

Unveiling the Complex Physical Processes of the Intraclustermedium with Sunyaev-Z'eldovich Observations of Galaxy Clusters

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Dick Bond (CITA), Christoph Pfrommer (HITS),
Jon Sievers (Princeton, UKZN), (& Debora Sijacki, ITC)

ESA/ESTEC
April 4 2013

~~Unveiling the Complex Physical
Processes of the
Intraclustermedium with
Sunyaev-Z'eldovich
Observations of Galaxy Clusters
Simulations~~ **Encore!**

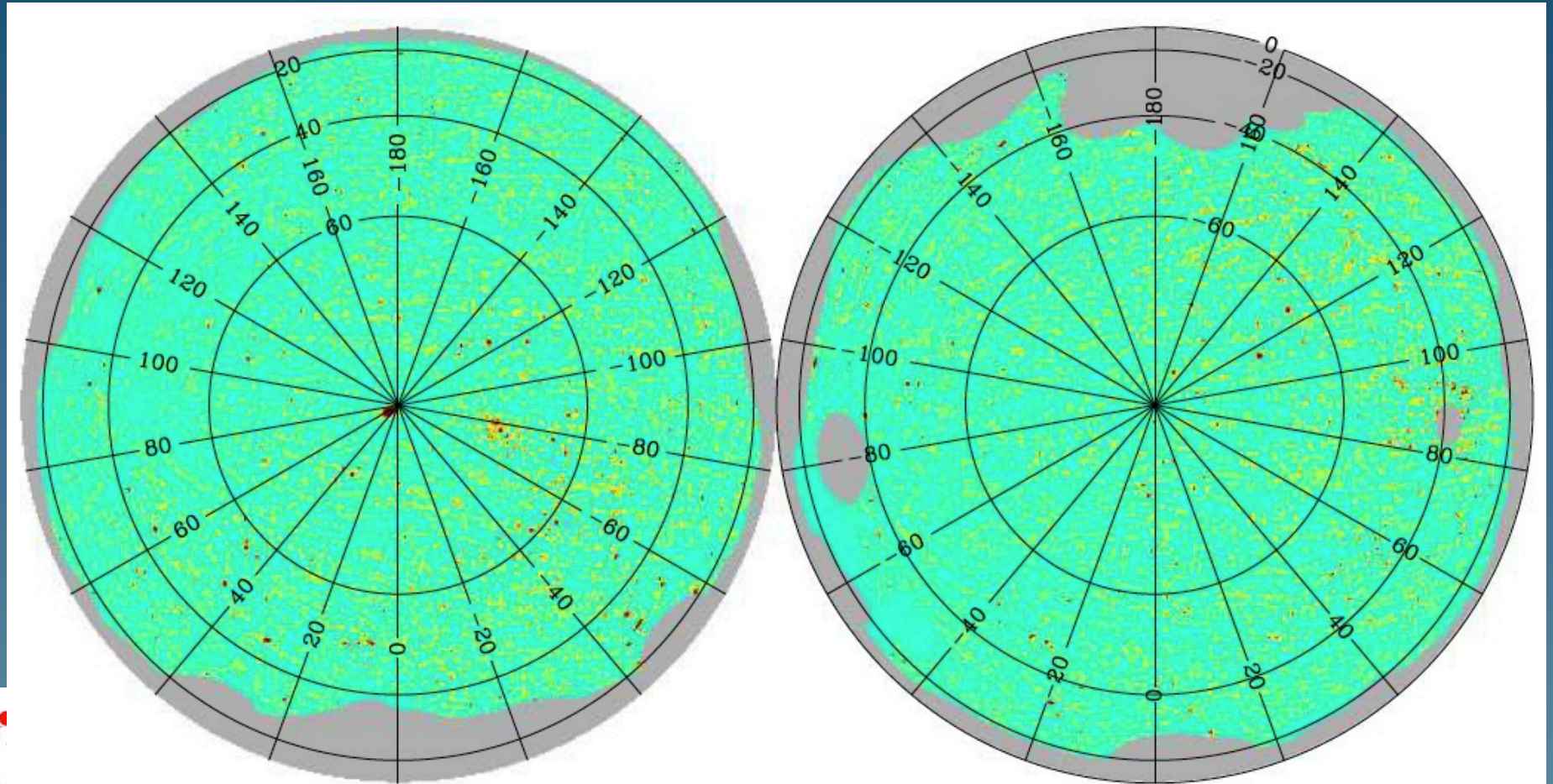
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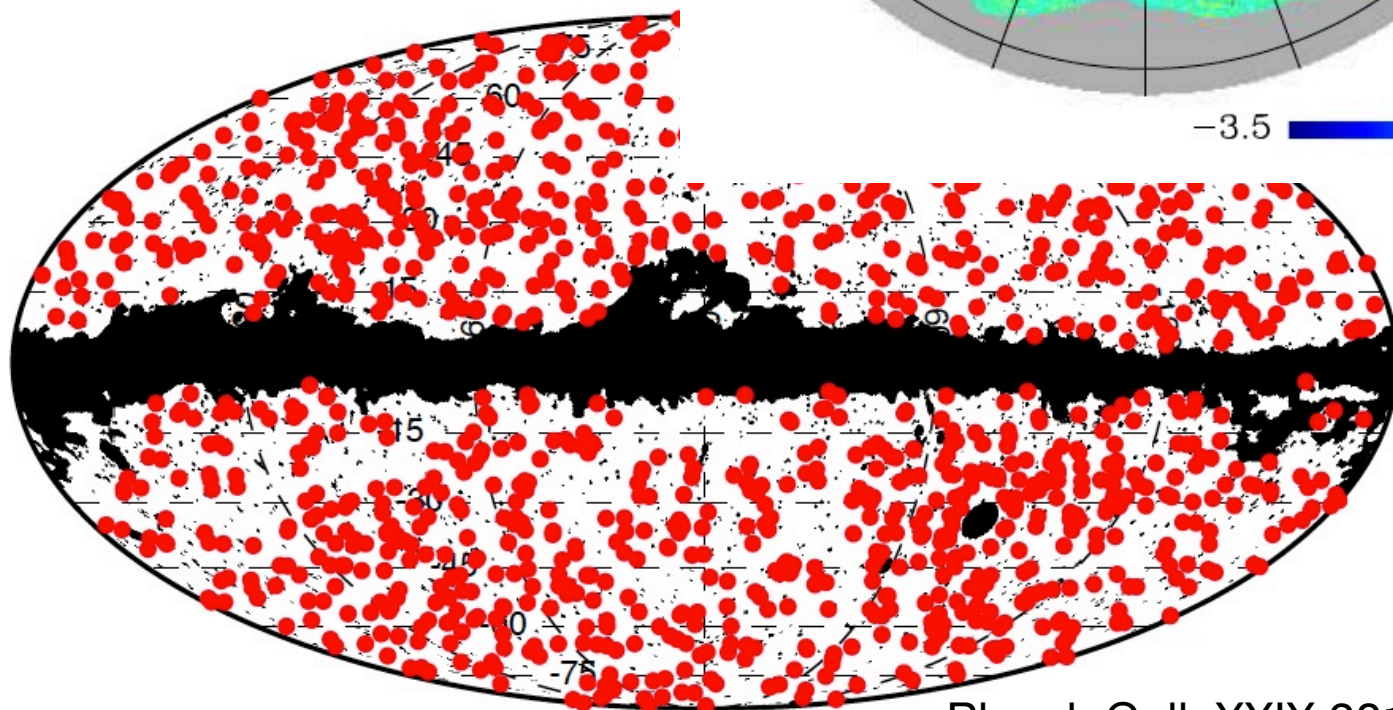
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SZ Machine!

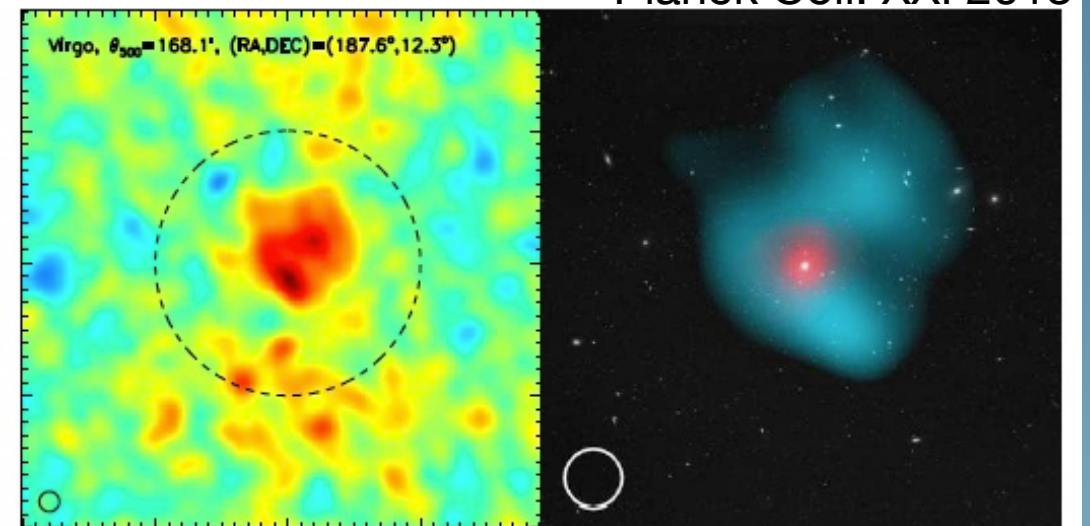
Beyond the primary CMB, Planck is producing exciting SZ results!



