Joint analysis of Archeops and WMAP observations of the CMB

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for the Archeops collaboration

The Archeops balloon borne experiment

Collaboration :
France : IAP, PCC-CdF (Paris), IAS, LAL (Orsay), CRTBT, LAOG, LPSC (Grenoble), DAPNIA/SPP (CEA), CESR/LAOMP (Toulouse)
United Kingdom : Queen Mary College
Italy : University of Rome, Florence, ASI
USA : Caltech, JPL, University of Minnesota

Main points:

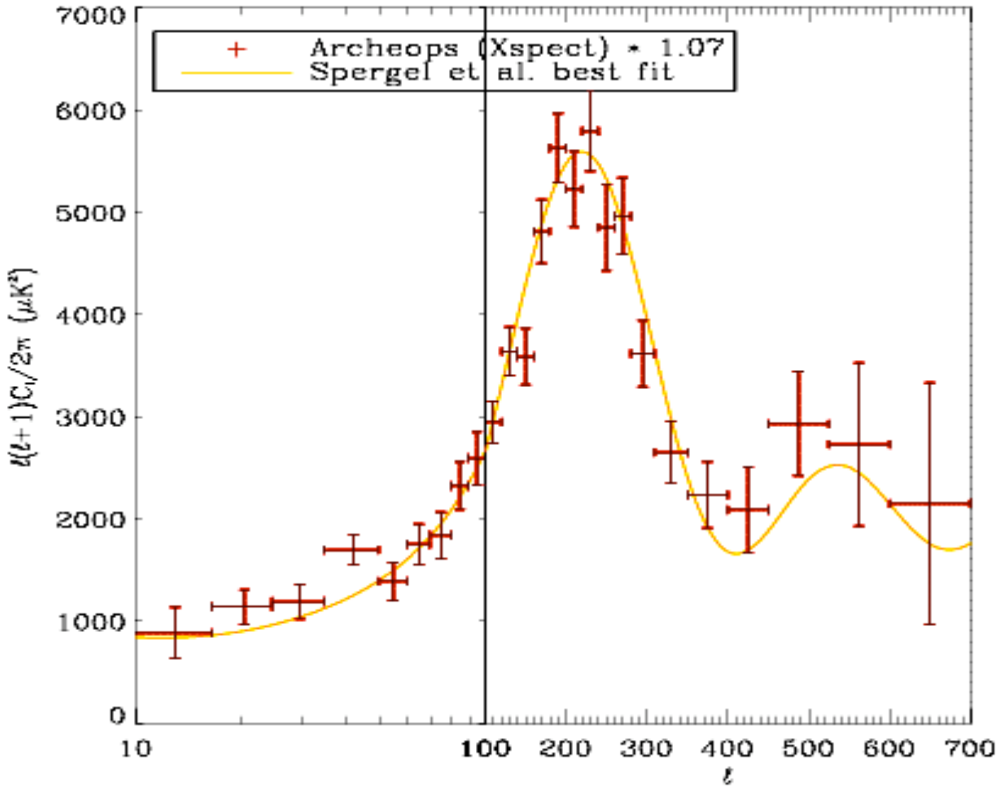
- large sky coverage ~ 30%
- angular resolution ~ 10′

→ wide range of angular scales covered $30 < l < 300$

- 22 spider web bolometers cooled to 100 mK → testbed for Planck HFI
- 4 frequencies: 143, 217, 353 and 545 GHz → systematic control, foregrounds separation

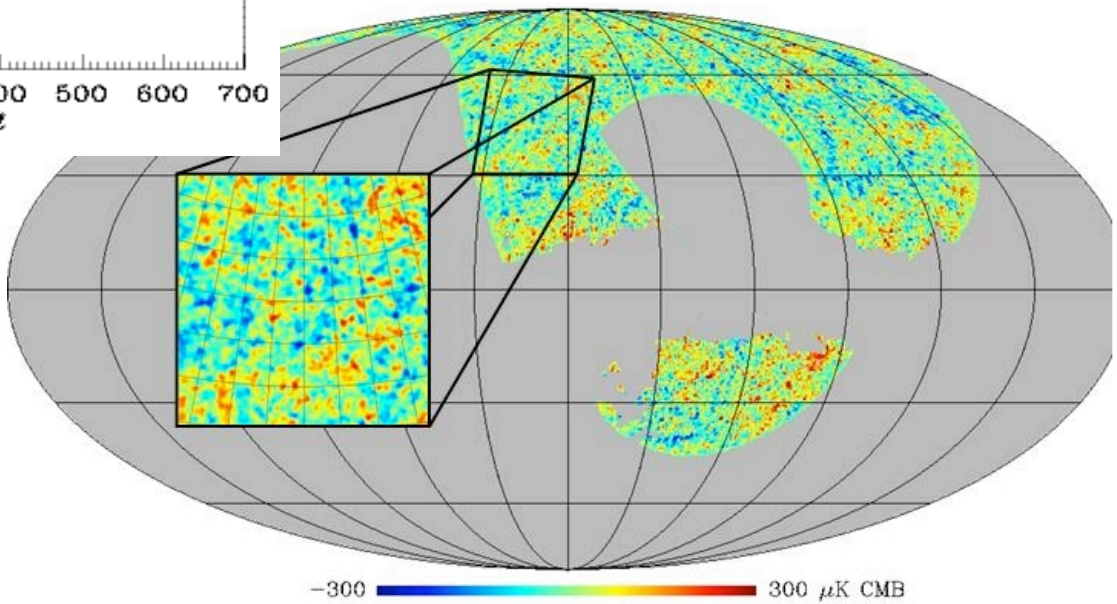
  polarimeters at 353 GHz → dust polarization

