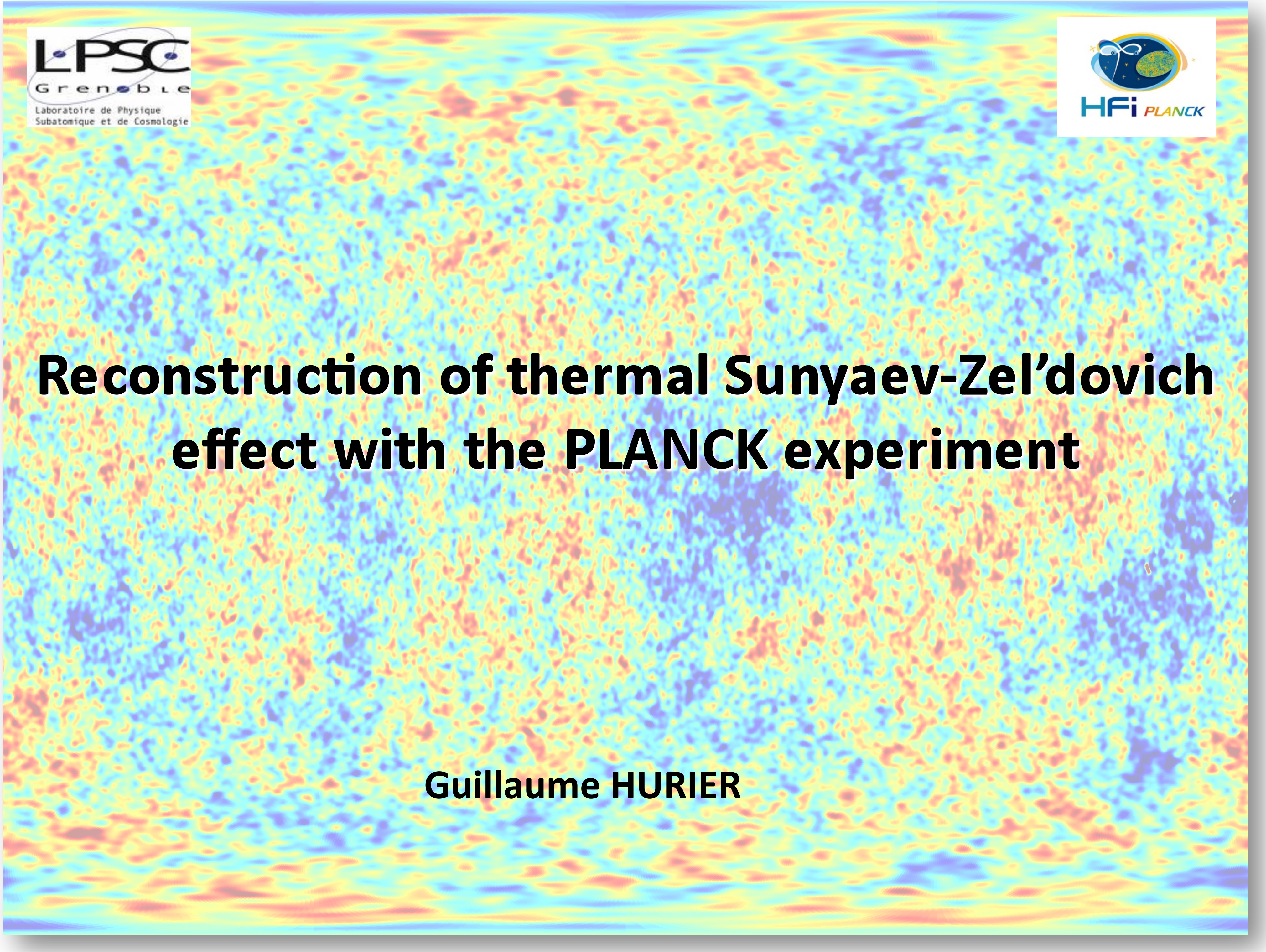


LPSC
Grenoble
Laboratoire de Physique
Subatomique et de Cosmologie

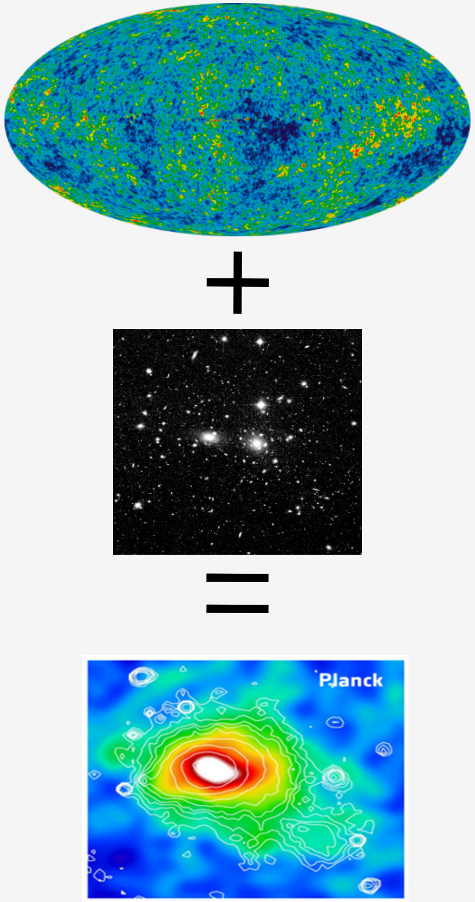
HFi PLANCK

Reconstruction of thermal Sunyaev-Zel'dovich effect with the PLANCK experiment

Guillaume HURIER

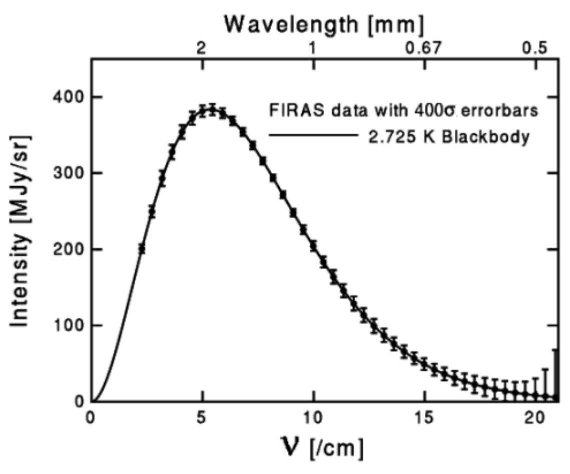
Outline

- Introduction
  - Cosmic Microwave Background
  - Galaxy clusters
  - PLANCK experiment
- Extraction of tSZ effect
  - MILCA (Hurier et al. 2010)
  - Application to simulated data
- PLANCK early results
  - New clusters discovery
  - ESZ catalog



Cosmic microwave background (CMB)

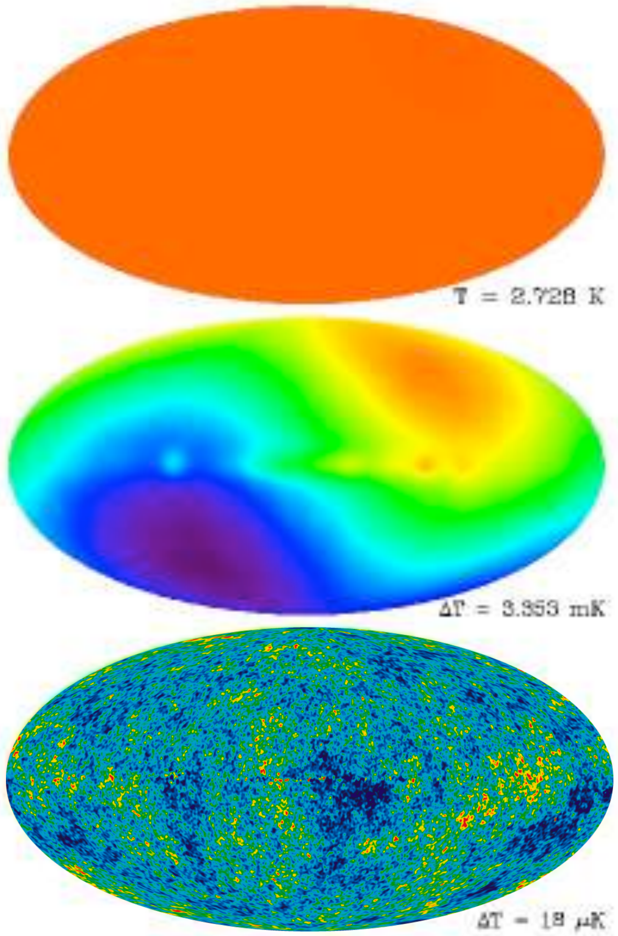
Isotropic and homogenous radiation at 2.725 K



