Title: XRay observations normalized ICM models: SZ scaling relations and cosmological implications

Date: Apr 27, 2009 02:45 PM

URL: http://pirsa.org/09040036

Abstract: We build simple, 'top-down', models for the gas density and temperature profiles for clusters of galaxies based on current high precision XRay observations so as to 'exactly' satisfy observed XRay scaling relation between temperature and mass. The gas is assumed to be in hydrostatic equilibrium along with a component of non-thermal pressure due to dispersion and the gas fraction reaches universal value only at or beyond the virial radius. For these models, we calculate the Sunyaev-Zel'dovich Effect (SZE) scaling relations. We show that all the predicted SZE scaling relations between the integrated SZE flux and the gas temperature, the gas mass, the total mass, as well as, the gas fraction are in excellent agreement with recent SZE observations by Bonamente etal (2008). The consistency between the global properties of clusters detected in X-Ray's and in SZE hints that we are looking at the same population of clusters as a whole. Implications for SZE power spectrum, SZE flux-M200 scaling relation and number counts are discussed

# X-Ray Observations Normalized ICM Models-
# SZ Scaling Relations
# and
# Cosmological Implications

**Subha Majumdar**
(Anya Chaudhuri, Jon Sievers, Christoph Pfrommer)

Tata Institute of Fundamental Research
Mumbai

# X-Ray Observations Normalized ICM Models- SZ Scaling Relations and Cosmological Implications

**Subha Majumdar**
(Anya Chaudhuri, Jon Sievers, Christoph Pfrommer)

Tata Institute of Fundamental Research
Mumbai

## SCALING RELATIONS and REASON TO STUDY THEM -

The relations between the different integrated properties of a cluster and with its mass are known as scaling relations.

Ex – Xray Flux – Mass / SZ-flux – Mass / GasTemp – Mass/ Xray Flux – Temp etc

A) Cosmology – cluster connection is mainly through mass. For example, the mass function of
- haloes (i.e clusters) depends sensitively on cosmology (like sigma8, DE etc).
- Many cluster surveys are planned/ongoing use clusters as cosmological probes.
- Similarly, new CMB anisotropies due to clusters depend on how these clusters of diff masses
- are distributed in the sky.

- B) Unfortunately, for most of these surveys/CMB anisotropies clusters masses are not directly
- measured. They have to inferred from cluster obervables (like flux).

- So, KNOWLEDGE OF SCALING RELATION IS CRUCIAL FOR USING CLUSTERS IN
- COSMOLOGY.
- **INCORRECT SCALINGS ----> INCORRECT COSMOLOGY.**

- C) Theoretical understanding needed because observationally one cannot go to large cluster
- radii to cover the entire mass of the cluster.

## SCALING RELATION IN OBSERVATIONS AND THEORY -

### OBSERVATIONS -

**1.** X-Ray/SZ observations can give the flux over a volume of the cluster. The volume is mainly limited by the sensitivity of the observations (ex- for xrays $r_{2500}$, sometimes $r_{500}$, SZ can be observed further away).

2. XRay spectroscopy gives temperature. Older observations assumed isothermality. Now, we can get temp profiles. Temperature quoted are weighted over range in radii by the Xray emission.

3. Masses can be inferred in several ways – a) directly from lensing , b) indirectly from dynamics of galaxies, c)from assuming the gas to be in hydrostatic equilibrium. Each has its advantages/disadvantages.

### THEORY ( Analytical or Simulations) -

1. In simulations, gas and dark matter particles are evolved from tiny perturbations at high z to form clusters at lower z's. The distribution of DM + gas, directly gives the different density and temp profiles The DM follows a universal profile known as NFW profile. Analytic models assume spatial symmetry.

2. From the temperature profiles, one can construct the 'emission weighted or 'spectroscopic-like' weighted average temperature for a cluster.

3. Different fluxes (say Xray/SZ) or masses within a cluster radius can be obtained from summing over particles (in simulations) or by integrating the analytical density profiles.

ON SCALING RELATIONS AND SELF-SIMILARITY -

Assumption: Gravity ONLY decides the thermodynamic state of the ICM. No preferred scale→ hence self-similar (first proposed by Kaiser)_

Mass $M_{\Delta c}$ is enclosed in radius $R_\Delta$ → $M_\Delta \sim \rho_c(z)\Delta_c R^3_\Delta$

$\rho_c(z) \sim E^2(z)$_

$R \sim M^{1/3} E^{-2/3}(z)$_

**1) M-T reln:**

$$M_{\Delta_c} \propto T^{3/2} E^{-1}(z)$$

**2) $L_X$-T reln:**

$$L_X = \int_V \left(\frac{\rho_{\rm gas}}{\mu m_p}\right)^2 \Lambda(T)\, dV$$

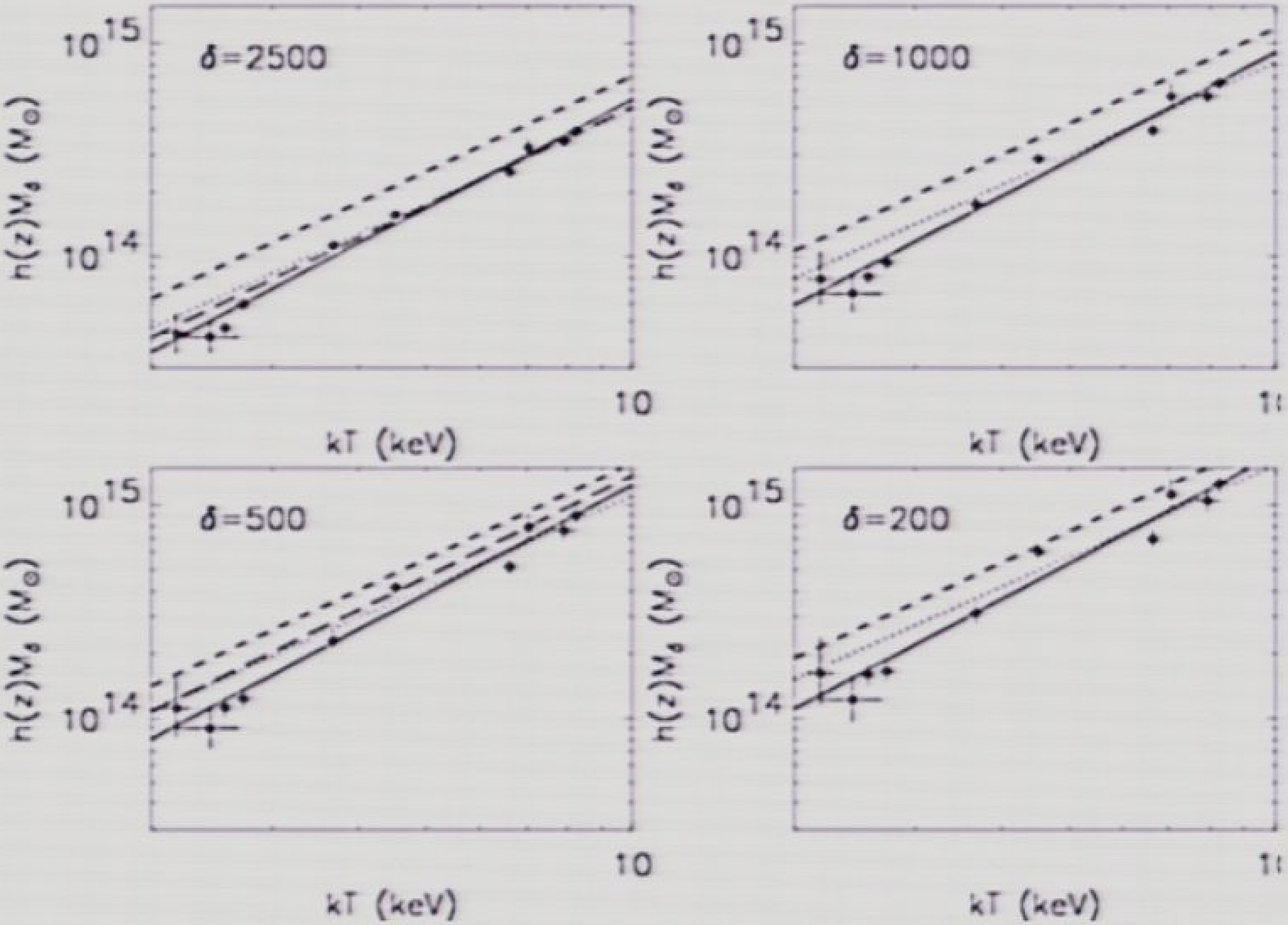
$$L_X \propto M_{\Delta_c} \rho_c T^{1/2} \propto T^2 E(z)$$

**3) SZ relns:**

$$\Delta S \propto \int y(\theta) \mathrm{d}\Omega \propto d_A^{-2} \int T n_e \mathrm{d}^3 r \propto d_A^{-2} T^{5/2} E^{-1}(z)$$

$$y_0 \propto T^{3/2} E(z) \propto L_X^{3/4} E^{1/4}(z)$$

## SIMULATIONS-VS-OBSERVATIONS -




(Observations by Arnaud etal, Simulations by Evrard etal)

Non-radiative sims way off.
Radiative in better but has much room for improvement (ask Daisuke, Christoph)

Q) So What is Going On ?

A) Our lack of full understanding of the physics !

Many experts work on, has spoken today, will speak after me, will keep working on…

I'm not going to focus on the micro physics
I'll something much naïve, something more phenomenological.
…and see what we get out of constructing simple model and observations!

Bottomline - Let X-Ray observations (much precise) aid SZ science

# A bit of motivation -

# A bit of motivation -

Most analytical or simulation models are **'bottom-up'** models.
Simulations have similar problems to KS model. Both have many similarities.

Present cluster models faces tension :

1. It fails to reproduce scaling relations at low masses (Xrays)
2. Used as SZ cluster templates -vs- "CBI-excess" .

# A bit of motivation -

Most analytical or simulation models are **'bottom-up'** models.
Simulations have similar problems to KS model. Both have many similarities.

Present cluster models faces tension :

1. It fails to reproduce scaling relations at low masses (Xrays)
2. Used as SZ cluster templates -vs- "CBI-excess" .

Ideally, one should just use 'observed scaling relns'.

Caveats – 1) Need good observations at higher redshifts also
2) There are no observations at virial radius.
3) SZ surveys have started but only two SZ observational scaling papers.
4) SZ flux is still measured at smaller radius.

# A bit of motivation -

Most analytical or simulation models are **'bottom-up'** models.
Simulations have similar problems to KS model. Both have many similarities.

Present cluster models faces tension :

1. It fails to reproduce scaling relations at low masses (Xrays)
2. Used as SZ cluster templates -vs- "CBI-excess" .

Ideally, one should just use 'observed scaling relns'.

Caveats – 1) Need good observations at higher redshifts also
2) There are no observations at virial radius.
3) SZ surveys have started but only two SZ observational scaling papers.
4) SZ flux is still measured at smaller radius.

Thus we need cluster model that will give SZ scaling relations that agree with observations at smaller radius, across a large mass range and which can then be used to predict scaling relations for the whole clusters.

# A bit of motivation -

Most analytical or simulation models are **'bottom-up'** models.
Simulations have similar problems to KS model. Both have many similarities.

Present cluster models faces tension :

1. It fails to reproduce scaling relations at low masses (Xrays)
2. Used as SZ cluster templates -vs- "CBI-excess" .

Ideally, one should just use 'observed scaling relns'.

Caveats – 1) Need good observations at higher redshifts also
2) There are no observations at virial radius.
3) SZ surveys have started but only two SZ observational scaling papers.
4) SZ flux is still measured at smaller radius.

Thus we need cluster model that will give SZ scaling relations that agree with observations at smaller radius, across a large mass range and which can then be used to predict scaling relations for the whole clusters.

**We build a very simple 'top-down' cluster model that fulfils these requirements.
Easier to run MCMC with analytic models**

## ANALYTIC MODELLING OF GALAXY CLUSTER - THE DARK MATTER

1. The primary component of a cluster is the dark matter halo (NFW).

2. The size / mass of a halo - depends on our definition.

a) They are connected by a constant over-density

b) Choice of overdensity - i) xray observations typically go upto $\Delta$ = 2500, 500
ii) Nbody sims use $\Delta$ = 200, $180\Omega_M$
iii) Virial radius is $\Delta$ = 170 (for sCDM), ~ 100 (LCDM)

$$r_{vir} = \left[ \frac{M_{vir}}{\frac{4\pi}{3}\rho_{crit}(z)\Delta_c(z)} \right]^{1/3}$$

c) Given NFW profile, one can covert between definitions.

d) Clusters do not have a well-defined outer boundary. A `good' boundary is the shock radius _ typically 2-3 virial radius.
Will be important later for normalization

The underlying variation is in halo concentration with cluster mass and redshift.
We use observed c-M relation from Comerford & Natarajan (2008)

## ANALYTIC MODELLING OF GALAXY CLUSTER - THE BARYONIC MATTER

1. Baryonic matter is dominated by Intra-cluster gas.

2. Following early X-ray observations, the most common and still used by many observers is the so called β-model, first proposed by Cavaliere & Fusco-Femiano (1976)_

$$n_e(r) = n_{e0}\left(1 + \frac{r^2}{r_c^2}\right)^{-3\beta/2} \qquad M_{\rm tot}(r) = \frac{3\beta k T_X}{G\mu m_p}\frac{r^3}{r_c^2 + r^2}$$

Recent observations and simulations for long time shows model to be incorrect at small and large radii. Especially, gas profiles tend to be steeper at outer region
**--> model underestimates total mass.**

3. Later improvement is incorporating non-isothermality and analytically solving for gas in equilibrium in NFW haloes (spherical/triaxial) by Makino & Suto. But has free parameters.

4. Komatsu & Seljak (2001) has proposed a 'Universal model for cluster gas' based on simple assumptions (with no free params). This is the favoured model at present.

## THE TEMPERATURE PROFILE -

### Cool Core Clusters -

Due to increased density at cluster cores, cooling time is less than hubble time _ gas can cool easily and forms cool core. Gas flows in to form 'cooling-flows'.

We motivate our temp profiles from Xray observation :

1) within the cool cores (Sanderson etal 2007)

$$T(r) \propto r^{.4}$$

2) Outside the cool cores, we take the temp profile to be 'polytropic'
(Vikhlinin etal 06, Sanderson 07, Arnaud etal 07, Sun etal 08)

$$T(r) \propto \rho(r)^{\gamma-1}$$

### Non Cool-core Clusters -

The temperature profile is taken to be polytropic through out. It is almost flat in the inner radii.
(Sanderson etal 2007, O'Hara etal 2007)

**Our final temp profiles matches very well the trend and extent seen in observations of falling temperatures at large cluster radii.**

## GAS DYNAMICAL EQUATION AND THE DENSITY PROFILE -

Solve
$$\frac{d\phi(x)}{dx} = \frac{1}{\rho(x)}\frac{dP(x)}{dx} + \frac{1}{\rho(x)}\frac{d[\rho(x)\sigma_r^2(x)]}{dx} + 2\beta(x)\frac{\sigma_r^2(x)}{x}$$

THERMAL PRESSURE DISPERSION PRESSURE ANISOTROPIC PRESSURE

$x = r/r_c$

We neglect the anisotropic term (typically small)

In general, most analytic models neglect non-thermal terms and only use term 1 (example, Komatsu-Seljak)

$$\frac{d\phi(x)}{dx} = \frac{1}{\rho(x)}\frac{dP(x)}{dx}$$

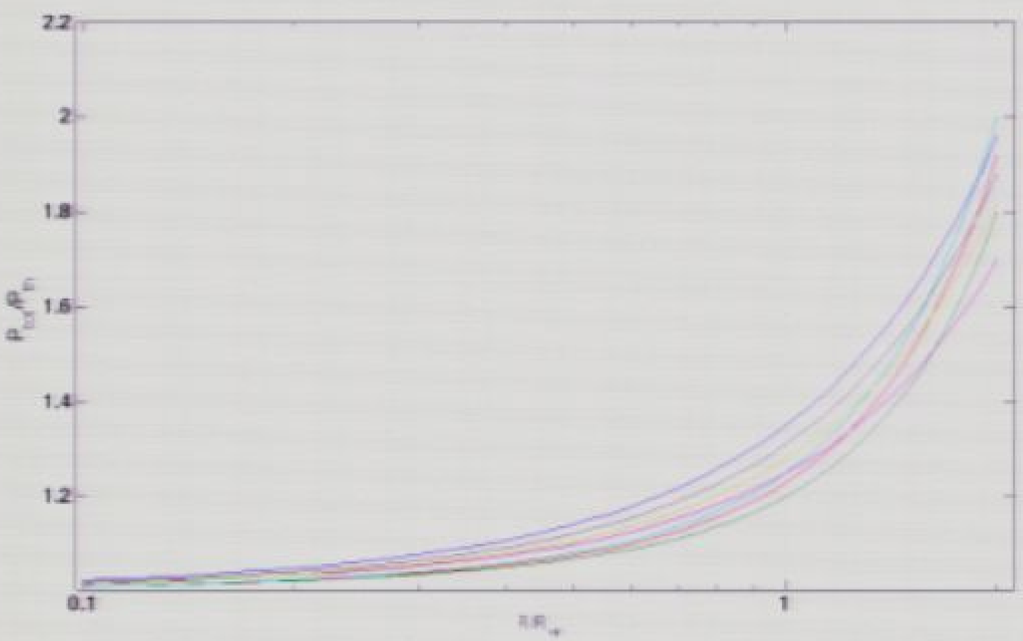
We know that neglecting non-thermal pressure biases mass-estimate
--> and hence scaling relations.
Bias is as bad as working with a beta-model mass estimate.

# NON THERMAL PRESSURE CONTRIBUTION -

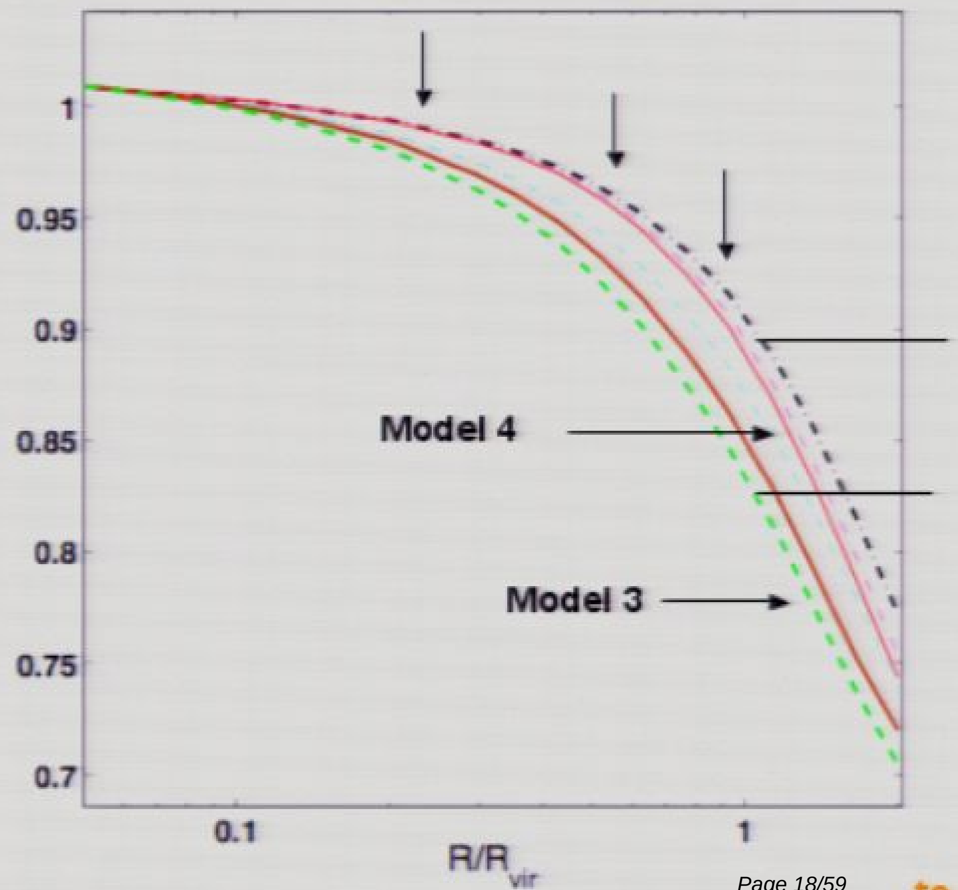
Xray observations do not give us any direct inputs into the non-thermal pressure support.