Main Archeops CMB results



Scientific flight February 2002,
12 hours of data

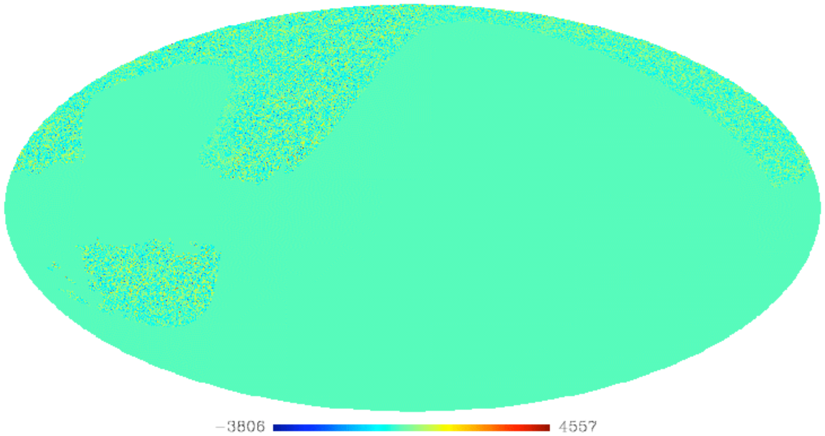
- ✓ Best measurement of the first acoustic peak before WMAP
- ✓ first link between COBE and small scale experiments

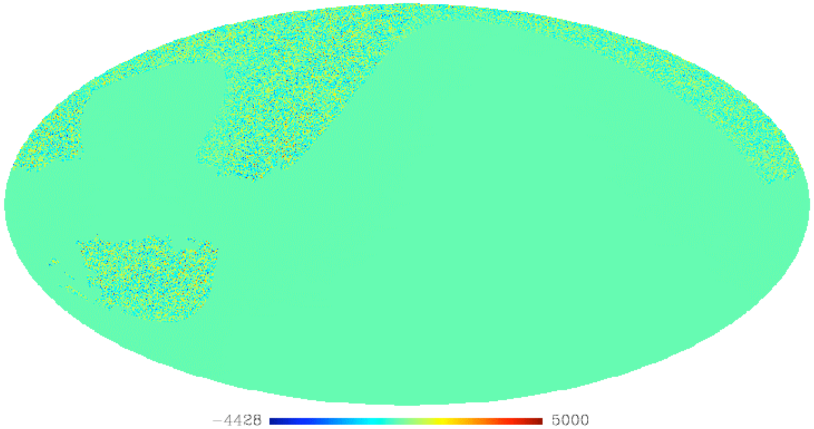


Why a joint analysis between Archeops and WMAP

- To check the compatibility of CMB anisotropies in a wide range of frequencies, from 41 to 217 GHz
- To look for possible residual foreground emission and systematics in maps
- To better constrain SZ emission in WMAP data

Data sets





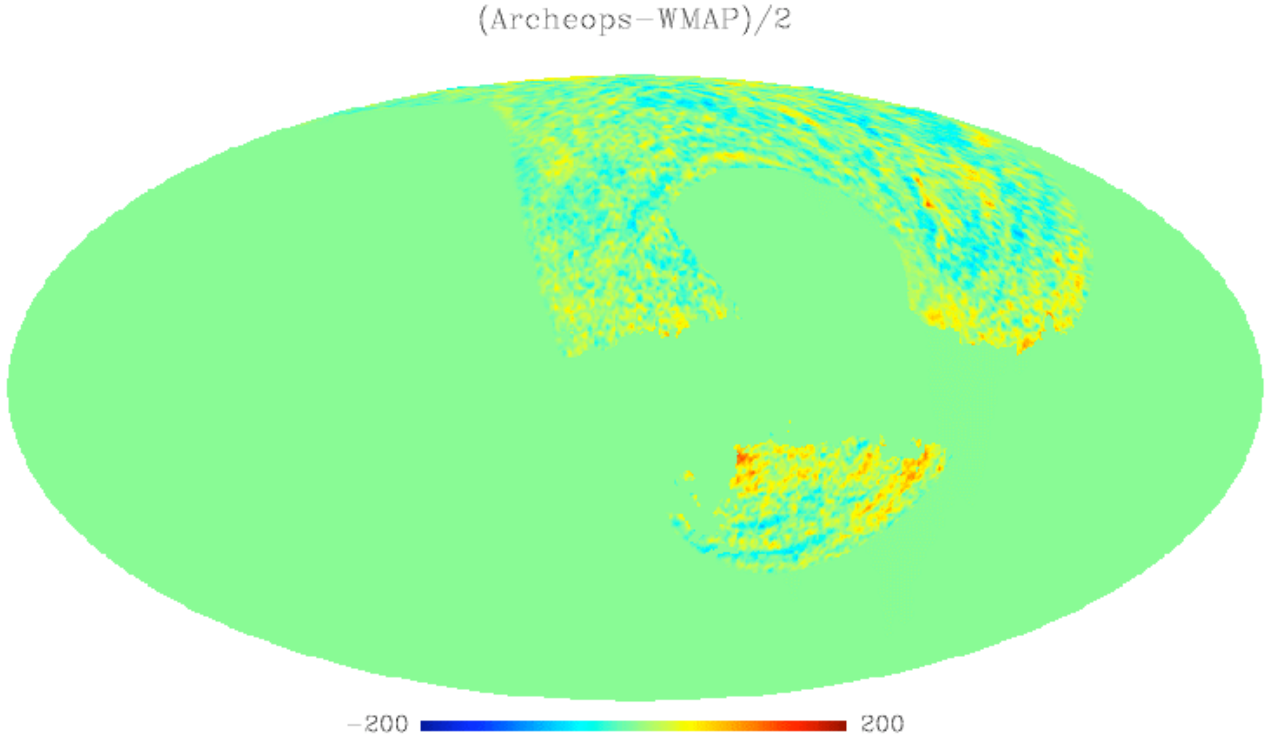
- ❑ Use Archeops observed maps from 6 detectors,
  4 maps at 143 GHz and 2 maps at 217 GHz
  Galactic dust emission and atmospheric emission has been removed from the maps