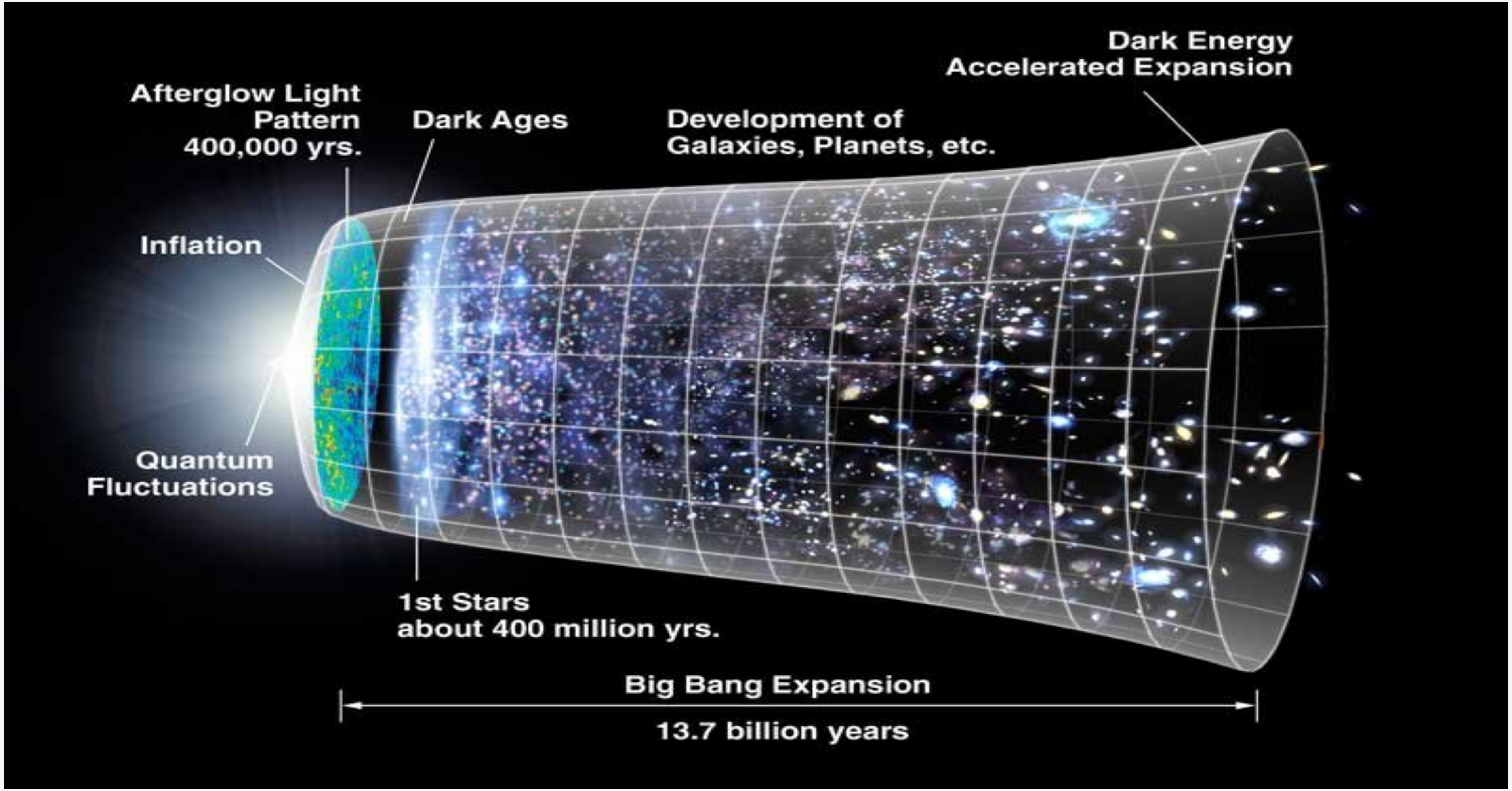
Black body radiation as mesured by COBE

Dipole : produced by the observator velocity in the CMB referential

Temperature anisotropies strongly depend on cosmological models



Universe history



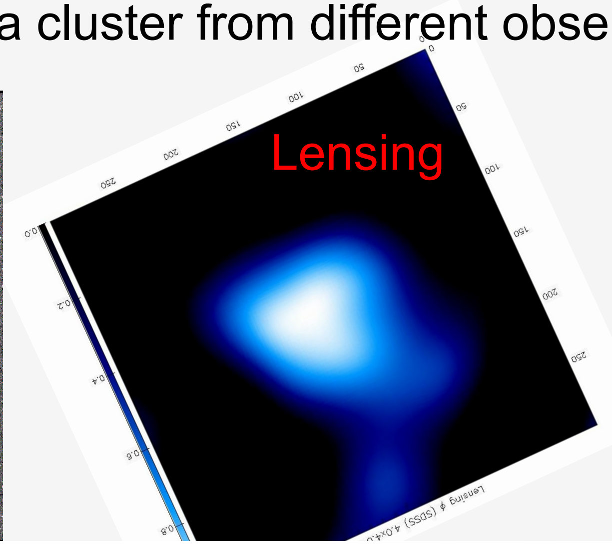
Galaxy clusters
Formation and observables

Formation bottom-up model : small structures → large structures

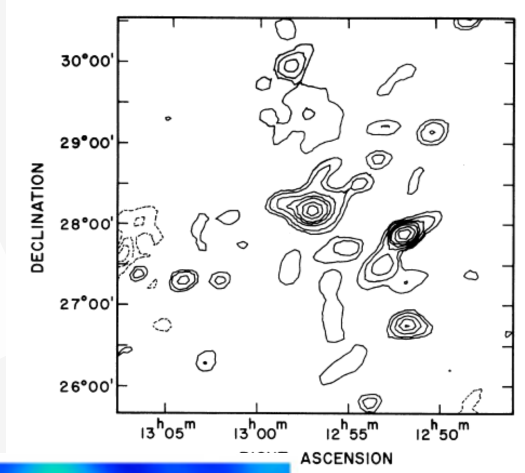
The Coma cluster from different observables

Optique

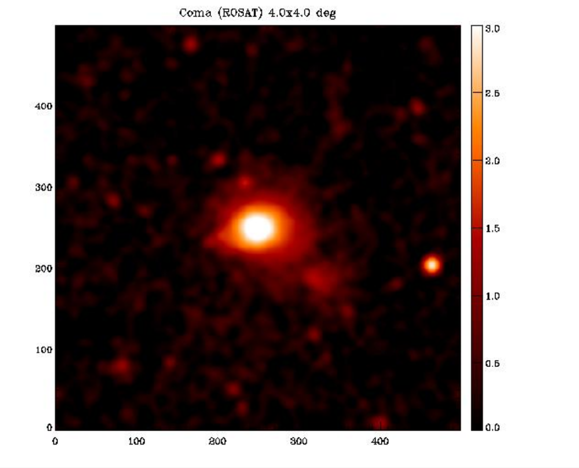
Lensing



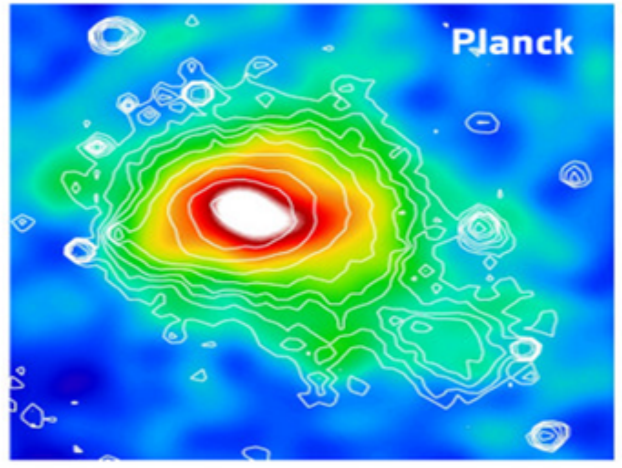
Radio



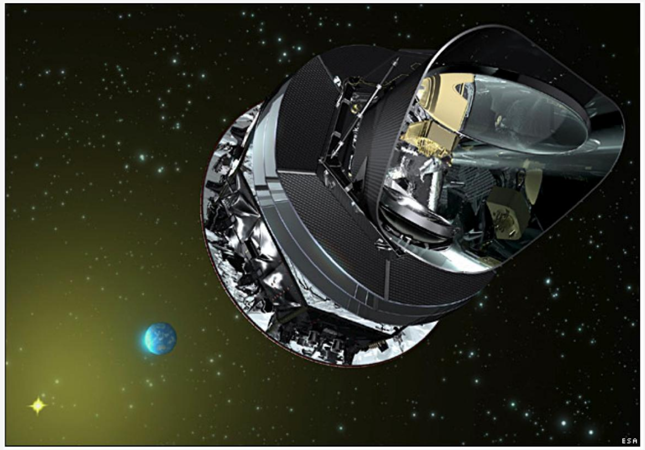
X-rays



TSZ



The PLANCK experiment



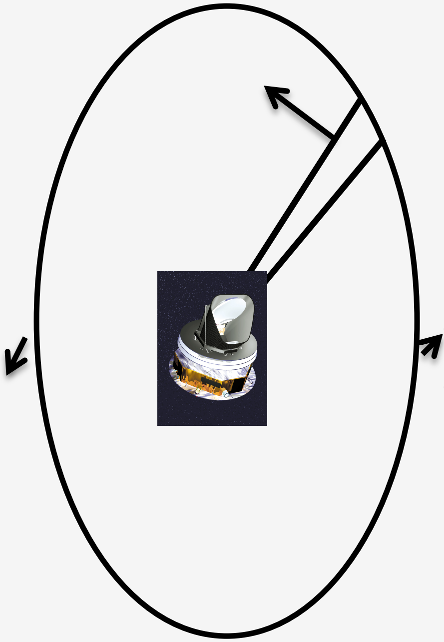
Launch the 14th May 2009
At L2 point of Earth/Solar system

2 instruments :
LFI : radiometers
HFI : bolometers at 0.1 K

9 frequency channels :
LFI : 30, 44, 70 GHz
HFI : 100, 143, 217, 353, 545 and 857 GHz