-3.5  5.0 $y \times 10^6$ Planck Coll. XXI 2013

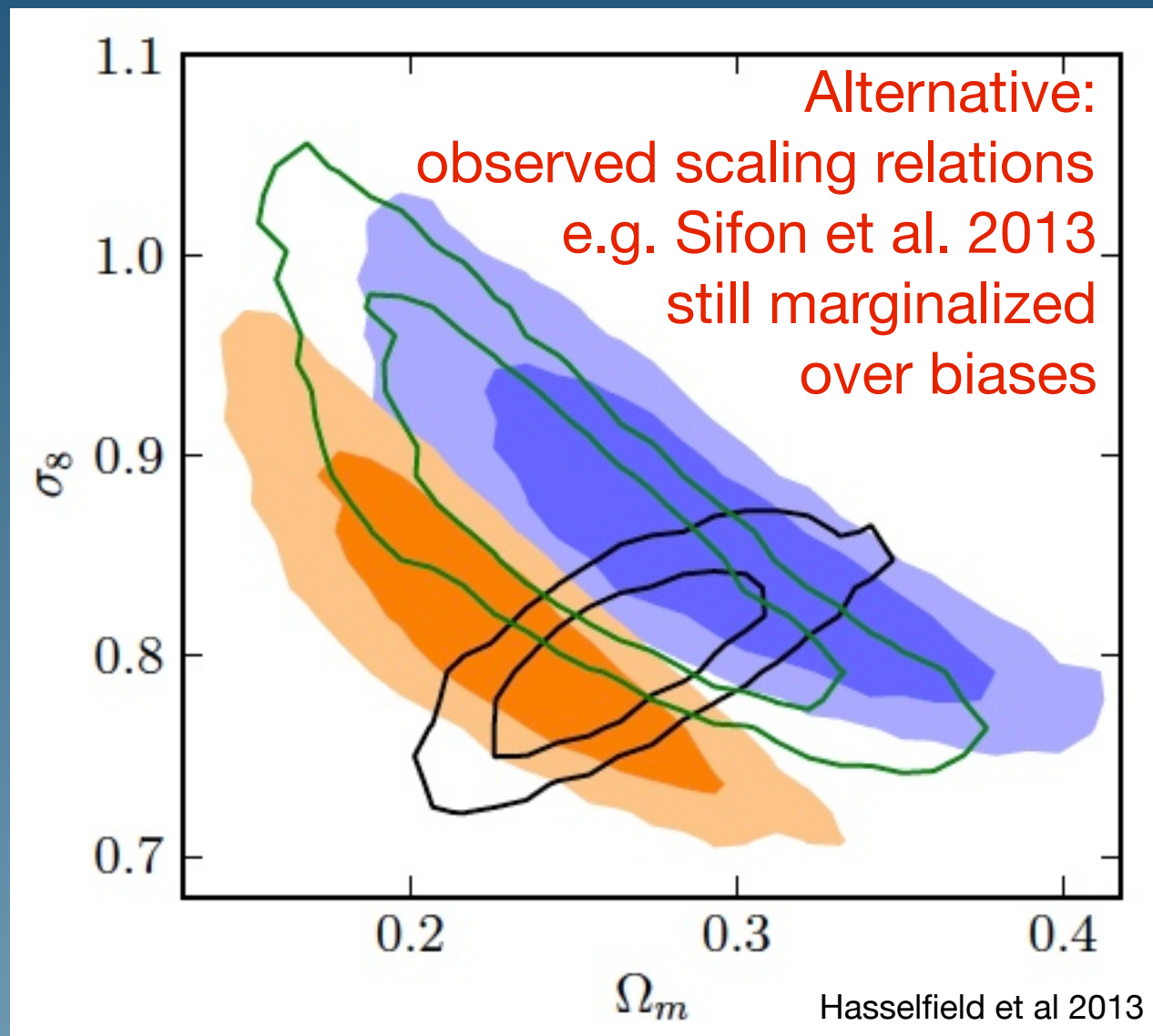


Planck Coll. XXIX 2013



Planck Coll. XXIX 2013

X-roads Cosmology & Astrophysics



Latest 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

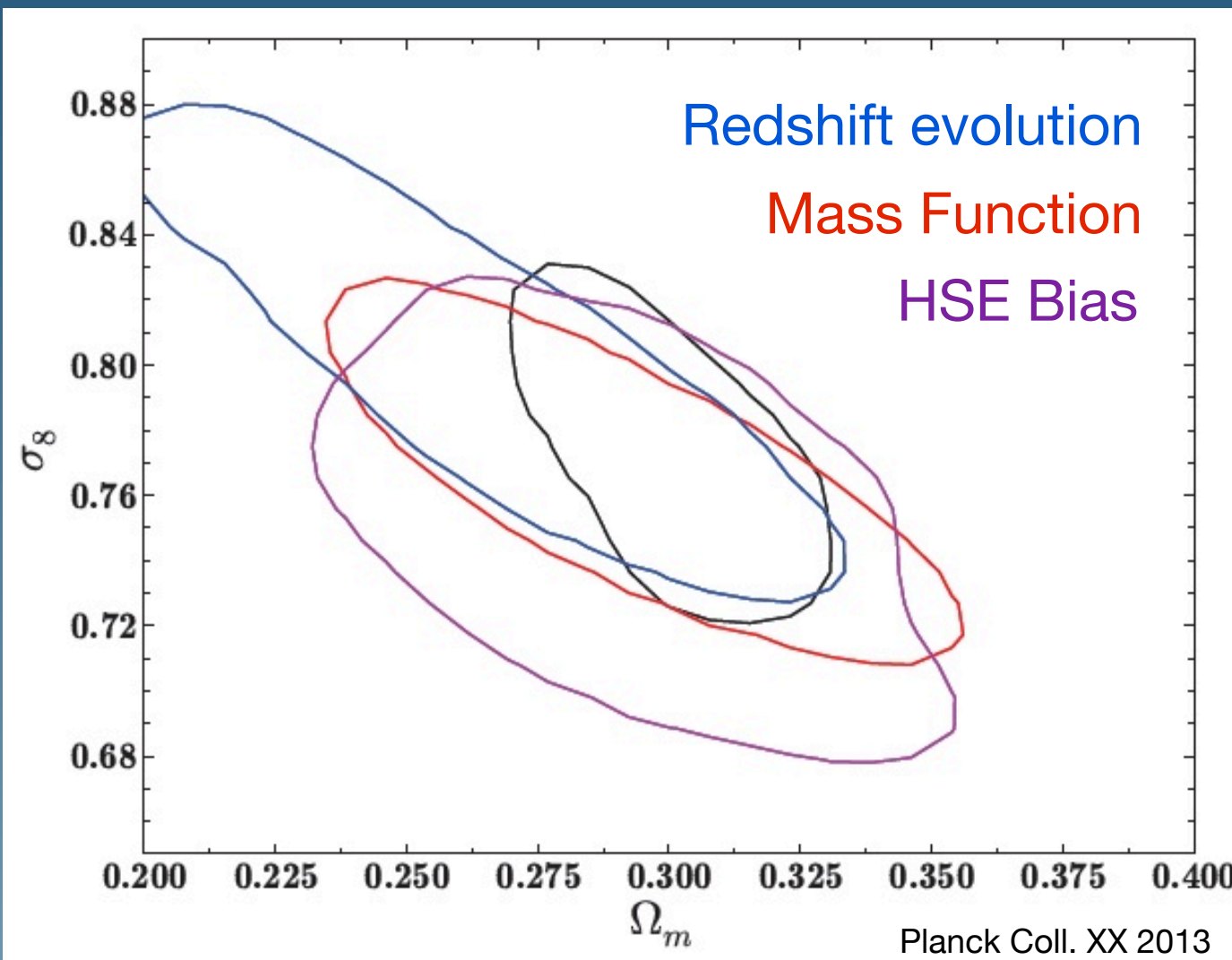
Simulations are a tool for understanding and quantifying
the important gas physics, biases, and scatter in surveys

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Modeling the ICM

Simulations:

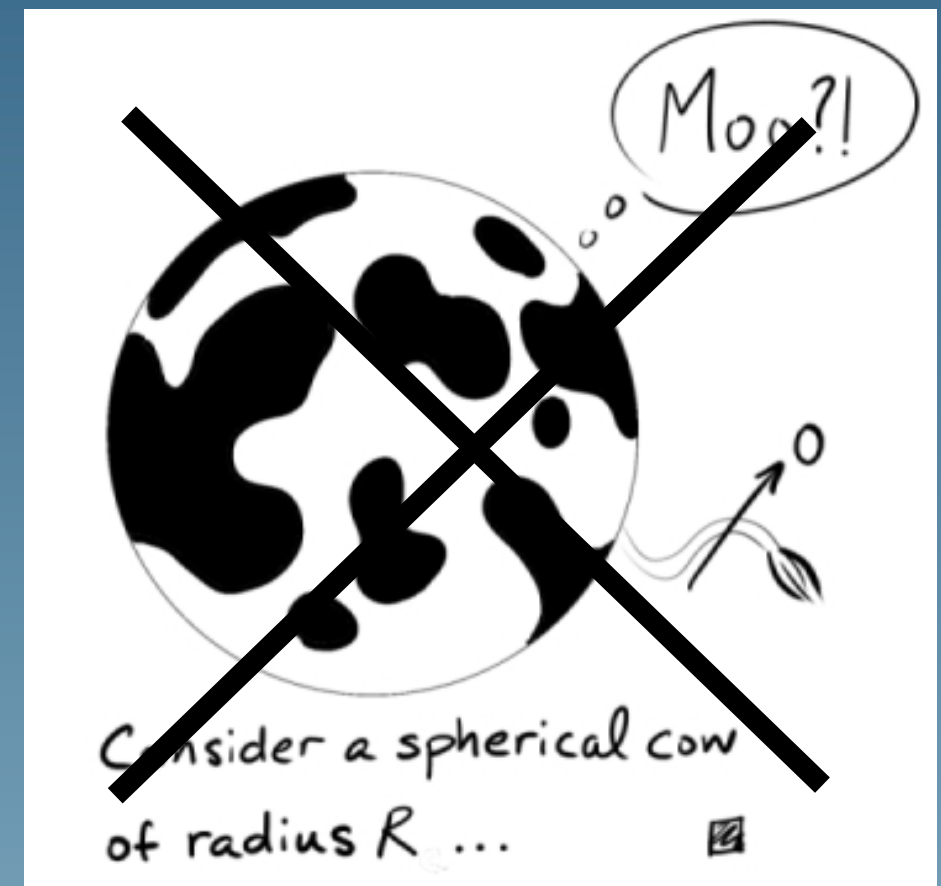
e.g. Da Silva et al 2000, Springel 2001, Bond et al 2002, BBPSS 2010

(Semi)Analytical:

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!

