The Planck mission

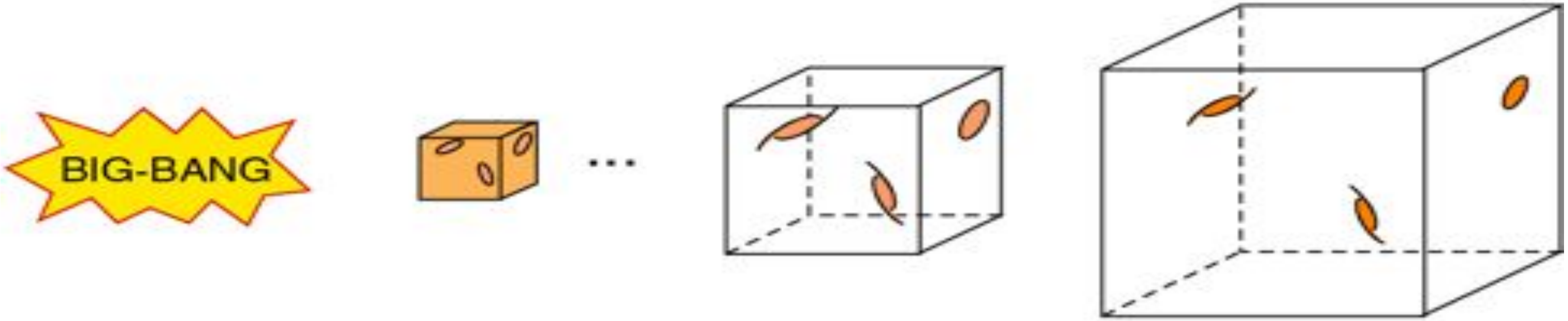
Jacques Delabrouille

Laboratoire APC, Paris

The Planck mission : outline

- Context and objectives
- Design and scientific programme
- Making it happen
- Data reduction
- Early results
- The future

The Big-Bang

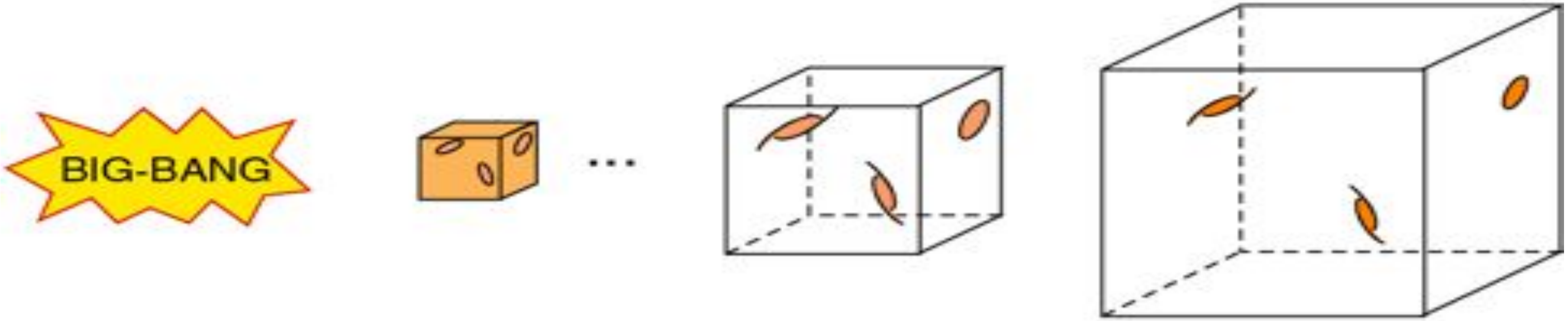


t = 0 — 10^{-35} sec inflation — 3 mn nucleosynthesis — 380,000 yrs decoupling — t ≈13.5 x 10^{9} yrs

Hot and dense —*expansion*→ Cold and tenuous

Homogeneous —*gravity*→ Structured

The Big-Bang



t = 0

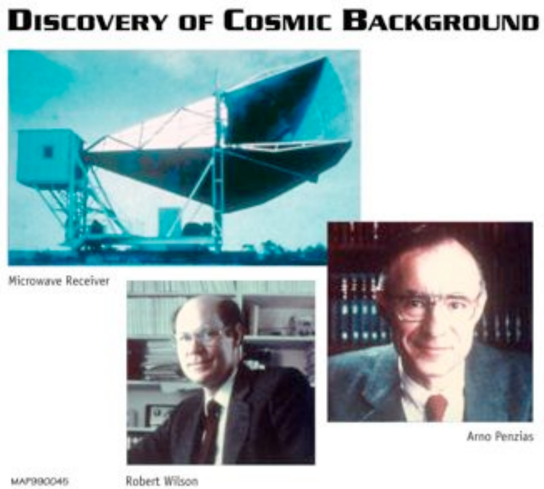
10^{-35} sec
inflation

3 mn
nucleosynthesis

380,000 yrs
decoupling

t ≈13.5 x 10^{9} yrs

Hot ionised plasma	Cold neutral atoms
OPAQUE	TRANSPARENT



Penzias et Wilson 1964 (Nobel prize 1978)

Predicts a Cosmic Background (≈3K blackbody)

Evolution of initial perturbations

INFLATION

Perturbations : $g_{\mu\nu} = g_{\mu\nu}^{(0)} + h_{\mu\nu}$

Inflationary parameters
Physics at ultra high energy

PLASMA
Particle interactions

Densities

Decoupling
t ~380.000 yrs

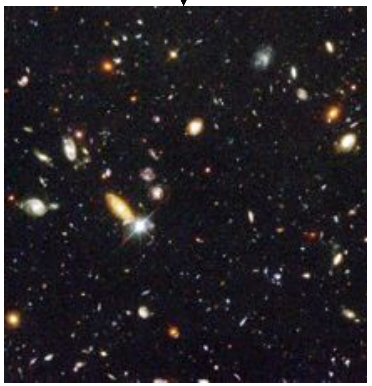
Temperature

- Hotter in denser regions
- Spectrally shifted by SW
- Spectrally shifted by Doppler

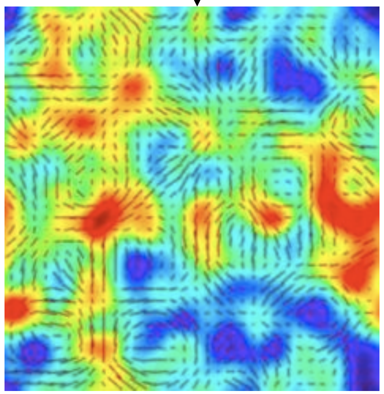
PHOTONS
Free propagation

MATTER
Gravitational collapse

Geometry
Expansion



Objects and structures



CMB Anisotropies

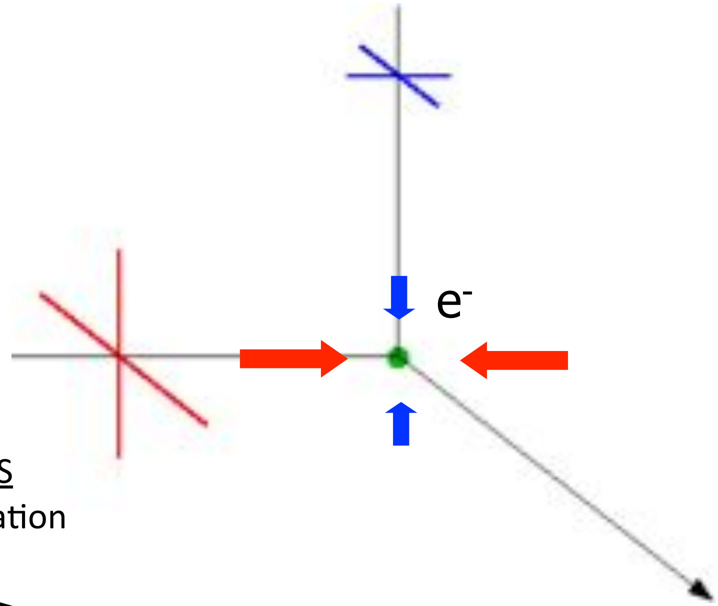
CMB anisotropic
at the 0.02 % level

Evolution of initial perturbations

INFLATION

Perturbations : $g_{\mu\nu} = g_{\mu\nu}^{(0)} + h_{\mu\nu}$

Inflationary parameters
Physics at ultra high energy



PLASMA
Particle interactions

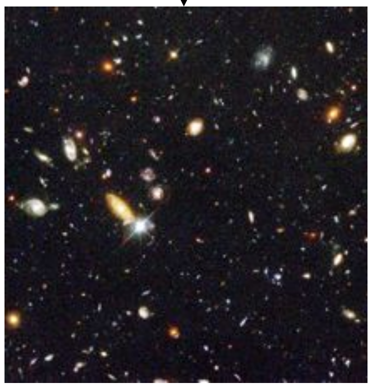
Densities

Decoupling
t ~380.000 yrs

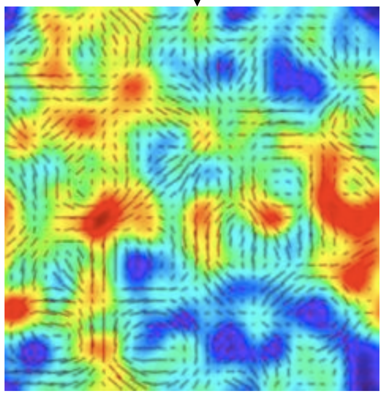
PHOTONS
Free propagation

MATTER
Gravitational collapse

Geometry
Expansion



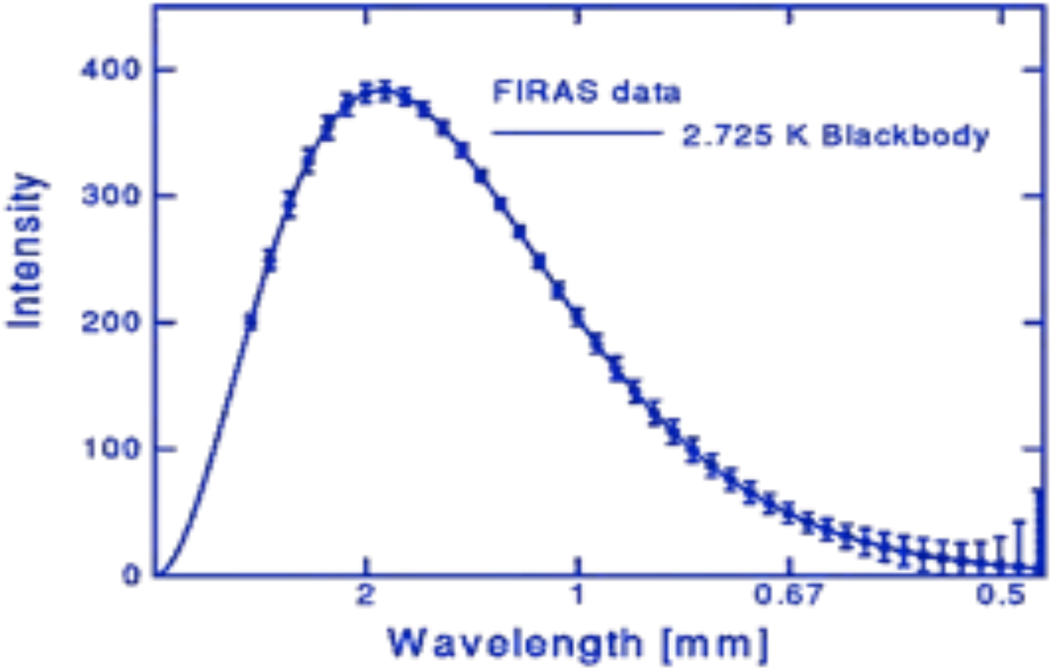
Objects and structures

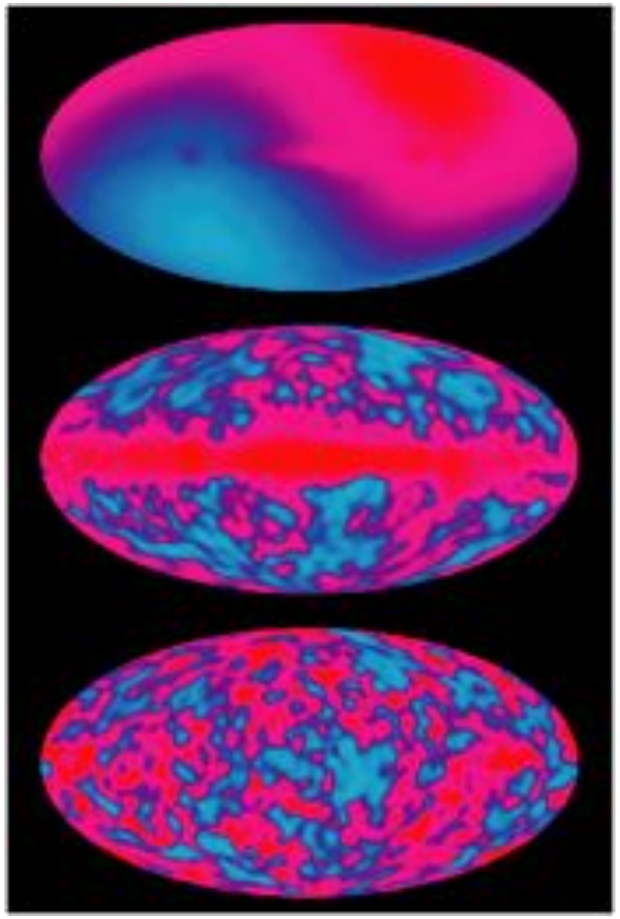


CMB Anisotropies

CMB anisotropies
polarised
at the 10% level

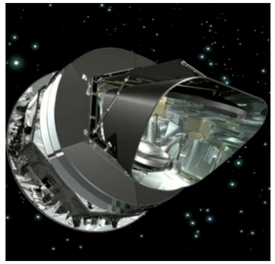
1992 : COBE

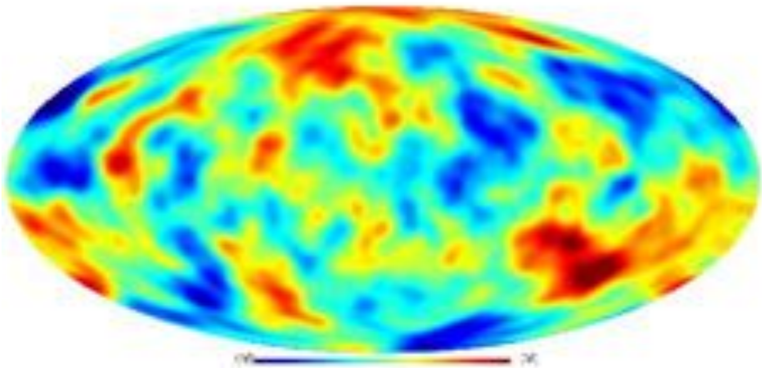


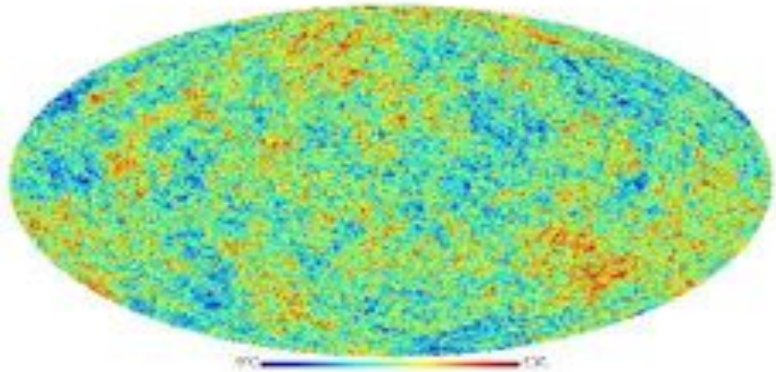


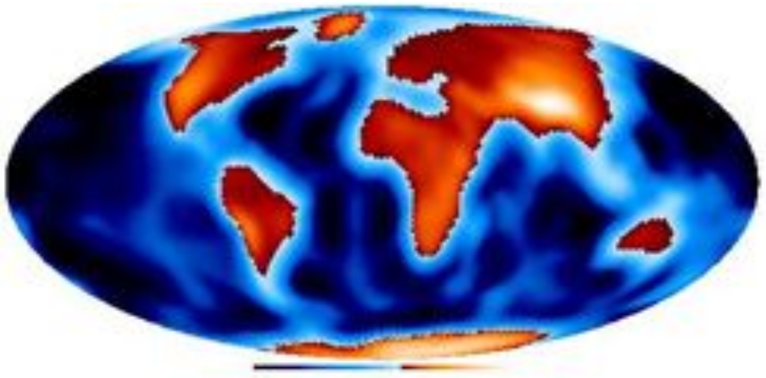
- ➡ FIRAS: Cosmological origin of the radiation
- ➡ DMR: Existence of fluctuations

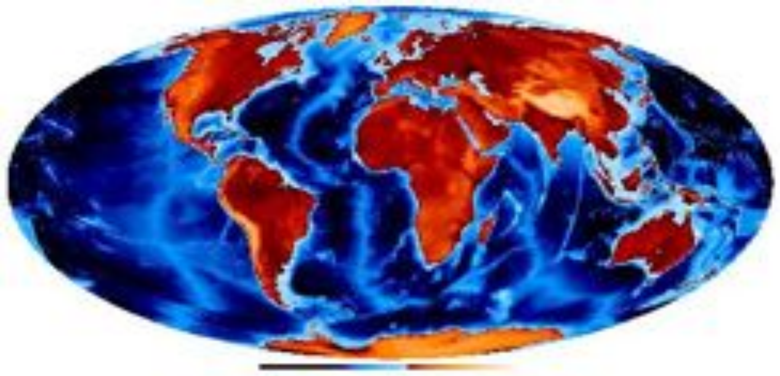
From COBE ... to Planck



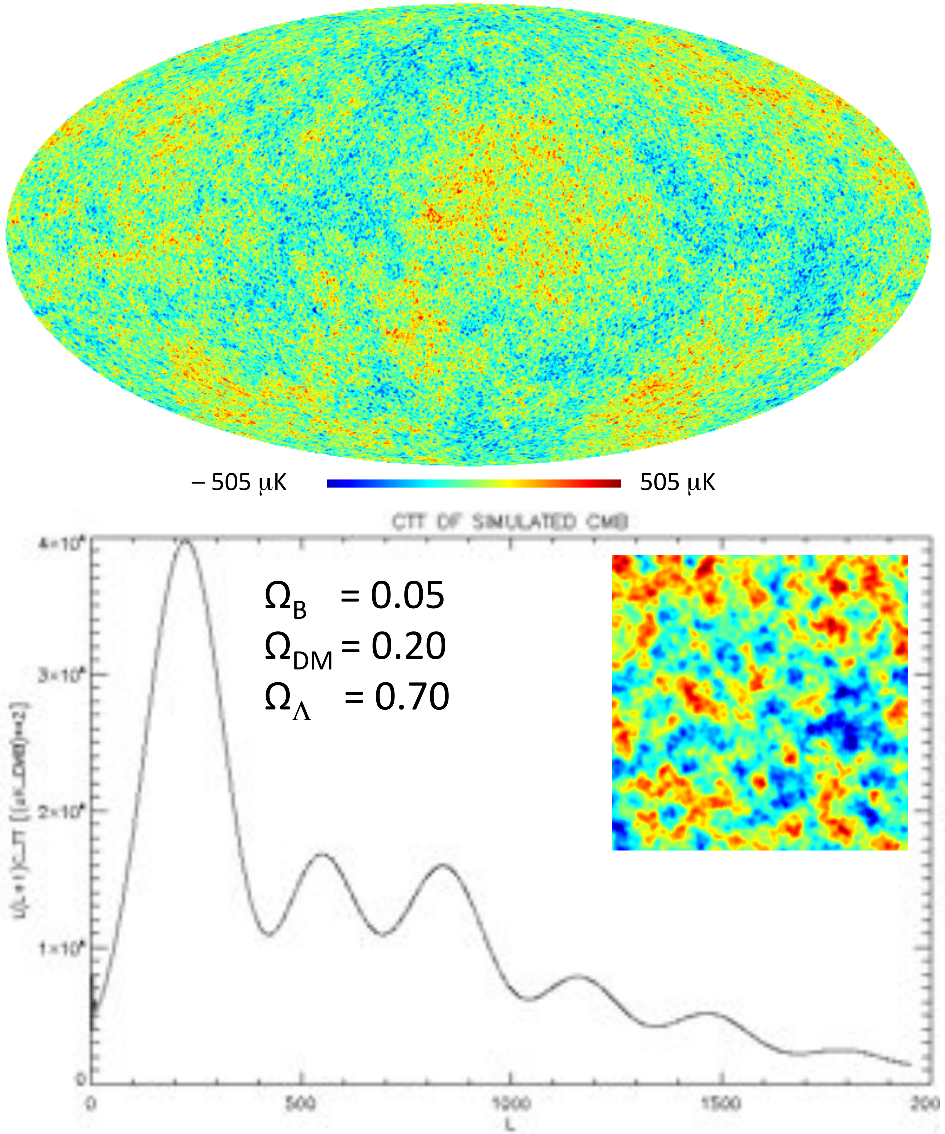


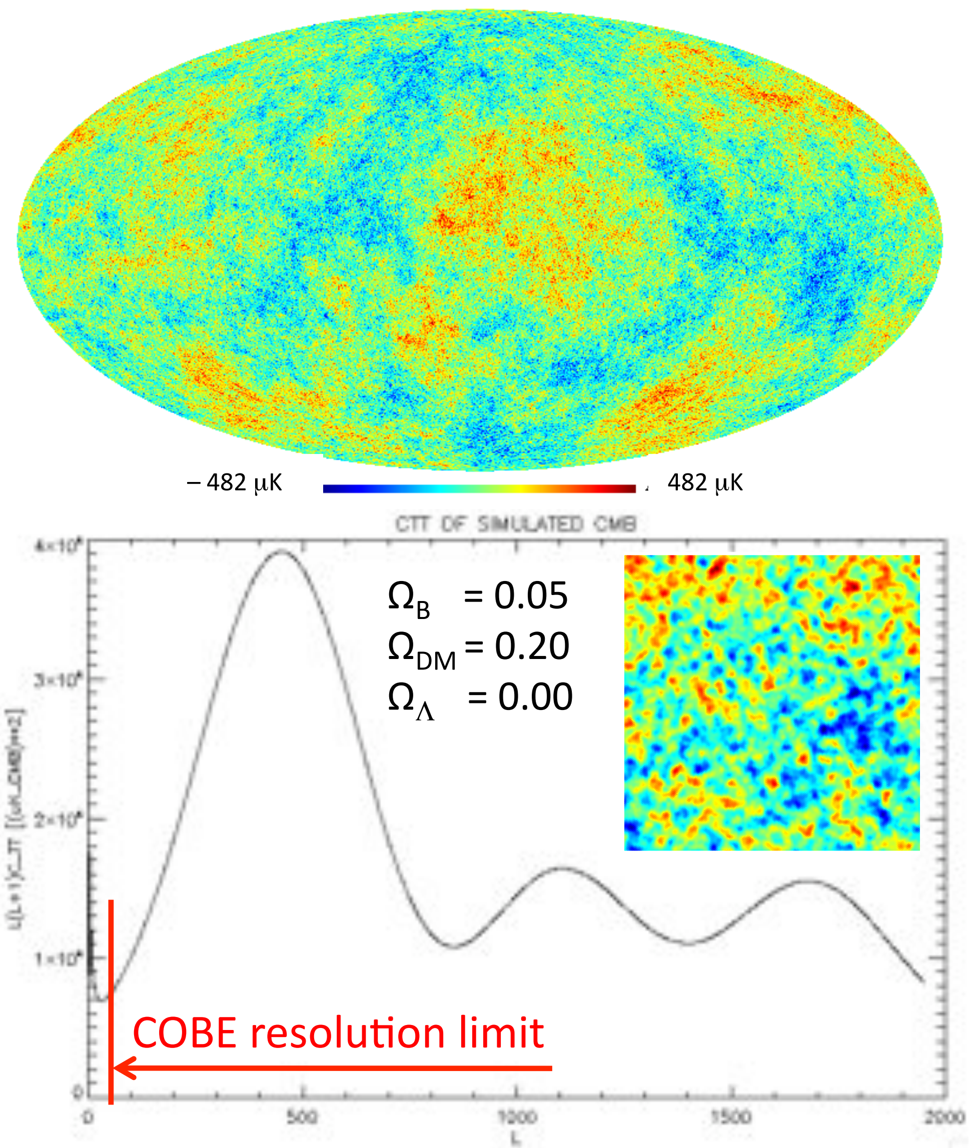






Predicted images of the 380,000 yrs old universe



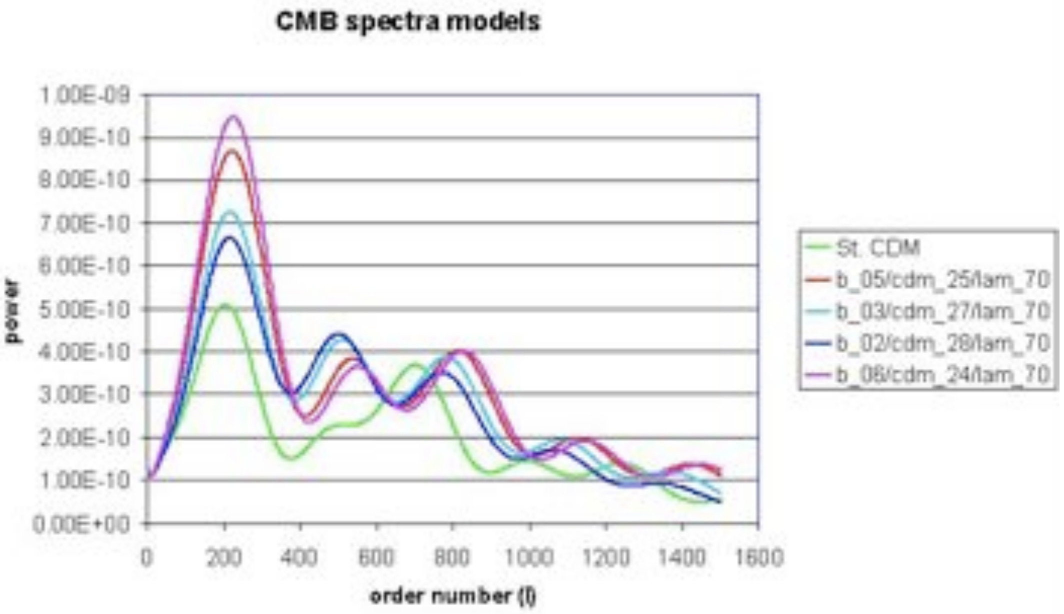


The CMB power spectrum

$$\frac{dT}{T_{CMB}}(\theta,\varphi) = \sum_{l,m} a_{lm} Y_{lm}(\theta,\varphi)$$

$$C_l = \langle |a_{lm}|^2 \rangle$$

$$\hat{C}_l = \frac{1}{2l+1} \sum |a_{lm}|^2$$



Measure 3 Stokes parameters

$$I = |E_0^2| + |E_{90}^2|$$

$$Q = |E_0^2| - |E_{90}^2|$$

$$U = |E_{45}^2| - |E_{135}^2|$$

} E (even parity), B (odd parity)

$$C_l = \begin{pmatrix} C_l^{TT} & C_l^{TE} & 0 \\ C_l^{TE} & C_l^{EE} & 0 \\ 0 & 0 & C_l^{BB} \end{pmatrix}$$