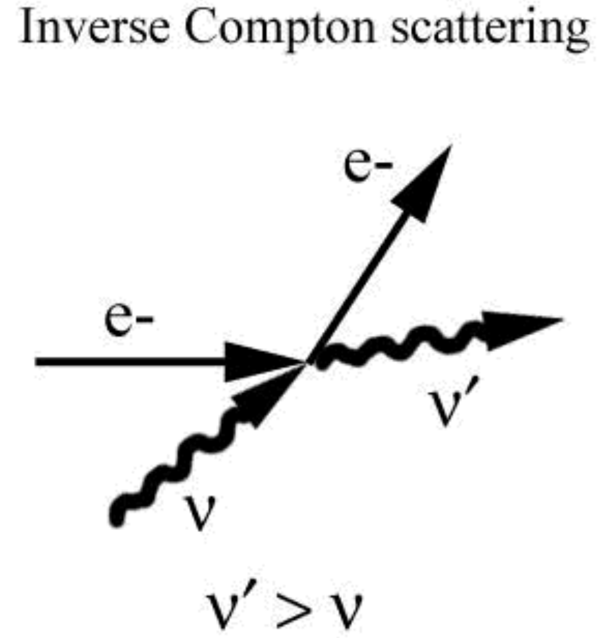
Nominal mission :
2 full sky coverage
Actually : 4th coverage almost completed

Pointing strategy:



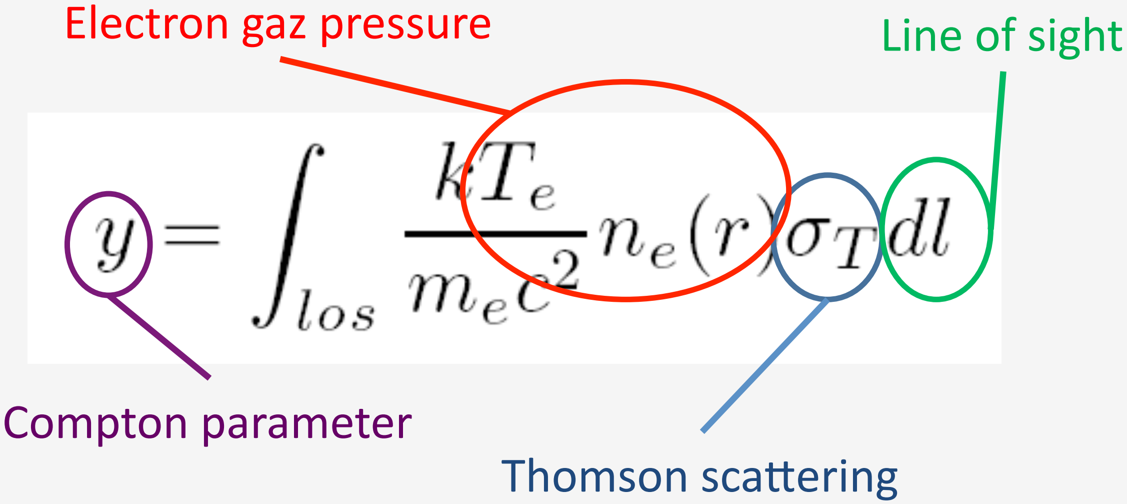
1 ring ~ 40 observations of the same sky area

Interaction between clusters and CMB:
tSZ effect



Shift of the electromagnetic spectrum

The intensity of tSZ is proportionnal to the integration of the pressure ($T_e n_e$) on the line of sight



Electron gaz pressure

Line of sight

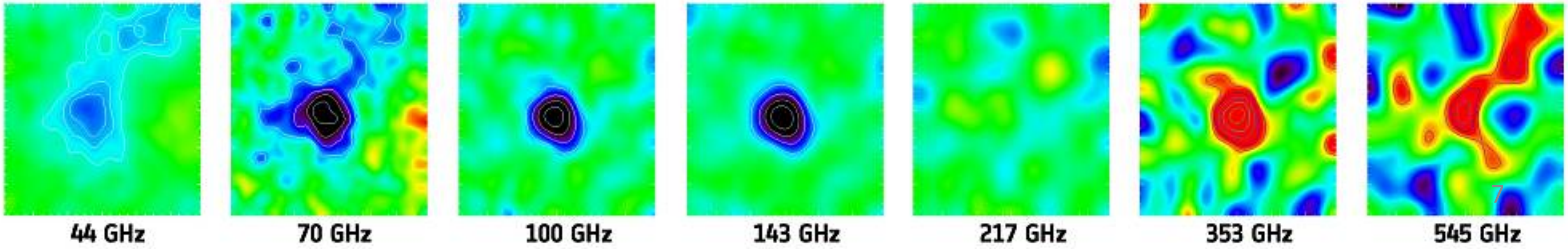
$$y = \int_{los} \frac{kT_e}{m_e c^2} n_e(r) \sigma_T dl$$

Compton parameter

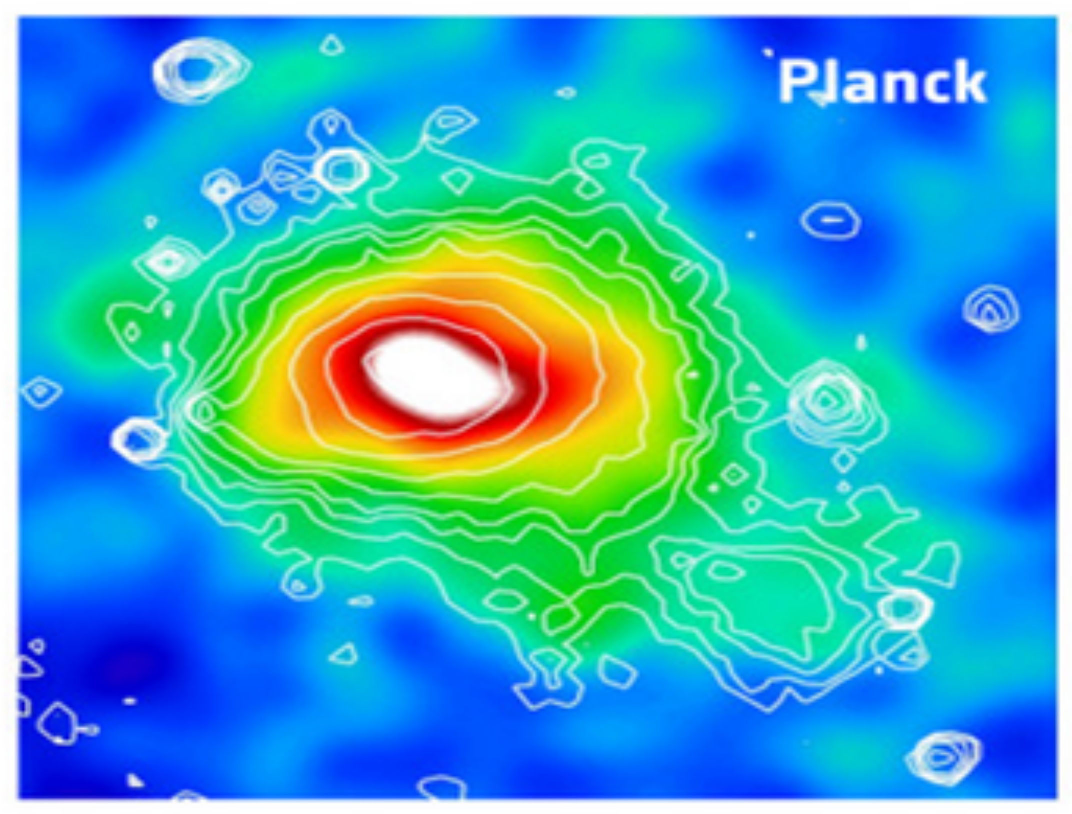
Thomson scattering

Frequency dependance ΔT = y*f(v)

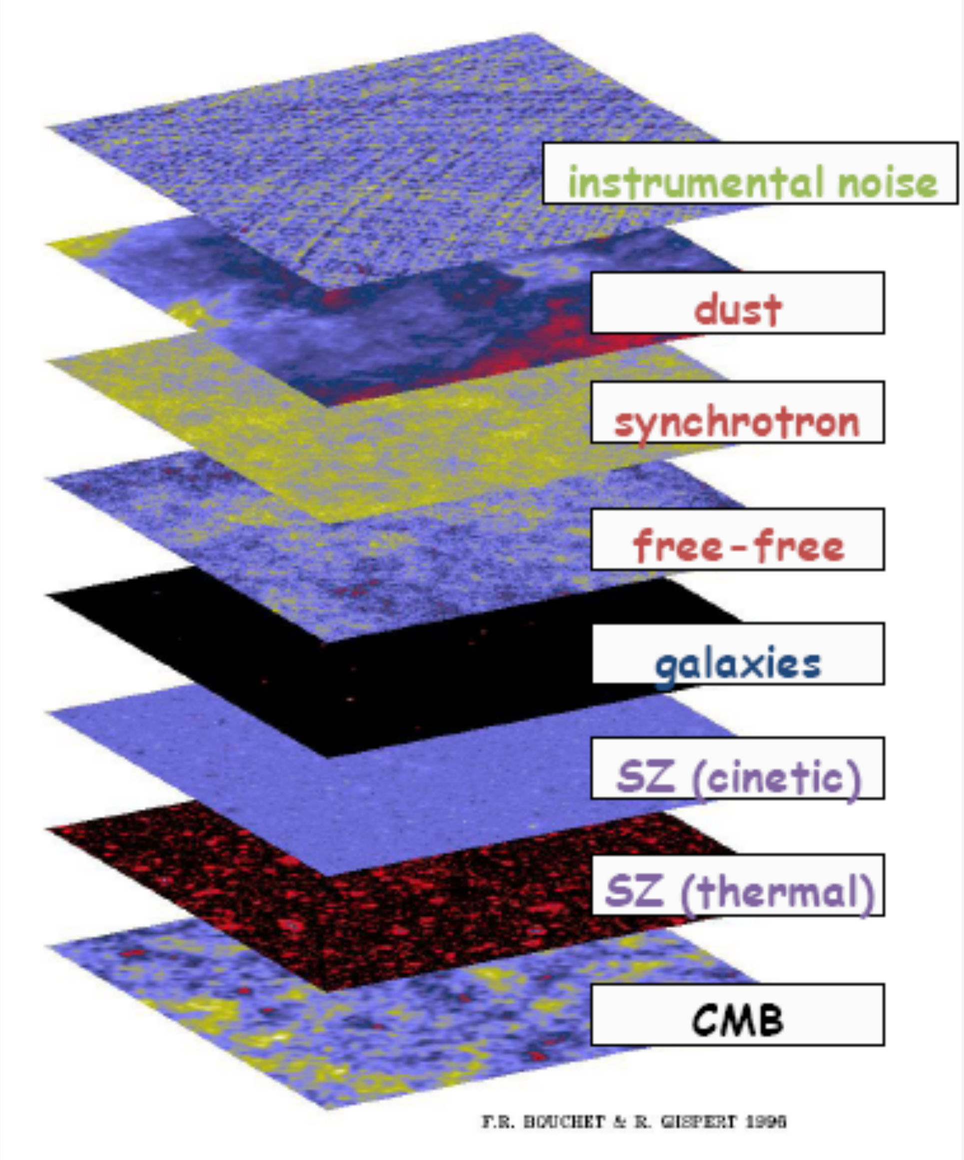
Abell 2319 in PLANCK data (cleaned maps)