Our Simulations

- Circa 2010:

Box lengths 200-400 Mpc h^{-1} (256^3 , 512^3)

Halo Mass resolution $10^{13} M_{\odot} h^{-1}$

Gadget2+ (SPH) with 3 “physics” models

- Non-radiative (Adiabatic)

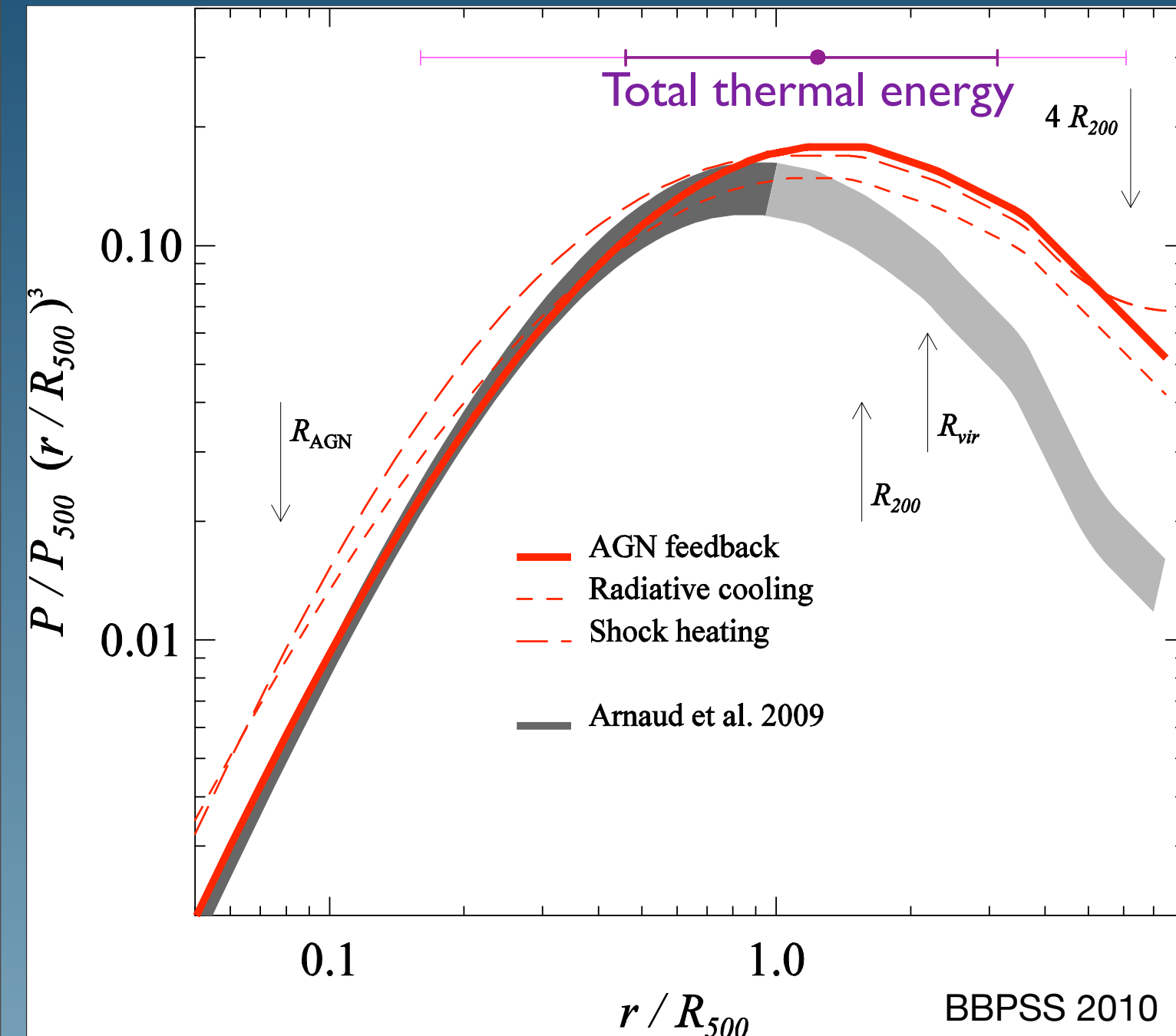
- Radiative cooling + SF + SNe + CR

- “AGN” feedback

~ 800 clusters with $M_{200} > 10^{14} M_{\odot} h^{-1}$

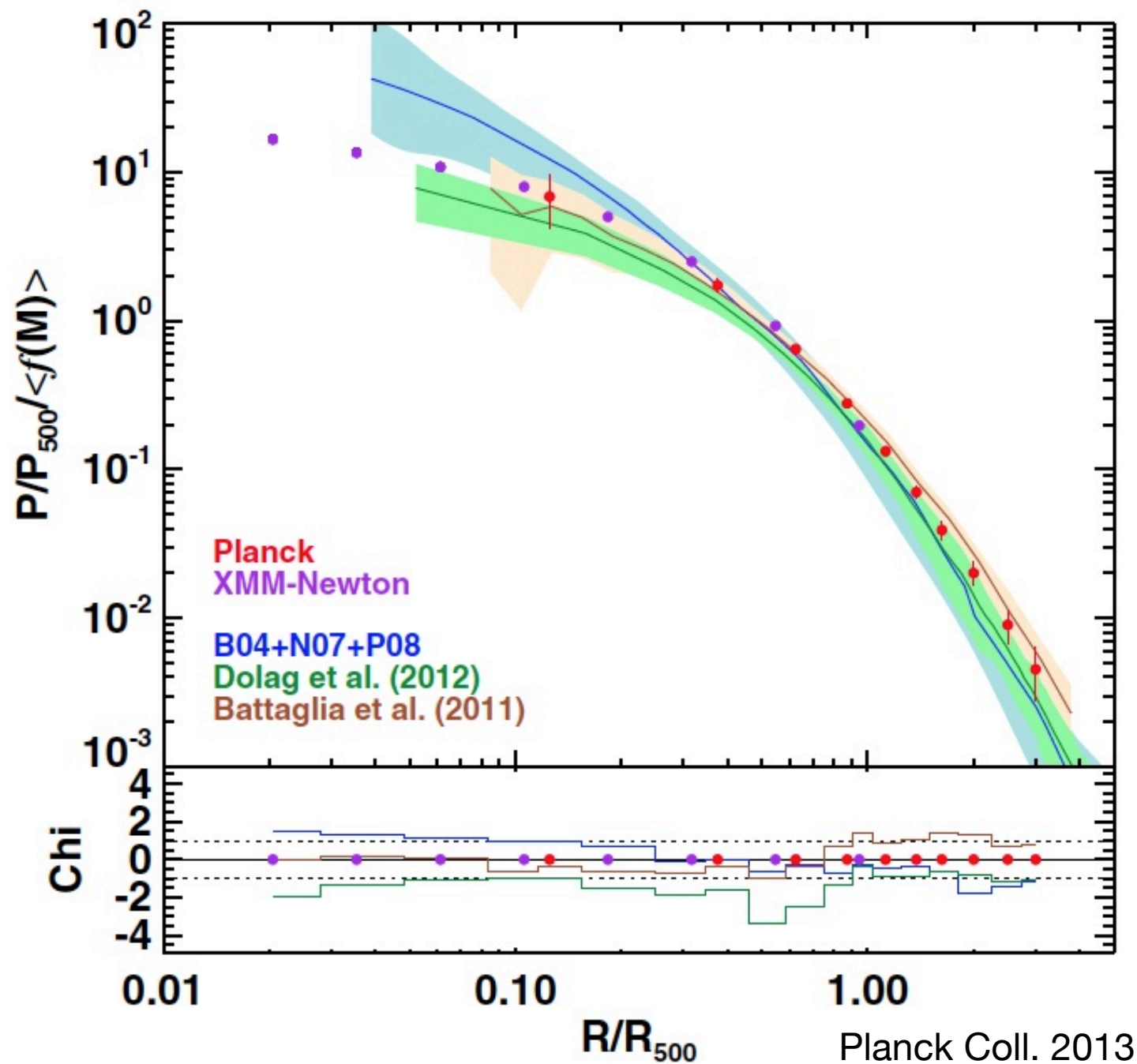
Unbiased

Simulation P_{th} Profile



- Stacked P_{th} profile
- $dE / d\ln R$ peak in E_{th}
- Virial Theorem
 - $Y - M$ relation
- HSE assumption
 - $\nabla P_{th} \propto M_{th}$
- Depends on “Gastrophysics”
- Scatter about $\langle P \rangle$
 - power spectrum