Simulations give a handle on non-thermal pressure. However, instead of adopting any particular simulation results, we only adopt the ***relative thermal/non-thermal pressure***. This quantity is more 'robust' across different simulations

Rasia, Pfrommer pvt communication




$$P_{NT}/P_T = \frac{\rho(x)\sigma_r^2(x)}{P(x)}$$



## GAS DYNAMICAL EQUATION AND THE DENSITY PROFILE -

Solve
$$\frac{d\phi(x)}{dx} = \frac{1}{\rho(x)}\frac{dP(x)}{dx} + \frac{1}{\rho(x)}\frac{d[\rho(x)\sigma_r^2(x)]}{dx} + 2\beta(x)\frac{\sigma_r^2(x)}{x}$$

THERMAL PRESSURE | DISPERSION PRESSURE | ANISOTROPIC PRESSURE

$x = r/r_c$

We neglect the anisotropic term (typically small)

In general, most analytic models neglect non-thermal terms and only use term 1 (example, Komatsu-Seljak)

$$\frac{d\phi(x)}{dx} = \frac{1}{\rho(x)}\frac{dP(x)}{dx}$$

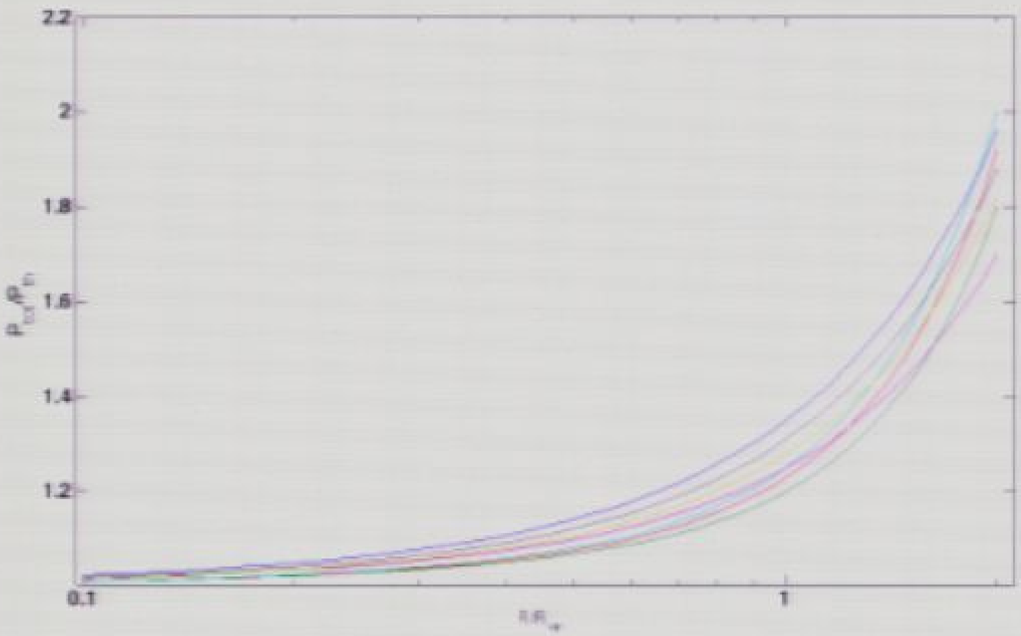
We know that neglecting non-thermal pressure biases mass-estimate
--> and hence scaling relations.
Bias is as bad as working with a beta-model mass estimate.

## NON THERMAL PRESSURE CONTRIBUTION -

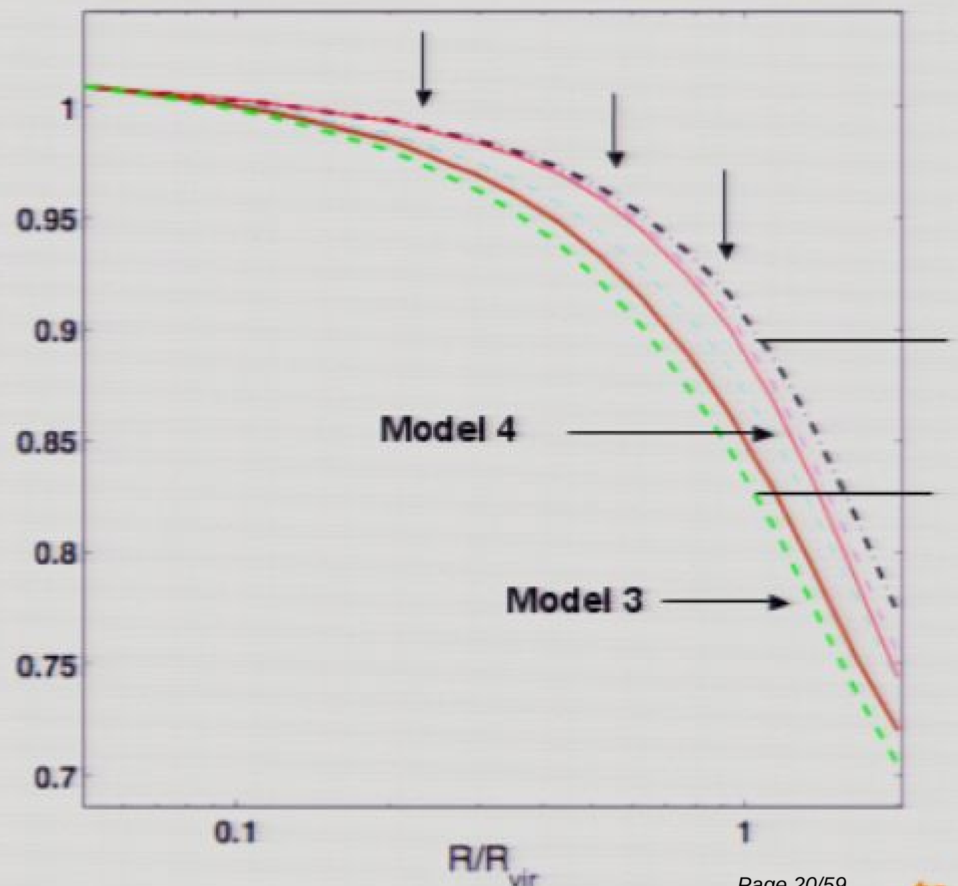
Xray observations do not give us any direct inputs into the non-thermal pressure support.

Simulations give a handle on non-thermal pressure. However, instead of adopting any particular simulation results, we only adopt the ***relative thermal/non-thermal pressure***. This quantity is more 'robust' across different simulations

Rasia, Pfrommer pvt communication




$$P_{NT}/P_T = \frac{\rho(x)\sigma_r^2(x)}{P(x)}$$



## GAS DYNAMICAL EQUATION AND THE DENSITY PROFILE -

Solve
$$\frac{d\phi(x)}{dx} = \frac{1}{\rho(x)}\frac{dP(x)}{dx} + \frac{1}{\rho(x)}\frac{d[\rho(x)\sigma_r^2(x)]}{dx} + 2\beta(x)\frac{\sigma_r^2(x)}{x}$$

THERMAL PRESSURE DISPERSION PRESSURE ANISOTROPIC PRESSURE

$x = r/r_c$

We neglect the anisotropic term (typically small)

In general, most analytic models neglect non-thermal terms and only use term 1 (example, Komatsu-Seljak)

$$\frac{d\phi(x)}{dx} = \frac{1}{\rho(x)}\frac{dP(x)}{dx}$$

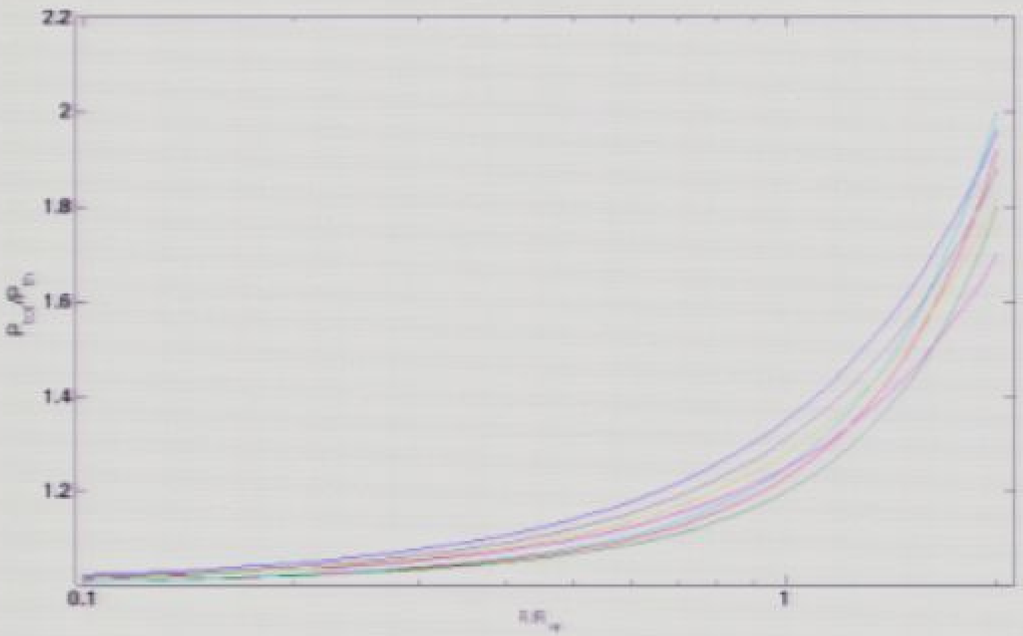
We know that neglecting non-thermal pressure biases mass-estimate
--> and hence scaling relations.
Bias is as bad as working with a beta-model mass estimate.

# NON THERMAL PRESSURE CONTRIBUTION -

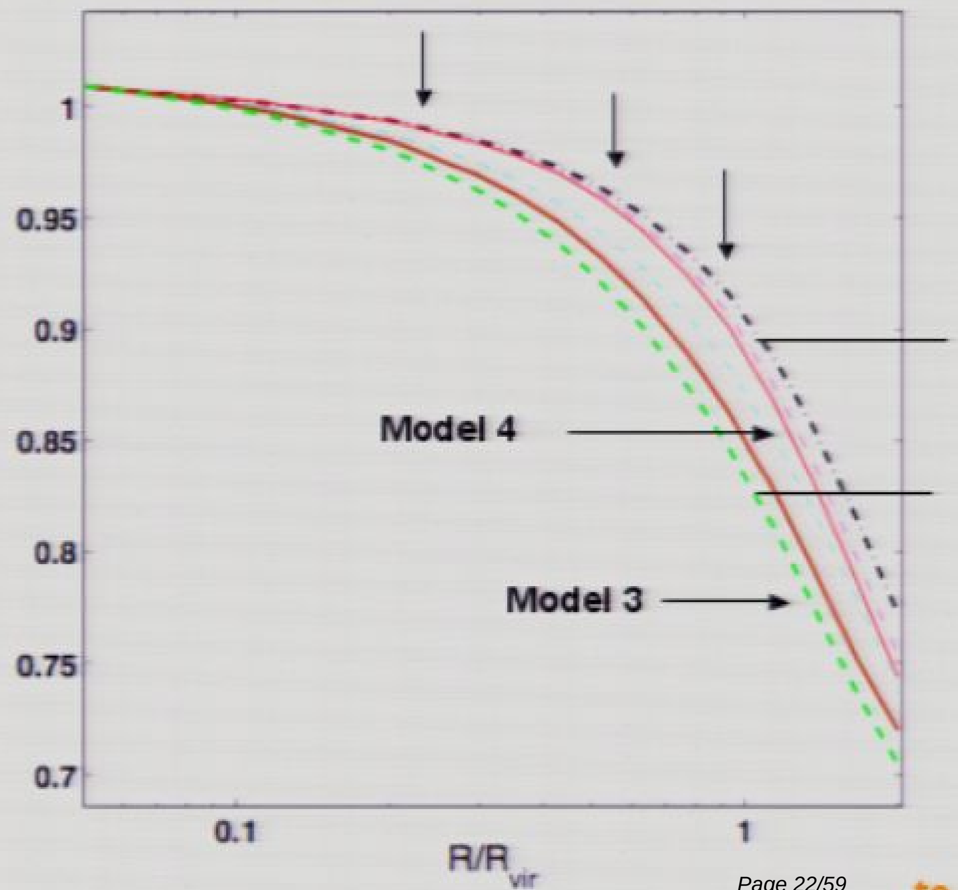
Xray observations do not give us any direct inputs into the non-thermal pressure support.

Simulations give a handle on non-thermal pressure. However, instead of adopting any particular simulation results, we only adopt the ***relative thermal/non-thermal pressure***. This quantity is more 'robust' across different simulations

Rasia, Pfrommer pvt communication

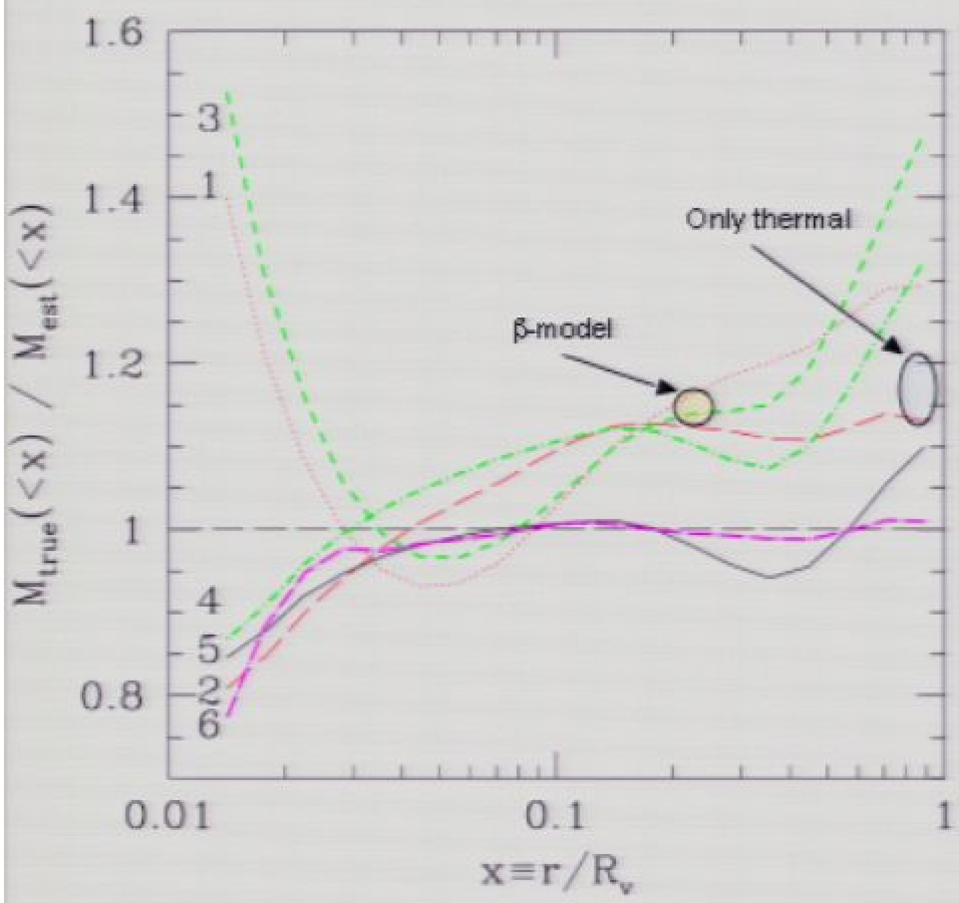



$$P_{NT}/P_T = \frac{\rho(x)\sigma_r^2(x)}{P(x)}$$

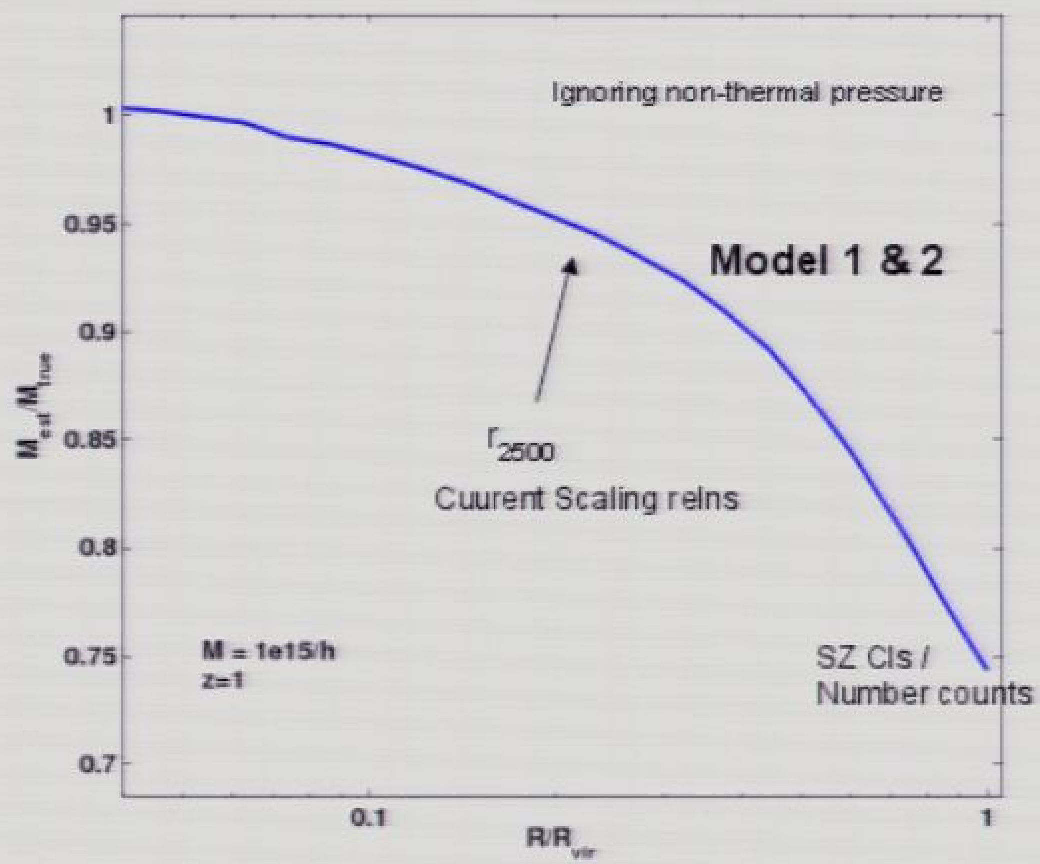


## ACTUAL CLUSTER MASS – VS – RECOVERED MASS -

Simple hydrostatic eqlm or ignoring non-thermal pressure, assumption of isothermality as well as commonly used beta model biases recovered cluster mass.