Cosmological parameters

- H — Hubble constant (rate of expansion)
- Ω_k — Spatial curvature
- Ω_m — Matter density
- Ω_b — Baryonic matter density
- Λ — Cosmological constant
- Δ_S^2, n_S, $dn_S/d\ln k$ — Spectrum of primordial scalar perturbations
- Δ_T^2, n_T — Spectrum of primordial tensor perturbations
- $r = \Delta_T^2 / \Delta_S^2$
- τ — Reionisation optical depth
- σ_8 — Amplitude of density perturbations on $8h^{-1}$ Mpc scales
- …

Geometry (H, Ω_k)

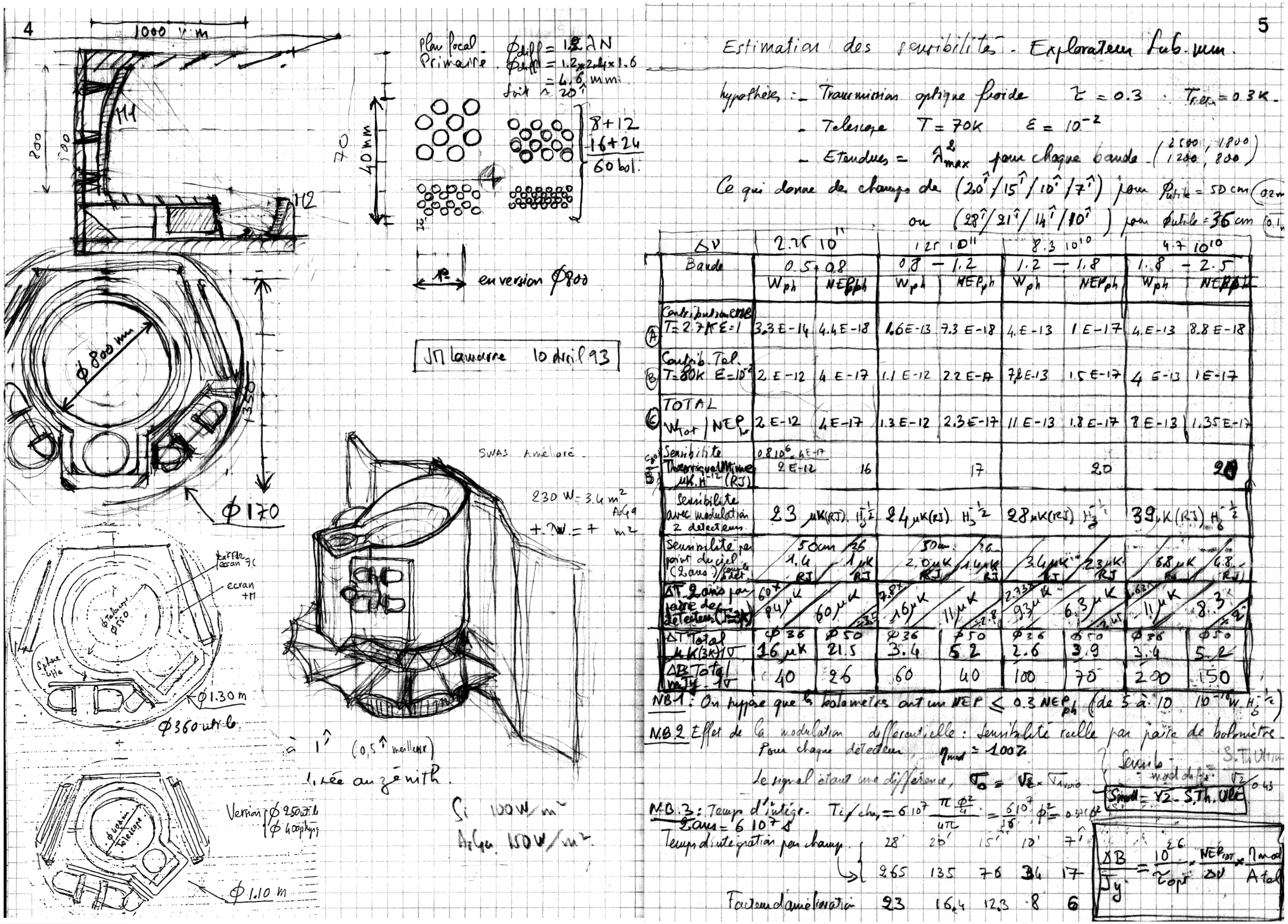
Matter Energy content (Ω_m, Ω_b, Λ)

Inflation (Δ_S^2, n_S, $dn_S/d\ln k$, Δ_T^2, n_T, r)

Main issues

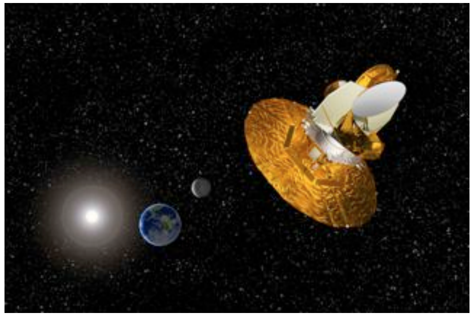
- **Sensitivity**
  - 30 years between detection of the CMB and detection of first anisotropies (at the level of 10^{-4})
  - SOLUTION: Very-sensitive detectors, long observing time
- **Foreground emission**
  - Do we see the primordial CMB, or astrophysical emission of a different origin?
  - SOLUTION: Multifrequency observations

1993 – IAS (Orsay)



Jean-Michel Lamarre's notebook

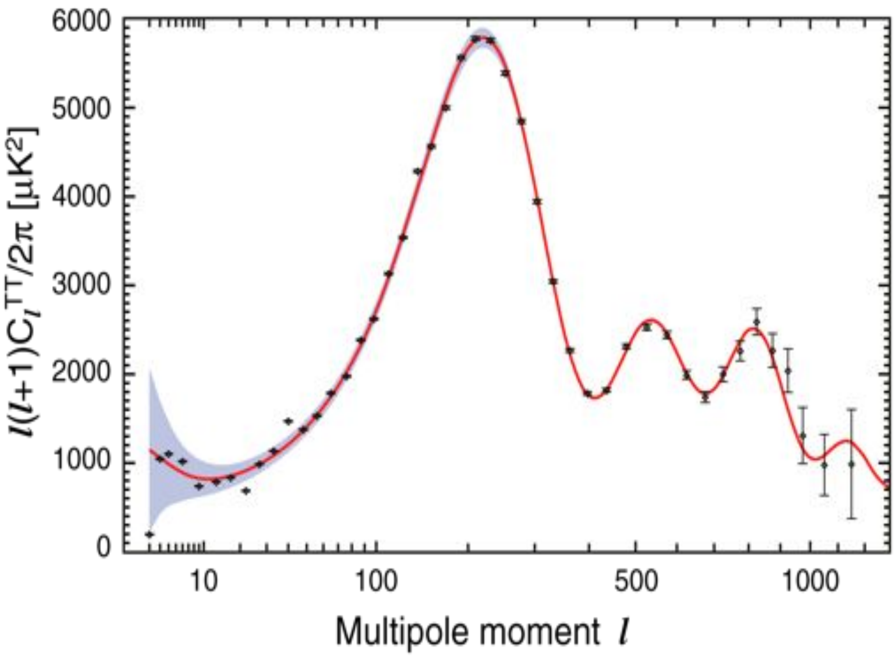
2001: WMAP

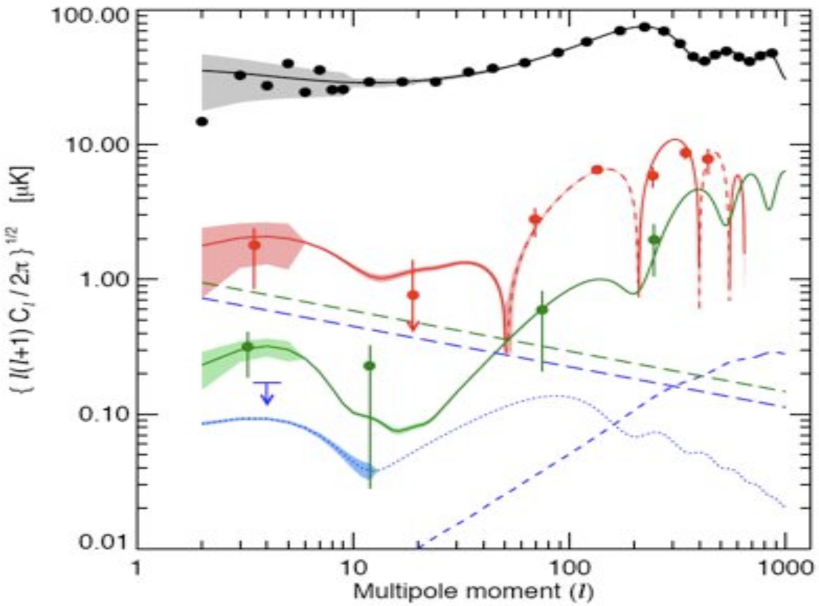


Spectacular measurement of temperature anisotropies !

Power spectrum compatible with prediction from standard Big-Bang with cosmological constant (ΛCDM)

Nice fit with 7 free parameters (Ω_b, Ω_m, Λ, H_0, n_s, σ_8, τ)





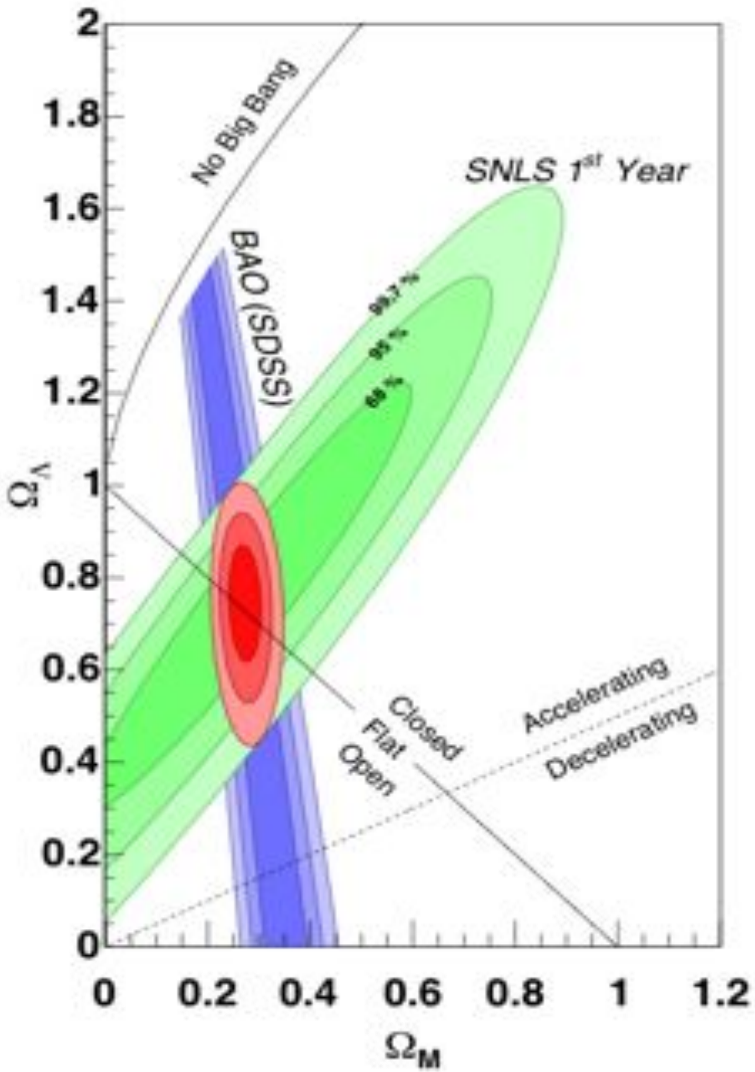
Larson et al., 2011

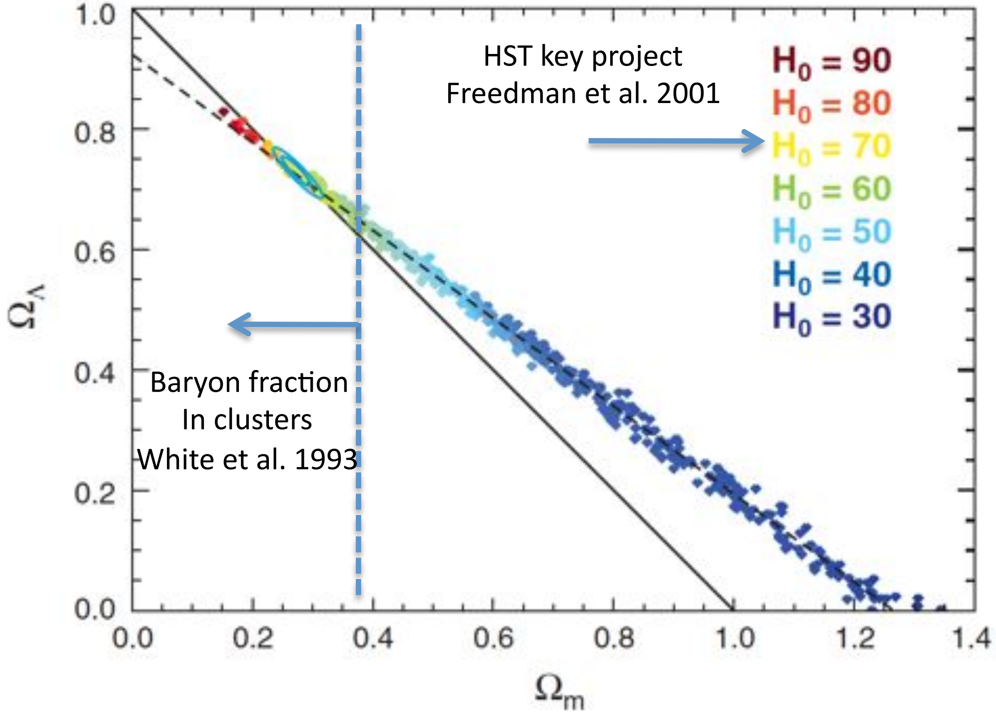
Page et al., 2005

Cosmological parameters

- $H = 70.4 \pm 1.4$
- $\Omega_b = 0.0456 \pm 0.0016$
- $\Omega_{cdm} = 0.227 \pm 0.014$
- $\Omega_\Lambda = 0.728 \pm 0.016$
- $\tau = 0.087 \pm 0.014$
- $\sigma_8 = 0.809 \pm 0.024$
- $0.013 < 1-n_S < 0.061$ 95% CL

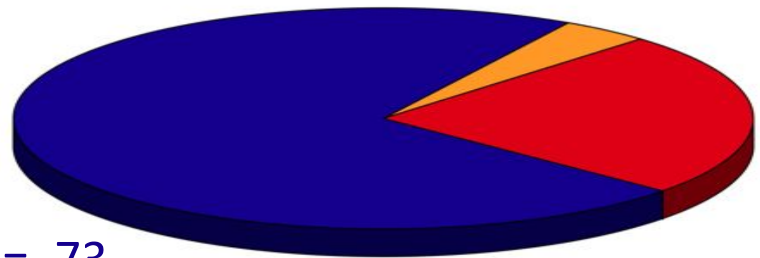
Concordance





Cosmic Pie

Camembert Cosmique



$\Omega_\Lambda = .73$

What is left for Planck ?

- Quite a lot !

- Accuracy issues
  - The CMB has not been mapped to the best possible accuracy
  - Polarisation has not been really measured - just detected
  - Cosmological parameters can and should be constrained better

- Model issues
  - Dark matter?
  - Dark energy?
  - Is the general model right?
  - Inflation? Is simple model for P(k) OK?
  - Admixture of isocurvature perturbations?
  - Signatures of e.g. cosmic strings?
  - Statistics of the CMB (non-gaussianity, alignments)

- A lot of astrophysics !

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Modified gravity ?

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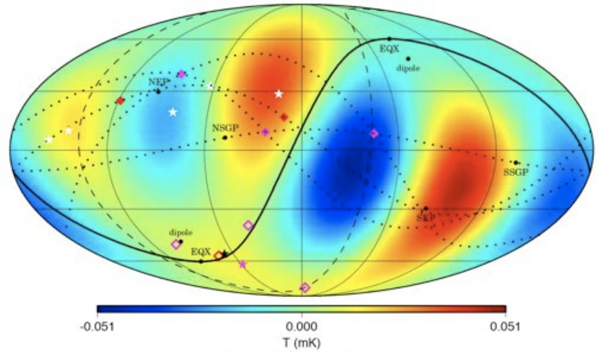
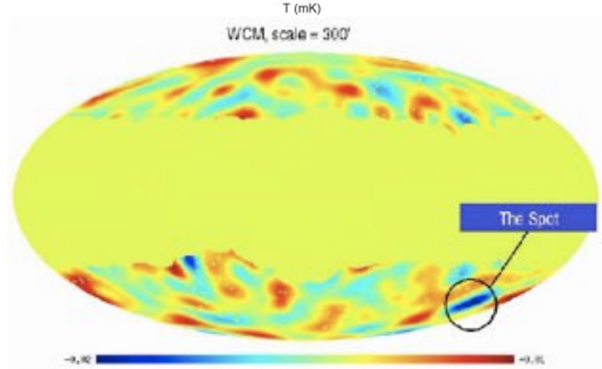
- A lot of astrophysics !

Copi et al., 2005





Cruz et al., 2006

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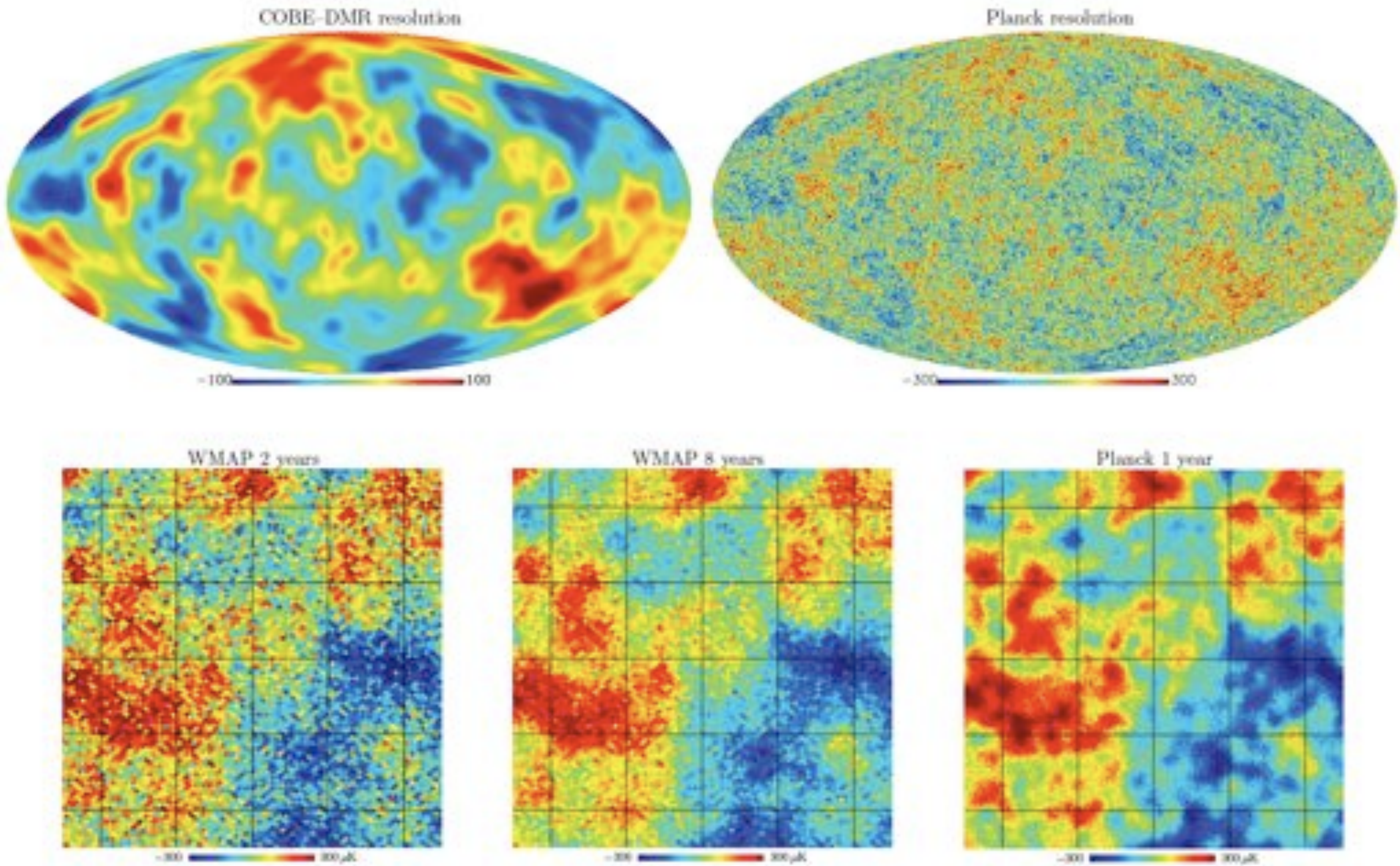
A third generation satellite

