

Title: Templates for the SZ Angular Power Spectrum

Date: Apr 29, 2010 09:45 AM

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Abstract: The Atacama Cosmology Telescope (ACT) has recently measured the CMB angular power spectrum from maps with arcminute resolution at 148 GHz. By fitting to a template for the SZ angular power spectrum, we constrain the model's amplitude $A_{\text{SZ}} < 1.63$ (95% confidence level) and the amplitude of matter perturbations $\sigma_8 < 0.86$ (95% CL). In this talk, we review the fiducial template and present additional templates for the SZ angular power spectrum based on different models for the hot gas in dark matter halos. We also discuss how the TSZ, KSZ, and SZ power spectra scale with σ_8 .

TEMPLATES for the SZ ANGULAR POWER SPECTRUM

Hy Trac (Harvard)

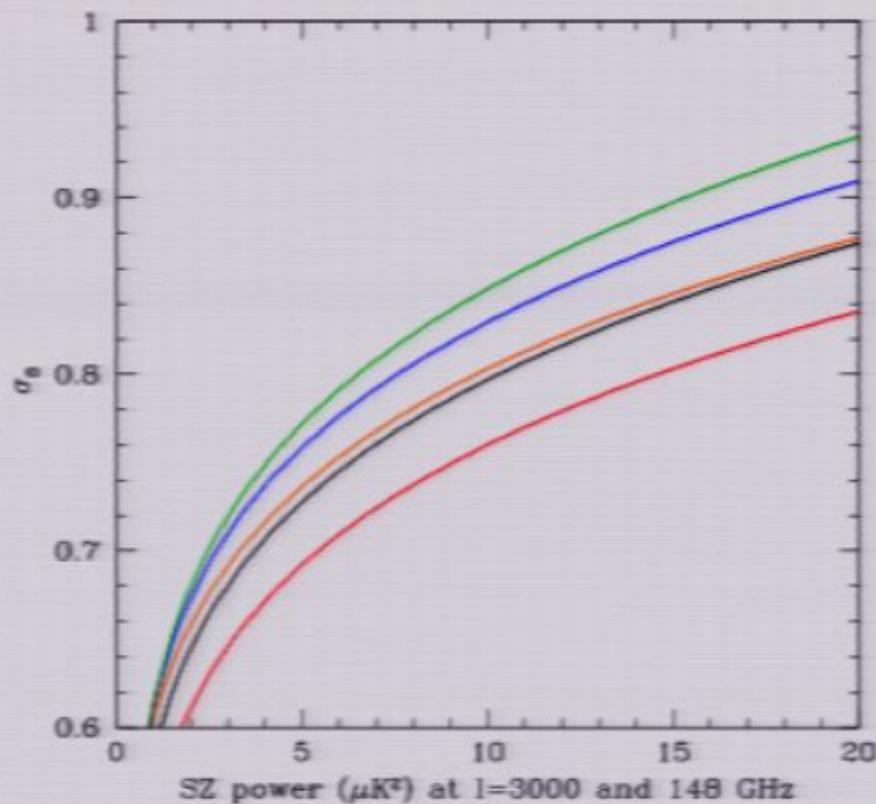
Paul Bode & Jerry Ostriker (Princeton)

The Atacama Cosmology Telescope Team



OUTLINE

- 1) Atacama Cosmology Telescope
- 2) TSZ, KSZ, and SZ power spectra
- 3) Dependence of C_l on σ_8
- 4) Constraints on σ_8 from ACT and SPT



See Suzanne's talk on ACT on Friday!

The ATACAMA COSMOLOGY TELESCOPE:
a MEASUREMENT of the $600 < l < 8000$
COSMIC MICROWAVE BACKGROUND POWER SPECTRUM
at 148 GHz

Fowler et al, 2010, arXiv:1001.2934

THE ATACAMA COSMOLOGY TELESCOPE

6 meter primary mirror

3 frequency bands at 148, 220, and 280 GHz

Arcminute resolution



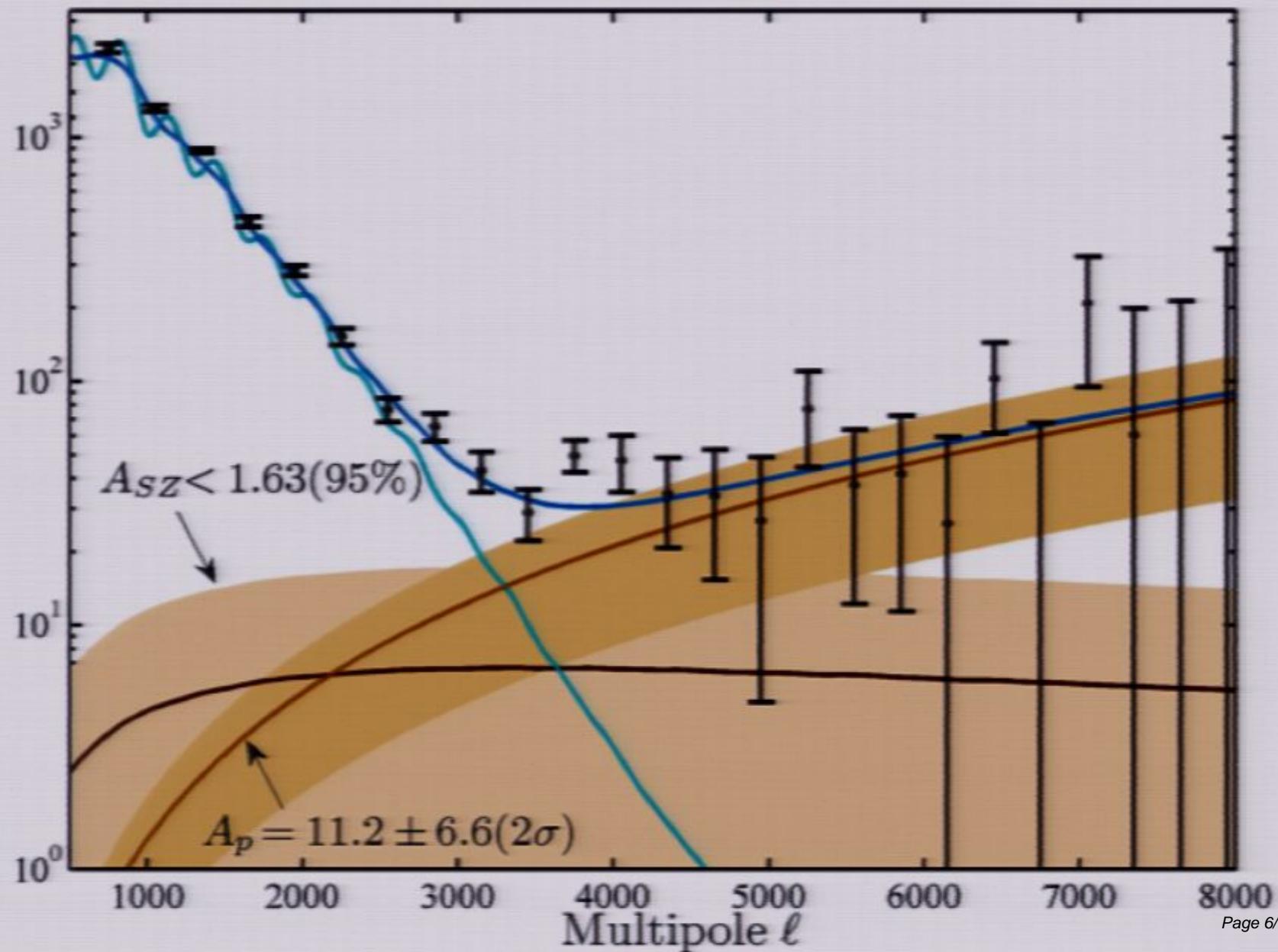
Fowler et al 2010

228 deg² at 148 GHz

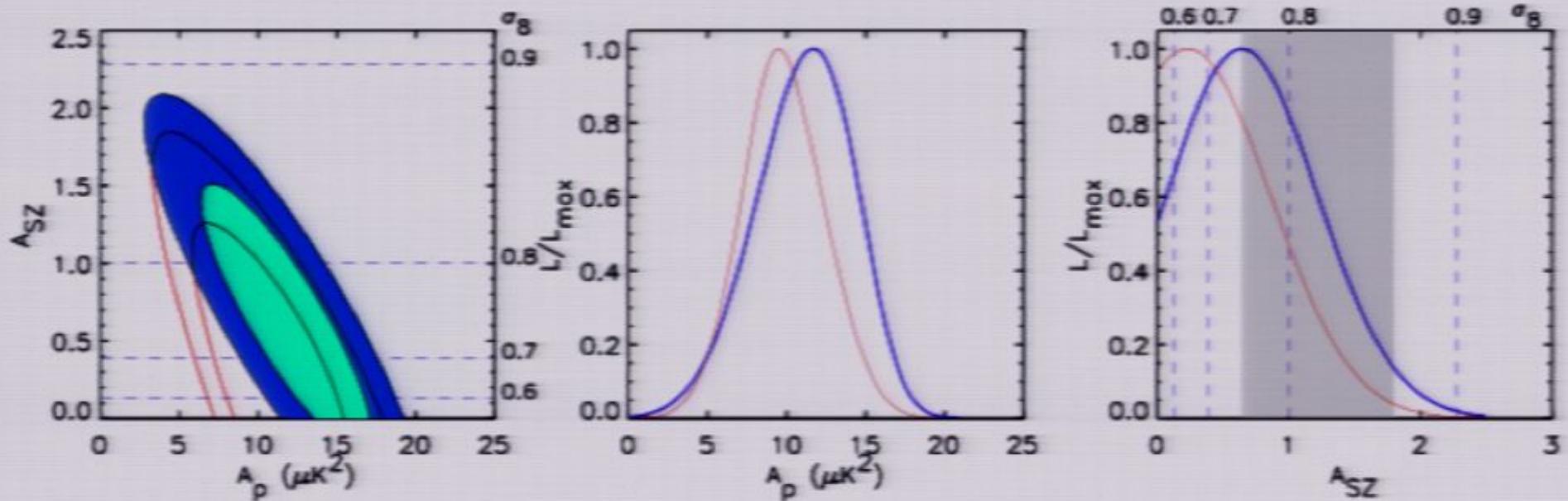
600 < ℓ < 8000

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ACT POWER SPECTRUM at 148 GHz (Fowler et al 2010)



SZ CONTRIBUTION at 148 GHz (Fowler et al 2010)



SZ model

- Template for ΛCDM cosmology with $\sigma_8 = 0.8$ (Sehgal et al 2010)
- Based on halo gas model calibrated against observations of the ICM (Bode et al 2009)

ACT constraints

- $A_{\text{SZ}} < 1.63$ (95% upper limit)