Planck P_{th} Profile



$\langle P_{th} \rangle$ profile from Planck
Stacked 62 low z clusters

at $r > R_{500}$ more $\langle P_{th} \rangle$
than the Universal
pressure profile
(Arnaud et al. 2010)

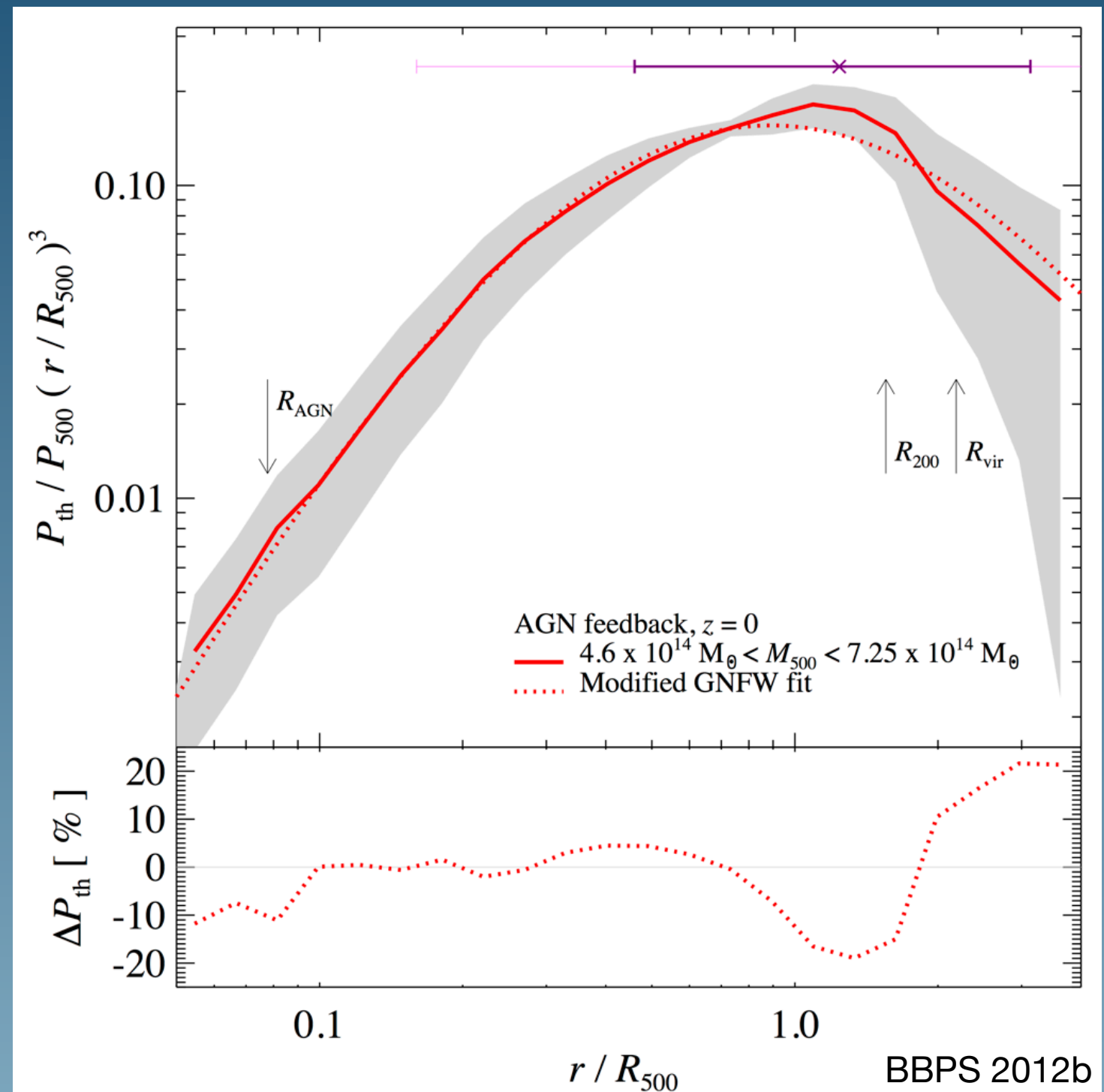
Similar results for Coma
Planck Coll. 2013

Variance in P_{th} Profiles

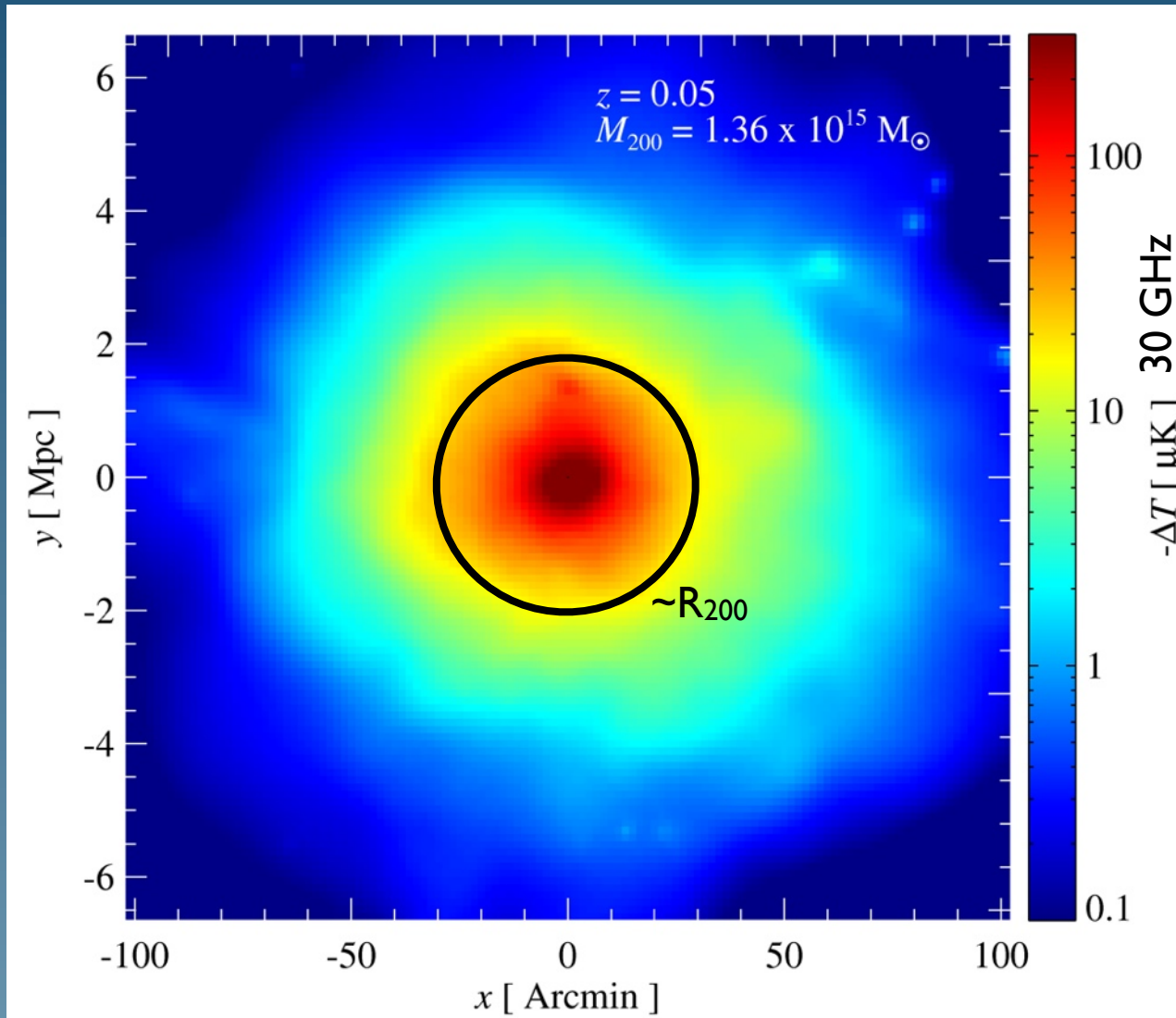
- Large variance around the $\langle P_{\text{th}} \rangle$ profile
- P_{th} clumps/variations

Impact:

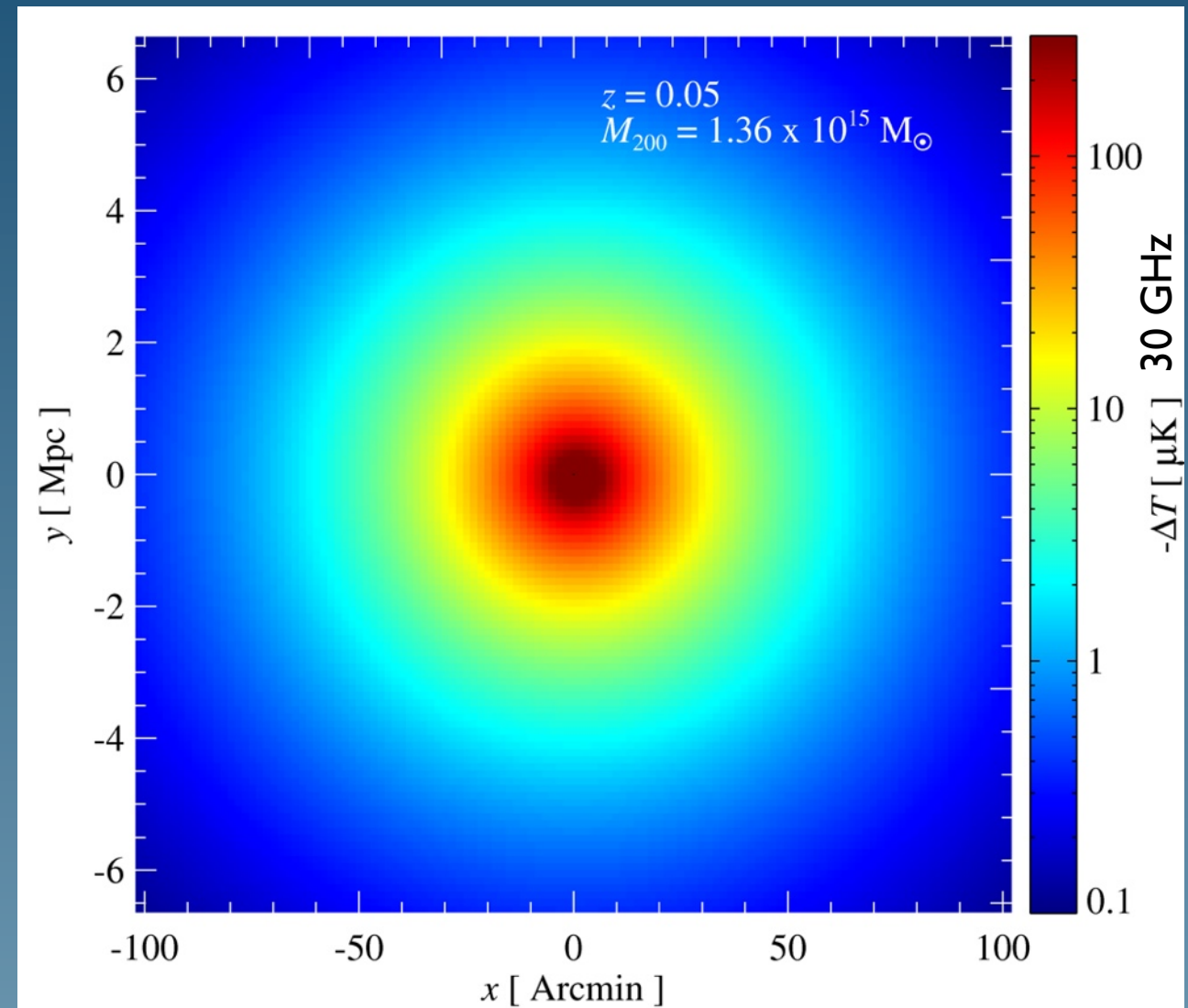
- tSZ power spectrum halo calculations
- Y-M relation (scatter)