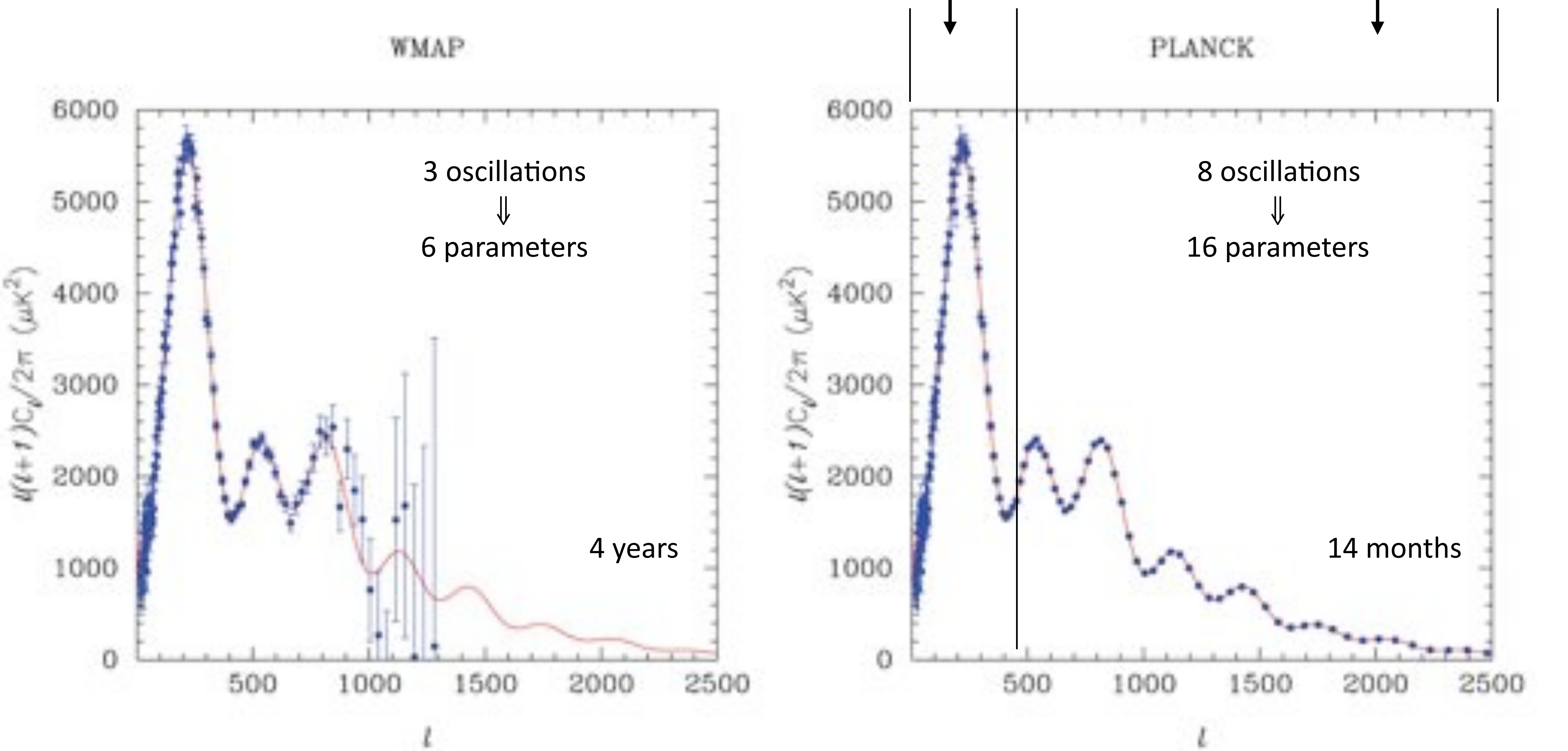


From WMAP to Planck

Personal interpretation of Nyquist's sampling theorem

Planck not better than WMAP

Planck much better than WMAP



TE with Planck

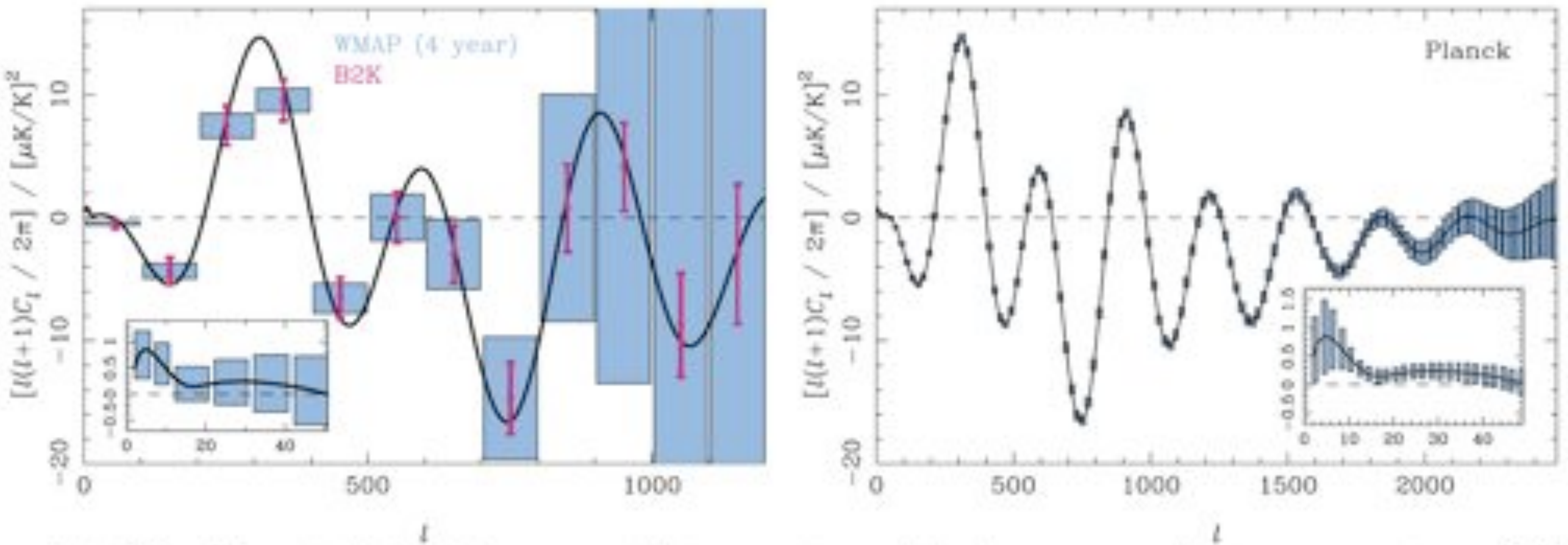


FIG 2.13.—Forecasts for the $\pm 1\sigma$ errors on the temperature-polarization cross-correlation power spectrum C_ℓ^{TE} in a ΛCDM model (with $r = 0.1$ and $\tau = 0.17$) from *WMAP* (4 years of observation) and BOOMERanG2K (left) and *Planck* (right). In the left-hand plot, flat band powers are estimated with $\Delta\ell = 100$ for both experiments for ease of comparison. The inset shows the *WMAP* forecasts on large angular scales with a finer $\Delta\ell$ resolution. For *Planck*, flat band powers are estimated with $\Delta\ell = 20$ in the main plot, but with $\Delta\ell = 2$ in the inset on large scales.

EE with Planck

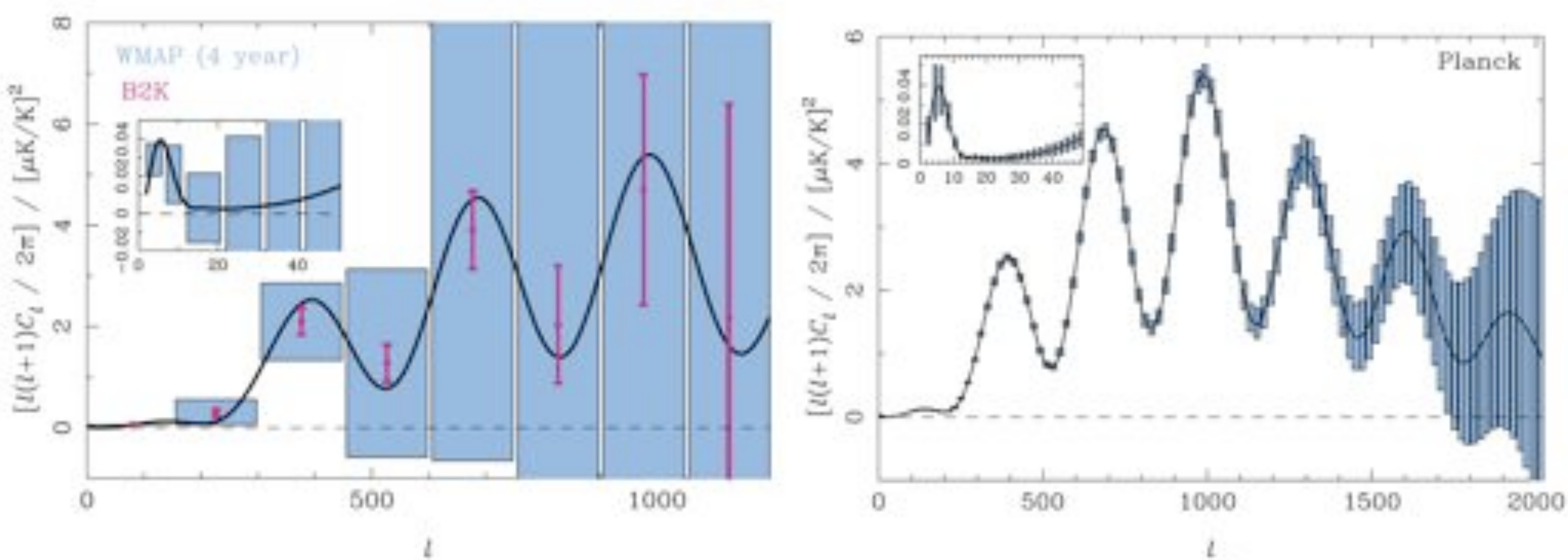


FIG 2.14.—Forecasts for the $\pm1\sigma$ errors on the E-mode polarization power spectrum C_ℓ^E from *WMAP* and B2K (left) and *Planck* (right). The cosmological model, and the assumptions about instrument characteristics, are the same as in Figure 2.13. For *WMAP* and B2K, flat band powers are estimated with $\Delta\ell = 150$ (with finer resolution on large scales for *WMAP* in the inset). For *Planck* we have used the same ℓ-resolution as in Figure 2.13.

BB with Planck

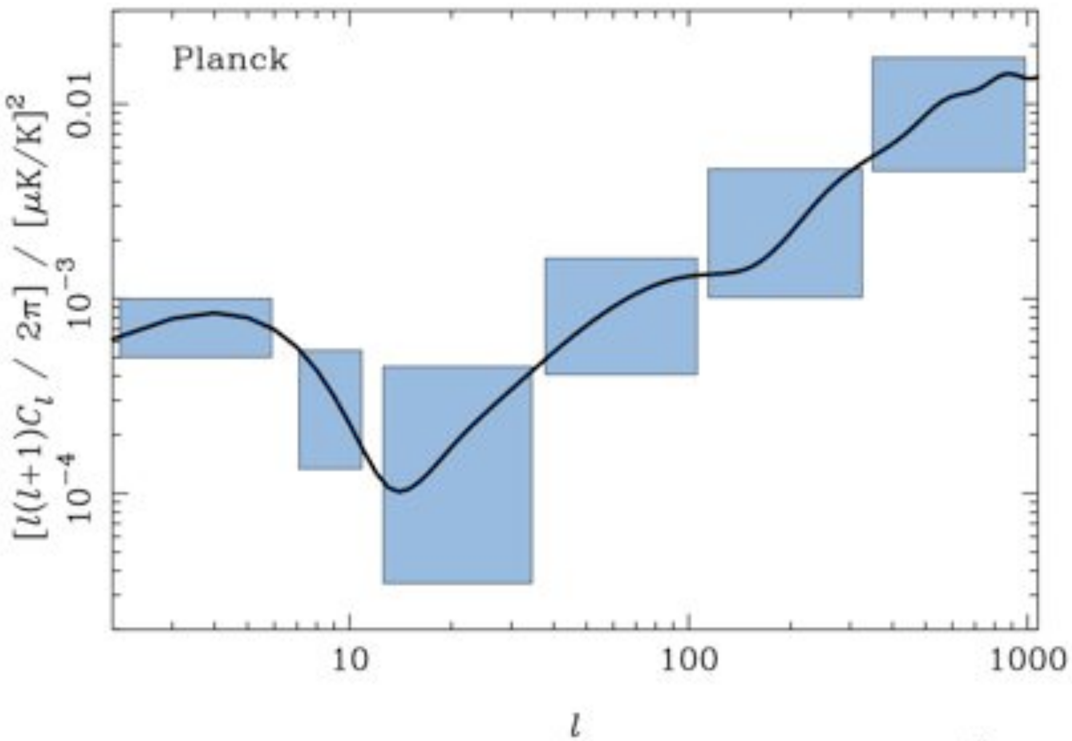


FIG 2.17.—Forecasts for the $\pm 1\sigma$ errors on the B-mode polarization power spectrum C_ℓ^B from *Planck* (for $r = 0.1$ and $\tau = 0.17$). Above $\ell \sim 150$ the primary spectrum is swamped by weak gravitational lensing of the E-polarization produced by the dominant scalar perturbations. The cosmological model, and the assumptions about instrument characteristics, are the same as in Figure 2.13.

Smoking gun for inflationary tensor modes
Constraints on model of inflation

Constraints on n_s

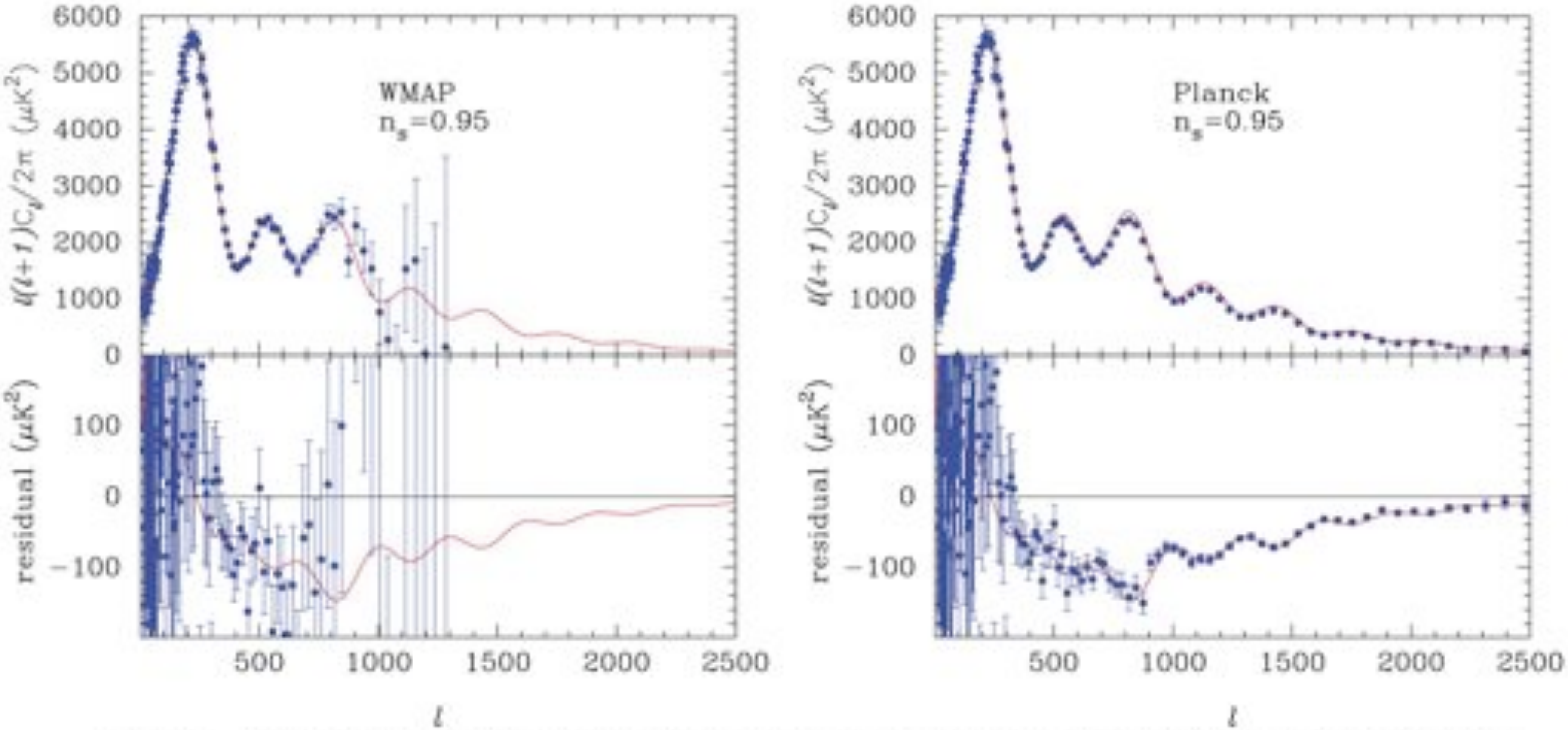


FIG 2.11.—The solid lines in the upper panels of these figures show the power spectrum of the concordance ΛCDM model with an exactly scale invariant power spectrum, $n_S = 1$. The points, on the other hand, have been generated from a model with $n_S = 0.95$ but otherwise identical parameters. The lower panels show the residuals between the points and the $n_S = 1$ model and the solid lines show the theoretical expectation for these residuals. The left and right plots show simulations for *WMAP* and *Planck*, respectively.

Constraints on running of n_s

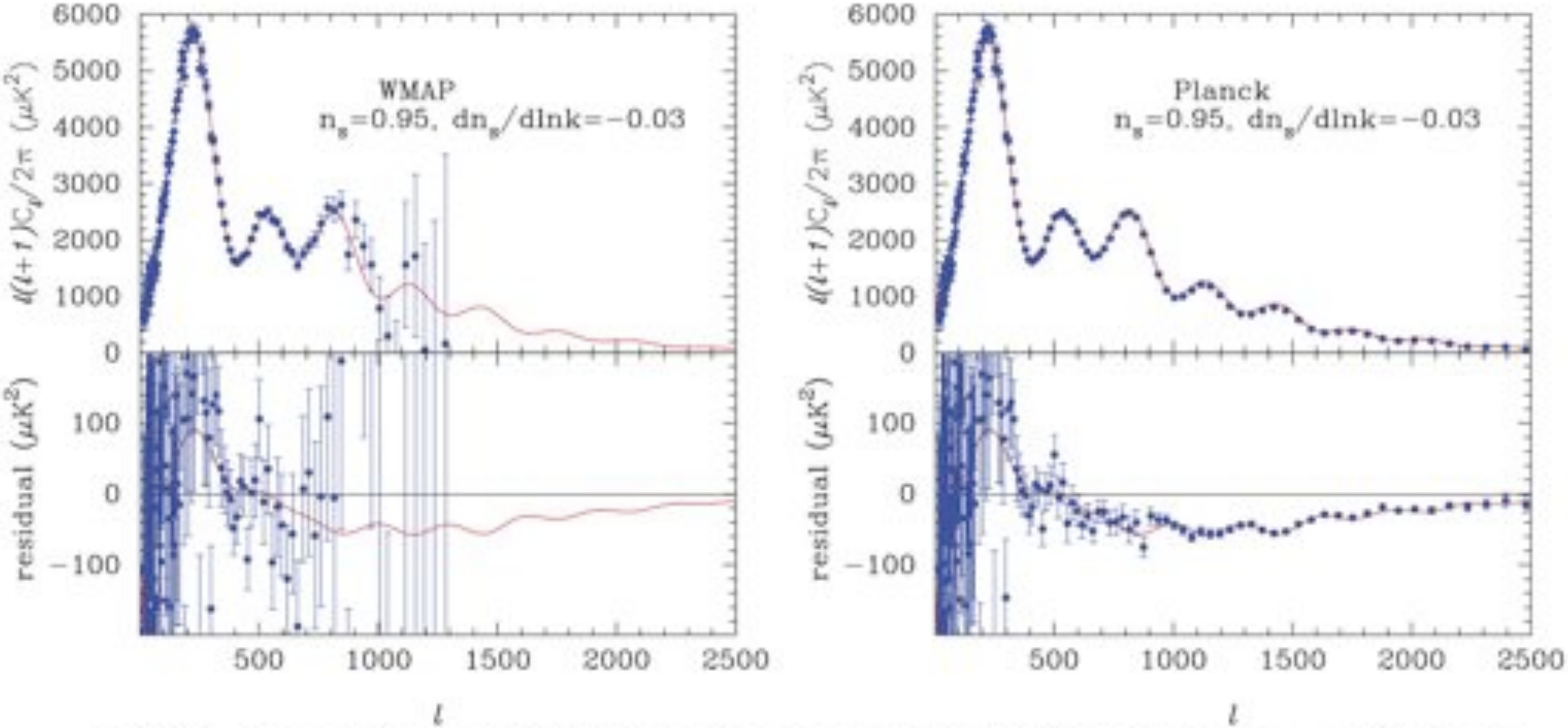


FIG 2.12.—Same as Figure 2.11, but now comparing the concordance ΛCDM model, having $n_S = 0.95$ and zero run (solid line), with a realisation of a model having with $n_S = 0.95$ (at a fiducial wavenumber of $k_0 = 0.05\ \mathrm{Mpc}^{-1}$) and a run of $dn_S/d\ln k = -0.03$.

Increased accuracy

For ΛCDM concordance model
7 parameters (as shown, + *h*)

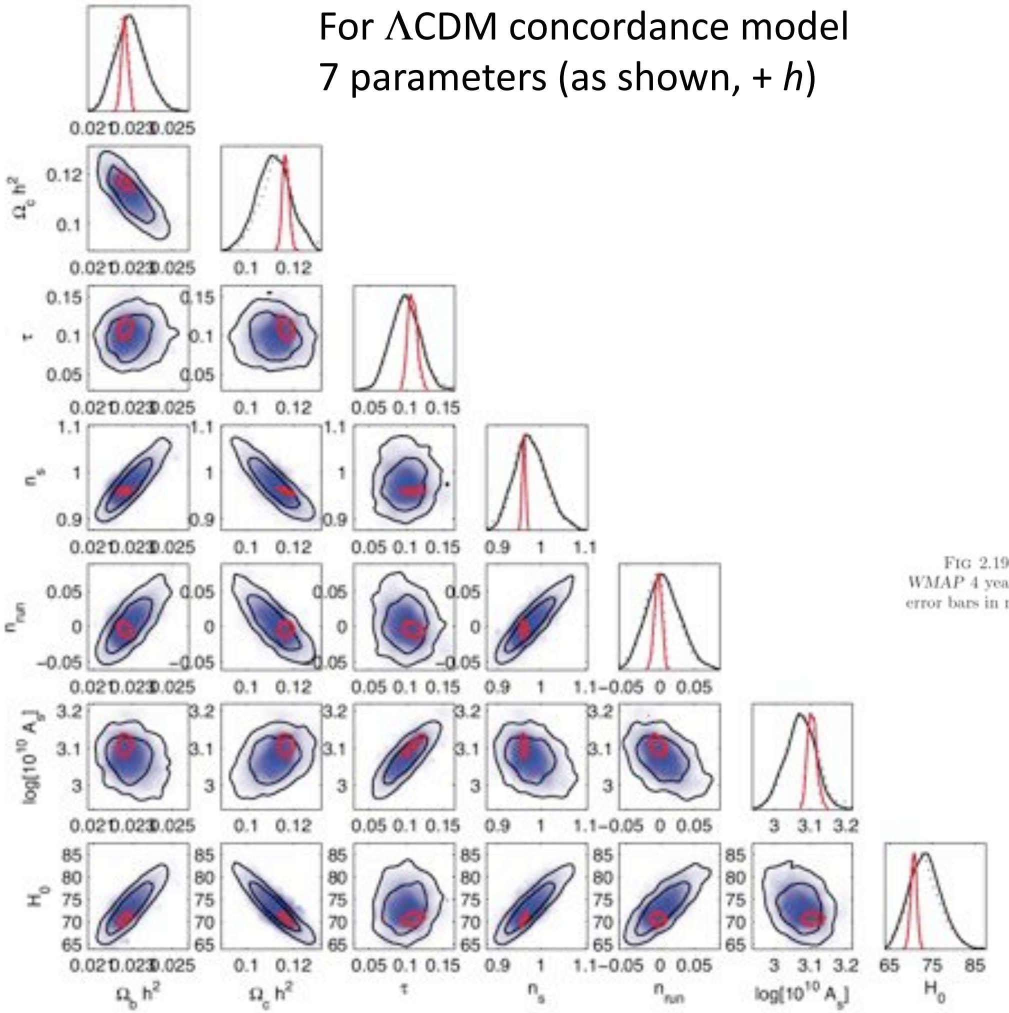


FIG 2.18.—Forecasts of 1 and 2σ contour regions for various cosmological parameters when the spectral index is allowed to run. Blue contours show forecasts for *WMAP* after 4 years of observation and red contours show results for *Planck* after 1 year of observations. The curves show marginalized posterior distributions for each parameter.