TEMPLATES for the SZ ANGULAR POWER SPECTRUM

HT, Bode, & Ostriker

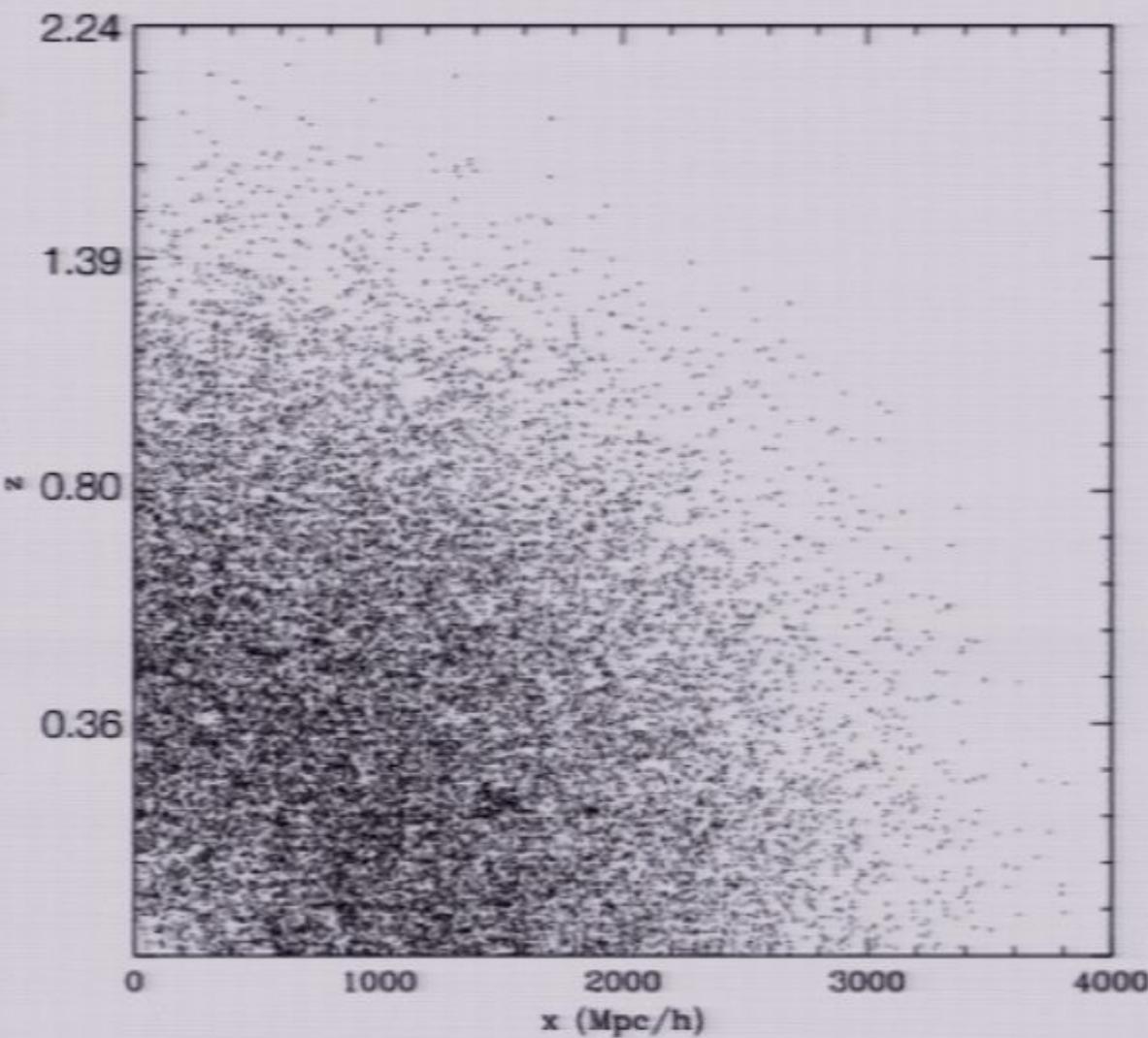
SZ SIMULATIONS (Sehgal et al 2010)

N-body simulation

- Λ CDM cosmology with $\sigma_8 = 0.8$
- $L = 1000 \text{ Mpc}/h$
- $N = 1024^3$

Light cone

- Covers octant of the sky
- $z < 3$: particles saved for modeling ICM and IGM
- $3 < z < 10$: surface mass and momentum density fields saved
- Halo gas models (Ostriker et al 2005, Bode et al 2007, 2009)



GASTRONOMY

Model	Star formation	Feedback	Comments	FoM
Adiabatic	No	No	Basic nonradiative gas physics	
Standard	Yes Lin et al 2003	Yes Bode et al 2009	Stellar and gas fractions and X-ray scaling relations match those from nearby clusters and groups	
Low-fgas	Yes 2x STD	Yes 2x STD	Low gas fractions agree with the observed (1σ) lower limit	
Nonthermal20	Yes Giordini et al 2009	No	20% nonthermal pressure No feedback needed to match observed X-ray scaling relations	

GAS AND STELLAR FRACTIONS

Standard

Adiabatic

Low-fgas

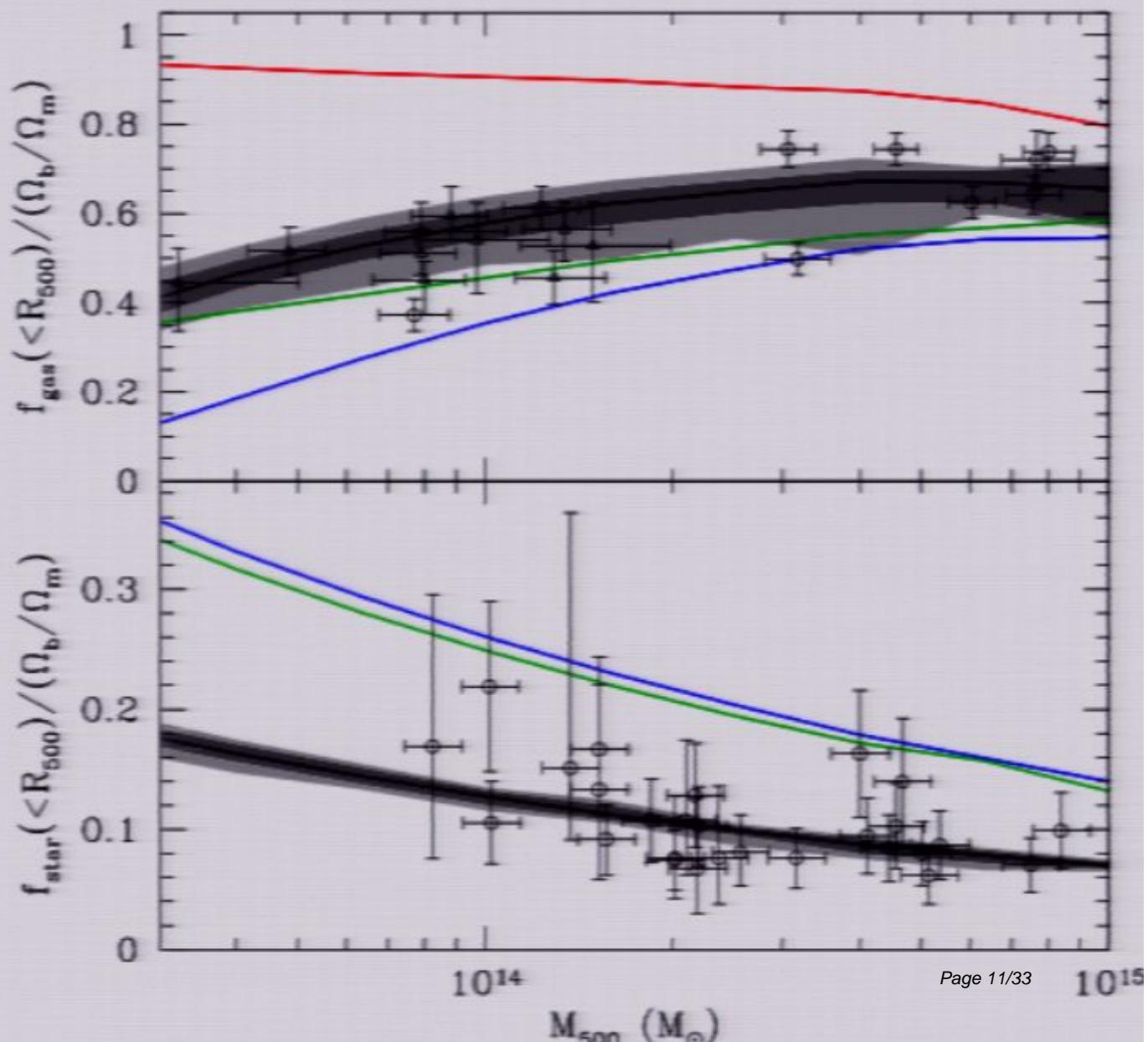
Nonthermal20

Gas fractions for $z < 0.2$

- Vikhlinin et al (2006)
- Sun et al (2009)

Stellar fractions

- Lin et al (2003)
- Giordini et al (2009)



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Adiabatic

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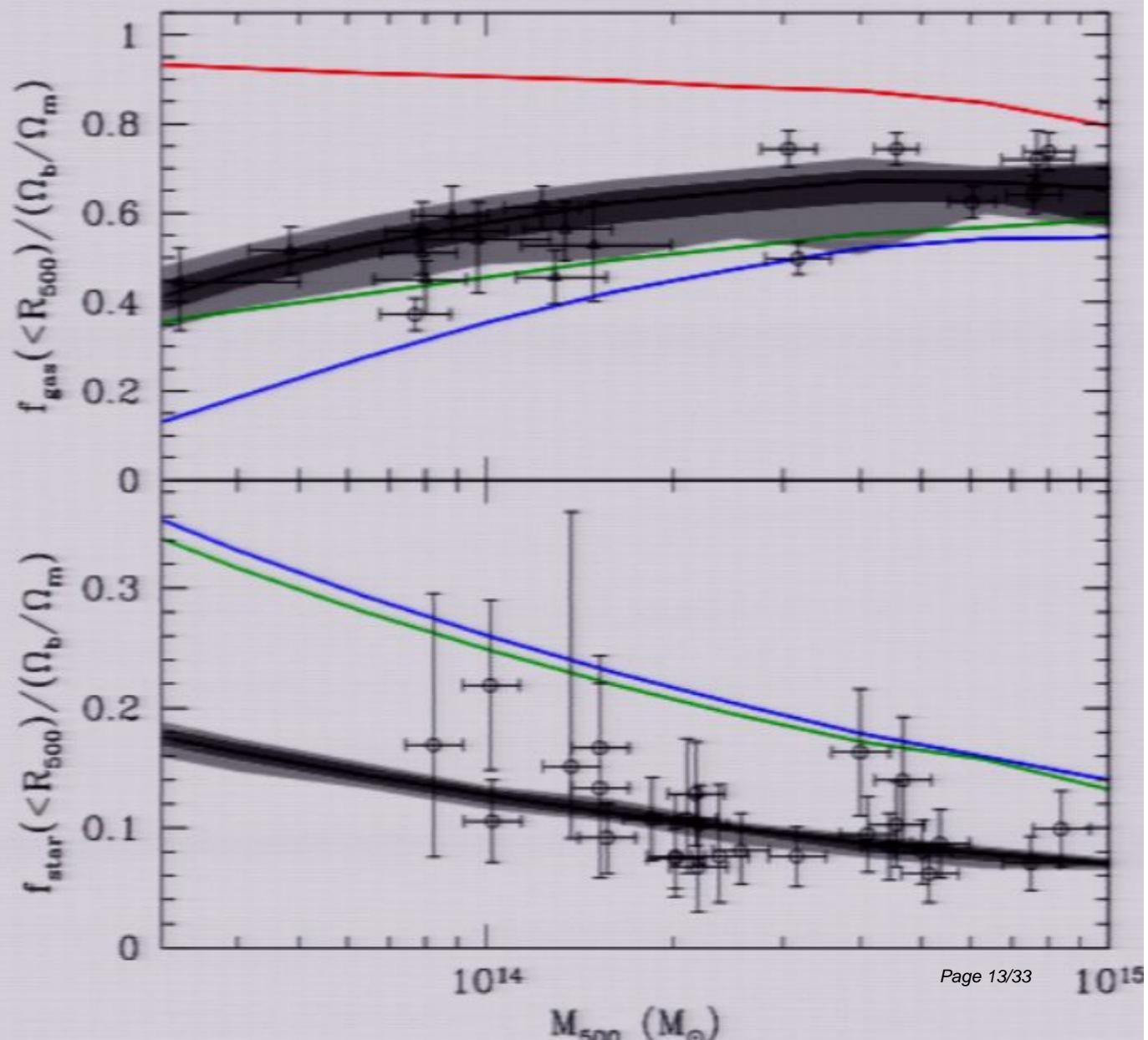
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GAS AND STELLAR FRACTIONS