ICM inhomogeneities

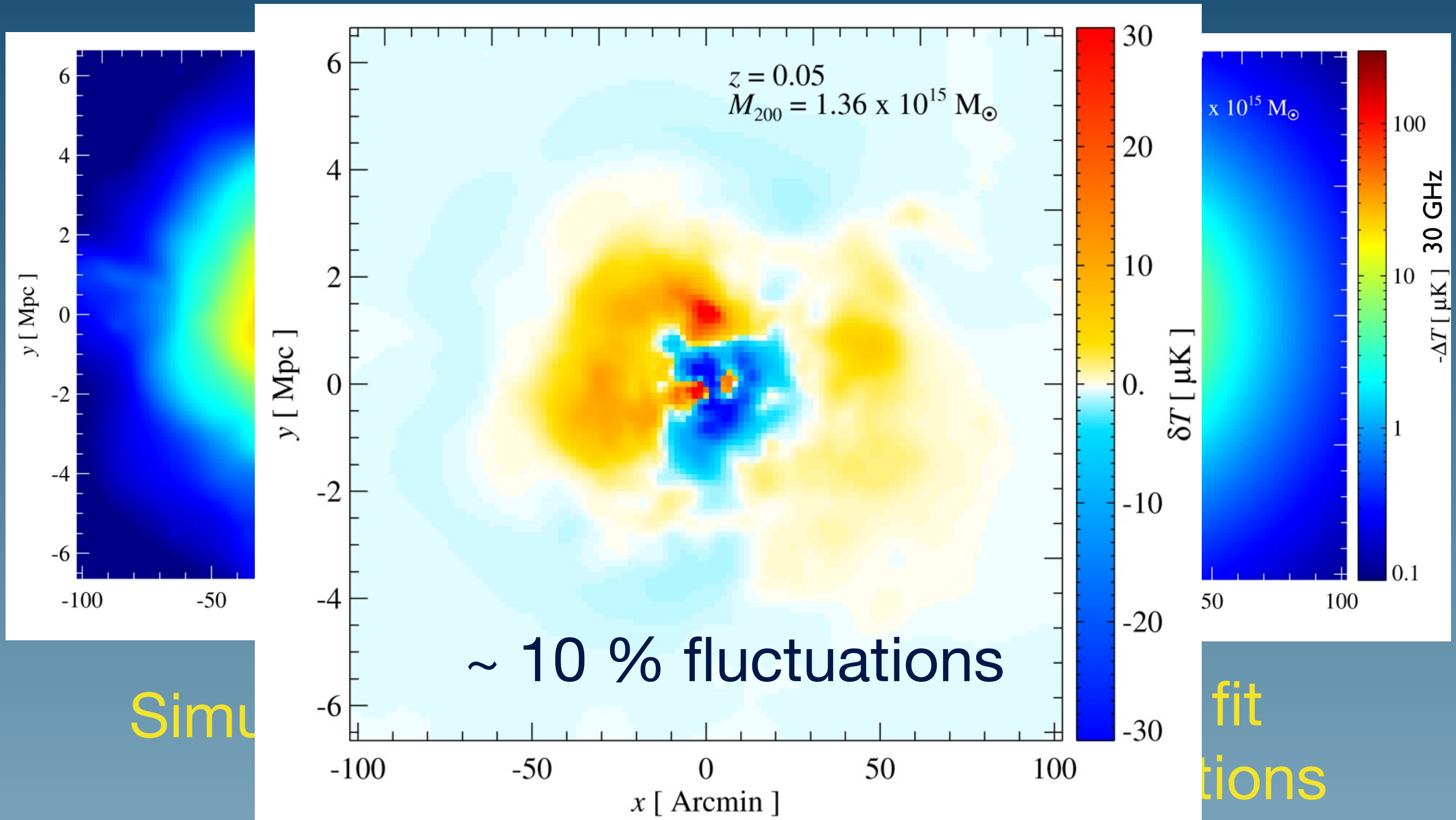


Simulated cluster



Spherical fit
from simulations

ICM inhomogeneities



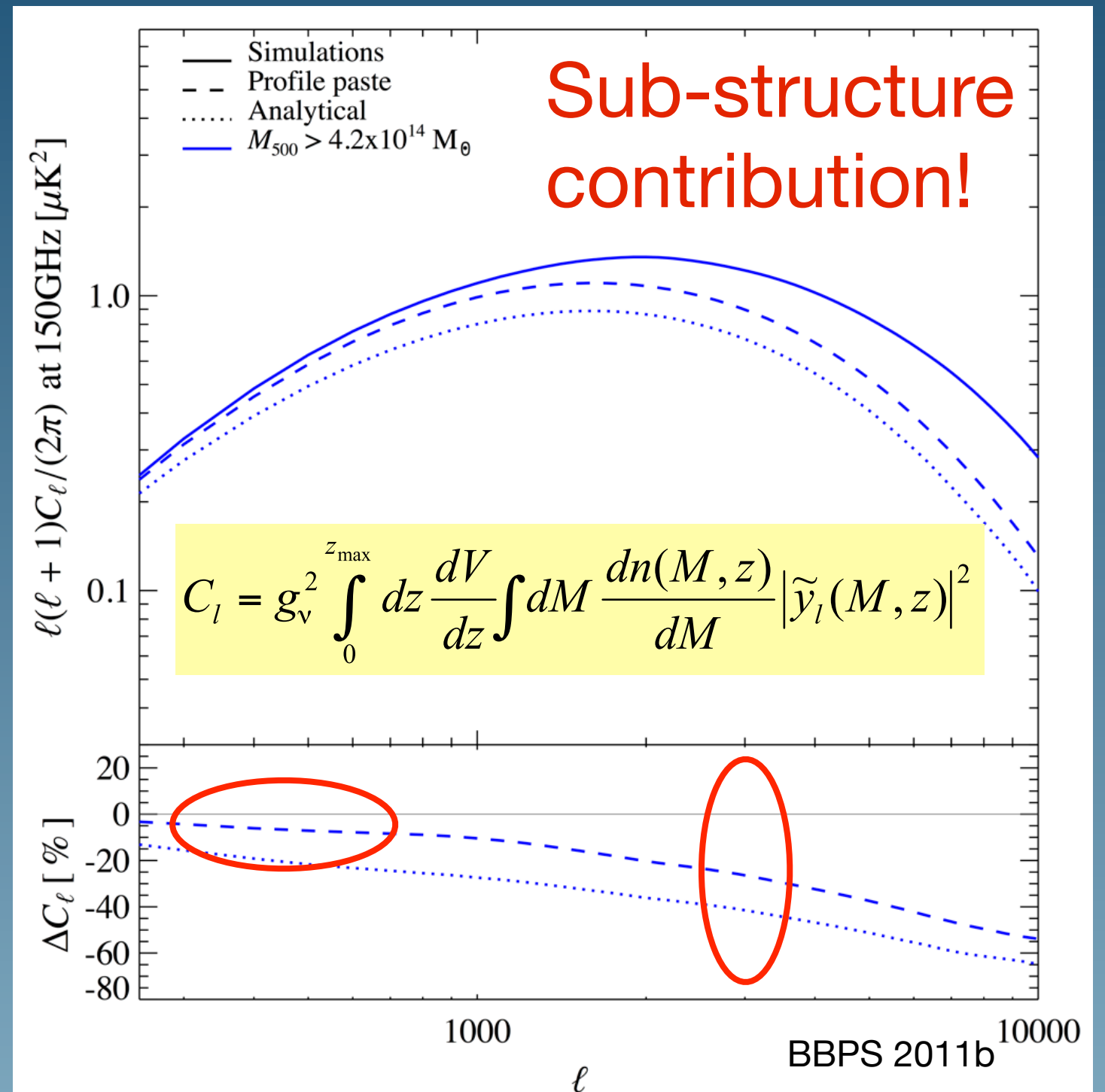
Simu

fit
tions

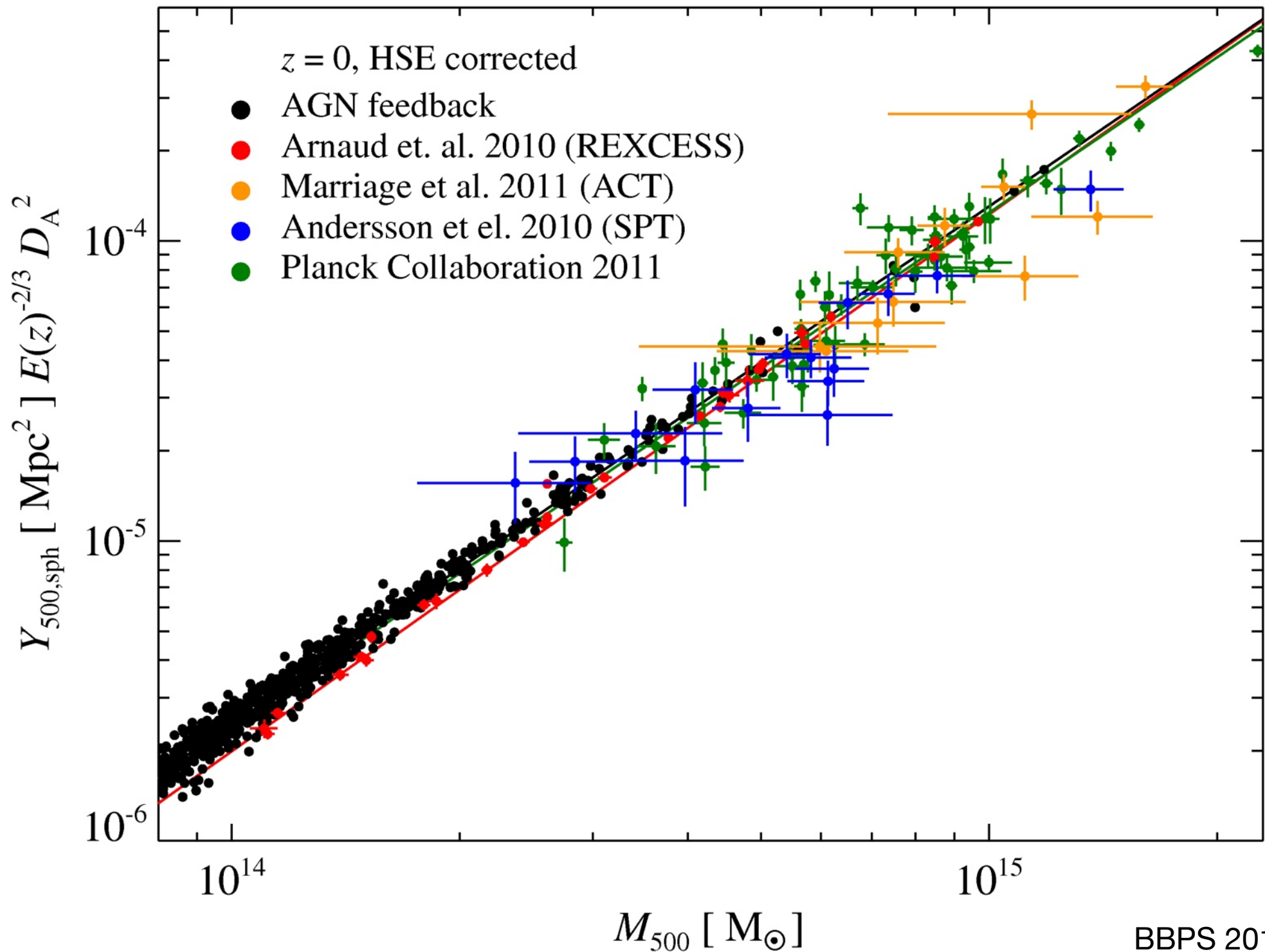
ICM inhomogeneities tSZ power spectrum

tSZ Power spectrum implications:

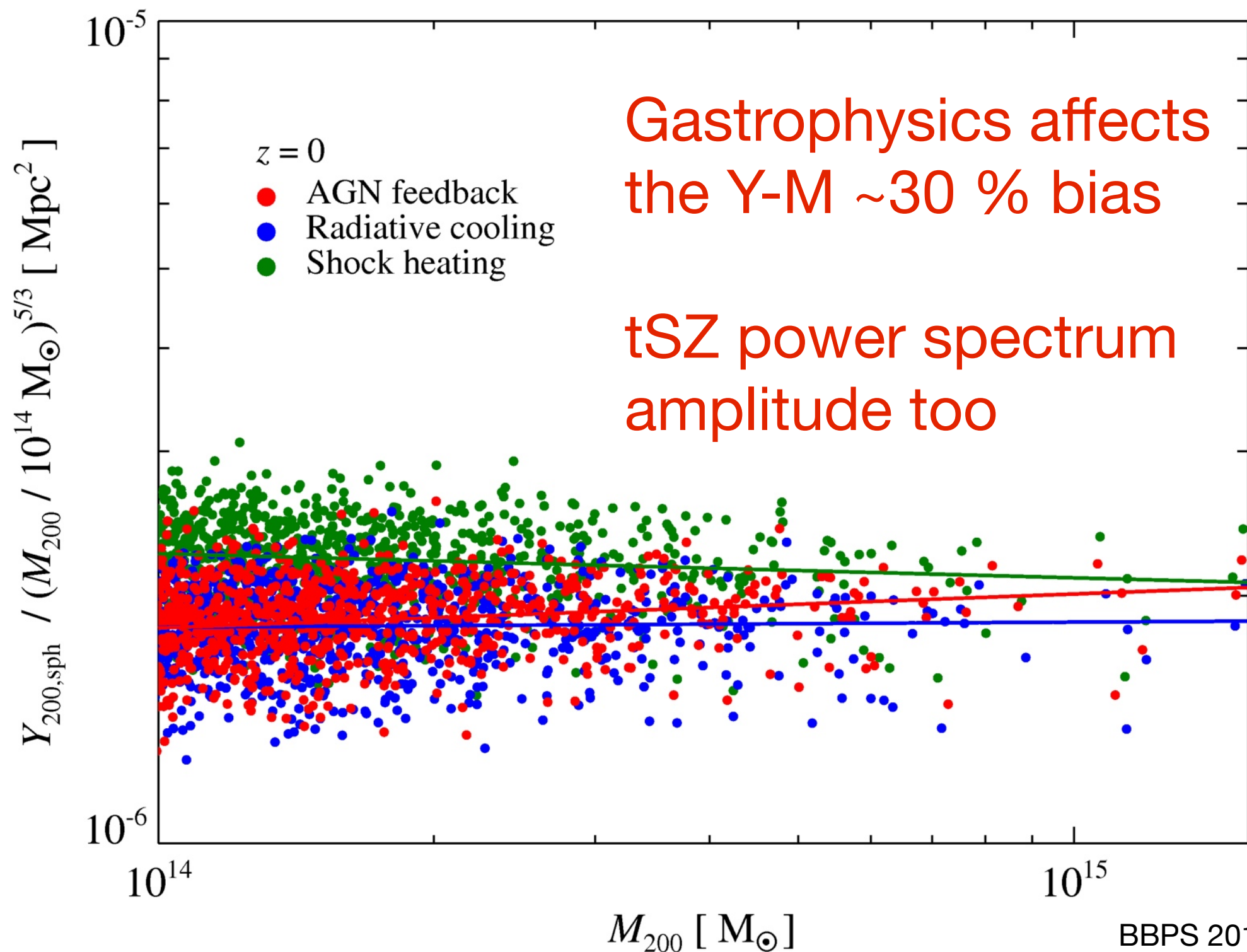
- High mass halos
25% at $\ell \sim 3000$
- All masses
15% at $\ell \sim 3000$
- Additional power from Non-uniformity must be included in Analytic calculations



