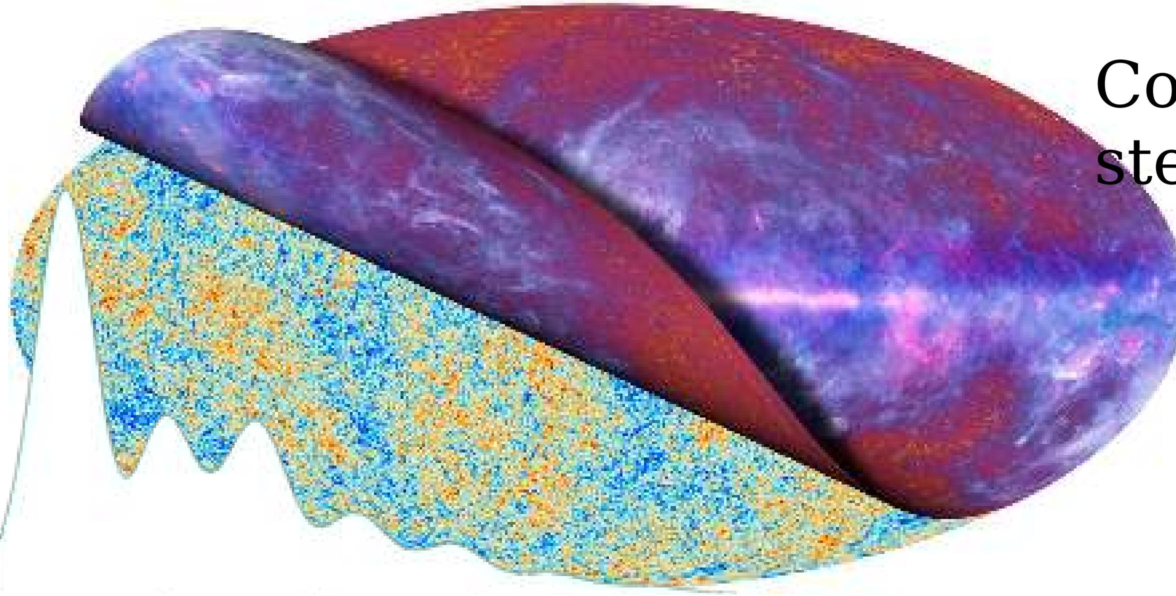


Contact :
stephane.ilic@gmail.com

(n'hésitez pas si vous avez des questions!)

Planck et le fond diffus cosmologique

Stéphane Ilić

- Centre de Physique Théorique (CPT), Marseillle
- Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse

(• Institut d'Astrophysique Spatiale (IAS), Orsay)

I. Un peu d'histoire…

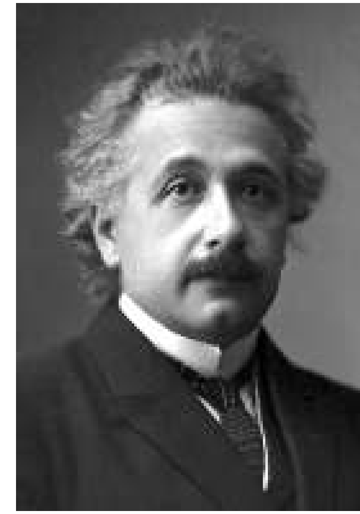
1915 : Relativité générale

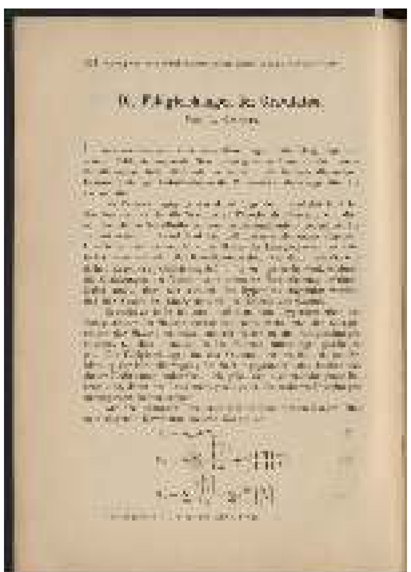
844 Sitzung der physikalisch-mathematischen Klasse vom 25. November 1915

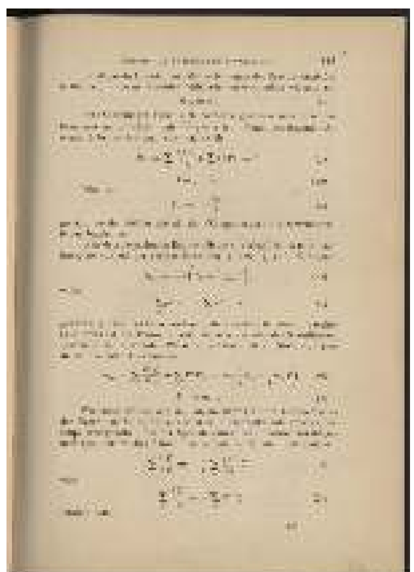
Die Feldgleichungen der Gravitation.

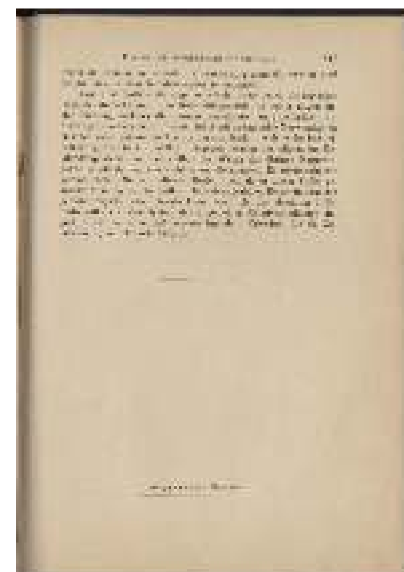
Von A. Einstein.

In zwei vor kurzem erschienenen Mitteilungen[1] habe ich gezeigt, wie man zu Feldgleichungen der Gravitation gelangen kann, die dem Postu-









1915 : Equations d'Einstein

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

1915 : Equations d'Einstein

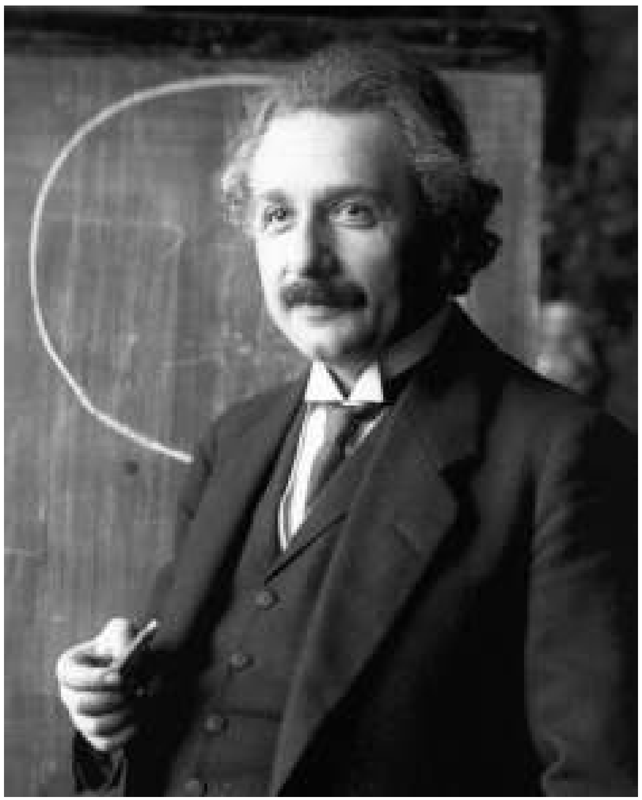
$$\underbrace{R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} + \Lambda g_{\mu\nu}}_{\text{Géométrie de l'Univers}} = \underbrace{\frac{8\pi G}{c^4} T_{\mu\nu}}_{\text{Contenu de l'Univers}}$$

Naissance de la Cosmologie moderne

1910s-20s :

L'Univers est...

...Statique



Einstein, Bondi, Gold, Hoyle...

...Dynamique

Lemaître, Gamov, ...

1929 : Fin du débat (?)

of the many stars which presumably exist in the central parts of these nebulae. The lack of depth in the absorption lines seems to be more pronounced among the smaller and fainter nebulae, and in N. G. C. 7619 the absorption is very weak.

It is hoped that velocities of more of these interesting objects will soon be available.

A RELATION BETWEEN DISTANCE AND RADIAL VELOCITY AMONG EXTRA-GALACTIC NEBULAE

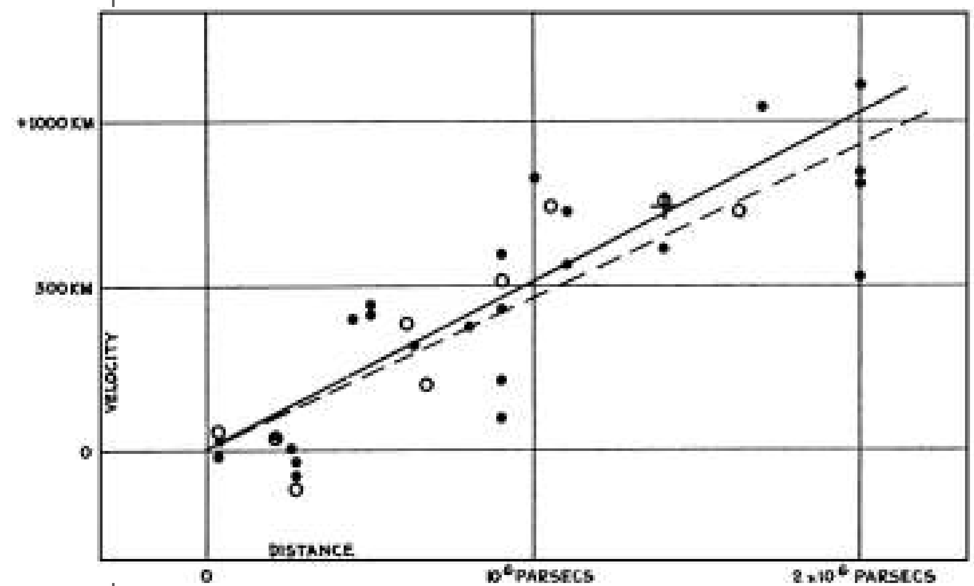
By Edwin Hubble

Mount Wilson Observatory, Carnegie Institution of Washington

Communicated January 17, 1929

Determinations of the motion of the sun with respect to the extra-galactic nebulae have involved a *K* term of several hundred kilometers which appears to be variable. Explanations of this paradox have been sought in a correlation between apparent radial velocities and distances, but so far the results have not been convincing. The present paper is a re-examination of the question, based on only those nebular distances which are believed to be fairly reliable.

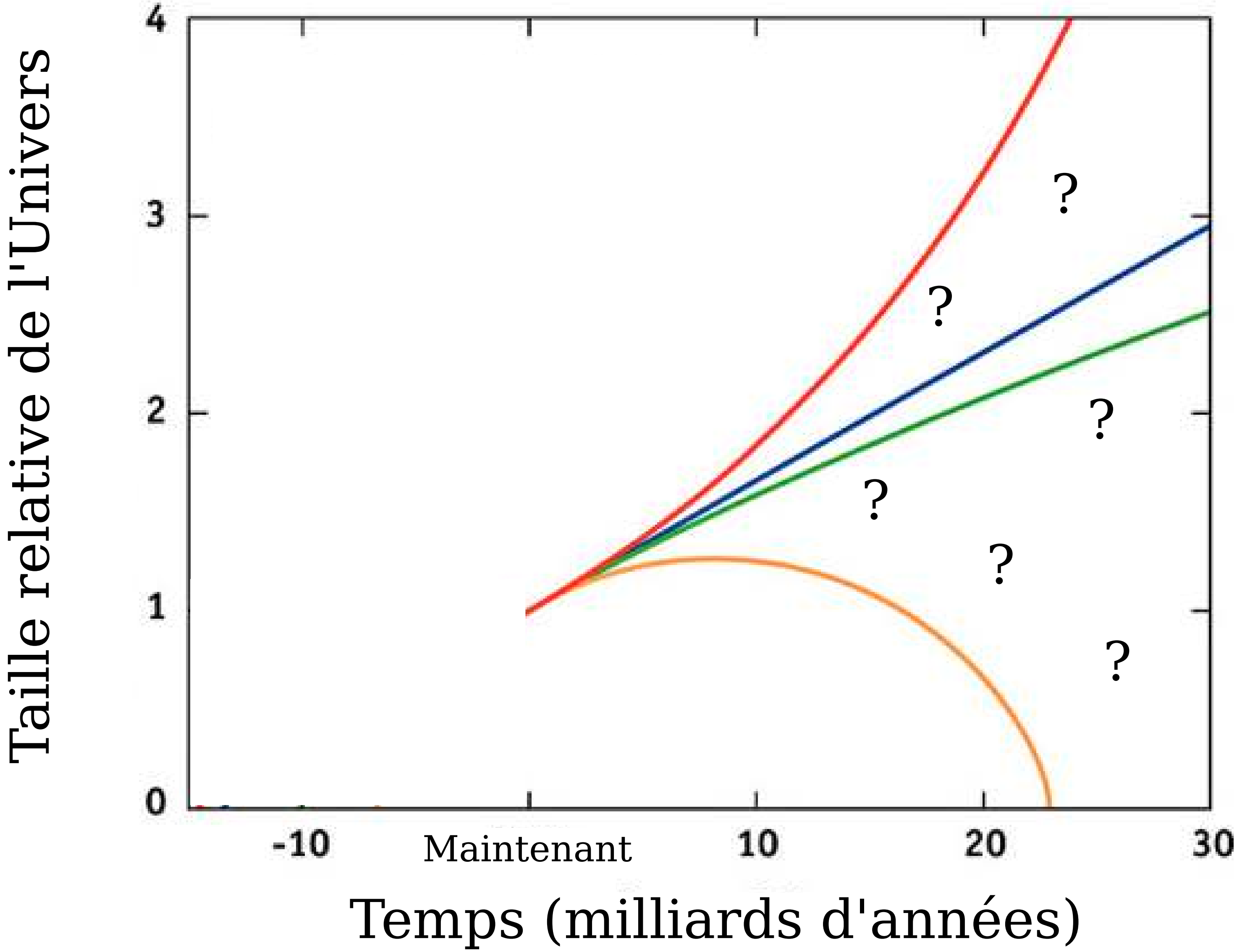
Distances of extra-galactic nebulae depend ultimately upon the application of absolute-luminosity criteria to involved stars whose types can