- ❑ Use 8 foreground cleaned maps from WMAP, from 41 to 90 GHz

- ❑ WMAP maps are rescanned following Archeops observation strategy, extracted timelines are high pass filtered (as done for Archeops) before reprojection onto maps

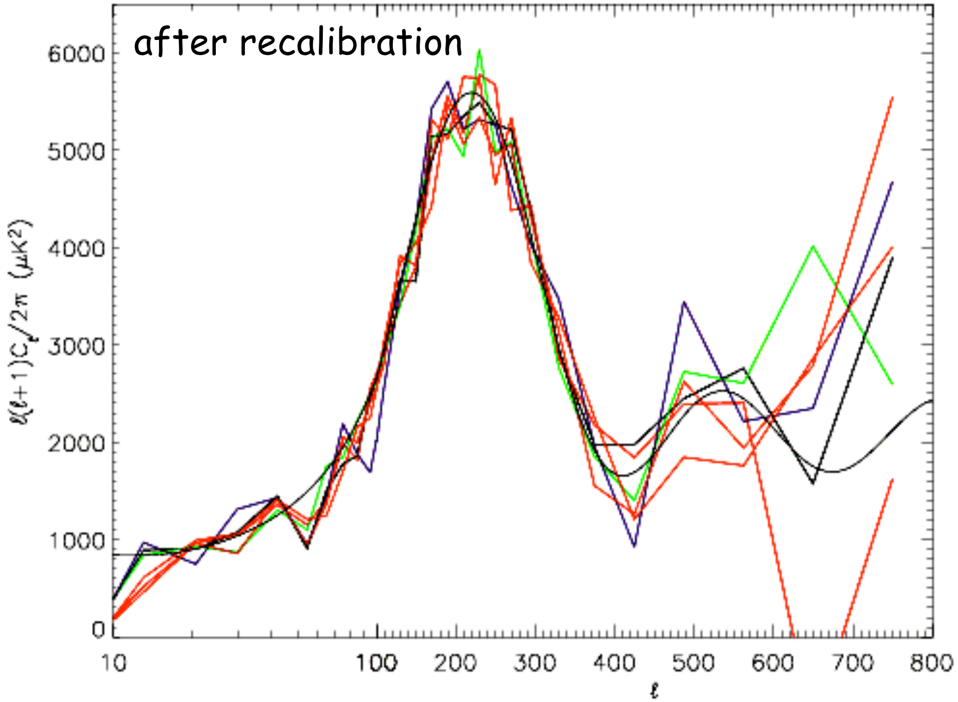
- ❑ Galactic and point source masks are applied

CMB map comparison



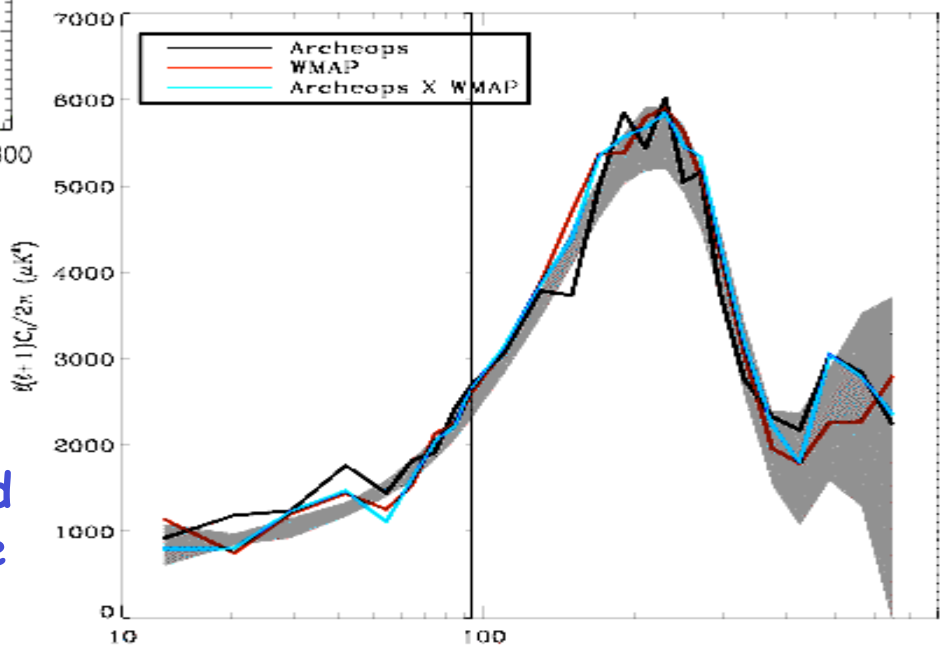
- Archeops and WMAP see the same structures with a high significance
- difference map shows stripes and residual galactic emission
- further investigation is needed