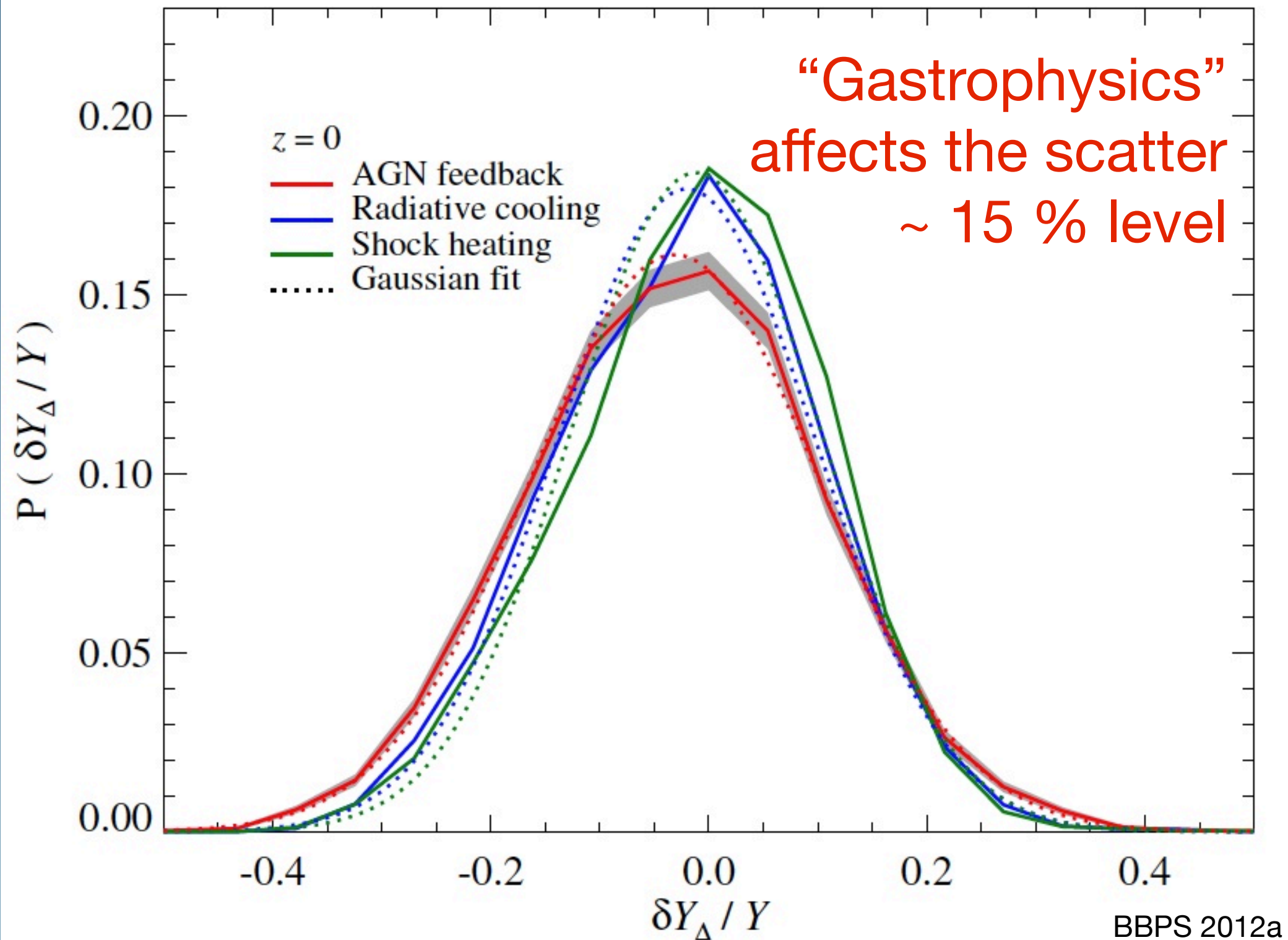
$Y_{\text{sph}} - M$ relation



$Y_{\text{sph}} - M$ relation



Y_{sph} - M relation



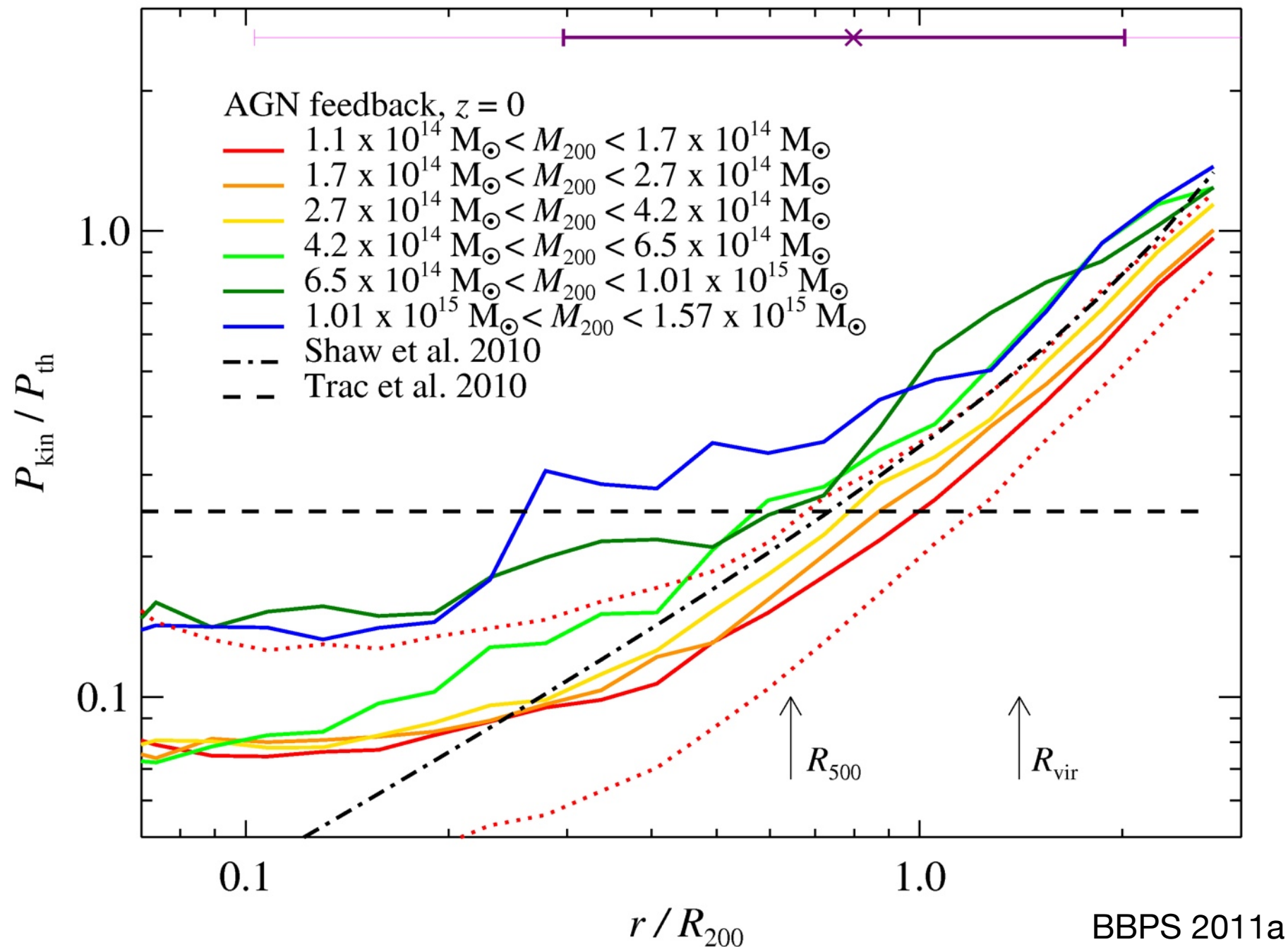
Non-thermal pressure

Long History:

Evrard 1990,
Kay et al. 2004,
Rasia et al. 2004,
Lau et al. 2009,
Ameglio et al. 2009
Meneghetti et al. 2010,
Nelson et al. 2012,
Rasia et al. 2012.....