Simulations (Rasia et al 2004)



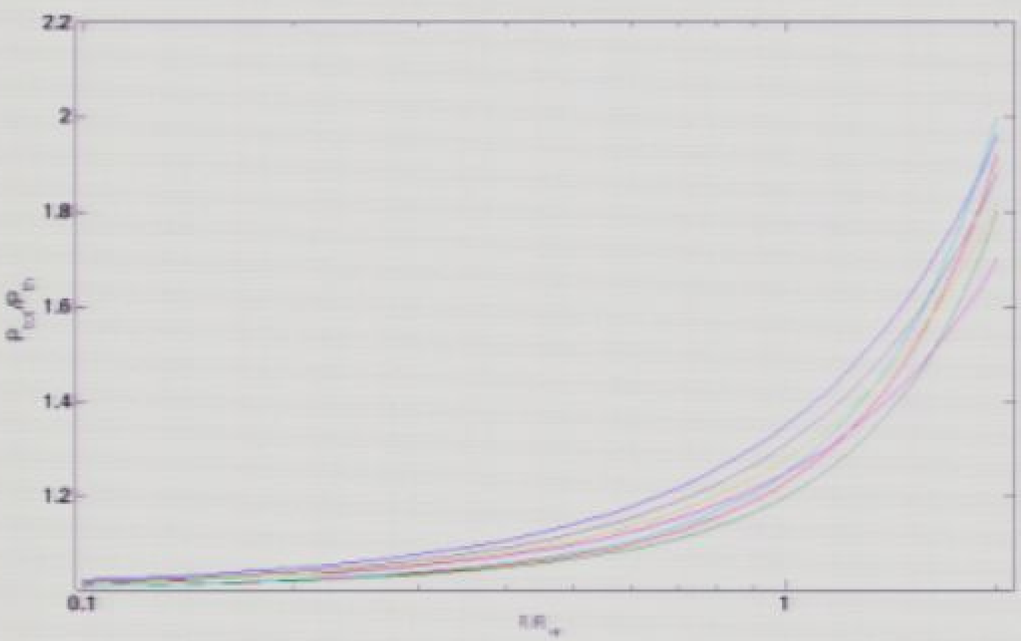

Model 1 non-thermal component

NON THERMAL PRESSURE CONTRIBUTION -

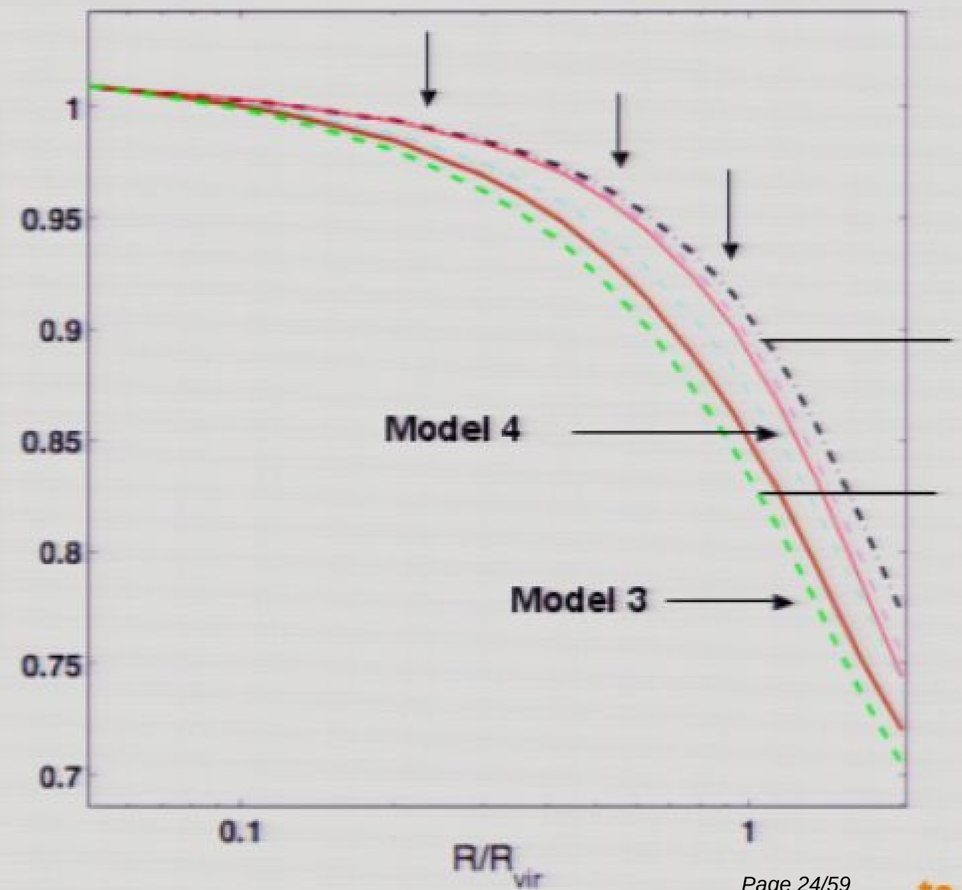
Xray observations do not give us any direct inputs into the non-thermal pressure support.

Simulations give a handle on non-thermal pressure. However, instead of adopting any particular simulation results, we only adopt the ***relative thermal/non-thermal pressure***. This quantity is more 'robust' across different simulations

Rasia, Pfrommer pvt communication




$$P_{NT}/P_T = \frac{\rho(x)\sigma_r^2(x)}{P(x)}$$



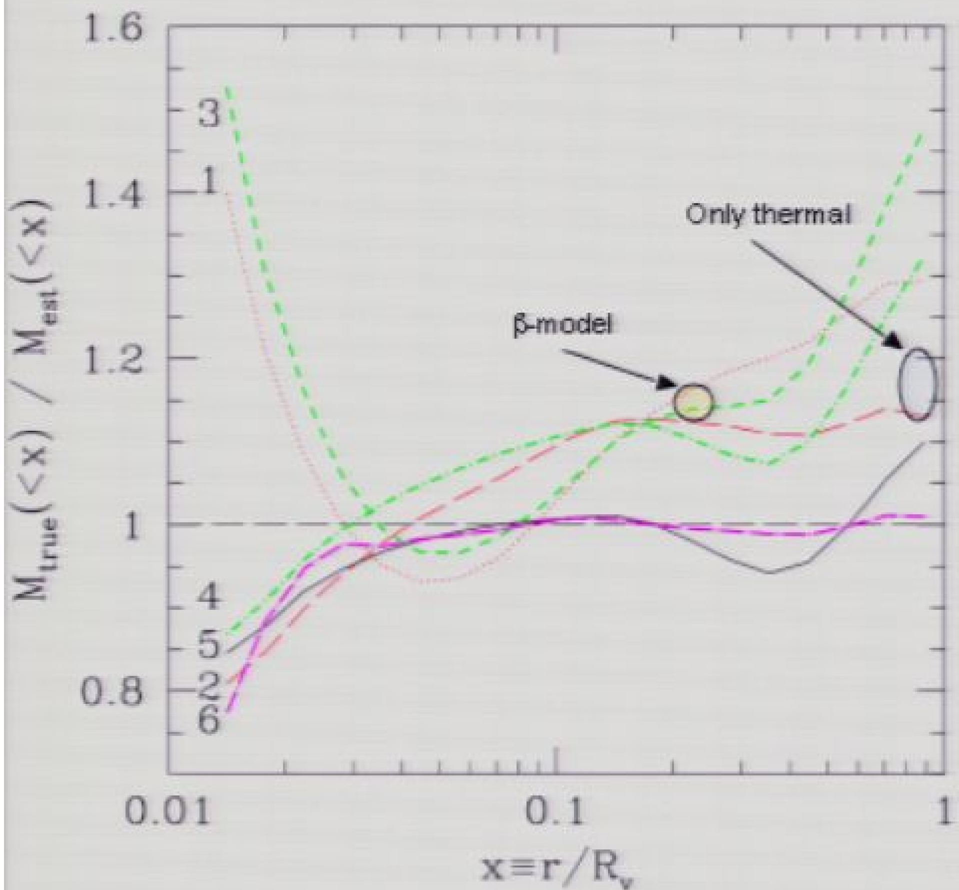



SZ Universe & the Future of Cluster Cosmology

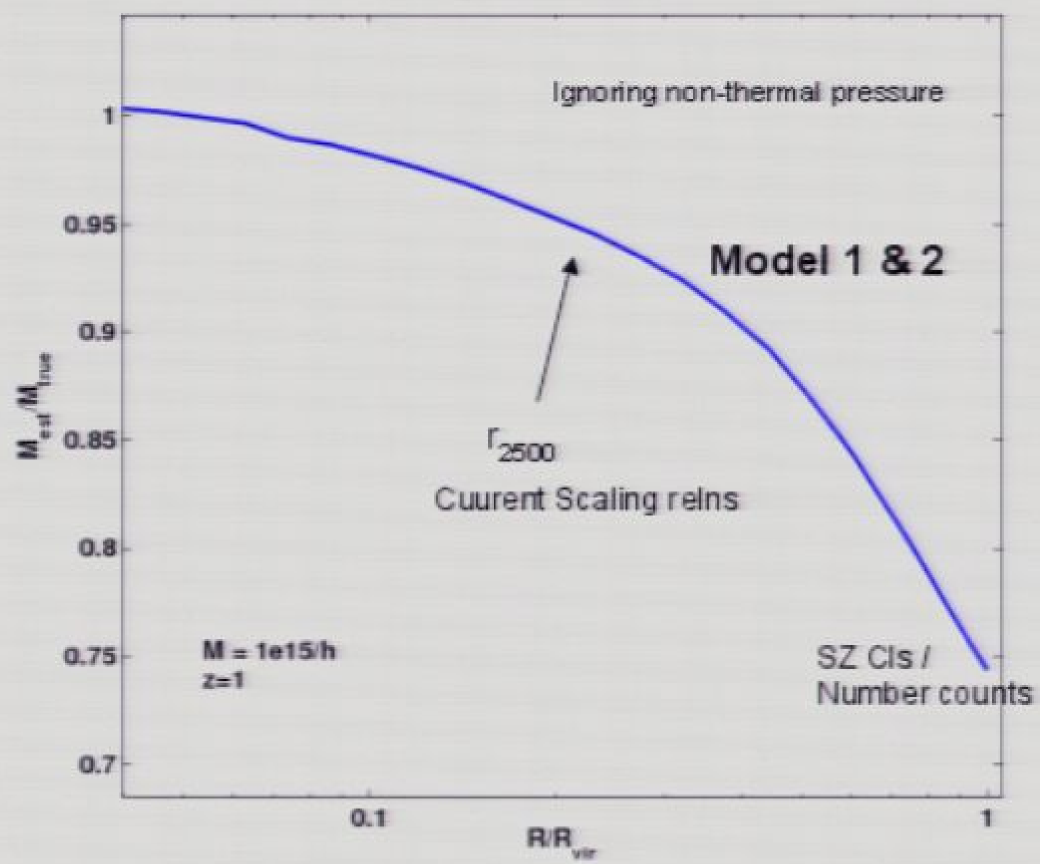
April 27-May 1, 2009

## ACTUAL CLUSTER MASS – VS – RECOVERED MASS -

**Simple hydrostatic eqlm or ignoring non-thermal pressure, assumption of isothermality as well as commonly used beta model biases recovered cluster mass.**




Simulations (Rasia et al 2004)




Model 1 non-thermal component



SZ Universe & the Future of Cluster Cosmology

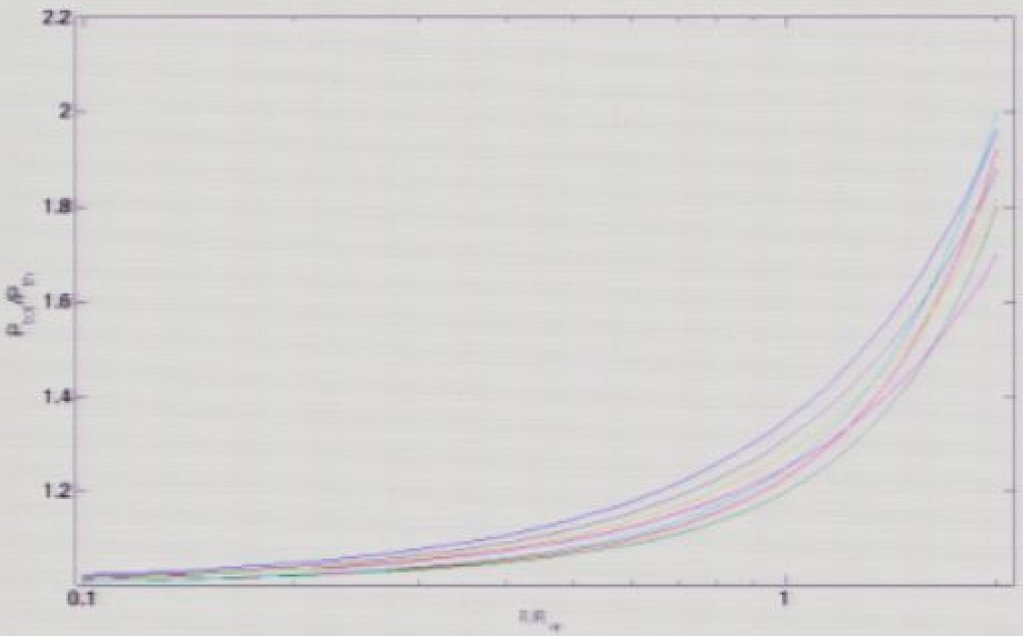
Perimeter Institute
April 27-May 1, 2009

# NON THERMAL PRESSURE CONTRIBUTION -

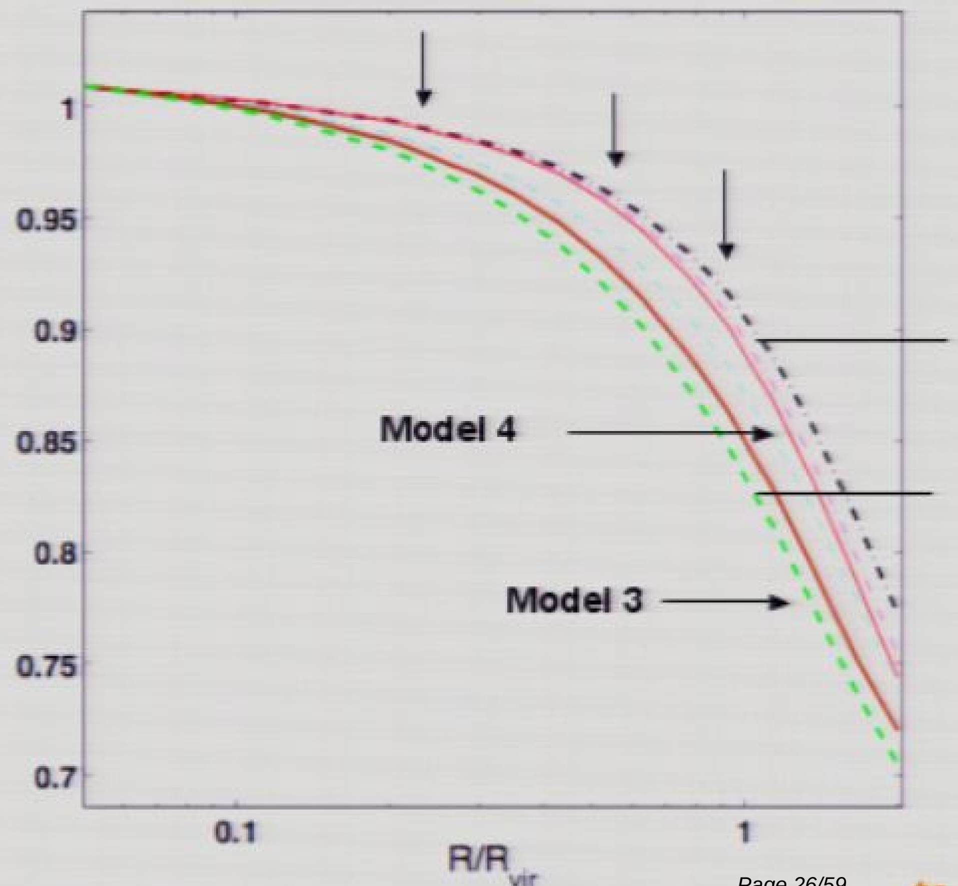
Xray observations do not give us any direct inputs into the non-thermal pressure support.

Simulations give a handle on non-thermal pressure. However, instead of adopting any particular simulation results, we only adopt the ***relative thermal/non-thermal pressure***. This quantity is more 'robust' across different simulations

Rasia, Pfrommer pvt communication




$$P_{NT}/P_T = \frac{\rho(x)\sigma_r^2(x)}{P(x)}$$

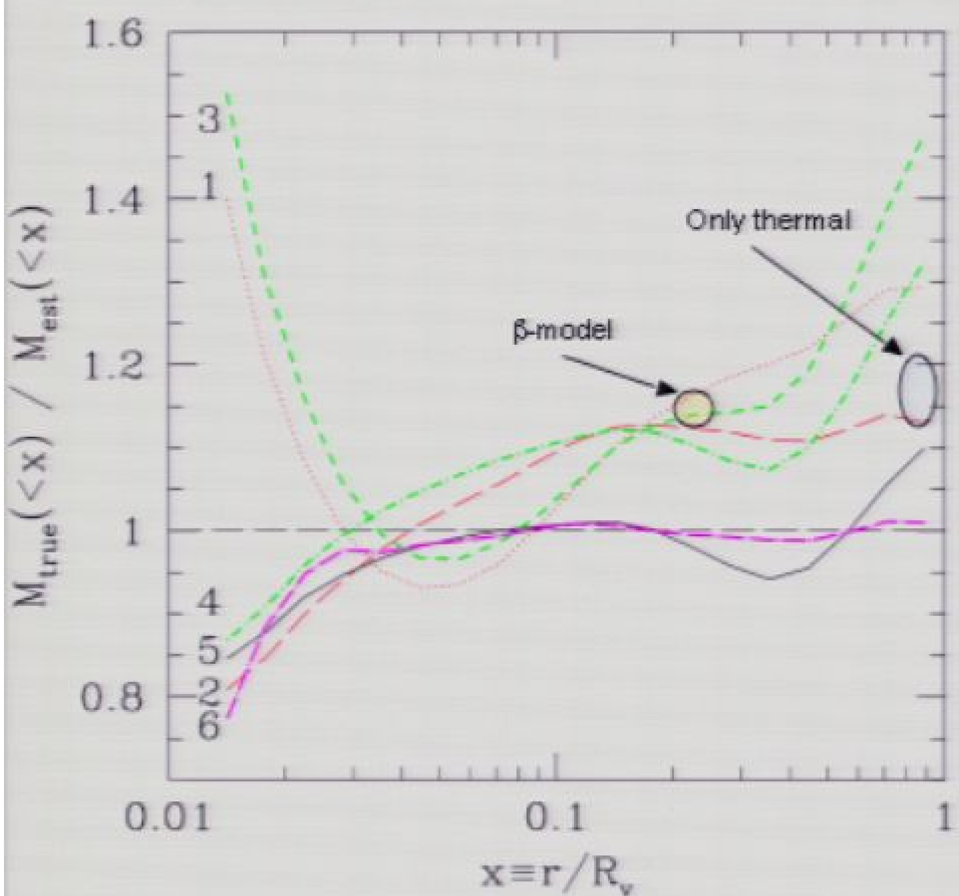




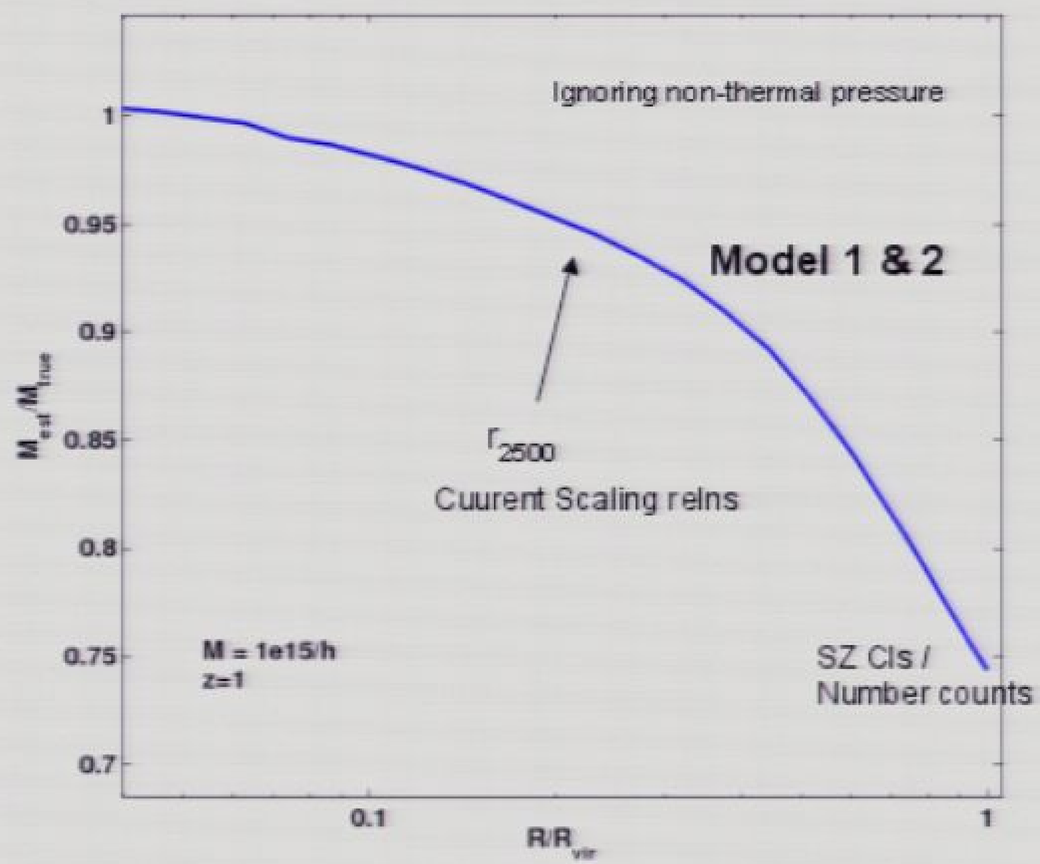

SZ Universe & the Future of Cluster Cosmology
te
April 27-May 1, 2009

# ACTUAL CLUSTER MASS – VS – RECOVERED MASS -

Simple hydrostatic eqlm or ignoring non-thermal pressure, assumption of isothermality as well as commonly used beta model biases recovered cluster mass.