Cross-power spectrum



Cross-power spectra between each map from Archeops and the best estimate of CMB map from WMAP (1^{st} yr)

Cross-power spectrum Archeops/WMAP with X-spect (Tristram et al. 2004)



CMB anisotropies are compatible in Archeops and WMAP (except for an amplitude coefficient)

Further investigations are needed to understand the CMB amplitude discrepancy

Model for joint multi-component analysis

We assume that the observations are a linear mixture of components + noise

Components are CMB, unresolved point sources, and possibly residual components

Observed maps in T CMB units:

$$x_i(\theta,\Phi) = \alpha_i \left(s_{cmb}(\theta,\Phi) + a_{i,ps}(\nu)\, s_{i,ps}(\theta,\Phi) \right) + \Sigma\, a_{ic}\, s_c(\theta,\Phi) + n_i(\theta,\Phi)$$

- α_i: recalibration factors for Archeops
- s_{cmb}: CMB
- $a_{i,ps}(\nu)\, s_{i,ps}$: Point sources
- $\Sigma\, a_{ic}\, s_c$: residual components
- n_i: noise

We assume
$a_{i,ps}(Krj) = (\nu_i/\nu_0)^{-2}$

→ Model in matrix form: $x = A\, s + n$

Method

- Compute all the cross- and auto-power spectra of the observed maps

- adjust their multi-component model:

$$\langle x_{lm} \cdot x_{lm}^{\dagger} \rangle = A \begin{pmatrix} C_{CMB}(l) & & & 0 \\ & C_{PS} & & \\ & & \ddots & \\ 0 & & & C_{Res}(l) \end{pmatrix} A^{\dagger} + \begin{pmatrix} N_{Q1}(l) & & & & 0 \\ & N_{Q2}(l) & & & \\ & & \ddots & & \\ & & & N_{143}(l) & \\ 0 & & & & N_{217}(l) \end{pmatrix}$$

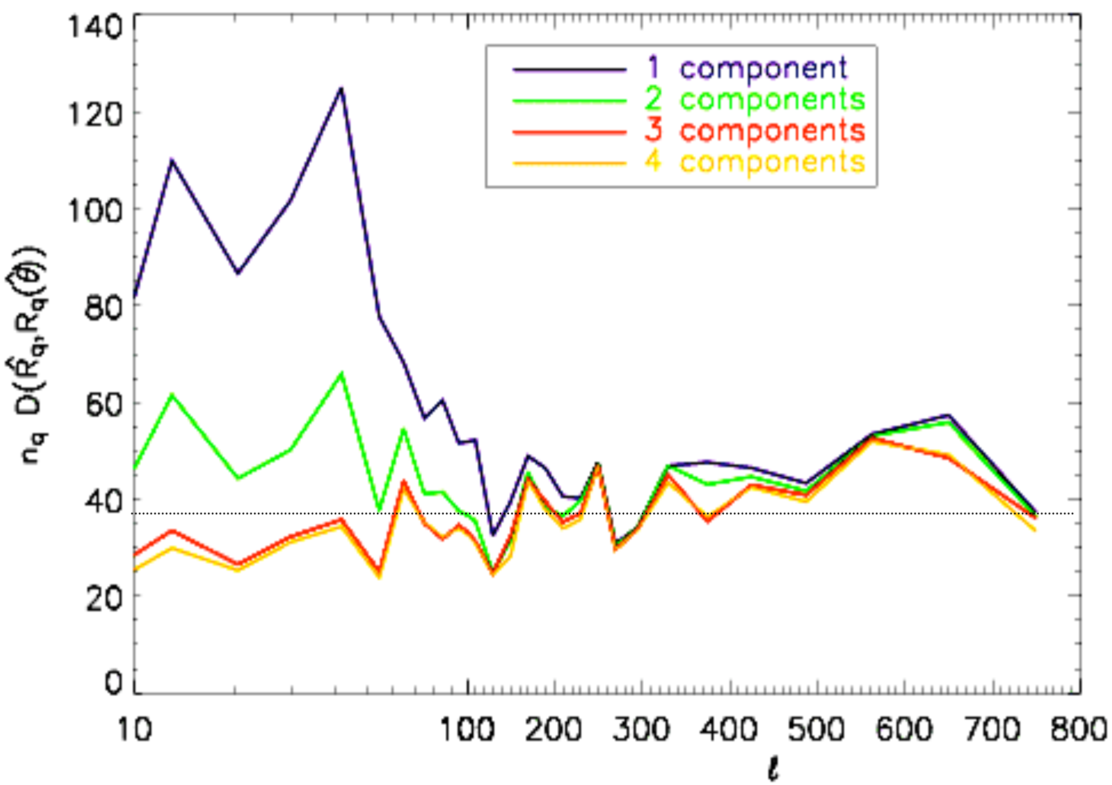
We assume a flat power spectrum of point sources.