Extraction of the tSZ effect



The microwave sky composition



F.R. BOUCHET & R. GISPERT 1996

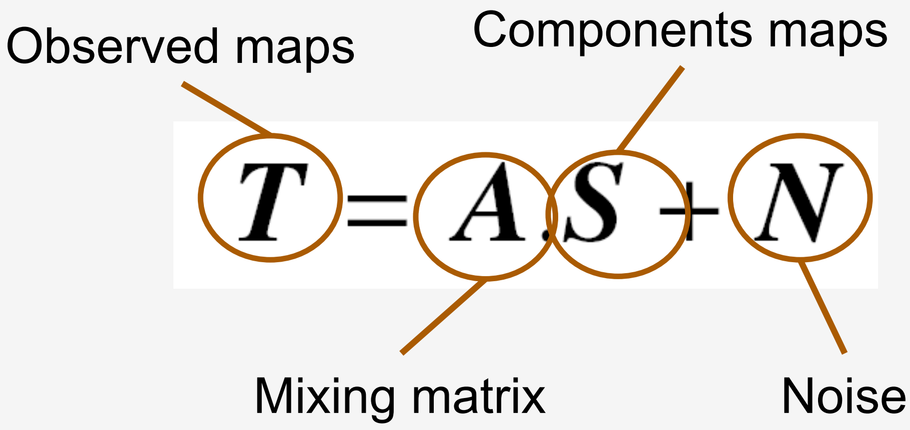
MILCA

Hurier et al. 2010, arXiv:1007.1149

MILCA (MODIFIED INTERNAL LINEAR COMBINATION ALGORITHM) :

WE INTEND TO EXTRACT A PHYSICAL COMPONENT FROM A MULTI-FREQUENCY OBSERVATION

Assumption : Each observed channel can be written as a linear combination of several components



$$T = A.S + N$$

1) Constraint on the electromagnetic spectrum of the reconstructed map

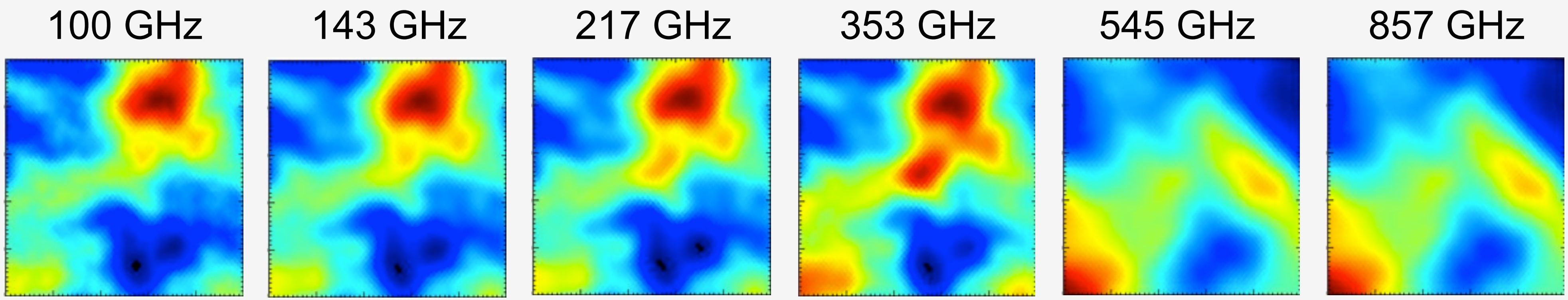
2) Constraint(s) on other component(s) spectrum to be removed

3) Reduction of bias by introducing prior information about the noise

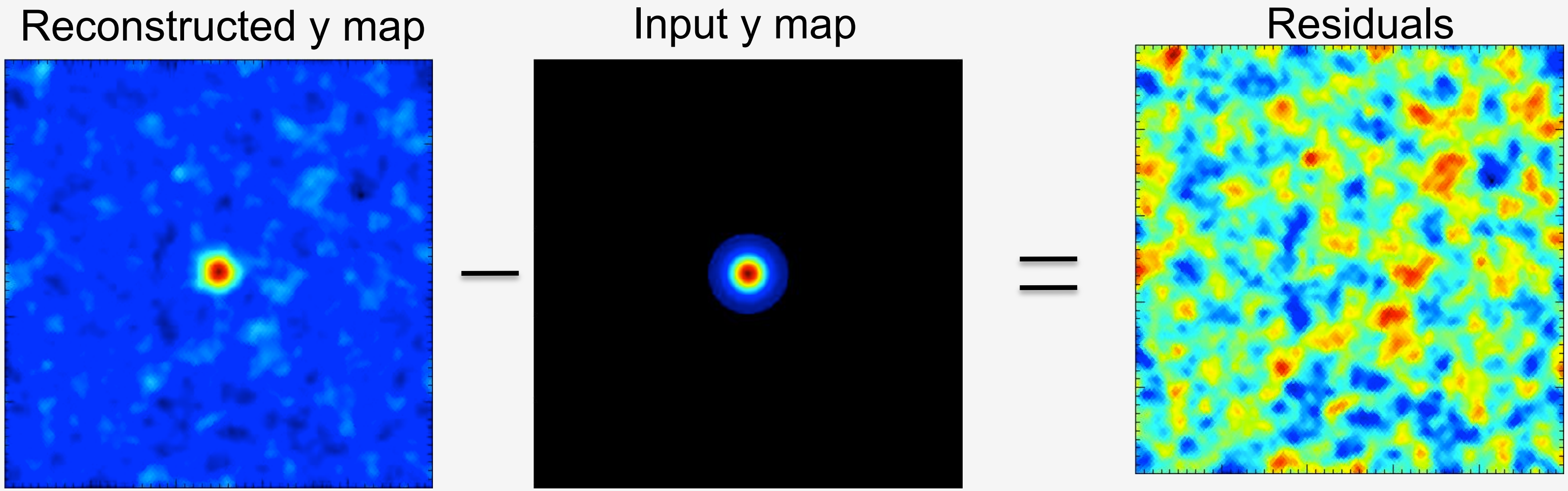
4) Minimization of the covariance matrix in the sub-space of extractible components.

5) Minimization of instrumental noise with remaining degrees of freedom

Reconstruction of tSZ on PLANCK simulations


100 GHz 143 GHz 217 GHz 353 GHz 545 GHz 857 GHz

Patch 2 by 2 degrees


Reconstructed y map − Input y map = Residuals

Estimation of errors

Statistical errors :

I) Compute noise map using PLANCK scanning strategy

II) Compute effective hit map for the tSZ constructed map

III) Compute power spectrum of the noise map

IV) Perform MC simulation of noise

Systematic errors :