Simulations (Rasia et al 2004)



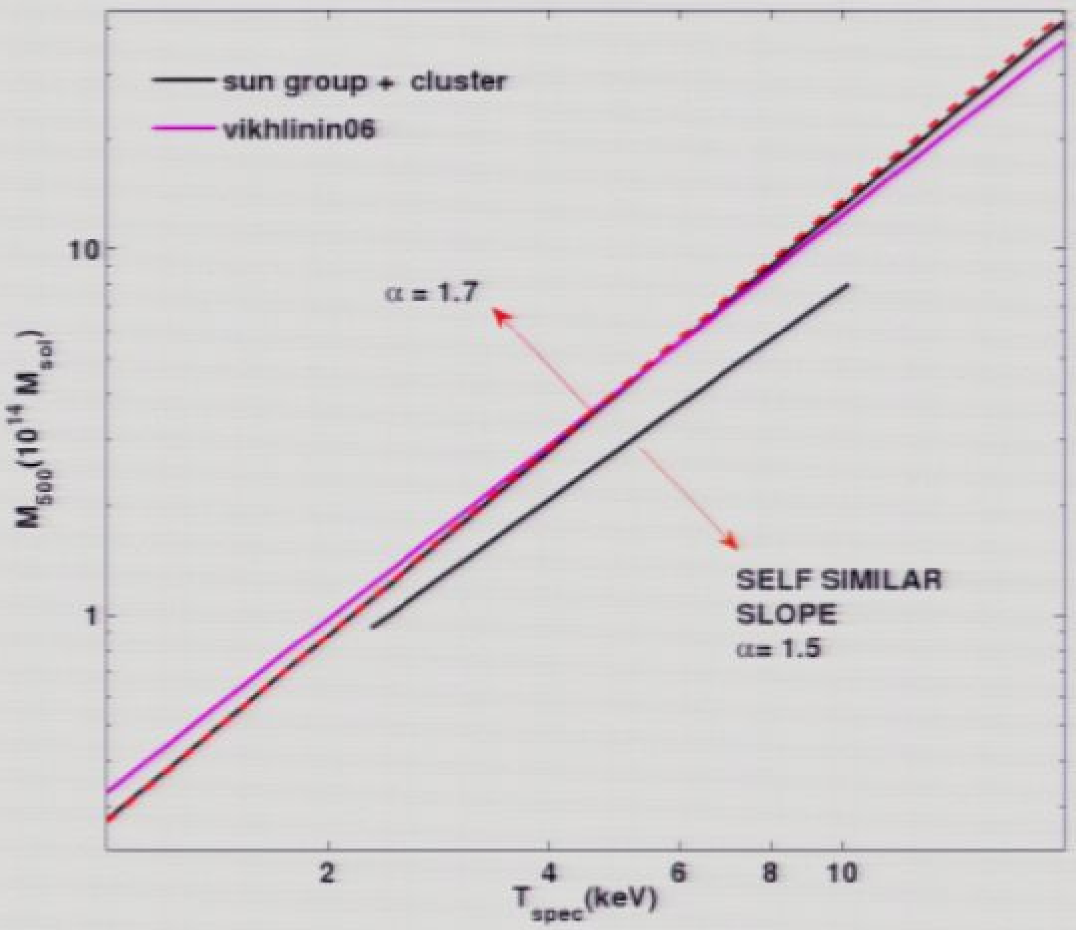

Model 1 non-thermal component

## NORMALIZING TEMPERATURE -

We hide our lack of knowledge of cluster gas physics by --> forcing the temperature to follow Xray observations 'exactly'.

OBSERVED M-T RELATIONS

$$M_\delta E(z) = A\left[\frac{T}{5keV}\right]^\alpha$$




We use M-T relation from Sun etal 2008 (more like a superset of previous data, like Vikhlinin)

$\alpha$ = 1.68 +/- 04 A = (2.85 +/- 0.18) $h^{-1}$e14 $M_0$

NORMALIZING GAS DENSITY -

Cooling/heating influences gas fraction as a function of radius.
However, at sufficiently large scale (virial radius and beyond), the integrated gas mass fraction attains Universal value.

$$M_{gas}\,(r > R_{vir}) \;=\; O(1)\;\Omega_b/\Omega_m\;\; M_{halo}\,(r > R_{vir})$$

Different cases:

Model 1 - Universal at $R_{vir}$; $P_{tot}/P_{thermal}$ from Rasia etal (2004).
Model 2 - 0.9 * Universal and $R_{vir}$; $P_{tot}/P_{thermal}$ from Rasia etal (2004).

Model 3 - Universal at $2R_{200}$; $P_{tot}/P_{thermal}$ for highest non-therm press
Model 4 - Universal at $2R_{200}$; $P_{tot}/P_{thermal}$ for intermediate non-therm press

Model 5 - Universal at $2R_{200}$; only thermal pressure
Model 6 - Universal at $R_{vir}$; only thermal pressure

Temperature influences density through dynamical equation. Once mass normalised, the density influences calculation of average temperature, needed for normalization.

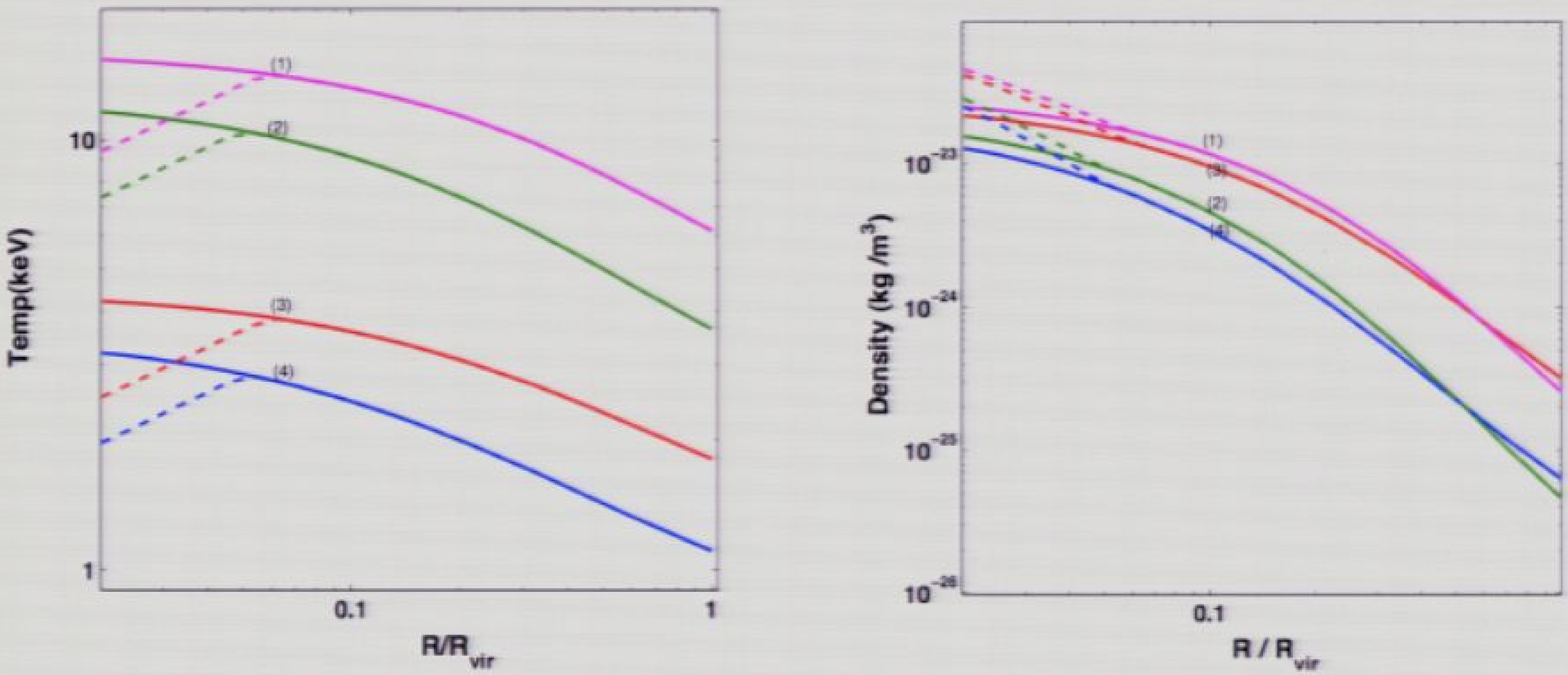
$$T_{sl} = \frac{\int n^2 T^{.75}/T^{1/2} dV}{\int n^2 T^{.75}/T^{3/2} dV}$$

Thus the set of equations need to be solved iteratively, for each model.

Temperature influences density through dynamical equation. Once mass normalised, the density influences calculation of average temperature, needed for normalization.

$$T_{sl} = \frac{\int n^2 T^{.75} / T^{1/2} dV}{\int n^2 T^{.75} / T^{3/2} dV}$$

Thus the set of equations need to be solved iteratively, for each model.

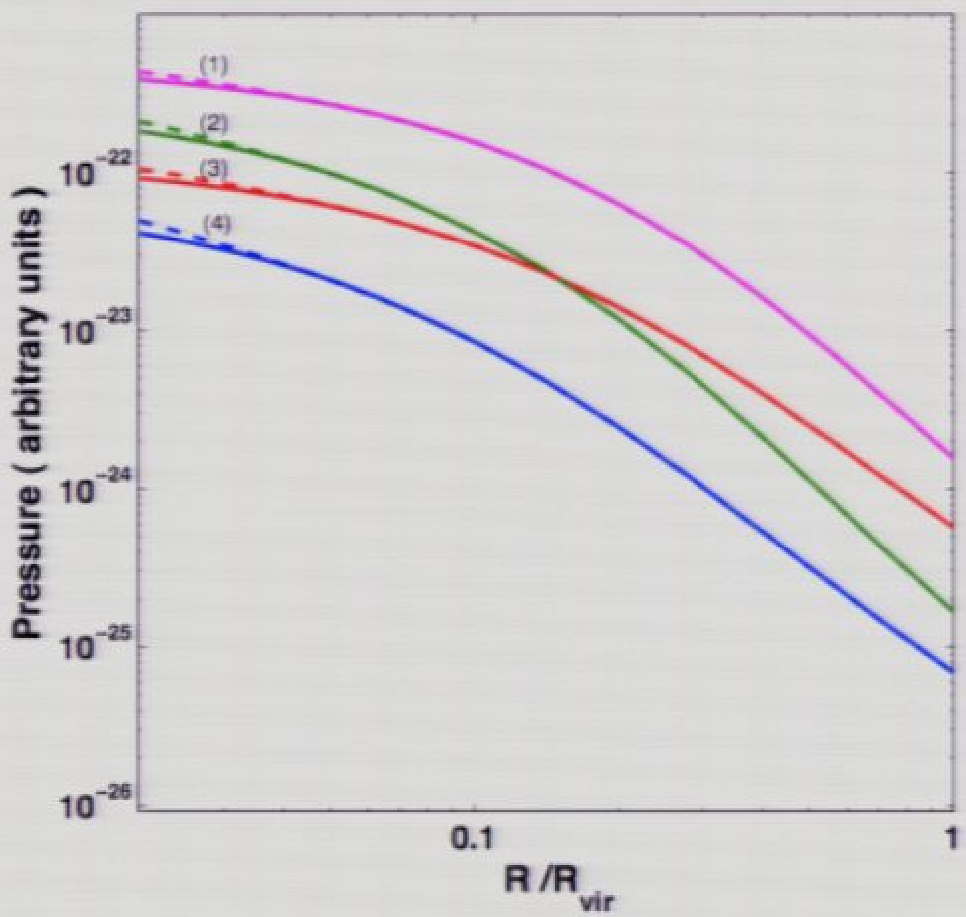



Cases: M ~ $10^{14}$/h $M_0$ , $10^{15}$/h $M_0$ , **z= 0.01, 1**

Temperature influences density through dynamical equation. Once mass normalised, the density influences calculation of average temperature, needed for normalization.

$$T_{sl} = \frac{\int n^2 T^{.75}/T^{1/2} dV}{\int n^2 T^{.75}/T^{3/2} dV}$$

Thus the set of equations need to be solved iteratively, for each model.




Cases: $M \sim 10^{14}/h\ M_0$ , $10^{15}/h\ M_0$ , **z= 0.01, 1**

Recap -

Till now, our entire modelling of cluster gas density and temperature is based upon

1. Recent high resolution xray observations for temp
2. universality of baryon fraction at largest radii
3. non-thermal component from simulations.

With these, we construct SZ properties of clusters, i.e

1a) SZ cluster scaling relations (and compare with recent Bonamente etal 2008 obs)

$$\log Y = A + B \log X$$

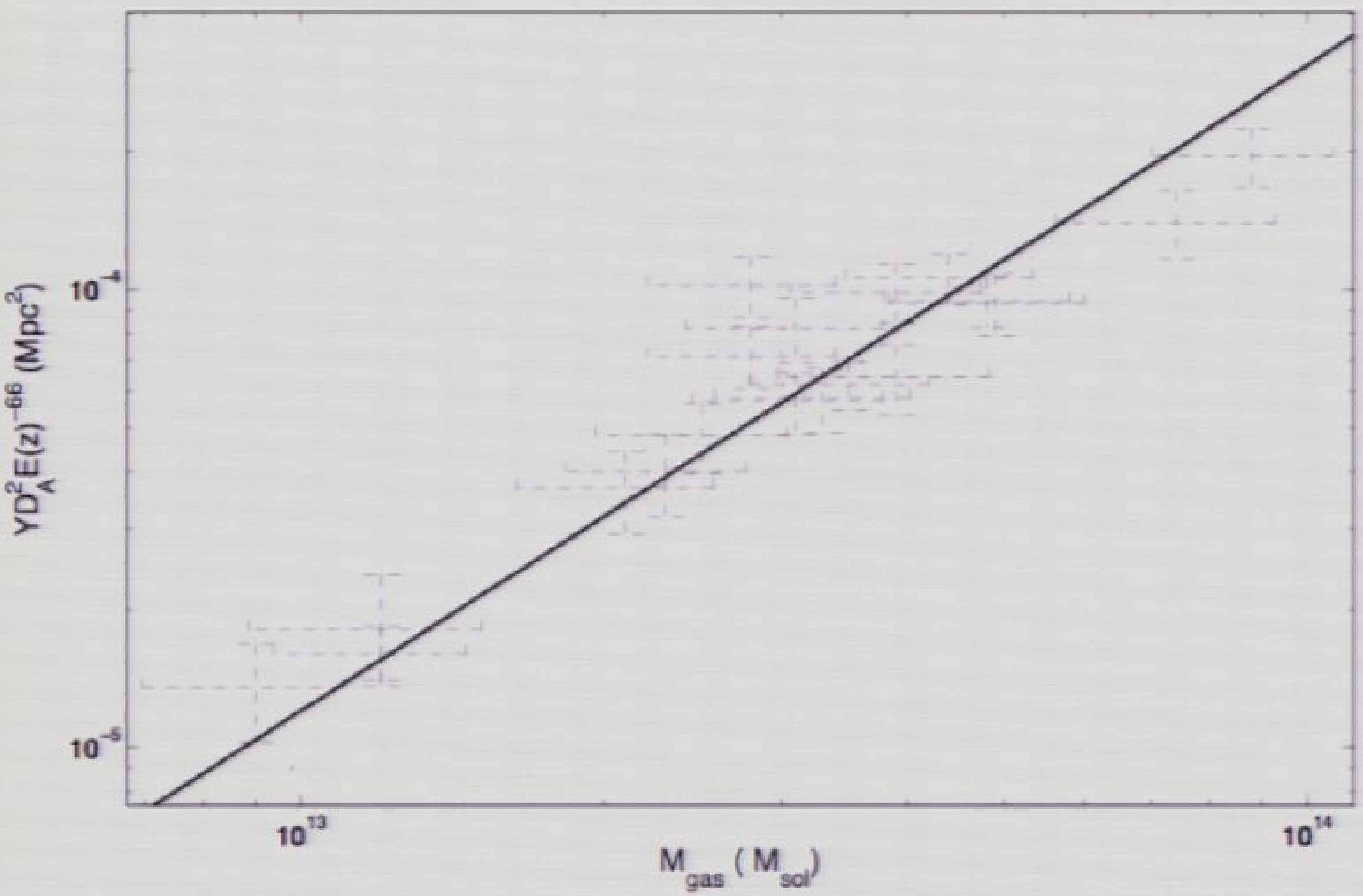
Y = SZ Flux

X = Gas Mass, Total Mass, Temperature

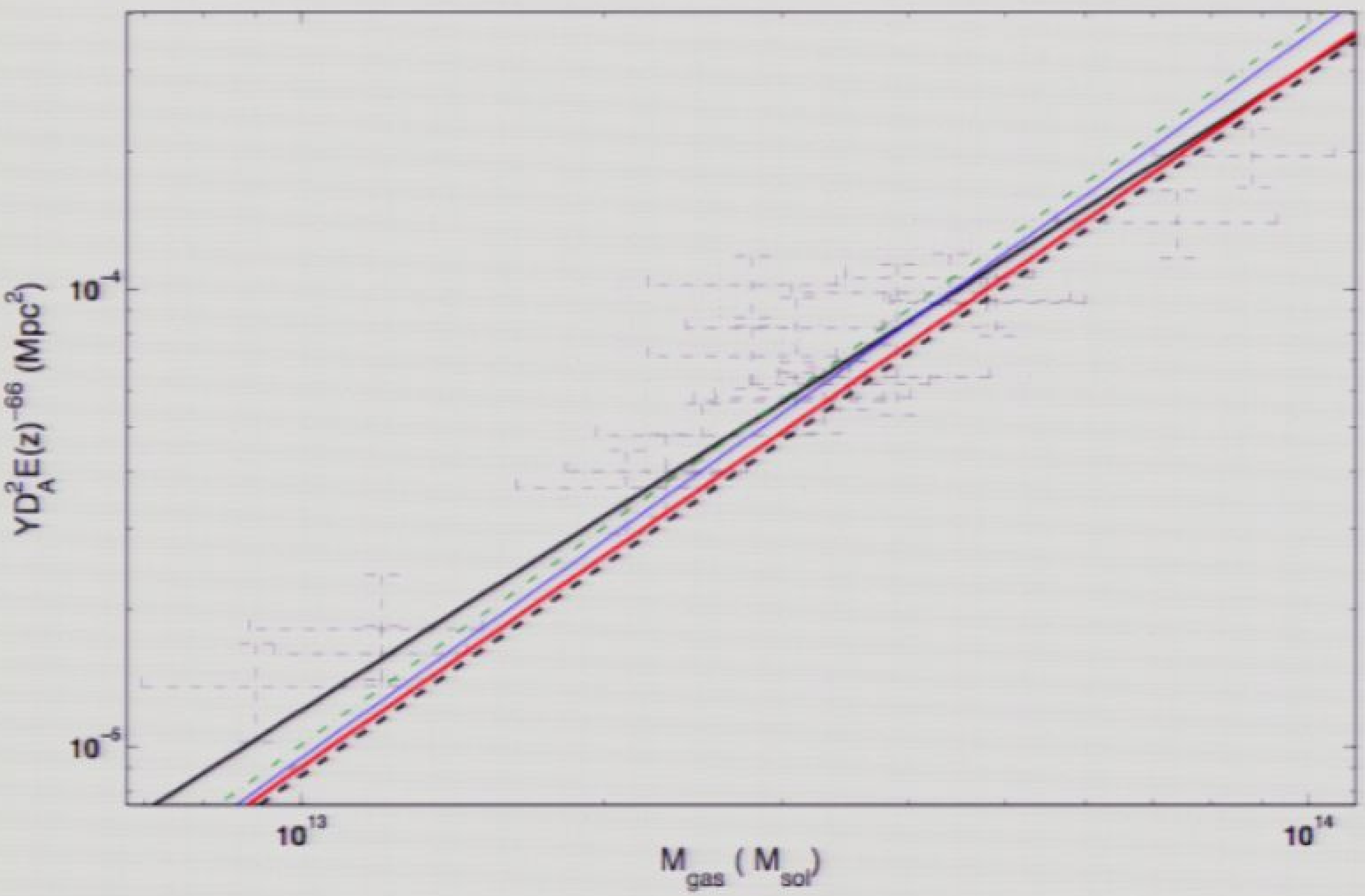
1b) SZ $M_{200}$ scaling reln needed for dndz ( more later by Christoph)

2) SZ power spectrum and compare with CBI+ observations (more later by Jonathan)