- estimate the relevant parameters:
  - component power spectra $C_{CMB}(l)$, $C_{Res}(l)$
  - CMB calibration in Archeops, α...
  - mixing parameters of the unknown components A_{ic}
  - amplitude of unresolved point sources C_{PS}
  - Noise power spectra $N_i(l)$

Results: number of components

We want to estimate the required number of residual components in data

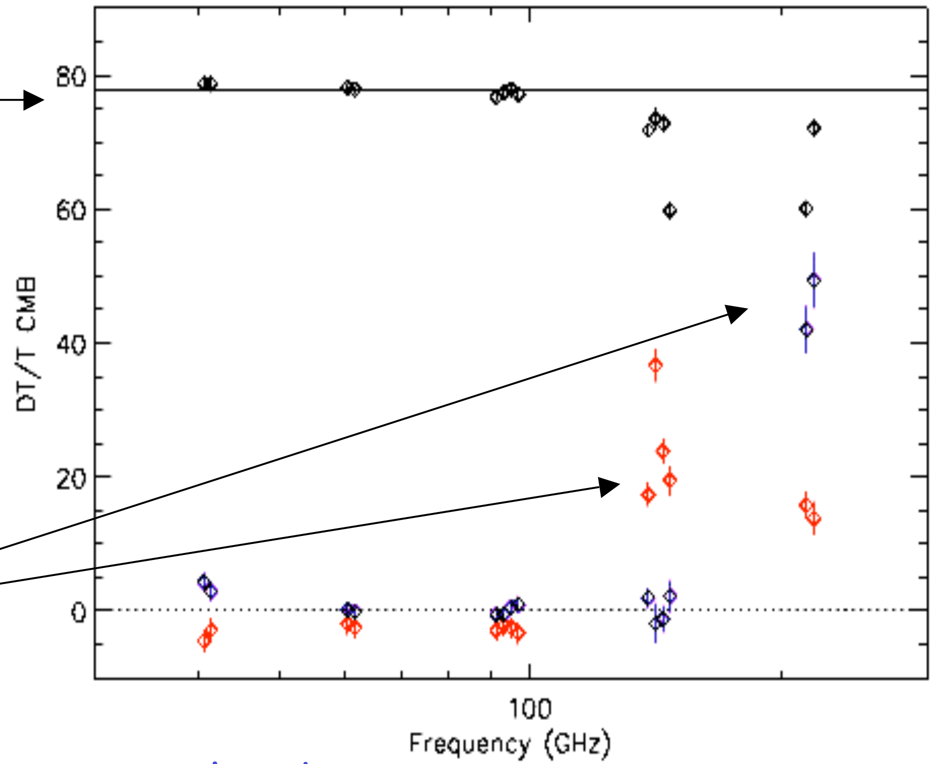
Goodness of fit for various number of estimated components :



3 significant components in maps:

CMB + 2 residuals

Results: amplitude of components



- CMB anisotropies

⇨ **Only component in common between Archeops and WMAP**

⇨ Archeops calibration on dipole is significantly underestimated

- 2 residual components

detected in Archeops only

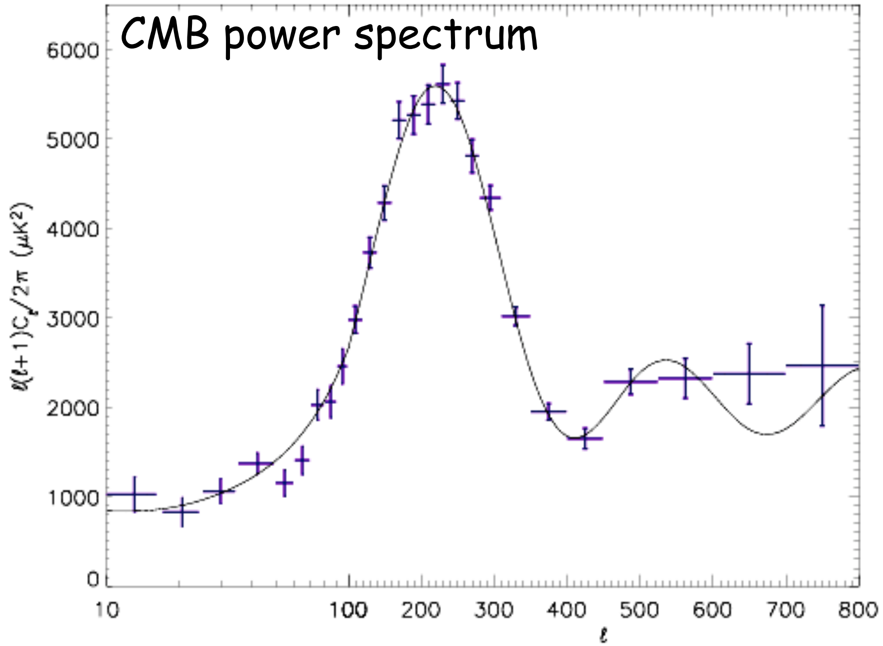
1st component has a relatively constant amplitude