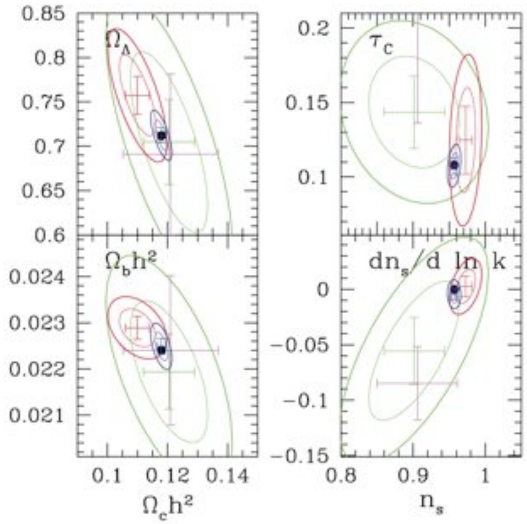


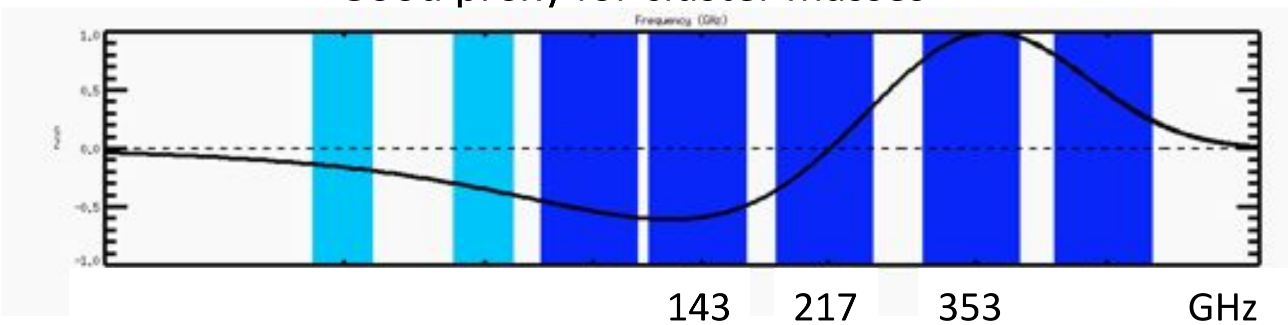
FIG 2.19.—Forecasts of 1 and 2σ contour regions for *WMAP* 4 years (green), for *Planck* 1 year (blue) and *WMAP* 4 years +ACT/SPT (red, see text). The input values of the parameters are given by the black dots. The error bars in magenta show the precision from current CMB data when the spectral index is allowed to run.

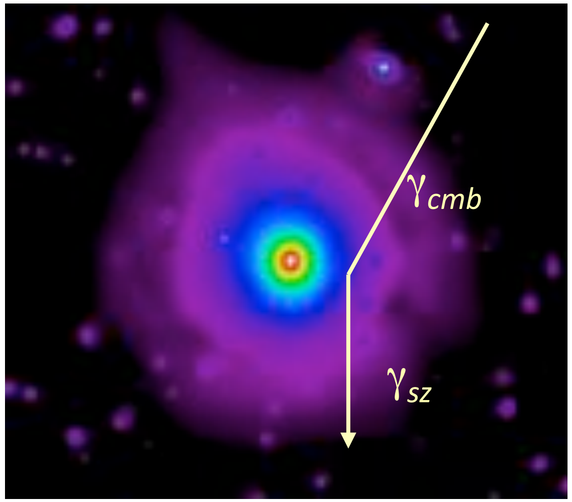
Bond et al., 2004

Galaxy clusters

- **Largest collapsed structures**
- Gas fraction M_g/M_{tot} →
  - Cosmological parameters (Ω_b/Ω_m)
- Angular vs. physical size →
  - Cosmological parameters (H,…)
- Number counts *dN/dMdz* →
  - Cosmological parameters (Ω_m)
  - Spectrum *P(k) (in particular* σ_8*)*
- Number counts *dN/dΩdz* →
  - Geometry $D_A(z)$, $H(z)$

- Sunyaev-Zel'dovich effect (SZ effect)
  - Inverse Compton on electrons
  - Possible detection at high *z*
  - Good proxy for cluster masses





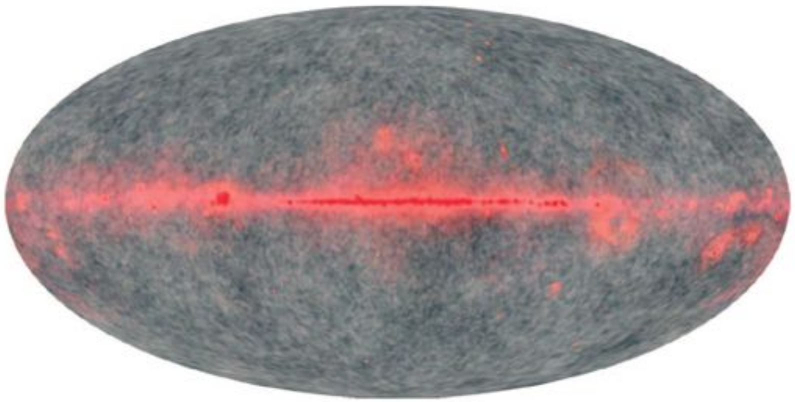
The multi-component sky

- The sky emits radiation via many different processes :
  - Interstellar medium (synchrotron, free-free, dust, modelcular lines…)
  - Sunyaev-Zel'dovich effect in galaxy clusters
  - Emission from numerous extragalactic sources

- Has always been a problem, from the first measurements of anisotropies!

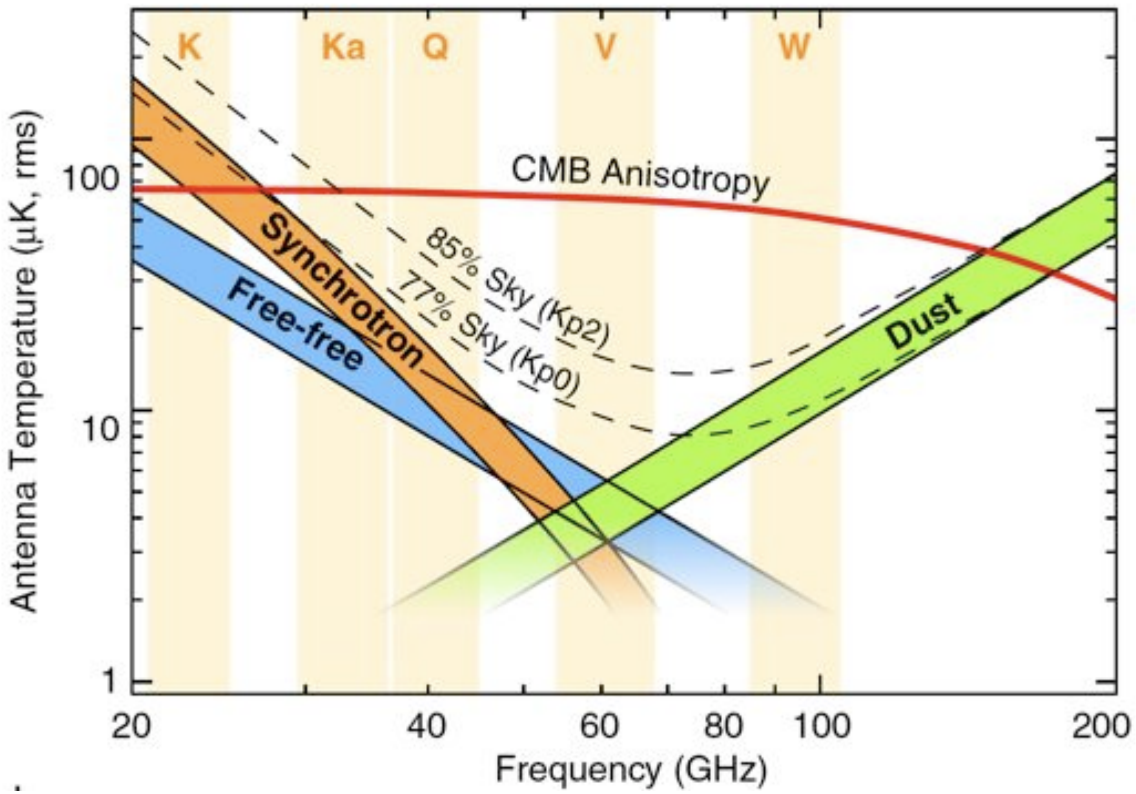
Solution :

multi-frequency observations
i.e. in colour…



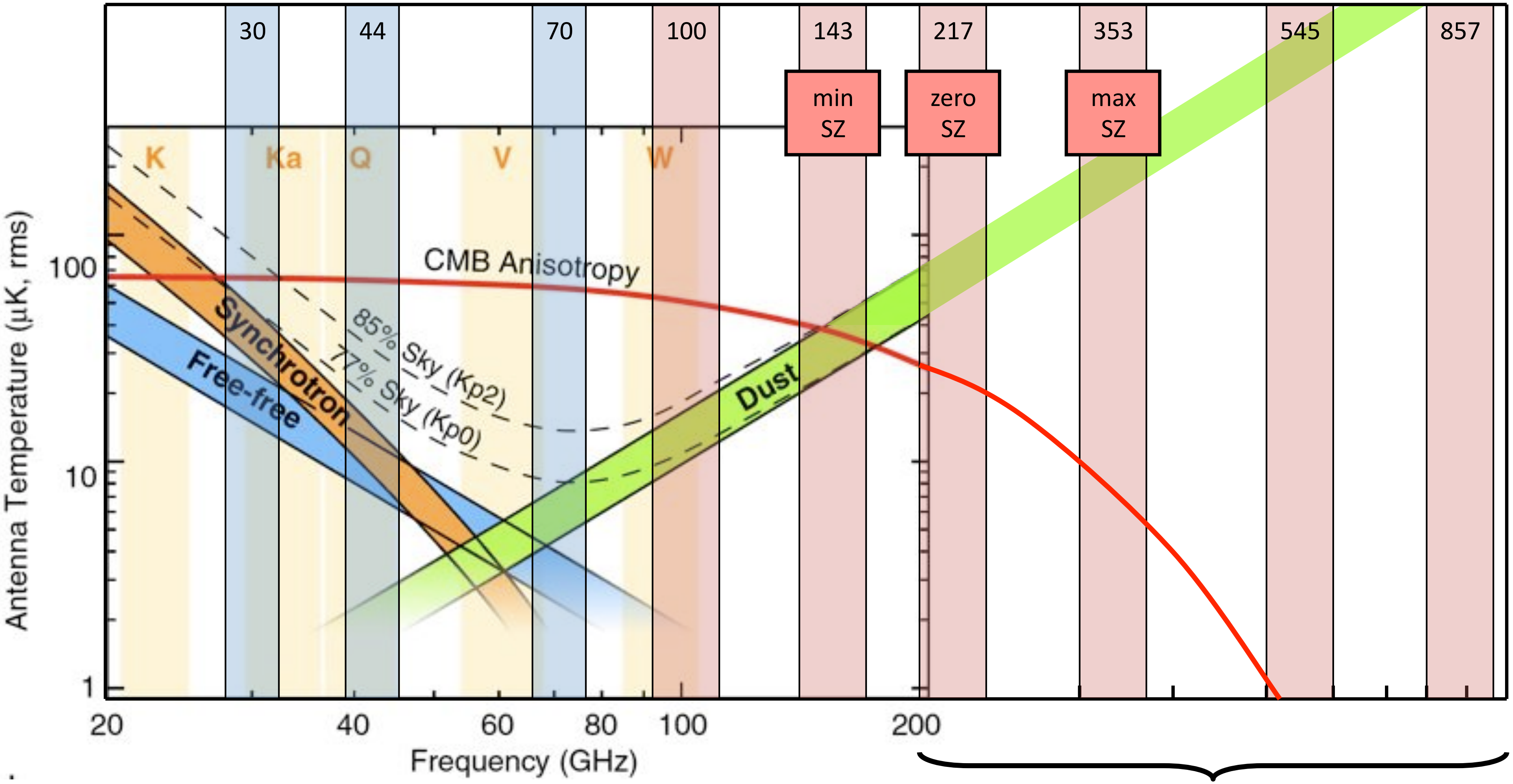
Bennett et al., ApJSS Volume 148, Issue 1, pp.97-117 (2003)

Multifrequency observations with WMAP



53 40 31 21 13 arcminute resolution

Multifrequency observations with Planck



53 40 31 21 13 arcminute resolution

33 24 14 10 7.1 5 arcminute resolution

The Planck design

- **The "ultimate" measurement of CMB temperature**
  - Down to the "smallest CMB scales" (5 arcminutes)
    - ➜ Large telescope (1.5 m projected diameter)
    - ➜ Some channels at small wavelengths ($\theta \approx \lambda/D$)
  - Sensitivity (fraction of a μK per square degree)
    - ➜ Not limited by instrumental noise
    - ➜ In some channels, photon noise dominates
    - ➜ Cryogenic mission (100 mK bolometers, 20K radiometers)
    - ➜ Intrinsic limitations due to foreground emissions
  - Full sky survey at 9 frequencies from 30 to 850 GHz
    - ➜ Identify unambiguously CMB by its spectral emission law
    - ➜ Subtract foreground contamination to Planck accuracy (!)
    - ➜ Two instruments LFI (radiometers) and HFI (bolometers)
- **A very good measurement of CMB polarisation**

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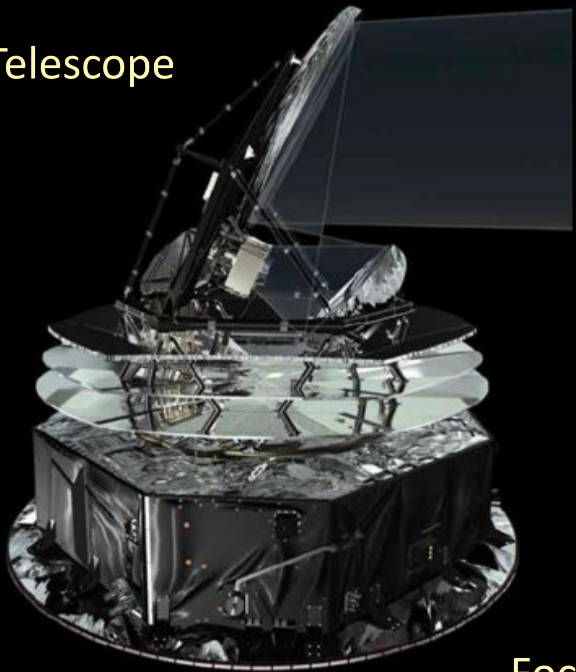
Planck fact sheet - 1

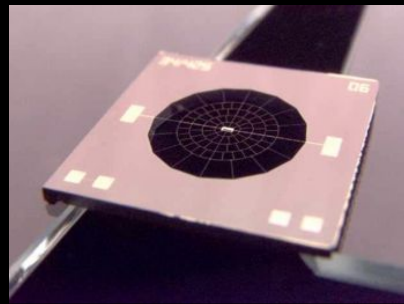
- 52 bolometers (HFI) et 22 radiometers (LFI)
- Off-axis Gregorian telescope: primary 1.5m, secondary 1m, main axis pointing at 85 degrees away from the spin axis
- Cryogenic mission:
  - warm launch
  - passive cooling of the telescope
  - complex cryogenic chain
  - 2 cryo-coolers (20 and 4 K)
  - open-cycle dilution $_3$He-$_4$He fridge fo 1.6K and 0.1K (48.000 litres of Helium)
- 2kW power

The Payload

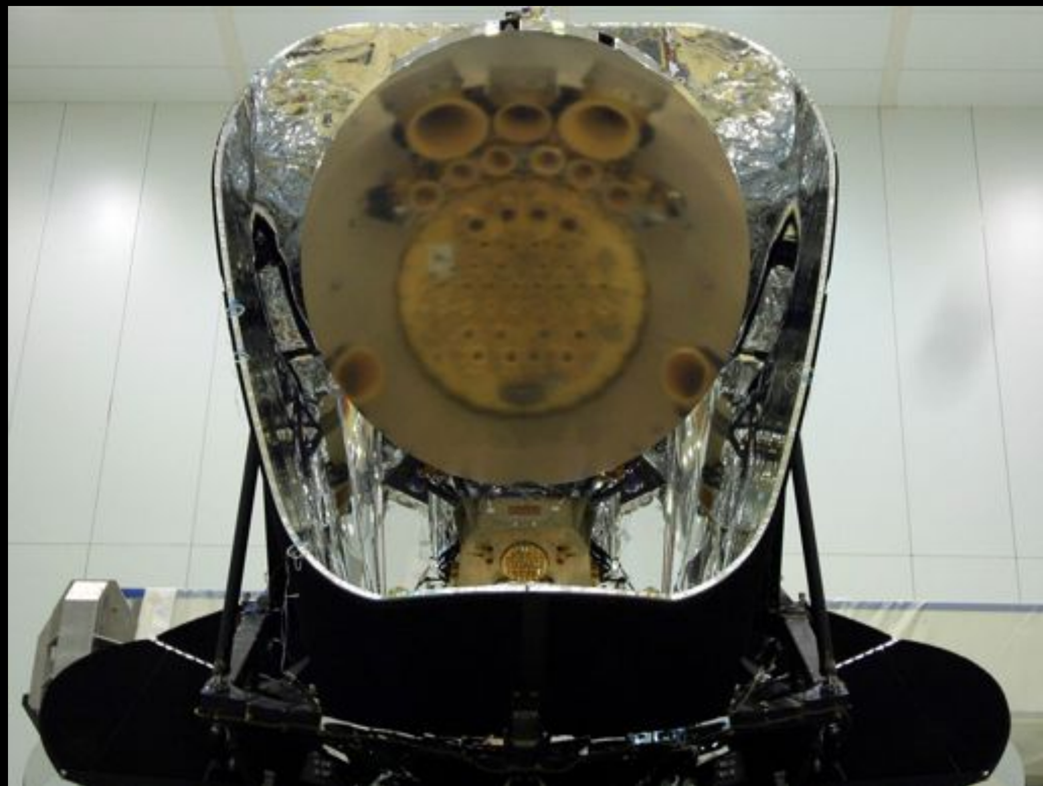
Telescope



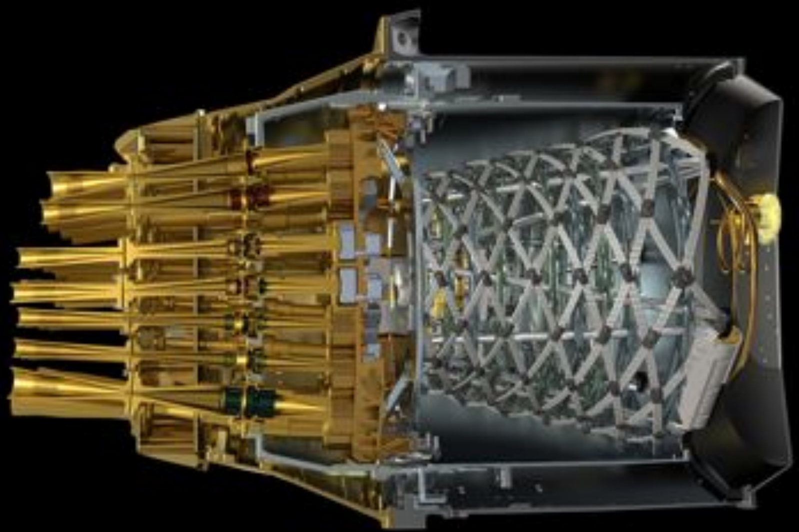
Spiderweb bolometer



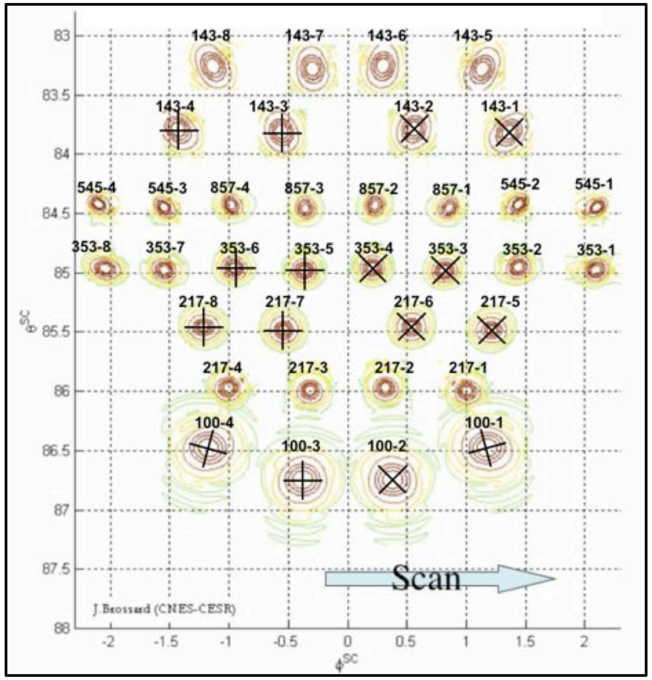
Focal plane

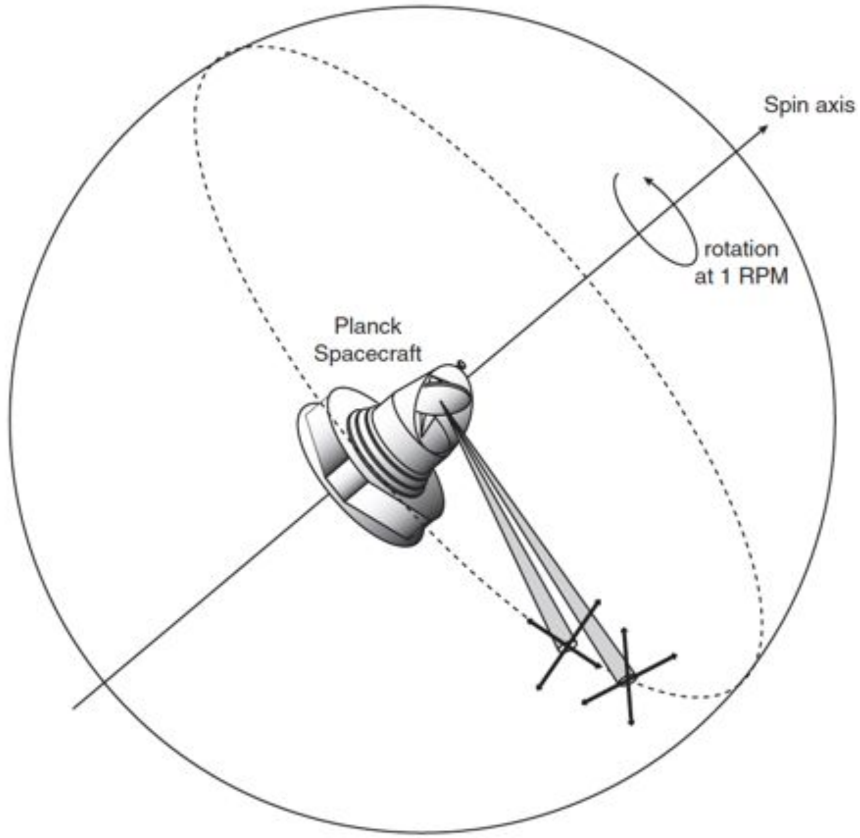


Planck HFI and global view



Planck scanning the sky





Measure 3 Stokes parameters

$$I = |E_0^2| + |E_{90}^2|$$
$$Q = |E_0^2| - |E_{90}^2|$$
$$U = |E_{45}^2| - |E_{135}^2|$$

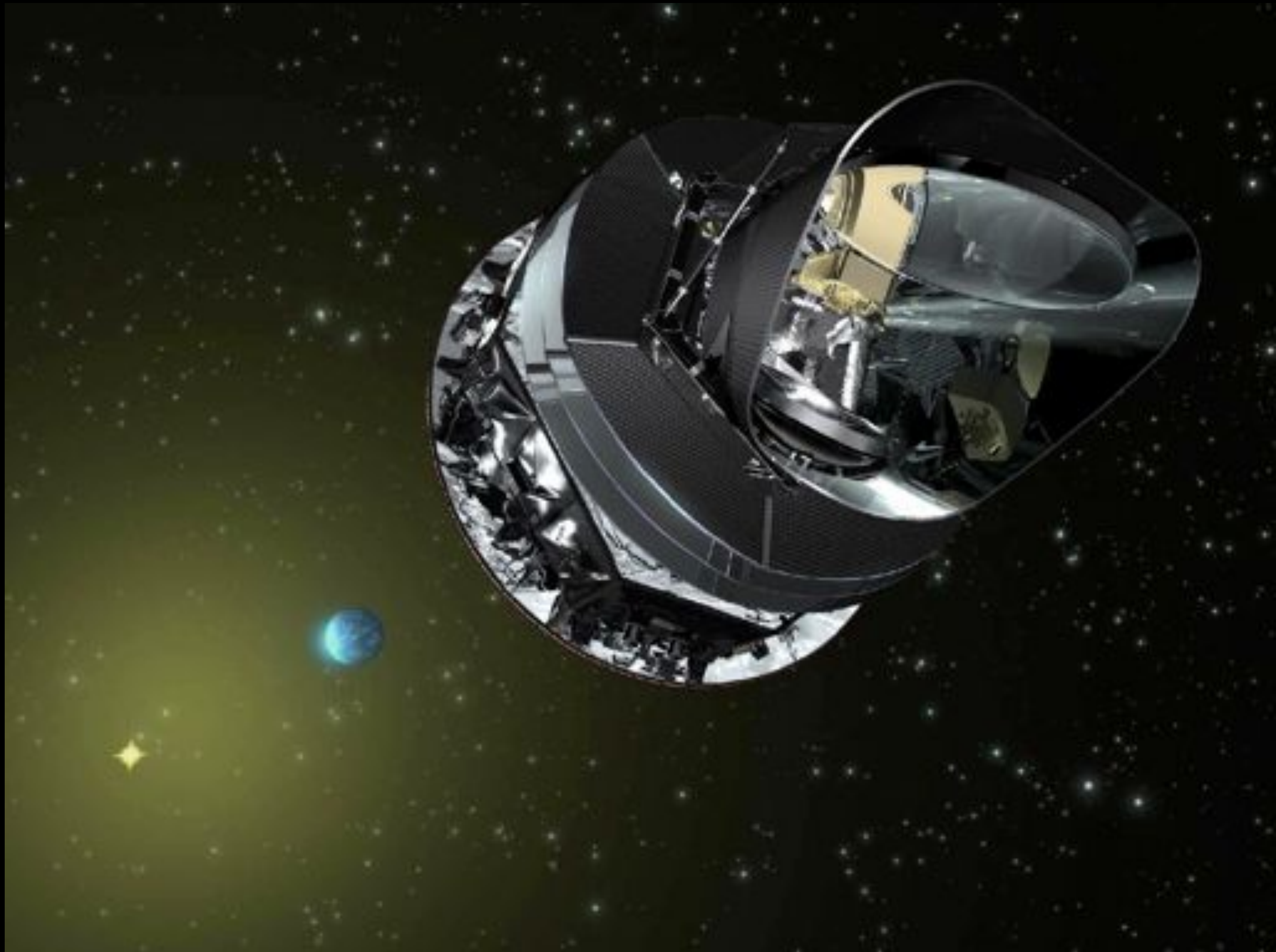
Planck fact sheet - 2

- 1900 kg at take-off
  - (Ariane 5, 14 may 2009)

