Title: Cosmological parameters from large and small scales CMB observations

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Abstract:

Cosmological parameters from large and small scales CMB observations

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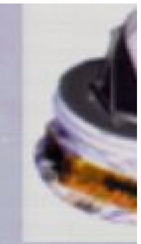
CNRS-Université Paris Sud 11

Orsay - France

with Nicolas Taburet, Nabila Aghanim, Mathieu Langer



Cosmological parameters from large and small scales CMB observations

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SZ signal

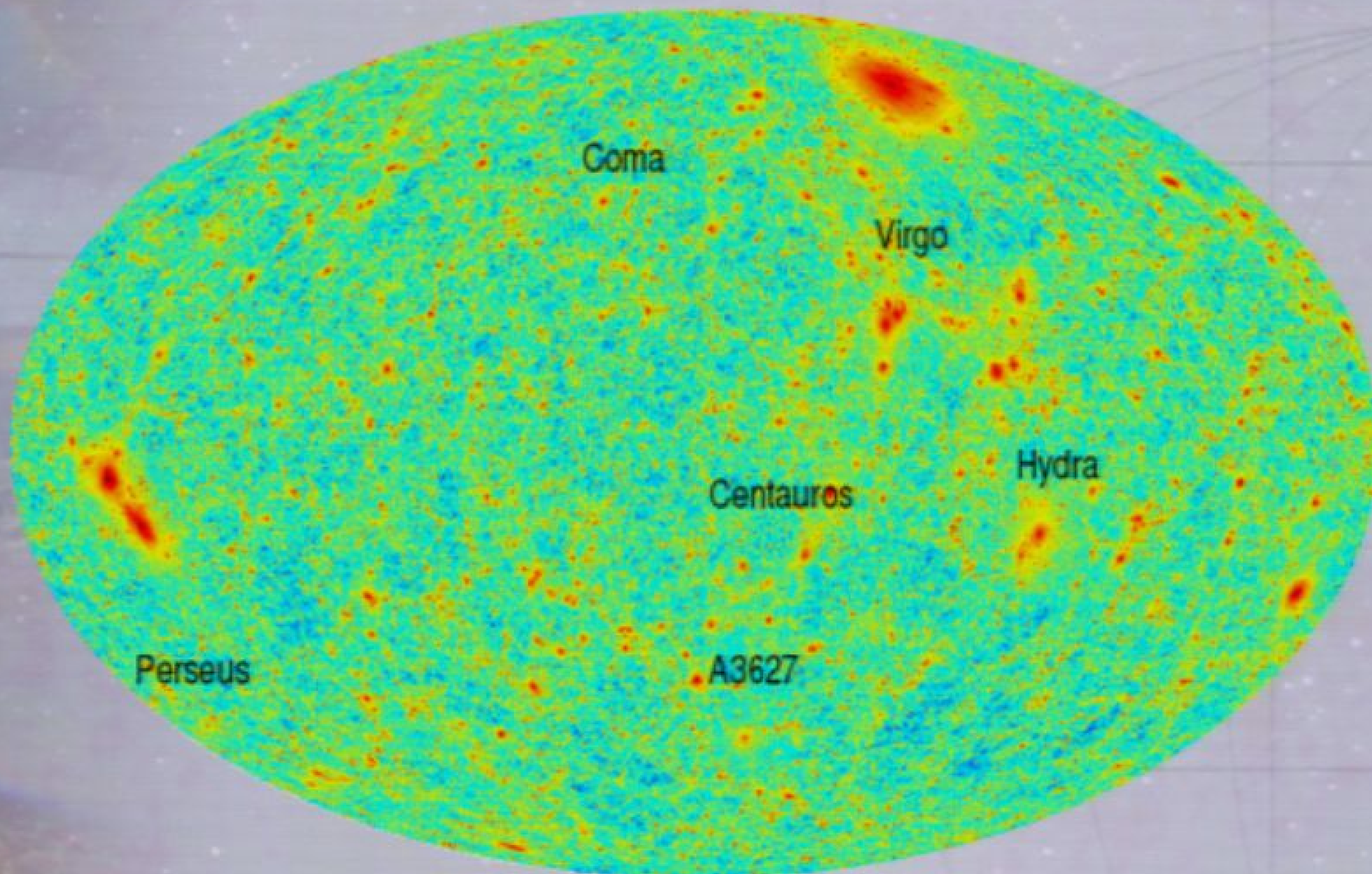
Foreground

Contaminant

cluster physics probe

Cosmological probe

Planck all sky map



credit: da Silva, Valente & Aghanim, CLEF

SZ as cosmological probe

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SZ as cosmological probe

- Use individual clusters

- Use maps/timelines
  - SZ cluster catalogs
    - number counts / scaling Relations

    problem with selection function & source extraction

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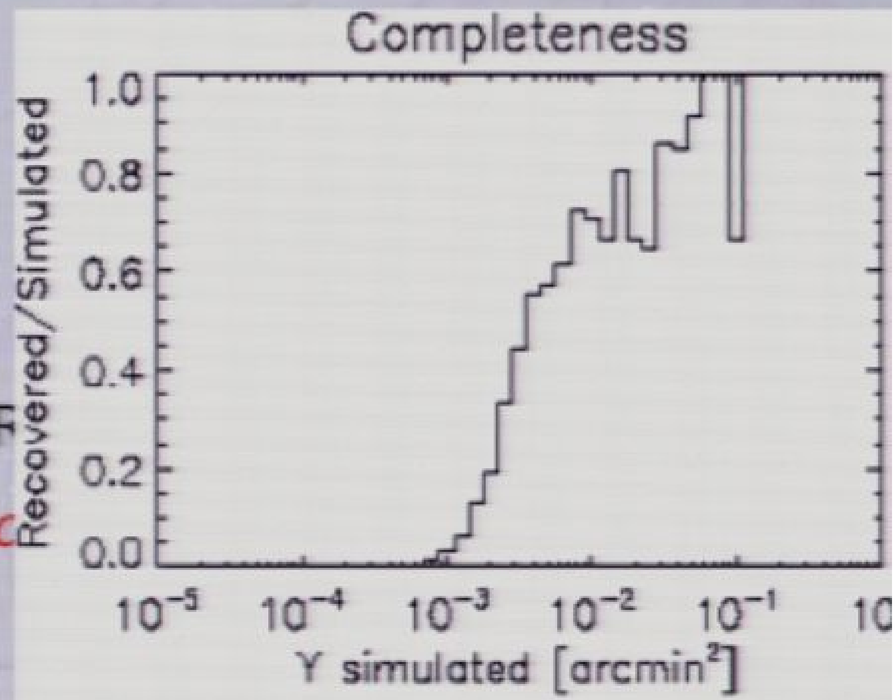

Matched multifilter on patches,
Planck WG5 challenge, *Herranz et al.*

SZ as cosmological probe

- Use individual clusters

- Use maps/timelines
  - SZ cluster catalogs
    - number counts / scaling Relations

    problem with selection function & source extraction

- Use the **power spectrum**
  - Already used in previous/current CMB analyses
    - CBI, VSA, ACBAR, BIMA, SZA, WMAP, ...

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How to take into account this contaminant signal and use its cosmological information at the same time ?