Standard

Adiabatic

Low-fgas

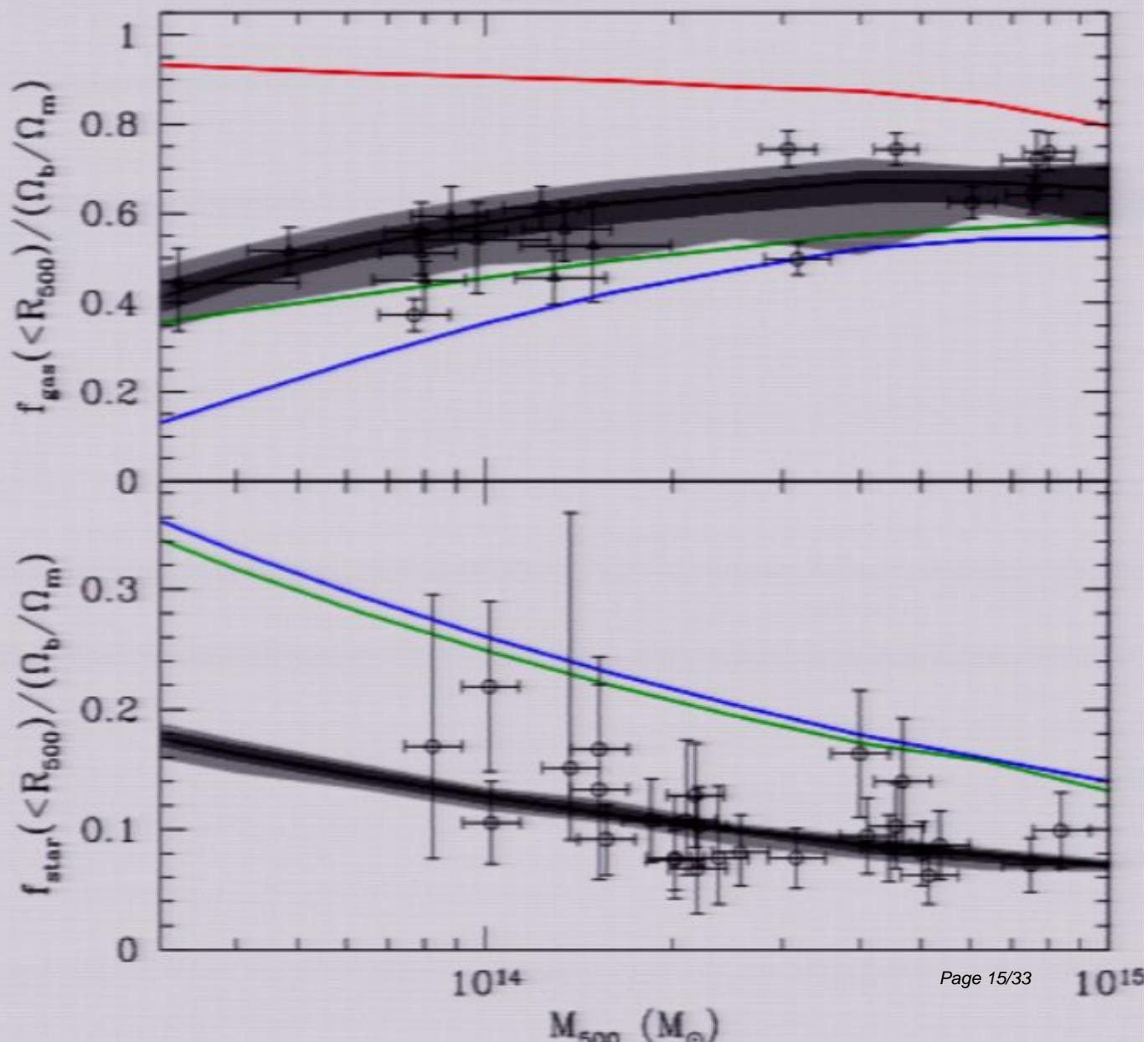
Nonthermal20

Gas fractions for $z < 0.2$

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Stellar fractions

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PRESSURE PROFILES

Standard

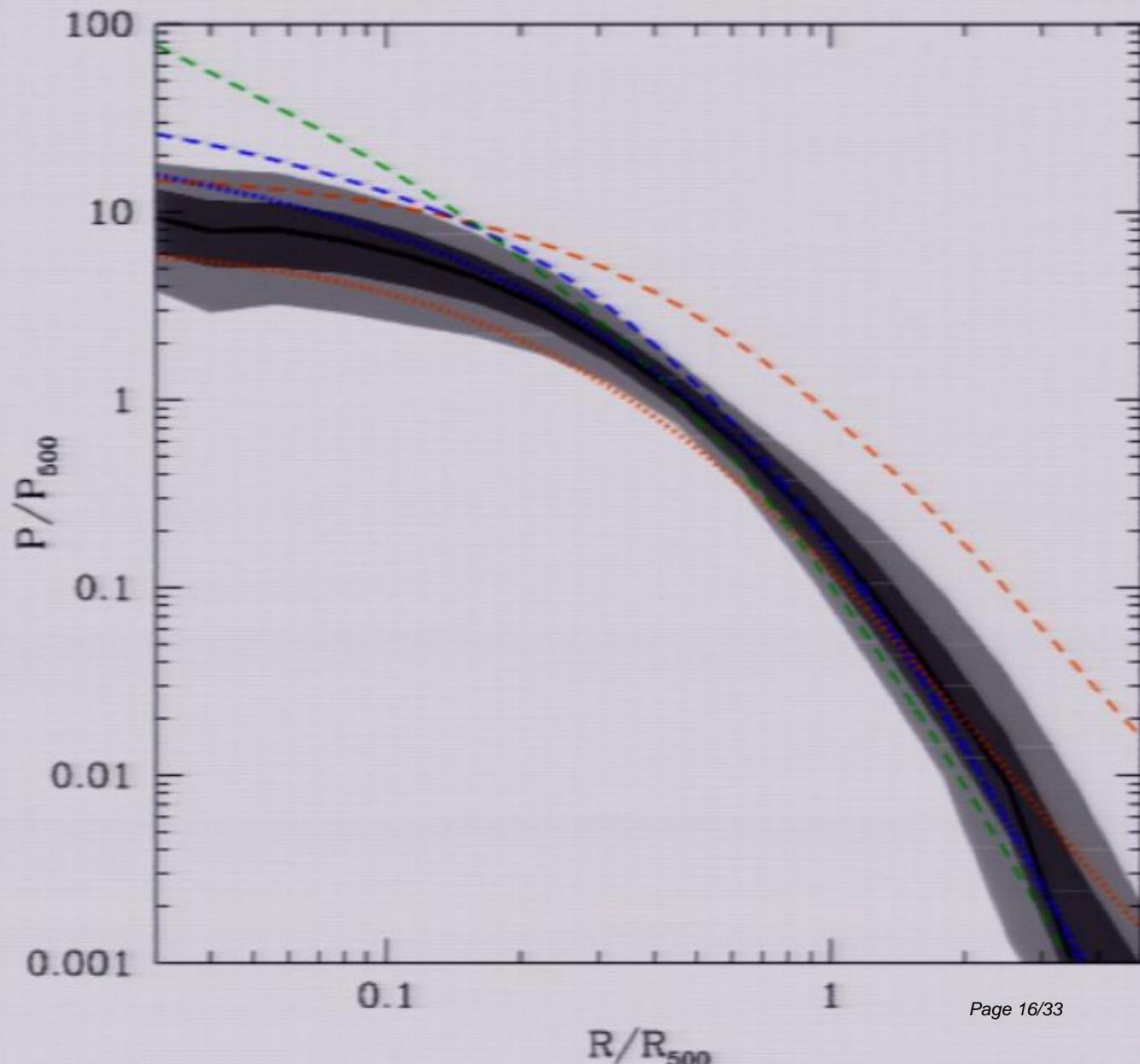
- $M_{500} > 10^{14}$ Msun
- $z < 0.2$

Amaud et al (2009)

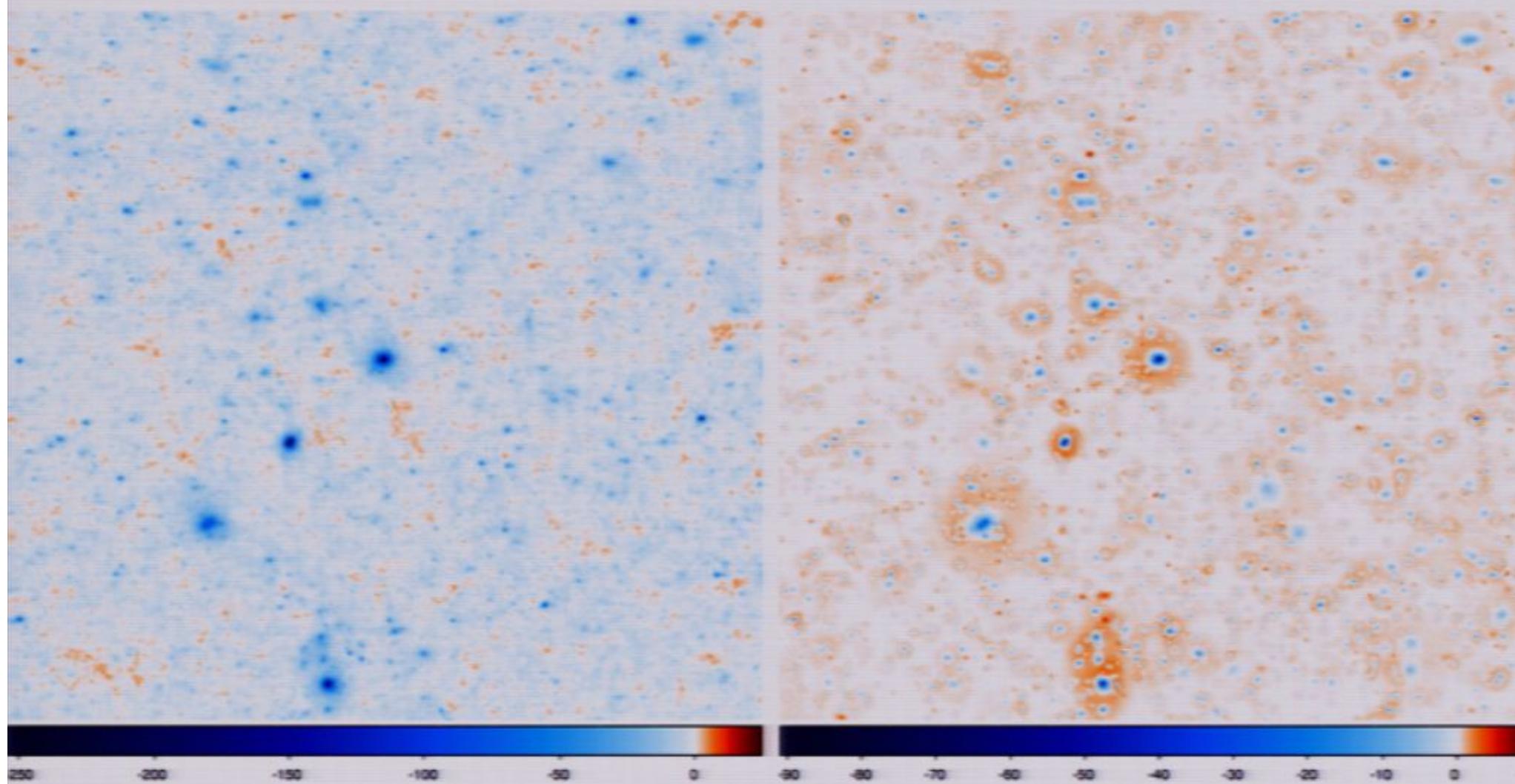
Komatsu & Seljak (2002)

Nagai et al (2007)