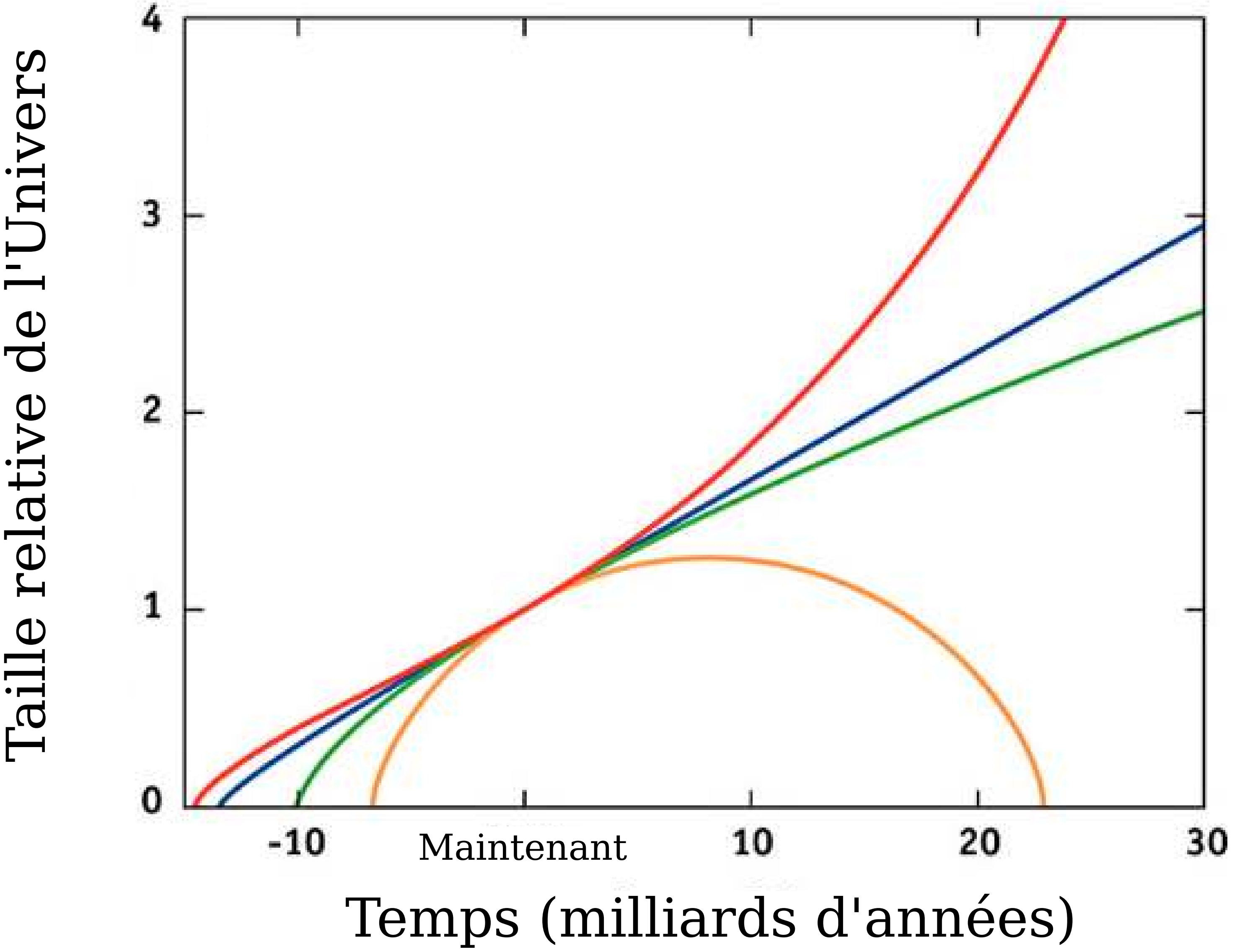
Vitesse = Distance x constante

=Univers en expansion

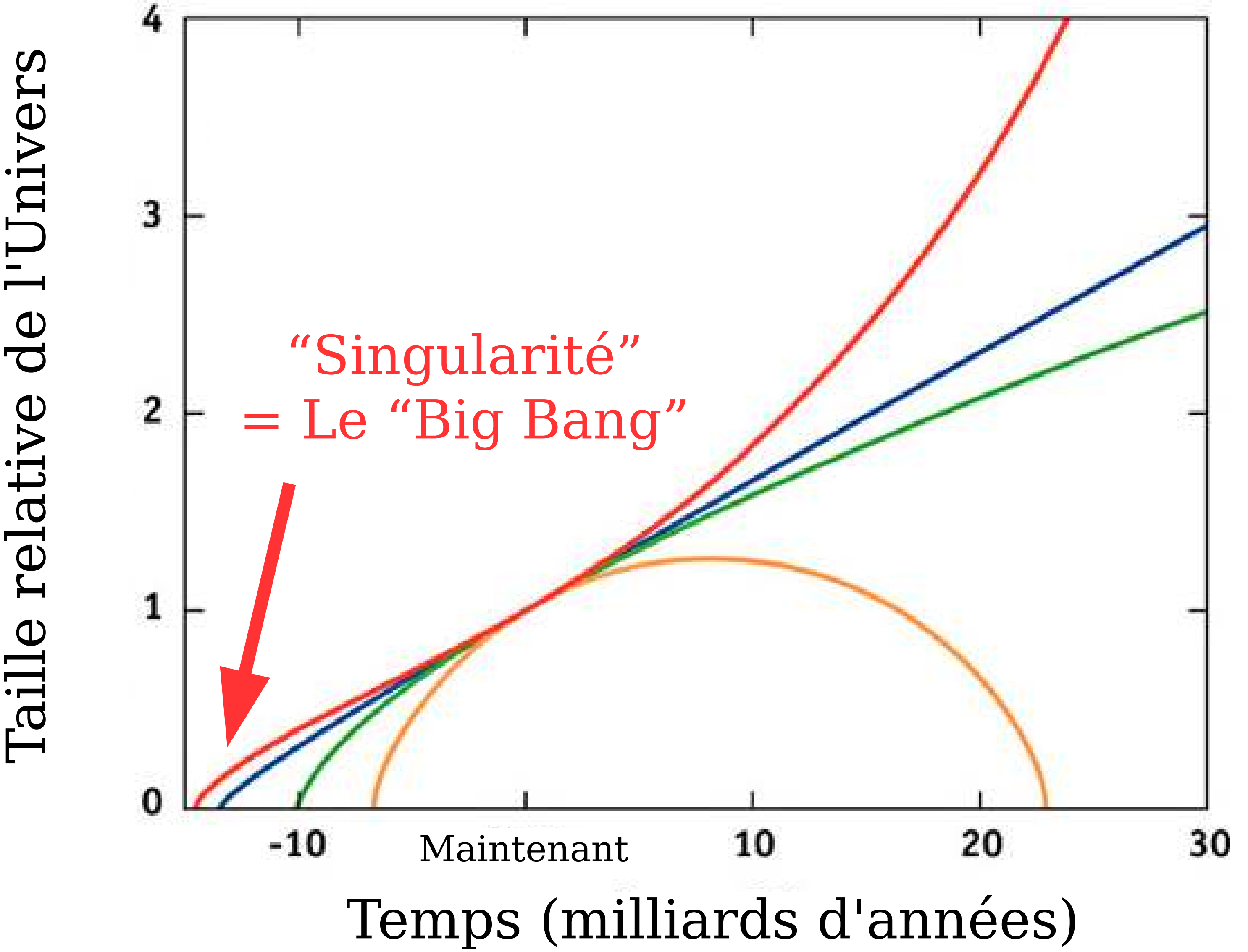
Expansion de l'Univers



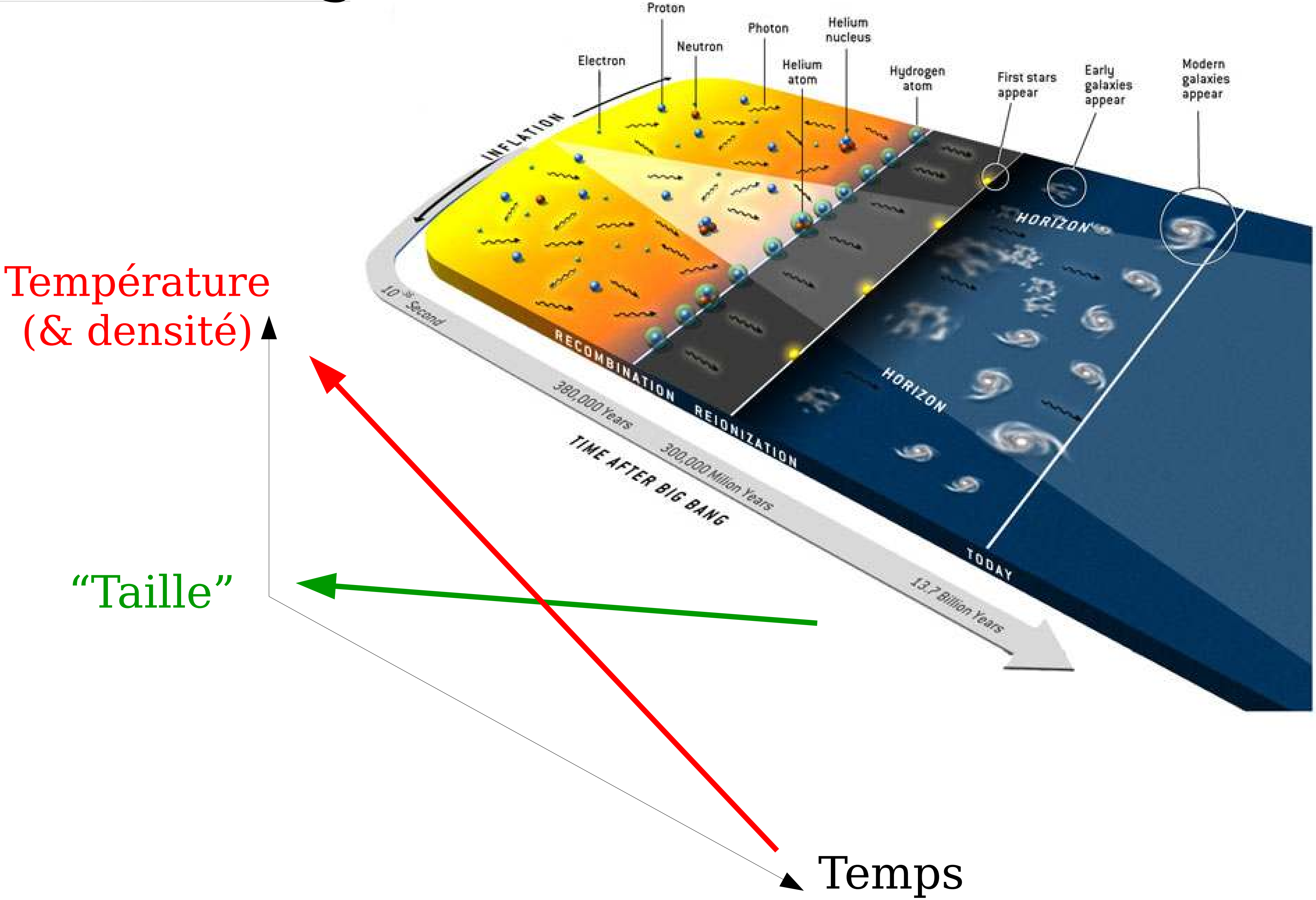
Expansion de l'Univers



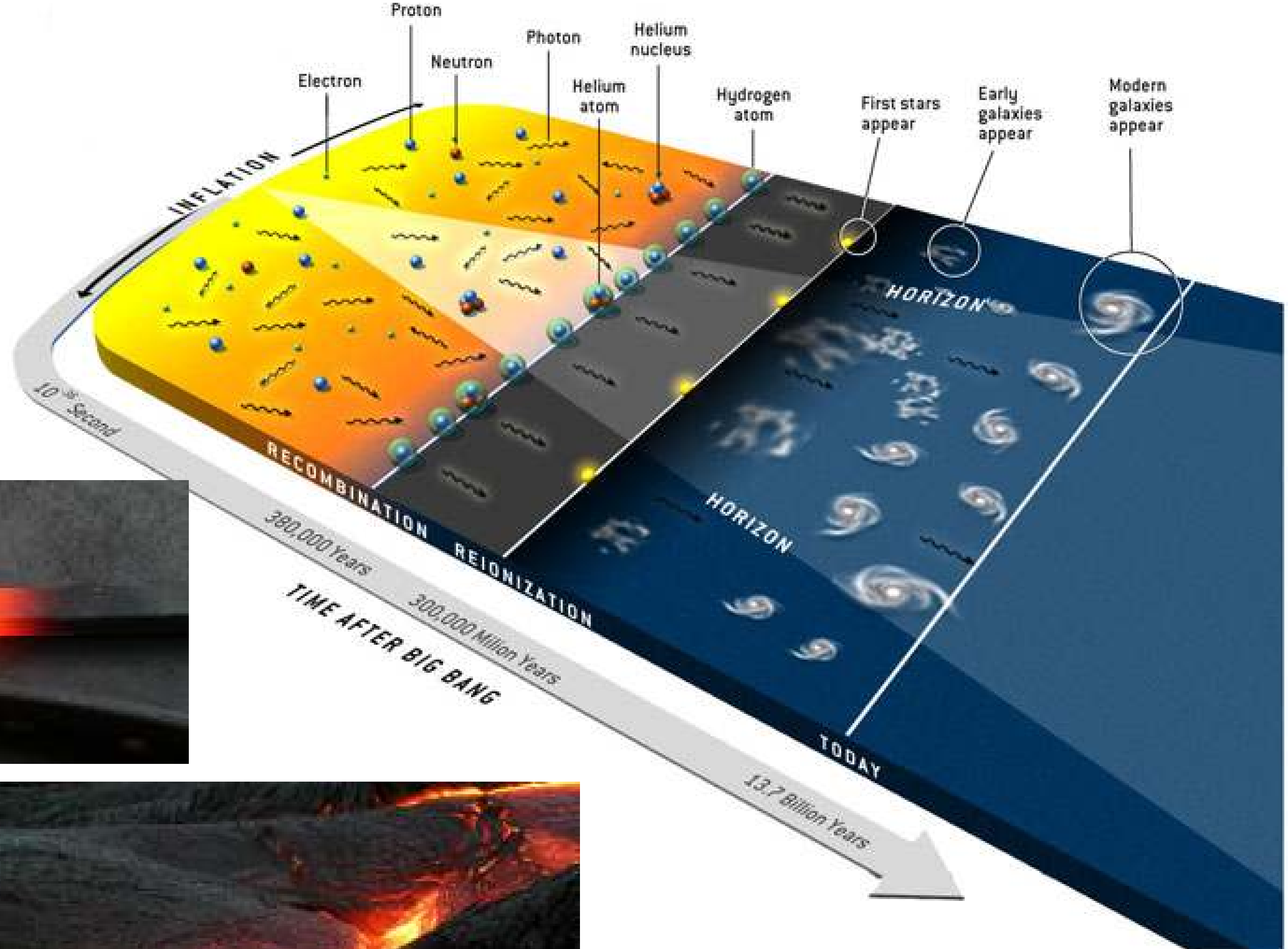
Expansion de l'Univers



Chronologie de l'Univers



Chronologie de l'Univers

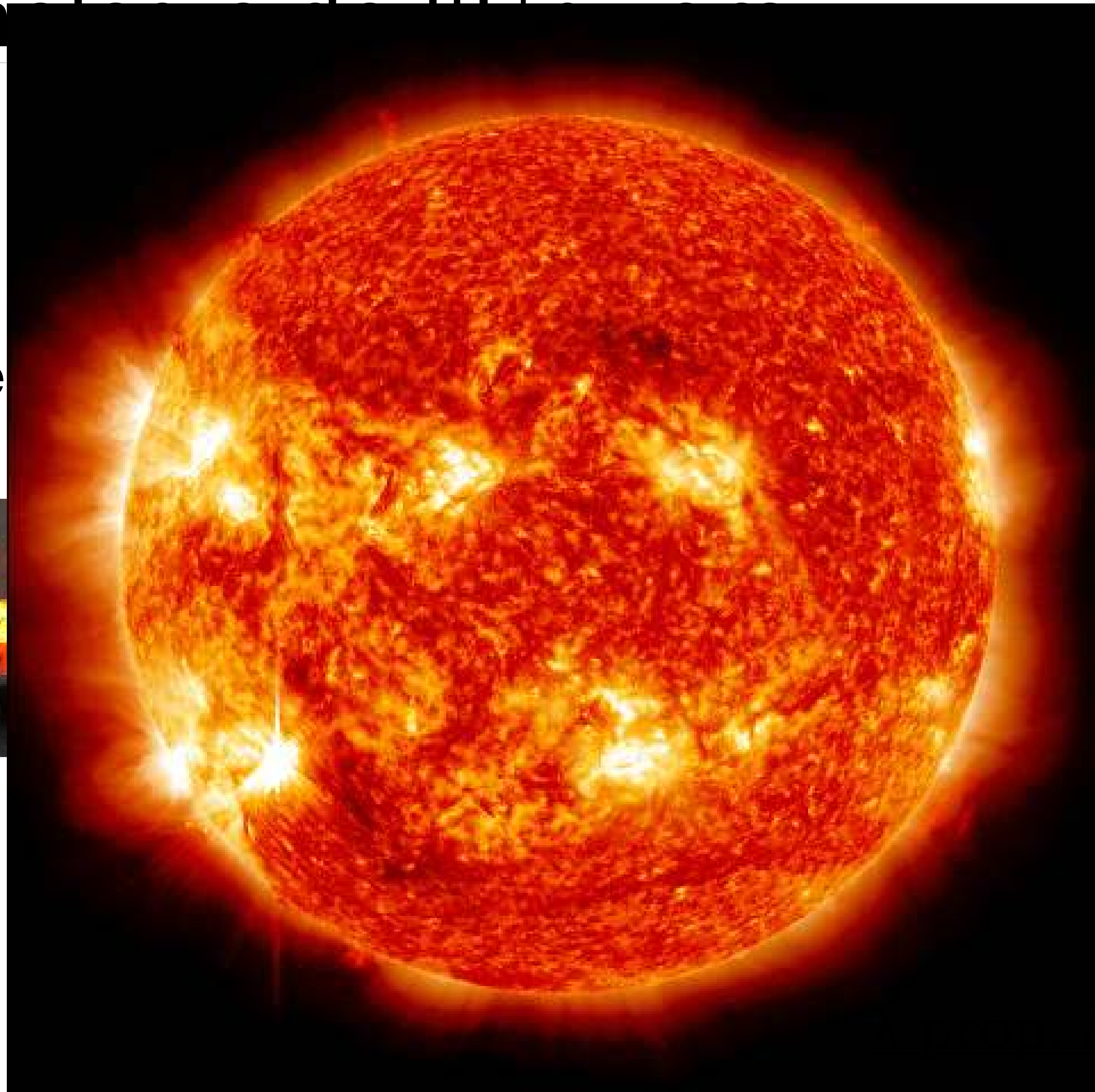


Rayonnement de corps noir :

<u>λ prop. à 1/T</u>

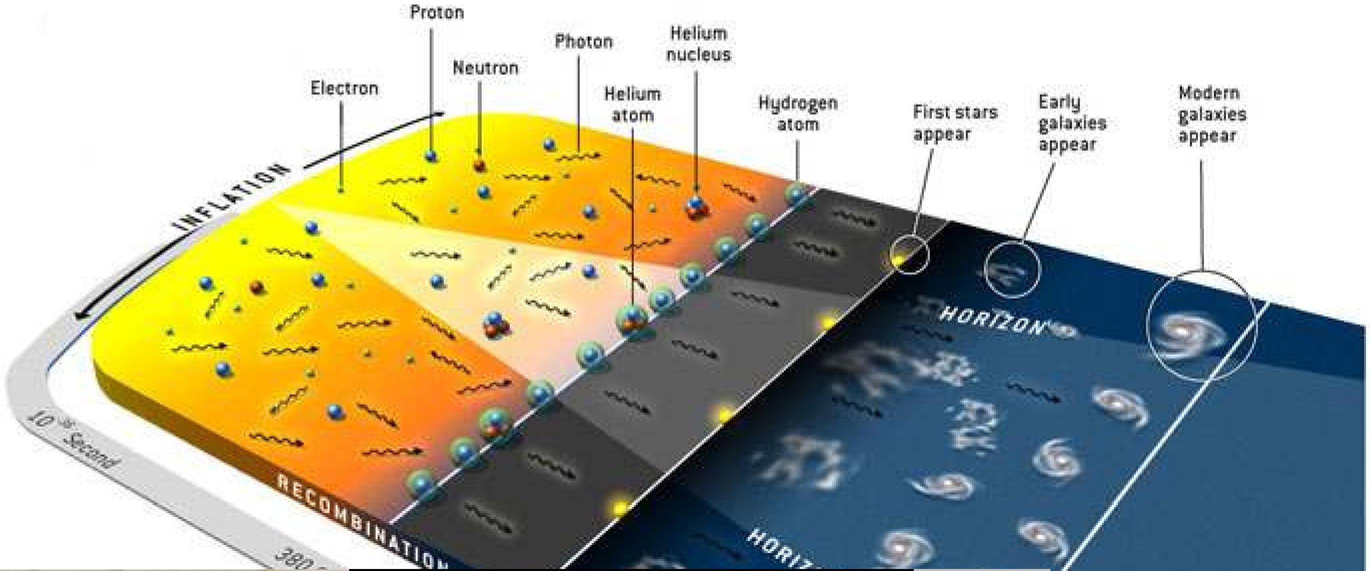
Chron

Rayonne
de corps



1/T

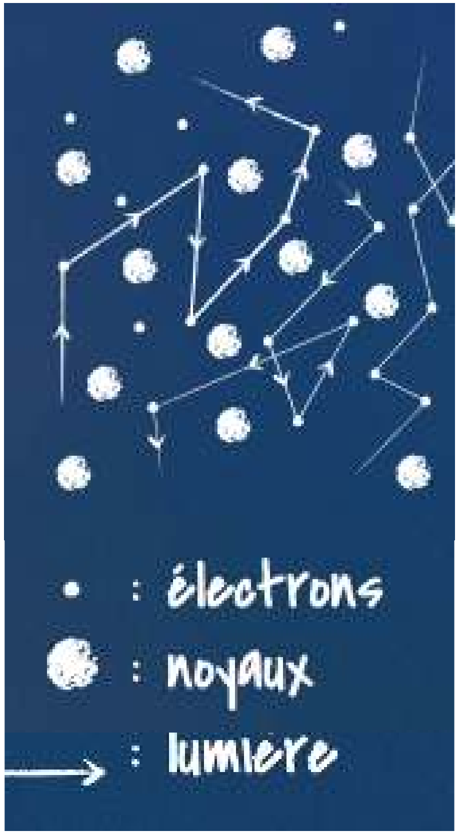
Chronologie de l'Univers

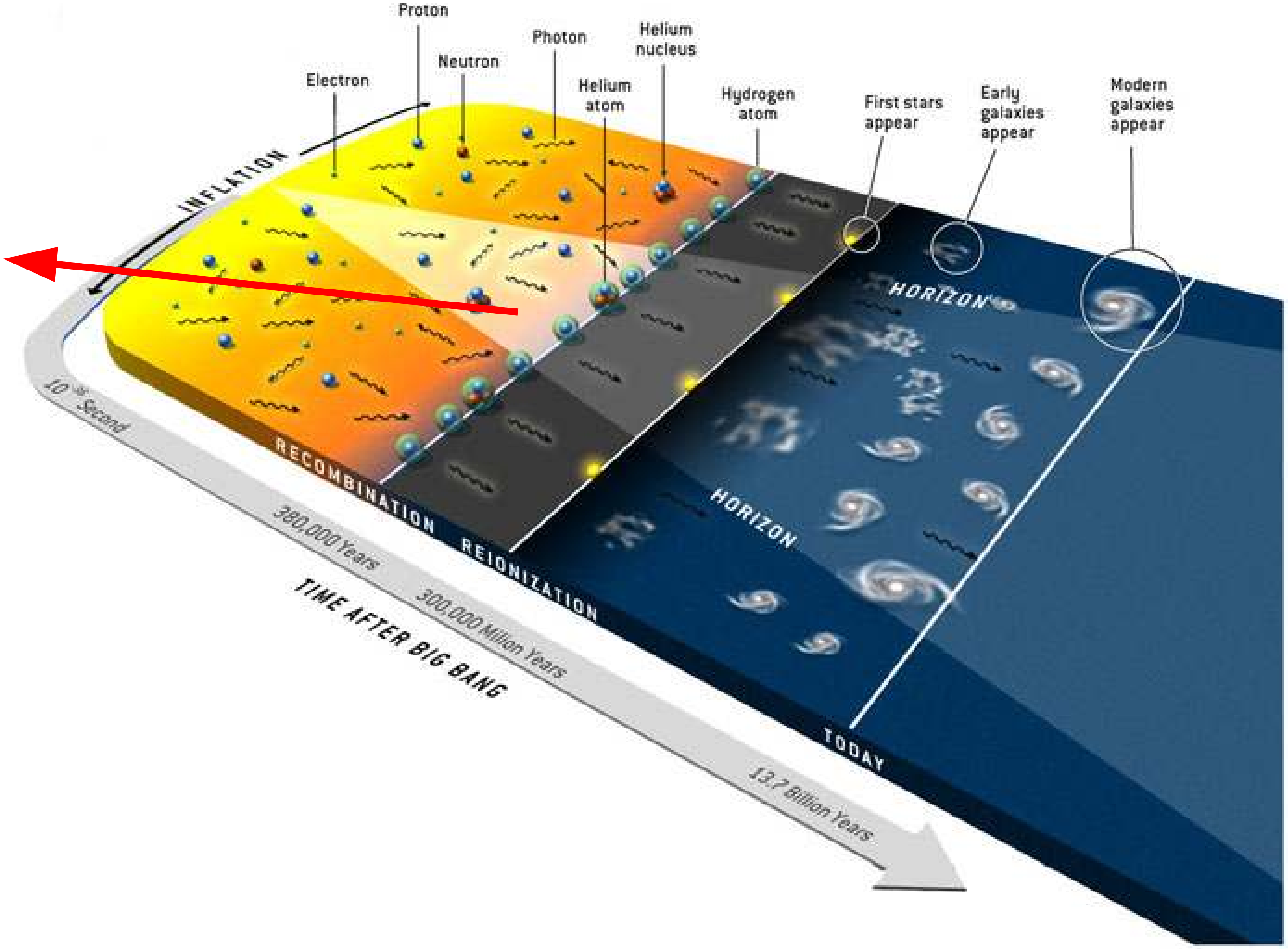


Rayonnement
de corps noir :