(continued)

in the Planck Power Spectrum context

Fitting cosmological parameters with CMB

- **Data : Cl**
  - Planck (+ CBI, SZA, ACBAR, ACT, APEX, QUAD, SPT, ACT ...)
- **Likelihood function**
  - Gaussian (+ non Gaussian)
- **Theoretical spectrum depending on cosmology**
  - more tricky
- **Modus operandi**
  - parameterizations + MCMC

SZ contaminant for CI
estimation

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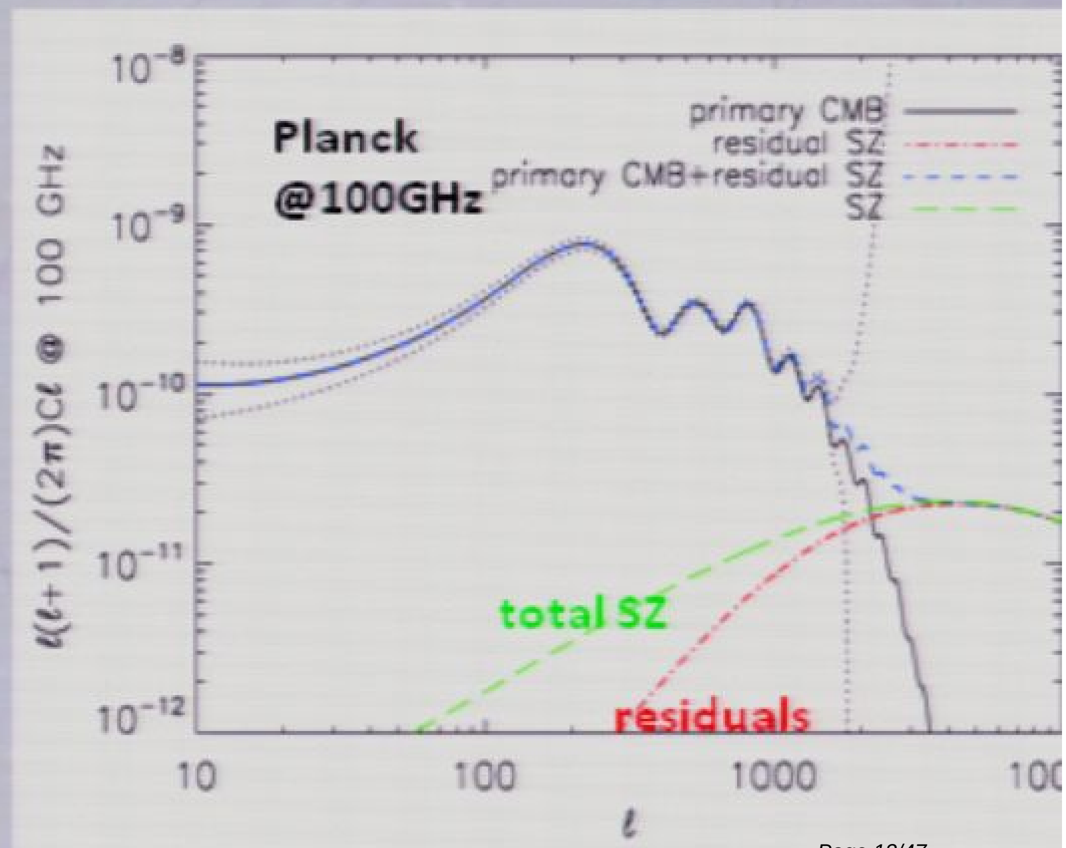
SZ contaminant for CI estimation

- Remove detected clusters
  - undetected clusters dominate at small scales
  - selection function



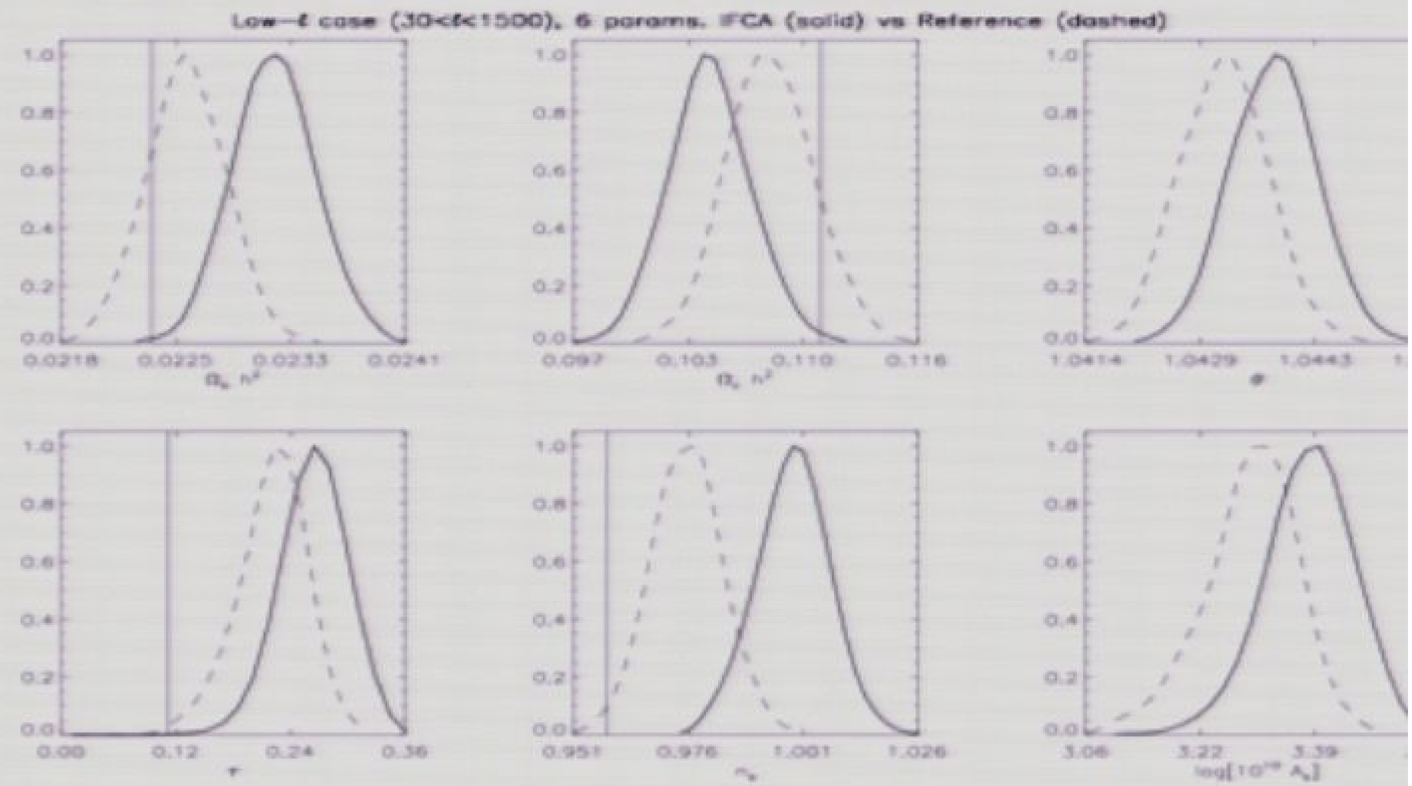
SZ contaminant for CI estimation

- Remove detected clusters
  - undetected clusters dominate at small scales
  - selection function

- cut $\ell > 1000$
  - still biased and bigger error bars

SZ contaminant for C
estimation

- Remove
  - undete
  - selectic
- cut ℓ > 1C
  - still bia
- Use component separation
  - kSZ remains
  - not enough



CosmoMC + residuals from Planck WG2 challenge component separation
from J-A Rubino-Martin

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Approach

- Fit the observed power spectrum with

$$C_\ell^{\mathrm{tot}} = C_\ell^{\mathrm{CMB}}(\hat{\theta}) + C_\ell^{\mathrm{SZ}}(\hat{\theta})$$

→ Total SZ signa

Already used in analyses of:

- CBI *(Readhead et al. 04, Bond et al.2005, Sievers et al. 09)*
- VSA *(Rebolo et al. 04)*
- ACBAR *(Kuo et al. 07, Reichardt et al. 08)*
- WMAP *(Spergel 03, Dunkley et al. 08)*
- BIMA *(Dawson et al. 06)*
- Combined *(Douspis et al. 06)*

Theoretical spectrum

- Analytical computation
- Numerical simulations
- mixed approach *eg Majumdar*

Numerical simulations

- Better and Better simulations.
- Allows to see the effects of Gas physics.

- Pb of resolution
  - box size : large scales
  - smoothing length : small scales *(White et al. 02)*
- Gas physics
  - cooling and feedback ...

da Silva, Pfrommer, Majumdar, Babul, Cao, Bond, Zhang et al.

