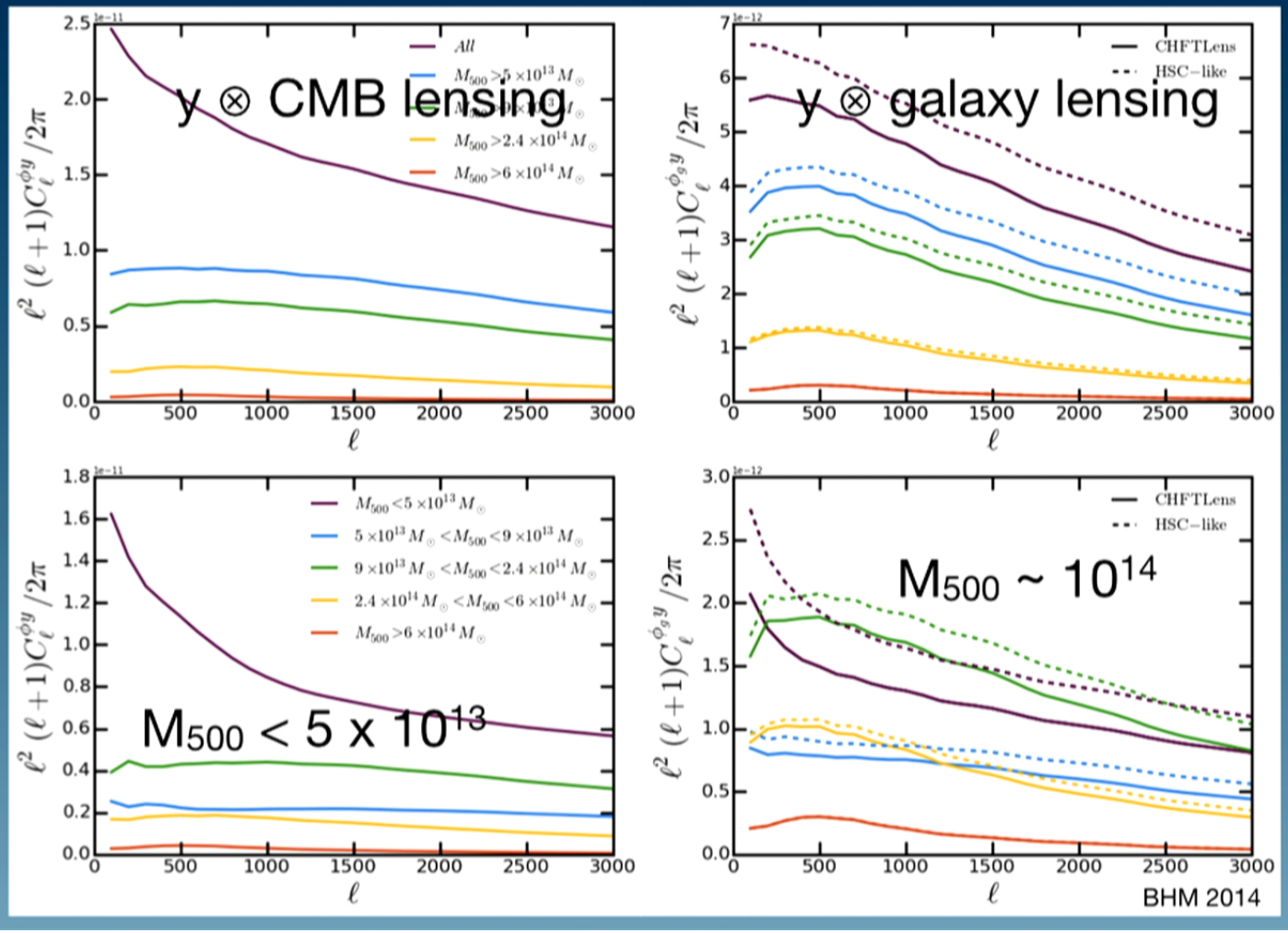
Detection of warm and diffuse baryons in large scale structure from the cross correlation of gravitational lensing and the thermal Sunyaev-Zeldovich effect