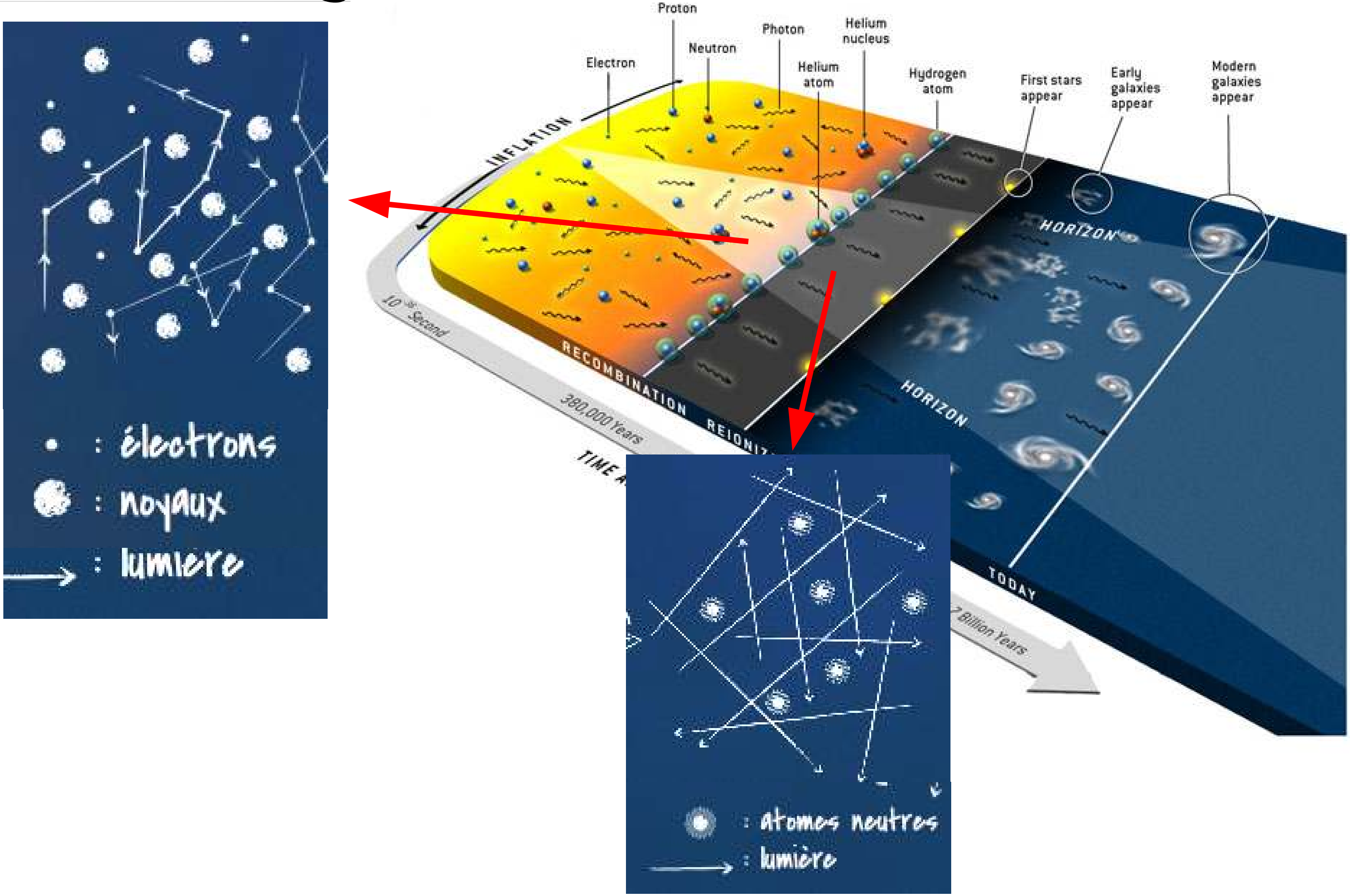
λ prop. à 1/T

Chronologie de l'Univers





Chronologie de l'Univers

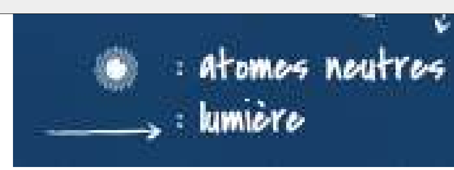


Chronologie de l'Univers

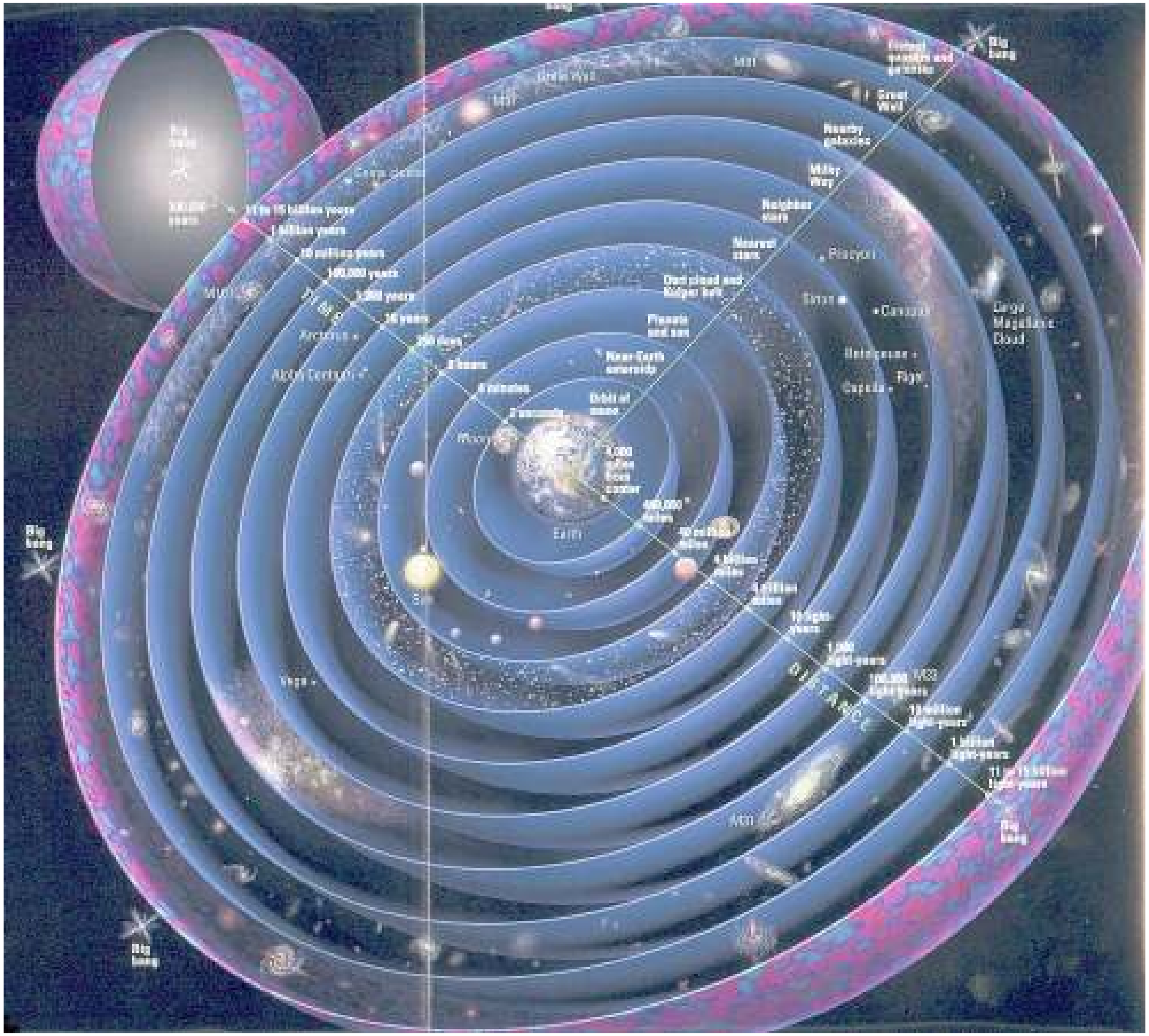
“Première” lumière libre de se propager dans l'Univers, émise il y a environ 13.7 milliards d'années (~400000 ans après le Big Bang)

=

Fond diffus cosmologique



L'ultime lumière...



L'ultime lumière...

I. Un peu d'histoire…

II. Détecter le FDC

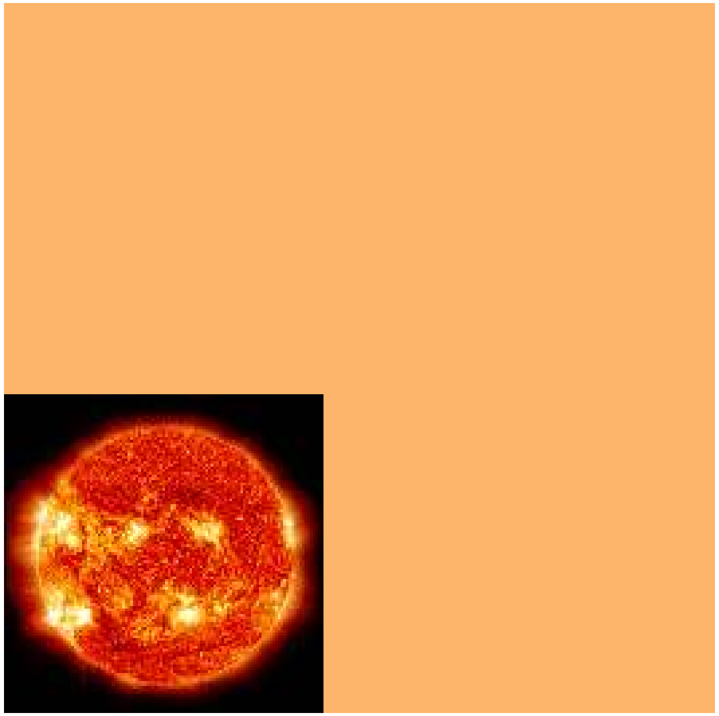
Le FDC à travers les âges...

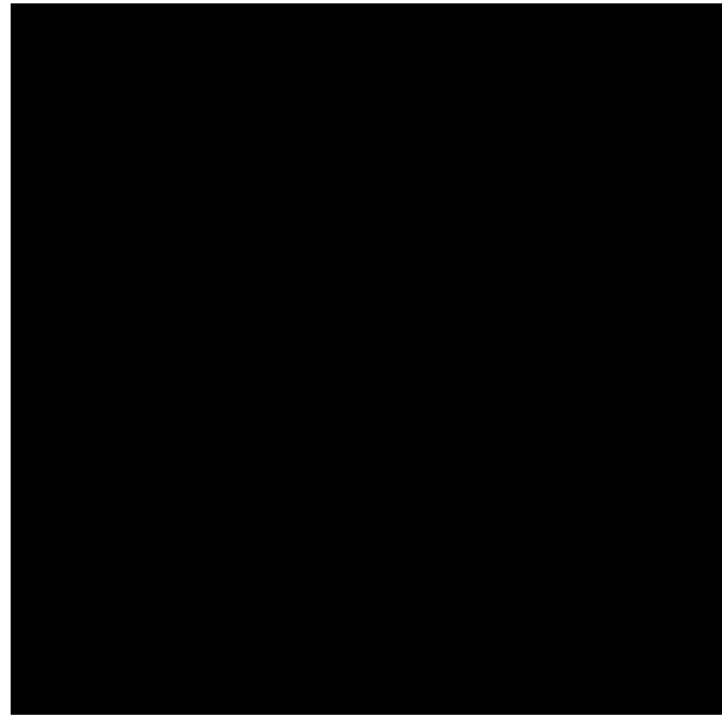
t=-13 millards d'années

t=maintenant

Taille Univers x ~1000
Longueur d'onde FDC x ~1000
Température FDC / ~1000

Le FDC à travers les âges...





t=-13 millards d'années

t=maintenant

Taille Univers x ~1000

Longueur d'onde FDC x ~1000

Température FDC / ~1000

“fond diffus micro-ondes”

Détecter le FDC

Prédictions….

1946 : G. Gamow → ~50K

1946 : R. Dicke → <20K

1948 : R. Alpher & R. Herman réestime Gamow → 5K.

1949 : Alpher and Herman ré-réestime Gamow → 28K.

1960s : Dicke ré-estime une “radiation d'arrière plan micro-ondes” à 40K

1964 : A. G. Doroshkevich and I. Novikov : radiation présentée comme detectable.

1964 :

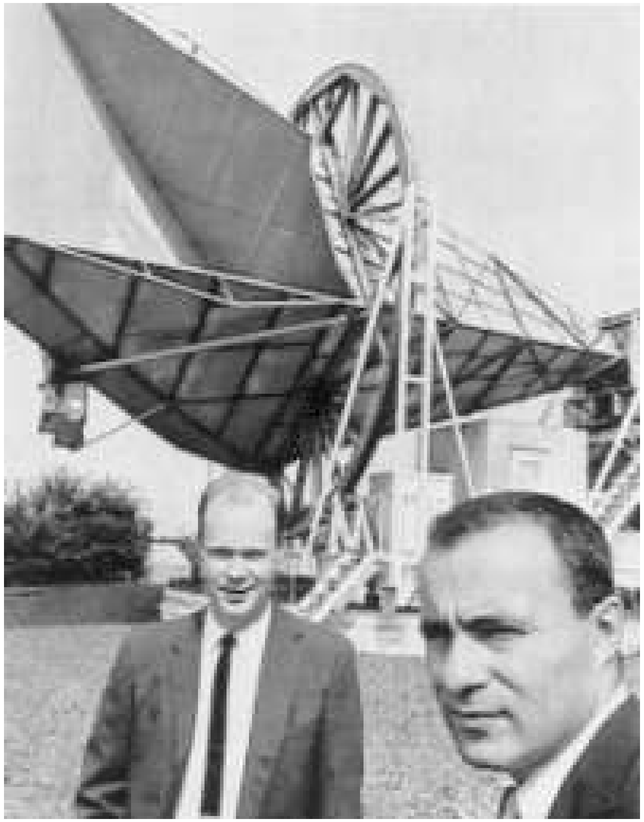
À l'Université de Princeton (USA) :

Robert H. Dicke, Jim Peebles, et David Wilkinson préparent une expérience pour essayer de mesurer cette “radiation micro-ondes”....

1964 : A Penzias & R. W. Wilson

Au même moment, à 60km de là (Holmdelm)....

...un bruit persistant...



1964 : A Penzias & R. W. Wilson

?

1964 : A Penzias & R. W. Wilson

?

Penzias : "To get rid of them, we finally found the most humane thing was to get a shot gun…and at very close range [we] just killed them instantly. It’s not something I’m happy about, but that seemed like the only way out of our dilemma"

1964 : A Penzias & R. W. Wilson

Penzias et Wilson entendent parler des prédictions de Dicke & cie à Princeton…

…Penzias contacte Dicke pour faire part de leur découverte…

…réaction de Dicke à ses collègues :
“Well boys, we've been scooped”

1964 : A Penzias & R. W. Wilson

Penzias et Wilson entendent parler des prédictions de Dicke & cie à Princeton…

…Penzias contacte Dicke pour faire part de leur découverte…

…réaction de Dicke à ses collègues :
“Well boys, we've been scooped”

“Les gars, on s'est fait ni[redacted]”

1978:

“for [the] discovery of cosmic microwave background radiation”

… seulement pour Penzias et Wilson

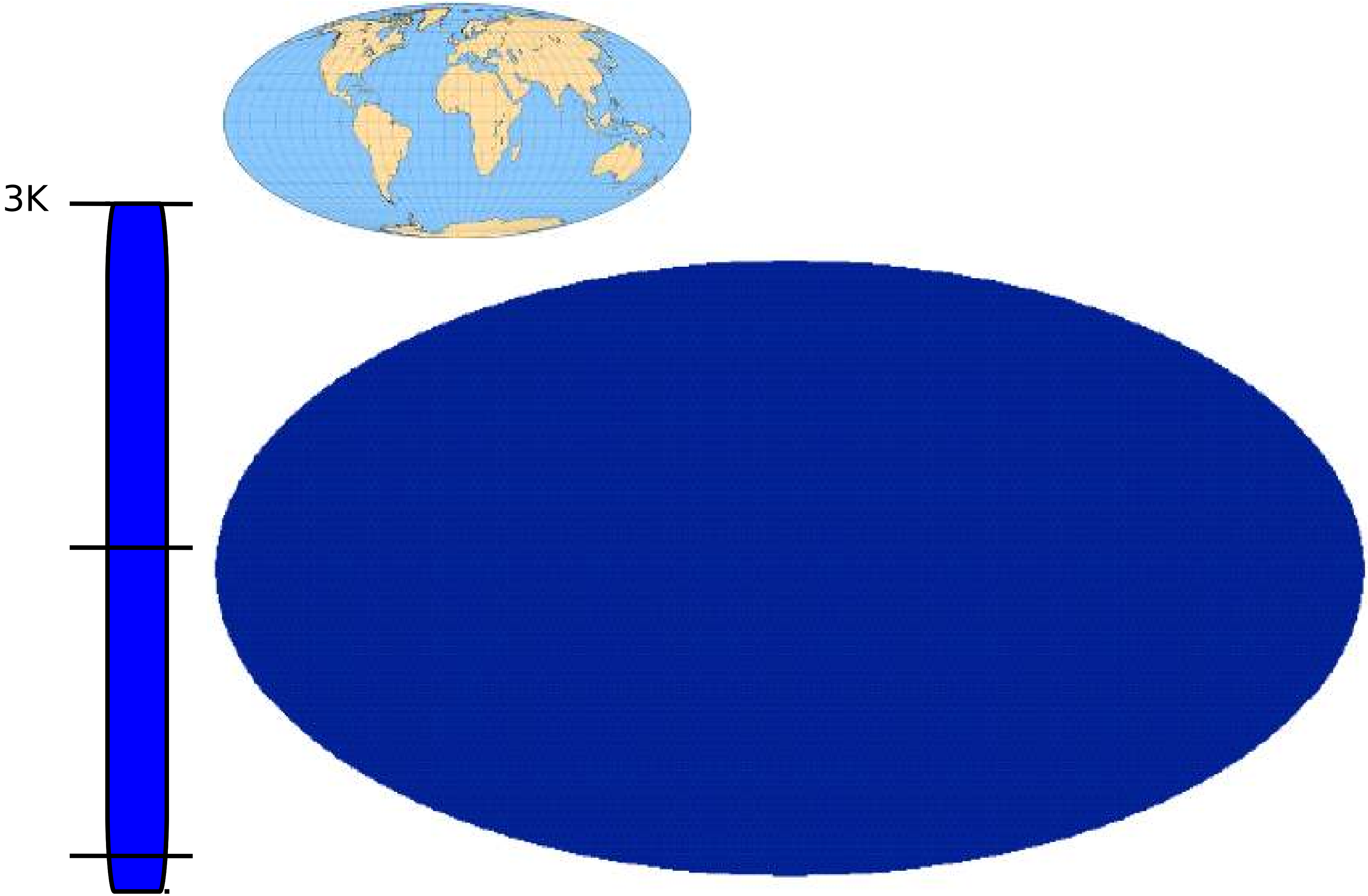
1978:

"for [the] discovery of cosmic microwave background radiation"

… seulement pour Penzias et Wilson

MORALE :
Fusil de chasse + pigeons = Prix Nobel

Le FDC vu par Penzias et Wilson



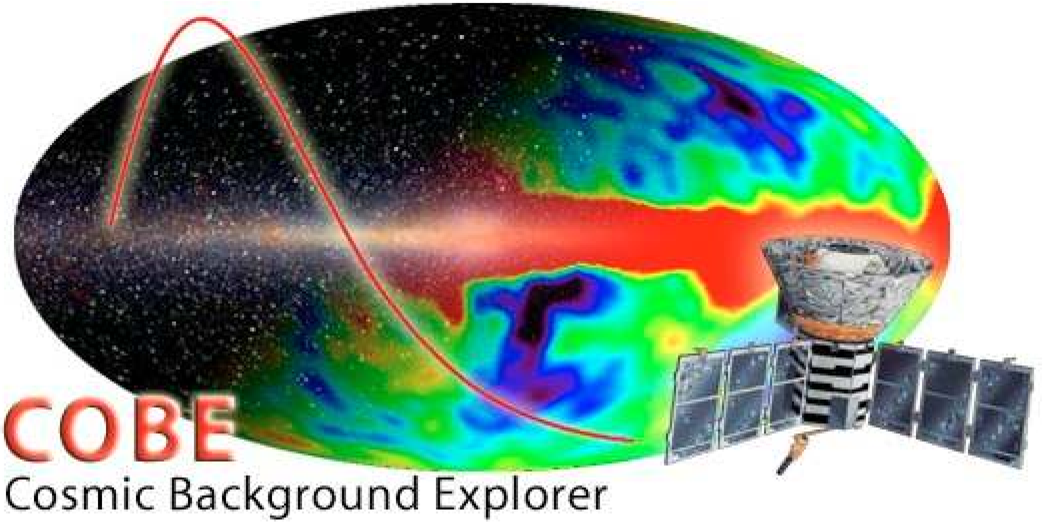
Aller plus loin

Est-ce bien le FDC ? Si oui :

- Spectre en fréquence caractéristique d'un corps noir

- (Petites) fluctuations attendues
1960s-90s : Sachs, Wolfe, Rees, Sciama…

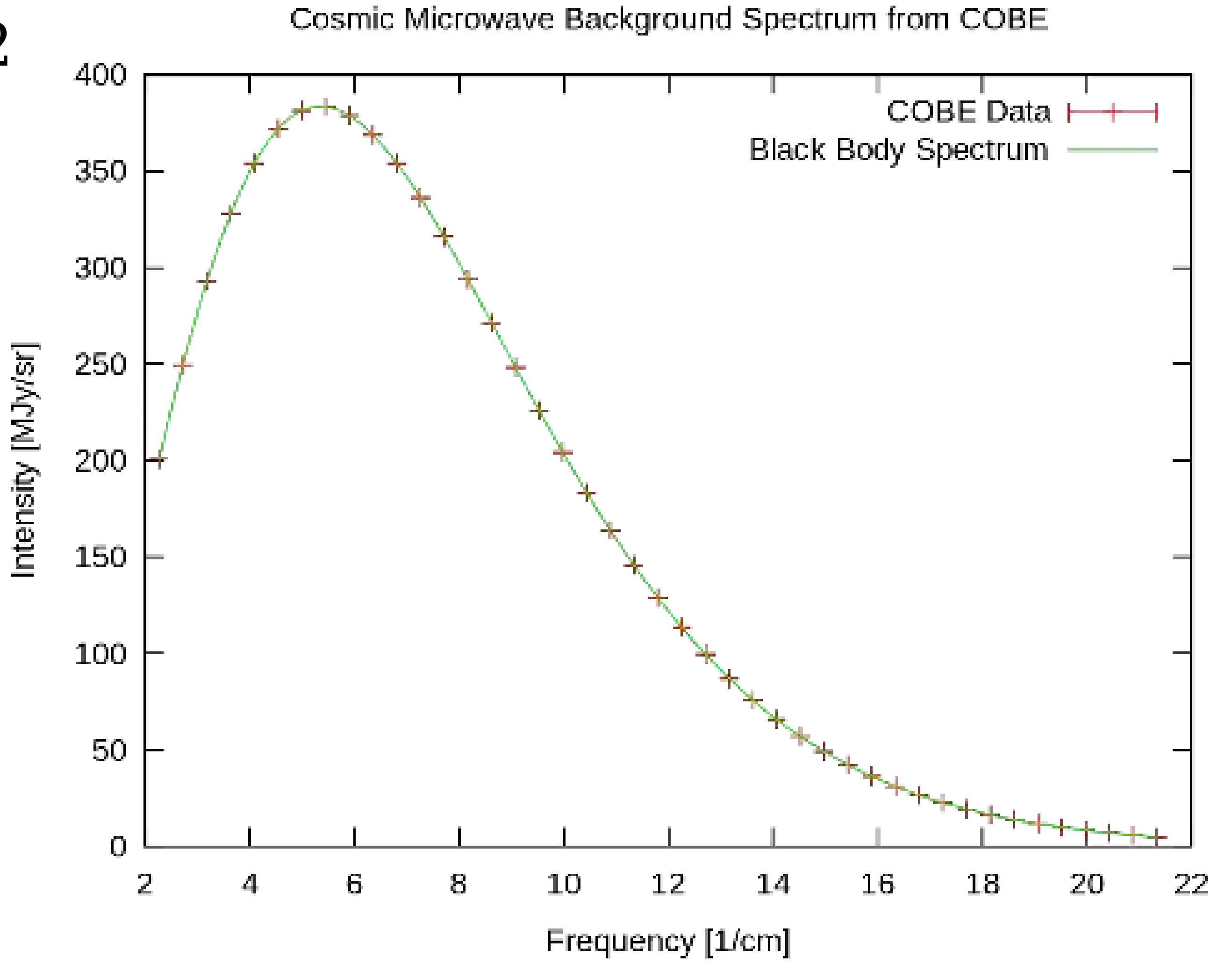
COBE: Cosmic Background Explorer



1974 : Appel à propositions de la NASA : 3 projets soumis
pour étudier le FDC → aucun sélectionné
1976 : Comité propose COBE à la NASA
1981 : Début construction (retardé)
1989 : Lancement du satellite (retardé) en orbite polaire