In near future, lot of efforts will pin down the scatter

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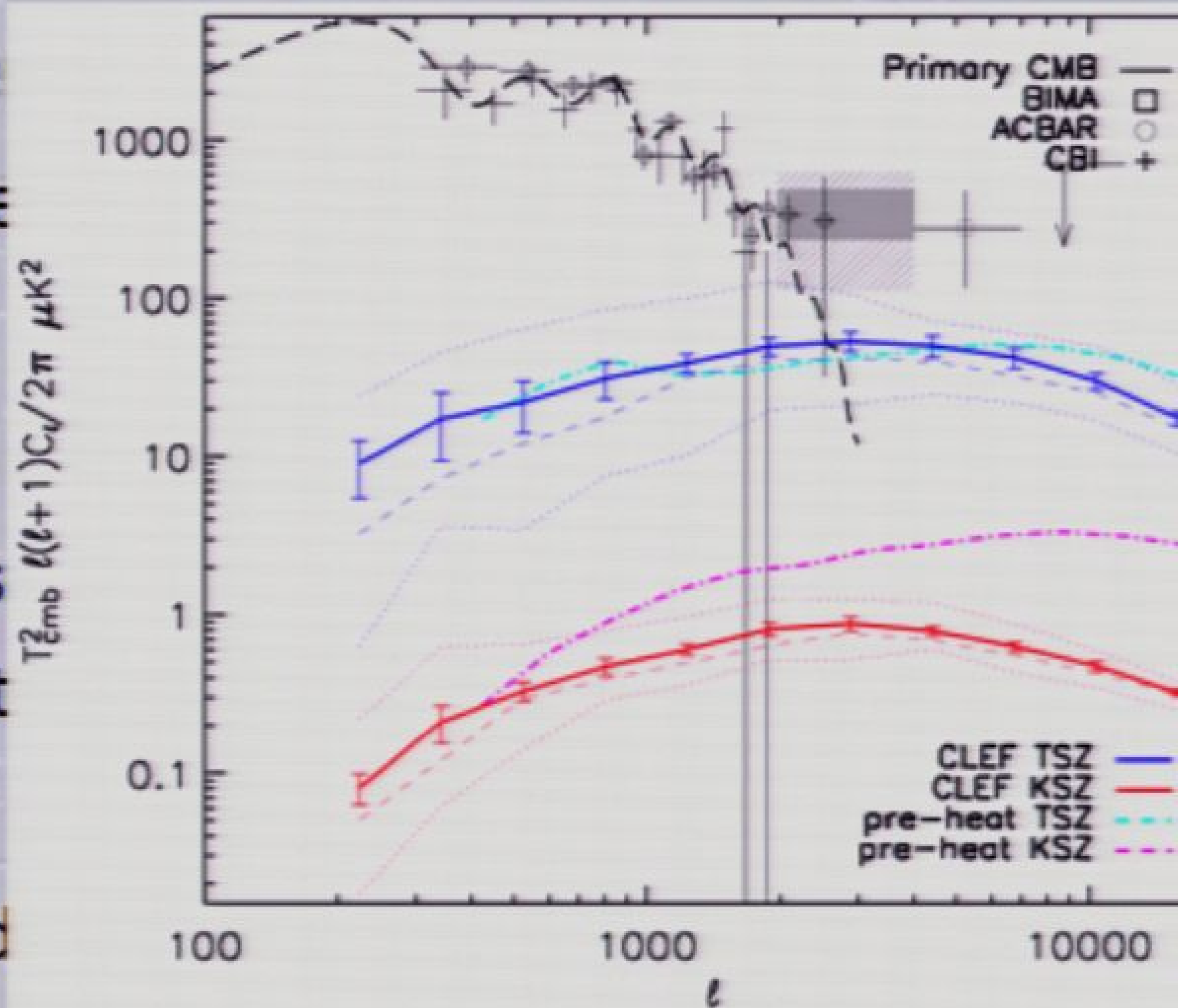

Da Silva & CLEF collaborati

In near future, lot of efforts will pin down the scatter

Analytical modeling

A natural approach is to model the SZ Power spectrum by keeping the cosmological parameter dependency

$$C_\ell(SZ) = g_\nu{}^2 \int_0^{z_{max}} dz \frac{dV}{dz} \int_{M_{min}}^{M_{max}} dM \frac{dn(M,z)}{dM} |y_\ell(M,z)|^2$$

Poissonian: *Komatsu & Seljak 02*

- SZ emission of a single cluster for a hot gas distribution (β profile)
- Choose a mass function to compute the cluster number counts on the sky (*dn/dM* *Sheth & Tormen 99*)
- Integrate over the sky *(Komatsu & Seljak 02)*

→ Included in a CAMB module to ease MCMC

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Parametrizations

For CMB observations fitting:

3 $$C_\ell^{\rm tot} = C_\ell^{\rm CMB}(\hat\theta) + C_\ell^{\rm SZ}(\hat\theta)$$

→ Analytical

2 $$C_\ell^{\rm tot} = C_\ell^{\rm CMB}(\hat\theta) + \sigma_8^7\,(\Omega_b h)^2\, C'_\ell(\hat\theta_0)$$

1 $$C_\ell^{\rm tot} = C_\ell^{\rm CMB}(\hat\theta) + A_{\rm SZ} C_\ell(\hat\theta_0)$$

Method 3

$$C_\ell^{\mathrm{tot}} = C_\ell^{\mathrm{CMB}}(\hat{\theta}) + C_\ell^{\mathrm{SZ}}(\hat{\theta})$$

A natural approach is to model the SZ Power spectrum by keeping the cosmological parameter dependency

- More constraints on parameters
- Also coherence between scales (eg σ_8)

• Takes full cosmological dependency
• Less heavy than numerical simulations

• Not so fast to compute
• Depends on gas properties and cuts

used in Komatsu & Seljak 02, Douspi s et al. 07, Taburet et al. 08, 09, Sievers et al. 09

Method 2

$$C_\ell^{\rm tot} = C_\ell^{\rm CMB}(\hat{\theta}) + \sigma_8^7\,(\Omega_b h)^2\,C'_\ell(\hat{\theta}_0)$$

- Choose your favorite description of C'_ℓ(SZ) as template assuming one cosmology (θ_0)
  - from numerical simulations
  - from analytical modelling
- use partial cosmological dependency of SZ signa

• fast to compute once one Cl available

• No shape variation with cosmology

used in Dawson et al. 06, Dunkley et al ., Sievers et al. 09

Method 3

$$C_\ell^{\rm tot} = C_\ell^{\rm CMB}(\hat\theta) + C_\ell^{\rm SZ}(\hat\theta)$$

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• No shape variation with cosmology

used in Dawson et al. 06, Dunkley et al ., Sievers et al. 09

Method 1

$$C_\ell^{\mathrm{tot}} = C_\ell^{\mathrm{CMB}}(\hat{\theta}) + A_{\mathrm{SZ}} C_\ell(\hat{\theta}_0)$$

- Choose your favorite description of $C'_\ell(SZ)$ as template assuming one cosmology (θ_0)
  - from numerical simulations
  - from analytical modelling
- use only the amplitude dependency

- Fast to compute once one Cl available

- No cosmological dependency
- Decorrelate large/small scales

used in *WMAP 1 & 3, Sievers et al. 09*

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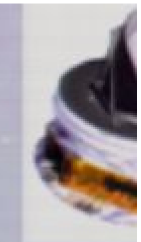
Tests in Planck case



- Simulate a set of "observed" C_ℓs including some SZ signal (with Planck 100GHz noise properties)
- Try to retrieve cosmological parameters with the 3 methods (3, 2, 1)
- Study Biases and Confidence intervals on cosmological parameters of 3 methods

We use Monte Carlo Markov Chain approach

– CosmoMC *(Lewis & Bridle 02 + Dunkley et al. 05)*
– CAMB module

ongoing work in Taburet et al. 09b soon

Pessimistic case

The SZ signal is not really known
(wrong gas description)

- *"Data" simulated from* $C_\ell(\theta_0, T_0, \beta_0)$
- Method 1: $C_\ell(SZ) = A\, C_\ell(\theta_0, T_1, \beta_1)$ or ...
- Method 2: $C_\ell(SZ) = \sigma_8^7 (\Omega_b h^2)^2\ C_\ell(\theta_0, T_1, \beta_1)$ or ...
- Method 3: $C_\ell(SZ) = C_\ell(\theta, T_1, \beta_1)$