Ludovic Van Waerbeke,[1,*] Gary Hinshaw,[1,2,†] and Norman Murray[3,4,‡]

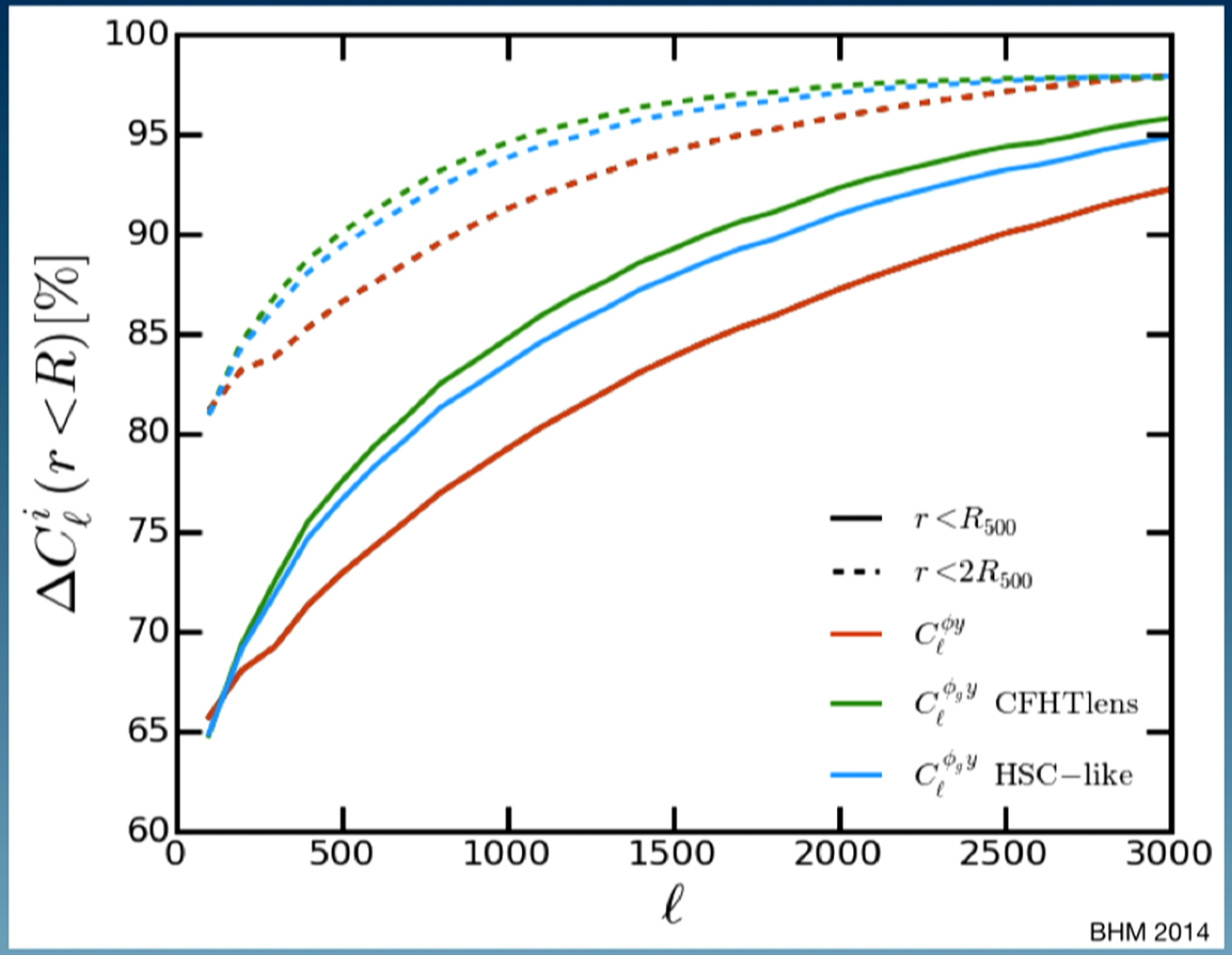
Ma+2014 & Hojjati+2014 - Interpretation of results

Several sigma detections of the cross correlations (~6σ)