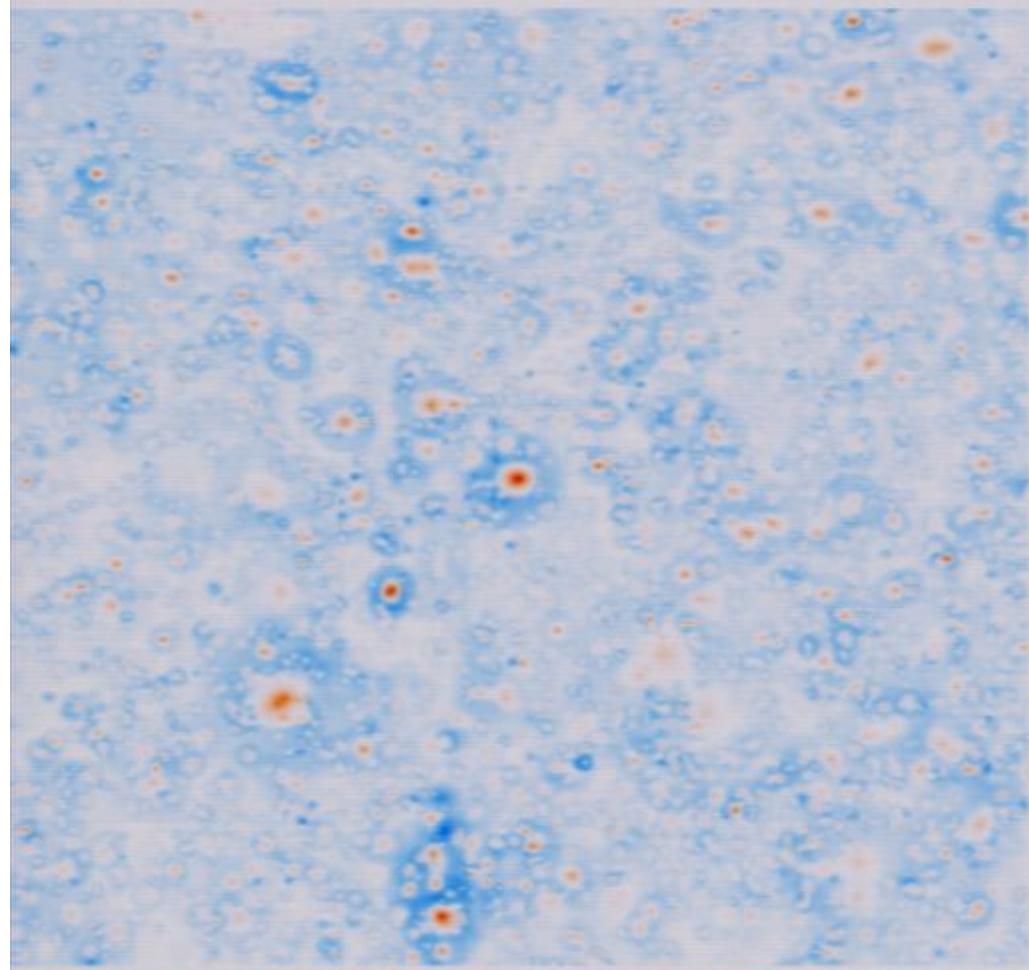
- $M_{500} = 10^{15}$ Msun
(dashed, upper)
- $M_{500} = 10^{14}$ Msun
(dotted, lower)
- $z = 0.2$



SZ TEMPERATURE FLUCTUATIONS at 148 GHz



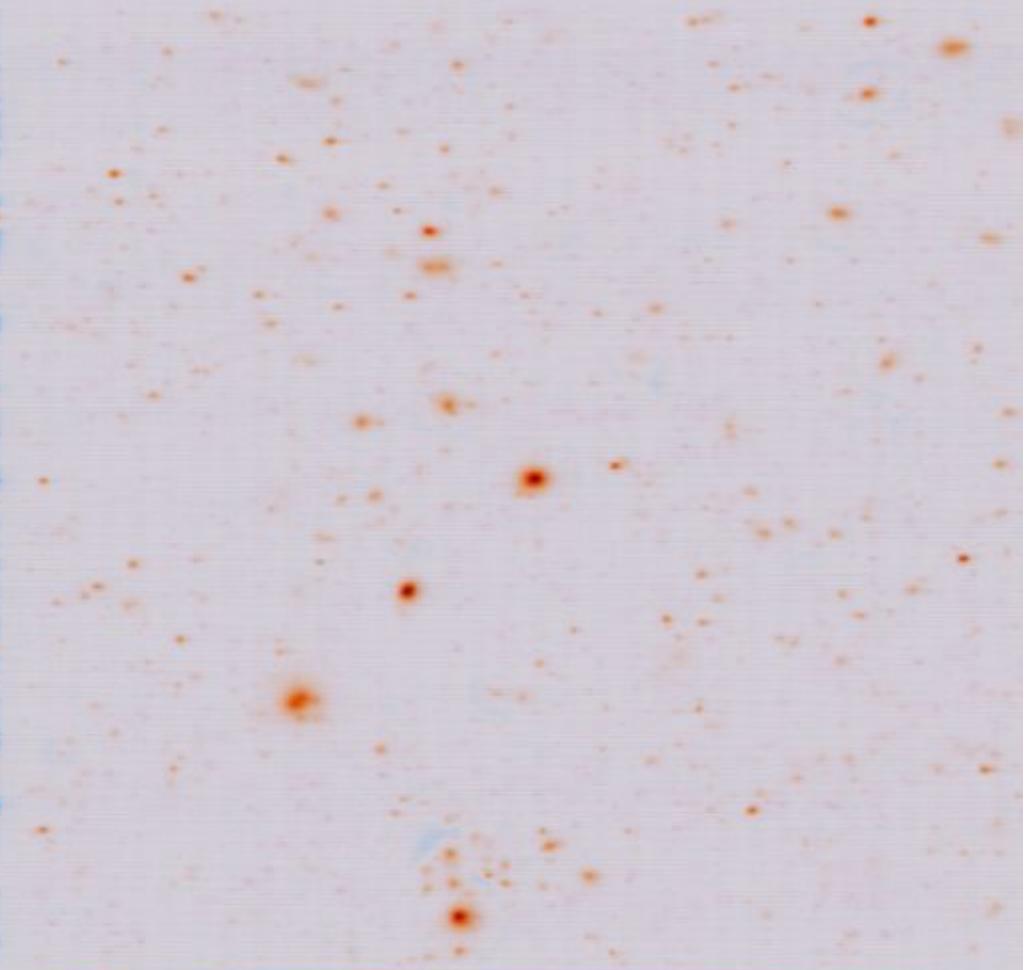
SZ TEMPERATURE FLUCTUATIONS at 148 GHz



10 0 10 20 30 40 50 60 70 80 90

$SZ_{\text{LOW-FGAS}} - SZ_{\text{STANDARD}}$

Pirsa: 1004097



-10 0 10 20 30 40 50 60 70 80

$SZ_{\text{NONTHERMAL20}} - SZ_{\text{STANDARD}}$

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TSZ ANGULAR POWER SPECTRUM

Standard

Adiabatic

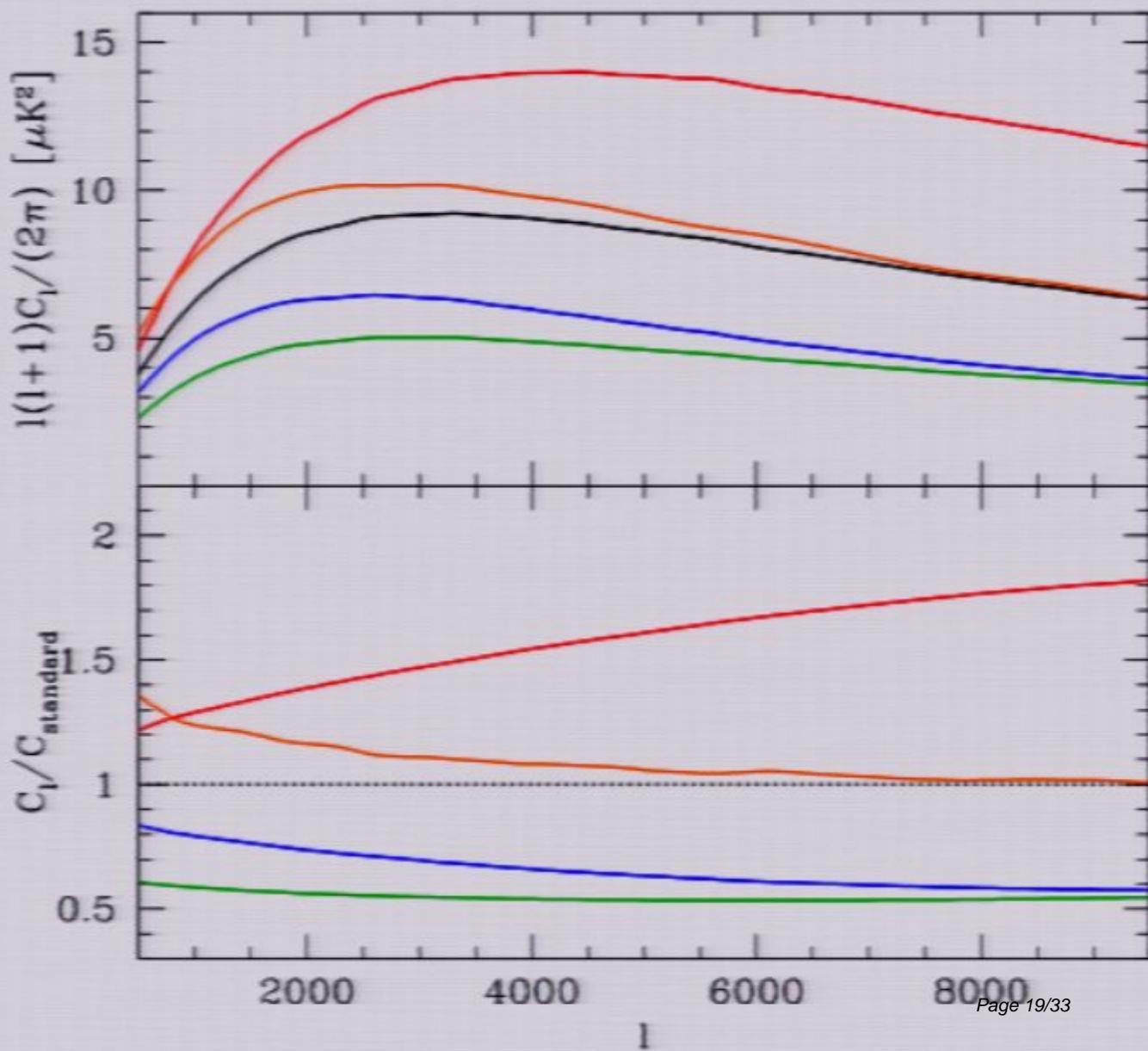
Low-fgas

Nonthermal20

Komatsu & Seljak (2002)