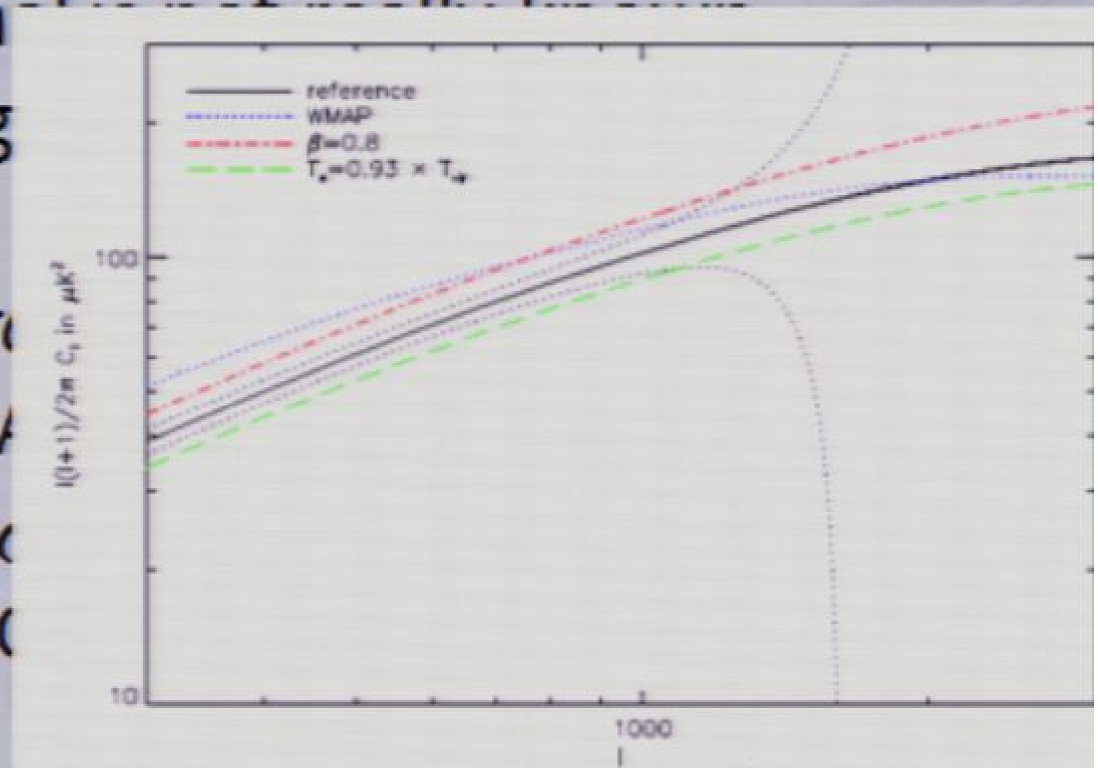
- test Method 3 with T change of -7%
- test Method 3 with β=0.7 and β=0.8 (instead of 0.66)

Pessimistic case

The SZ sign

(wrong

- *"Data" simulated fr*
- Method 1: C_ℓ(SZ) =
- Method 2: C_ℓ(SZ) =
- Method 3: C_ℓ(SZ) =



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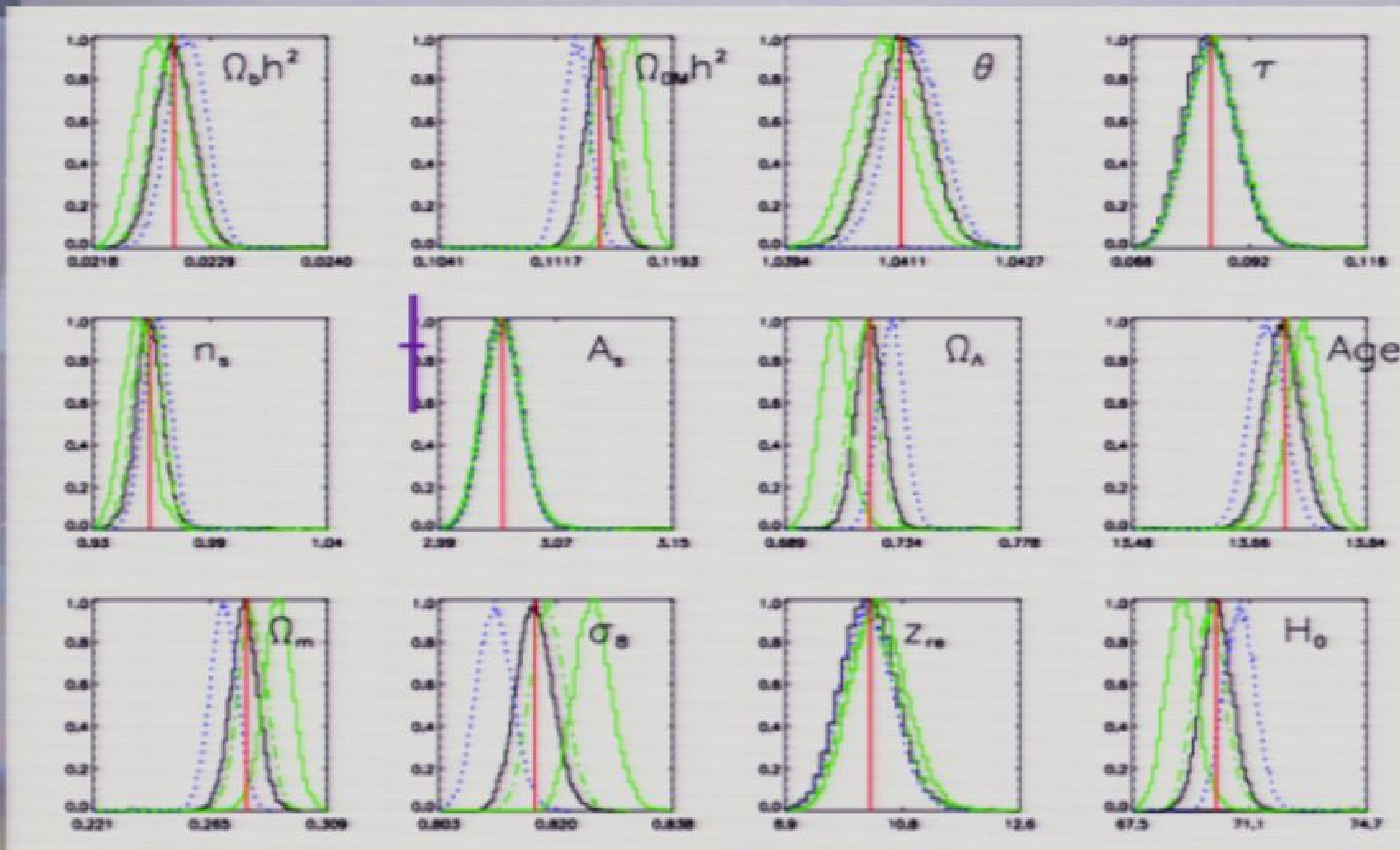
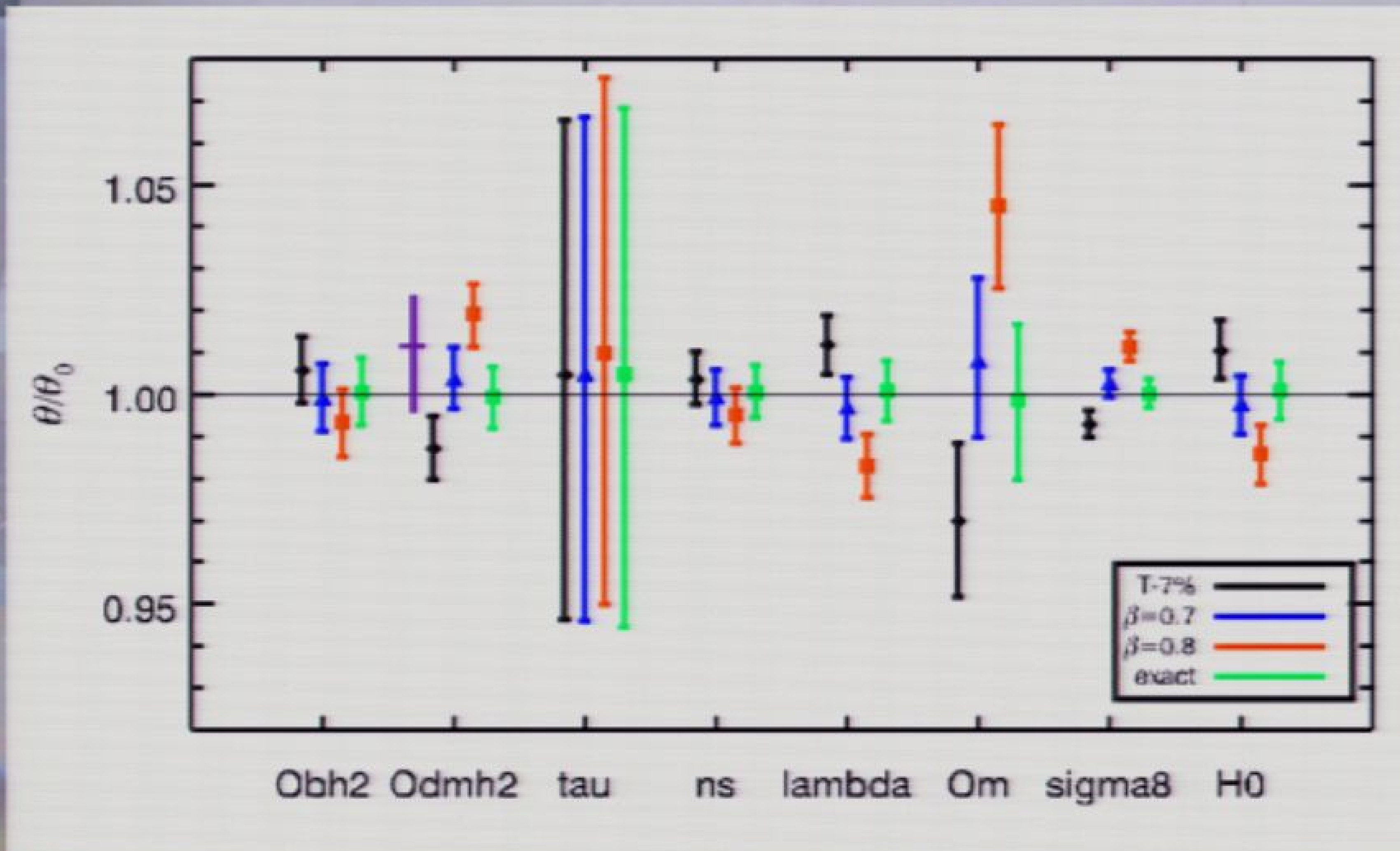