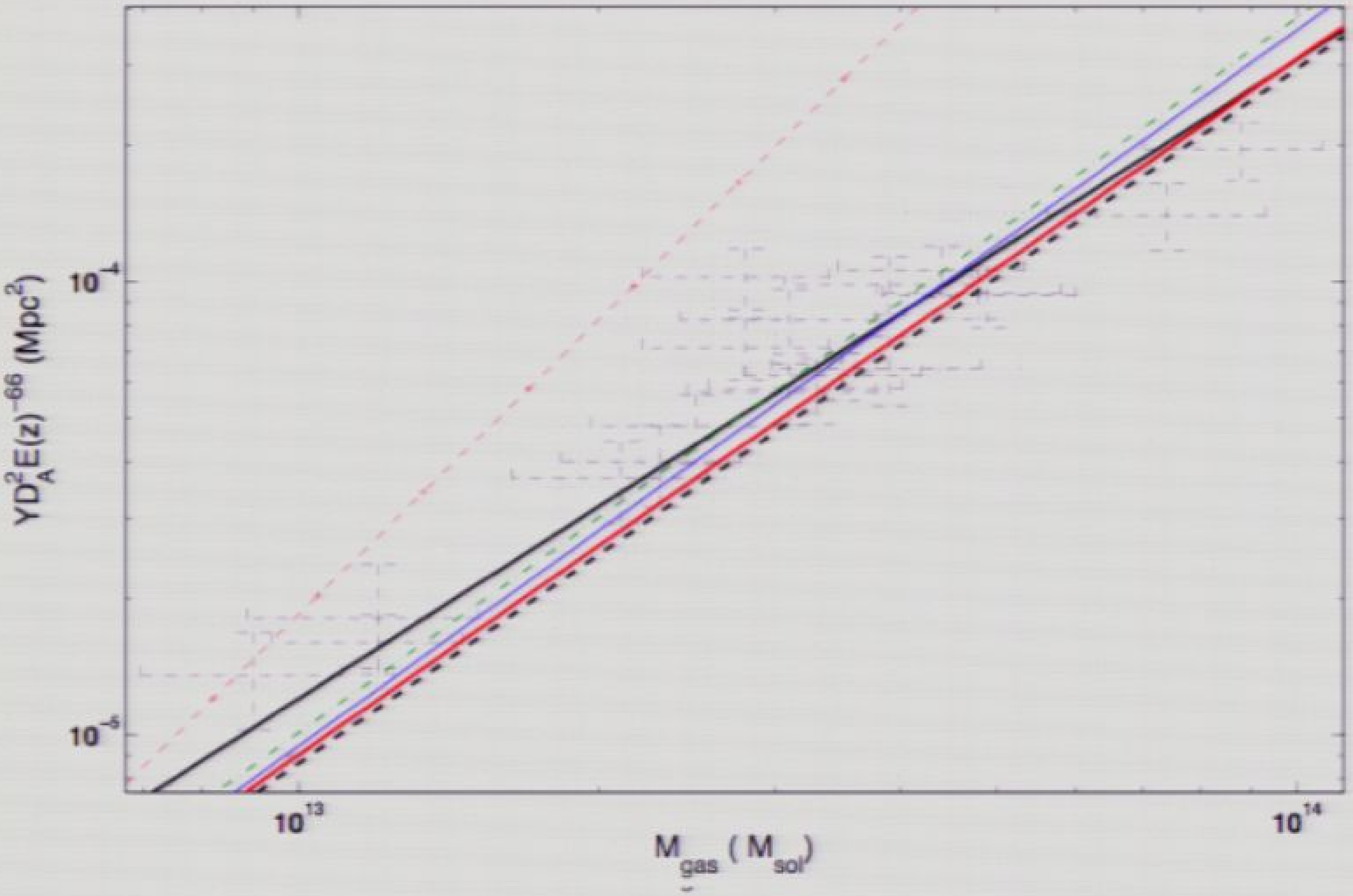
## SZFlux - $M_{gas}$



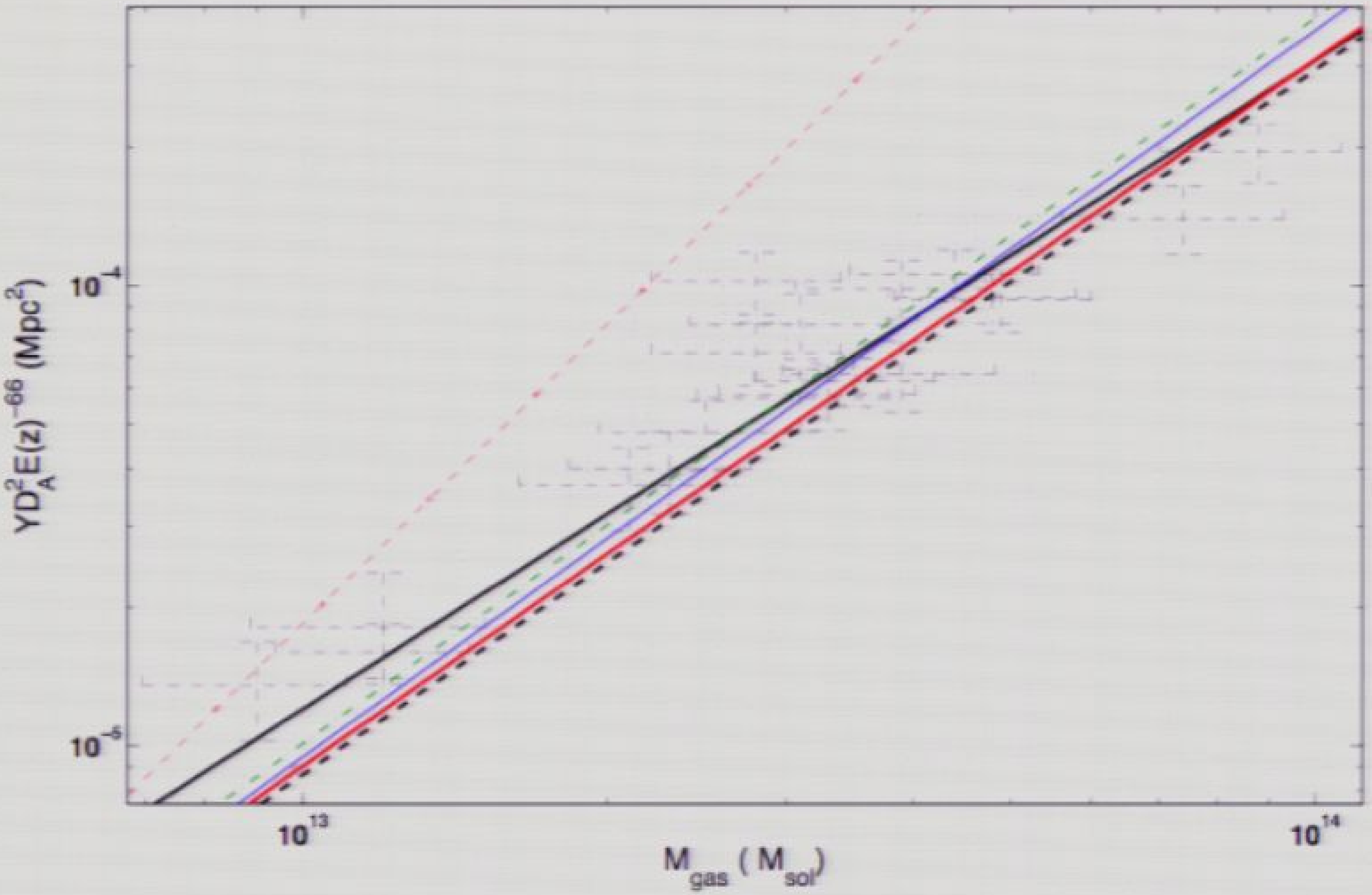

**SZFlux - $M_{gas}$**




**SZFlux - $M_{gas}$**

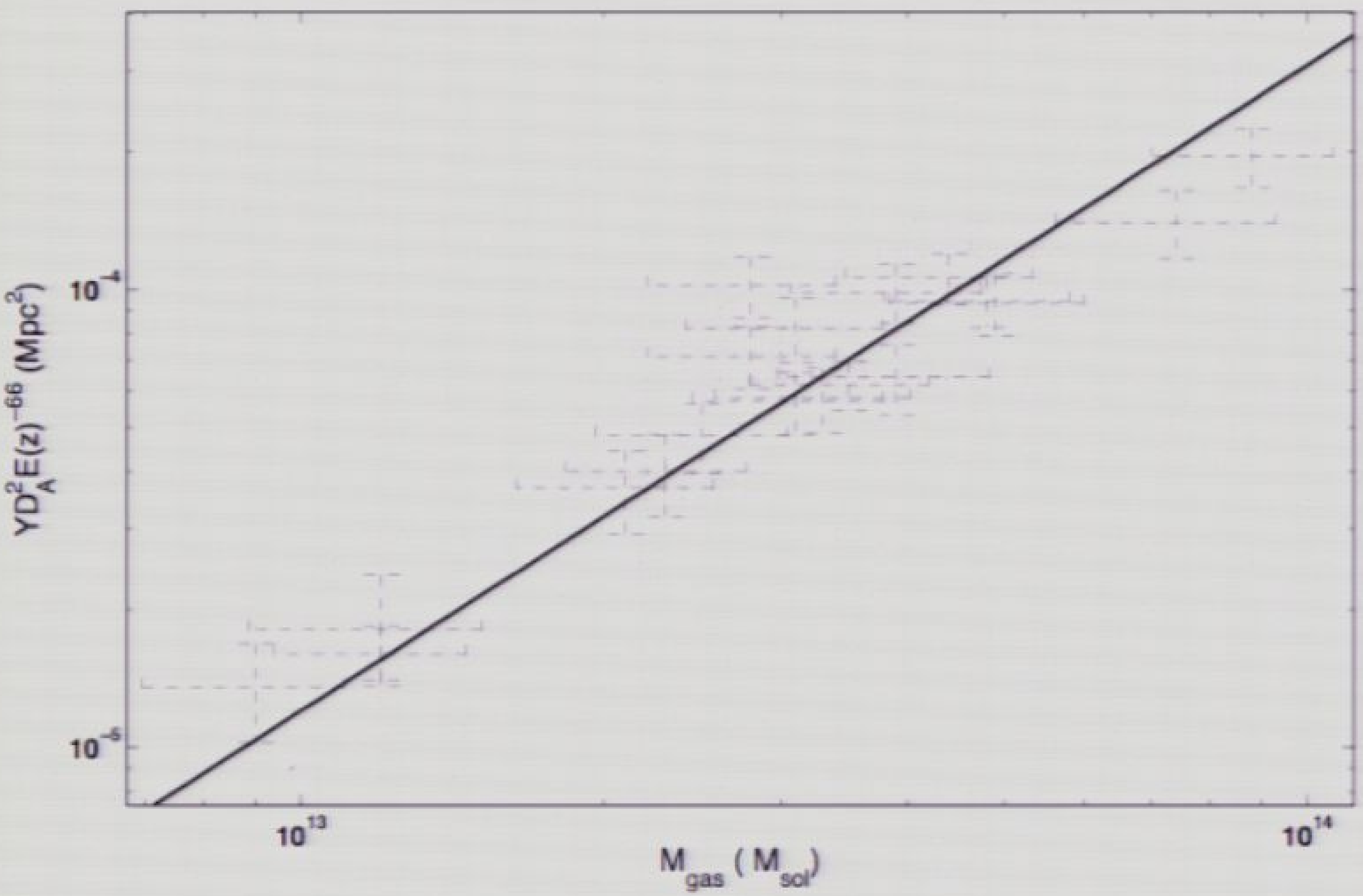



**SZFlux - $M_{gas}$**

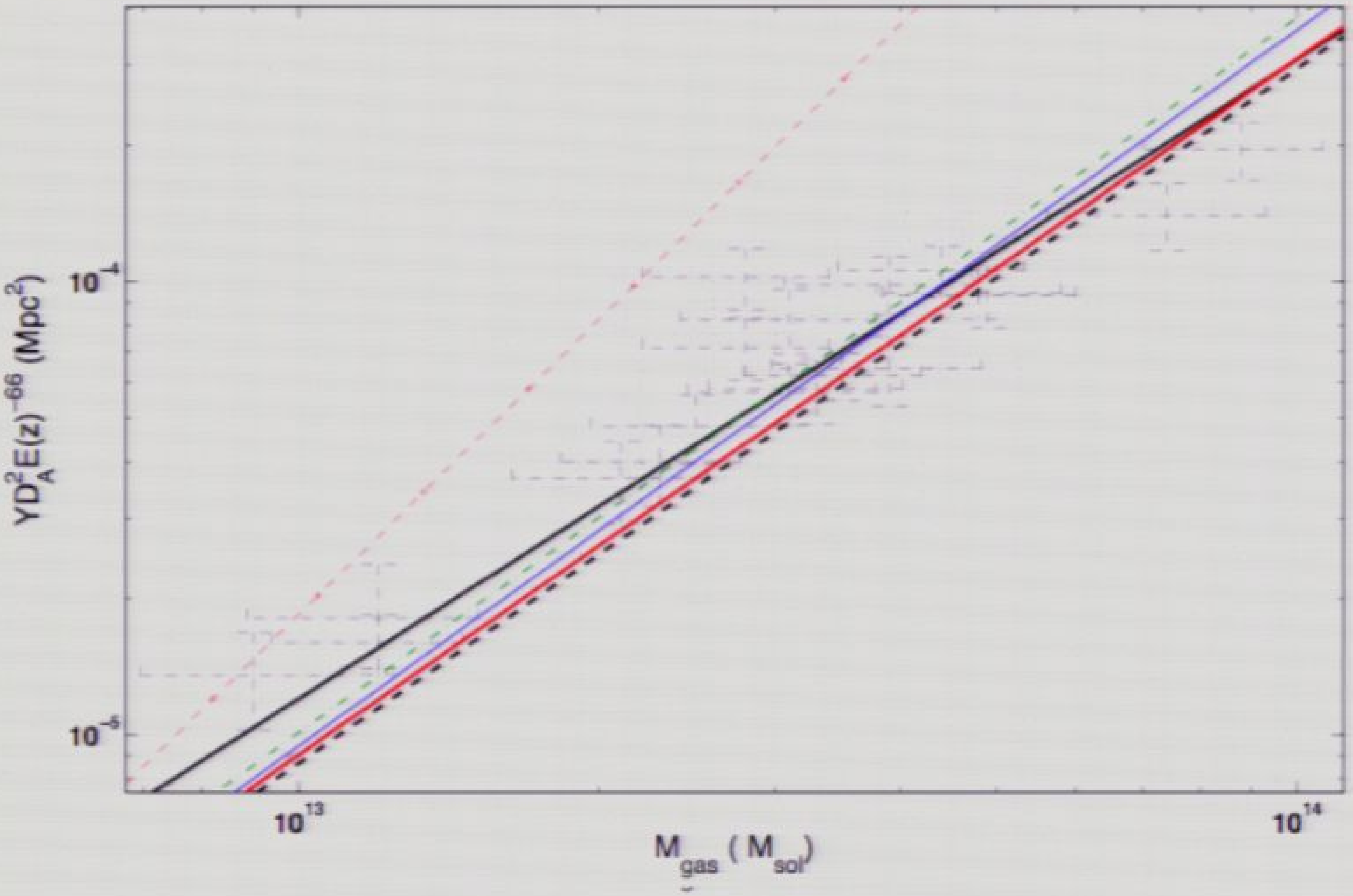



**SZFlux - $M_{gas}$**

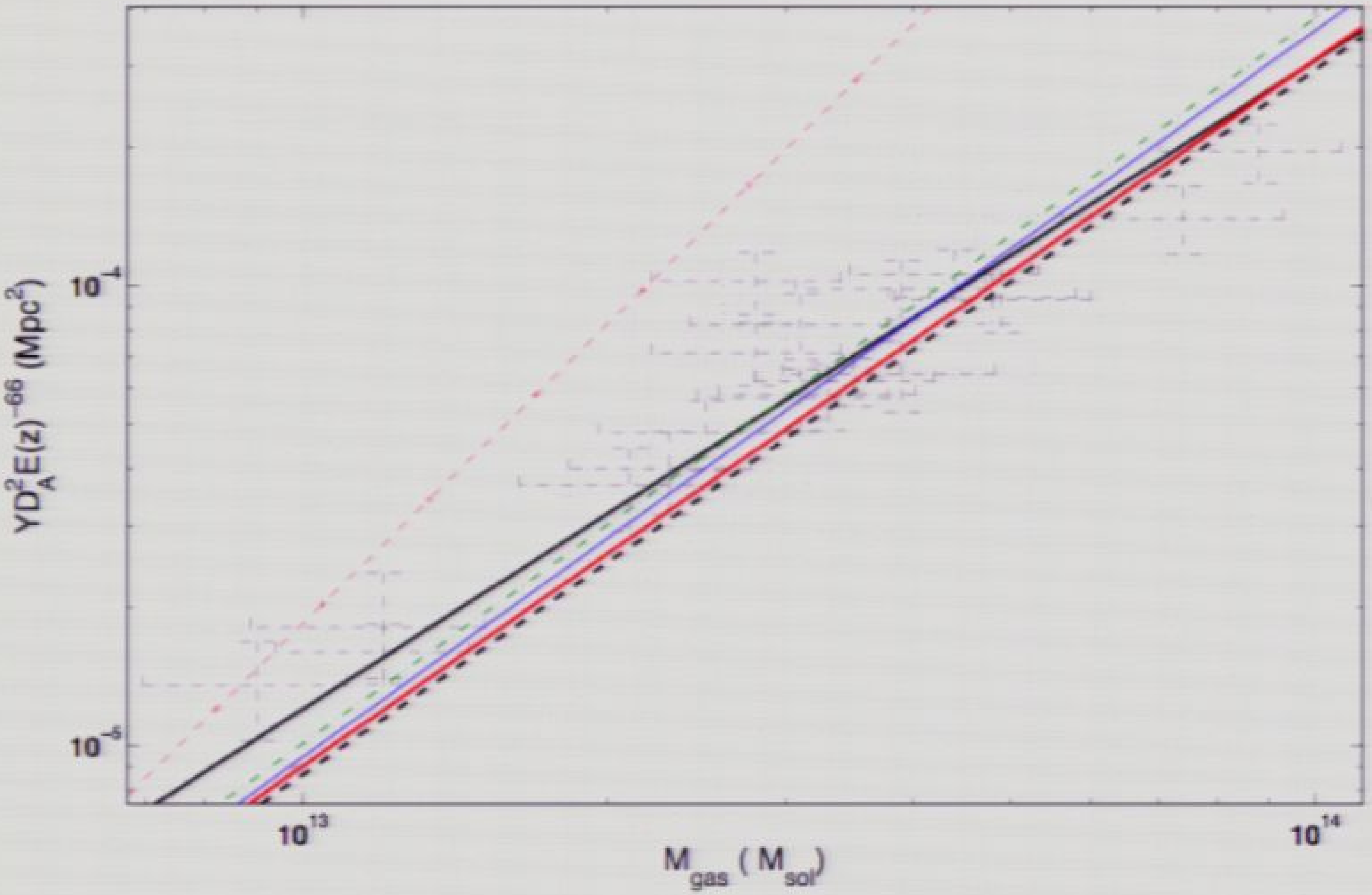
| | A | B | $\chi^2$ | A | B | $\chi^2$ |
|---|---|---|---|---|---|---|
| Bonamente | | | .9252 | | | .6713 |
| model 1 | -25.55 | 1.5794 | 1.0343 | | | .5754 |
| model 2 | -25.51 | 1.5781 | .9274 | | | .4987 |
| model 3 | -25.0082 | 1.5357 | 1.3435 | | | .7916 |
| model 4 | -24.98 | 1.5321 | 1.5741 | | | .9812 |
| thermal 1 | -25.1567 | 1.5405 | 2.53 | | | 1.48 |
| thermal 2 | -25.577 | 1.5725 | 2.28 | | | 1.31 |
| K S | -32.0122 | 2.1758 | 10.50 | | | 5.2296 |