COBE: Cosmic Background Explorer

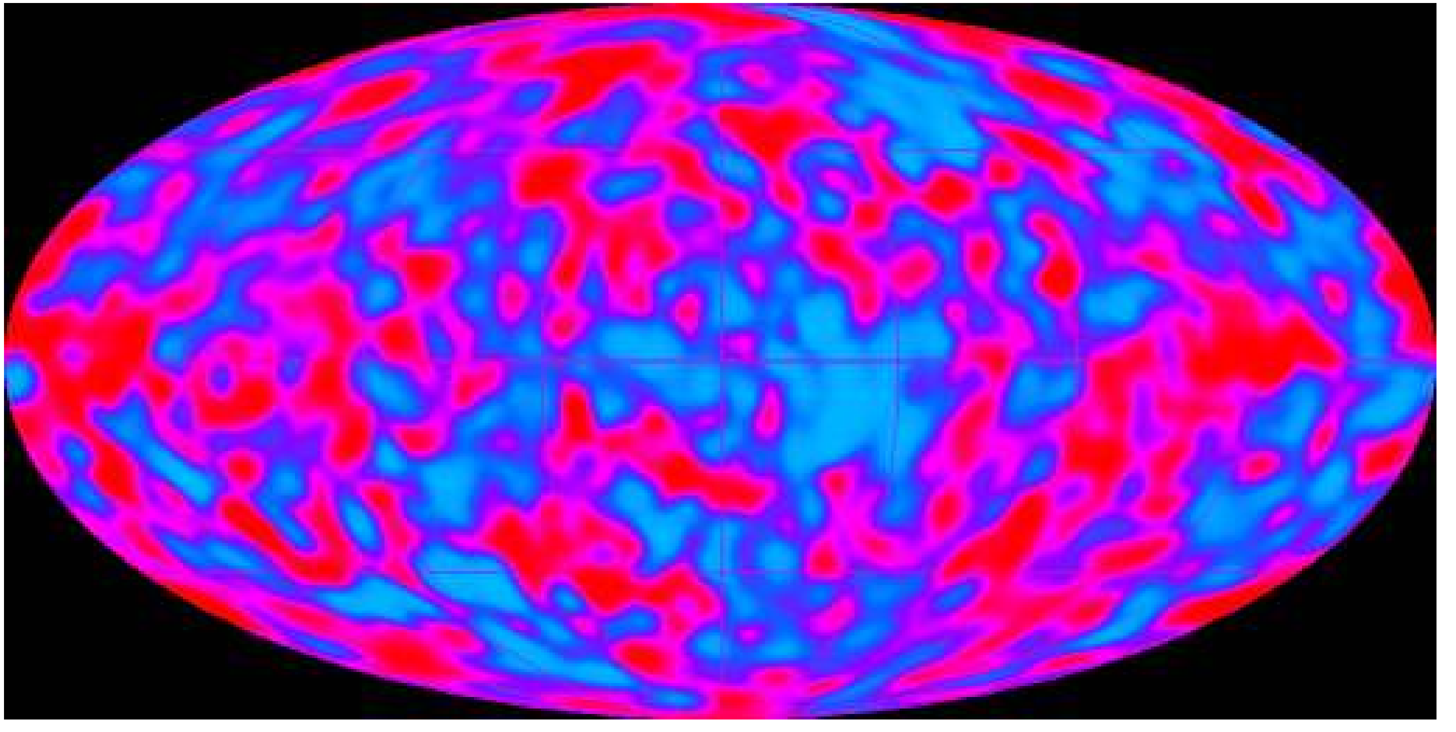
Avril '92



Corps noir ? …check

COBE: Cosmic Background Explorer

Avril '92

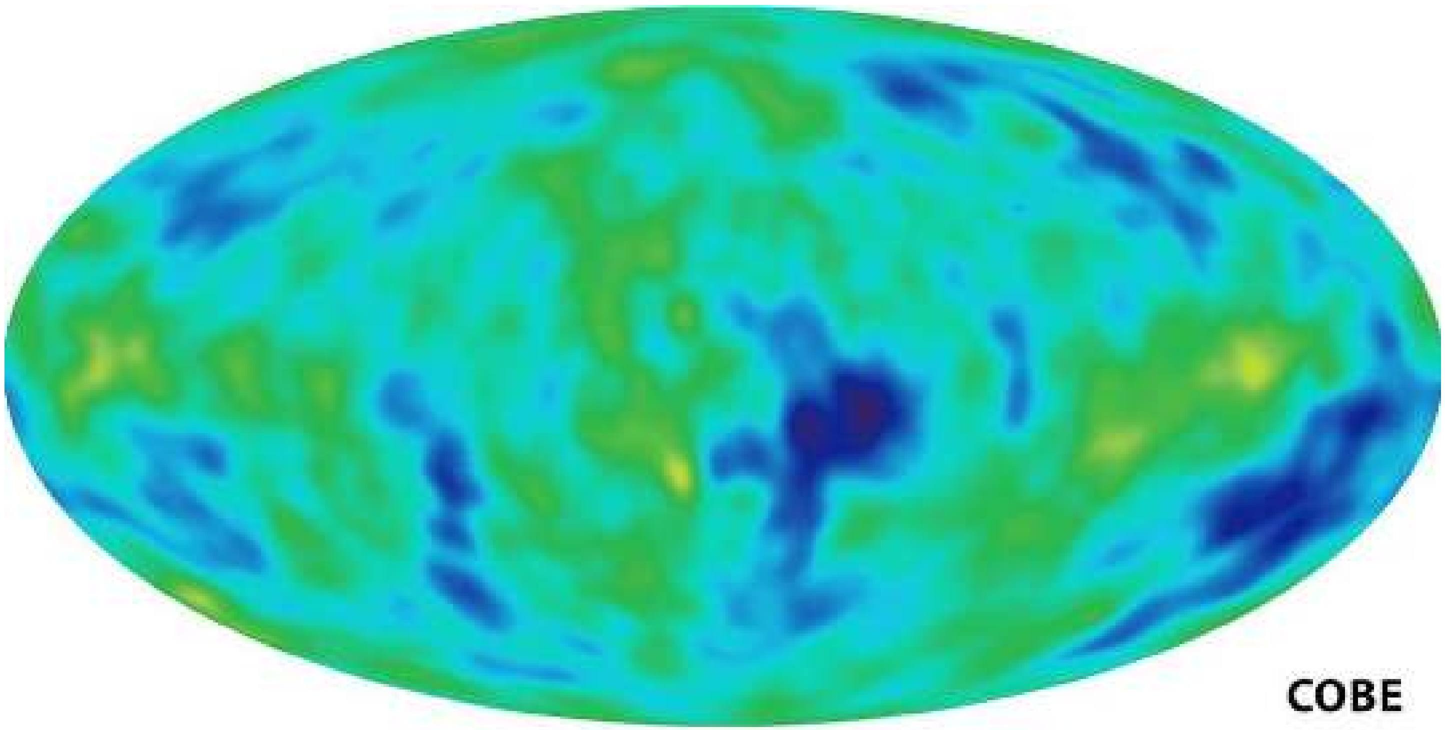


$\delta \sim 10^{-5}$

Fluctuations ? …check

COBE: Cosmic Background Explorer

Avril '92



$\delta \sim 10^{-5}$

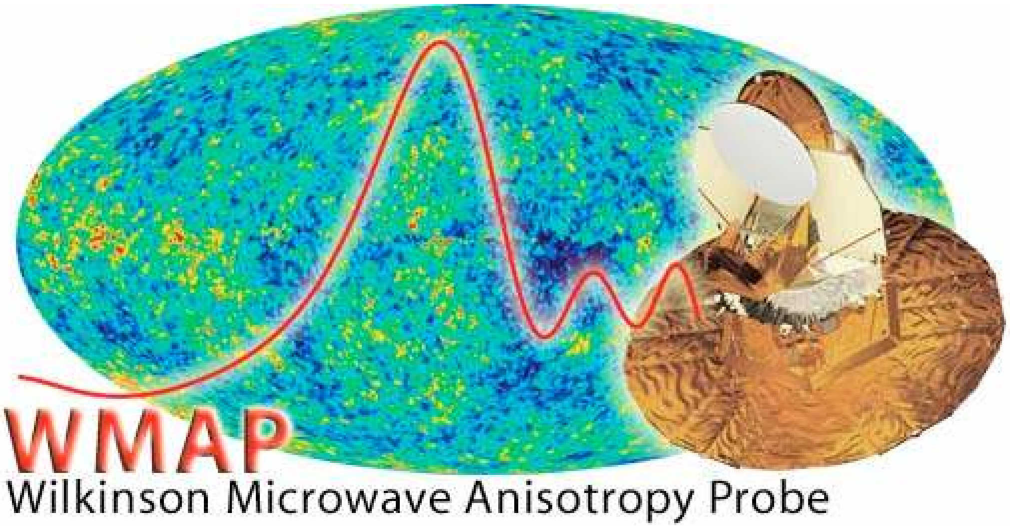
Fluctuations ? ...check

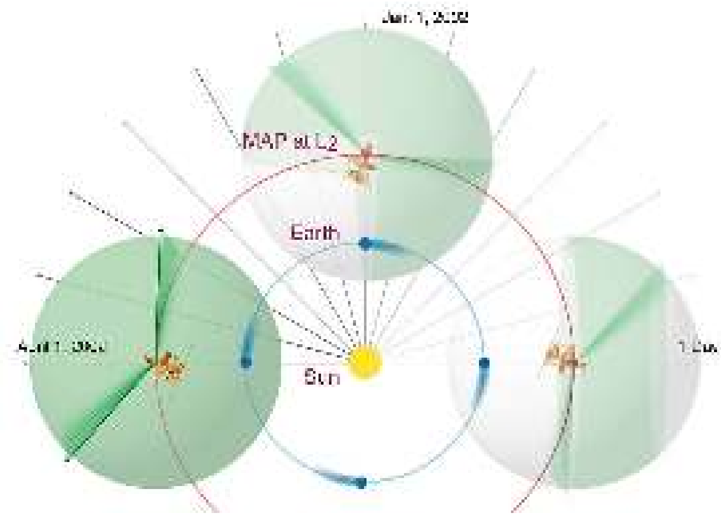
COBE: Cosmic Background Explorer

Attribué à J. C. Mather and G. F. Smoot : “for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation”

Prix Nobel ? ...check

WMAP

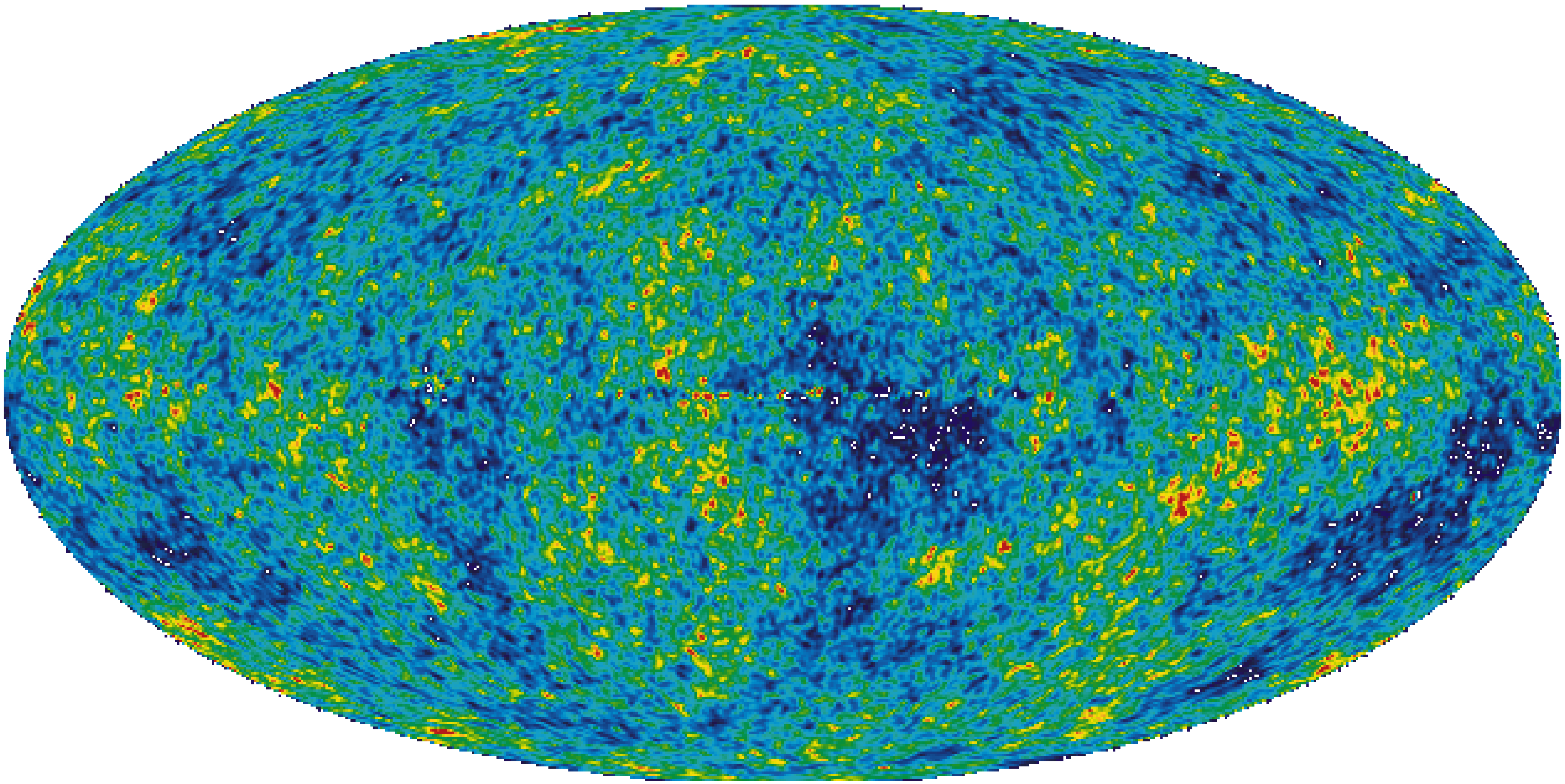




1995 : Proposé à la NASA
1997 : Approuvé pour développement
2001 : Lancement et trajet vers L2

WMAP

2001-2010 : 9 ans de fonctionnement et de données



(… mais pas de prix Nobel)

Planck

Objectif :

Mesure utlime du FDC sur tout le ciel
par un satellite dédié

Mission sélectionnée par l'ESA
en 1996 (lancée en 2009)

La collaboration Planck

La collaboration Planck

Planck 2015 results. XIII. Cosmological parameters

Planck Collaboration: P. A. R. Ade, N. Aghanim, M. Arnaud, M. Ashdown, J. Aumont, C. Baccigalupi, A. J. Banday, R. B. Barreiro, J. G. Bartlett, N. Bartolo, E. Battaner, R. Battye, K. Benabed, A. Benoît, A. Benoit-Lévy, J.-P. Bernard, M. Bersanelli, P. Bielewicz, A. Bonaldi, L. Bonavera, J. R. Bond, J. Borrill, F. R. Bouchet, F. Boulanger, M. Bucher, C. Burigana, R. C. Butler, E. Calabrese, J.-F. Cardoso, A. Catalano, A. Challinor, A. Chamballu, R.-R. Chary, H. C. Chiang, J. Chluba, P. R. Christensen, S. Church, D. L. Clements, S. Colombi, L. P. L. Colombo, C. Combet, A. Coulais, B. P. Crill, A. Curto, F. Cuttaia, L. Danese, R. D. Davies, R. J. Davis, P. de Bernardis, A. de Rosa, G. de Zotti, J. Delabrouille, F.-X. Désert, E. Di Valentino, C. Dickinson, J. M. Diego, K. Dolag, H. Dole, S. Donzelli, O. Doré, M. Douspis, A. Ducout, J. Dunkley, X. Dupac, G. Efstathiou, F. Elsner, T. A. Enßlin, H. K. Eriksen, M. Farhang, J. Fergusson, F. Finelli, O. Forni, M. Frailis, A. A. Fraisse, E. Franceschi, A. Frejsel, S. Galeotta, S. Galli, K. Ganga, C. Gauthier, M. Gerbino, T. Ghosh, M. Giard, Y. Giraud-Héraud, E. Giusarma, E. Gjerløw, J. González-Nuevo, K. M. Górski, S. Gratton, A. Gregorio, A. Gruppuso, J. E. Gudmundsson, J. Hamann, F. K. Hansen, D. Hanson, D. L. Harrison, G. Helou, S. Henrot-Versillé, C. Hernández-Monteagudo, D. Herranz, S. R. Hildebrandt, E. Hivon, M. Hobson, W. A. Holmes, A. Hornstrup, W. Hovest, Z. Huang, K. M. Huffenberger, G. Hurier, A. H. Jaffe, T. R. Jaffe, W. C. Jones, M. Juvela, E. Keihänen, R. Keskitalo, T. S. Kisner, R. Kneissl, J. Knoche, L. Knox, M. Kunz, H. Kurki-Suonio, G. Lagache, A. Lähteenmäki, J.-M. Lamarre, A. Lasenby, M. Lattanzi, C. R. Lawrence, J. P. Leahy, R. Leonardi, J. Lesgourgues, F. Levrier, A. Lewis, M. Liguori, P. B. Lilje, M. Linden-Vørnle, M. López-Caniego, P. M. Lubin, J. F. Macías-Pérez, G. Maggio, N. Mandolesi, A. Mangilli, A. Marchini, P. G. Martin, M. Martinelli, E. Martínez-González, S. Masi, S. Matarrese, P. Mazzotta, P. McGehee, P. R. Meinhold, A. Melchiorri, J.-B. Melin, L. Mendes, A. Mennella, M. Migliaccio, M. Millea, S. Mitra, M.-A. Miville-Deschênes, A. Moneti, L. Montier, G. Morgante, D. Mortlock, A. Moss, D. Munshi, J. A. Murphy, P. Naselsky, F. Nati, P. Natoli, C. B. Netterfield, H. U. Nørgaard-Nielsen, F. Noviello, D. Novikov, I. Novikov, C. A. Oxborrow, F. Paci, L. Pagano, F. Pajot, R. Paladini, D. Paoletti, B. Partridge, F. Pasian, G. Patanchon, T. J. Pearson, O. Perdereau, L. Perotto, F. Perrotta, V. Pettorino, F. Piacentini, M. Piat, E. Pierpaoli, D. Pietrobon, S. Plaszczynski, E. Pointecouteau, G. Polenta, L. Popa, G. W. Pratt, G. Prézeau, S. Prunet, J.-L. Puget, J. P. Rachen, W. T. Reach, R. Rebolo, M. Reinecke, M. Remazeilles, C. Renault, A. Renzi, I. Ristorcelli, G. Rocha, C. Rosset, M. Rossetti, G. Roudier, B. Rouillé d'Orfeuil, M. Rowan-Robinson, J. A. Rubiño-Martín, B. Rusholme, N. Said, V. Salvatelli, L. Salvati, M. Sandri, D. Santos, M. Savelainen, G. Savini, D. Scott, M. D. Seiffert, P. Serra, E. P. S. Shellard, L. D. Spencer, M. Spinelli, V. Stolyarov, R. Stompor, R. Sudiwala, R. Sunyaev, D. Sutton, A.-S. Suur-Uski, J.-F. Sygnet, J. A. Tauber, L. Terenzi, L. Toffolatti, M. Tomasi, M. Tristram, T. Trombetti, M. Tucci, J. Tuovinen, M. Türler, G. Umana, L. Valenziano, J. Valiviita, B. Van Tent, P. Vielva, F. Villa, L. A. Wade, B. D. Wandelt, I. K. Wehus, M. White, S. D. M. White, A. Wilkinson, D. Yvon, A. Zacchei, and A. Zonca

(Affiliations can be found after the references)

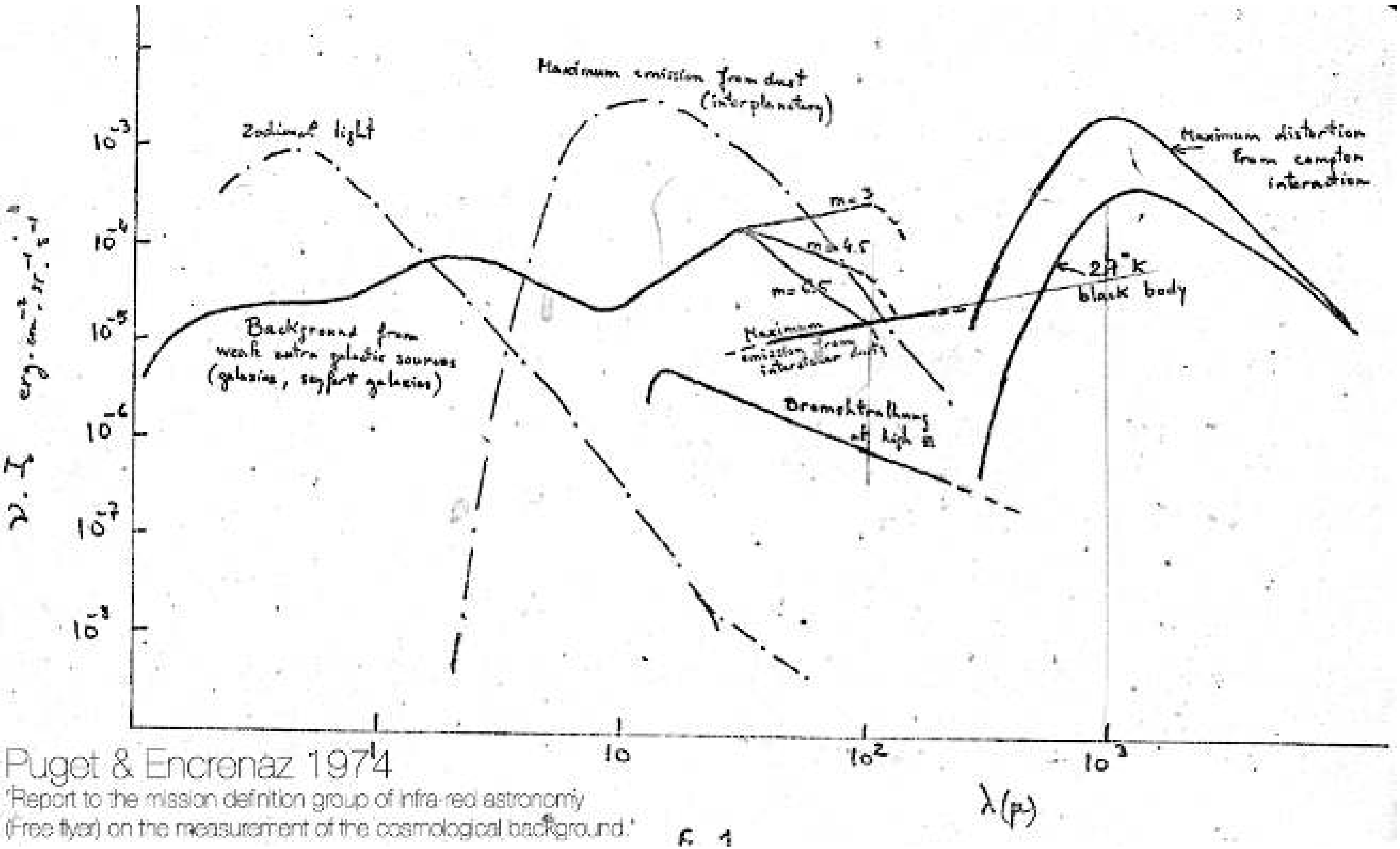
February 5 2015

ABSTRACT

This paper presents cosmological results based on full-mission *Planck* observations of temperature and polarization anisotropies of the cosmic microwave background (CMB) radiation. Our results are in very good agreement with the 2013 analysis of the *Planck* nominal-mission temperature data, but with increased precision. The temperature and polarization power spectra are consistent with the standard spatially-flat six-parameter ΛCDM cosmology with a power-law spectrum of adiabatic scalar perturbations (denoted "base ΛCDM" in this paper). From the *Planck* temperature data combined with *Planck* lensing, for this cosmology we find a Hubble constant, $H_0 = (67.8 \pm 0.9)$ km s^{-1}Mpc^{-1}, a matter density parameter