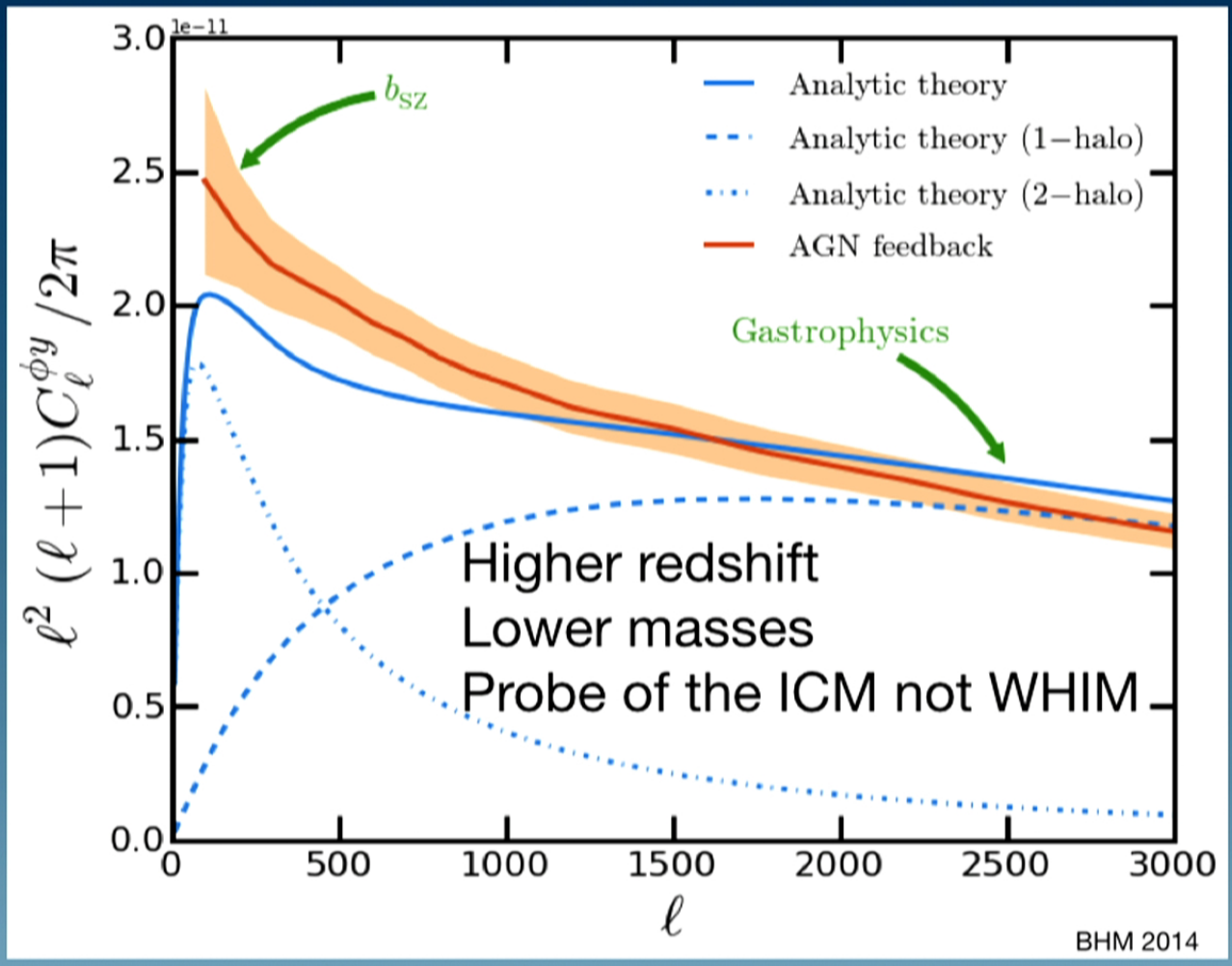
Cross correlate with lensing



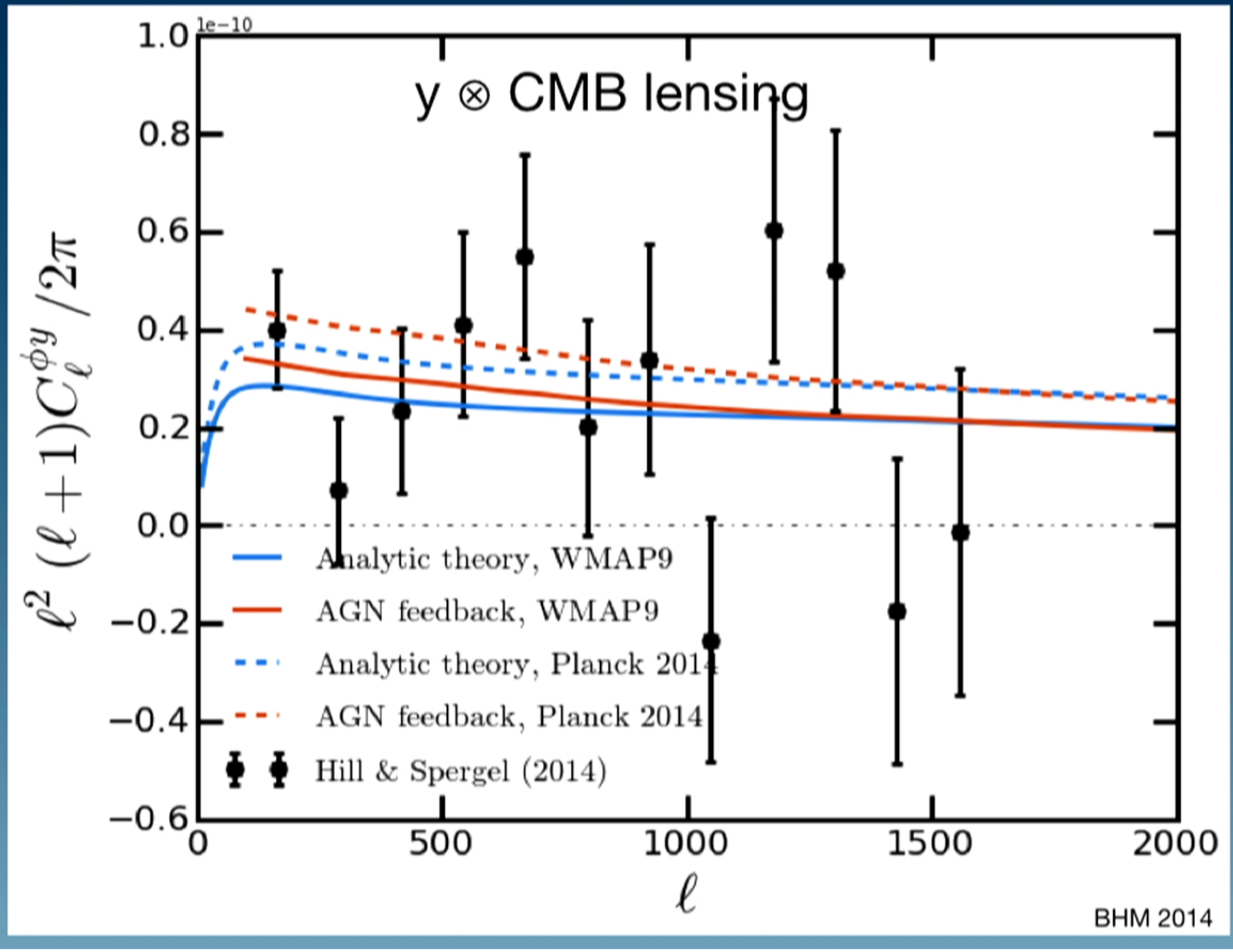
Cross correlate with lensing