Wrong assumptions on gas properties introduce biases of few σ on some C.P.

Pessimistic case



Wrong assumptions on gas properties introduce biases of few σ on some C.P.

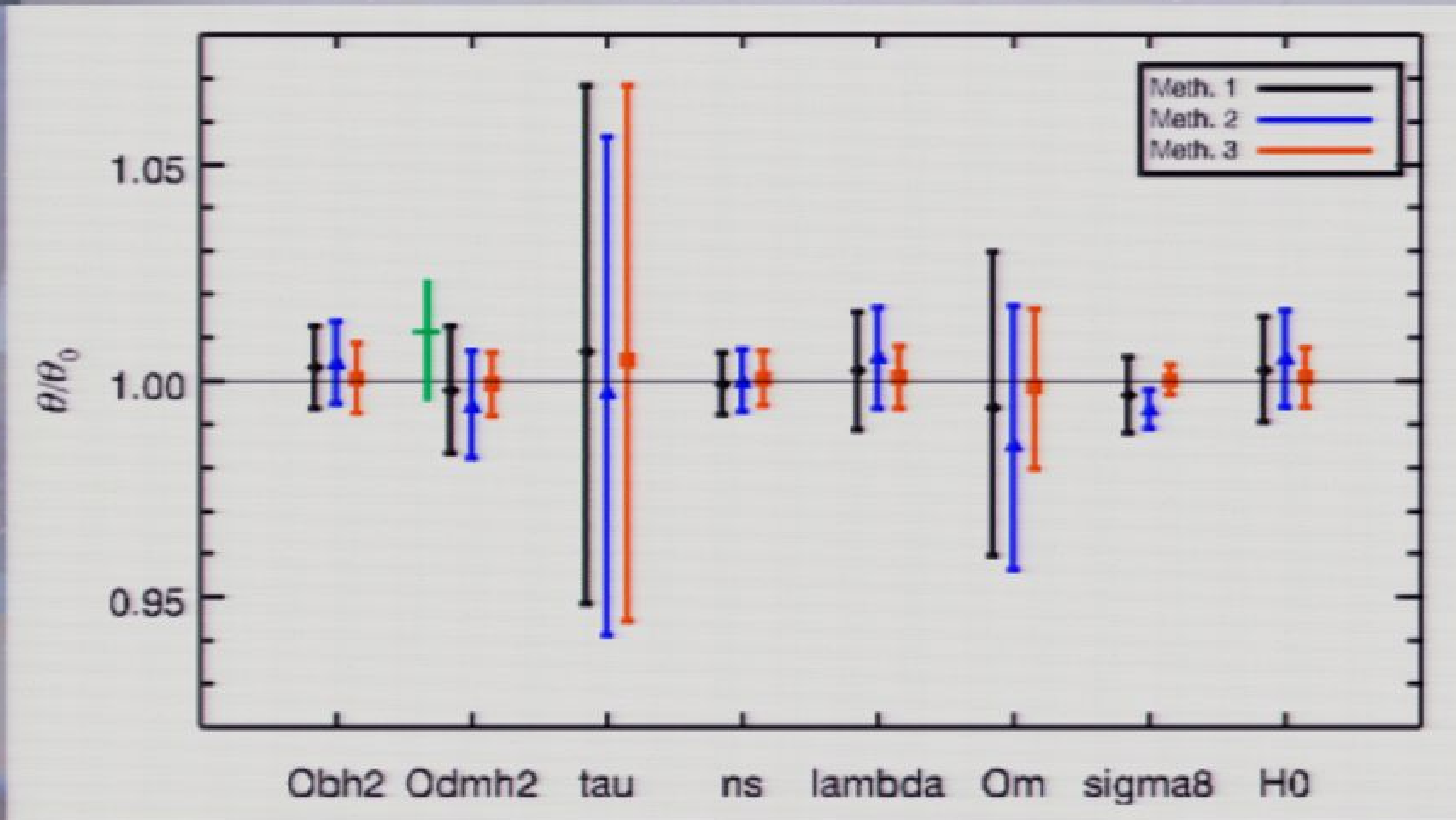
Middle case

The SZ signal is not perfectly known

(wrong template : wrong cosmology)

- *"Data" simulated from $C_\ell(\theta_0)$ [or C_ℓ(NS)]*
- Method 1: $C_\ell(SZ) = A\, C_\ell(\theta_1)$
- Method 2: $C_\ell(SZ) = \sigma_8^7 (\Omega_b h^2)^2 C_\ell(\theta_1)$
- Method 3: $C_\ell(SZ) = C_\ell(\theta)$

Middle case



- Method 2 slighlty biased (highly for σ_8) unlike M3
- M1 less biased but bigger error bars…