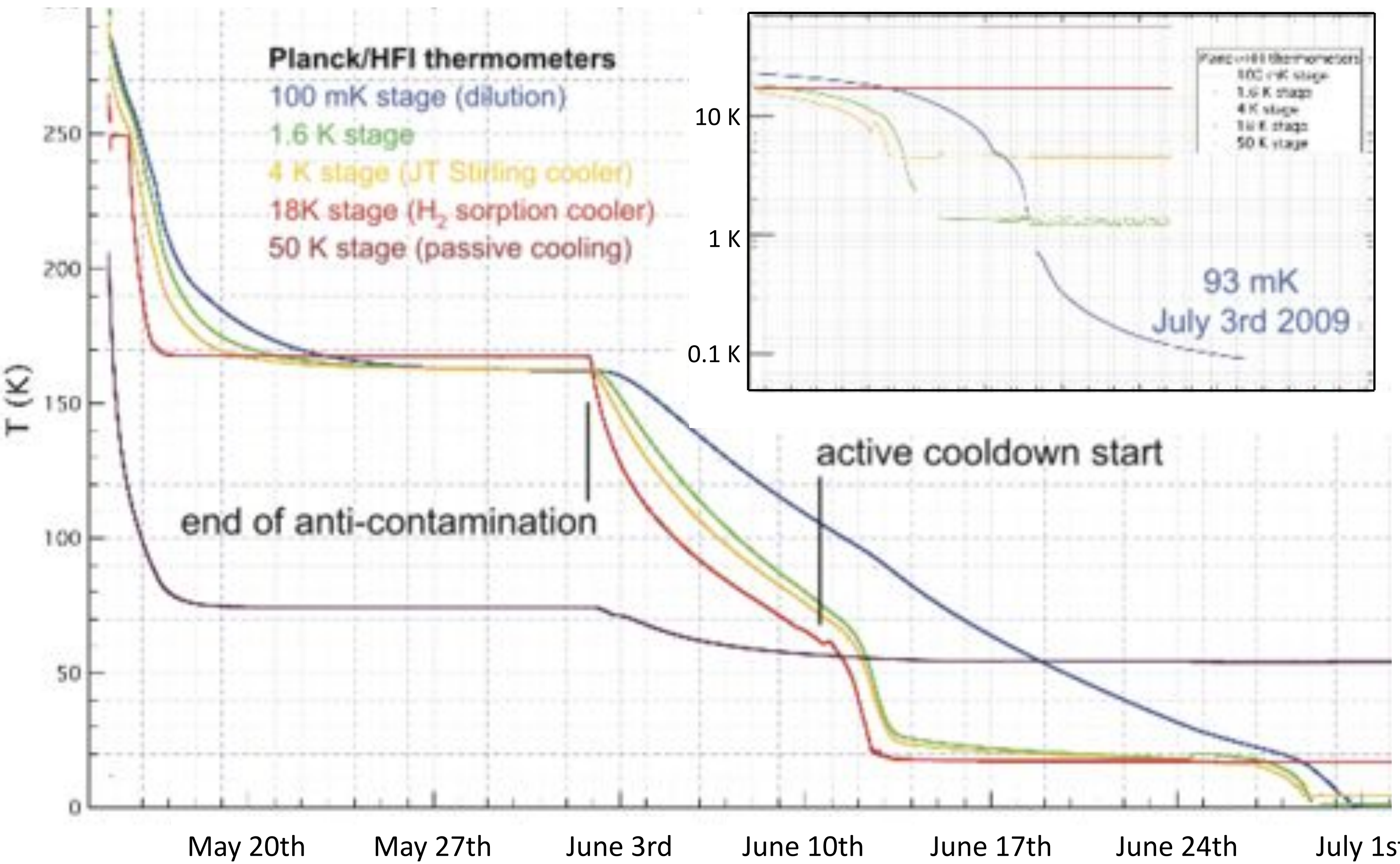
- Small halo orbit
  - around Lagrange point L2
- Scanning at 1 rpm
- 4 complete maps of the continuum sky at 9 frequencies: 30-850 GHz (1 cm - 350 microns)
- Telemetry: 100 kbit/s (3 hours download per day), 2 TBytes per year

Kourou, 14th May 2009 !

En route to L2



Planck cooling down



Planck fact sheet - 3

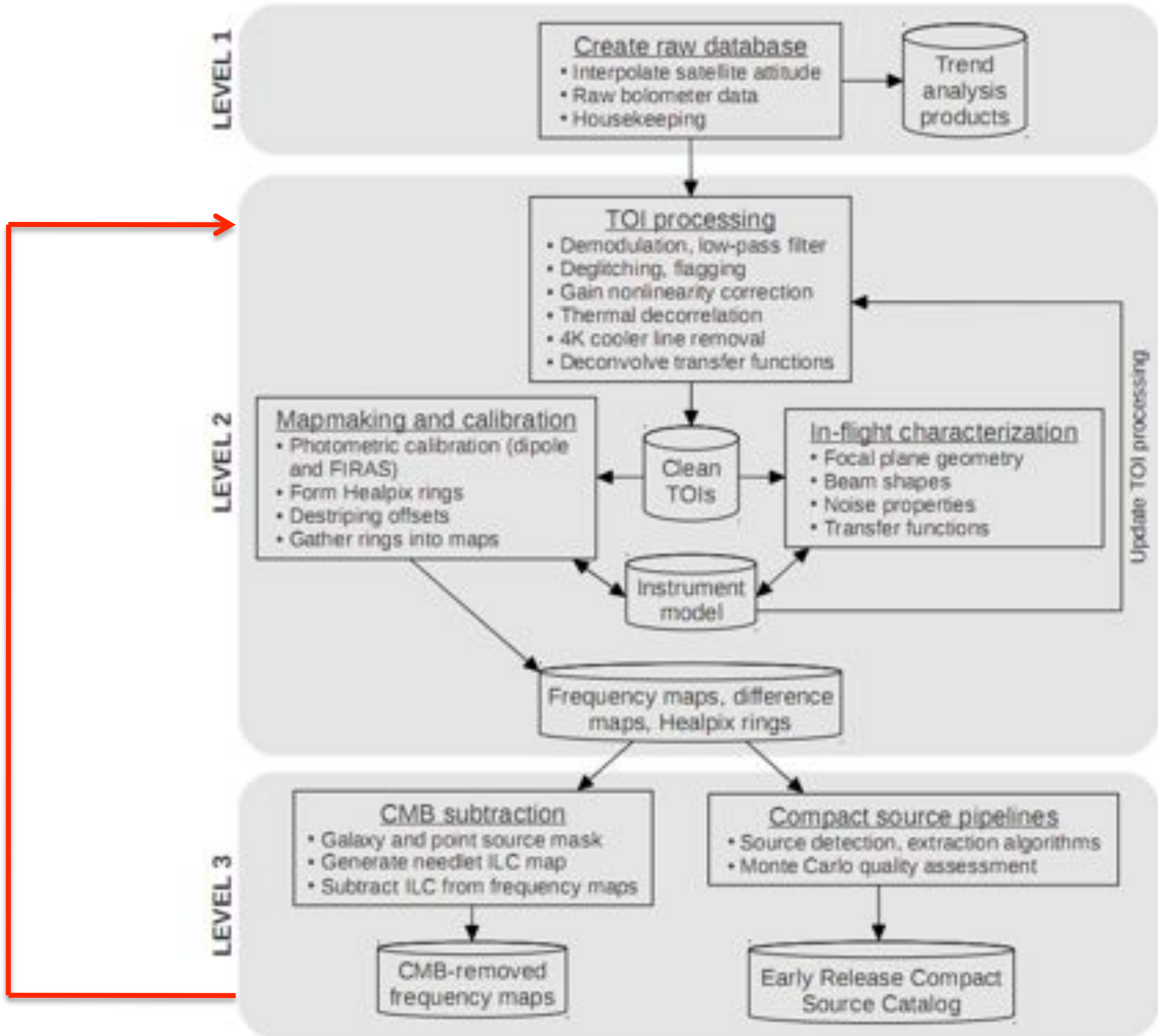
- Made by
  - Agencies: ESA, CNES, ASI, NASA
  - Industry: Thales-Alenia Space, Air Liquide
  - Research and higher education: CNRS, CEA, universities, 13 labs
- The scientists
  - 29 laboratories, 300-600 scientists
- Cost
  - About 650 M€ total (mission + instruments)
  - 450 M€ ESA cost (M mission)
  - HFI instrument: 150 M€, (56% France)

Bologna, November 2008

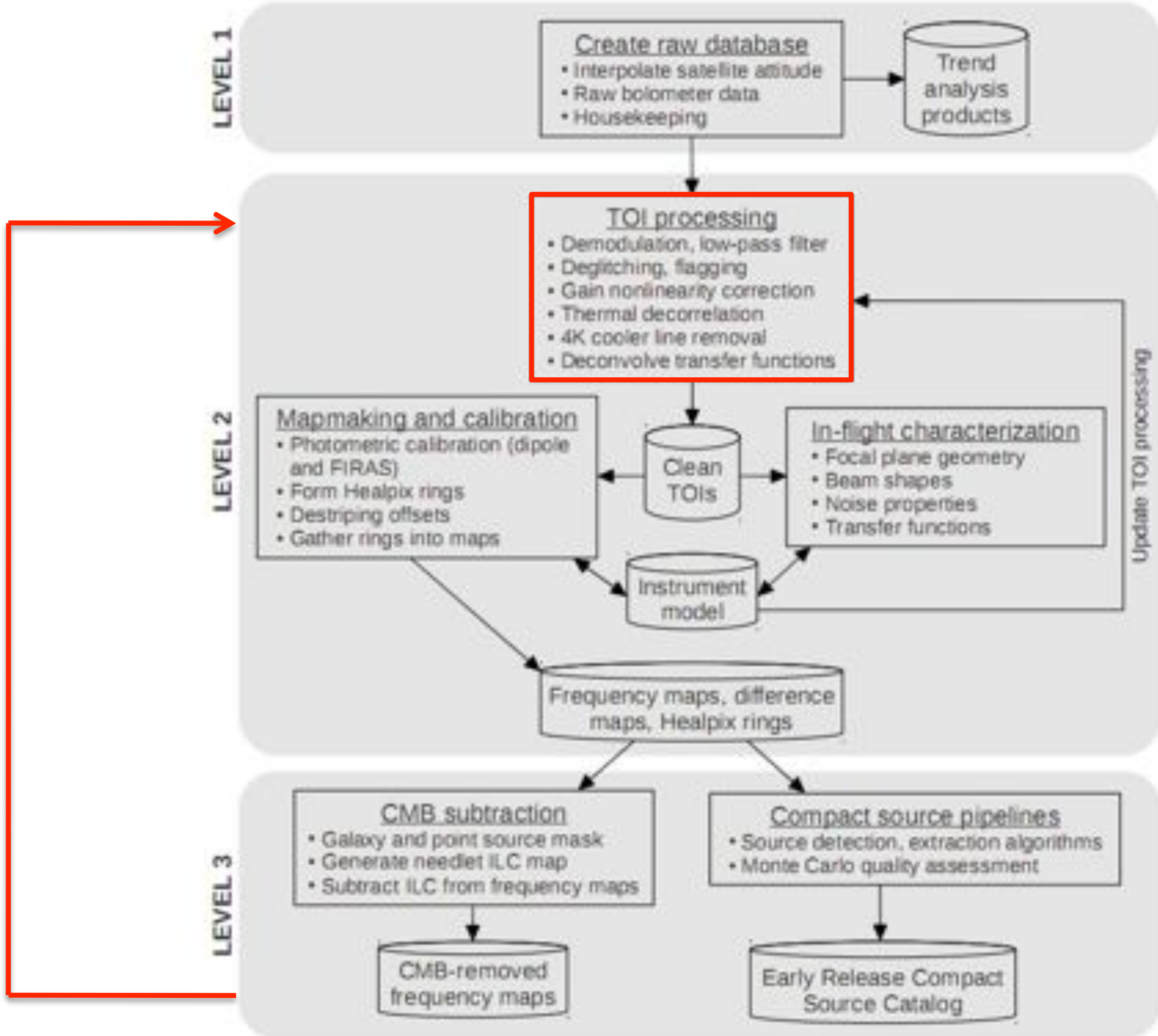
The Planck mission : outline

- Context and objectives
- Design and scientific programme
- Making it happen
- ➡ Data reduction
- Early results
- The future

The processing pipeline so far



Timeline processing



Raw timelines

HFI Core Team: HFI Data Processing

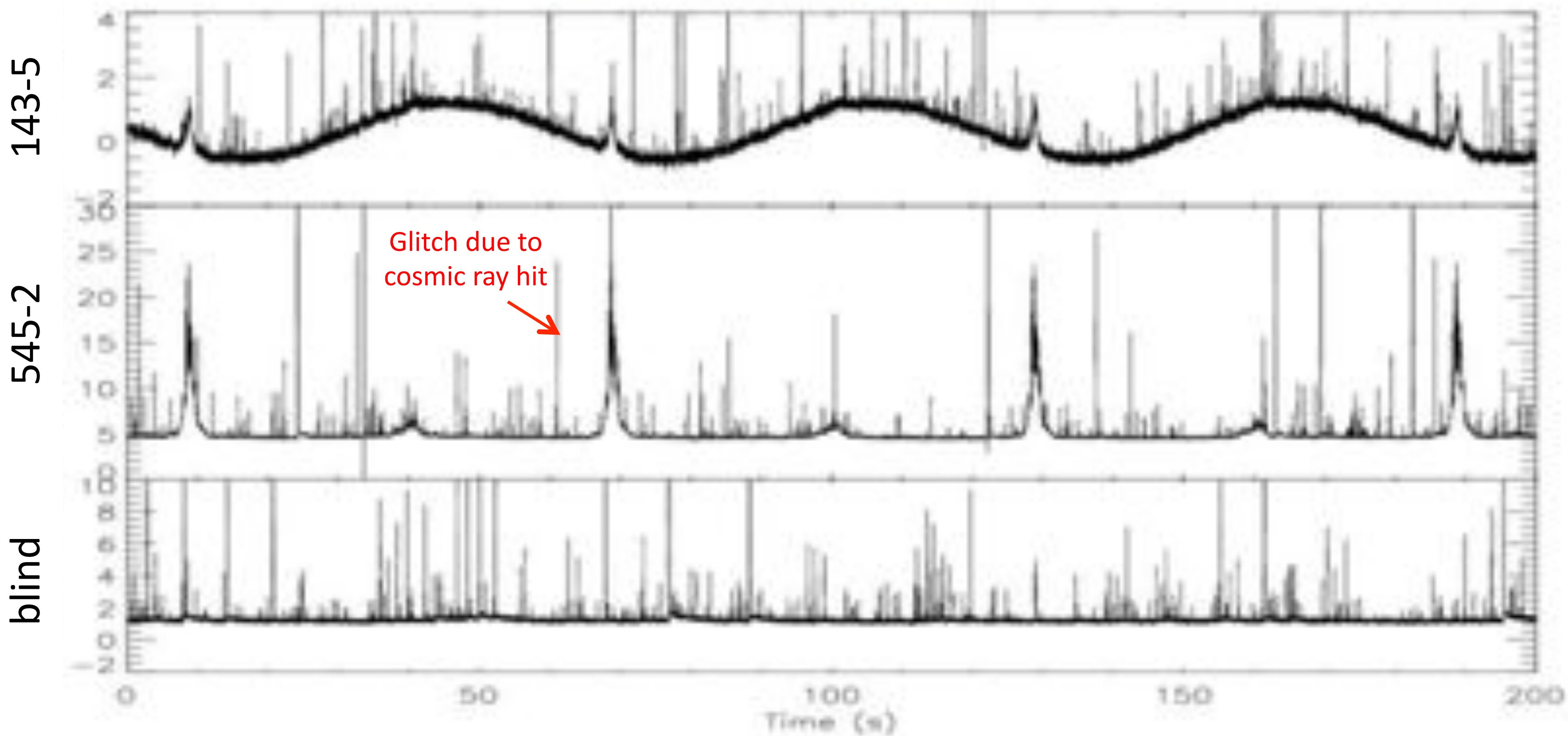
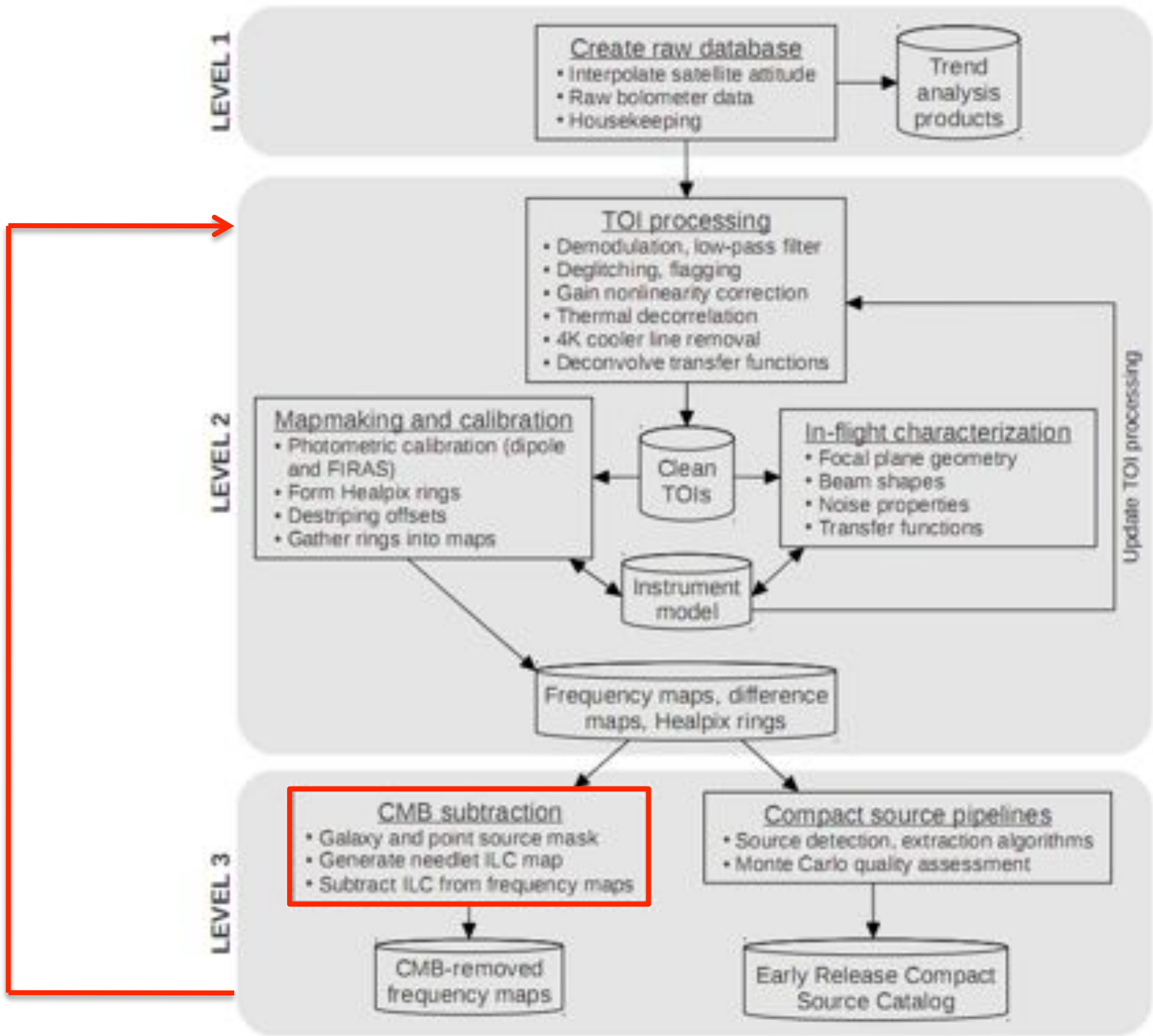
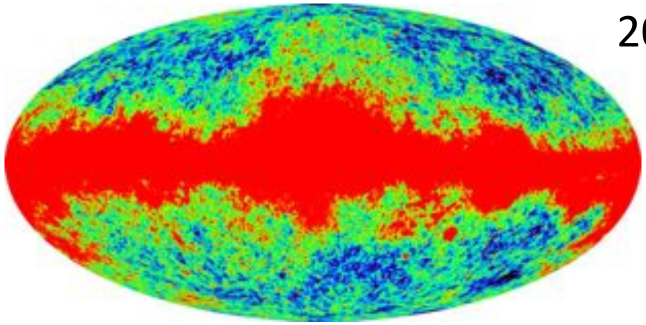


Figure 4. Raw TOIs for three bolometers, the '143-5' (top), '545-2' (middle), and 'Dark1' (bottom) illustrating the typical behaviour of a detector at 143 GHz, 545 GHz, and a blind detector over the course of three rotations of the spacecraft at 1 rpm. At 143 GHz, one clearly sees the CMB dipole with a 60 s period. The 143 and 545 GHz bolometers show vividly the two Galactic Plane crossings, also with 60 s periodicity. The dark bolometer exhibits a nearly constant baseline together with a population of glitches from cosmic rays similar to those seen in the two upper panels.