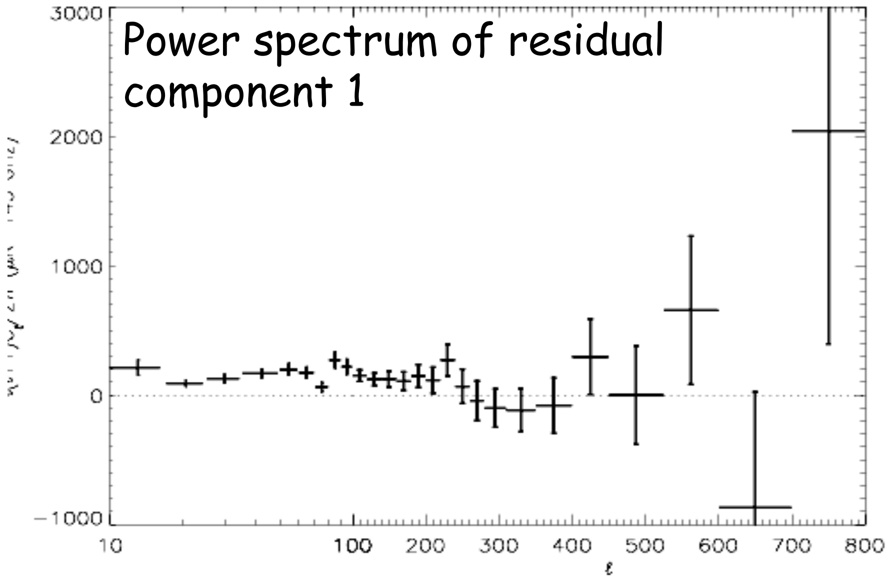
2nd component is detected at 217 GHz only

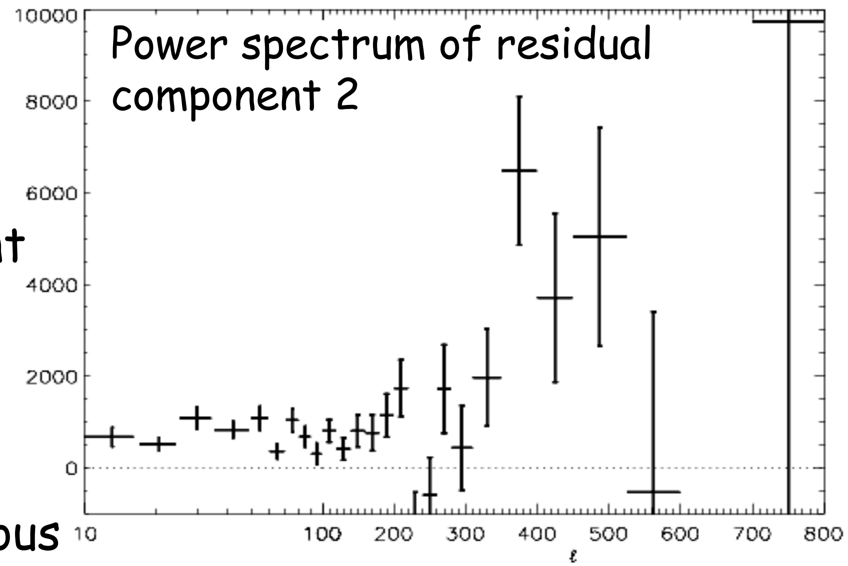
- Point source power spectrum: $C_{PS} = (19.8 \pm 11.8) \times 10^{-3}\ \mu K^2$

Consistant with other estimates (Komatsu et al., Patanchon et al.)