Relative to standard model

$\pm 45\%$ differences at $l = 3000$



KSZ ANGULAR POWER SPECTRUM

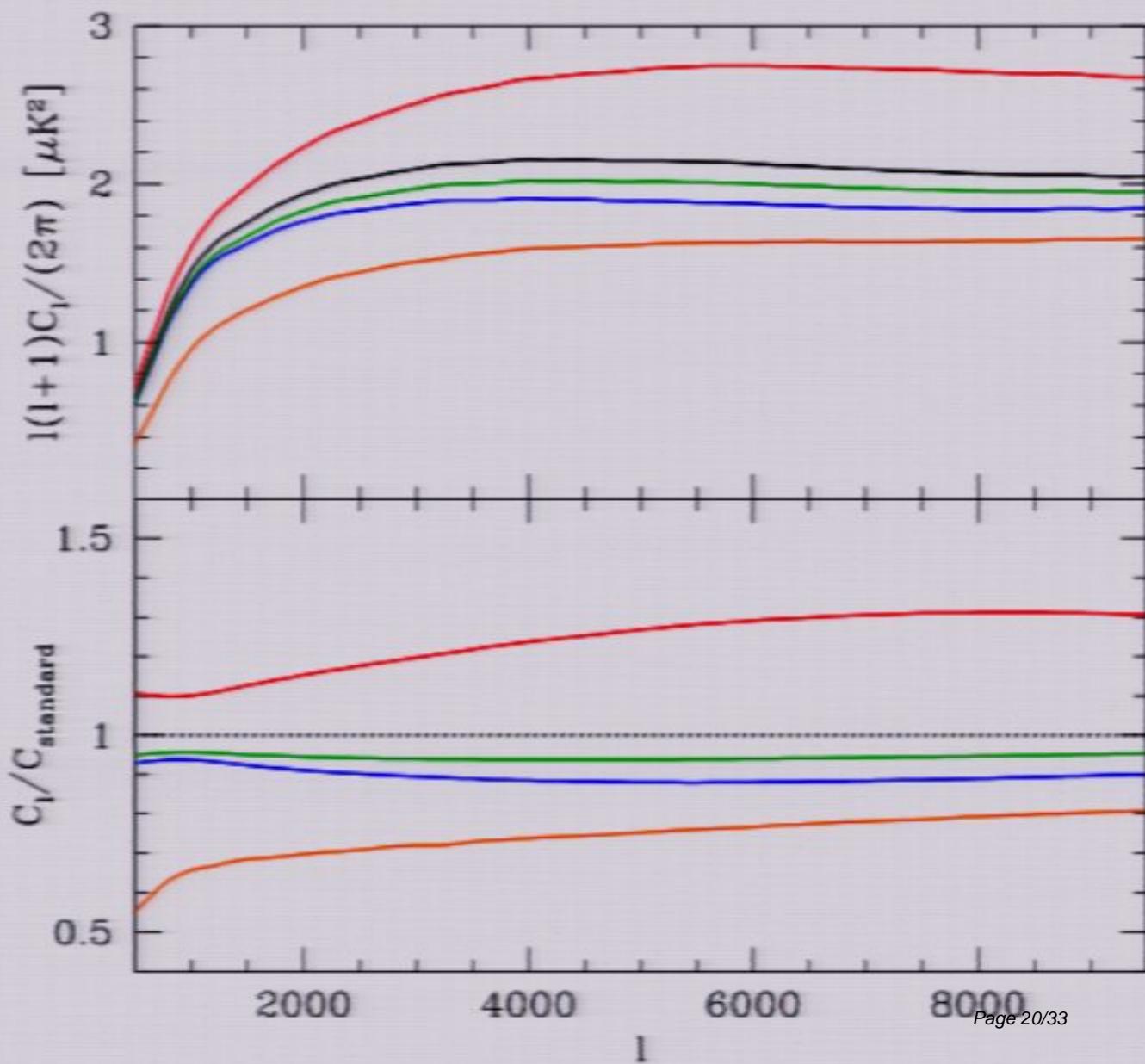
Standard ($z_{\text{reion}} = 10$)

Adiabatic

Low-fgas

Nonthermal20

Standard ($z_{\text{reion}} = 6$)



TSZ ANGULAR POWER SPECTRUM

Standard

Adiabatic

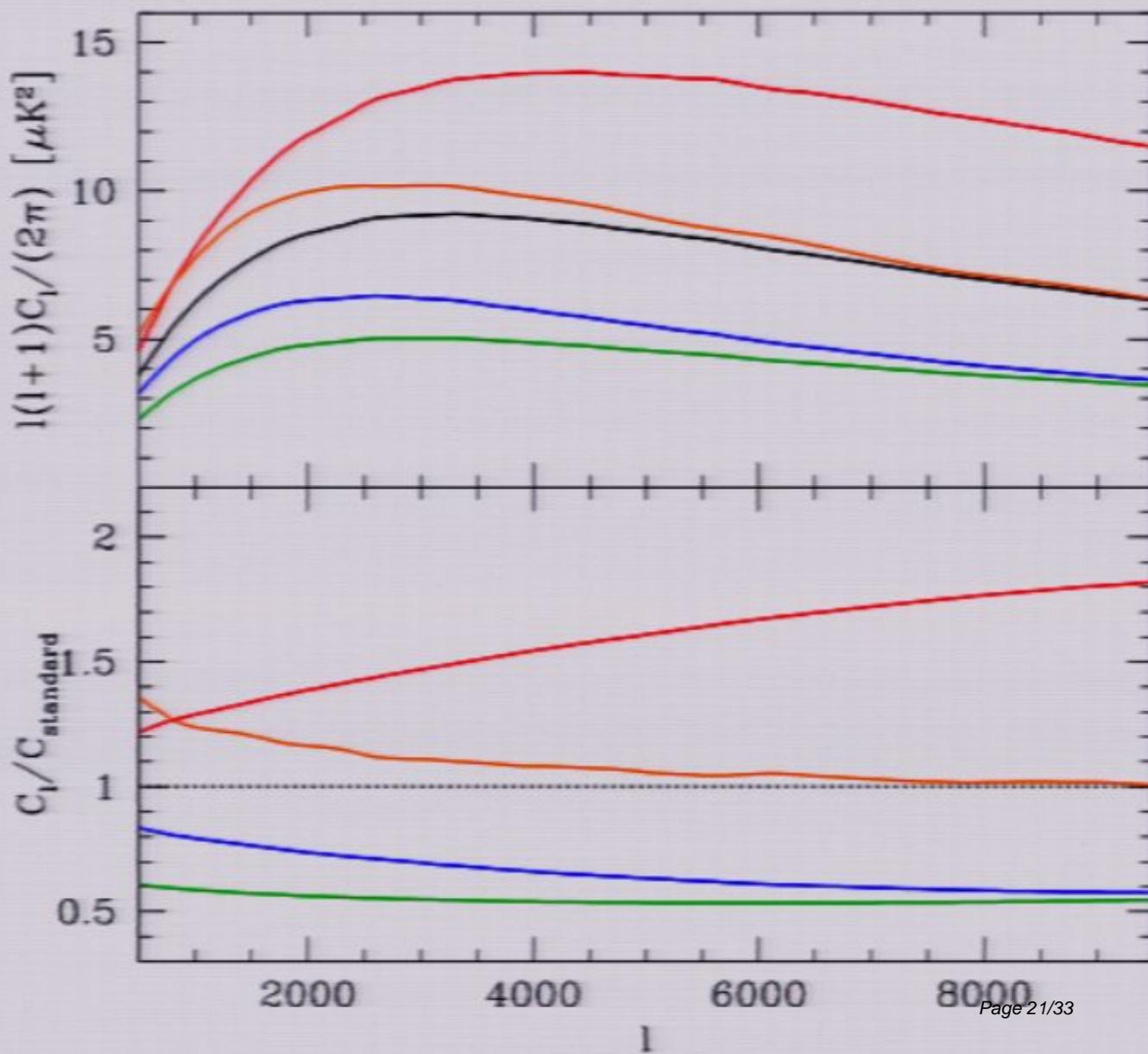
Low-fgas

Nonthermal20

Komatsu & Seljak (2002)

Relative to standard model

$\pm 45\%$ differences at $l = 3000$



KSZ ANGULAR POWER SPECTRUM

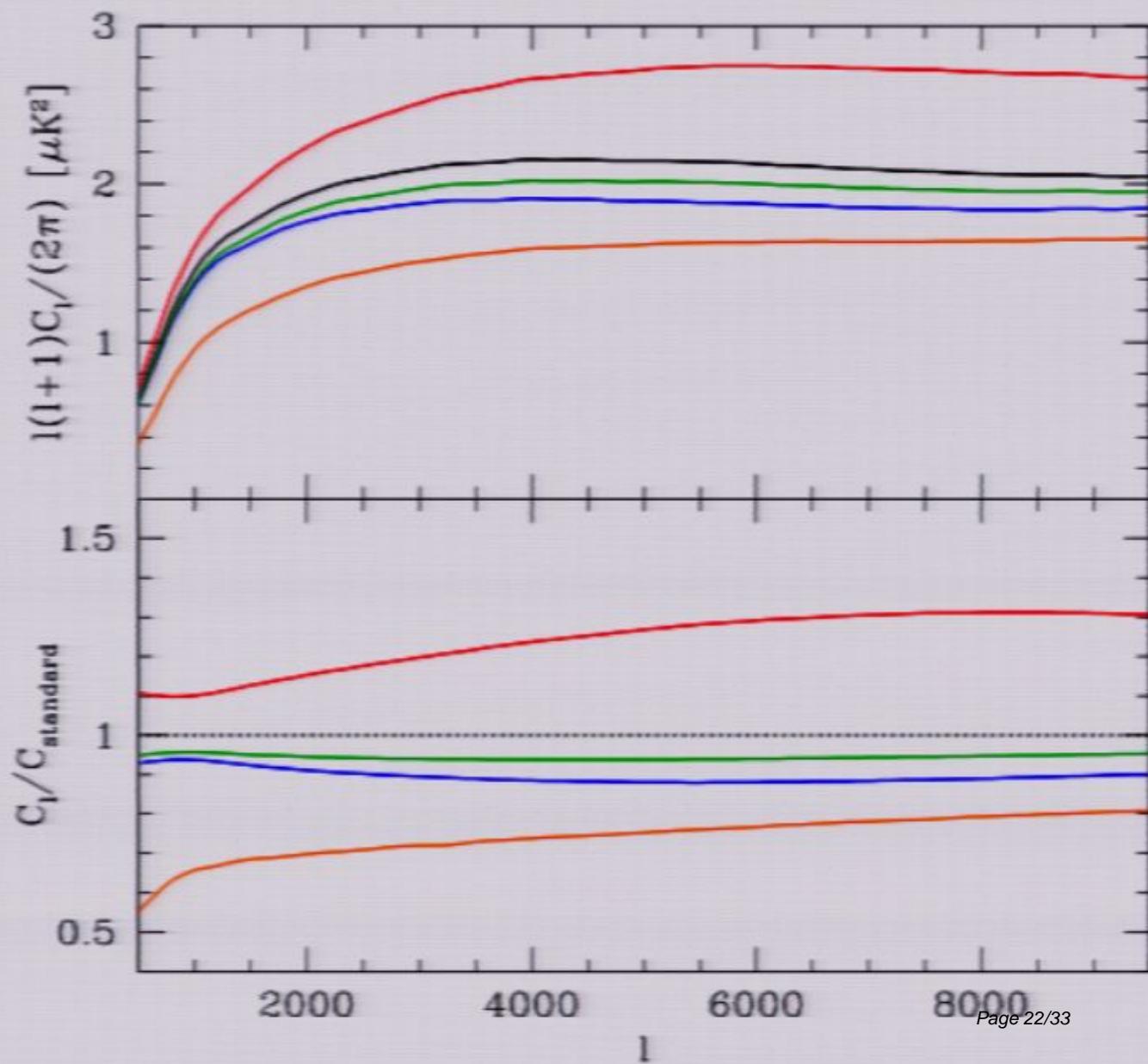
Standard ($z_{\text{reion}} = 10$)

Adiabatic

Low-fgas

Nonthermal20

Standard ($z_{\text{reion}} = 6$)