## SZFlux - $M_{gas}$



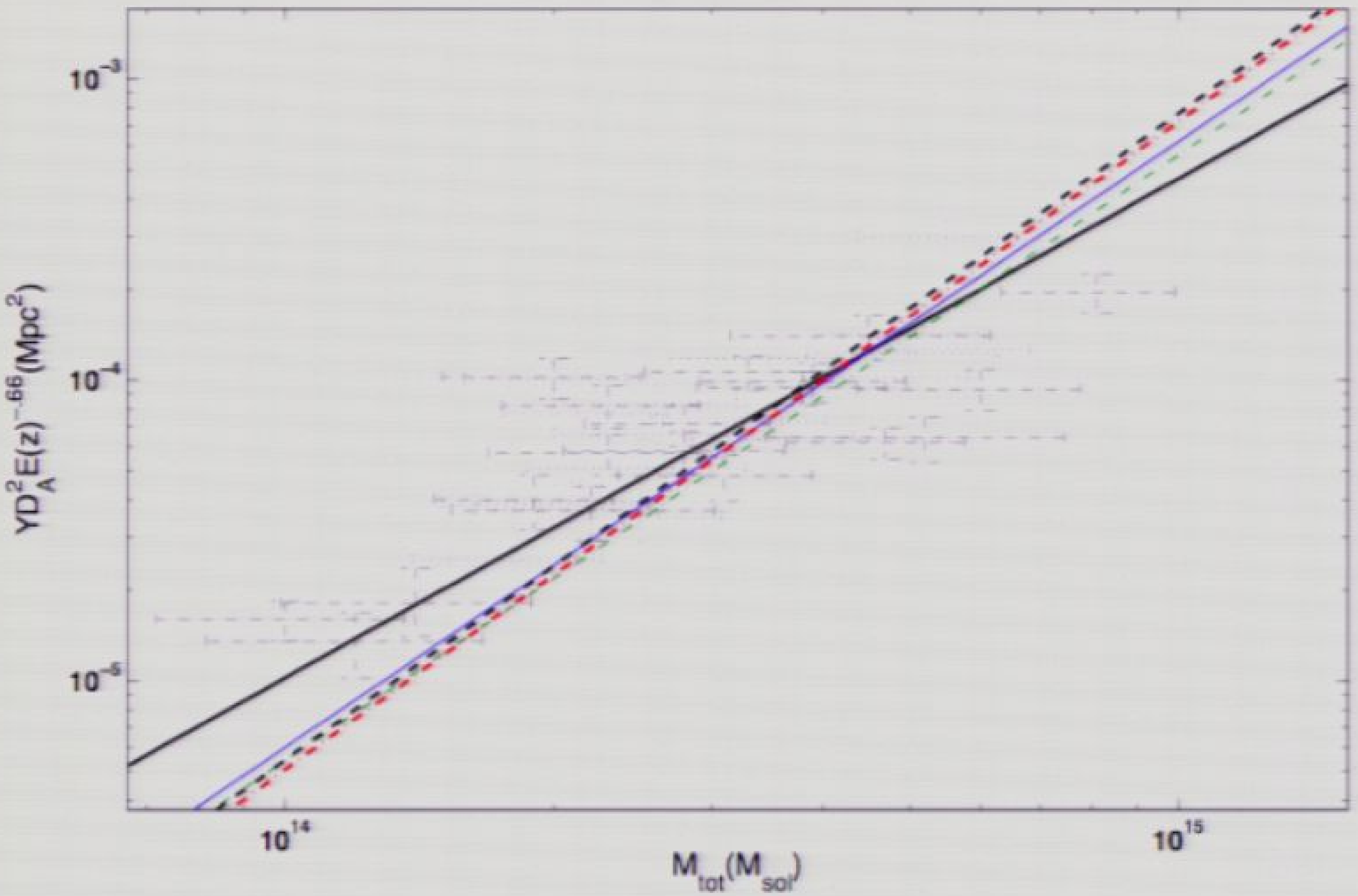

**SZFlux - $M_{gas}$**



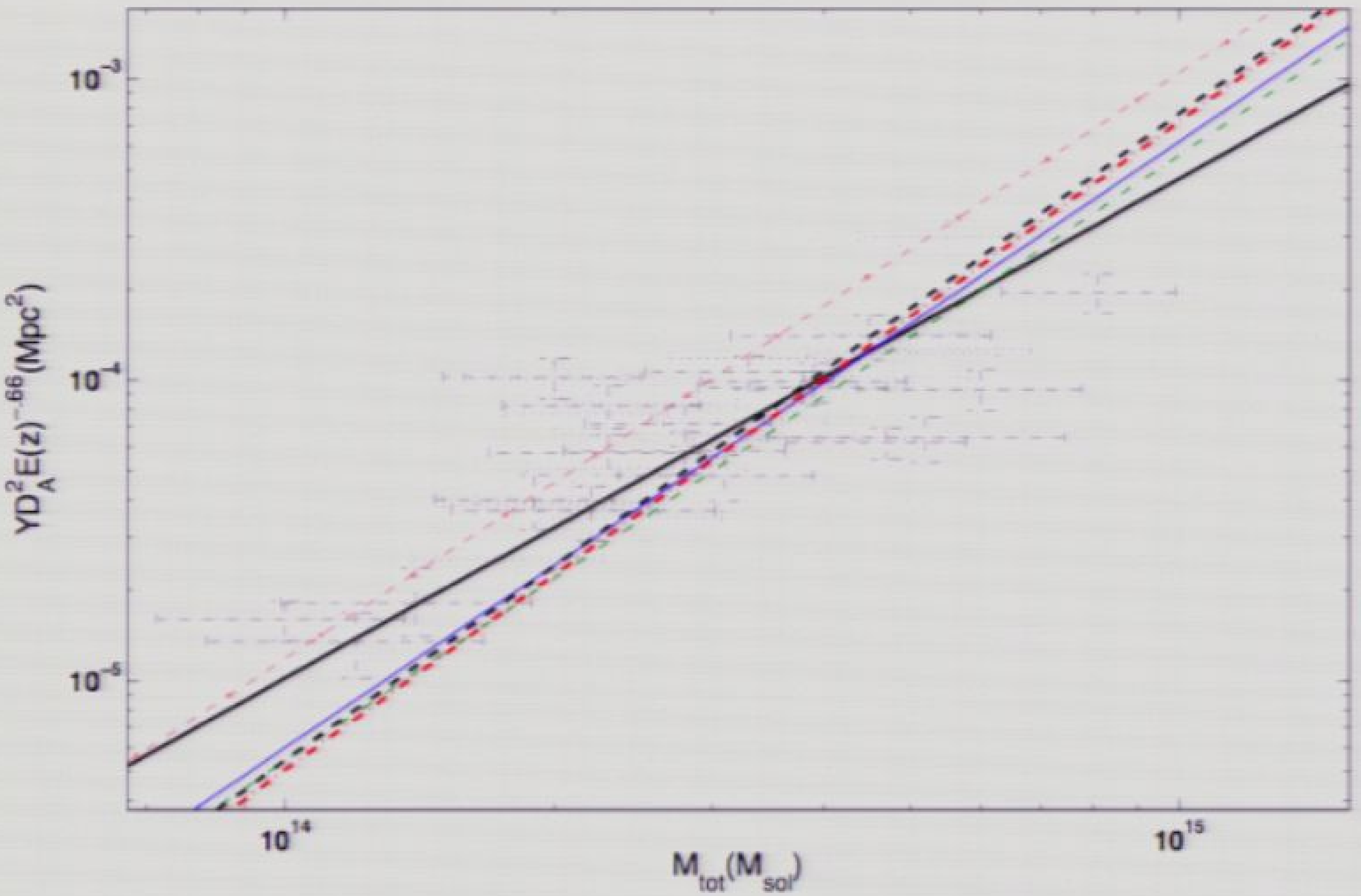

**SZFlux - $M_{gas}$**

| | A | B | $\chi^2$ | A | B | $\chi^2$ |
|---|---|---|---|---|---|---|
| Bonamente | | | .9252 | | | .6713 |
| model 1 | -25.55 | 1.5794 | 1.0343 | | | .5754 |
| model 2 | -25.51 | 1.5781 | .9274 | | | .4987 |
| model 3 | -25.0082 | 1.5357 | 1.3435 | | | .7916 |
| model 4 | -24.98 | 1.5321 | 1.5741 | | | .9812 |
| thermal 1 | -25.1567 | 1.5405 | 2.53 | | | 1.48 |
| thermal 2 | -25.577 | 1.5725 | 2.28 | | | 1.31 |
| K.S. | -32.0122 | 2.1758 | 10.50 | | | 5.2296 |

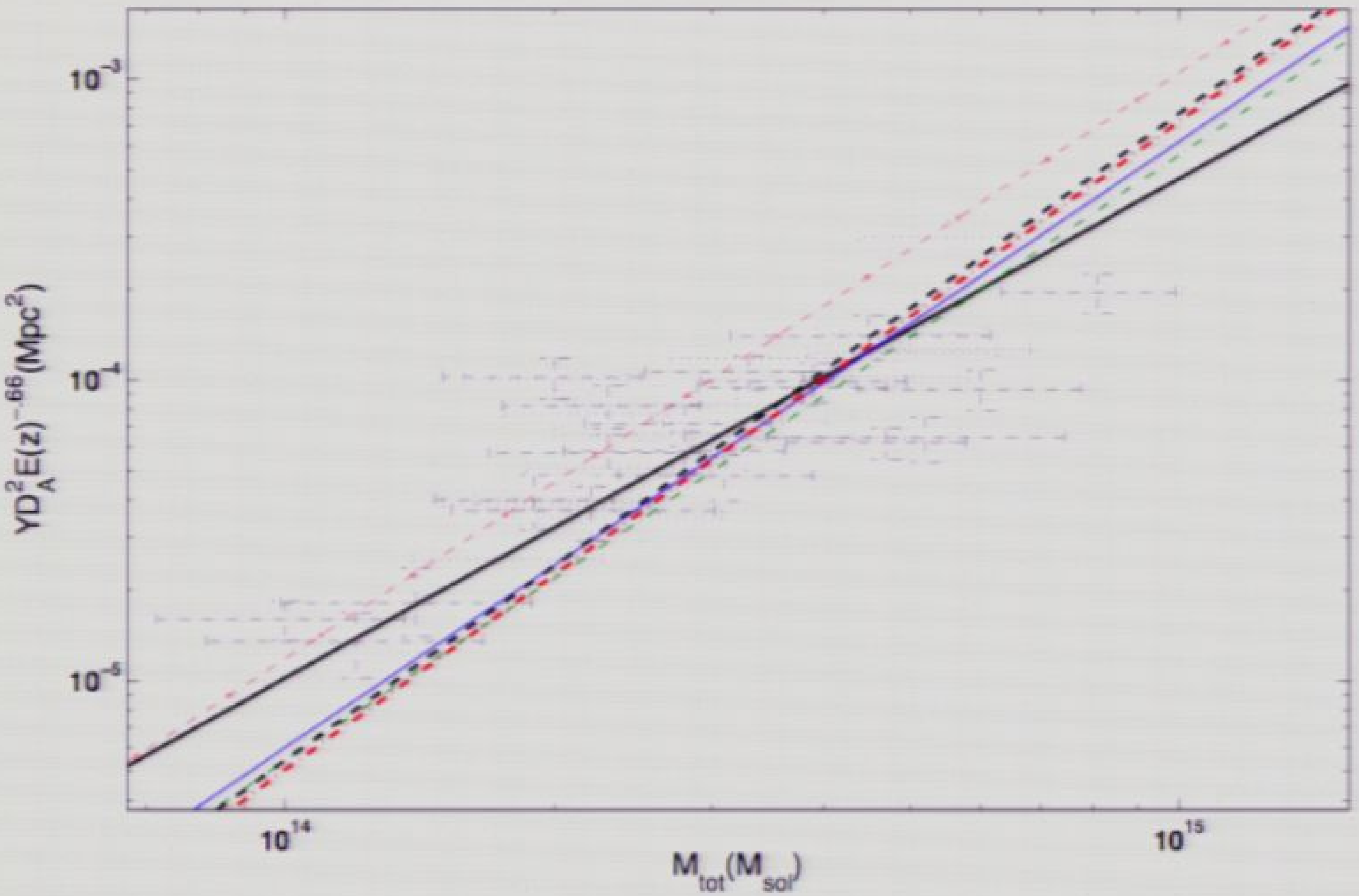
SZFlux - $M_{tot}$




## SZFlux - $M_{tot}$

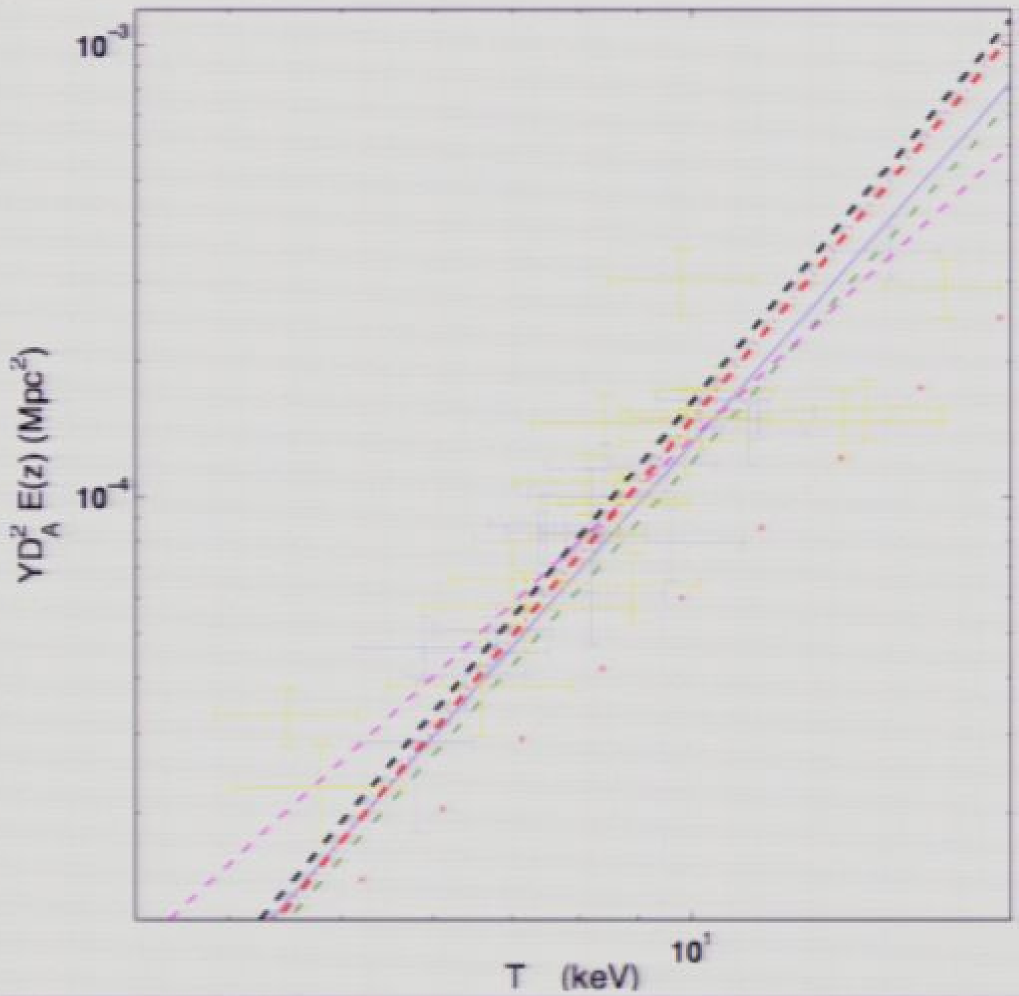



## SZFlux - $M_{tot}$




SZFlux - $M_{tot}$

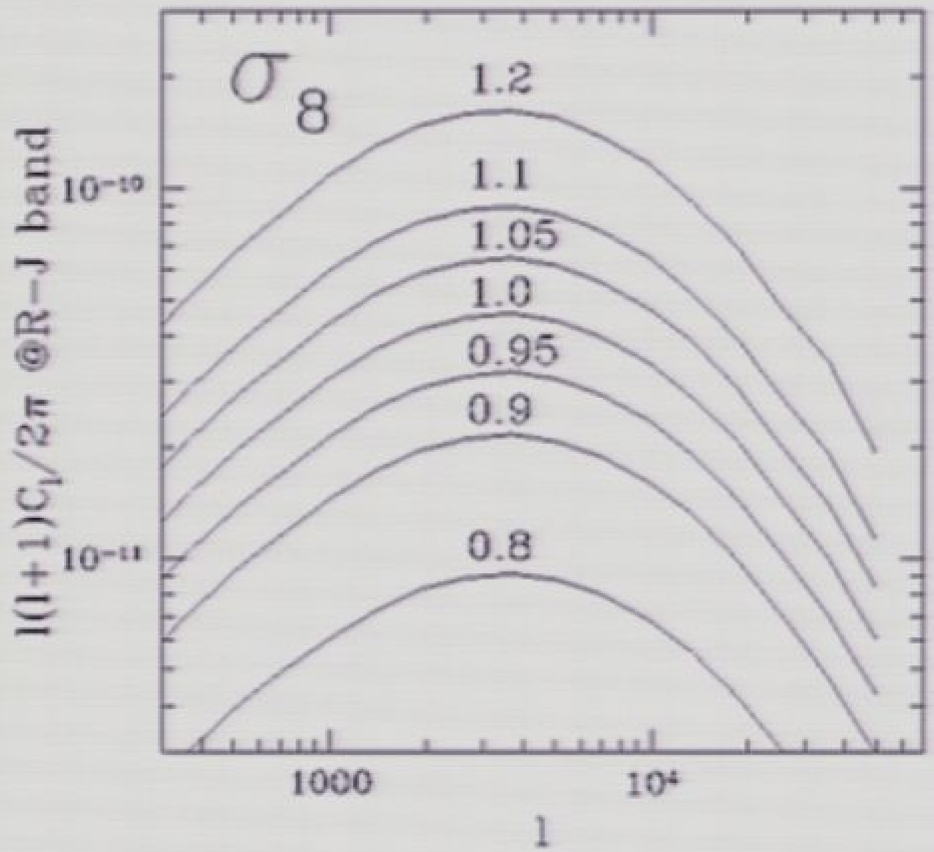
| | A | B | $\chi_1^2$ | A | B | $\chi_2^2$ |
|---|---|---|---|---|---|---|
| Bonamente | | | 1.5714 | | | .7214 |
| model 1 | -33.43 | 2.015 | 1.8299 | | | .8878 |
| model 2 | -33.45 | 2.013 | 2.0959 | | | 1.0584 |
| model 3 | -35.46 | 2.1546 | 1.8868 | | | .8945 |
| model 4 | -35.37 | 2.1504 | 1.7617 | | | .8255 |
| thermal 1 | -35.1914 | 2.1431 | 1.66 | | | .7303 |
| thermal 2 | -34.05 | 2.0626 | 1.64 | | | .74 |
| K-S | -32.2853 | 1.9549 | 2.5651 | | | 1.1946 |



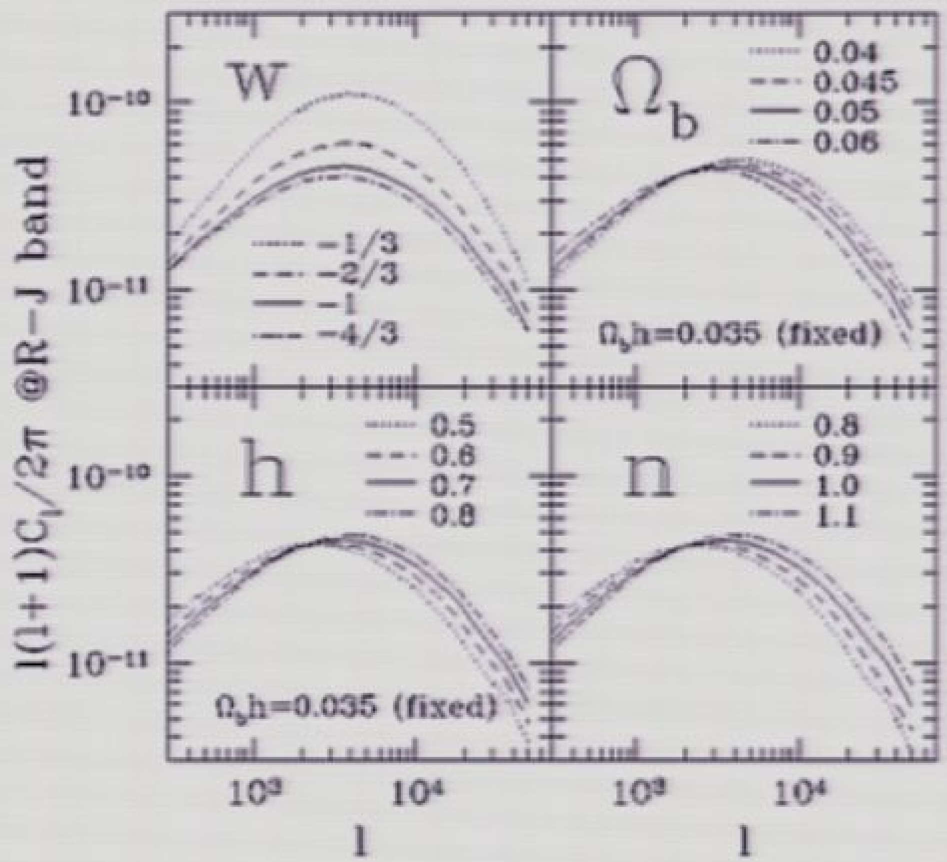

## SZFlux - Temp

| | A | B | $\chi_1^2$ | A | B | $\chi_2^2$ |
|---|---|---|---|---|---|---|
| Bonamente | | | .8362 | | | .2034 |
| model 1 | -6.7967 | 2.9158 | 1.0769 | | | .2969 |
| model 2 | -6.8358 | 2.9134 | 1.3164 | | | .4582 |
| model 3 | -6.9282 | 3.0997 | 1.0768 | | | .2903 |
| model 4 | -6.8790 | 3.0895 | 1.1217 | | | .3172 |
| thermal 1 | -6.7716 | 3.0696 | 1.68 | | | .64 |
| thermal 2 | -6.702 | 2.954 | 1.31 | | | .4420 |
| K-S | -6.47 | 2.28 | 7.47 | | | 2.7399 |