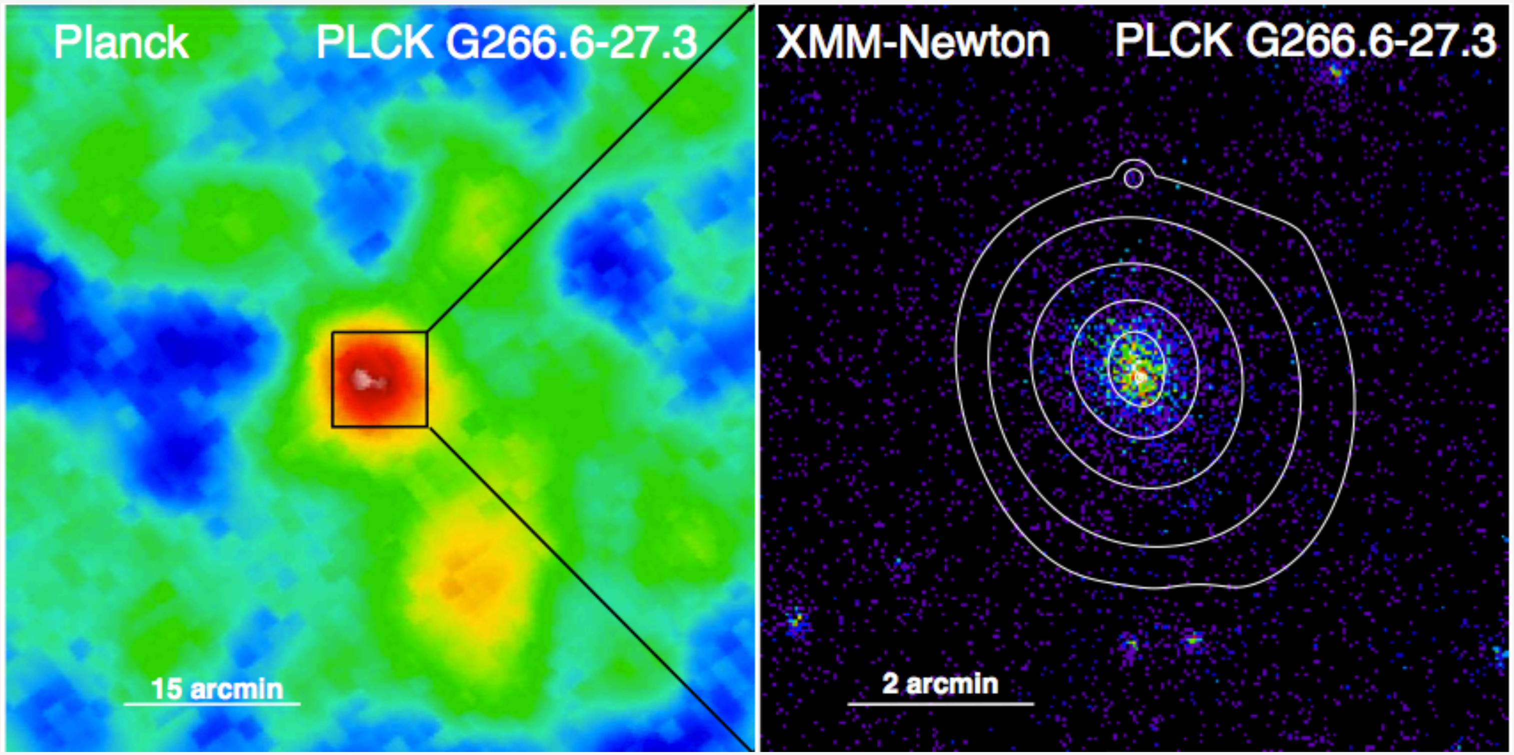
I) Calibration uncertainties

II) Relativistic correction of tSZ spectrum

III) Other components residuals

High z cluster detection

Used (in complement of several methods) :
- in the ESZ (PLANCK SZ catalog) validation process
- in the XMM follow up target selection

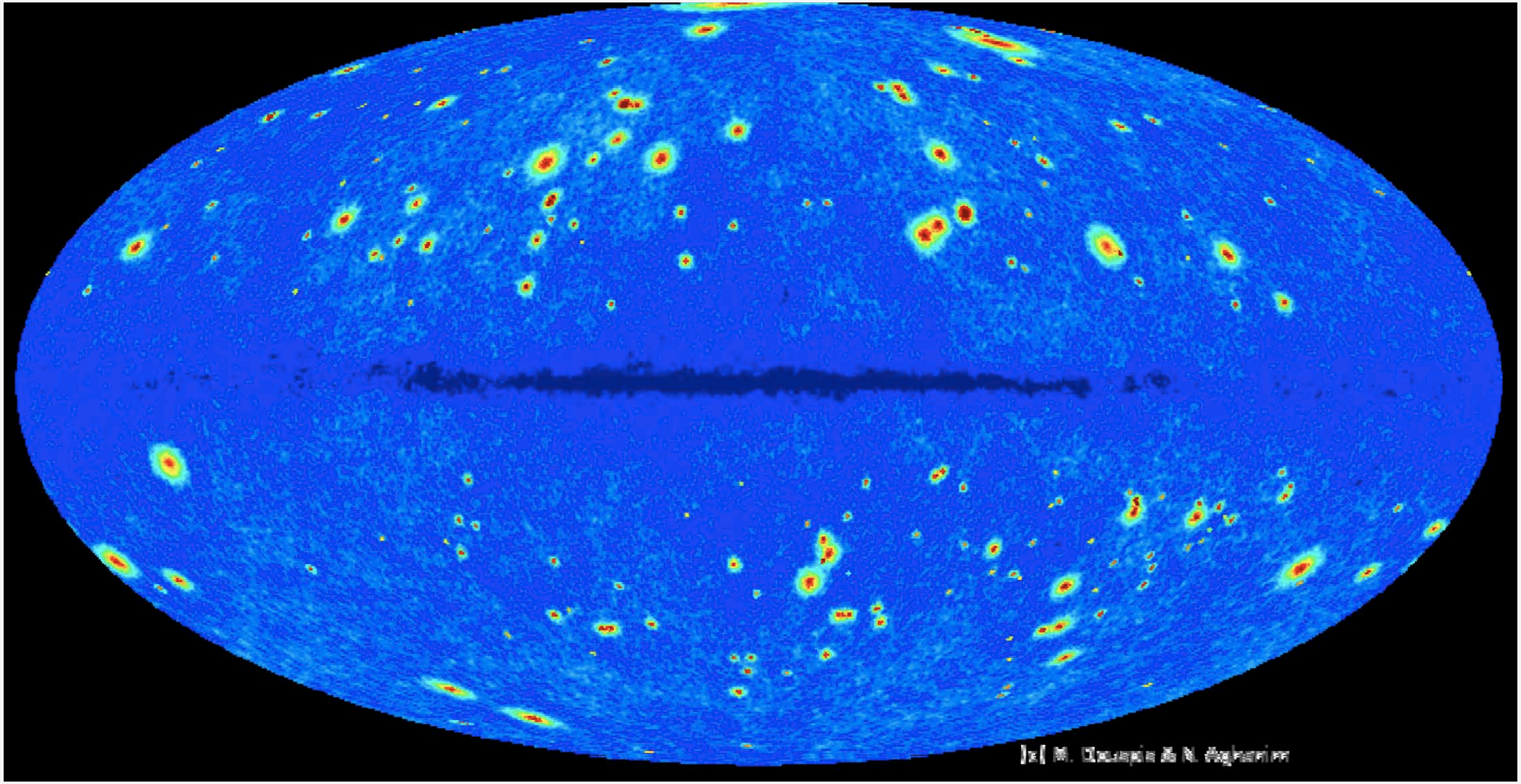


Y_{500} = (4.1 +/- 0.9) 10^{-4} arcmin^2

z ~ 1

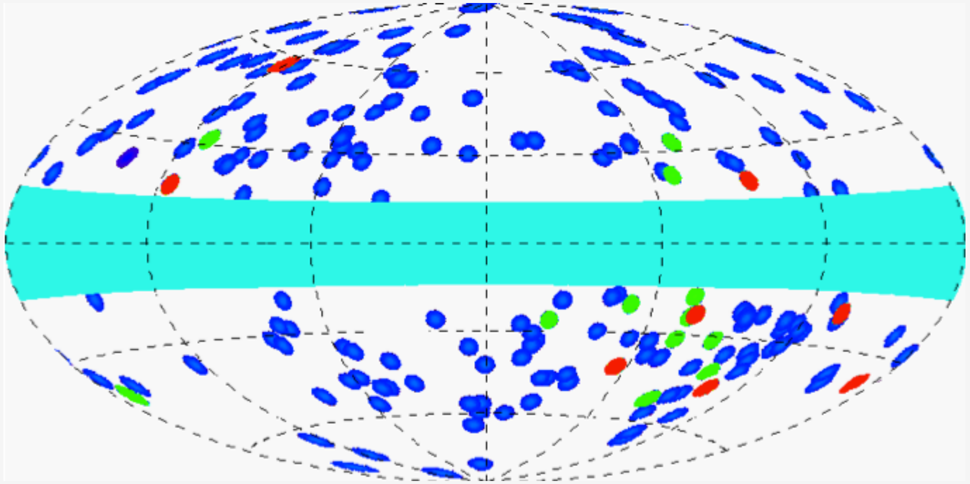
The PLANCK collaboration, arXiv : 1106.1376v2

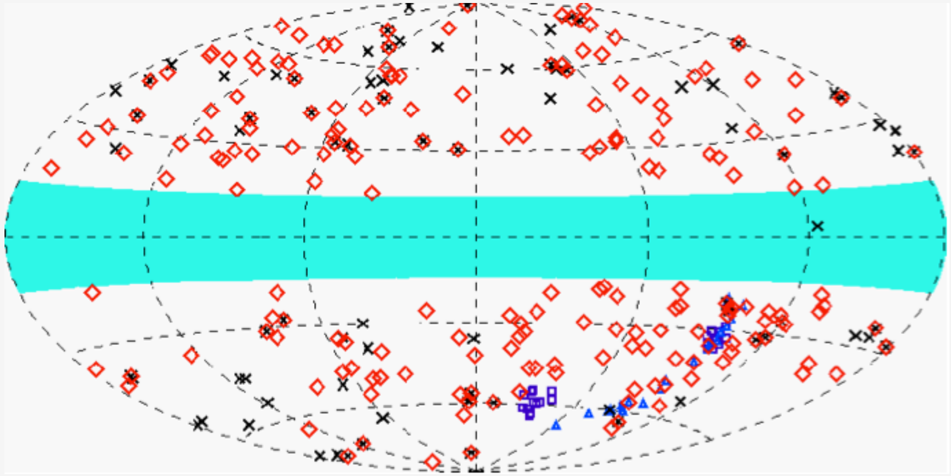
Detection of tSZ with PLANCK



Early SZ catalog

Ref : The Planck Collaboration 2011 Early paper





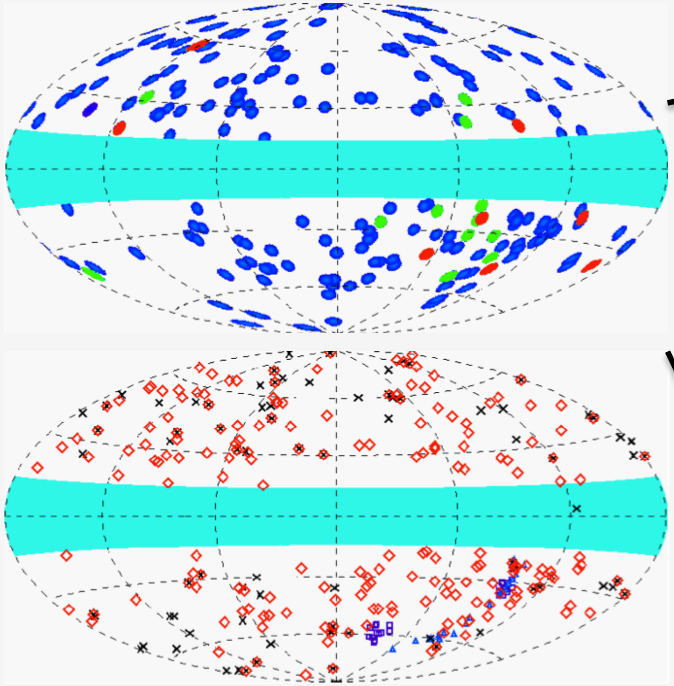
Position of 189 clusters of the catalog :