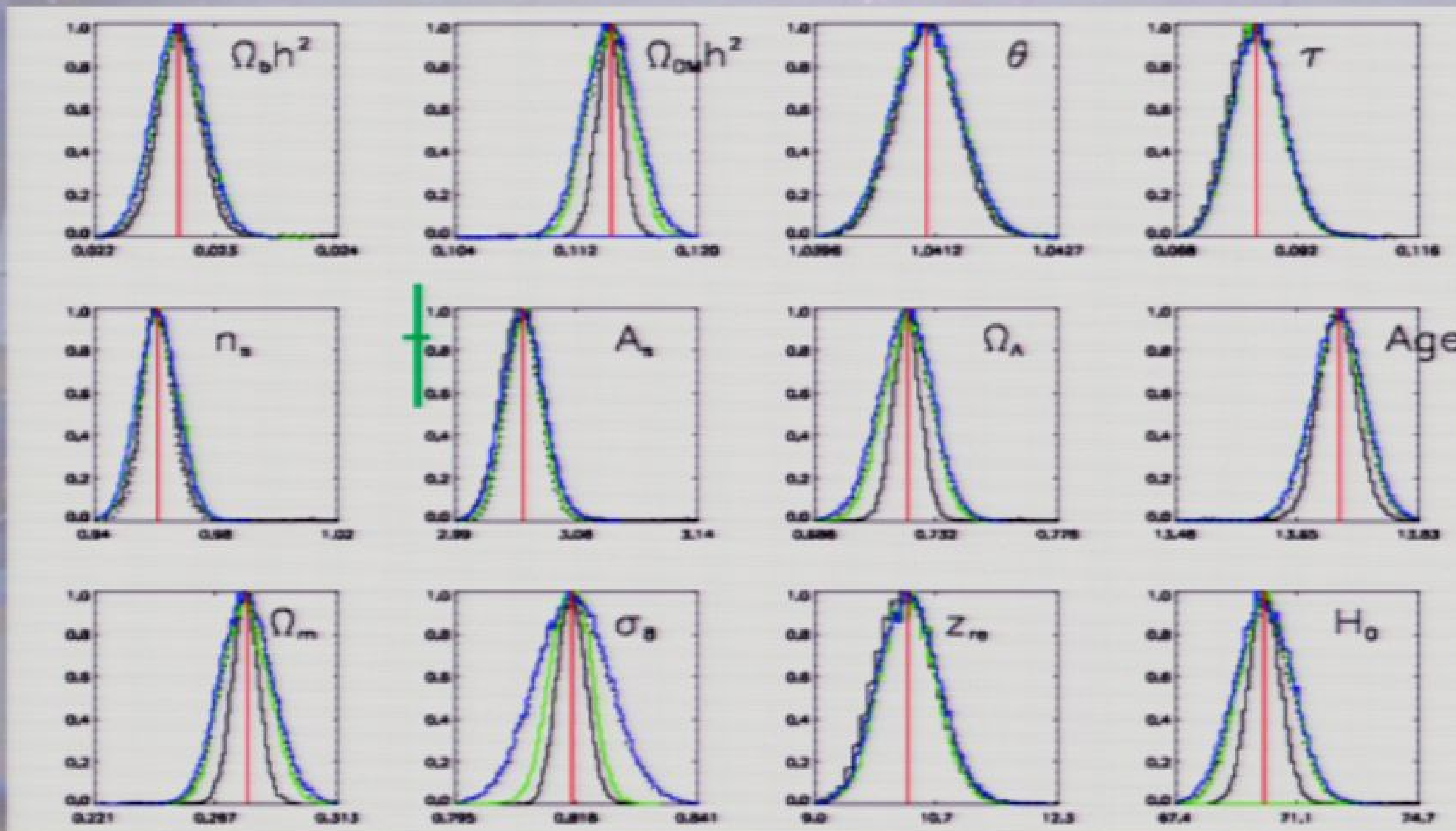
Optimistic case

The SZ signal is perfectly known

(good Cosmology and gaz physics template)

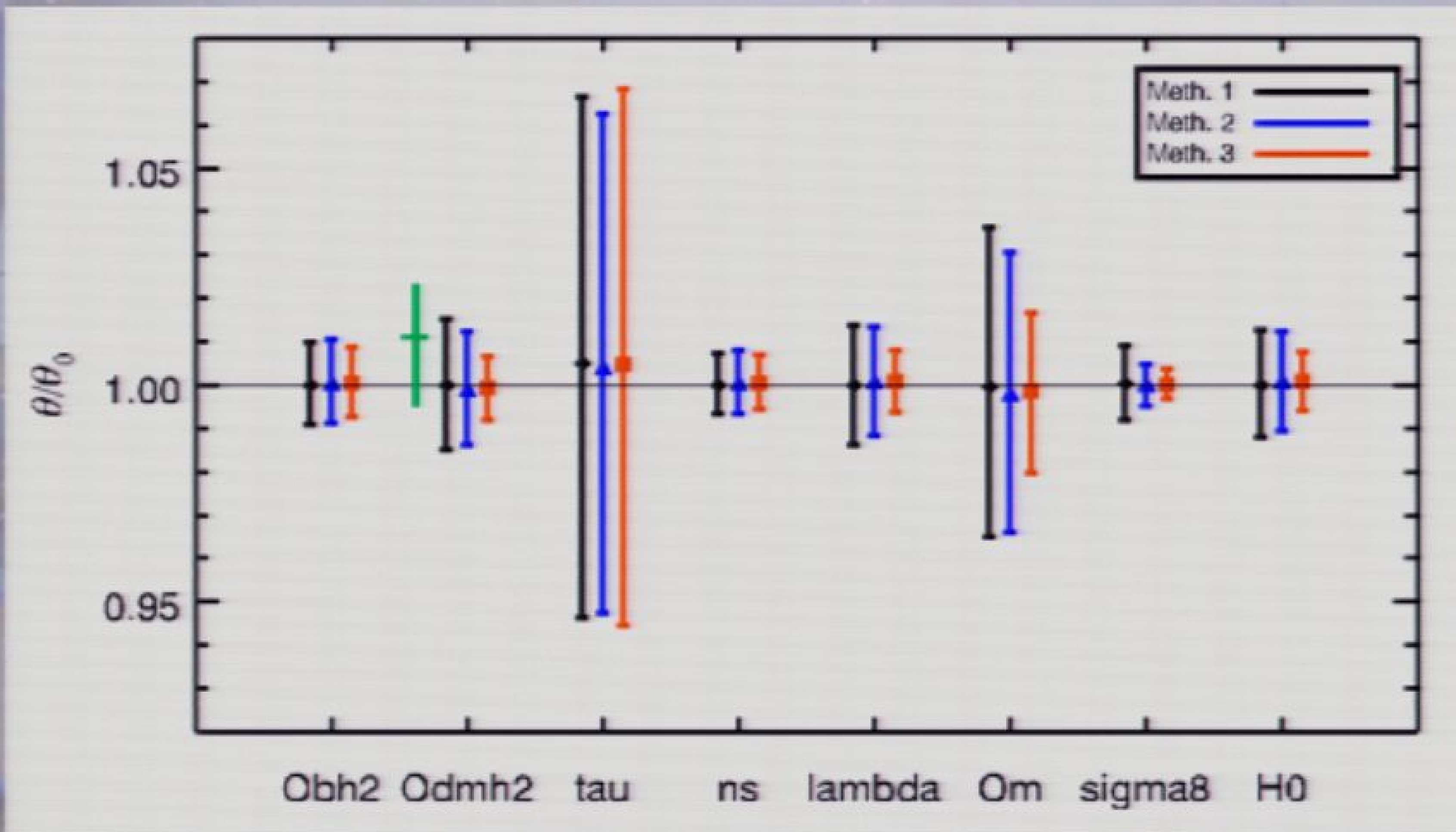
- *"Data" simulated from $C_\ell(\theta_0)$ [or C_ℓ(NS)]*
- Method 1: $C_\ell(SZ) = A\, C_\ell(\theta_0)$
- Method 2: $C_\ell(SZ) = \sigma_8^7 (\Omega_b h^2)^2\, C_\ell(\theta_0)$
- Method 3: $C_\ell(SZ) = C_\ell(\theta)$