http://www.cosmos.esa.int/web/planck/publications

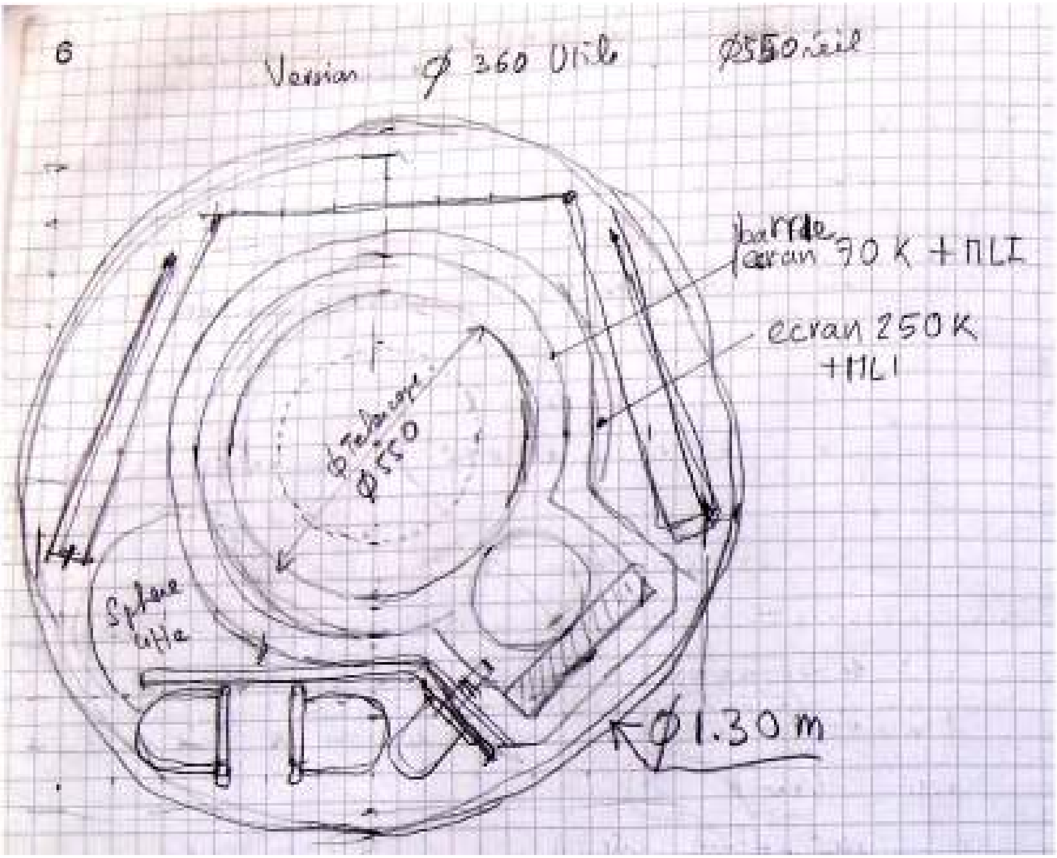
Planck : un long chemin…

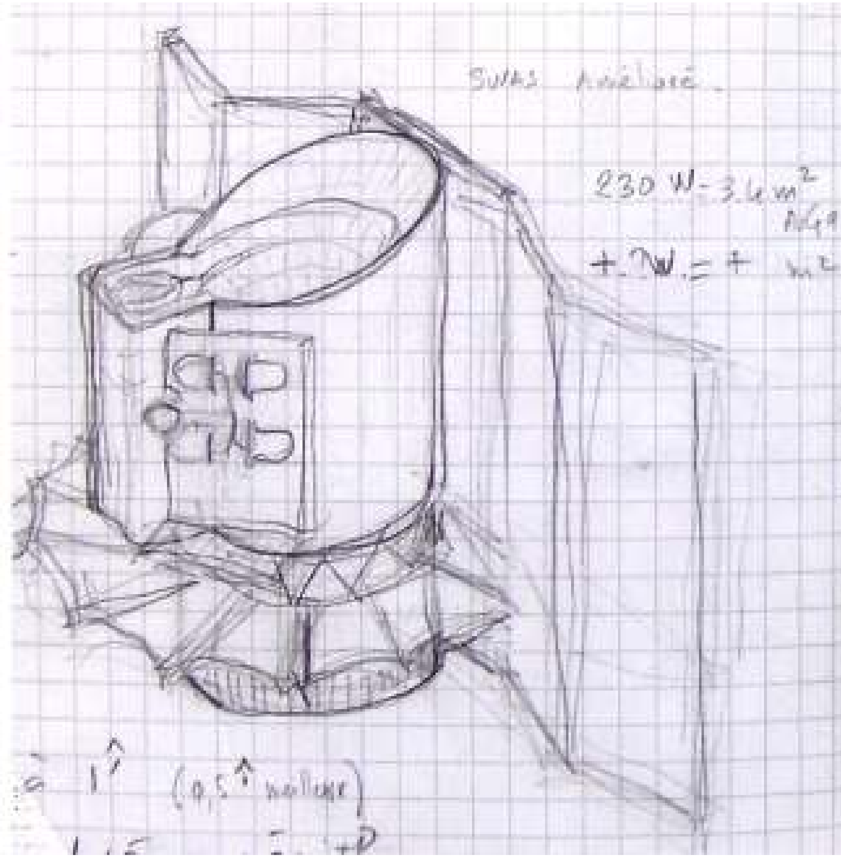


Puget & Encrenaz 1974
"Report to the mission definition group of infra-red astronomy
(Free flyer) on the measurement of the cosmological background."

Planck : un long chemin…

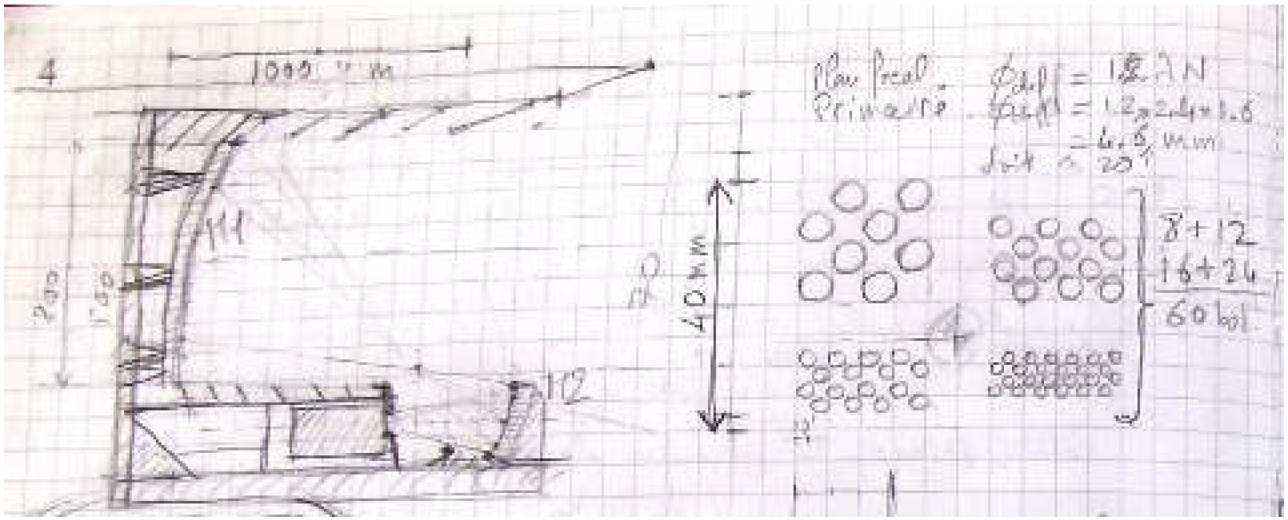
1993: premier design de Jean-Michel Lamarre



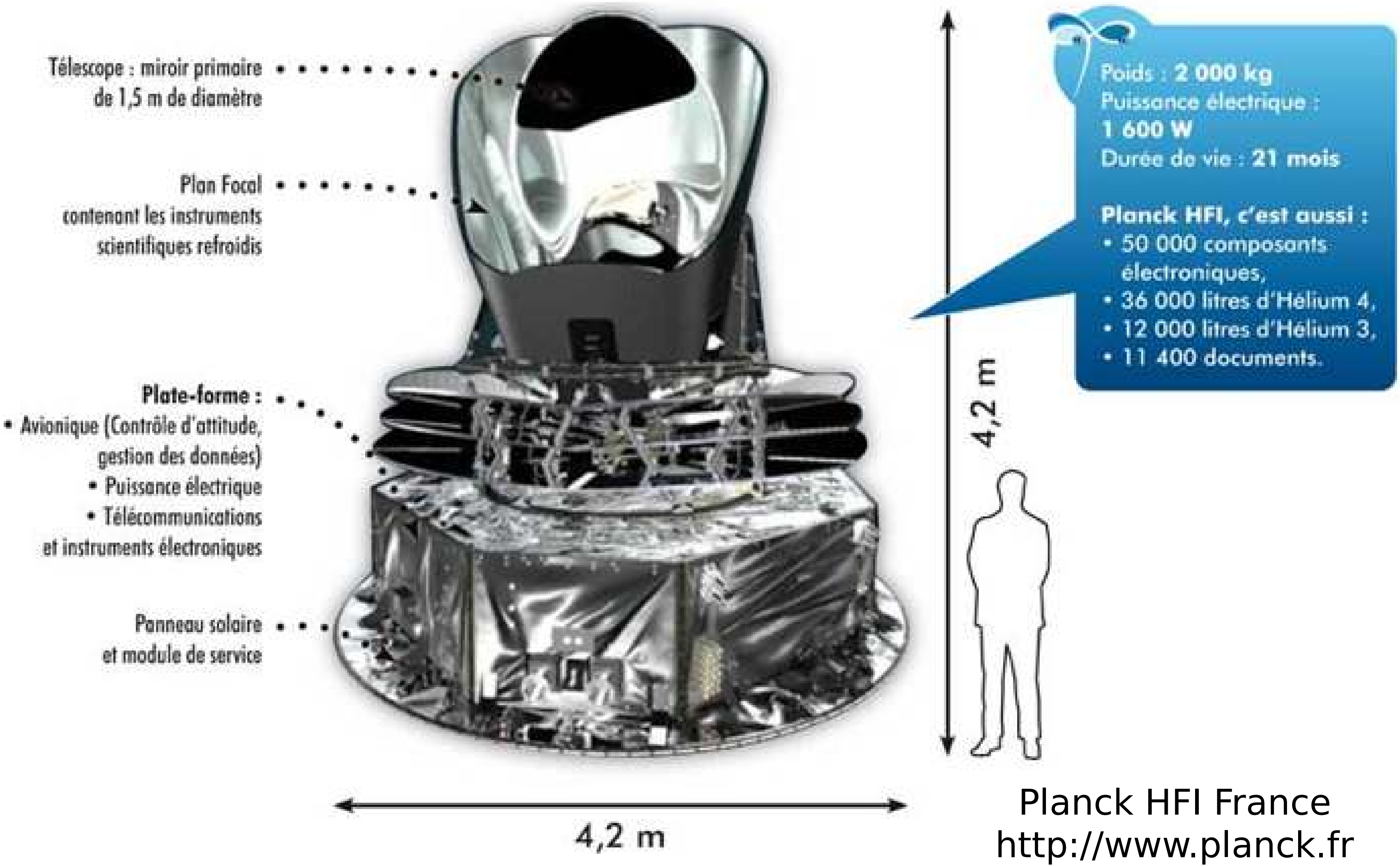


Planck : un long chemin...