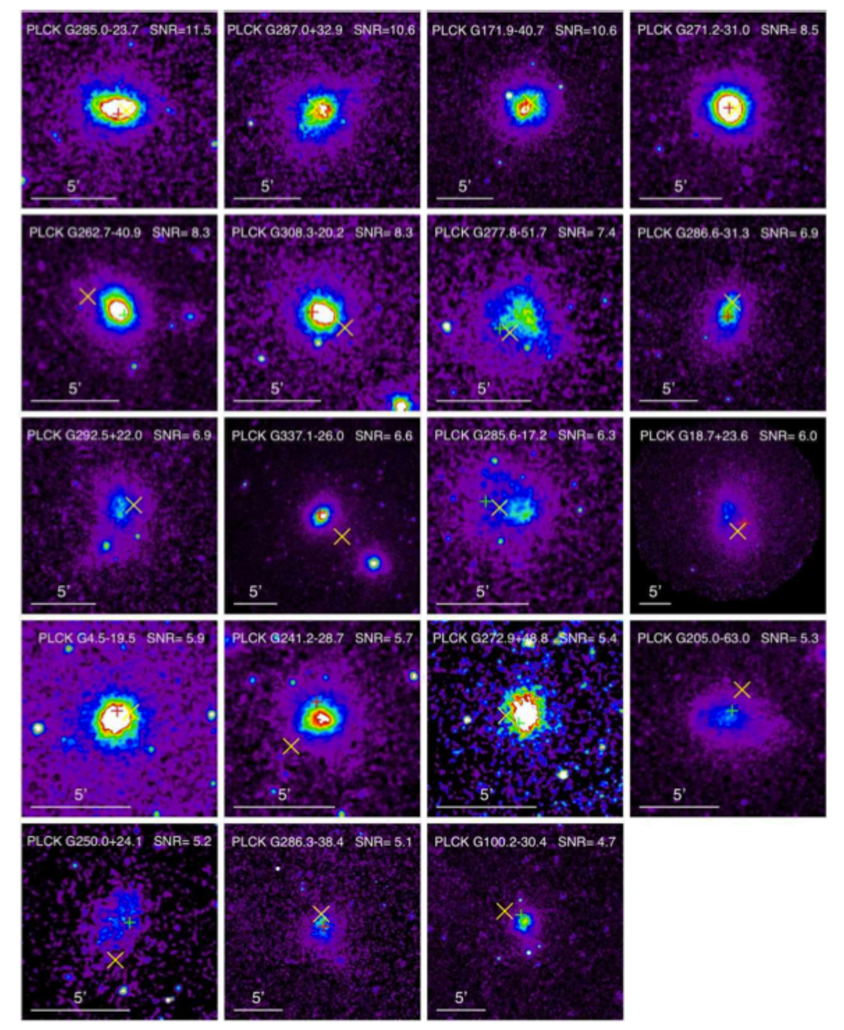
- Known X-ray clusters
- New clusters, validated in X-ray (19)
- New clusters (8)