# On To SZ Power Spectrum -



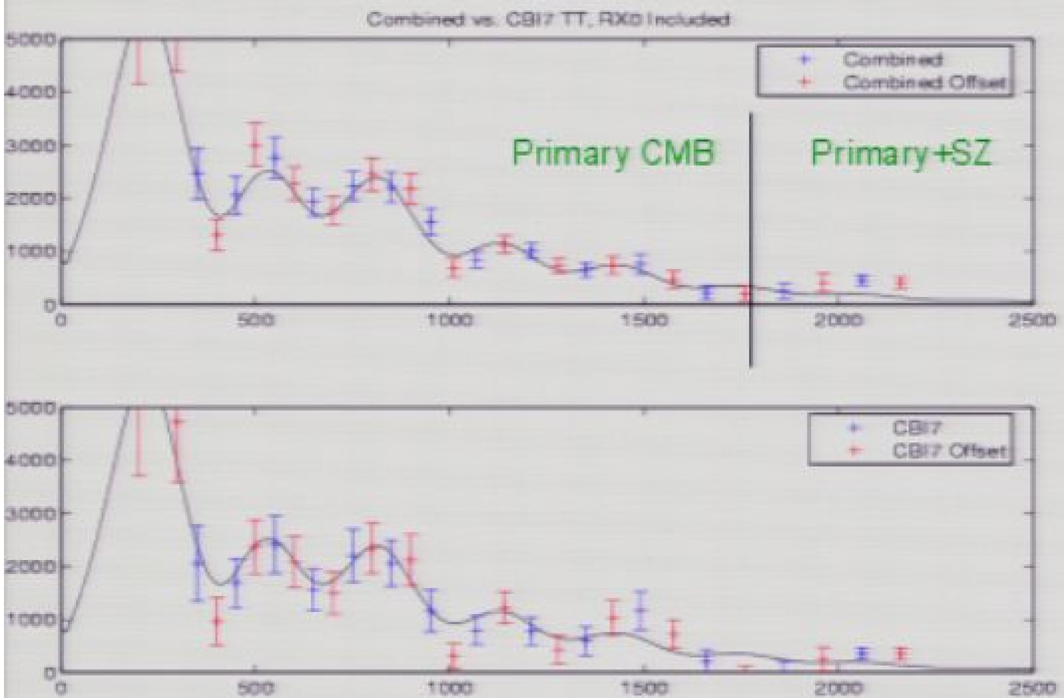

$C_l \sim \sigma_8^{6\text{-}7}$

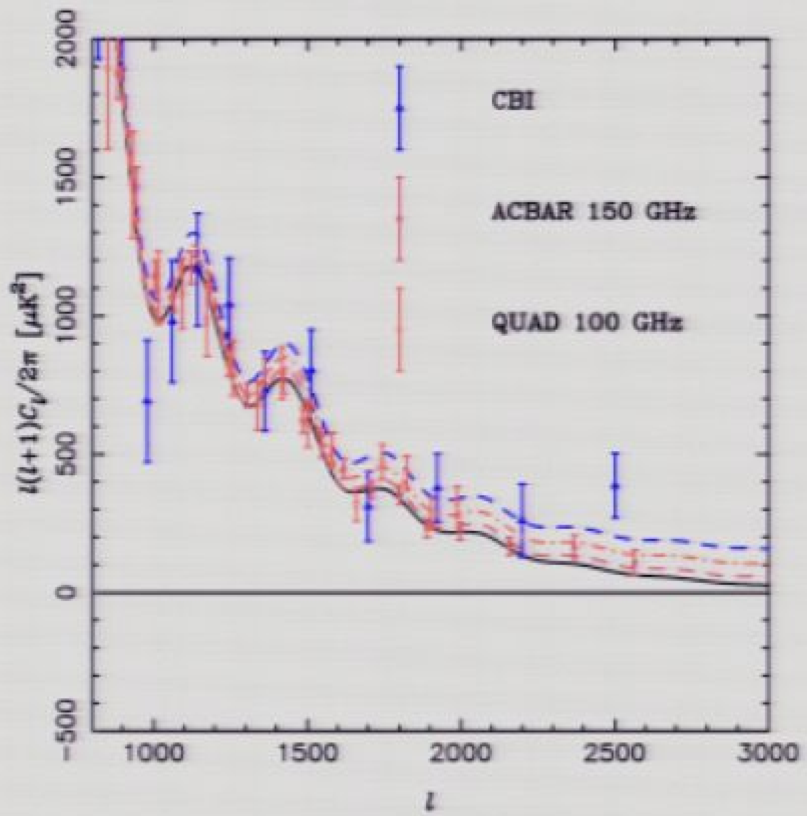



Effect of other parameters are subdued under the effect of $\sigma_8$.

Komatsu & Seljak 2002

# EXCESS OF CMB ANISOTROPY OBSERVED AT SMALL ANGULAR SCALES -



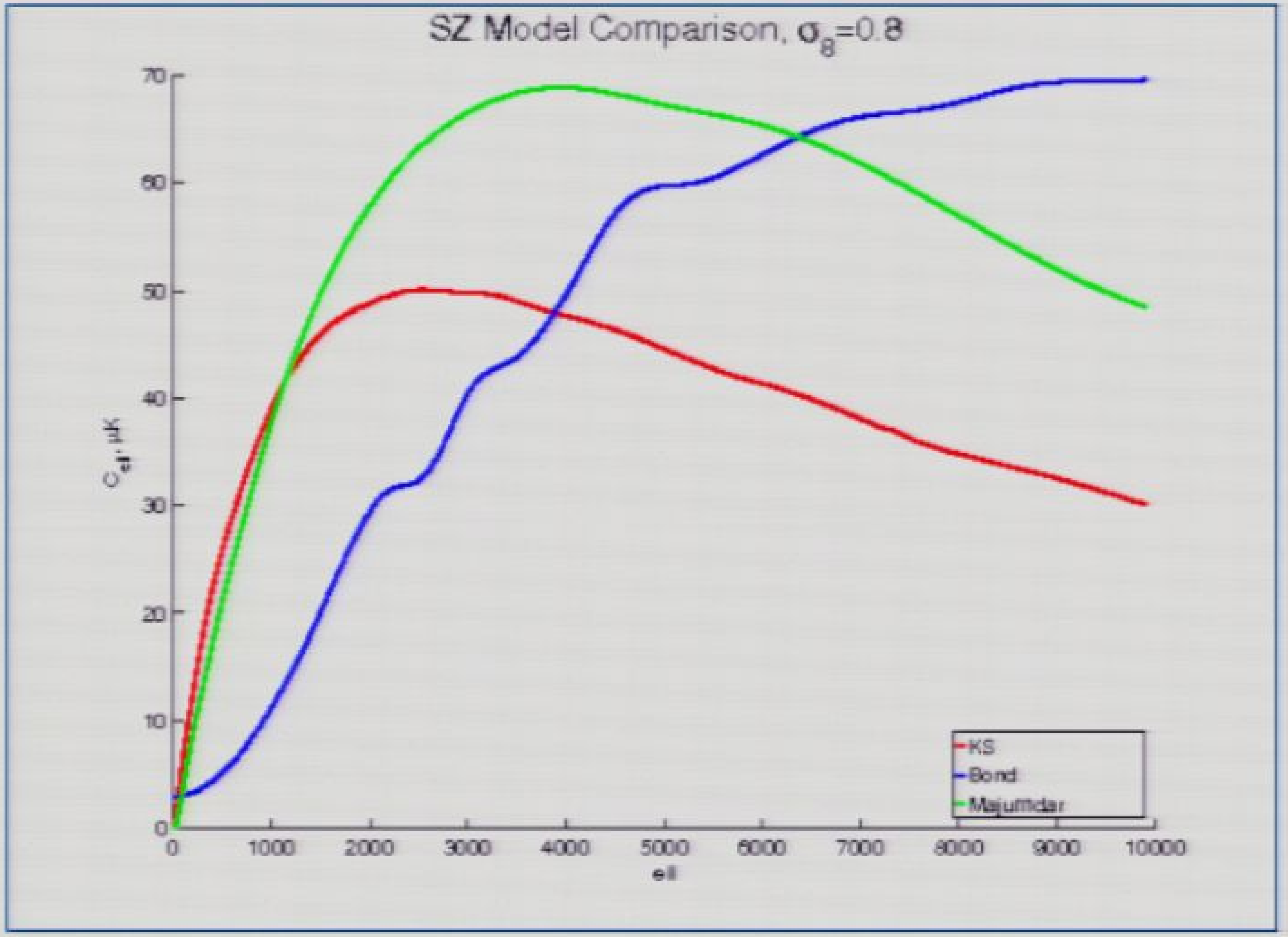

Sievers etal (2009) [and previously Bond etal (2006)] analyized CBI data + radio sources at 30 GHz and found "excess" CMB anisotropy at l > 1500. Moreover, ACBAR & BIMA data also agree with CBI excess, if excess has SZ freq dependence.

They use two different SZ cluster templates: 1) Analytic Komatsu Seljak and 2) SPH simulation
They find $\sigma_8$ =0.922±.047 and $\sigma_8$ =0.988±.049. Previous result was $\sigma_8$ = 1.0 - 1.05

# SZ CI WITH NEW SZ TEMPLATE AND $\sigma_8$ -

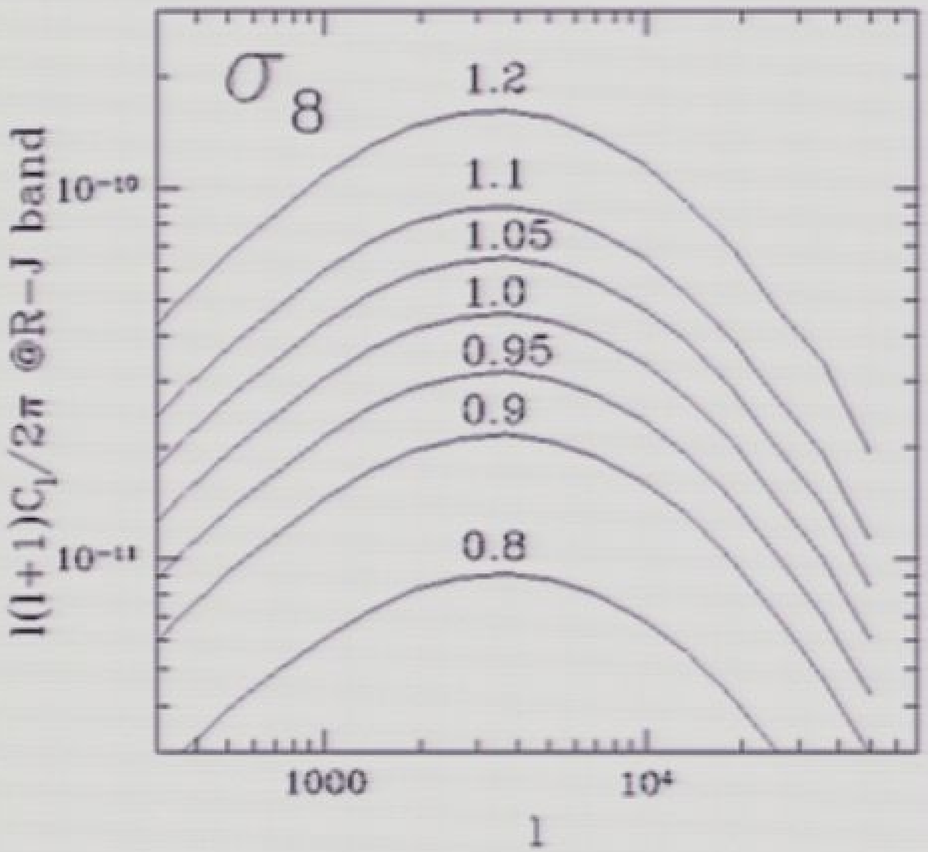
More in Jon Siever's talk

# SZ Cl WITH NEW SZ TEMPLATE AND $\sigma_8$ -

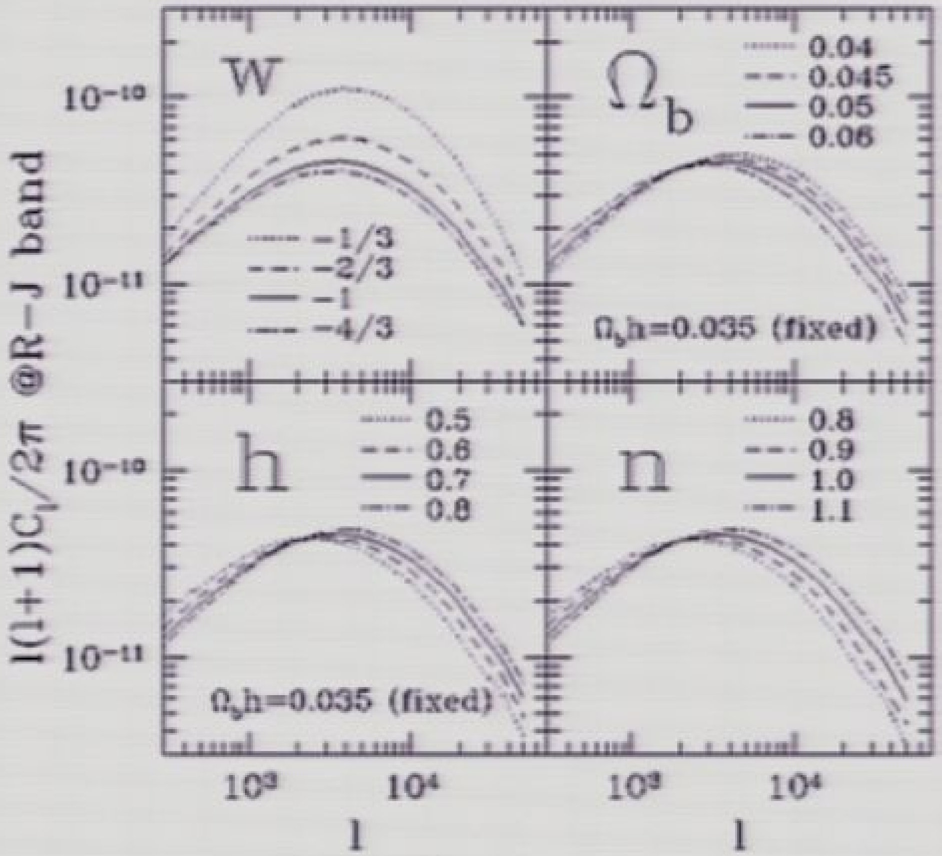



More in Jon Siever's talk

# On To SZ Power Spectrum -



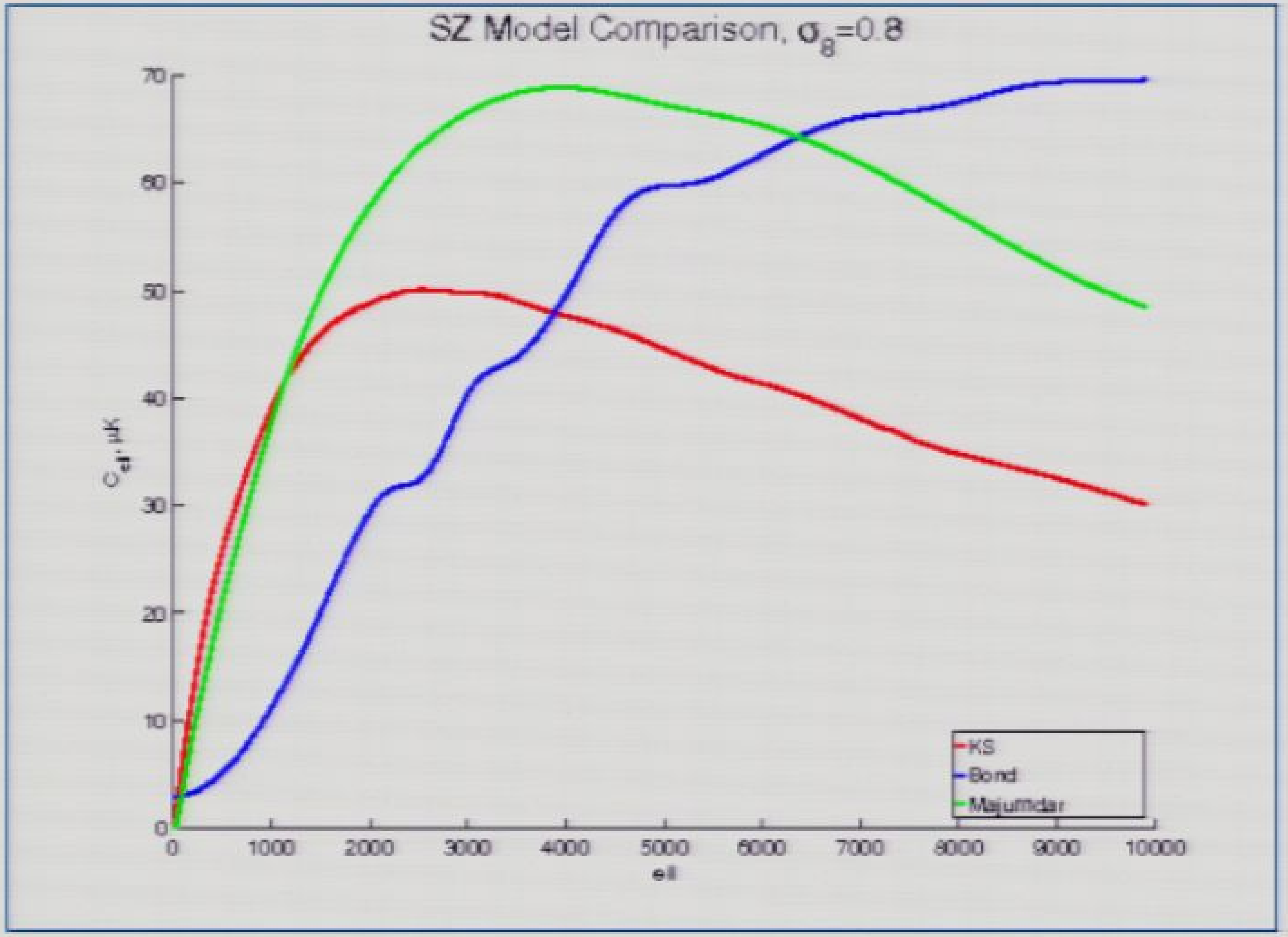

$C_l \sim \sigma_8^{6\text{-}7}$




Effect of other parameters are subdued under the effect of $\sigma_8$.