1993: design de Jean-Michel Lamarre



Planck

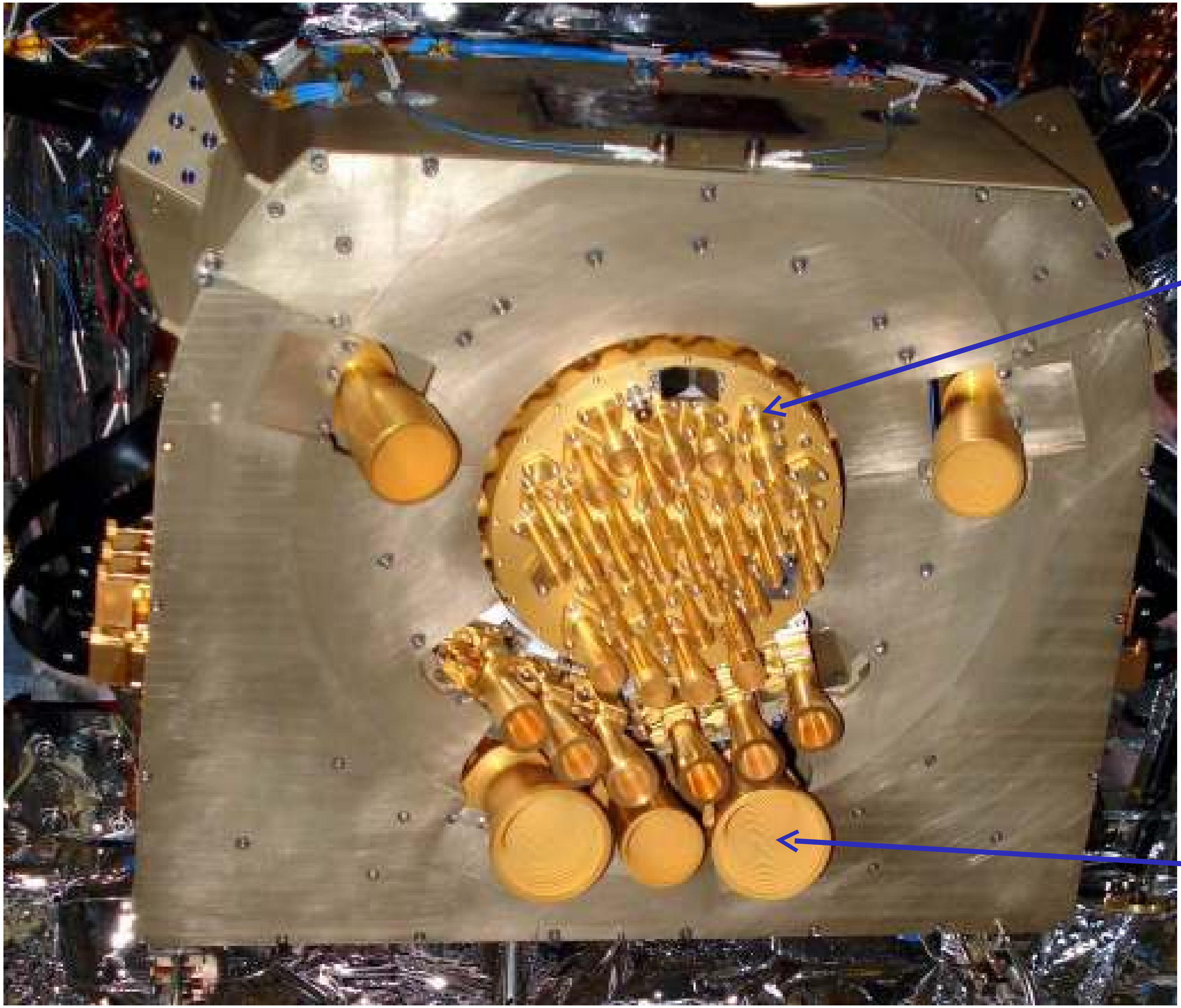


Planck HFI France
http://www.planck.fr

Planck

Planck, ESA, HFI & LFI

Le coeur de Planck : HFI & LFI



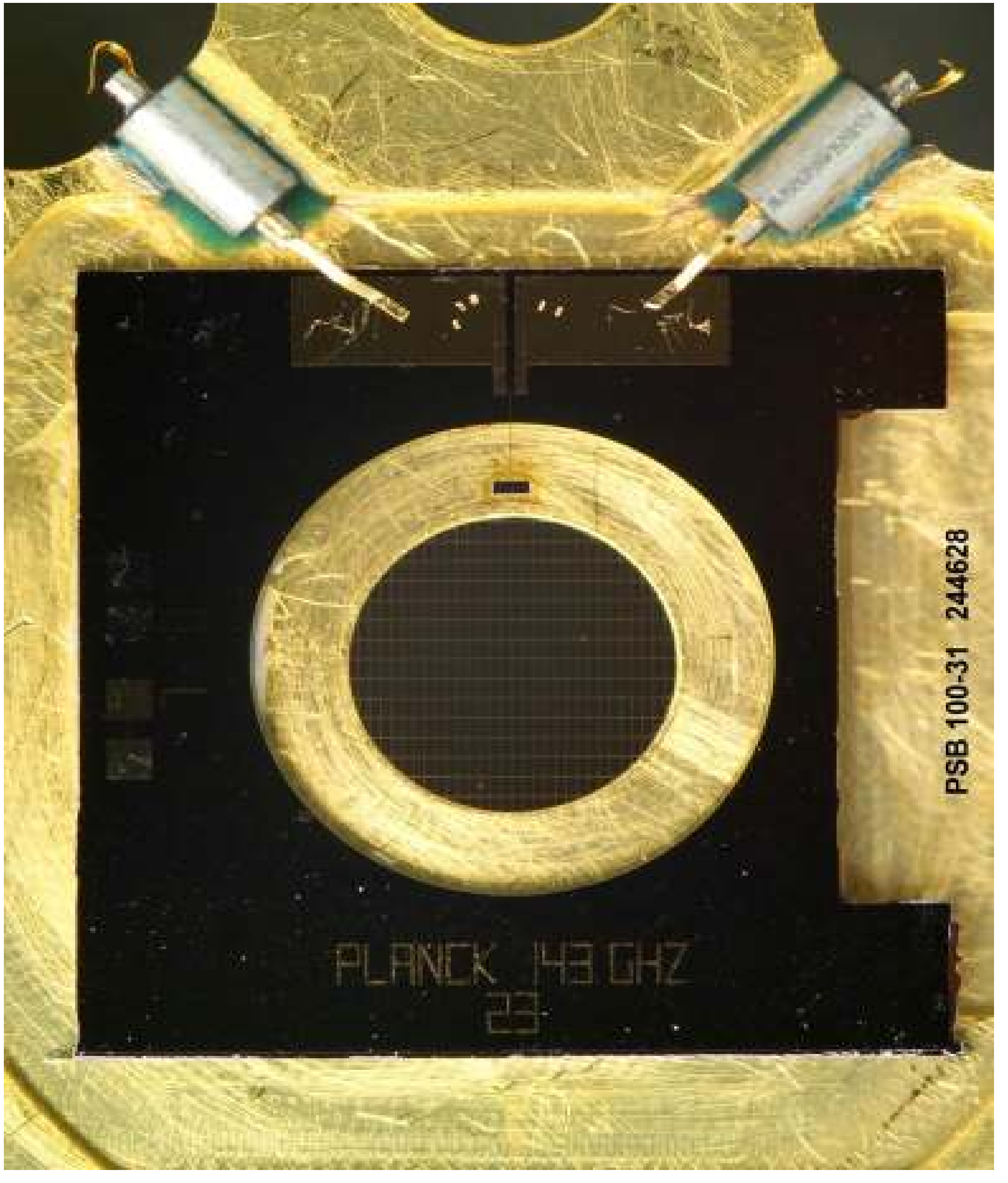
HFI
fonctionne
à 0.1K

Fabriqué sous
responsabilité
IAS, Orsay

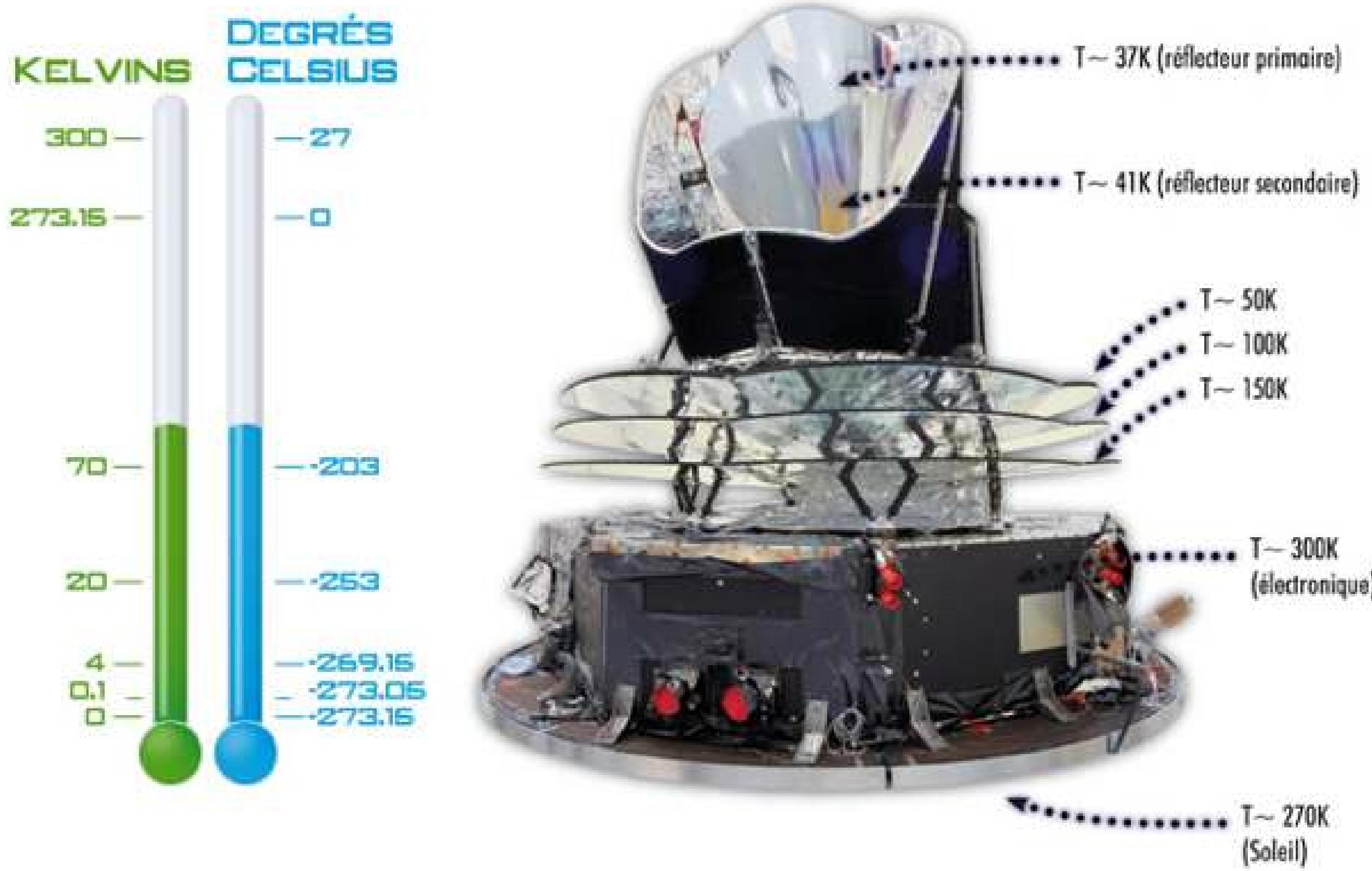
LFI

Planck, ESA, HFI & LFI

Le coeur de Planck : HFI & LFI



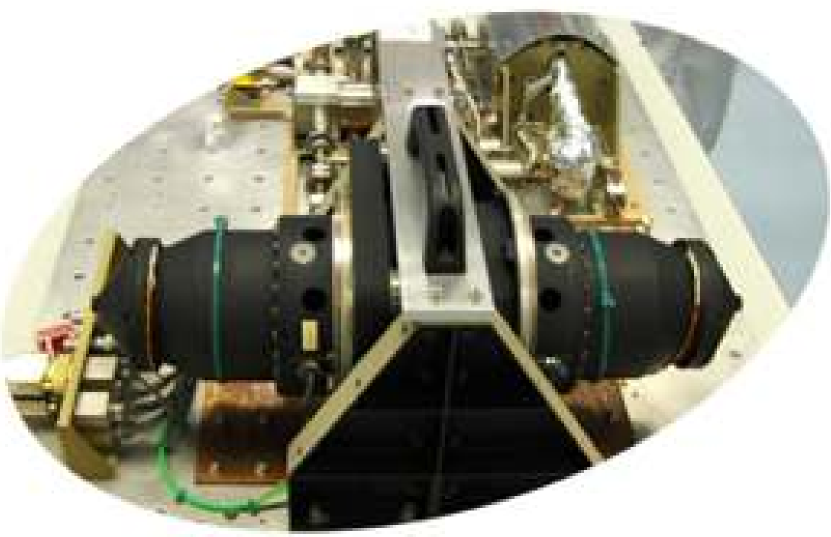
Architecture thermique



Planck HFI France
http://www.planck.fr

Architecture thermique

0.1K

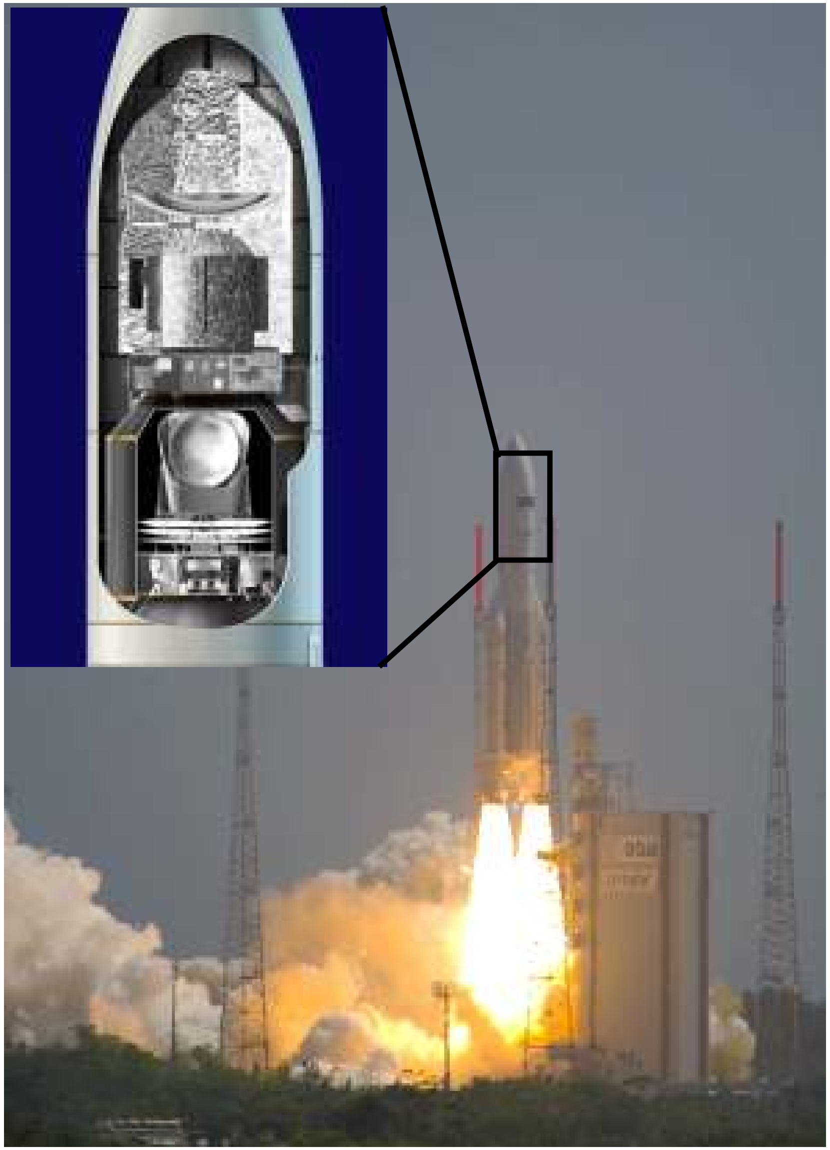


4K

20K

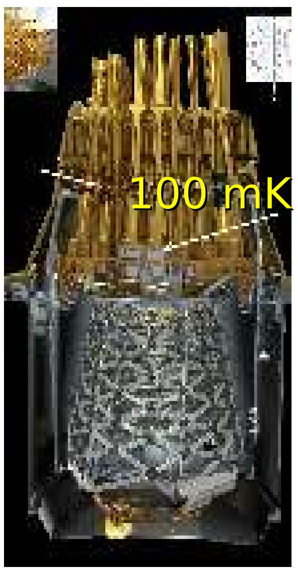
Planck HFI France
http://www.planck.fr

Lancement de Planck (& Herschel)



Succès technique

stabilité: 0.1mK



Cryostat:
dilution
He3/He4

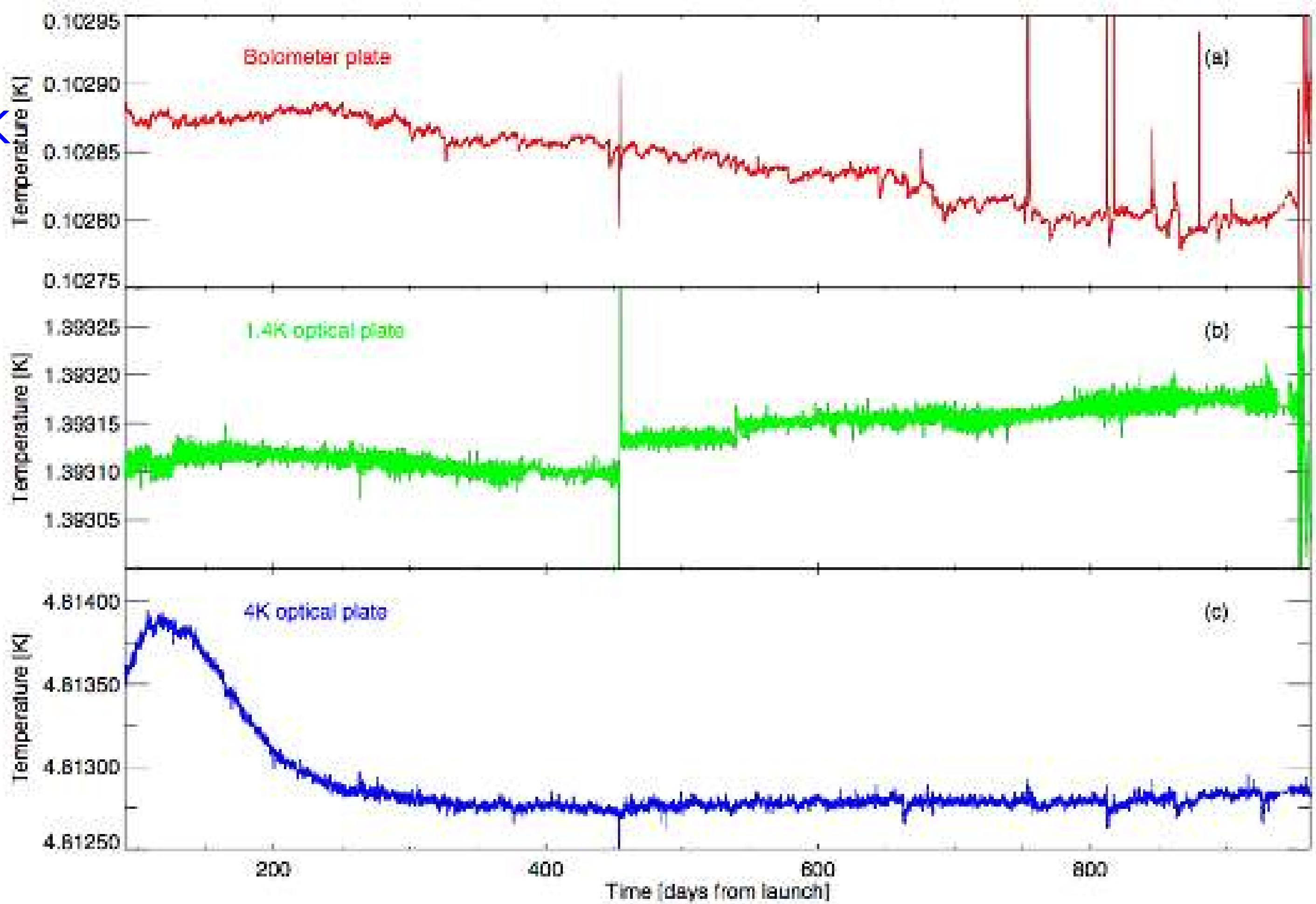
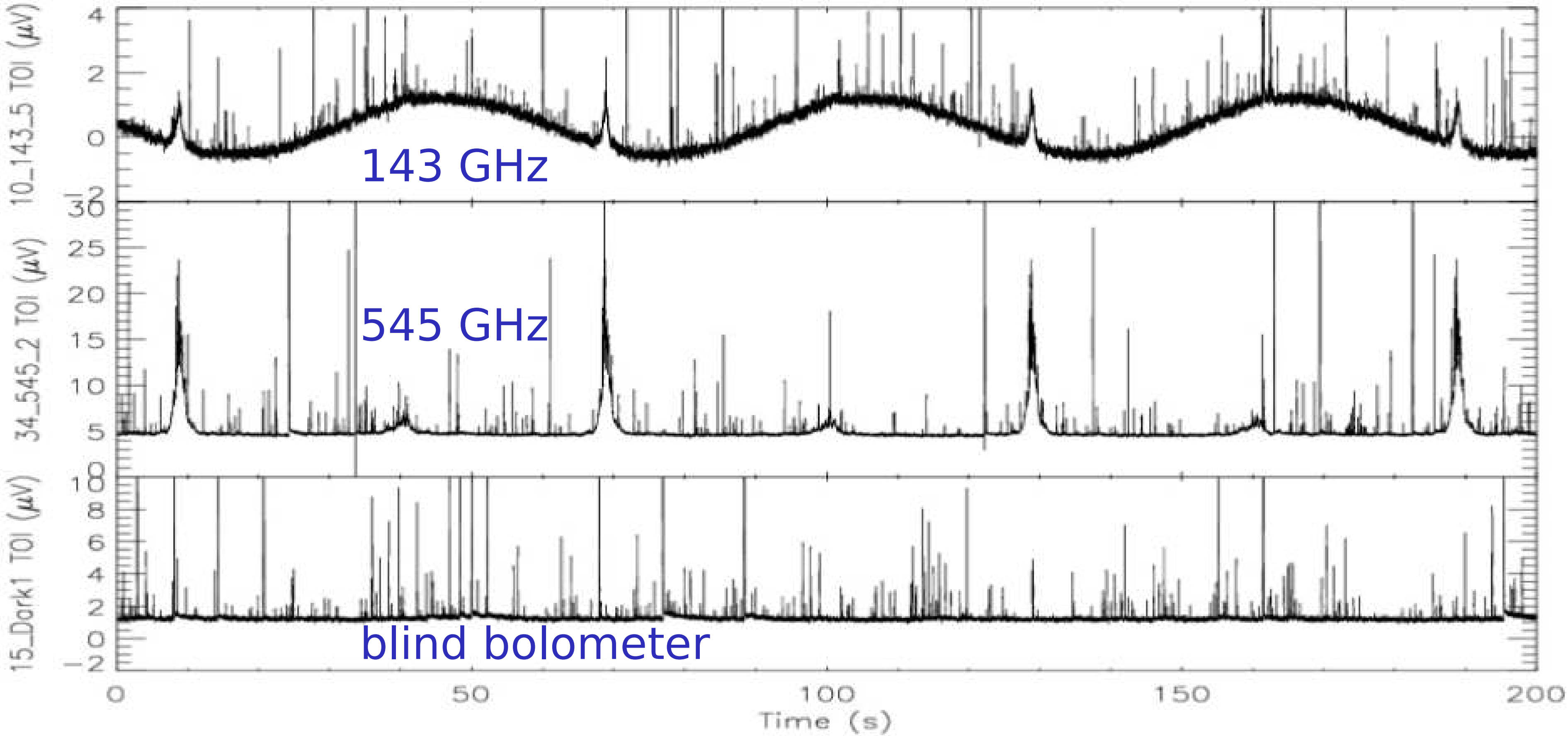


Fig. 7. The impressive stability of the HFI thermal stages during operations. Shown is the temperature evolution of the bolometer stage (*top*), the 1.6 K optical filter stage (*middle*) and the 4-K cooler reference load stage (*bottom*). The horizontal axis displays days since the beginning of the nominal mission.

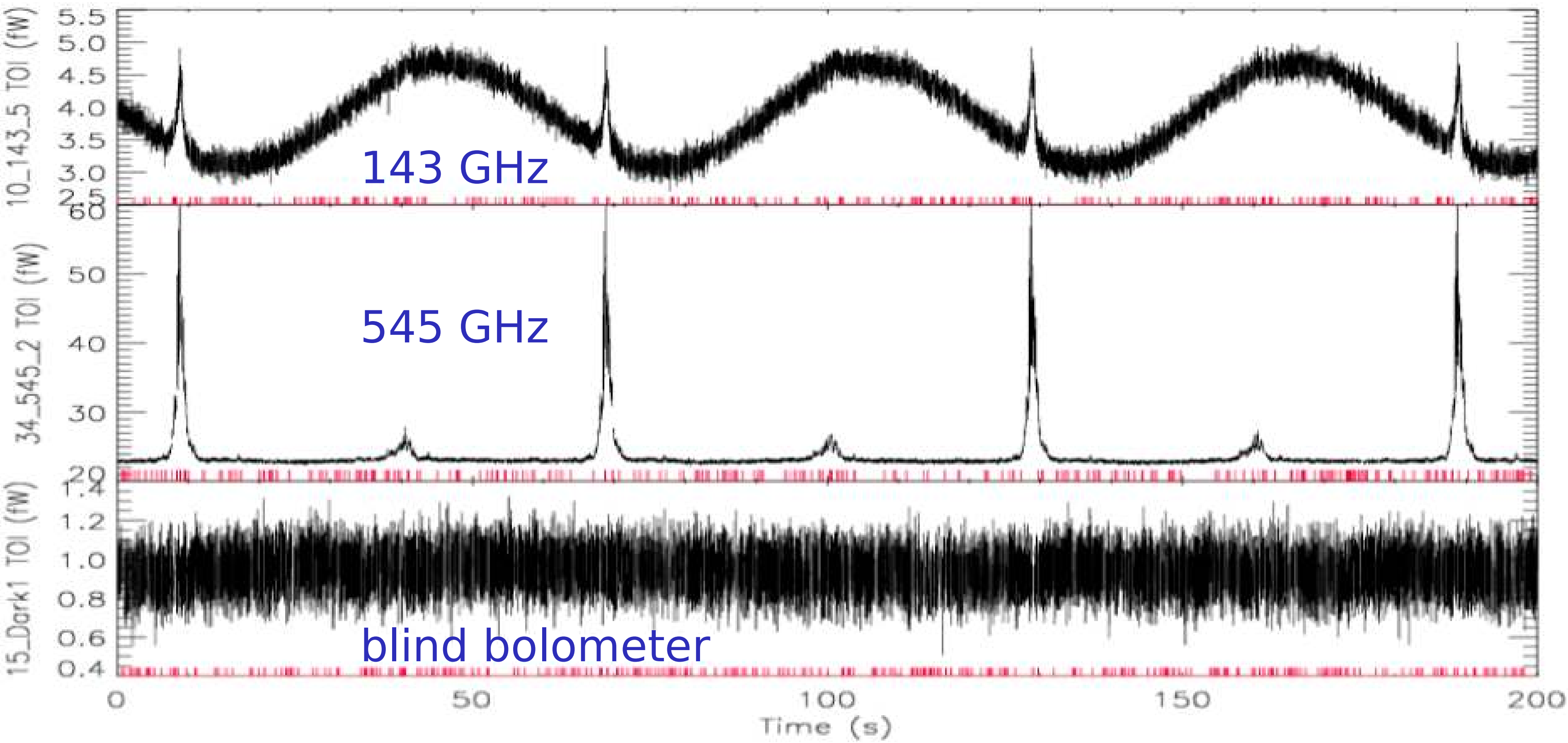
Planck Collab, 2013, 1

…mais avec imprévus



Planck-HFI Core Team, 2011

...mais bien gérés



de <20% de données perdues à cause des glitches
(ça aurait pu être bien, bien pire….)

Planck-HFI Core Team, 2011

Centre d'opération à Orsay

(c) H. Dole

Planck HFI – Instrument Operation Room – Institut d’Astrophysique Spatiale

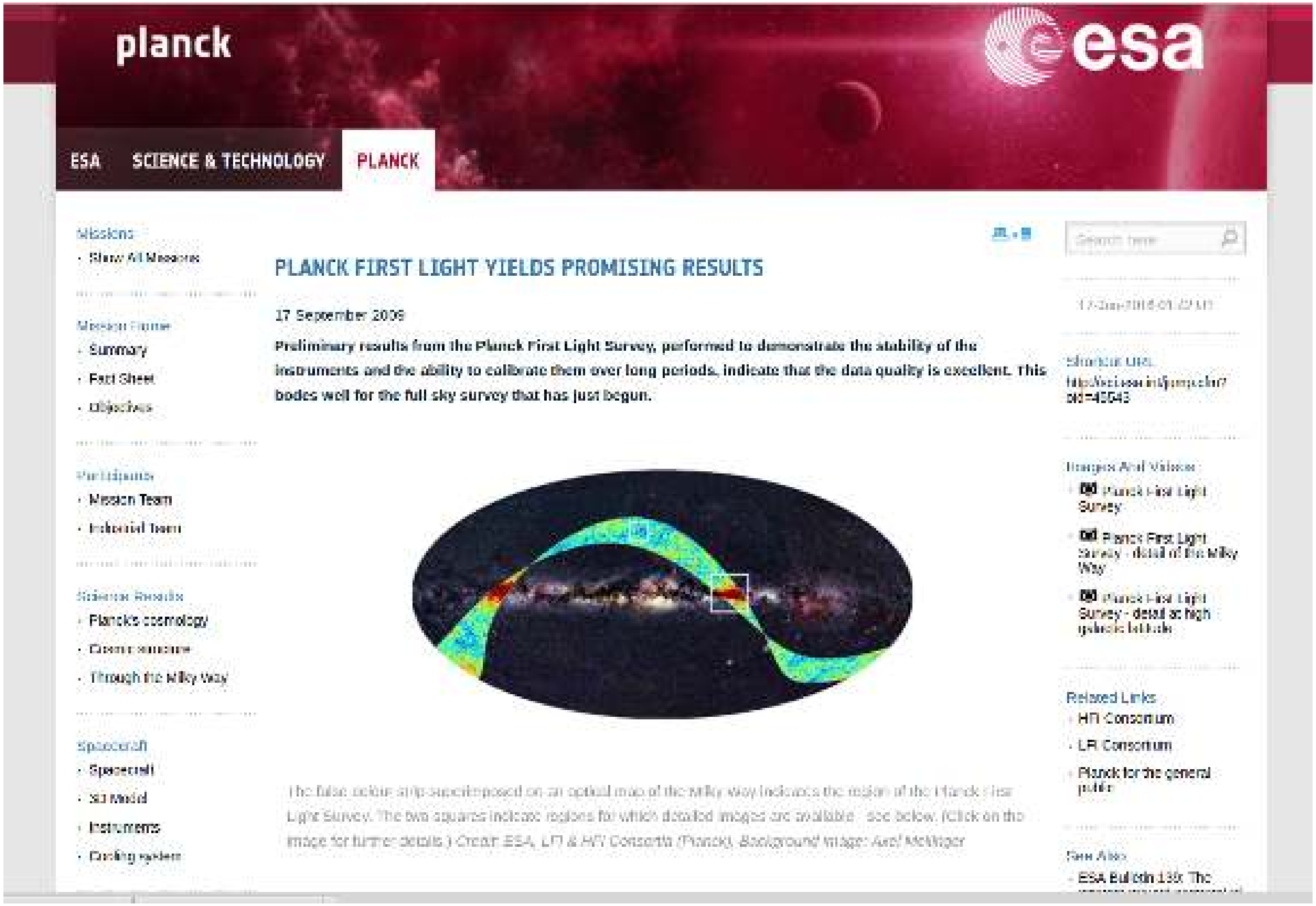
- Segment Sol de Planck-HFI
- IAS
  - surveillance quotidienne de l’instrument HFI
- IAP
  - Data Processing Center
  - ordinateur cluster IBM dédié à Planck de 1 128 cœurs, offrant 13 Teraflops
  - production des cartes du ciel:
    - 2 jours de calcul et traitement sur ce cluster
    - équivalent à 6 ans sur un micro-ordinateur, s’il avait
      - 200To de disque dur et un accès rapide aux disques (lecture de 11 CDROM en 1 seconde)

I. Un peu d'histoire…

II. Détecter le FDC

III. Le FDC vu par Planck

“Planck first light”



“Planck first light”

Differences at low *l* in Planck's first light sky map of the cosmic microwave background from WMAP's and COBE's

Short title: Differences at low *l* in Planck's first light sky map from WMAP's and COBE's