SZ ANGULAR POWER SPECTRUM at 148 GHz

Standard

Adiabatic

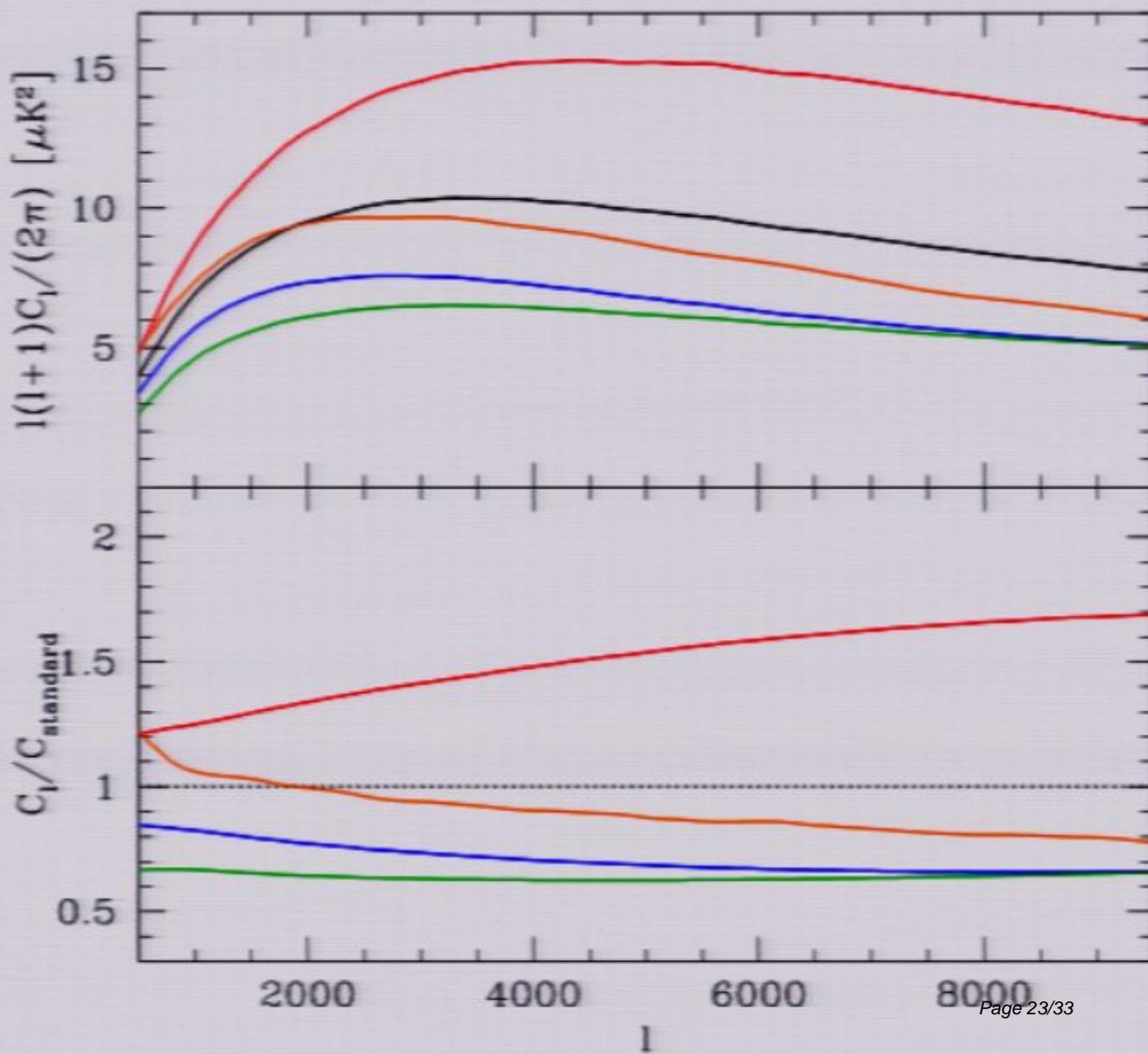
Low-fgas

Nonthermal20

Komatsu & Seljak (2002)

Relative to standard model

±40% differences at $l = 3000$



DEPENDENCE OF C_l ON σ_8

Calculate SZ power spectra for arbitrary σ_8 without having to run additional simulations

- C_l can be broadly divided into halo and IGM components
- Rescale contribution from each halo
 - Weight each C_h by ratio of mass function $dn(\sigma_8)/dn(0.8)$
 - Rescale velocities by $(\sigma_8/0.8)$
- Rescale contribution from IGM
 - $C_{TSZ} \propto \sigma_8^{>2}$ and $C_{KSZ} \propto \sigma_8^{>4}$

Parameterize dependence of C_l on σ_8

- Scaling factor
 - $A_{SZ} = C_l(\sigma_8)/C_l(0.8) = (\sigma_8/0.8)^\alpha$
- Scaling index
 - $\alpha = \alpha(l, \sigma_8, \text{gas model})$

POWERLAW SCALING INDEX

Standard

Adiabatic

Low-fgas

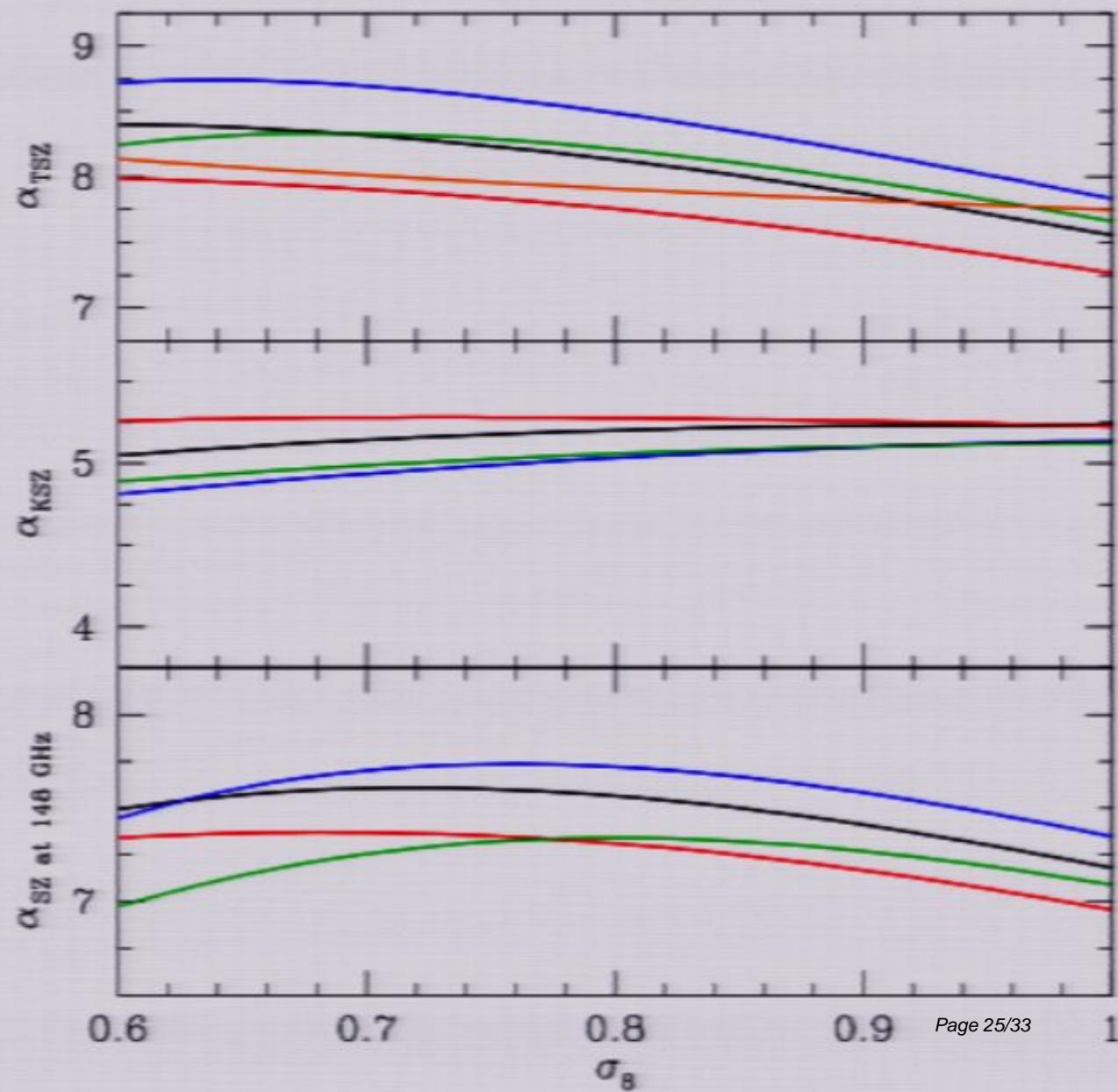
Nonthermal20

Komatsu & Seljak (2002)

Powerlaw scaling

$C_l \propto (\sigma_8/0.8)^\alpha$

α at $l = 3000$



CONSTRAINTS ON σ_8

Standard

Adiabatic

Low-fgas

Nonthermal20

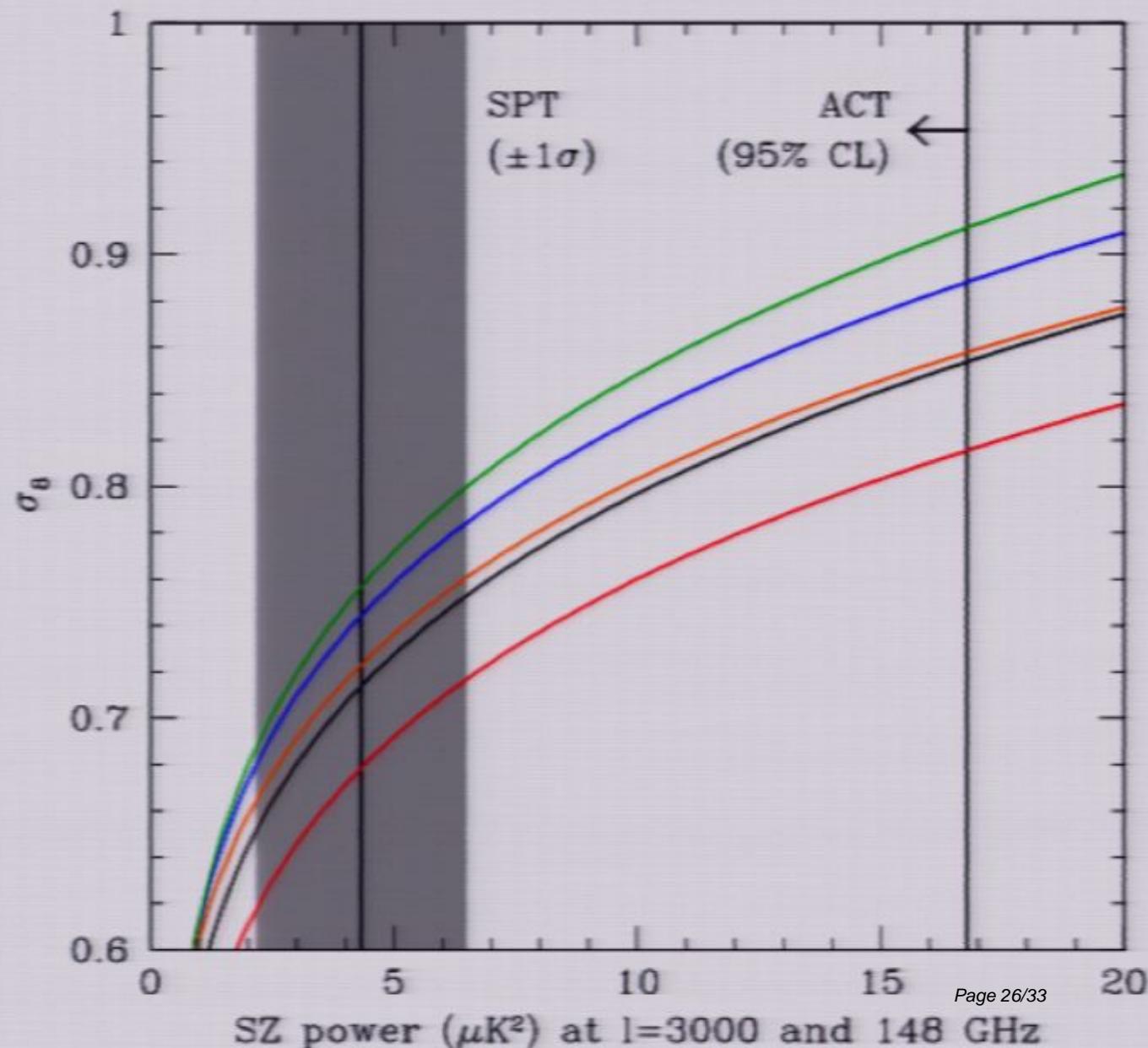
Komatsu & Seljak (2002)

ACT (Fowler et al 2010)

- $A_{STD} < 1.63$ (95% CL)