Planck ESZ sample versus other tSZ experiments

Reliability, robustness

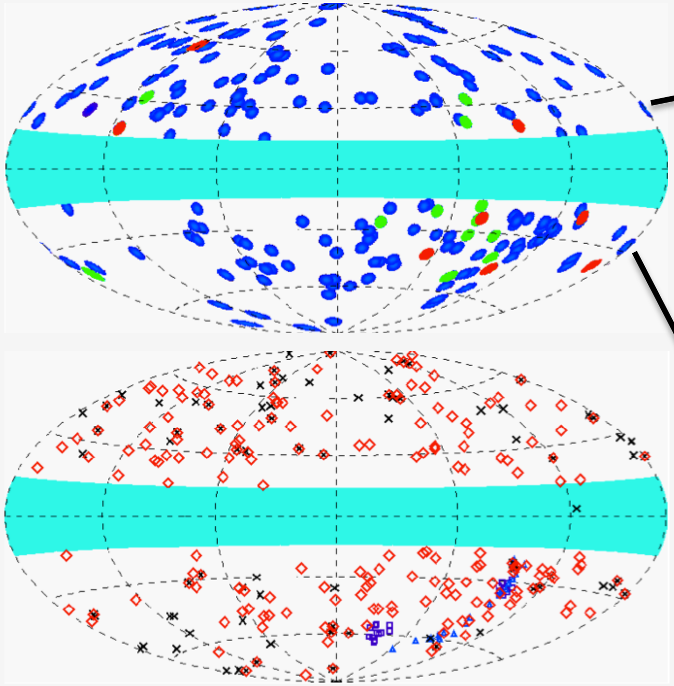
XMM follow up

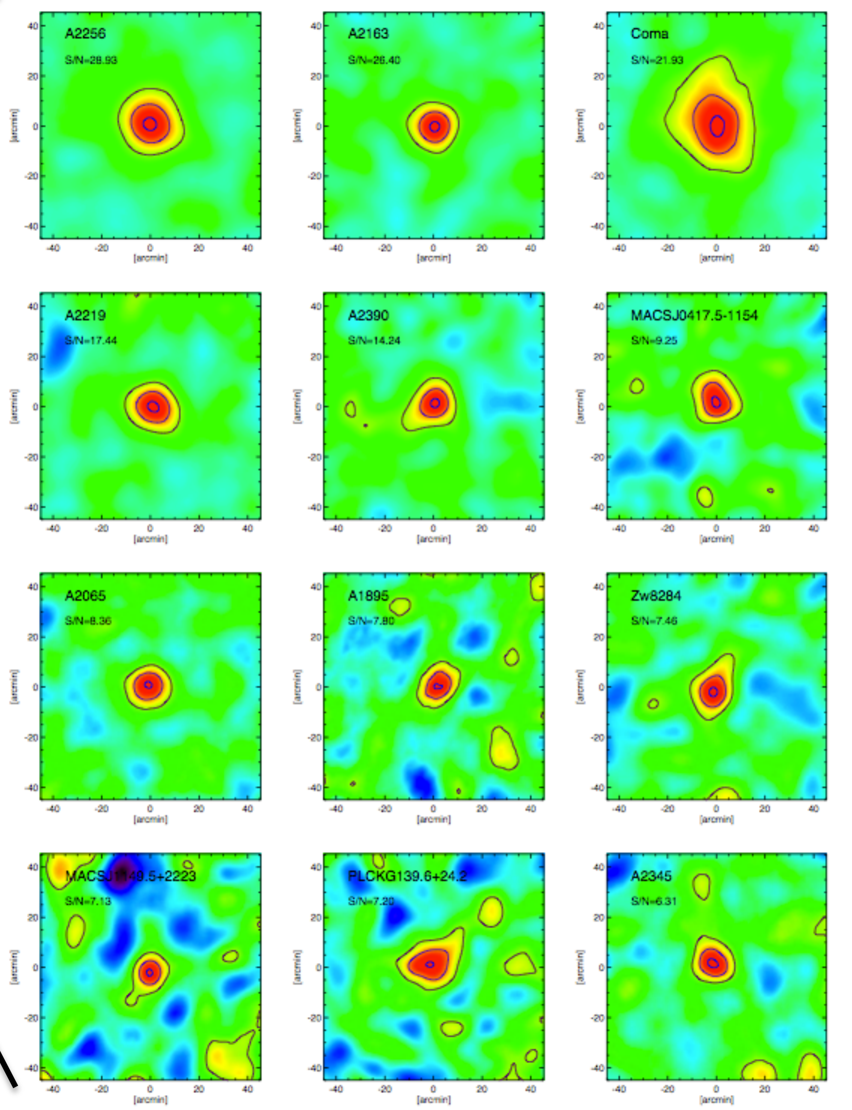




X-ray counterpart for the 19 validated clusters discovered by PLANCK

ESZ catalogue



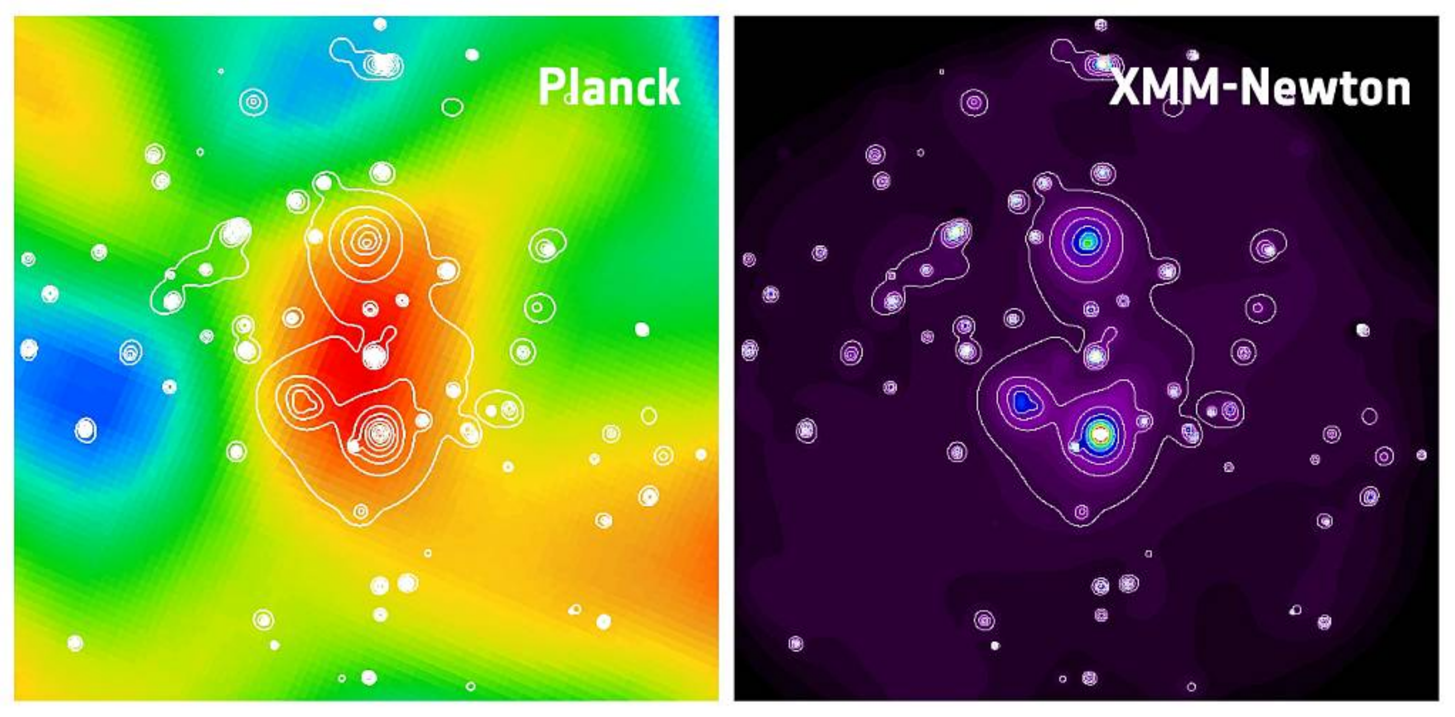


Redshift → Clusters Mass

Mass + selection function →
Matter power spectrum →
cosmological parameters

Conclusions

- tSZ effect can be extract with from PLANCK data with high signal to noise ratio and allow the detection of new clusters.



- MILCA allow a low noise, low bias reconstruction of tSZ effect.

- The ESZ sample present a unique dataset of cluster across the full sky with high reliability and high robustness.

THANKS

Questions

?

MILCA

Hurier et al. 2010, arXiv:1007.1149

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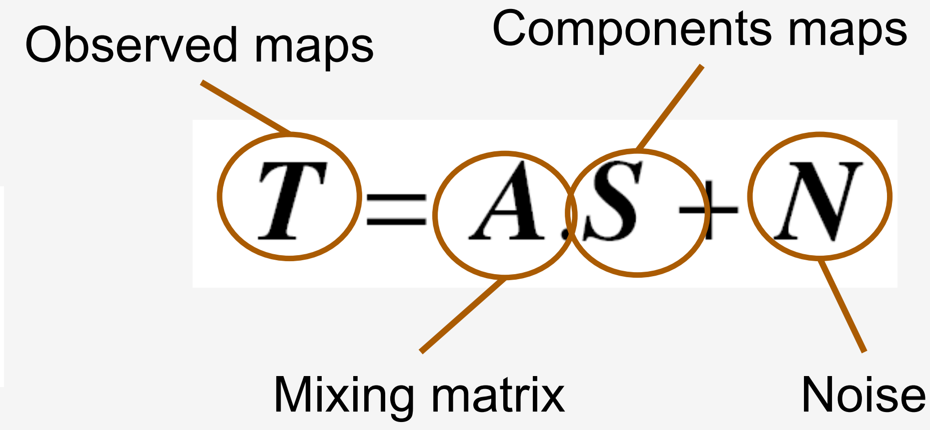


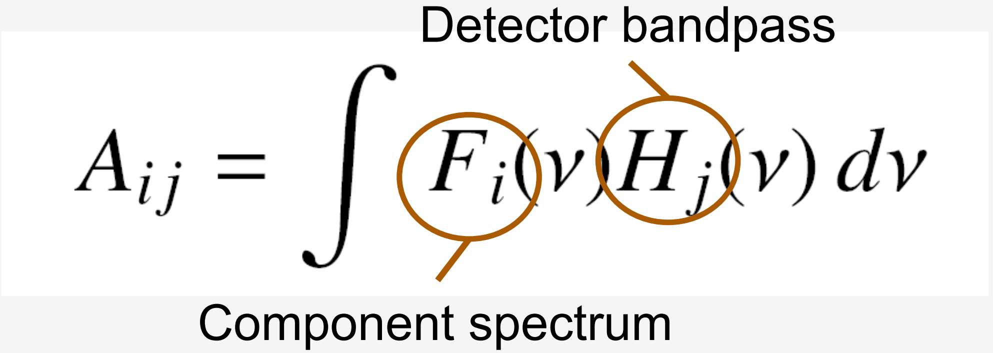
Observed maps

Components maps

$$T = A . S + N$$

Mixing matrix

Noise



Detector bandpass

$$A_{ij} = \int F_i(\nu) H_j(\nu)\, d\nu$$

Component spectrum

MILCA

So far we search a solution in the form of a linear combination of observed channels

$$S_c = \boldsymbol{w}^T . \boldsymbol{T},$$

1)Constraint on the electromagnetic spectrum of the reconstructed map

$$g = \sum_i f_i w_i = 1,$$

2)Minimisation of the variance

3)Constraint(s) on other componen(s) spectrum to be removed

$$\begin{pmatrix} 2.C_T & -f \\ f^T & 0 \end{pmatrix} \begin{pmatrix} w \\ \lambda \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

MILCA

So far we search a solution in the form of a linear combination of observed channels

$$S_c = w^T.T,$$

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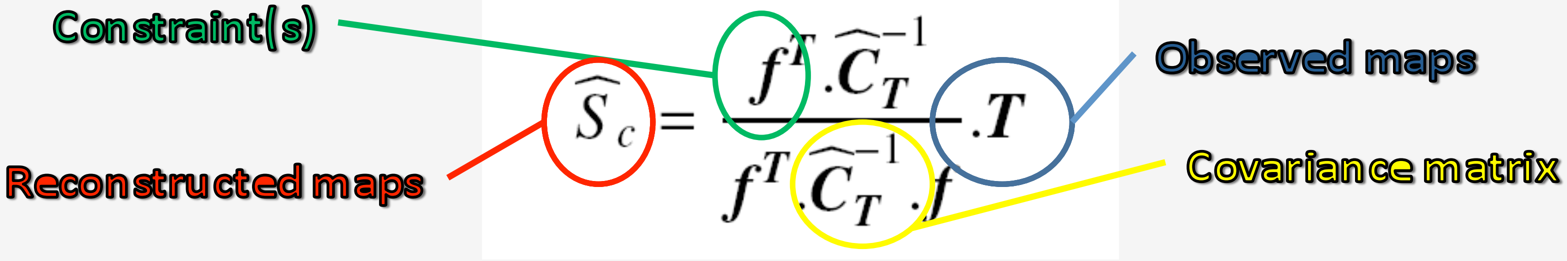
$$\begin{pmatrix} 2.C_T & -f \\ f^T & 0 \end{pmatrix}\begin{pmatrix} w \\ \lambda \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

3)Constraint(s) on other componen(s) spectrum to be removed



Constraint(s)

Observed maps

$$\widehat{S}_c = \frac{f^T.\widehat{C}_T^{-1}}{f^T.\widehat{C}_T^{-1}.f}.T$$

Reconstructed maps

Covariance matrix

MILCA

Covariance matrix of components

$$C_T = A.C_S.A^T + C_N,$$

Covariance matrix of observated channels

Noise covariance matrix

$$\widehat{S}_c = S_c + \frac{1}{\left(\widehat{C_S^{-1}}\right)_{cc}} . \sum_{j \neq c} \left(\widehat{C_S^{-1}}\right)_{cj} .S_j$$

Constraint(s)

Reconstructed maps

$$\widehat{S}_c = \frac{f^T.\widehat{C_T}^{-1}.T}{f^T.\widehat{C_T}^{-1}.f}$$

Observed maps

Covariance matrix

MILCA

Covariance matrix of components

$$C_T = A.C_S.A^T + C_N,$$

Covariance matrix of observated channels

Noise covariance matrix

$$\widehat{S}_c = S_c + \frac{1}{\left(\widehat{C_S^{-1}}\right)_{cc}} . \sum_{j\neq c} \left(\widehat{C_S^{-1}}\right)_{cj} .S_j$$

Estimation of C_N :

-Using scan strategy (redundancy)

4)Reduction of bias by introducing
Prior information about the noise

$$\tilde{C}_T = C_T - C_N$$

Constraint(s)

Reconstructed maps

$$\widehat{S}_c = \frac{f^T.\widehat{C}_T^{-1}}{f^T.\widehat{C}_T^{-1}.f}.T$$

Observed maps

Covariance matrix

MILCA

Singular value decomposition

$$\widetilde{C}_T = UDU^T$$

5)Minimization of the covariance matrix in the sub-space of extractible components.

$$\hat{C}_T = U \left[\begin{array}{c|c} D_{i,j} & 0 \\ \hline 0 & 0 \end{array}\right] U^T$$