Optimistic case



- Obviously no bias
- Different intervals on cosmological parameters

Optimistic case



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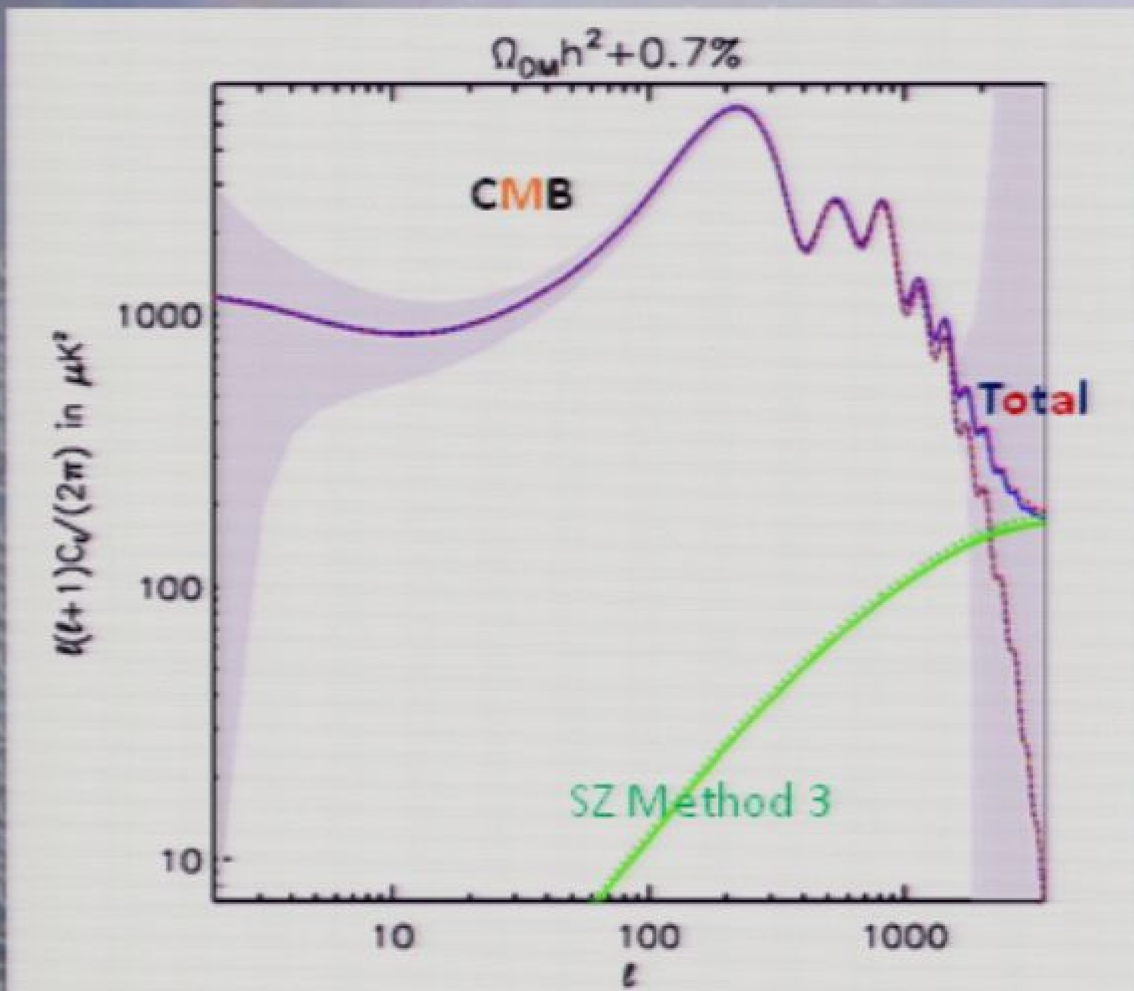
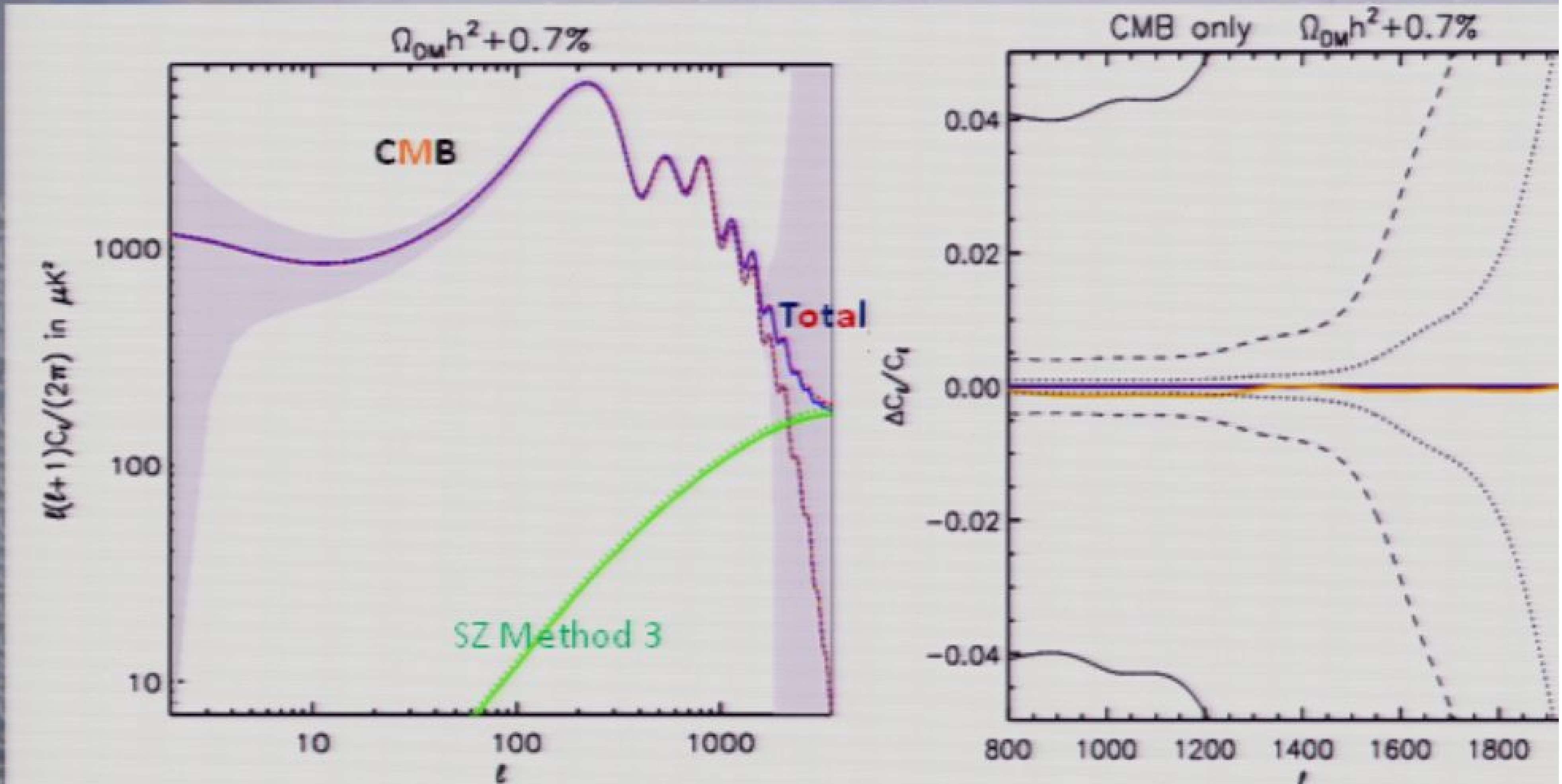
Intervals: $\Omega_{DM} \cdot h^2$



CMB degeneracies broken by SZ

Intervals: $\Omega_{DM} \cdot h^2$



CMB degeneracies broken by SZ

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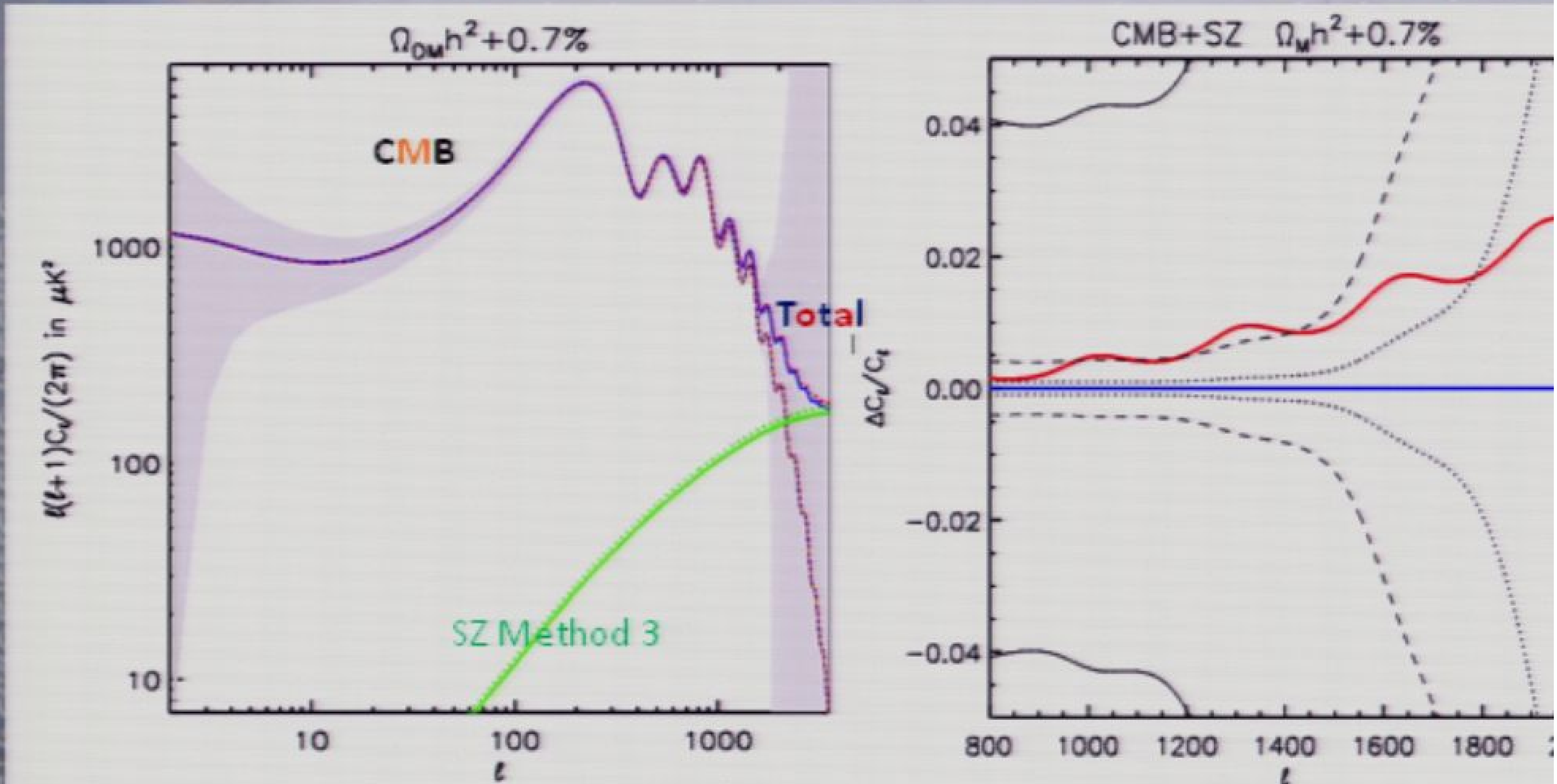