Keith S Cover

New evidence for lack of CMB power on large scales

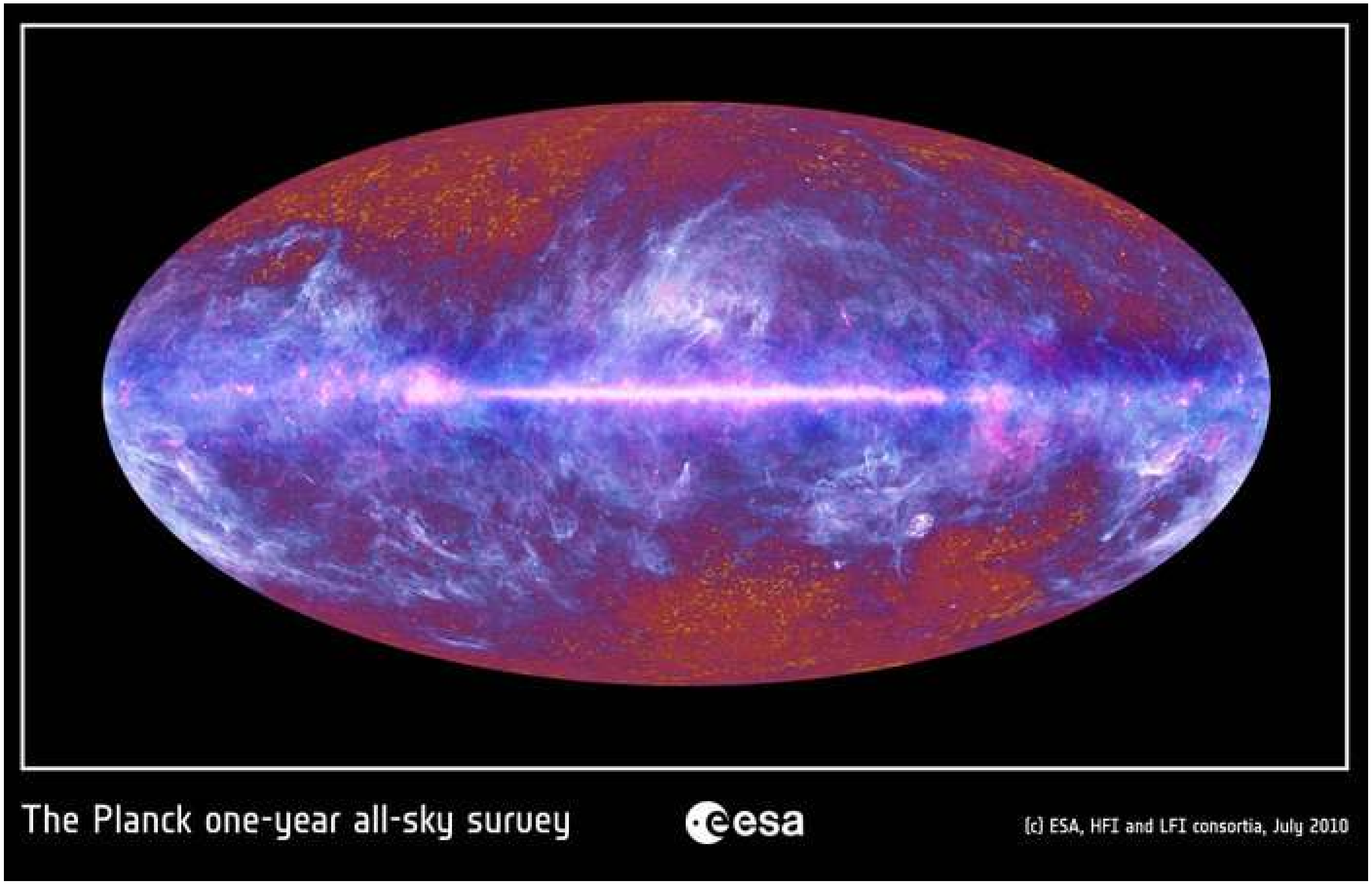
Hao Liu[1] and Ti-Pei Li[1,2,3]

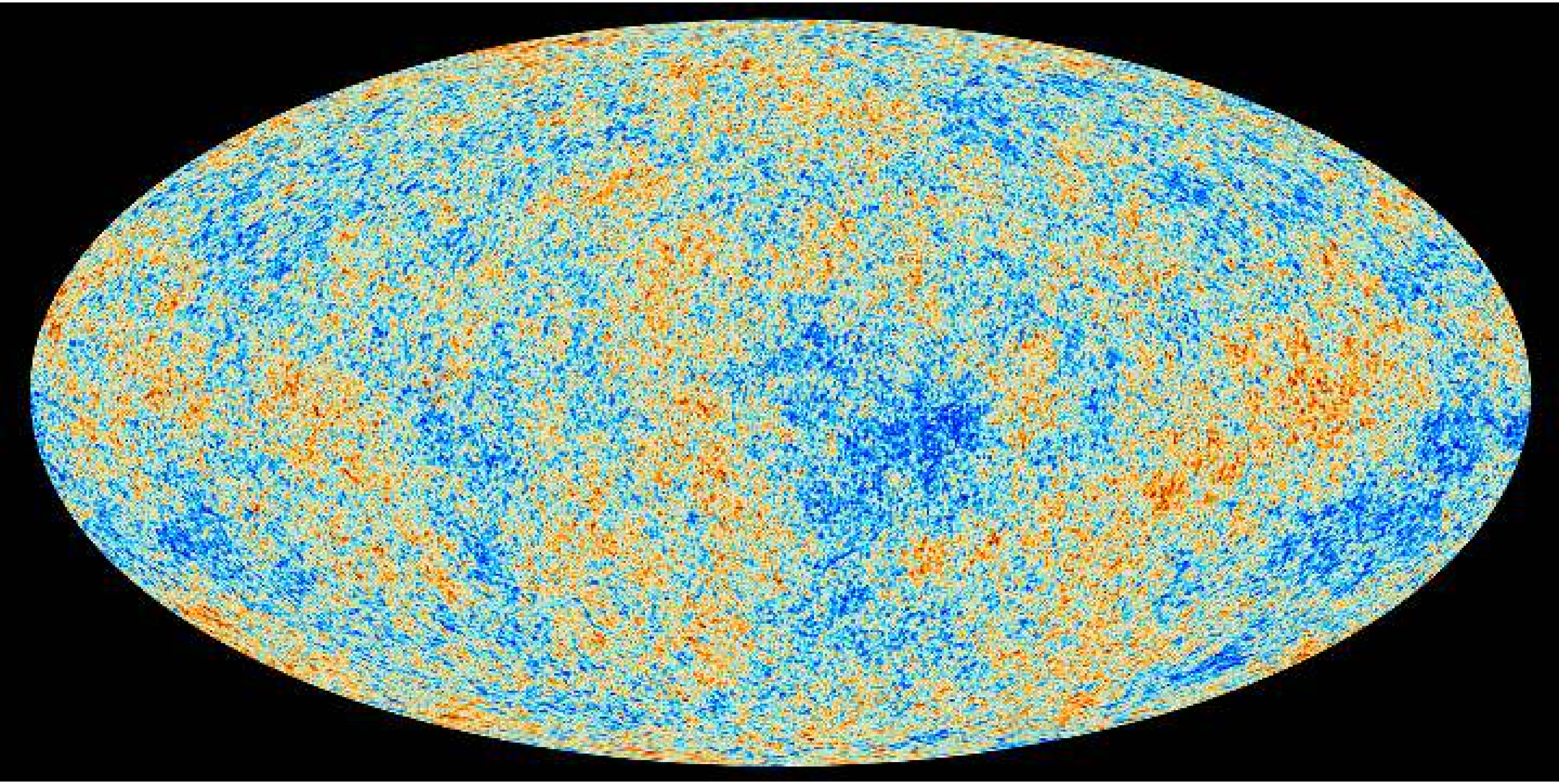
ABSTRACT

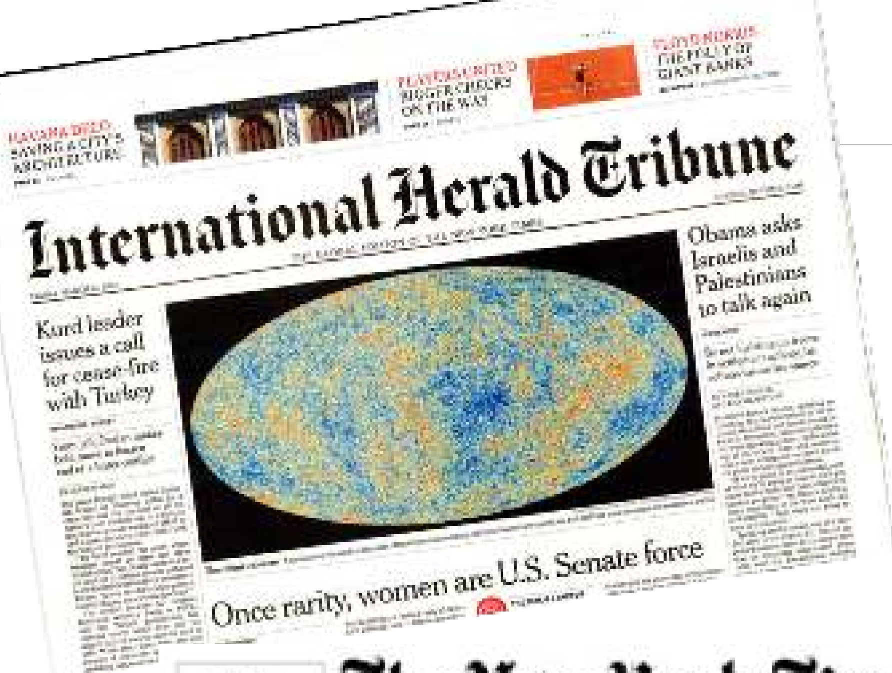
A digitalized temperature map is recovered from the first light sky survey image published by the Planck team, from which an angular power spectrum is derived. The amplitudes of the low multipoles measured from the preliminary Planck power spectrum are significantly lower than that reported by the WMAP team. Possible systematical effects are far from enough to explain the observed low-l differences.

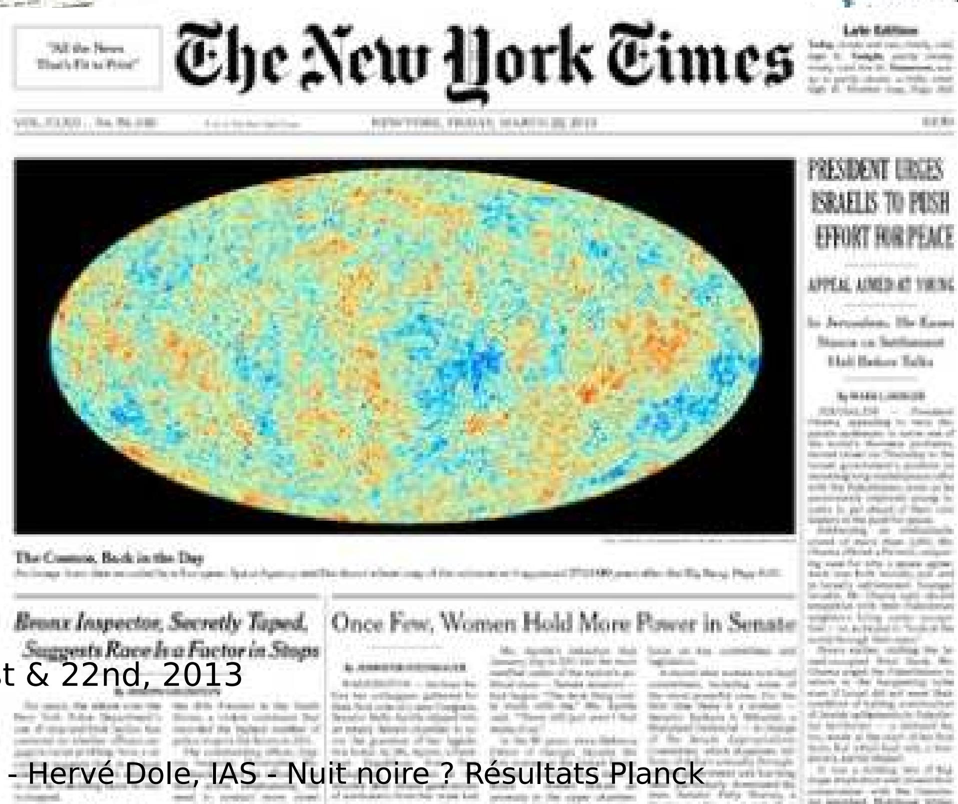
Subject headings: cosmic microwave background — cosmology: observations