Component power spectra

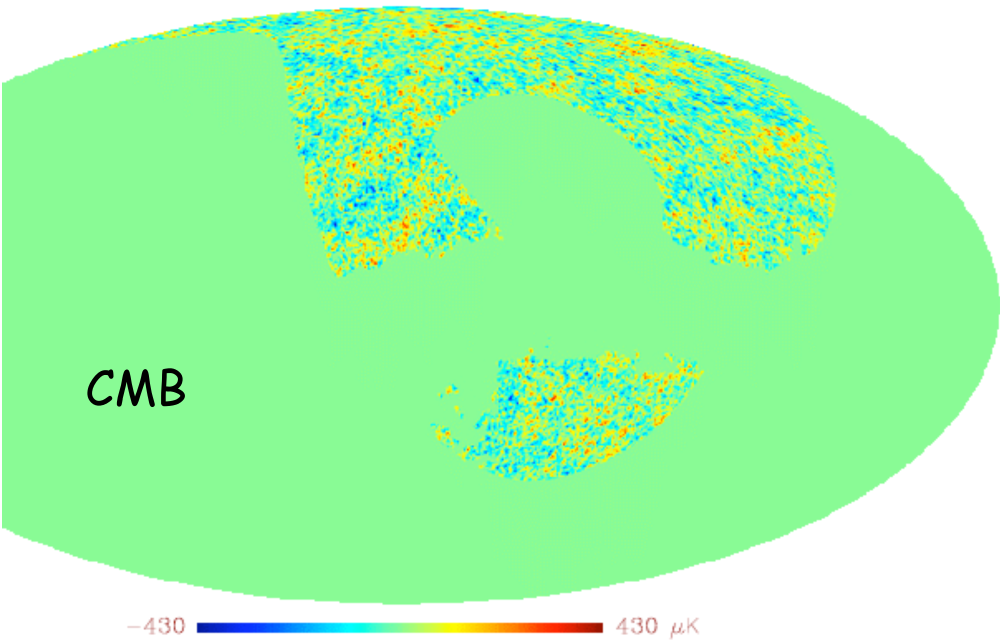


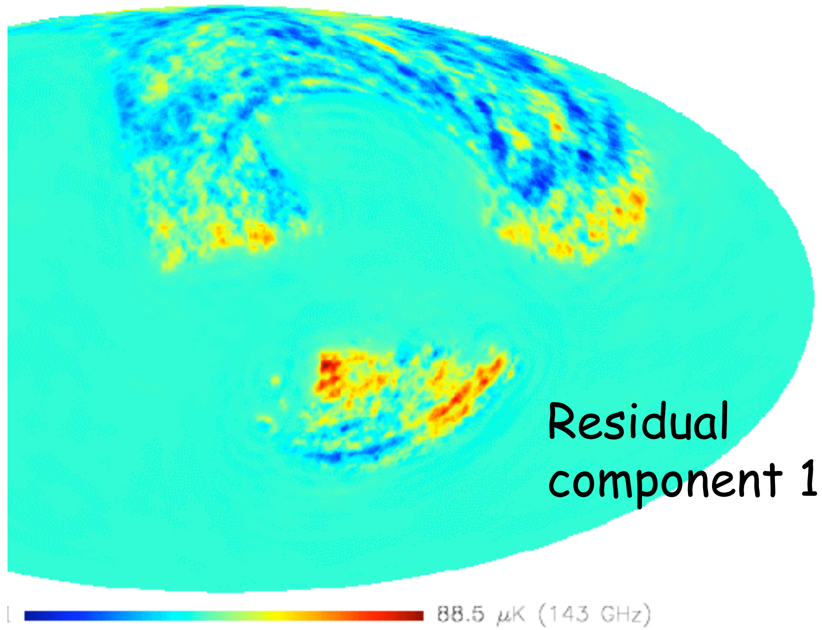


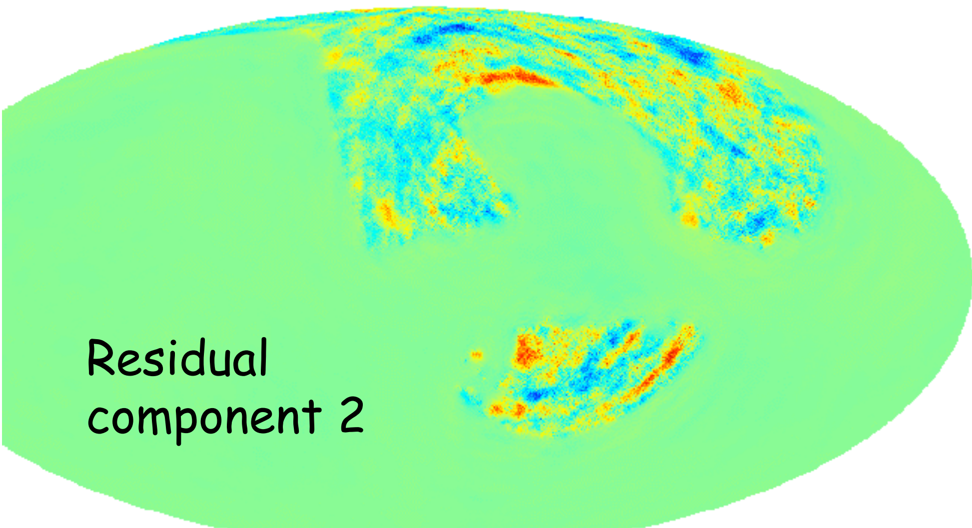


- ✓ CMB power spectrum is compatible with best fit WMAP model
- ✓ power spectrum of 1st residual component in Archeops forms a plateau for l < 250, and is not detected at higher l
- ✓ 2nd component, detected at 217 GHz only, has been already reported in previous Archeops publication

Component maps







→ Residual components are a mixture of residual atmospheric emission and galactic emission

Constraints on thermal SZ emission

New Model:

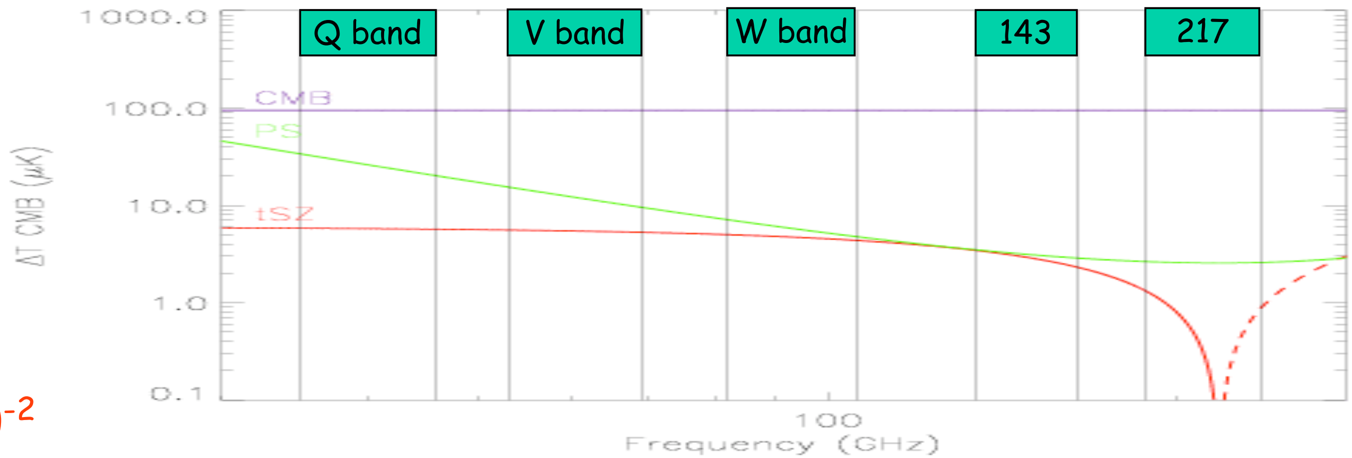
3 astrophysical components: CMB, thermal SZ, unresolved point sources
+ 2 residuals