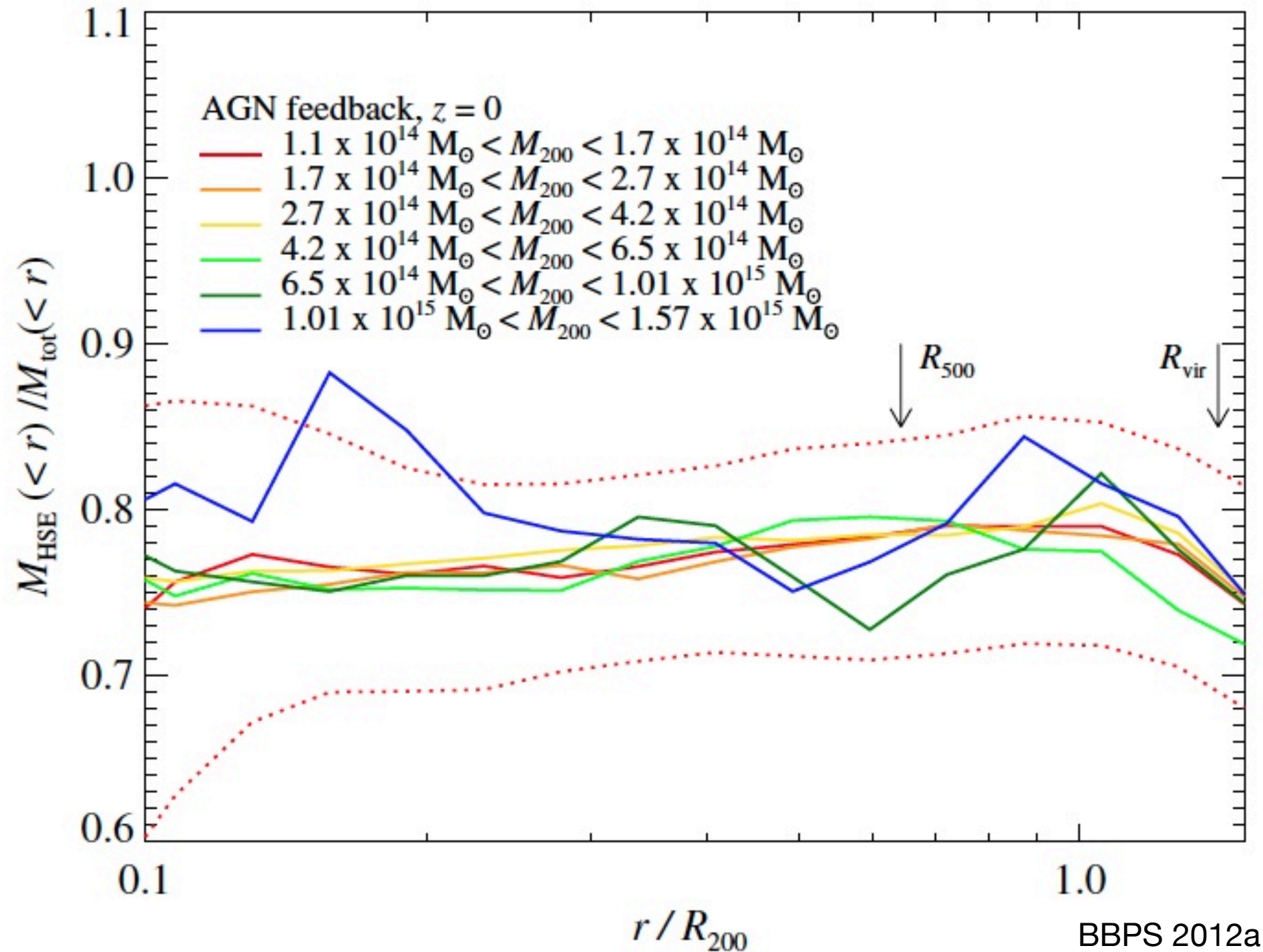
Hard to model
for semi-analytic
methods

bias in HSE
masses

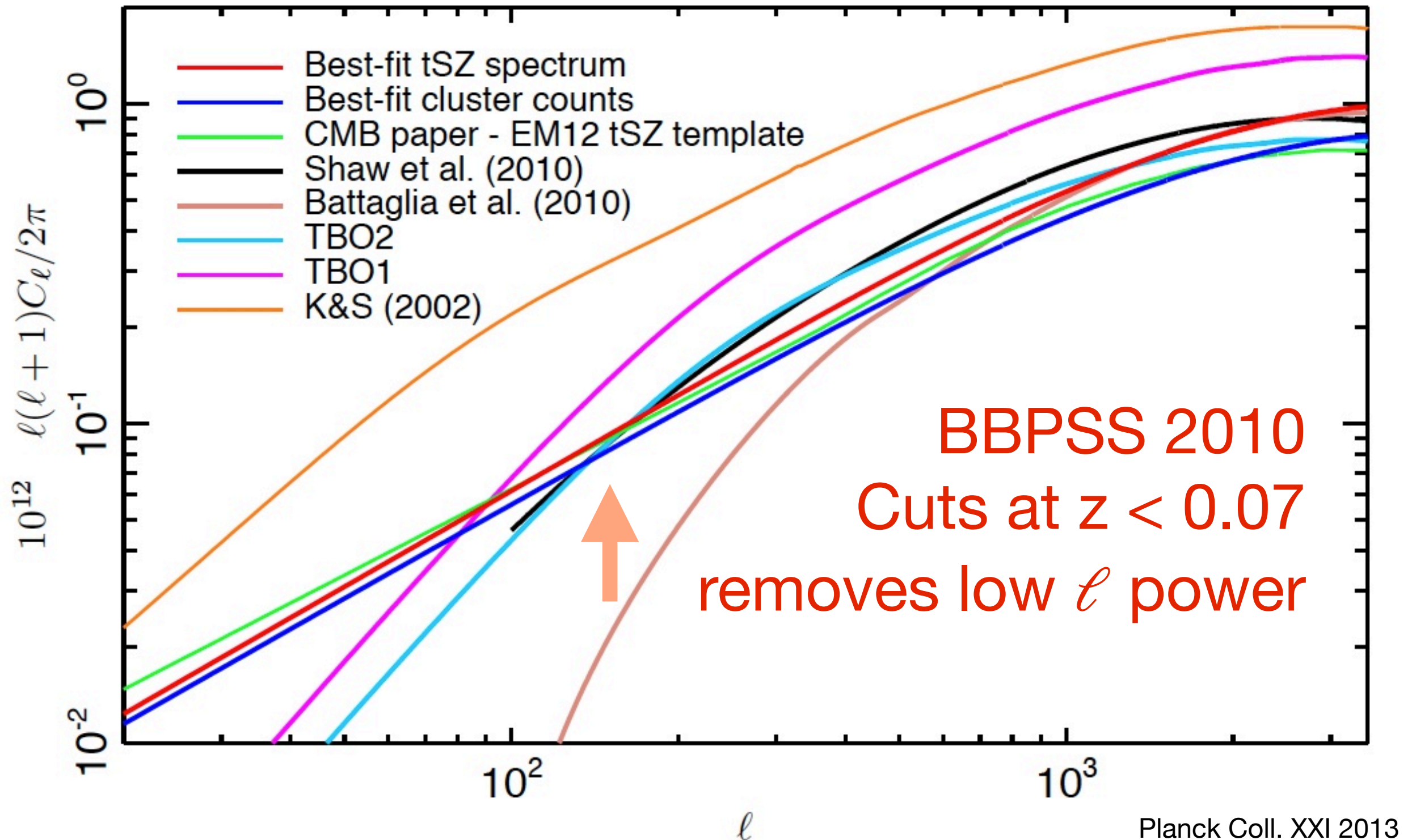


Independent of “Gastrophysics”

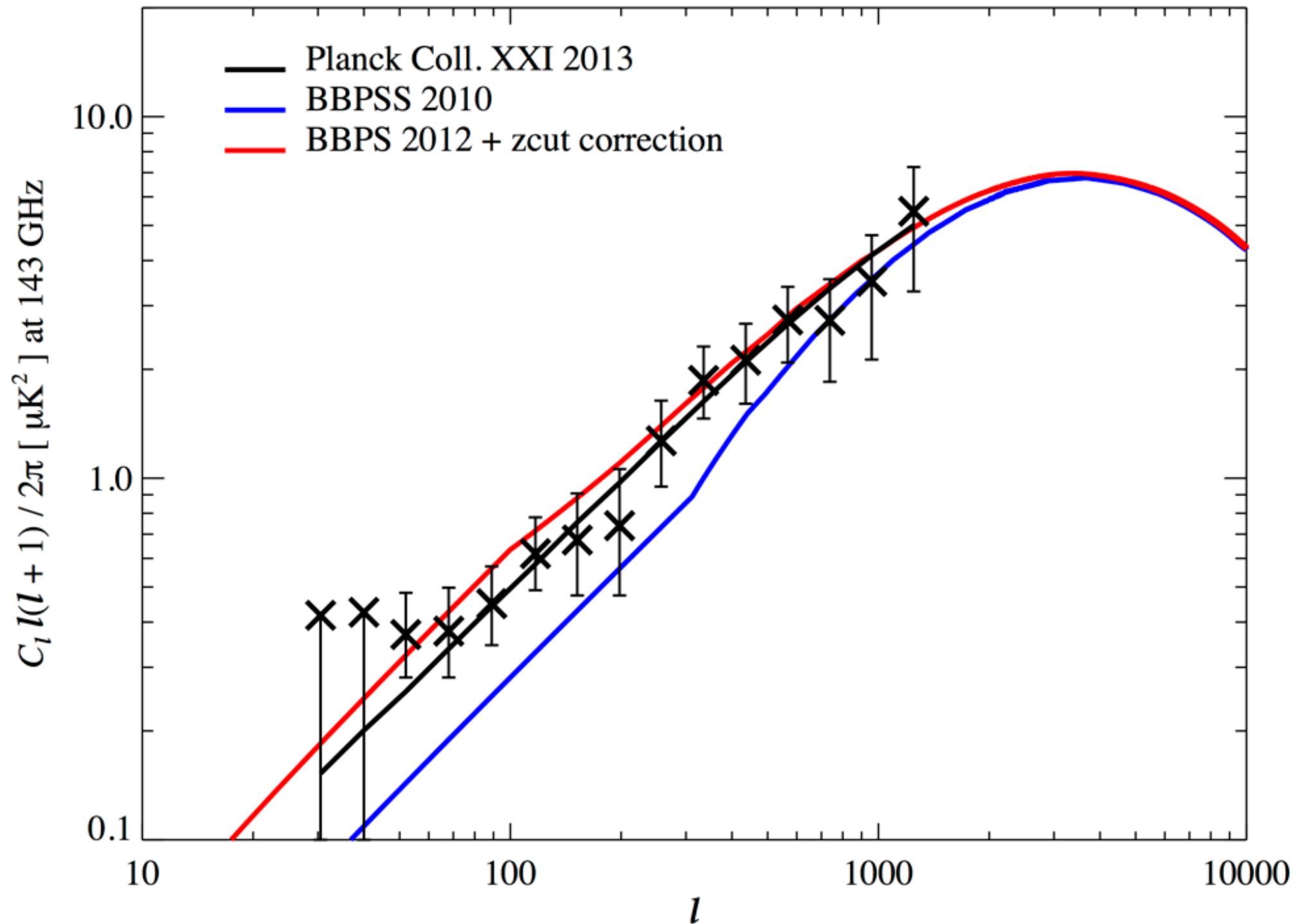
HSE Bias



Planck Y PS (aside)



Planck Y PS (aside)



Summary

- Gastrophysics affects:
< $P_{th}(r)$ >, scaling relations, and σ
- Clusters are not smooth
15% effect on the power spectrum
- HSE Bias, is a tricky business
Is mass the avenue for cluster cosmology?
- Redshift cuts affect the low ℓ power

Simulations aid in understanding the ICM,
but more is required for cluster cosmology