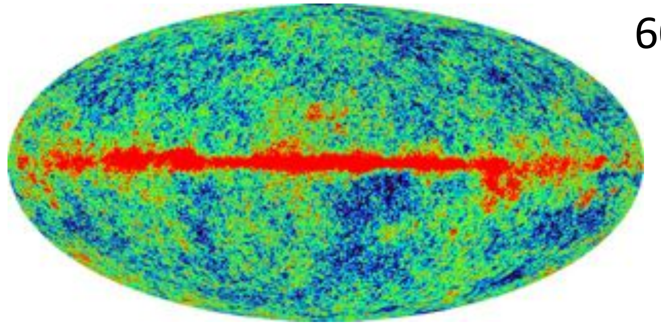
Component separation



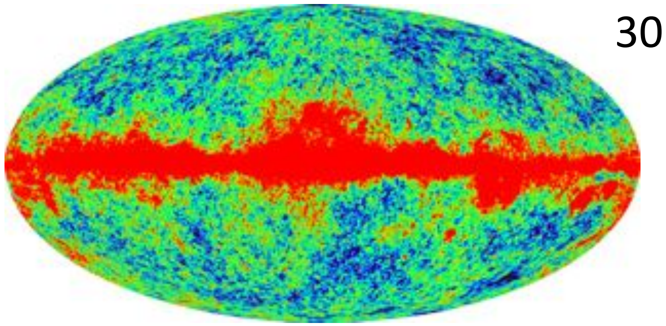
Component separation (on WMAP)



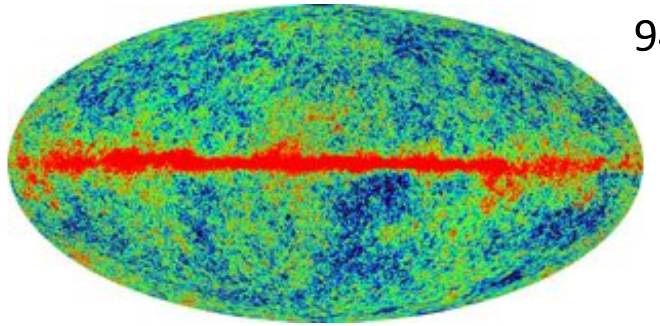
20 GHz



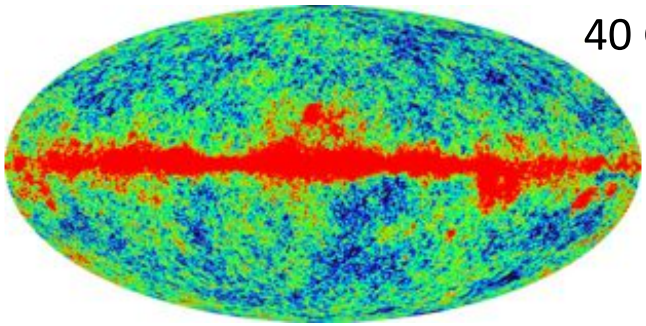
60 GHz



30 GHz



94 GHz



40 GHz

Maps are not stationary.

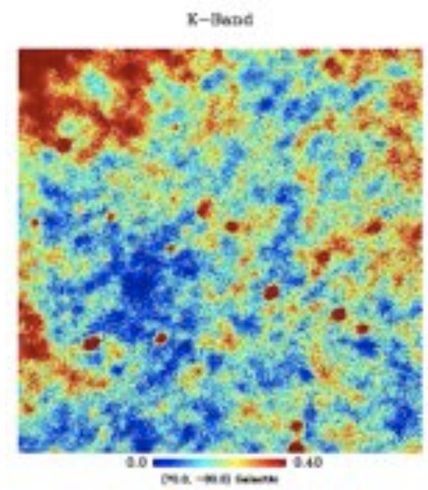
They are not all at the same resolution.

⇩

Construction of linear filters that depend both on pixel and scale (ILC on needlet frames)

CMB and foreground emission

Original map



WMAP K band at 23 GHz dominated by galactic synchrotron

In a given pixel:

- CMB?
- galactic ISM?
- radio source ?

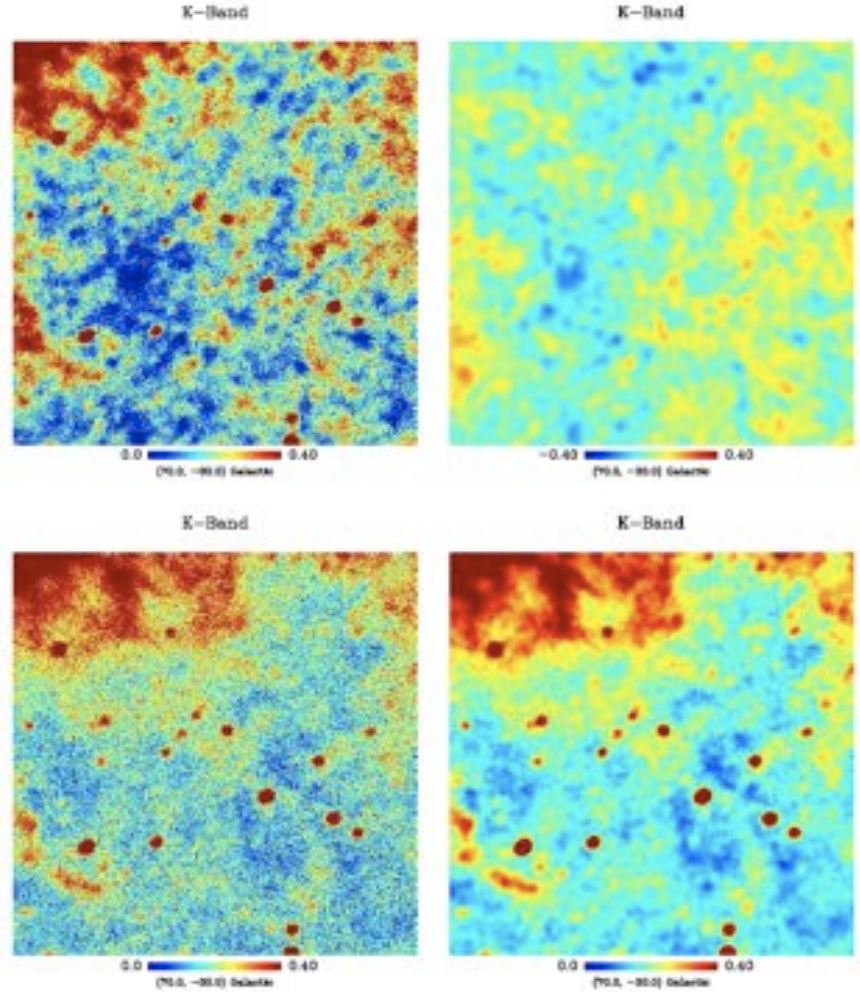
CMB and foreground emission

Delabrouille, Cardoso, Le Jeune et al., 2009, A&A 493, 835
Ghosh, Delabrouille, Remazeilles et al., 2011, MNRAS, 412, 883

Original map

Estimated CMB

CMB subtraction

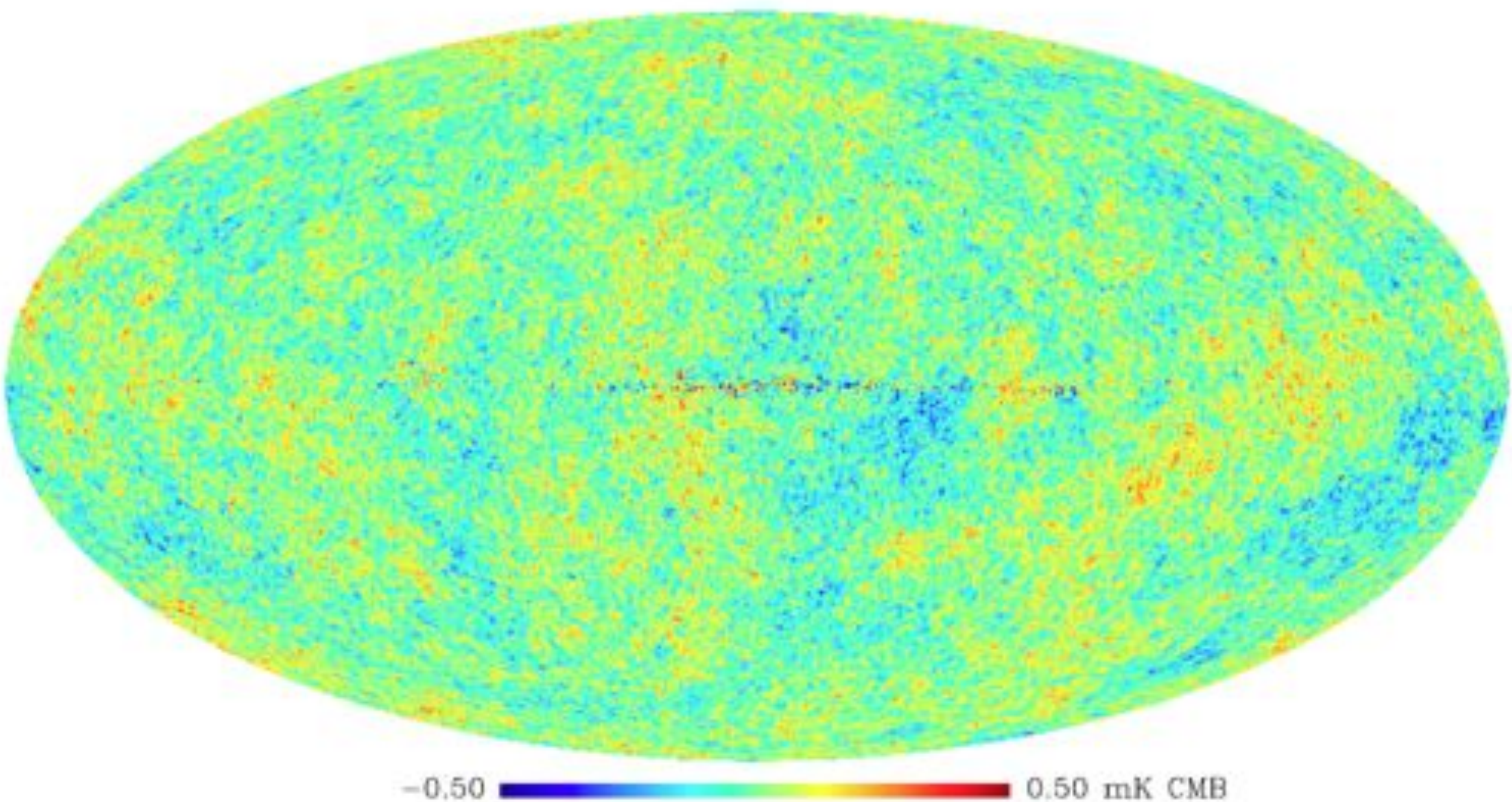


Map with no CMB

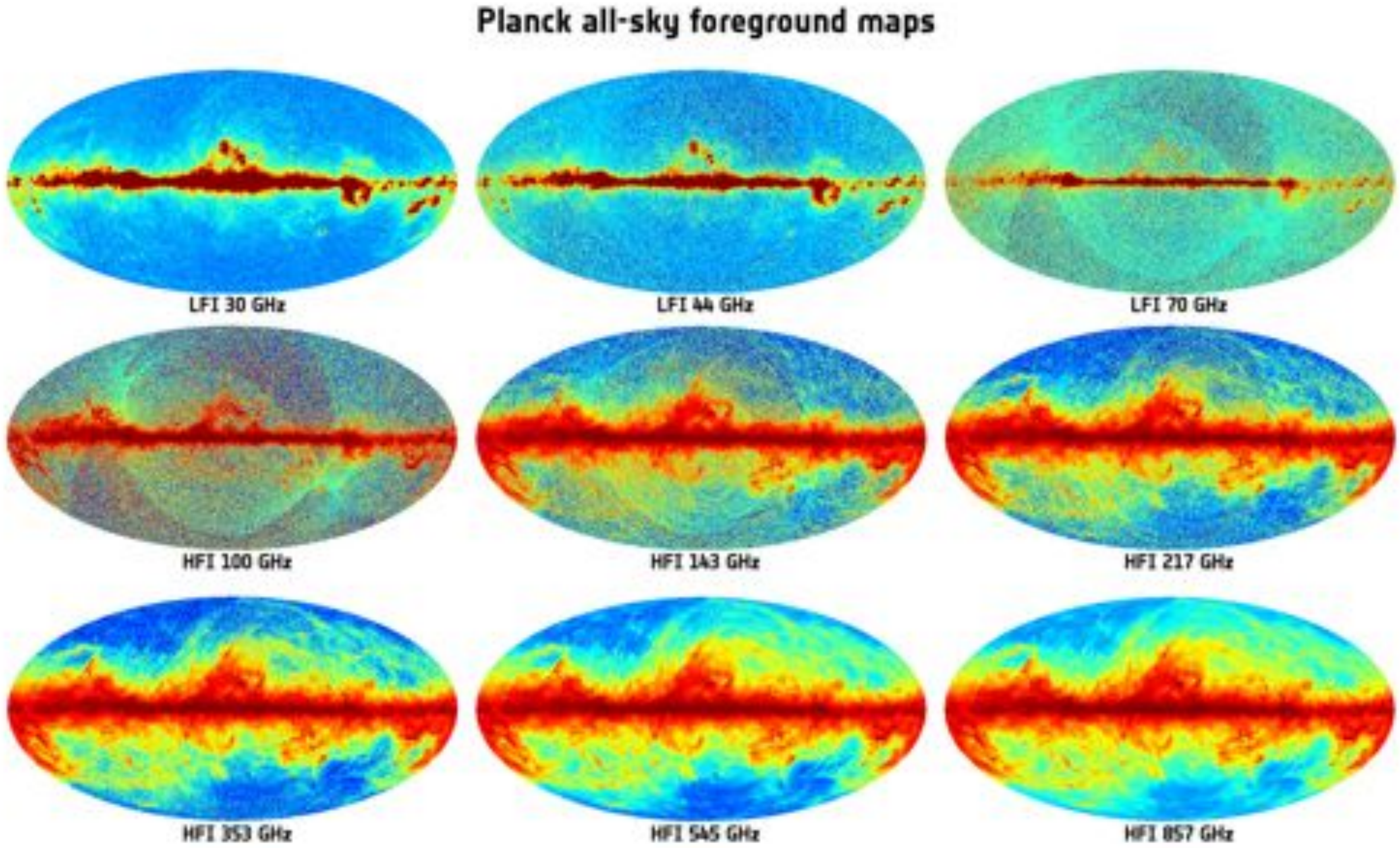
Map after
Additional filtering

The CMB

5 year needlet ILC map



Maps after subtraction of the CMB



The Planck mission : outline

- Context and objectives
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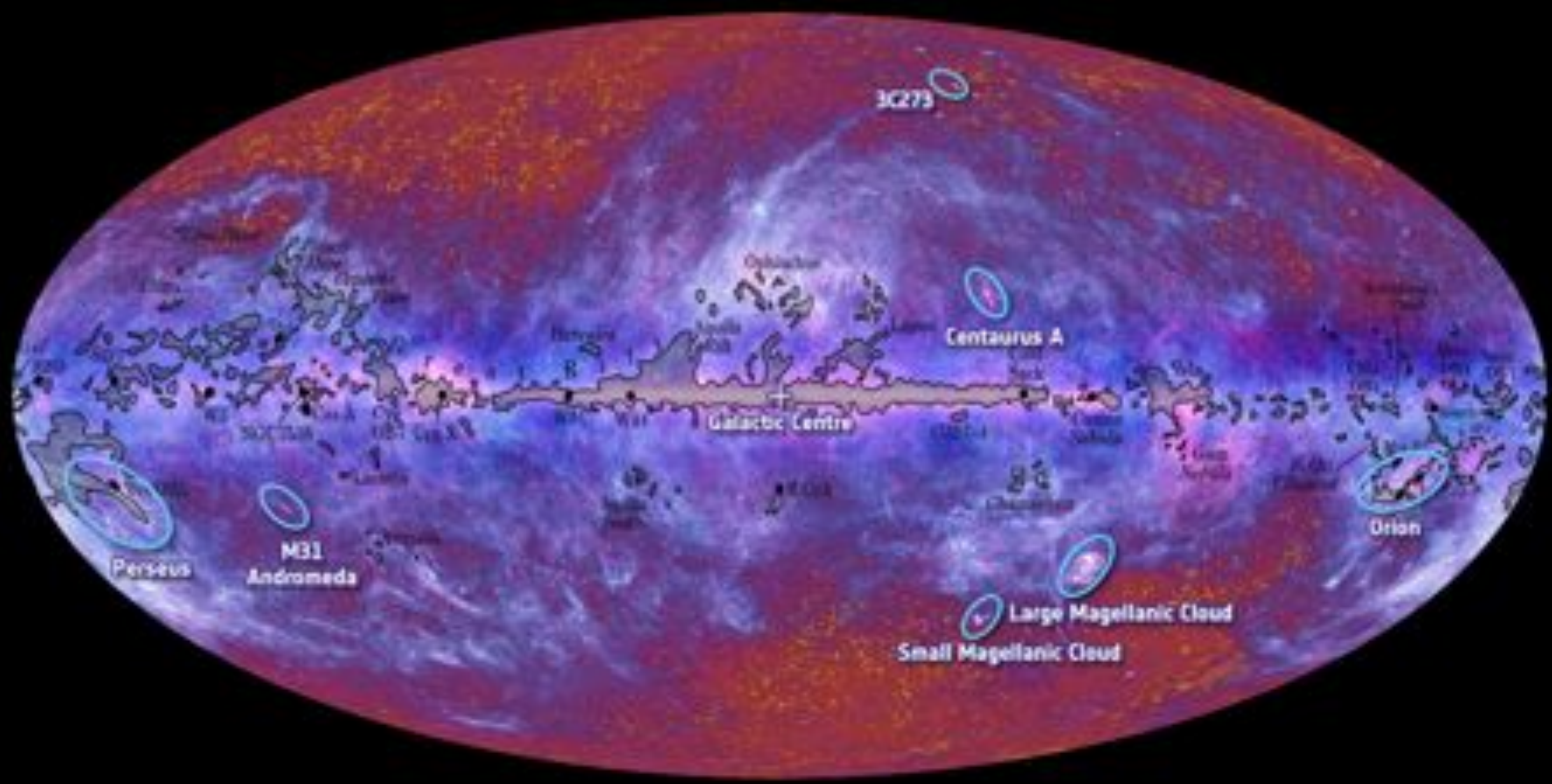
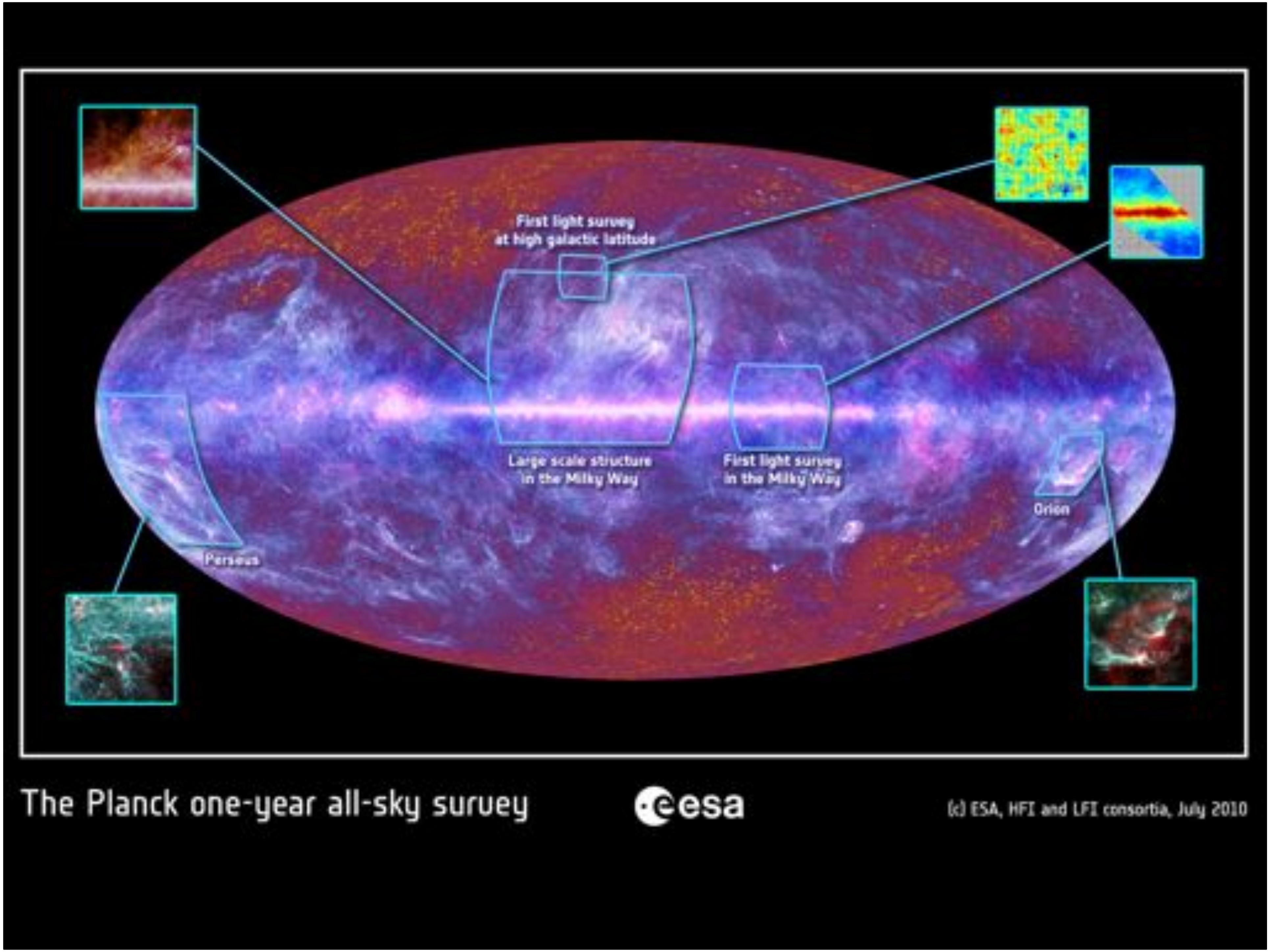
- Making it happen
- Data reduction
- ⇨ Early results
- The future



The Planck one-year all-sky survey


First light survey at high galactic latitude
Large scale structure in the Milky Way
First light survey in the Milky Way
Orion
Perseus
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010

Early papers

- Mission, performance, data processing — 6 papers
- Clusters of galaxies — 5 papers
  - Catalogue of clusters detected by Planck
  - Scaling relations between SZ, X-ray, and optical observables
- Point sources and infrared background — 6 papers
  - ERCSC
  - Spectrum of background anisotropies
- Galactic science — 8 papers
  - Cold cores and clumps
  - Thermal dust emission
  - Spinning dust emission

25 publications submitted early January 2011 to A&A (preprints available on arXiv)