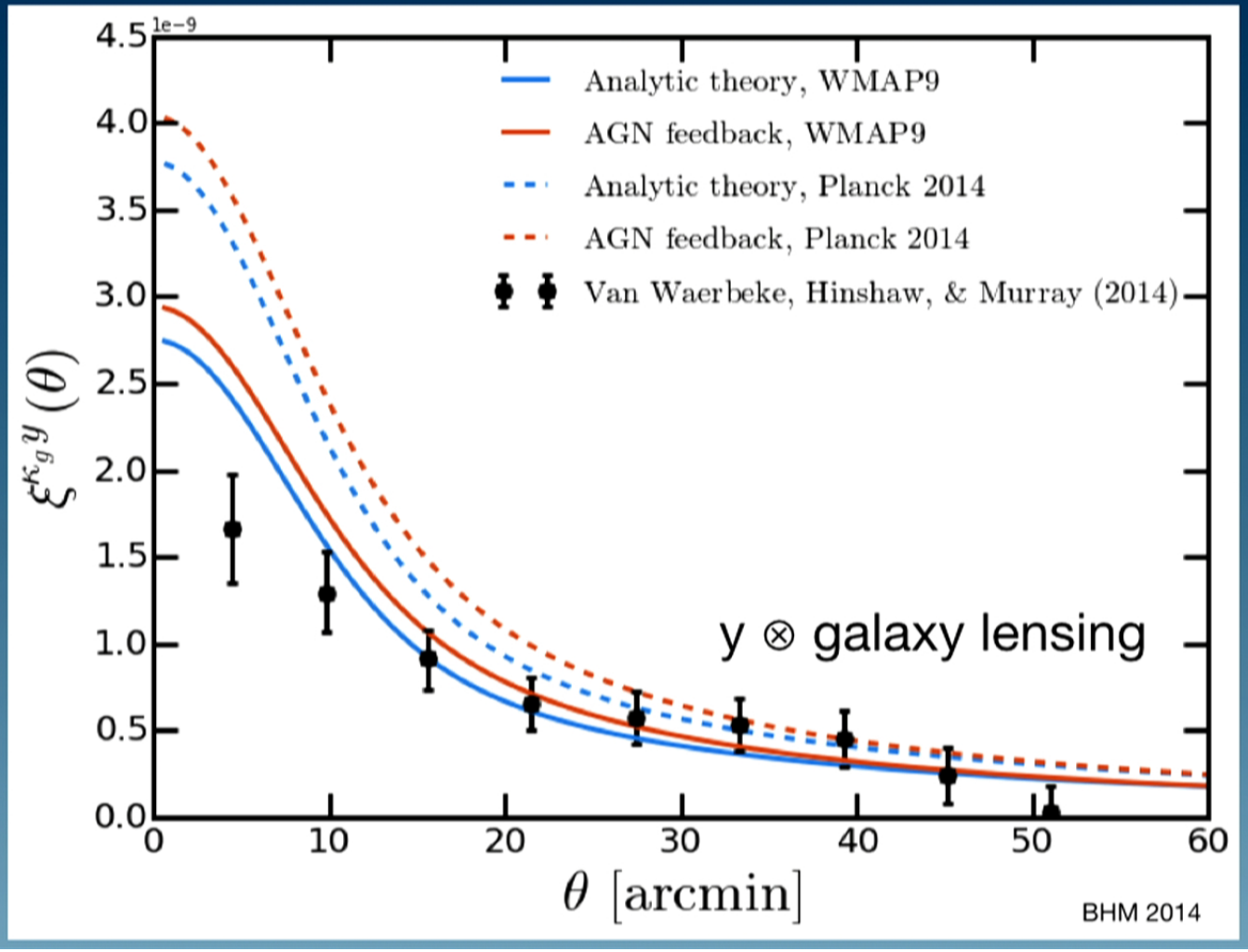
Cross correlate with lensing



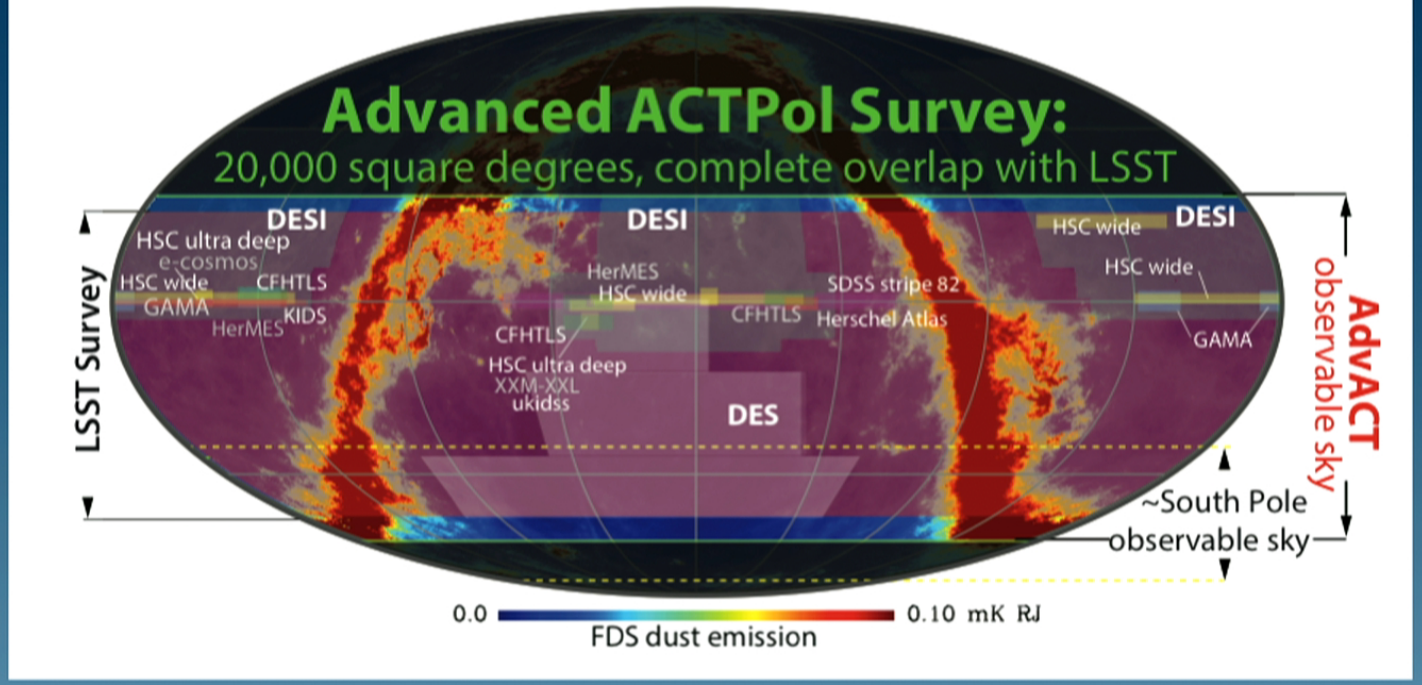
Cross correlate with lensing