Observed maps in T CMB units:

$$x_i(\theta,\Phi) = \alpha_i \left(s_{cmb}(\theta,\Phi) + a_{i,sz}(\nu)\, s_{sz}(\theta,\Phi) + a_{i,ps}(\nu)\, s_{ps}(\theta,\Phi)\right) + \Sigma\, a_{ic}\, s_c(\theta,\Phi) + n_i(\theta,\Phi)$$

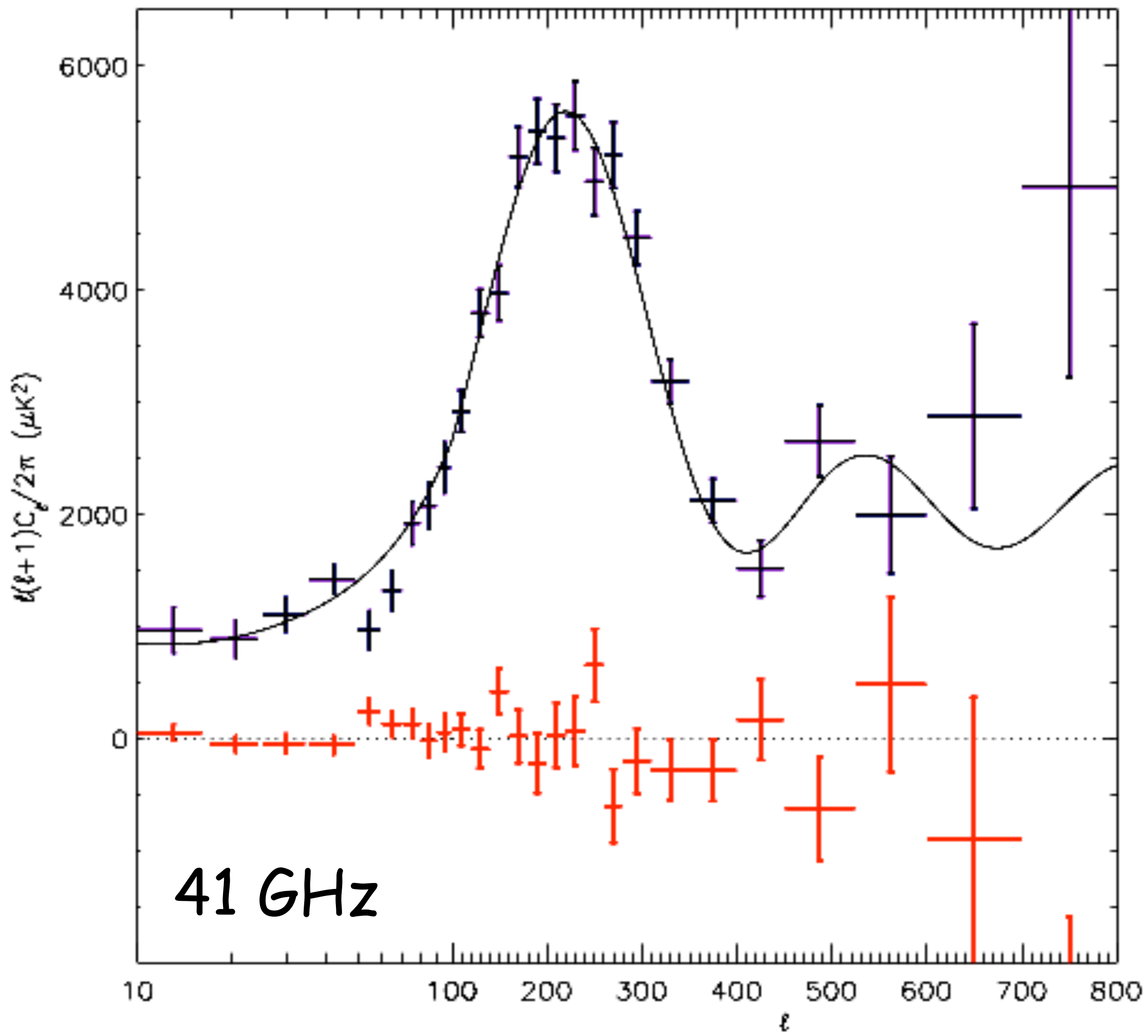
We add SZ in the model, $a_{i,sz}(\nu)$ is perfectly known

E.M spectra of components:



We assume
$a_{i,ps}(Krj) = (\nu_i/\nu_0)^{-2}$

Results: CMB and SZ power spectrum



SZ emission has no contribution in WMAP data

$\sigma^2_{SZ} < 2.3\% \, \sigma^2_{CMB}$ (95% c.l.)
in the 1st acoustic peak
at 41 GHz

Conclusions

- Joint analysis shows that Archeops and WMAP data are compatible

    - The only component in common between Archeops and WMAP is CMB.
    - CMB anisotropies are compatible in WMAP and Archeops data, except for an amplitude coefficient.
    - Cross-power spectrum is compatible with best fit WMAP model

- Archeops is systematically under-calibrated by ~6-8 % for the best channels.

- two weak residual components are detected in Archeops maps. They are attributed to a mixture of residual atmospheric emission and galactic emission.

- Archeops allows to constrain thermal SZ effect in WMAP data. We showed that there is no evidence of SZ effect, $\sigma^2_{SZ} < 2.3\% \, \sigma^2_{CMB}$ (95% c.l.) in the 1st acoustic peak at 41 GHz