SPT (Lueker et al 2009)

- $A_{STD} = 0.42 \pm 0.21$



KSZ ANGULAR POWER SPECTRUM

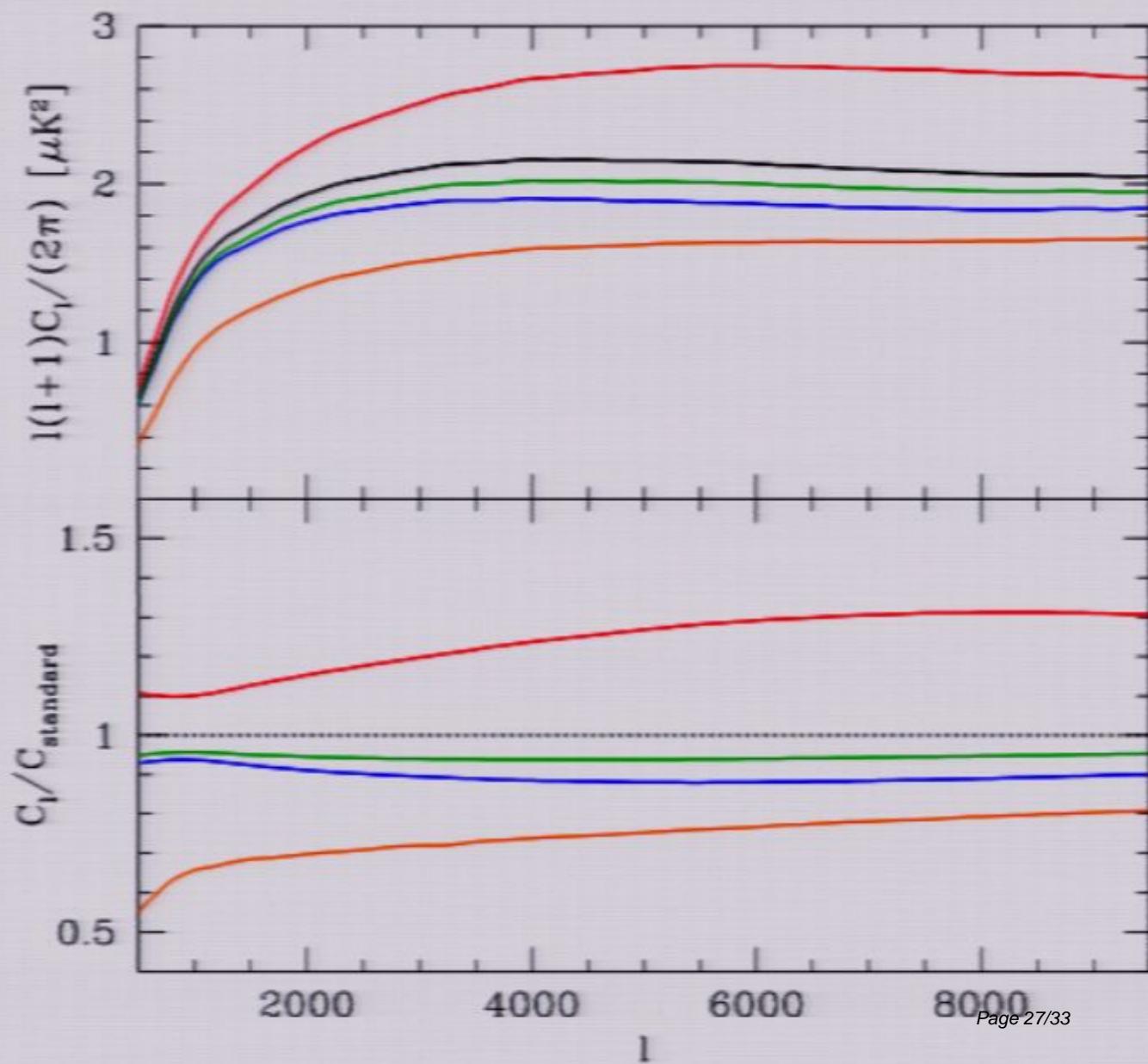
Standard ($z_{\text{reion}} = 10$)

Adiabatic

Low-fgas

Nonthermal20

Standard ($z_{\text{reion}} = 6$)



TSZ ANGULAR POWER SPECTRUM

Standard

Adiabatic

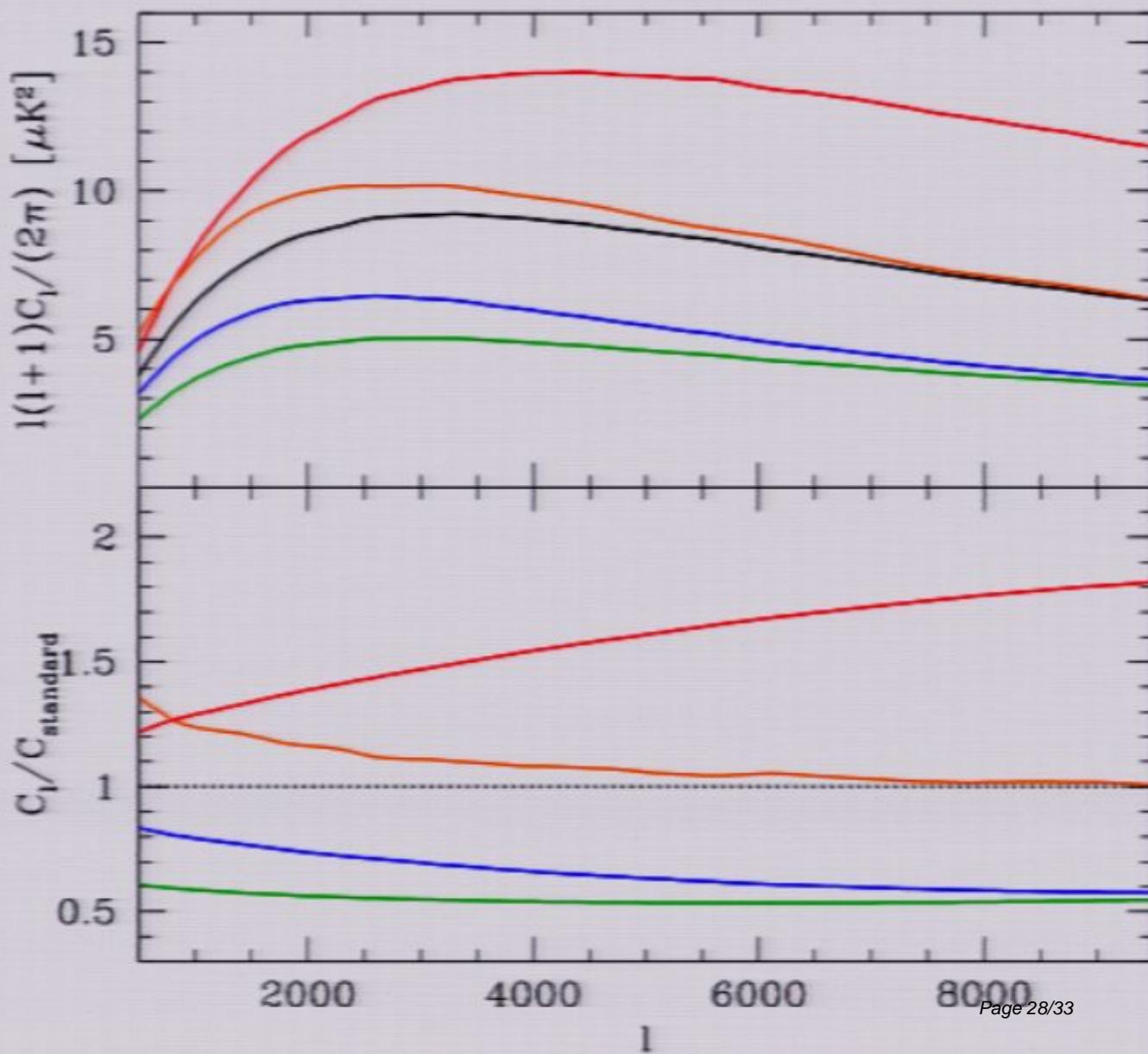
Low-fgas

Nonthermal20

Komatsu & Seljak (2002)

Relative to standard model

$\pm 45\%$ differences at $l = 3000$



SZ ANGULAR POWER SPECTRUM at 148 GHz

Standard

Adiabatic

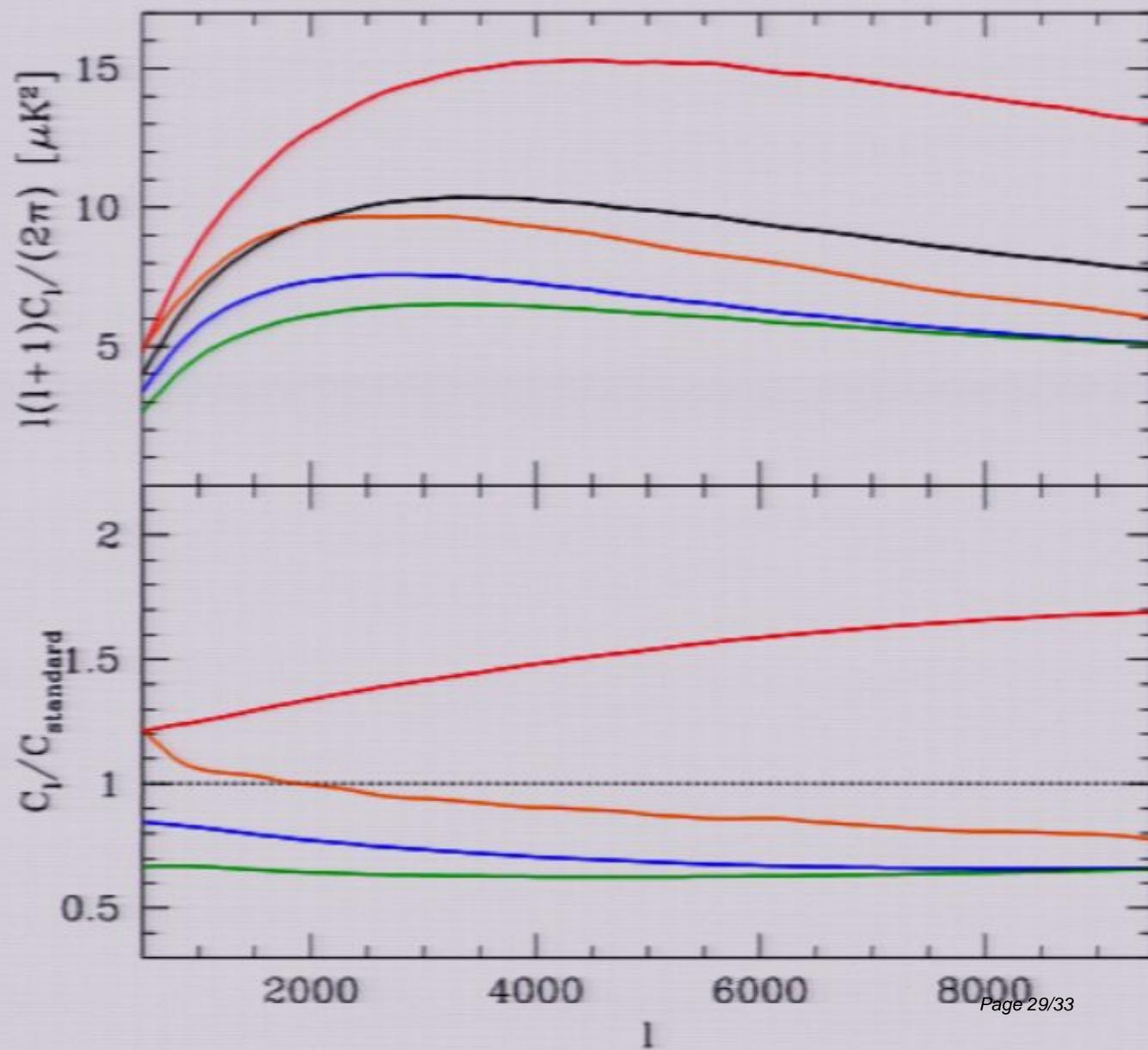
Low-fgas

Nonthermal20

Komatsu & Seljak (2002)