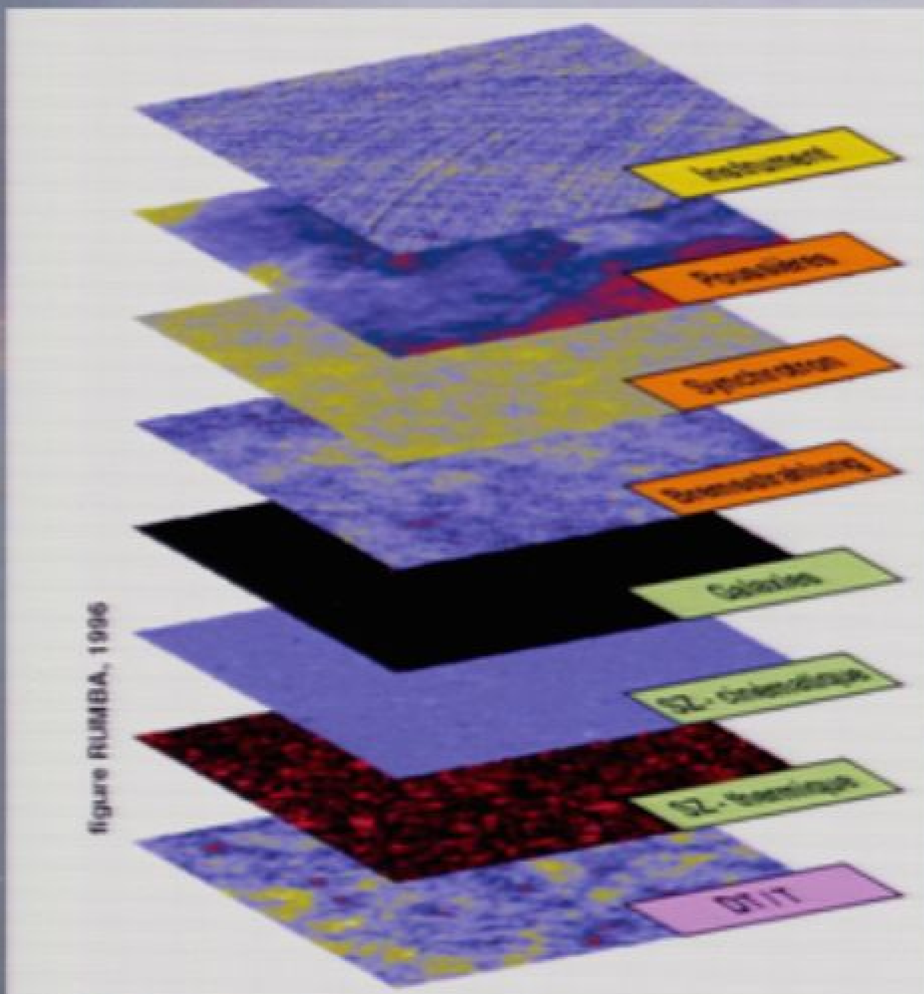
CMB degeneracies broken by SZ

Simple approach allows to use SZ as cosmological probe

- M1 & M2 :
  - sensitive to the template; cosmological and gas phys
    M1: bias goes in extra-parameters
  - less precision
- M3 :
  - better precision
  - more sensitive to uncertainties on gas properties **but will be reduced by future surveys, future theoretica work and simulations**

Biases and error bars differences quantified in *Taburet et al. 09b*

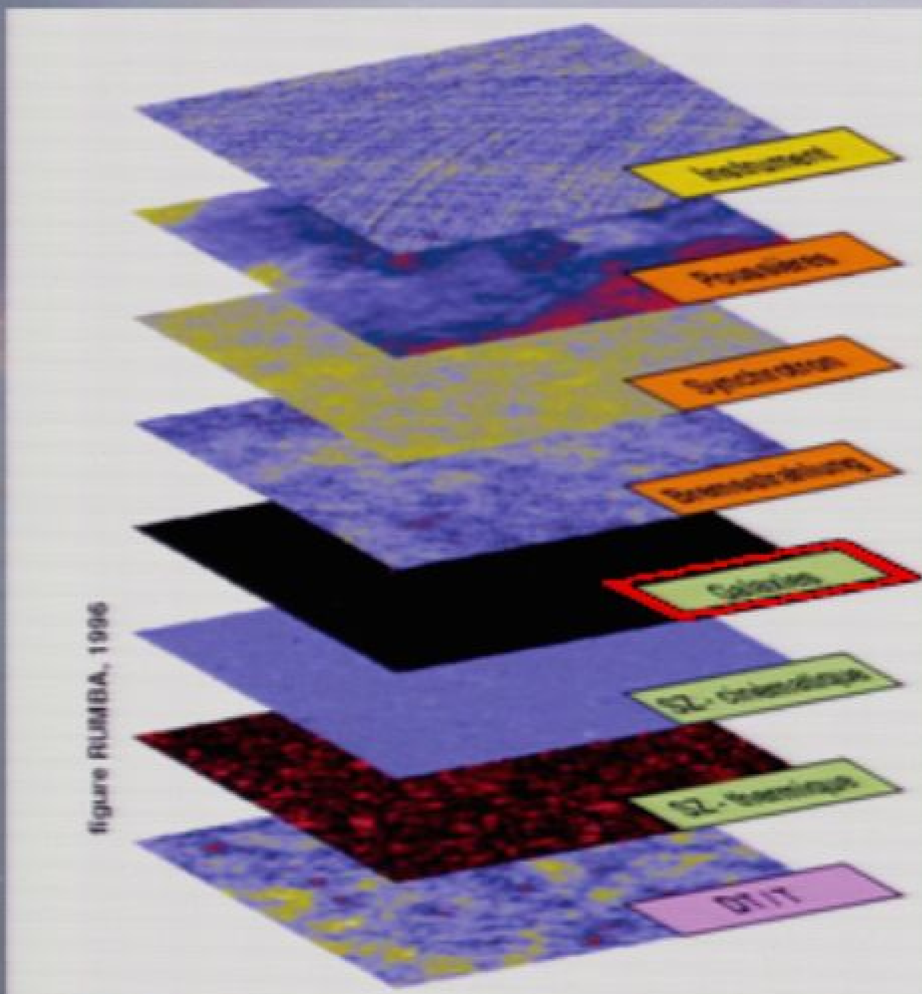
Cosmology & foregrounds



Description

- CMB OK
- SZ ~OK with limitations

Cosmology & foregrounds



Description

- CMB OK
- SZ ~OK with limitations
- Point sources !!
- Huge effort in CBI, SZA, SPT ...
- Potentially cosmological information too

Conclusions

- Using CMB data (including SZ) is not so easy
- Taking full cosmology dependency of SZ power spectrum allows better determination of cosmological parameters
- Cluster cosmology linked to cluster astrophysics
- Sensitivity of gas properties will go down with our increasing knowledge of clusters
- Next step is point sources *(should depend on cosmology too)*

MAY 14th 2009 !!

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