Astronomy & Astrophysics manuscript no. Planck2011-1.1
January 12, 2011

Planck Early Results: The *Planck* mission

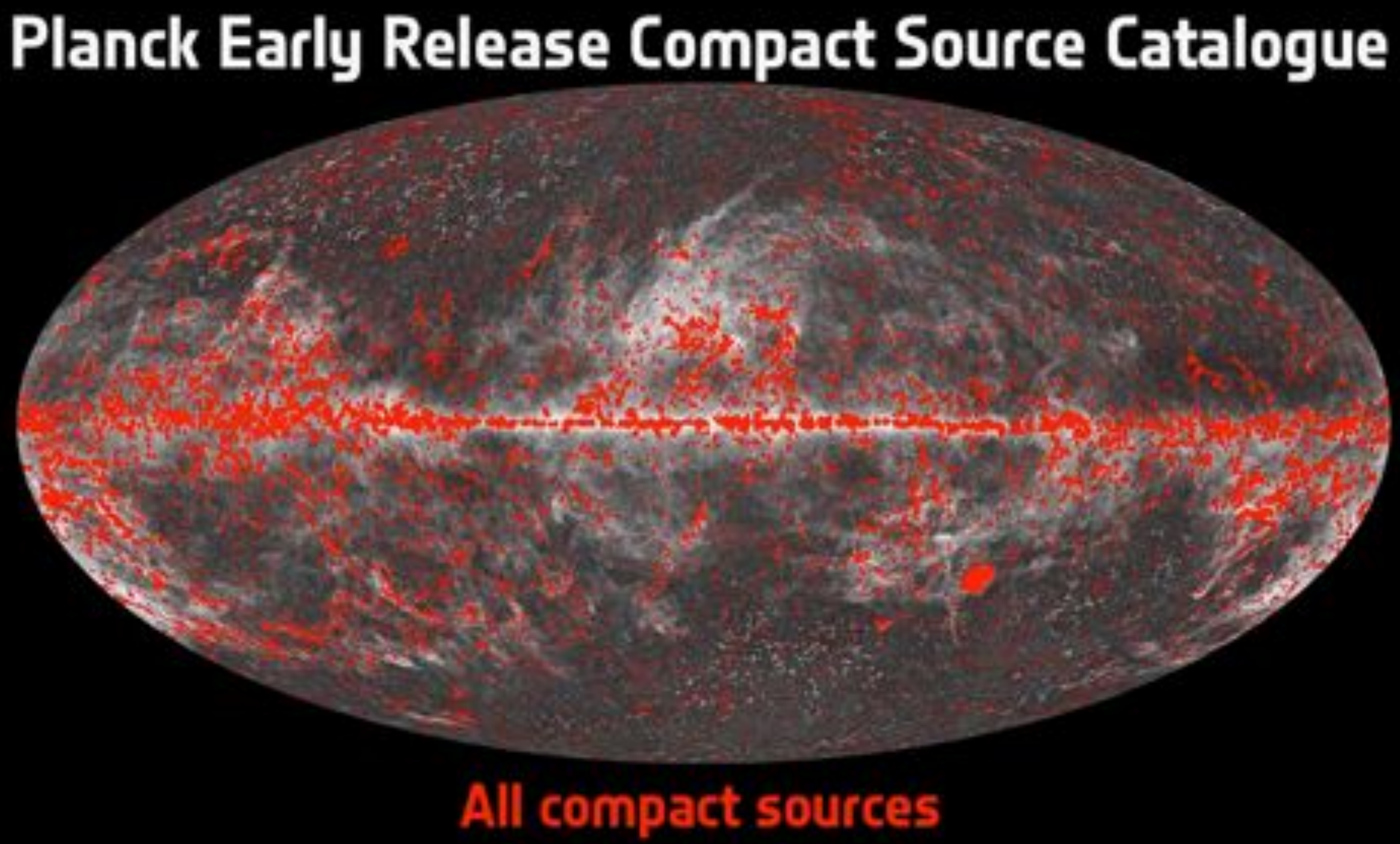
Planck Collaboration: P. A. R. Ade[78], N. Aghanim[51], M. Arnaud[64], M. Ashdown[62,87], J. Aumont[51], C. Baccigalupi[76], M. Baker[35], A. Balbi[29], A. J. Banday[85,8,69], R. B. Barreiro[58], J. G. Bartlett[3,60], E. Battaner[89], K. Benabed[52], K. Bennett[36], A. Benoît[52], J.-P. Bernard[85,8], M. Bersanelli[27,44], R. Bhatia[56], J. J. Bock[60,9], A. Bonaldi[40], J. R. Bond[5], J. Borrill[68,80], F. R. Bouchet[52], T. Bradshaw[75], M. Bremer[36], M. Bucher[3], C. Burigana[43], R. C. Butler[43], P. Cabella[29], C. M. Cantalupo[68], B. Cappellini[44], J.-F. Cardoso[65,3,52], R. Carr[33], M. Casale[33], A. Catalano[3,63], L. Cayón[20], A. Challinor[88,62,11], A. Chamballu[49], J. Charra[51], R.-R. Chary[50], L.-Y Chiang[55], C. Chiang[19], P. R. Christensen[72,30], D. L. Clements[49], S. Colombi[52], F. Couchot[67], A. Coulais[63], B. P. Crill[60,73], G. Crone[36], M. Crook[75], F. Cuttaia[43], L. Danese[76], O. D'Arcangelo[59], R. D. Davies[61], R. J. Davis[61], P. de Bernardis[26], J. de Bruin[35], G. de Gasperis[29], A. de Rosa[43], G. de Zotti[40,76], J. Delabrouille[3], J.-M. Delouis[52], F.-X. Désert[47], J. Dick[76], C. Dickinson[61], K. Dolag[69], H. Dole[51], S. Donzelli[44,56], O. Doré[60,9], U. Dörl[69], M. Douspis[51], X. Dupac[34], G. Efstathiou[88], T. A. Enßlin[69], H. K. Eriksen[56], F. Finelli[43], S. Foley[35], O. Forni[85,8], P. Fosalba[53], M. Frailis[42], E. Franceschi[43], M. Freschi[34], T. C. Gaier[60], S. Galeotta[42], J. Gallegos[34], B. Gandolfo[35], K. Ganga[3,50], M. Giard[85,8], G. Giardino[36], Y. Giraud-Héraud[3], J. González[33], J. González-Nuevo[76], K. M. Górski[60,91], S. Gratton[62,88], A. Gregorio[28], A. Gruppuso[43], G. Guyot[46], J. Haissinski[67], F. K. Hansen[56], D. Harrison[88,62], G. Helou[9], S. Henrot-Versillé[67], C. Hernández-Monteagudo[69], D. Herranz[58], S. R. Hildebrandt[9,66,57], E. Hivon[52], M. Hobson[87], W. A. Holmes[60], A. Hornstrup[13], W. Hovest[69], R. J. Hoyland[57], K. M. Huffenberger[90], A. H. Jaffe[49], T. Jagemann[34], W. C. Jones[19], J. J. Juillet[83], M. Juvela[18], P. Kangaslahti[60], E. Keihänen[18], R. Keskitalo[60,18], T. S. Kisner[68], R. Kneissl[32,4], L. Knox[22], M. Krassenburg[36], H. Kurki-Suonio[18,38], G. Lagache[51], A. Lähteenmäki[1,38], J.-M. Lamarre[63], A. E. Lange[50], A. Lasenby[87,62], R. J. Laureijs[36], C. R. Lawrence[60], S. Leach[76], J. P. Leahy[61], R. Leonardi[34,36,23], C. Leroy[51,85,8], P. B. Lilje[56,10], M. Linden-Vørnle[13], M. López-Caniego[58], S. Lowe[61], P. M. Lubin[23], J. F. Macías-Pérez[66], T. Maciaszek[6], C. J. MacTavish[62], B. Maffei[61], D. Maino[27,44], N. Mandolesi[43], R. Mann[77], M. Maris[42], E. Martínez-González[58], S. Masi[26], M. Massardi[40], S. Matarrese[25], F. Matthai[69], P. Mazzotta[29], A. McDonald[35], P. McGehee[50], P. R. Meinhold[23], A. Melchiorri[26], J.-B. Melin[12], L. Mendes[34], A. Mennella[27,42], C. Mevi[35], R. Miniscalco[35], S. Mitra[60], M.-A. Miville-Deschênes[51,5], A. Moneti[52], L. Montier[85,8], G. Morgante[43], N. Morisset[48], D. Mortlock[49], D. Munshi[78,88], A. Murphy[71], P. Naselsky[72,30], P. Natoli[29,2,43], C. B. Netterfield[15], H. U. Nørgaard-Nielsen[13], F. Noviello[51], D. Novikov[49], I. Novikov[72], I. J. O'Dwyer[60], I. Ortiz[33], S. Osborne[82], P. Osuna[33], C. A. Oxborrow[13], F. Pajot[51], R. Paladini[81,9], B. Partridge[37], F. Pasian[42], T. Passvogel[36], G. Patanchon[3], D. Pearson[60], T. J. Pearson[9,50], O. Perdereau[67], L. Perotto[66], F. Perrotta[76], F. Piacentini[26], M. Piat[3], E. Pierpaoli[17], S. Plaszczynski[67], P. Platania[59], E. Pointecouteau[85,8], G. Polenta[2,41], N. Ponthieu[51], L. Popa[54], T. Poutanen[38,18,1], G. Prézeau[9,60], S. Prunet[52], J.-L. Puget[51], J. P. Rachen[69], W. T. Reach[86], R. Rebolo[57,31], M. Reinecke[69], J.-M. Reix[83], C. Renault[66], S. Ricciardi[43], T. Riller[69], I. Ristorcelli[85,8], G. Rocha[60,9], C. Rosset[3], M. Rowan-Robinson[49], J. A. Rubiño-Martín[57,31], B. Rusholme[50], E. Salerno[7], M. Sandri[43], D. Santos[66], G. Savini[74], B. M. Schaefer[84], D. Scott[16], M. D. Seiffert[60,9], P. Shellard[11], A. Simonetto[59], G. F. Smoot[21,68,3], C. Sozzi[59], J.-L. Starck[64,12], J. Sternberg[36], F. Stivoli[45], V. Stolyarov[87], R. Stompor[3], L. Stringhetti[43], R. Sudiwala[78], R. Sunyaev[69,79], J.-F. Sygnet[52], D. Tapiador[33], J. A. Tauber[36] *, D. Tavagnacco[42], D. Taylor[33], L. Terenzi[43], D. Texier[33], L. Toffolatti[14], M. Tomasi[27,44], J.-P. Torre[51], M. Tristram[67], J. Tuovinen[70], M. Türler[48], G. Umana[39], L. Valenziano[43], J. Valiviita[56], J. Varis[70], L. Vibert[51], P. Vielva[58], F. Villa[43], N. Vittorio[29], L. A. Wade[60], B. D. Wandelt[52,24], C. Watson[35], S. D. M. White[69], M. White[21], A. Wilkinson[61], D. Yvon[12], A. Zacchei[42], and A. Zonca[23]

(Affiliations can be found after the references)

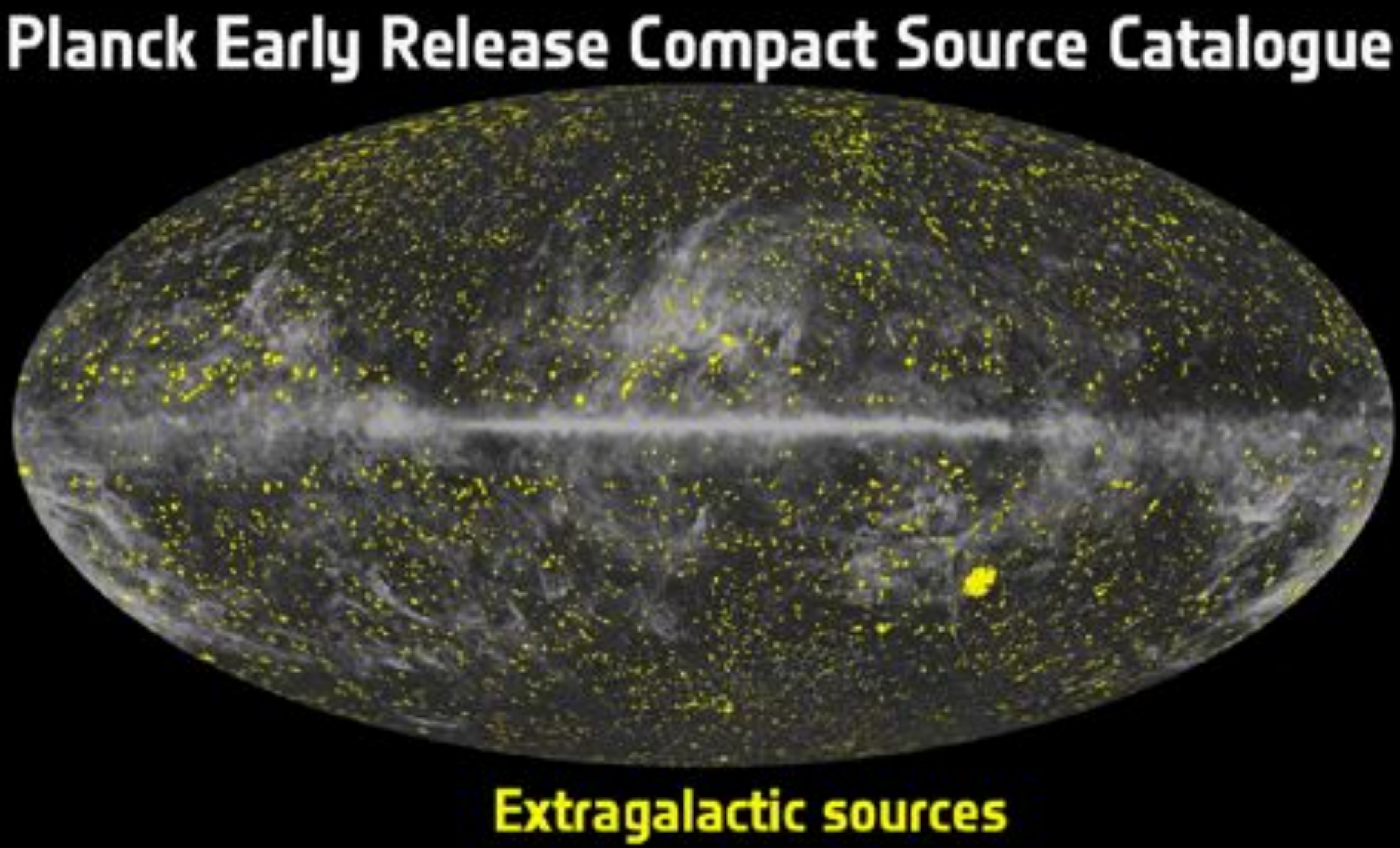
Preprint online version: January 12, 2011

The ERCSC

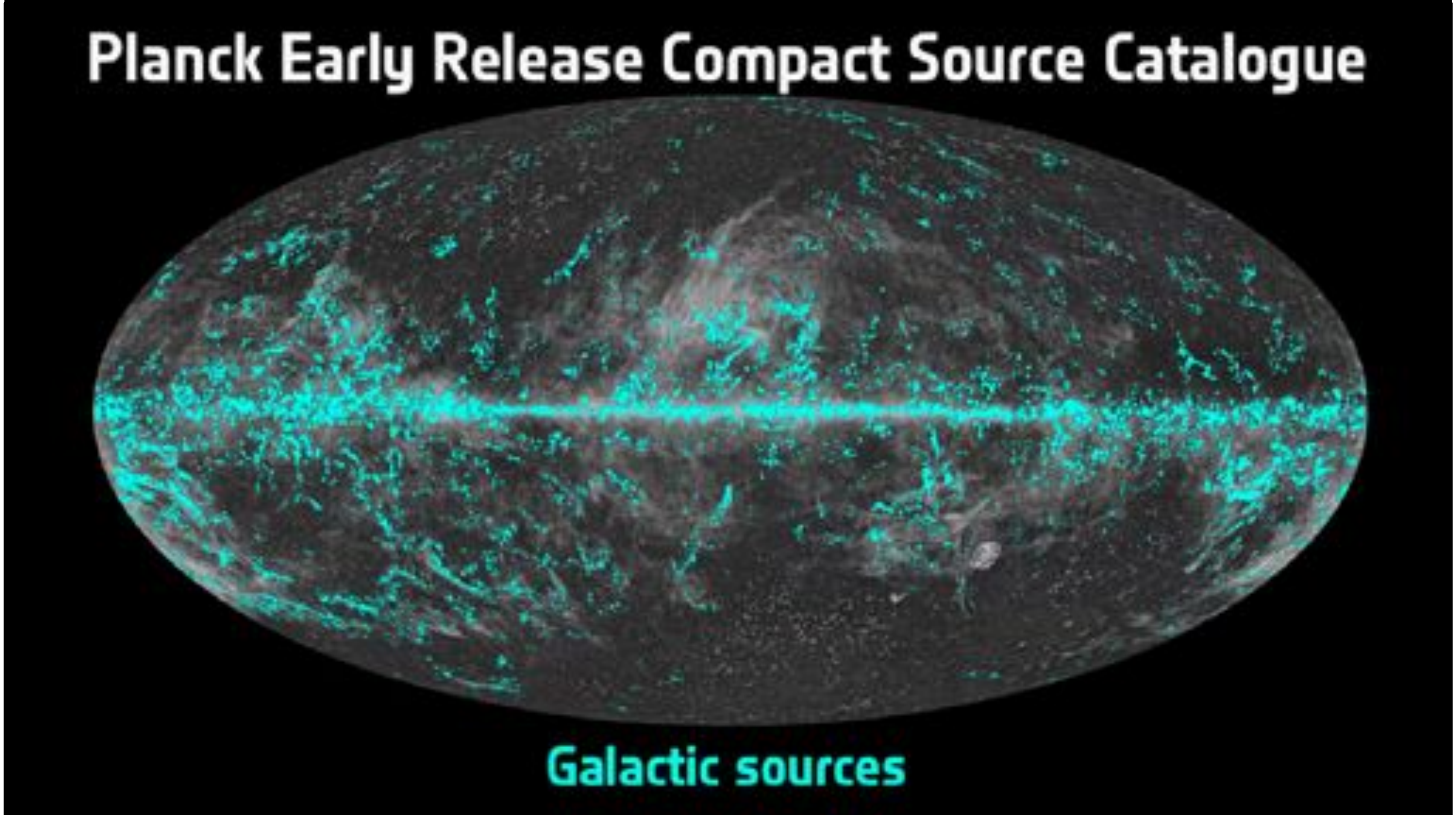
15,000 sources with fluxes > 200-600 mJy
Catalogue made public (follow-up with Herschel)



The ERCSC

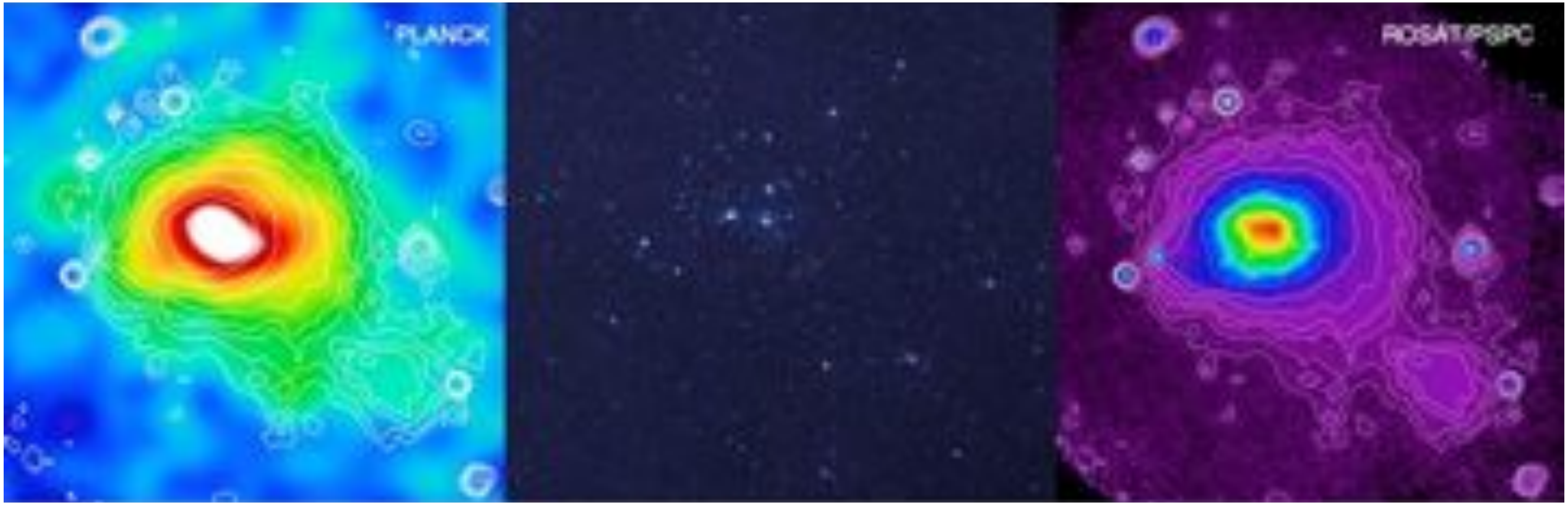

Planck Early Release Compact Source Catalogue
Extragalactic sources

The ERCSC


Planck Early Release Compact Source Catalogue
Galactic sources

Galaxy clusters

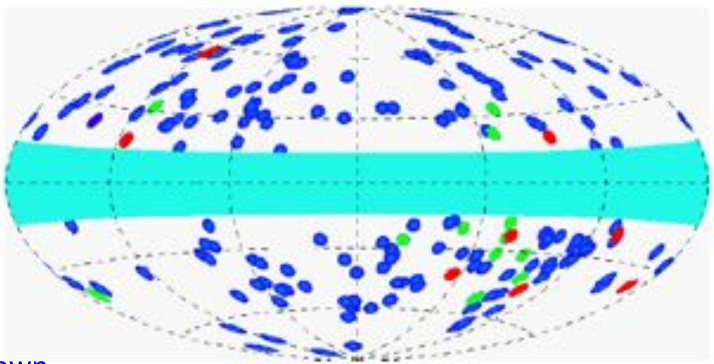
COMA cluster



Planck Optical (Hubble) X-ray

The cluster catalogue

- 199 clusters detected by Planck
- Most of them ROSAT clusters
- 30 new clusters (20 in ESZ)



Known
Confirmed XMM, AMI
Not yet confirmed

- Many more to come

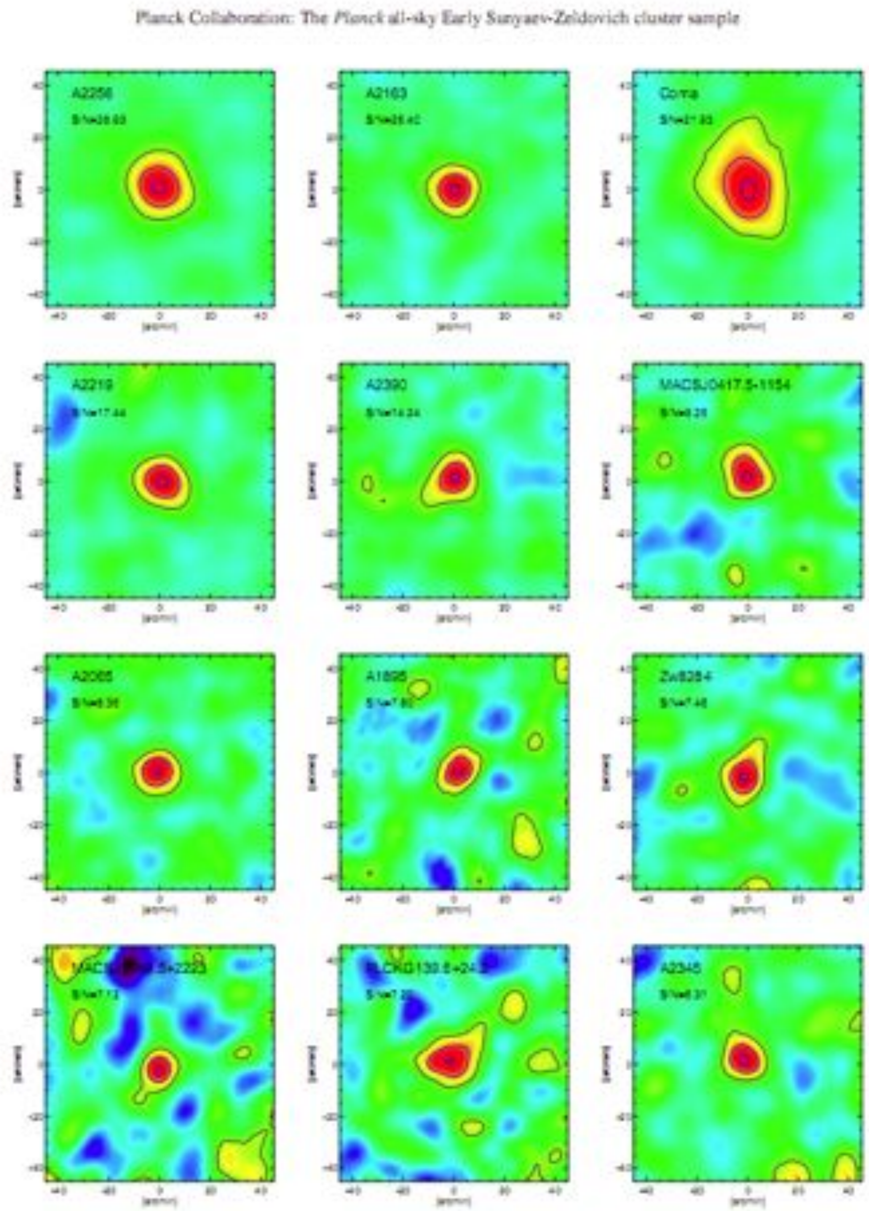


Fig. 6. Illustrations of reconstructed y-maps (1.5° × 1.5°, smoothed to 13 arcmin) for clusters spanning S/N from 29 to 6 from the upper left to the lower right.