Constraint(s)

Reconstructed maps

$$\widehat{S}_c = \frac{f^T.\widehat{C_T}^{-1}.T}{f^T.\widehat{C_T}^{-1}.f}$$

Observed maps

Covariance matrix

MILCA

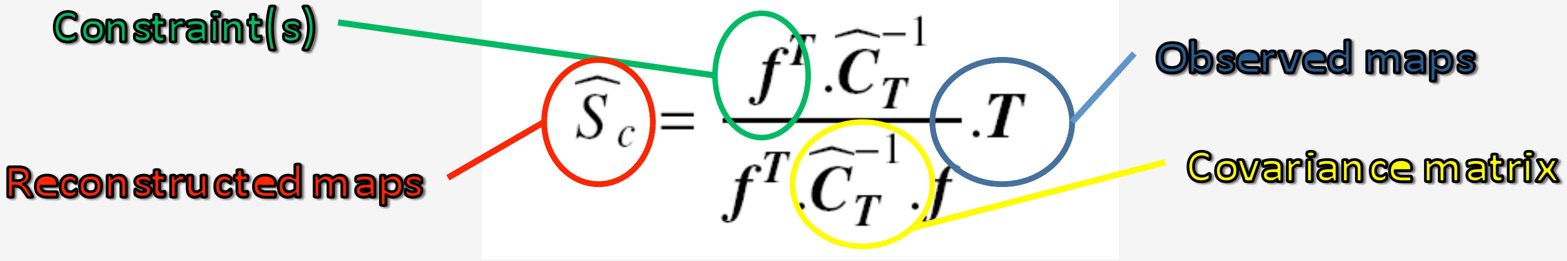
Singular value decomposition

$$\tilde{C}_T = UDU^T$$

$$\hat{C}_T = U \left[\begin{array}{c|c} D_{i,j} & 0 \\ \hline 0 & (U^T C_N U)_{i,j} \end{array}\right] U^T$$

5)Minimization of the covariance matrix in the sub-space of extractible components.

6)Minization of instrumental noise with Remaining degrees of freedom



Constraint(s)

Observed maps

$$\widehat{S}_c = \frac{f^T.\widehat{C}_T^{-1}}{f^T.\widehat{C}_T^{-1}.f}.T$$

Covariance matrix

Reconstructed maps

Estimation of statistical errors

I) Compute noise map using PLANCK scanning strategy

II) Compute effective hit map for the tSZ constructed map

<u>Ideal case : white noise assumption</u>

III) Using hit map to determine the σ by pixel by hit

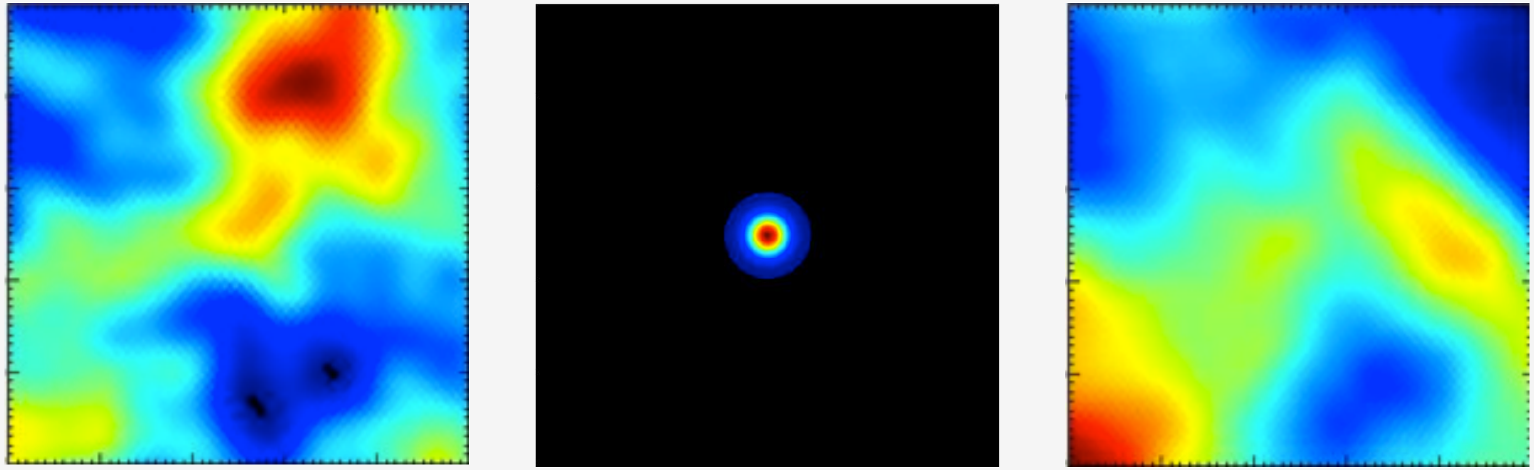
<u>real case : correlated noise</u>

III) Compute power spectrum of the noise map

IV) Perform MC simulation of noise

Erreur syste

Reconstruction of tSZ on PLANCK simulations



CMB

tSZ

Y_{500} = 1.3 10^{-3} arcmin^2

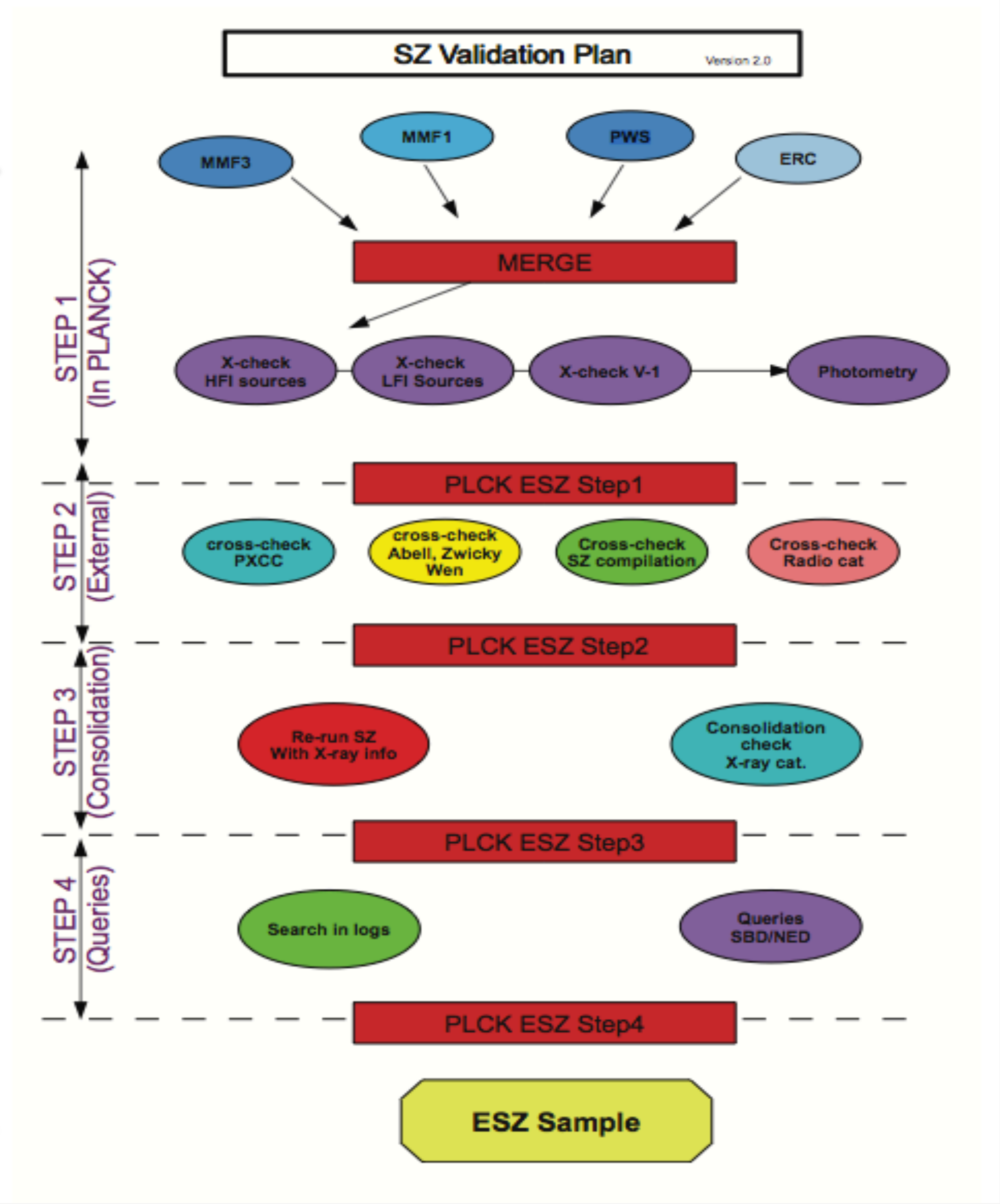
Dust

(T = 17K, β_d =1.8)

+ NOISE (4 surveys)

All frequency maps are set to a common resolution
before performing the separation

New data


SZ Validation Plan
Version 2.0
MMF3
MMF1
PWS
ERC
MERGE
STEP 1 (In PLANCK)
X-check HFI sources
X-check LFI Sources
X-check V-1
Photometry
PLCK ESZ Step1
STEP 2 (External)
cross-check PXCC
cross-check Abell, Zwicky Wen
Cross-check SZ compilation
Cross-check Radio cat
PLCK ESZ Step2
STEP 3 (Consolidation)
Re-run SZ With X-ray info
Consolidation check X-ray cat.
PLCK ESZ Step3
STEP 4 (Queries)
Search in logs
Queries SBD/NED
PLCK ESZ Step4
ESZ Sample