Cross correlate with lensing

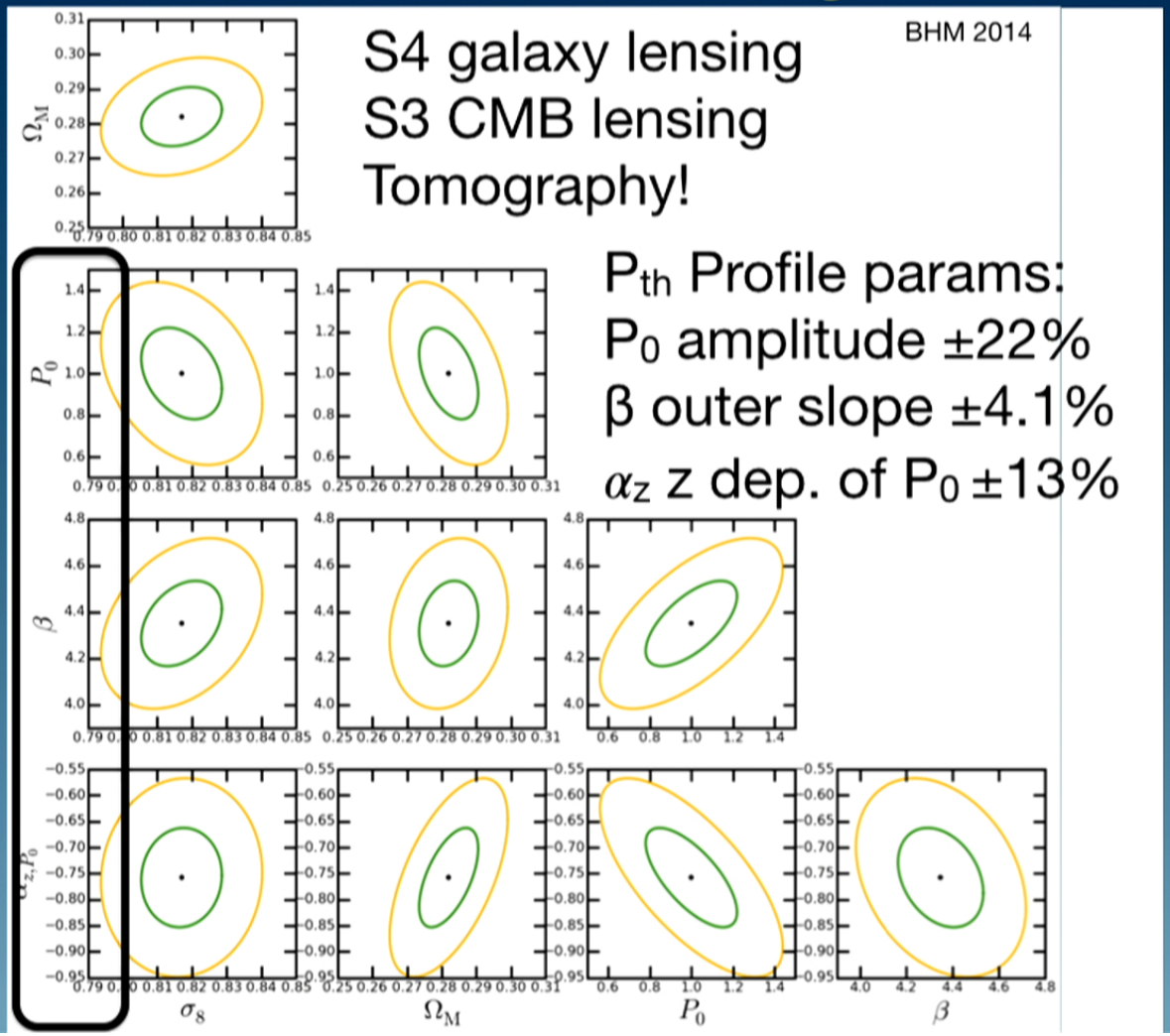


AdvACT + other surveys



Funded, large area, multiple frequency bands