Relative to standard model

$\pm 40\%$ differences at $l = 3000$



POWERLAW SCALING INDEX

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Adiabatic

Low-fgas

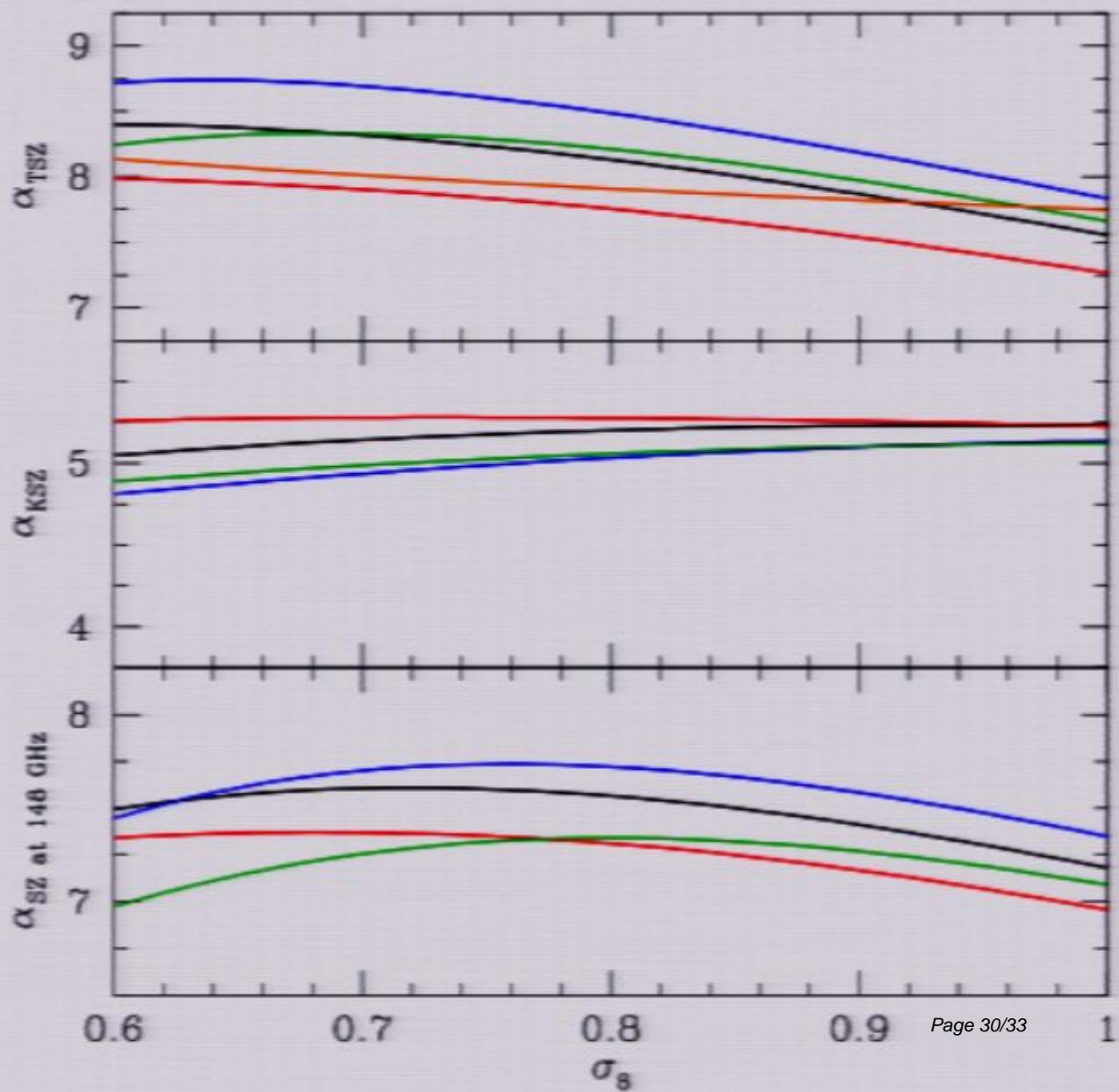
Nonthermal20

Komatsu & Seljak (2002)

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α at $l = 3000$



SUMMARY

4 gas models are compared to study how gas physics influence the SZ effect

- adiabatic, standard, low-fgas, and nonthermal20
- standard model has been used by ACT and SPT to fit for the SZ power

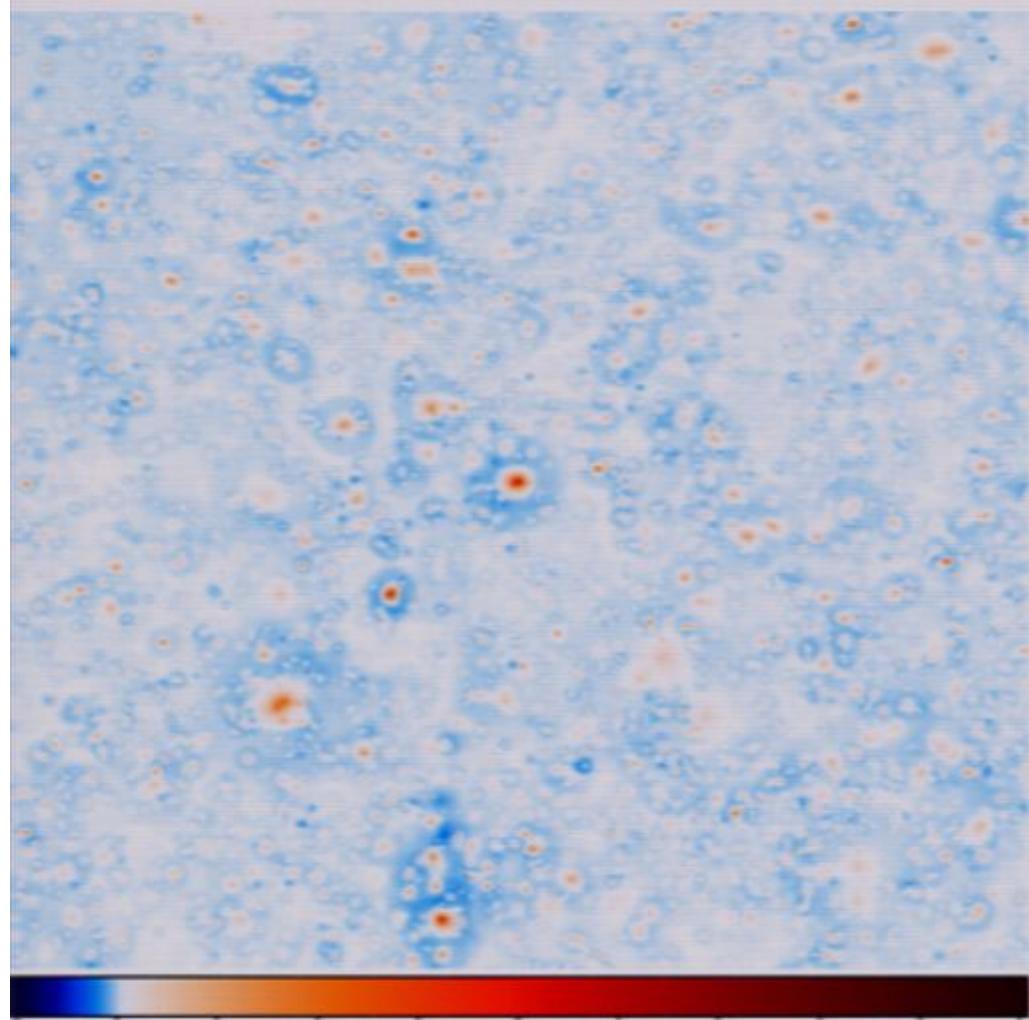
Star formation and feedback

- As gas mass and energy is removed through star formation and as gas is pushed out to larger radii by feedback, the SZ power spectrum decreases in amplitude.

Bulk and random gas motions

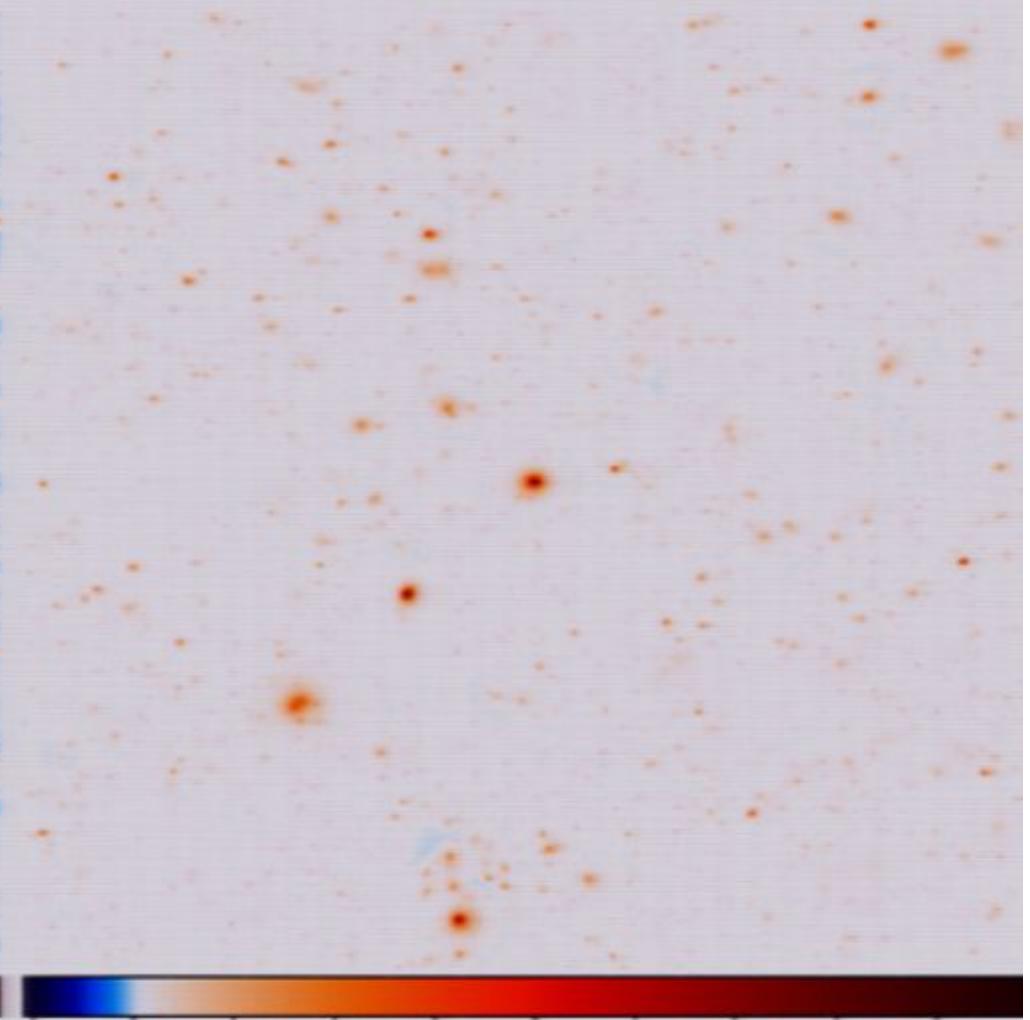
- Nonthermal pressure support can have stronger effects than energetic feedback on reducing the thermal contribution to the SZ angular power spectrum.

SZ TEMPERATURE FLUCTUATIONS at 148 GHz



SZ_lowESS STANDARD vs SZ_STANDARD

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SZ_lowHEALING vs SZ_STANDARD

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PRESSURE PROFILES

Standard

- $M_{500} > 10^{14}$ Msun
- $z < 0.2$

Amaud et al (2009)

Komatsu & Seljak (2002)

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