Two superclusters discovered with Planck

Planck Collaboration: *XMM-Newton* follow-up for validation of *Planck* cluster candidates

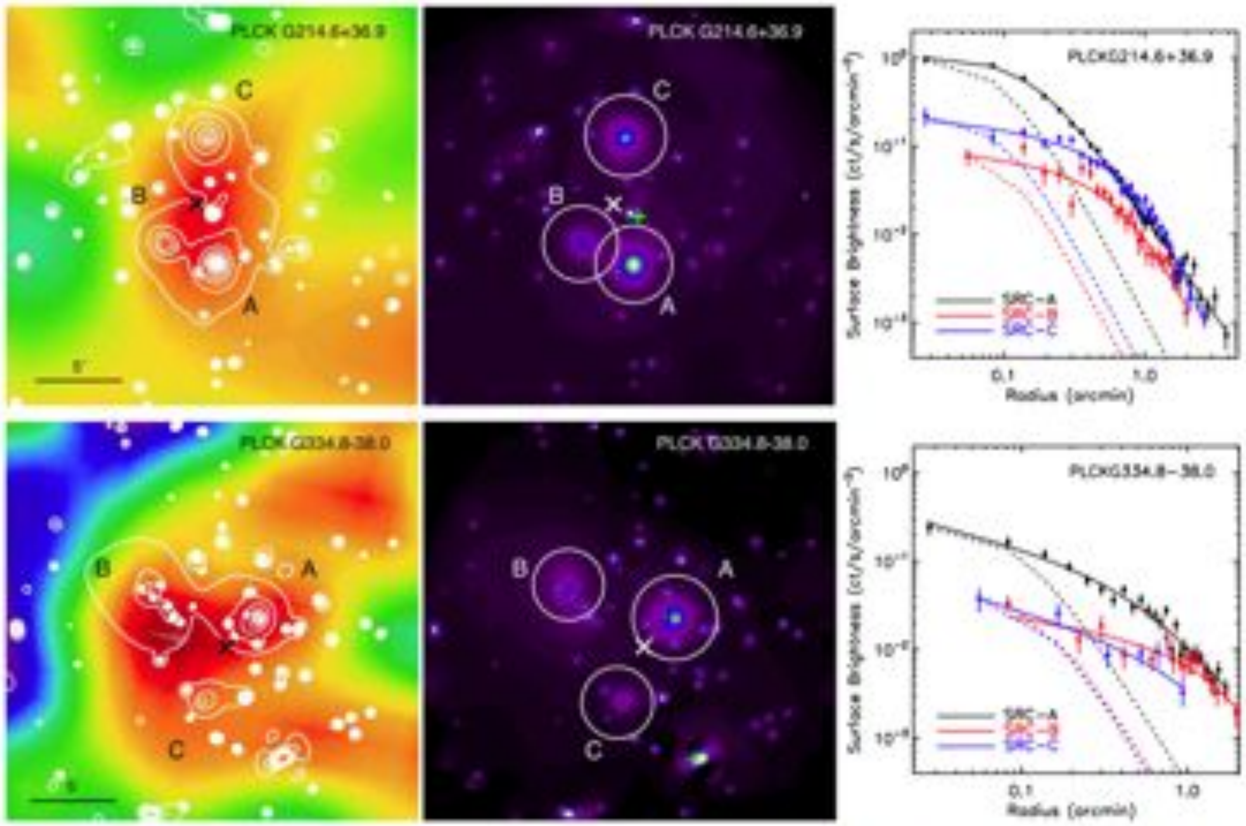


Fig. 12: The triple systems PLCK G214.6+37.0 (top) and PLCK G334.8-38.0 (bottom). The left panels show the *Planck* Y_{SZ} map (derived from an Internal Linear Combination method) with contours from the *XMM-Newton* wavelet filtered [0.3 – 2] keV image (middle panels) overlaid in white. The cross marks the position of the re-extraction centre for flux re-analysis. Extended components found in the *XMM-Newton* image are marked with letters (see text and Table 2). The circles in each *XMM-Newton* image denote the estimated R_{500} radius for each component. The right panels show the X-ray surface brightness profiles of the three components for each super cluster (points with uncertainties), and the best-fitting β-model (solid lines) compared to the profile of the Point Spread Function normalised at the central level (dashed lines).

Spinning dust

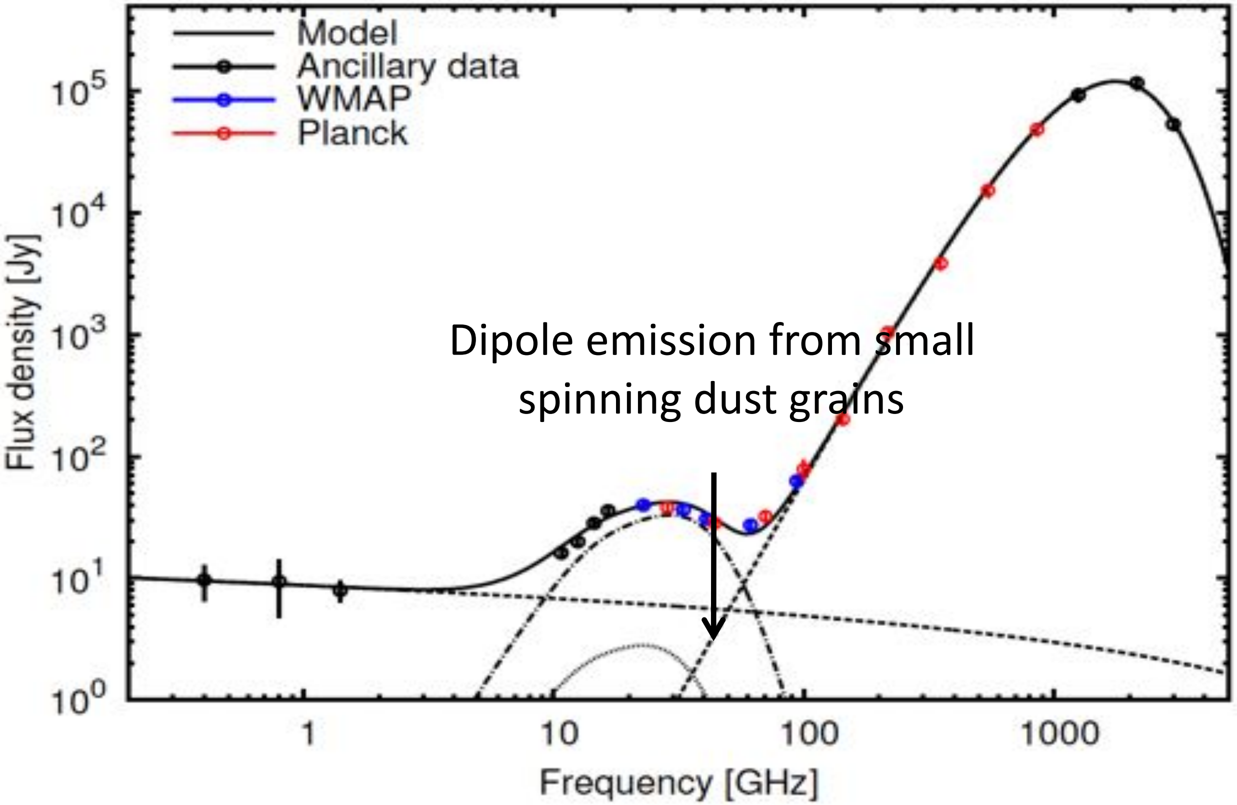
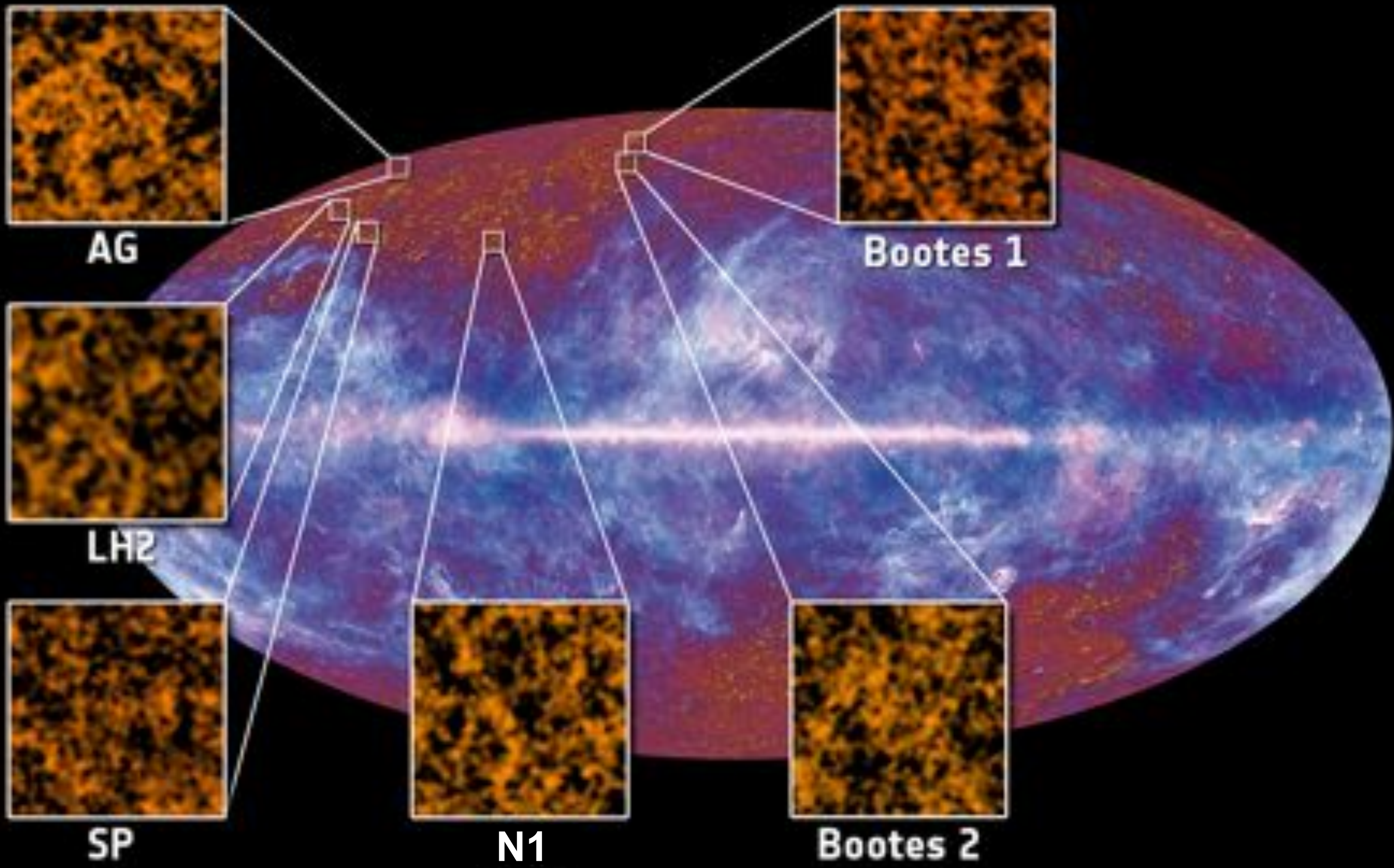
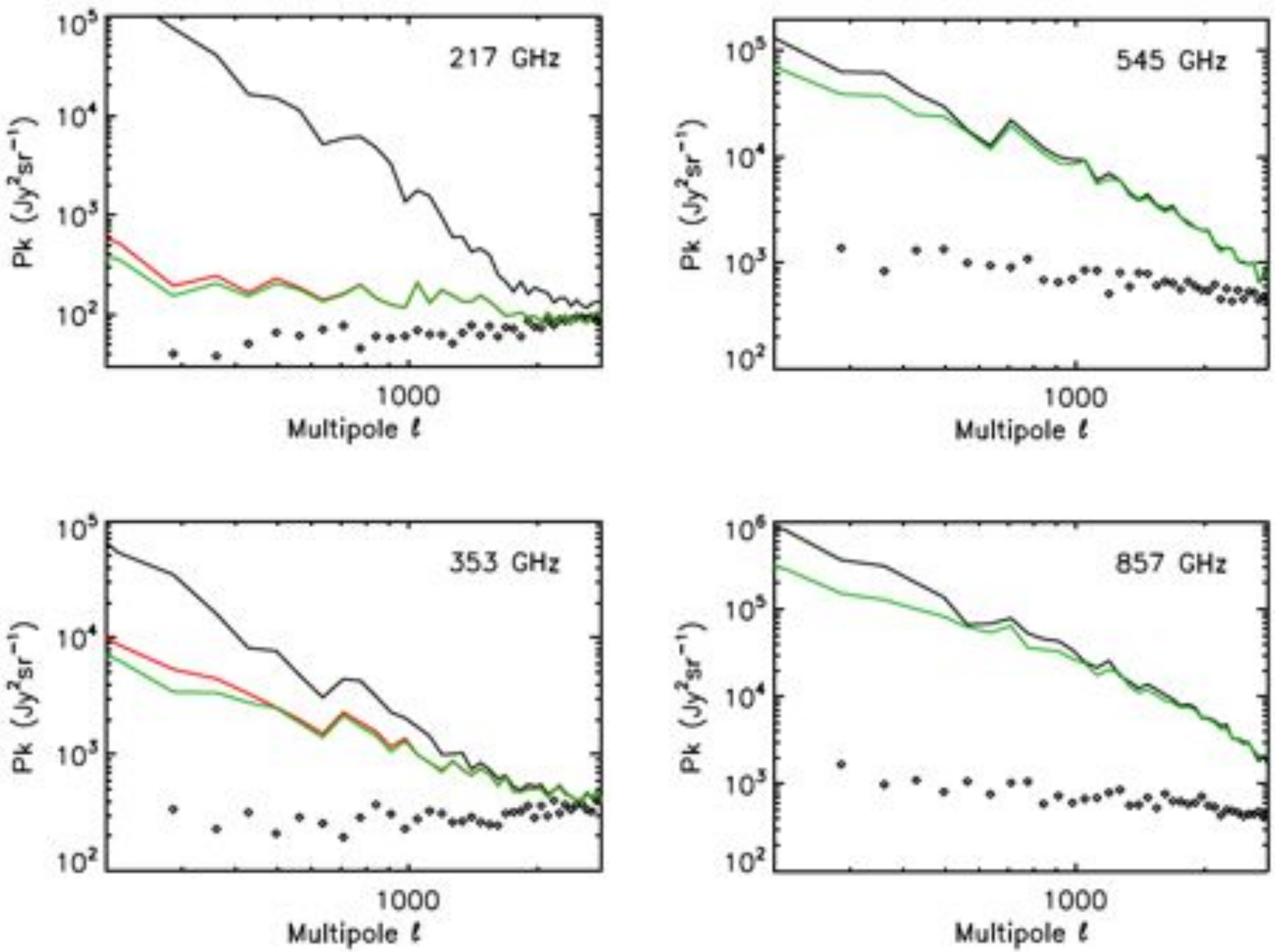


Fig. 4. Spectrum of G160.26-18.62 in the Perseus molecular cloud. The best-fitting model consisting of free-free, spinning dust, and thermal dust is shown. The spinning dust model consists of two components: high density molecular gas (dot-dashed line) and low density atomic gas (dotted line).

Cosmic Infrared Background Anisotropies



Cosmic Infrared Background Anisotropies



The Planck mission : outline

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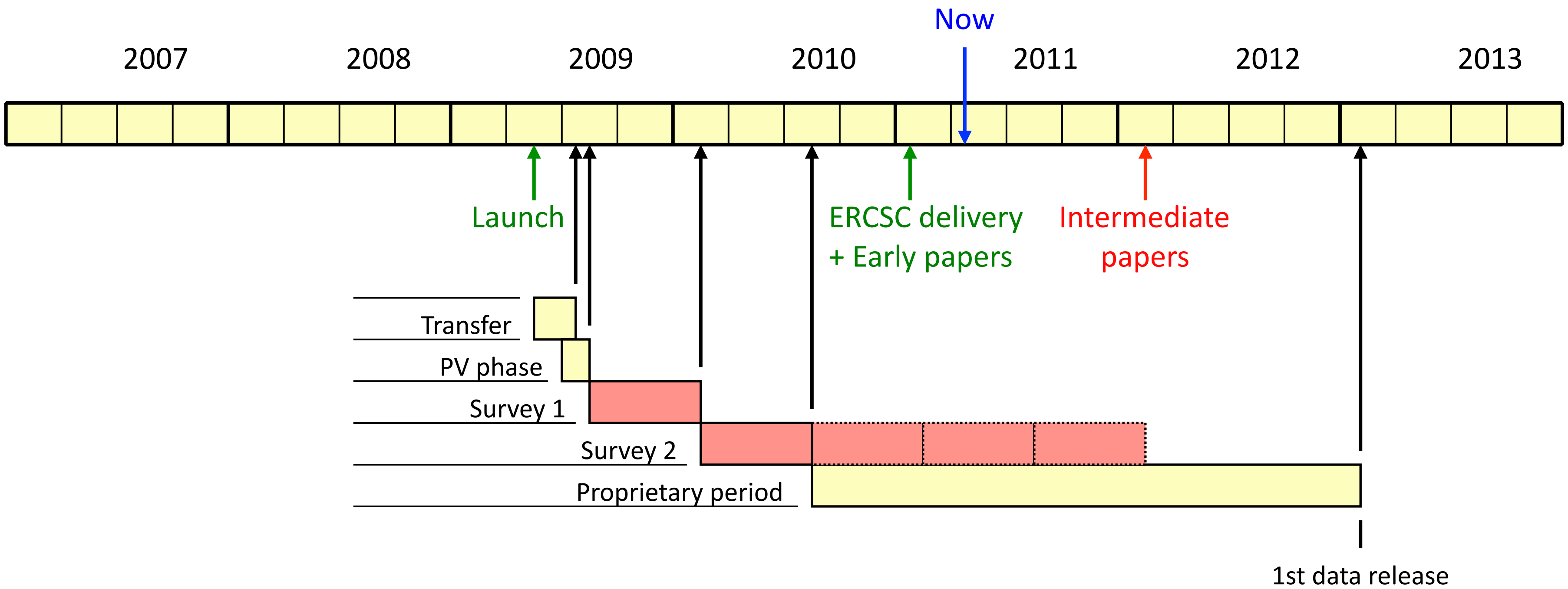
- Design and scientific programme
- Making it happen
- Data reduction
- Early results
- ➡ The future

Calendar

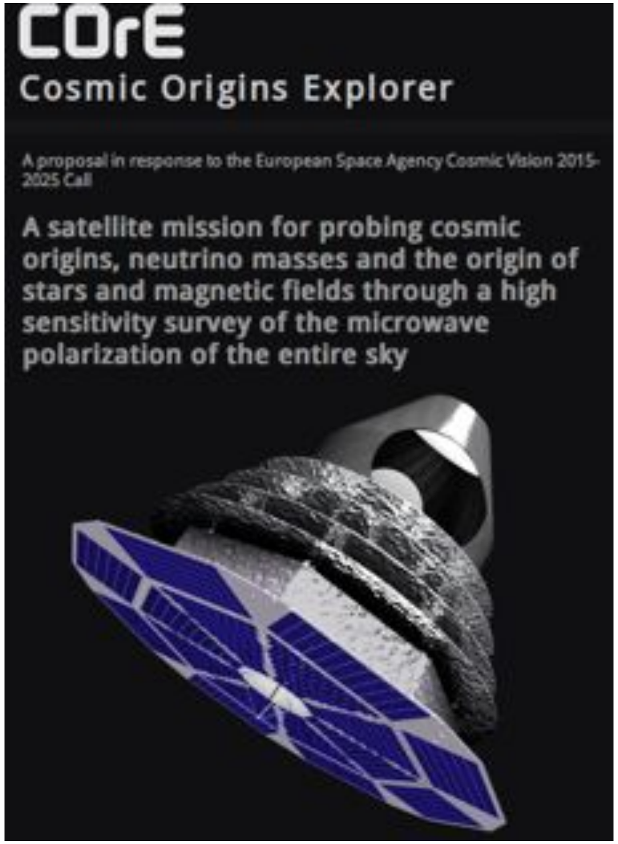


<u>Data products :</u>

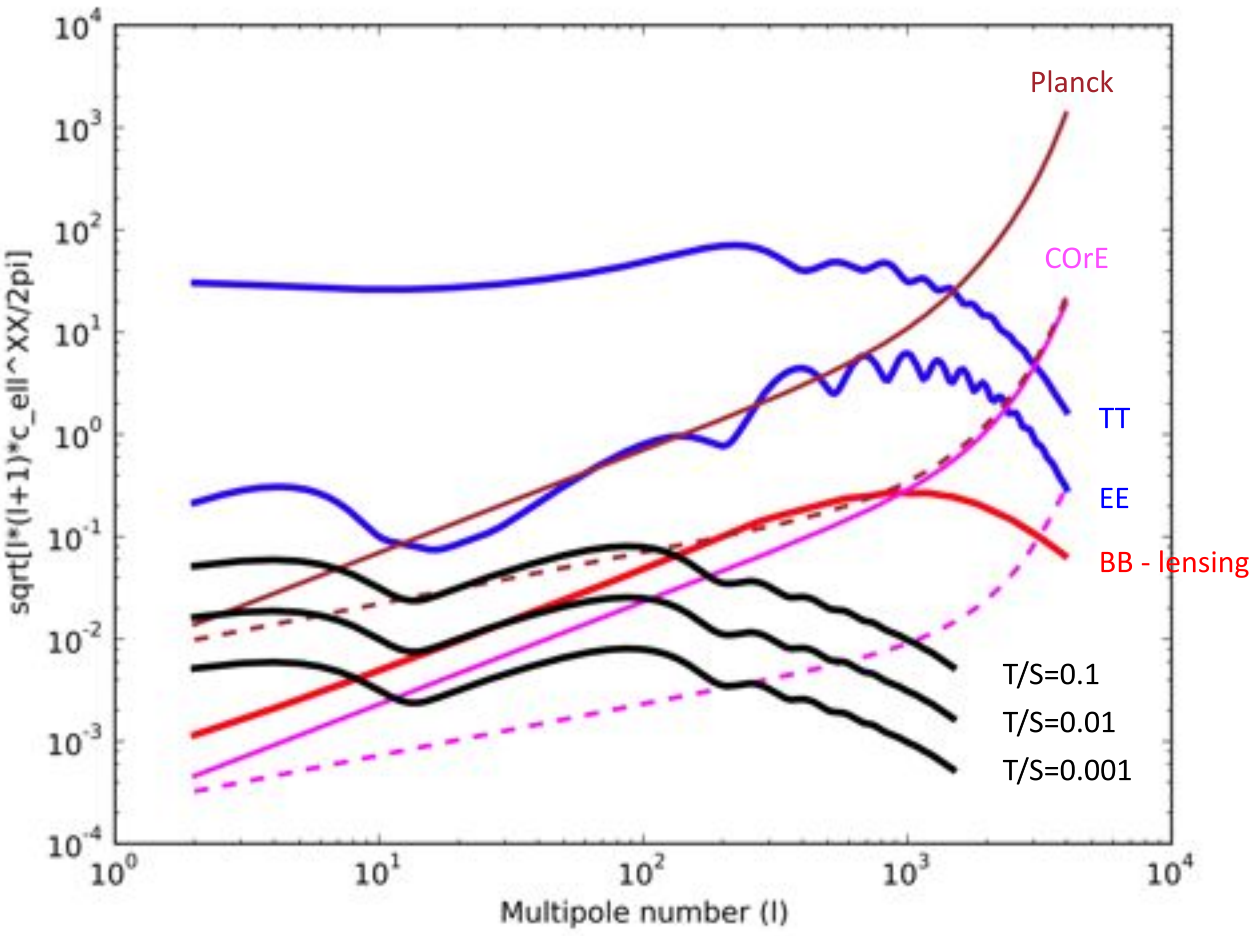
- ERCSC (early release compact source catalog) for early follow-up (e.g. with Herschel)
- Clean, calibrated timelines
- Maps per frequency band (temperature and polarisation)
- Maps of components (CMB, synchrotron, free-free, dust, SZ effect, …)
- Final compact source catalogs (radiosources, IR galaxies, galactic sources, SZ clusters)
- CMB power spectra

COrE

- Extremely-precise measurement of temperature and polarisation of the sky at millimetre wavelengths
  - 30 times more sensitive than Planck
  - 15 frequency bands
- Measure of B-modes of CMB polarisation
- Very broad scientific programme
- www.core-mission.org



Comparison with Planck



Thank you for your attention !