Potential for cross correlations is huge!

Cross correlate with lensing forecast



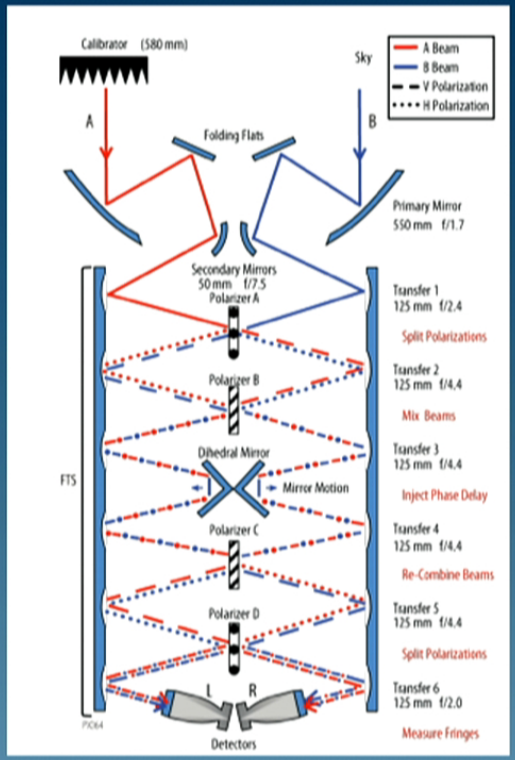
PIXIE

The Primordial Inflation Explorer (PIXIE): A Nulling Polarimeter for Cosmic Microwave Background Observations arXiv:1105.2044