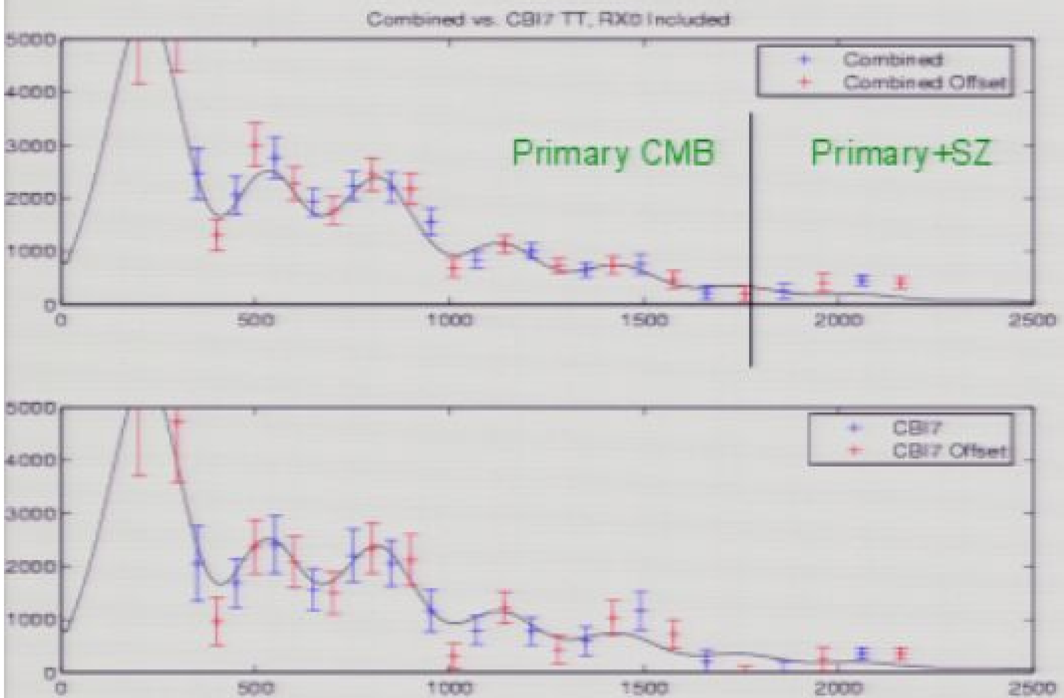
Komatsu & Seljak 2002

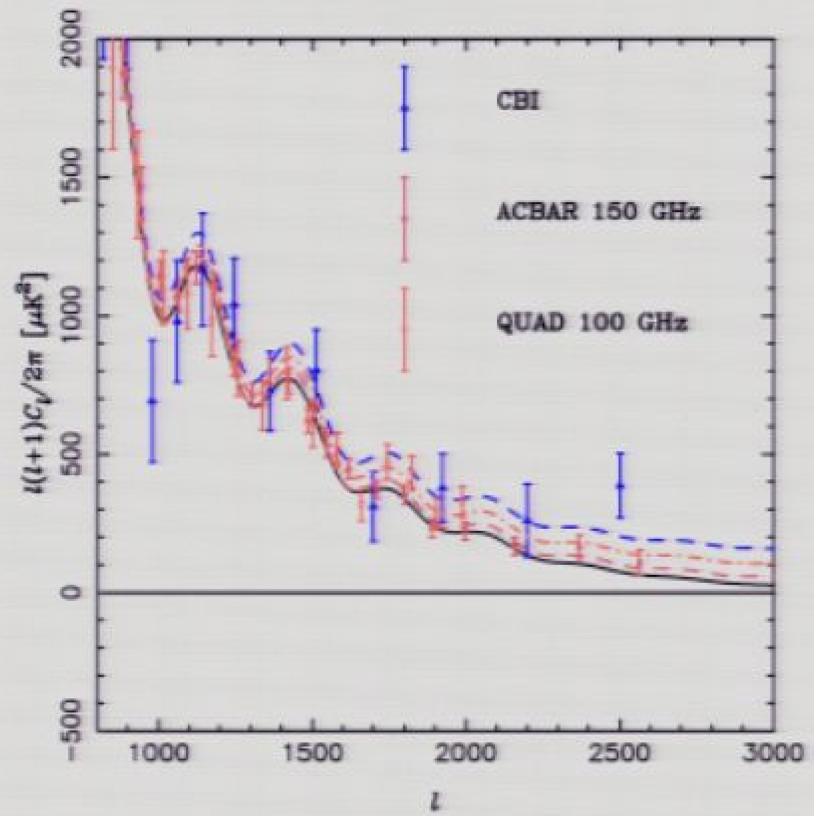
# SZ Cl WITH NEW SZ TEMPLATE AND $\sigma_8$ -




More in Jon Siever's talk

# EXCESS OF CMB ANISOTROPY OBSERVED AT SMALL ANGULAR SCALES -




Sievers etal (2009) [and previously Bond etal (2006)] analyized CBI data + radio sources at 30 GHz and found "excess" CMB anisotropy at l > 1500. Moreover, ACBAR & BIMA data also agree with CBI excess, if excess has SZ freq dependence.

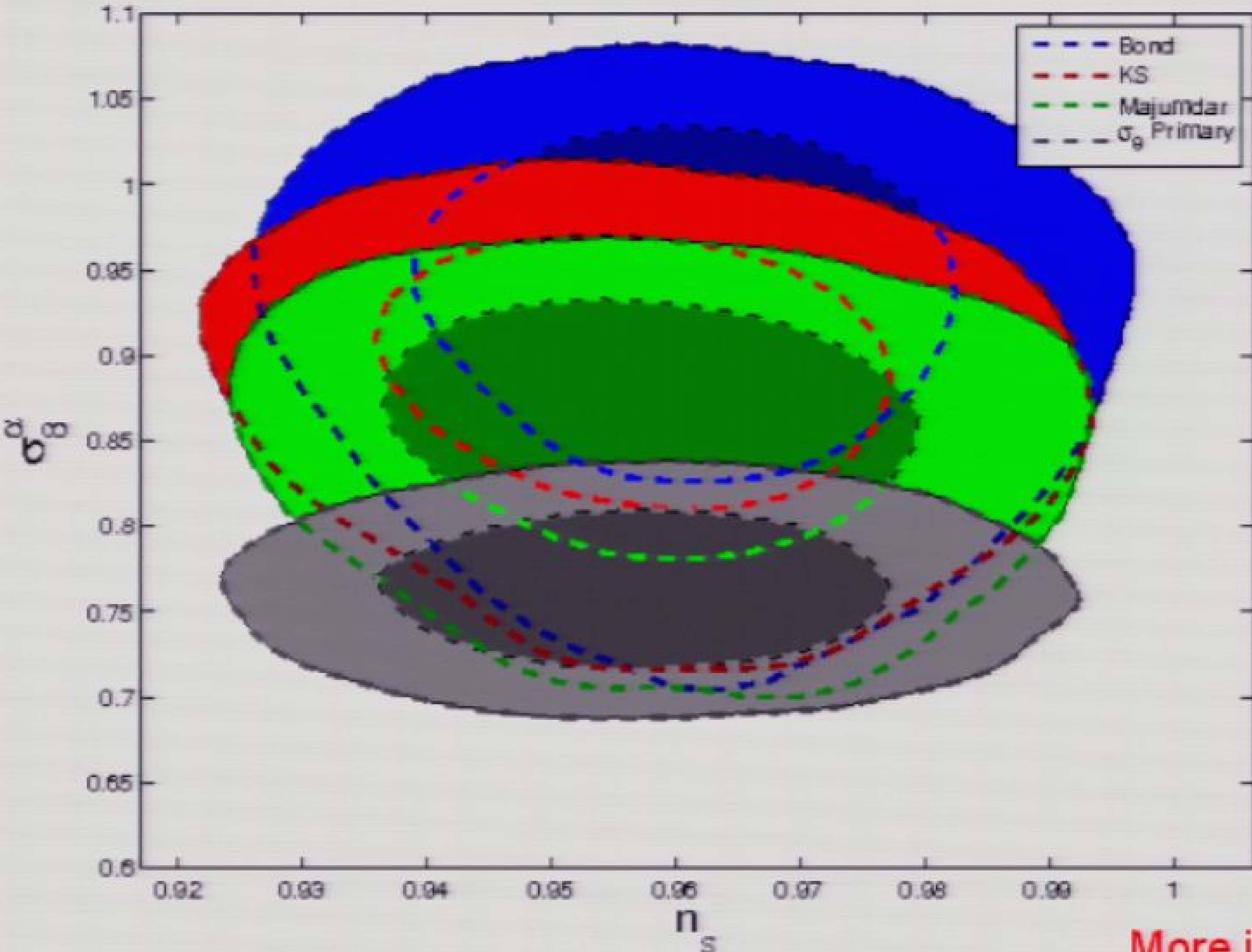
They use two different SZ cluster templates: 1) Analytic Komatsu Seljak and 2) SPH simulation They find $\sigma_8$ =0.922±.047 and $\sigma_8$ =0.988±.049. Previous result was $\sigma_8$ = 1.0 - 1.05

## SZ CI WITH NEW SZ TEMPLATE AND $\sigma_8$ -

More in Jon Siever's talk

# SZ CI WITH NEW SZ TEMPLATE AND $\sigma_8$ -

$\sigma_8$ = 0.851+/.055 w/out BIMA (including quad 2yr,acbar,cbi,sza,wmap5)

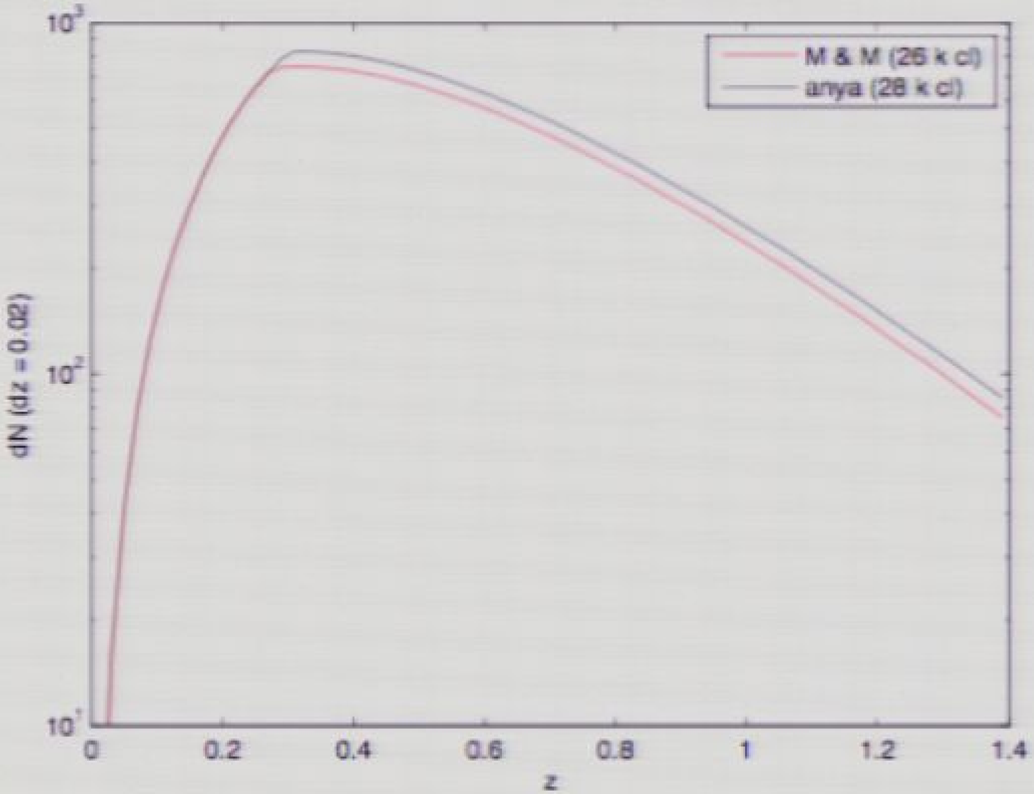



More in Jon Siever's talk

# SZ Flux - M200 relation and number counts -

$Y_{200} - M_{tot}$ Scaling relation(Nonthermal-thermal)

| | $A_{200}$ | $B_{200}$ |
|---|---|---|
| model 1(fid) | -28.0669 | 1.6123 |
| non th 7 | -28.1709 | 1.6197 |
| non th 4 | -28.1946 | 1.6216 |
| non th 1 | -28.2073 | 1.6221 |
| model 1 (thermal) | -28.2302 | 1.6247 |




Imp if you want to do 'precision cosmology'

More in Christoph's talk

## SUMMARY AND CONCLUSIONS -

**We have build a 'bottom-up' model of cluster gas density and temperature profiles, normalized so as to give observed Xray mass-temp scaling relation.** The resultant pressure profiles have been used to construct SZ cluster templates.

The non self-similar Xray scaling results in non self-similar SZ scaling relations. **We compare our results with the recently observed SZ scaling relations (Y-T, Y-Mgas, Y-Mtot) by Bonamente et al and find excellent agreement.**

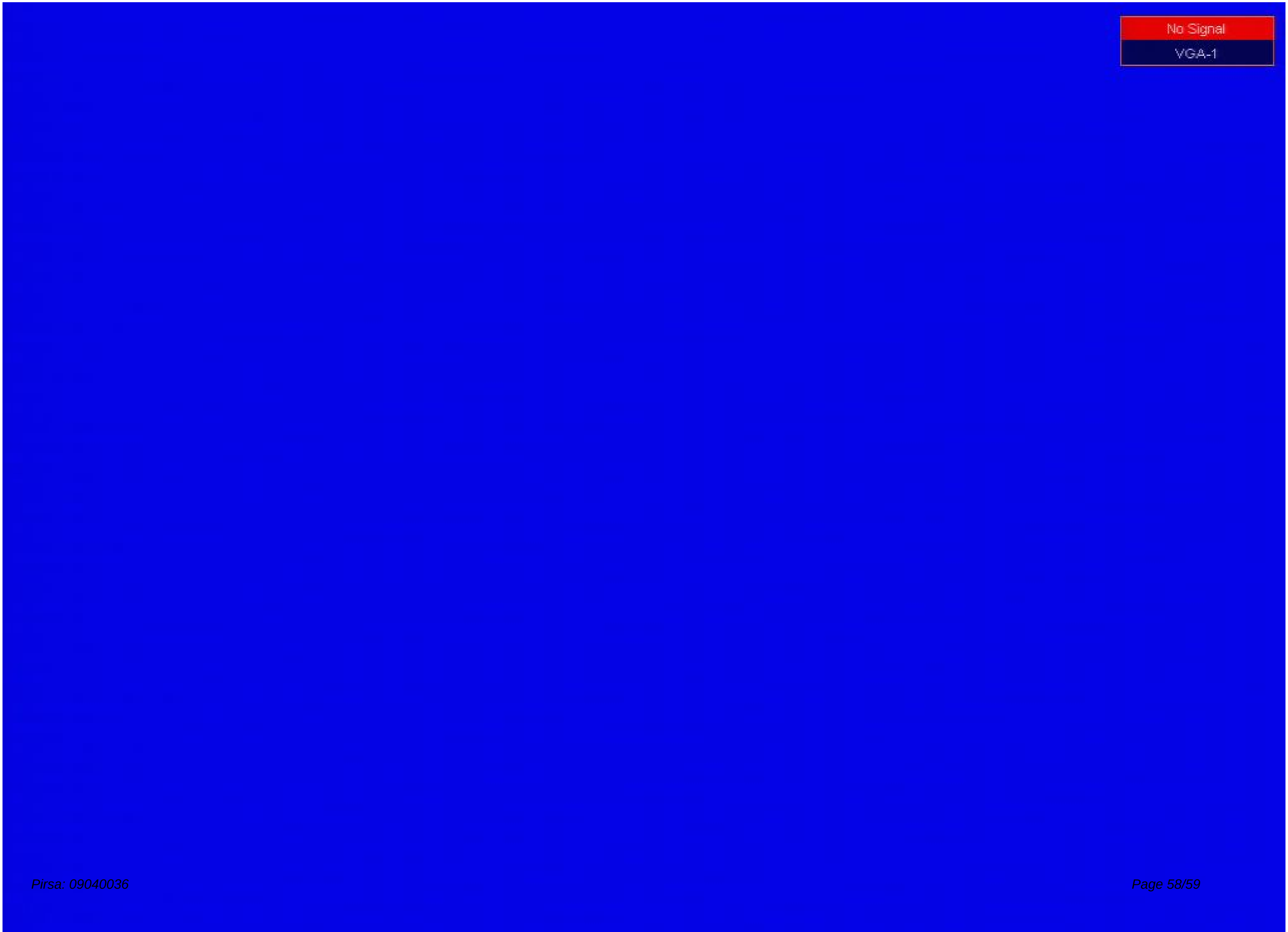
.

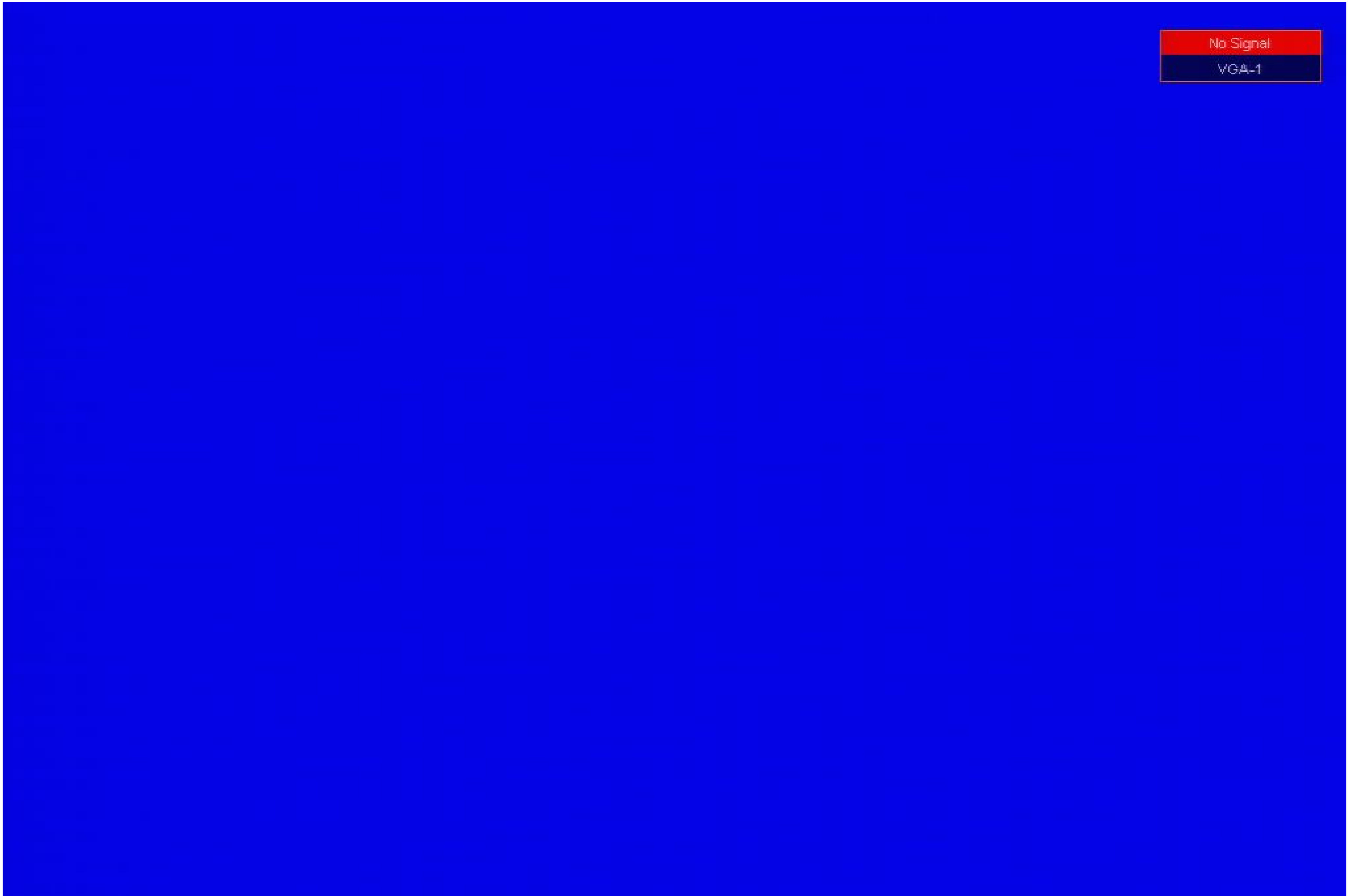
There are two imp implications of this result -

1) We can say that we are observing the same 'family' of clusters in XRay and SZ, thus making modeling of SZ selection of cluster for surveys easier.

2) We can more confidently predict Y-M200 scaling reln used for cluster surveys. This Is important if we want to do so called 'precision cosmology'

**We use the SZ templates to calculate the expected SZ power spectrum** as arc-min scales. We compare our results to CBI observed anisotropy to constrain »$_8$.
**Our best fit _$_8$ ~ 0.84. This is within the 1-sigma error bar of the best fit _$_8$ ~ 0.817** from WMAP. In contrast, previous and recent studies, using other cluster templates have got sigma8 ~ 0.93 – 1.0 (i.e 4-7 sigma away from WMAP value)_


No Signal
VGA-1


No Signal
VGA-1