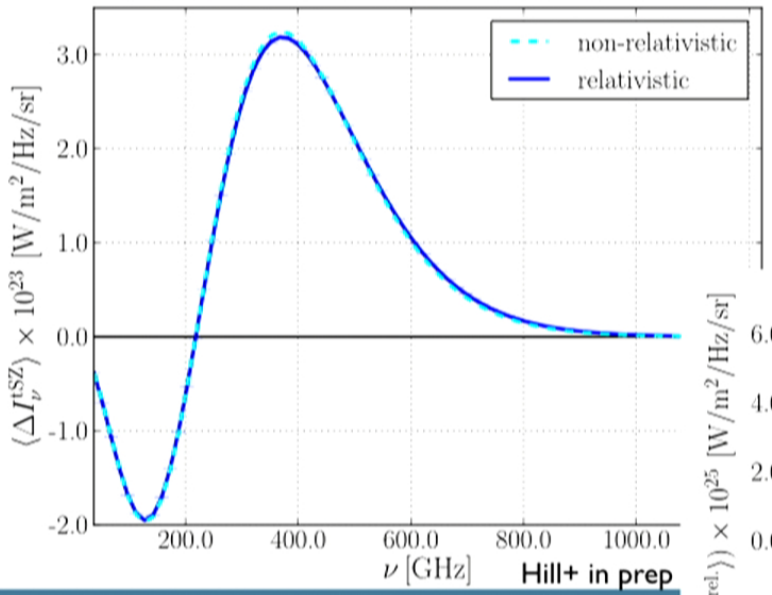
A. Kogut[1] D.J. Fixsen[1,2] D.T. Chuss[1] J. Dotson[3] E. Dwek[1] M. Halpern[4] G.F. Hinshaw[4] S.M. Meyer[5] S.H. Moseley[1] M.D. Seiffert[6] D.N. Spergel[7] and E.J. Wollack[1]

B-mode experiment $r < 10^{-3}$
Full sky, Polarizing Michelson interferometer
400 spectral channels from 30 GHz - 6 THz

Great measurements of the CMB spectrum!



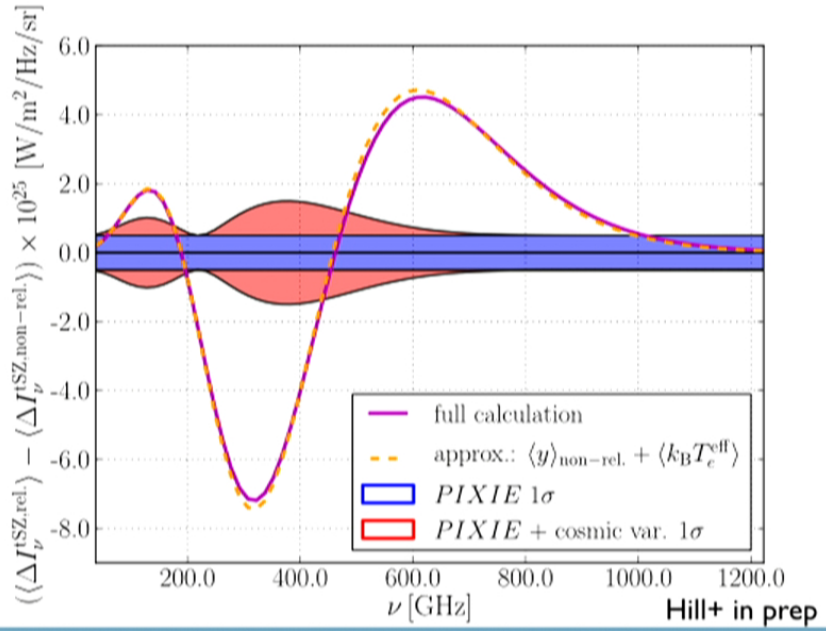
PIXIE



Same formalism as before

All sky <y> including relativistic corrections

<y> = <y>IGM + <y>Reion + <y>Halo + <y>Exotic



Current upper limits from FIRAS < 1.5 x 10^{-5}

Proposed upper limits from PIXIE < 2 x 10^{-9}

50 σ detection of the relativistic y