Planck après un an



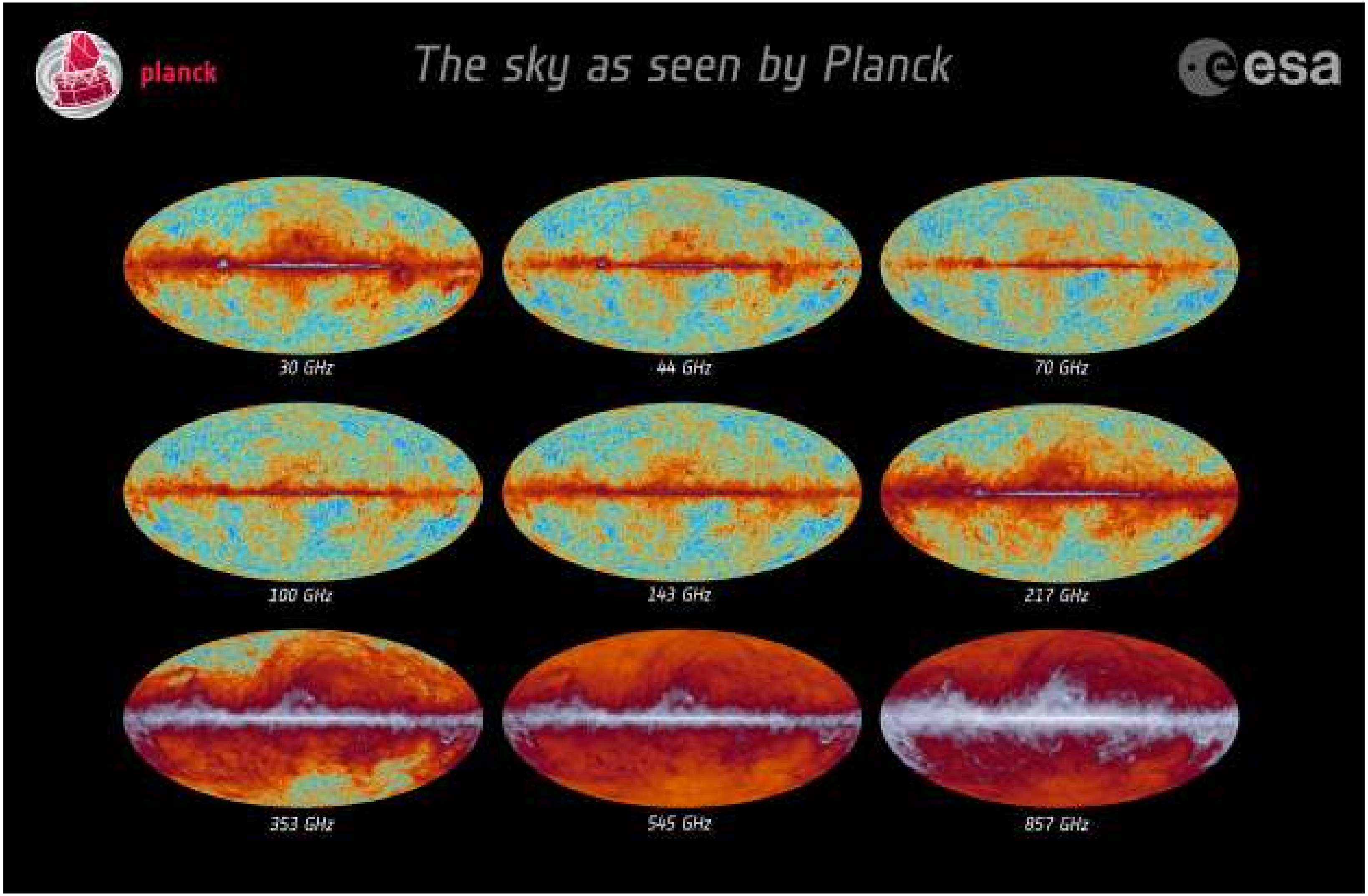




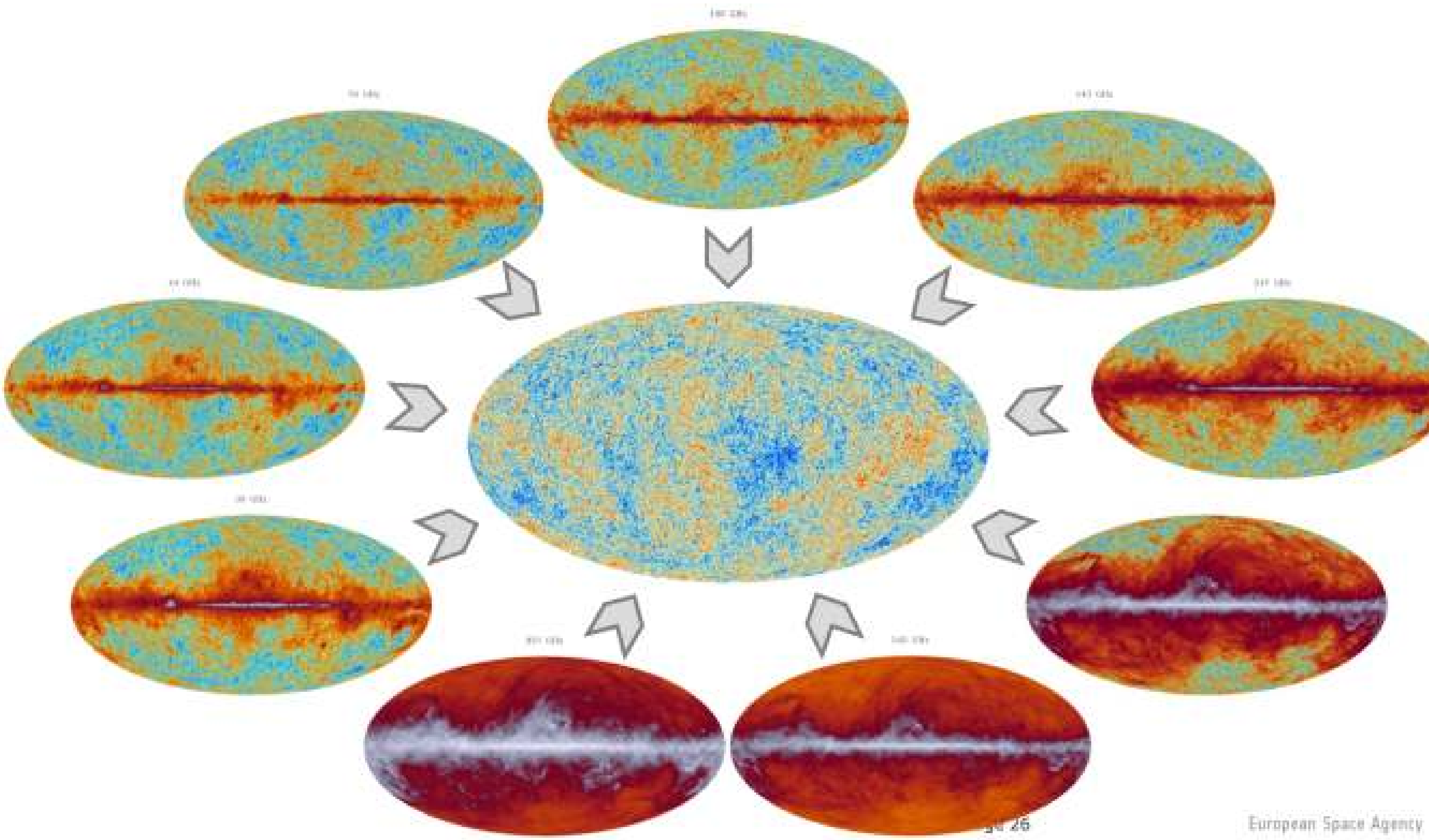


March 21st & 22nd, 2013

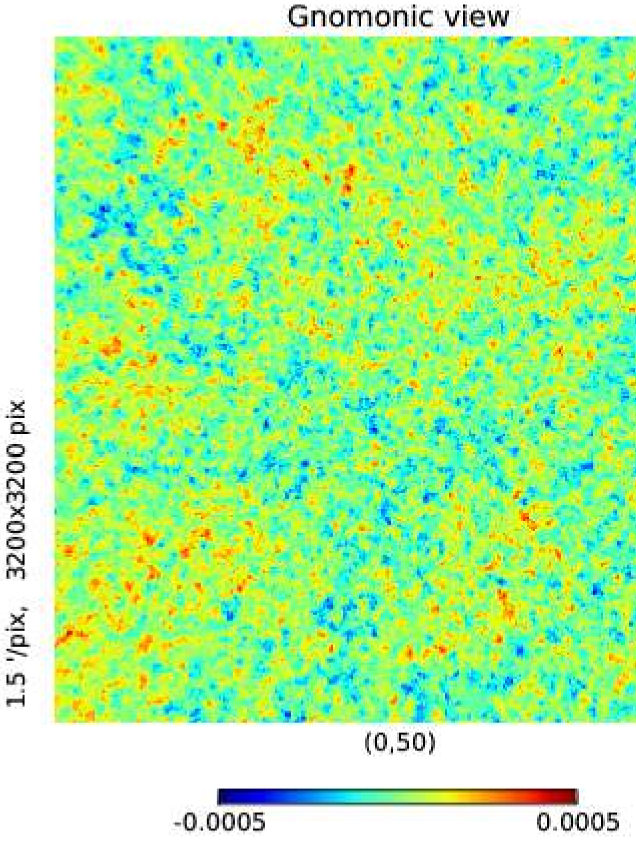
Les cartes de Planck

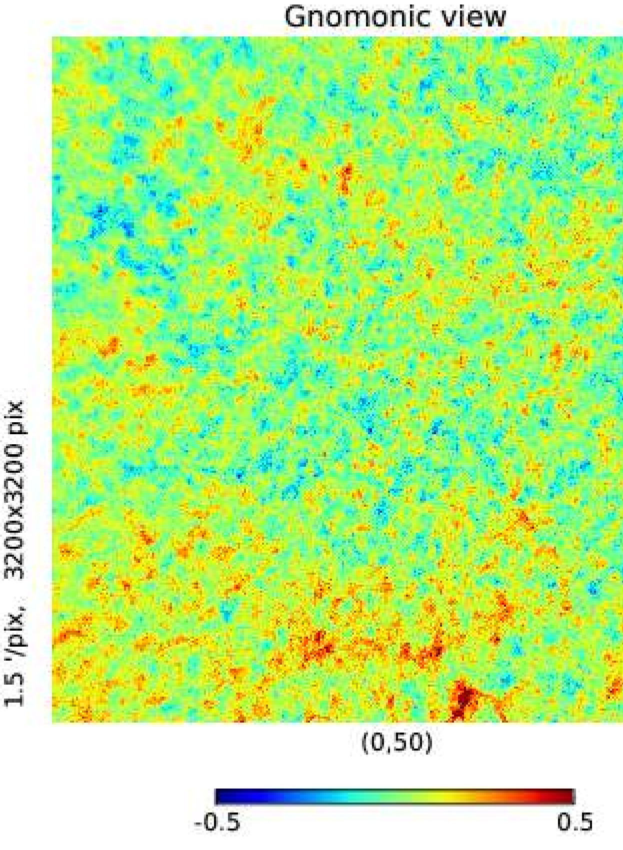


LA carte Planck

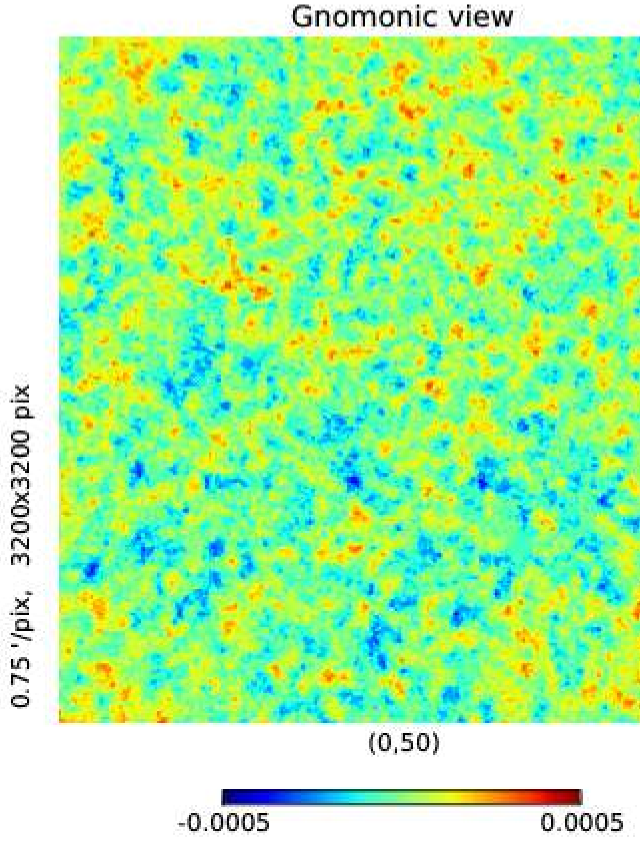


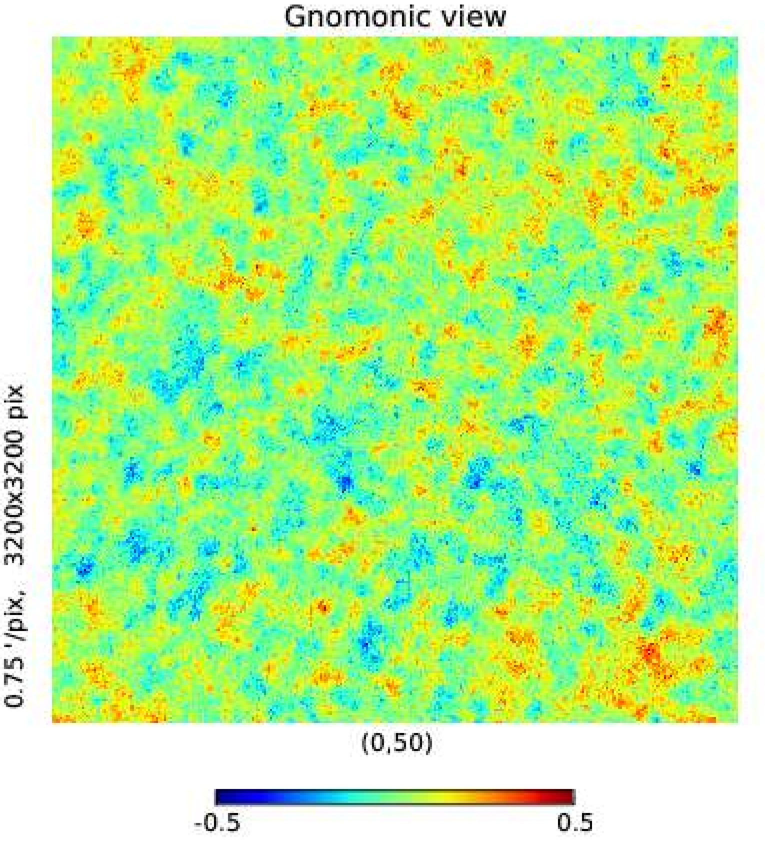
Planck (gauche) vs. WMAP (droite)



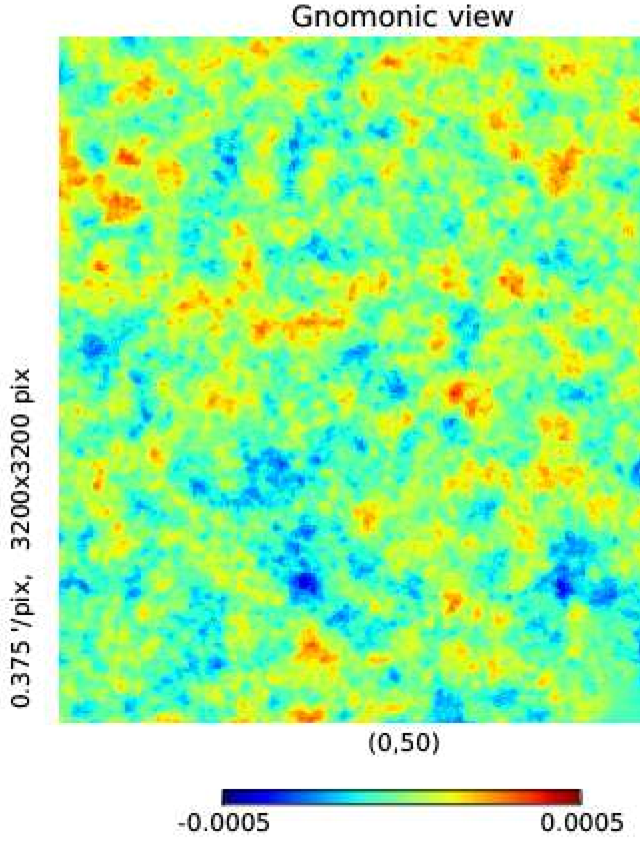


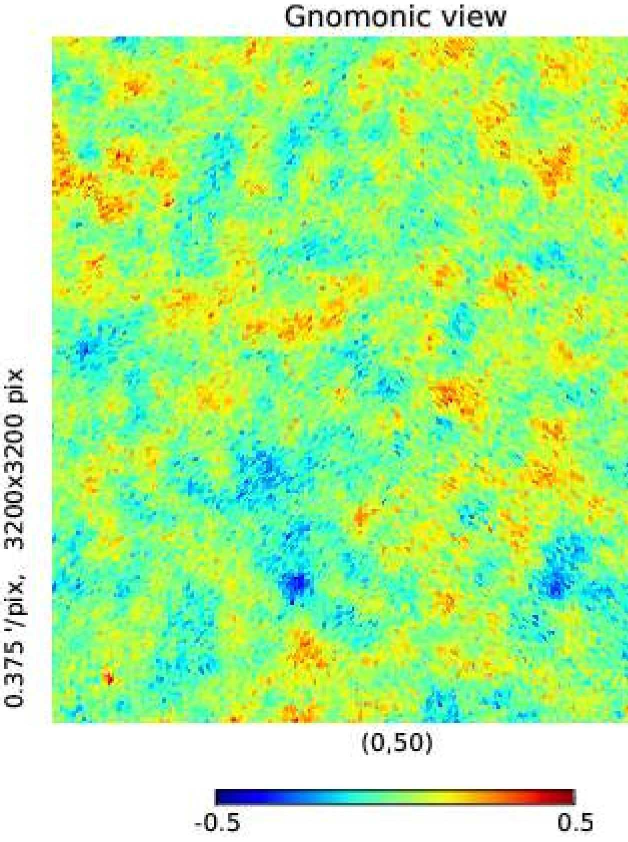
Planck (gauche) vs. WMAP (droite)



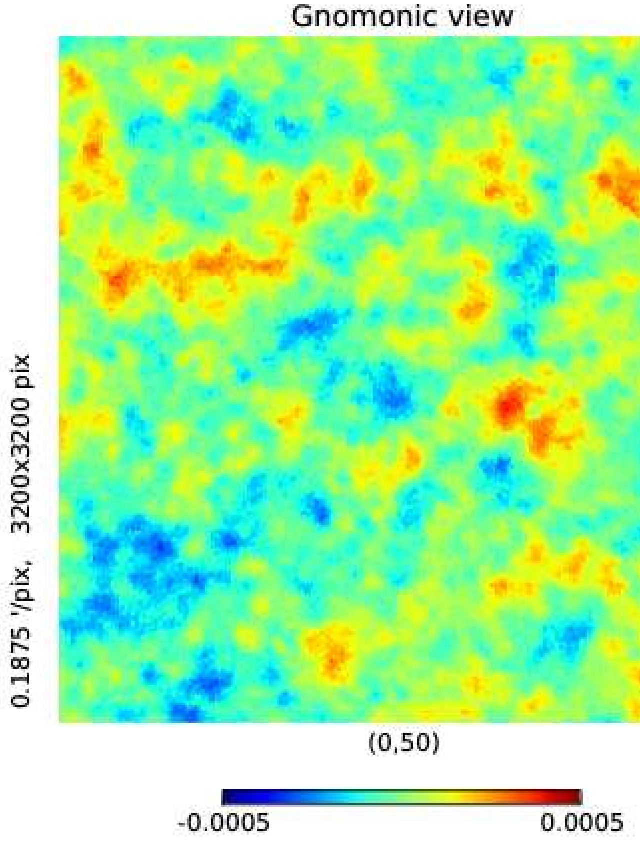


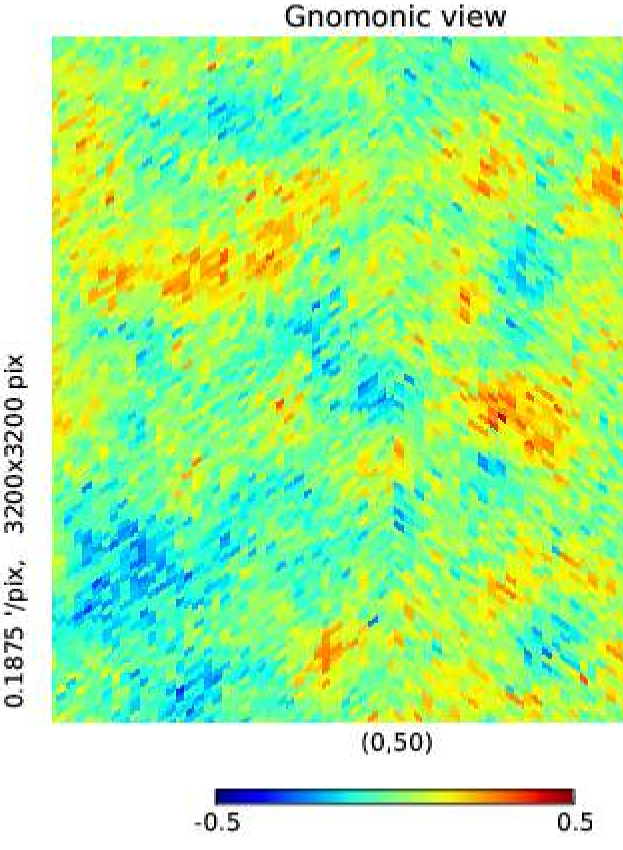
Planck (gauche) vs. WMAP (droite)



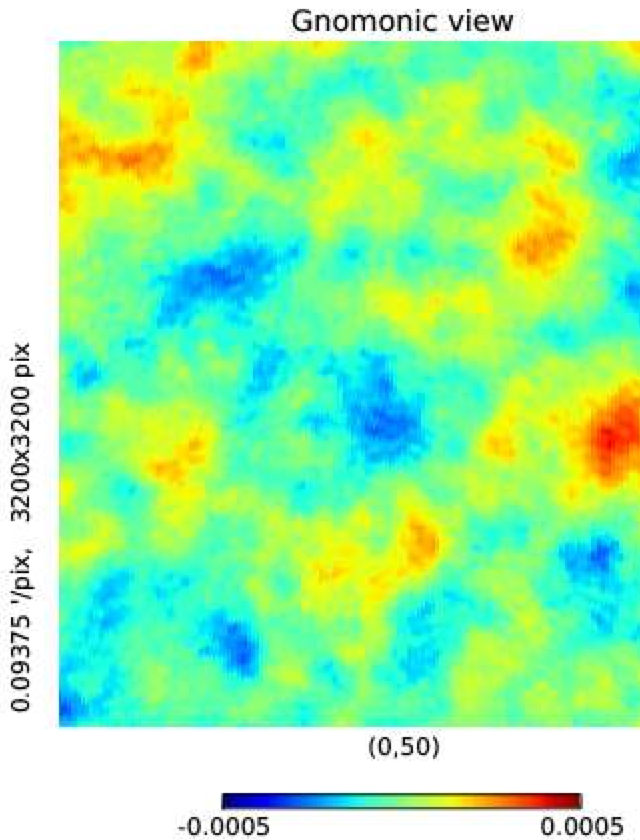


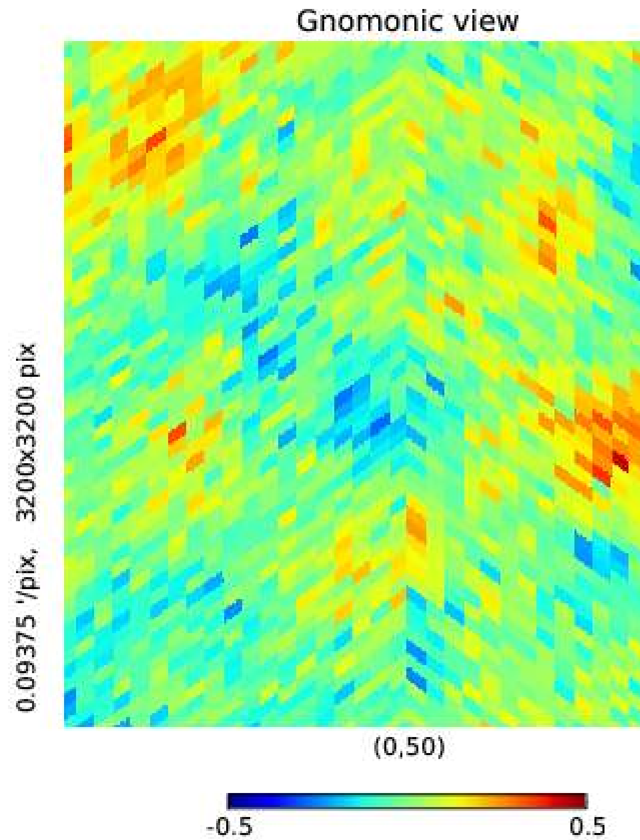
Planck (gauche) vs. WMAP (droite)



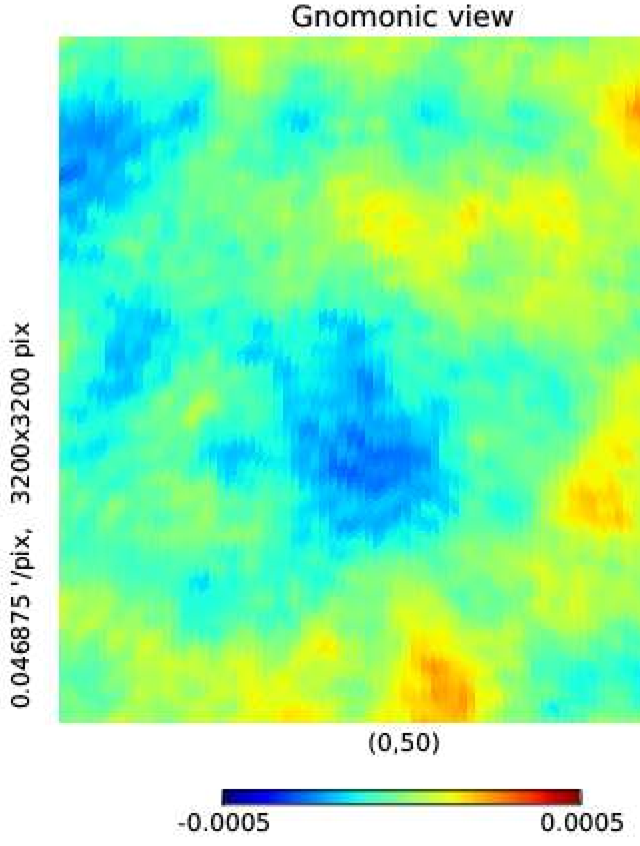


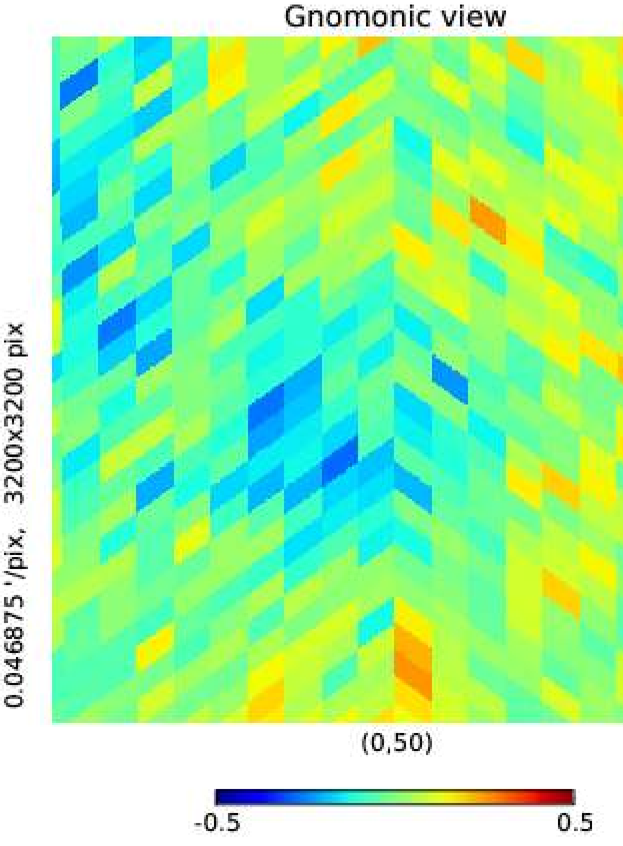
Planck (gauche) vs. WMAP (droite)



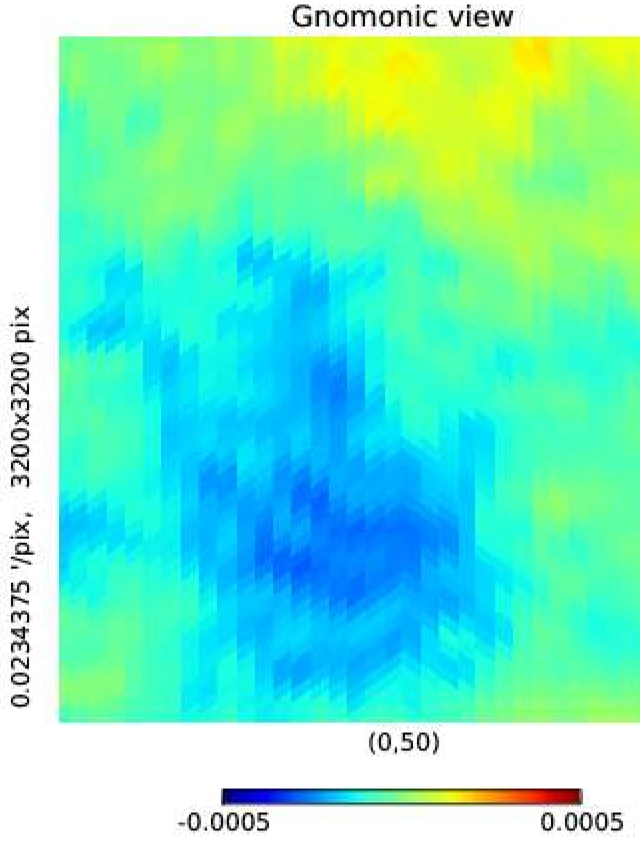


Planck (gauche) vs. WMAP (droite)

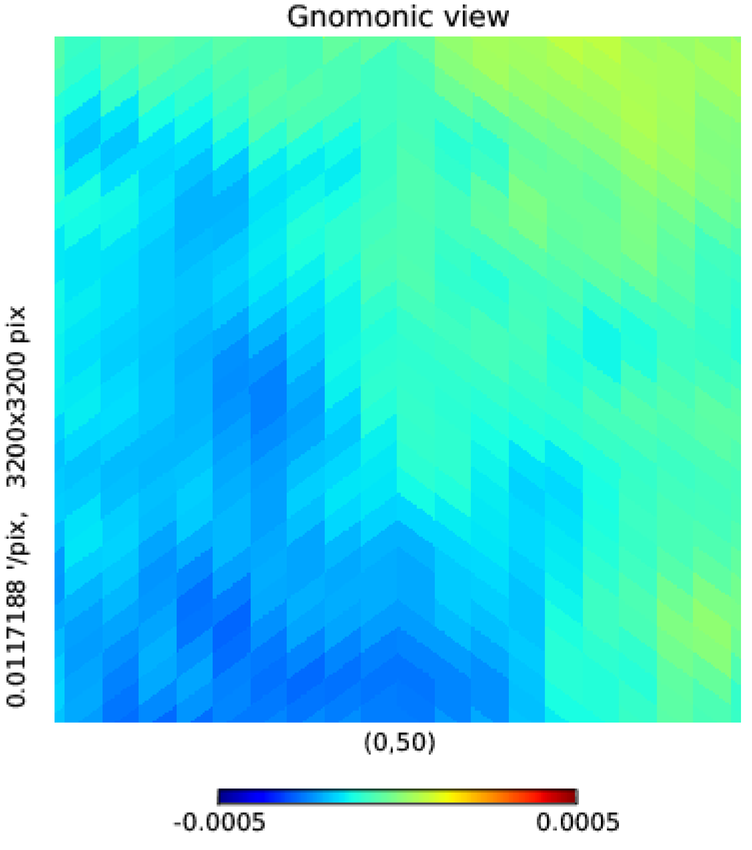


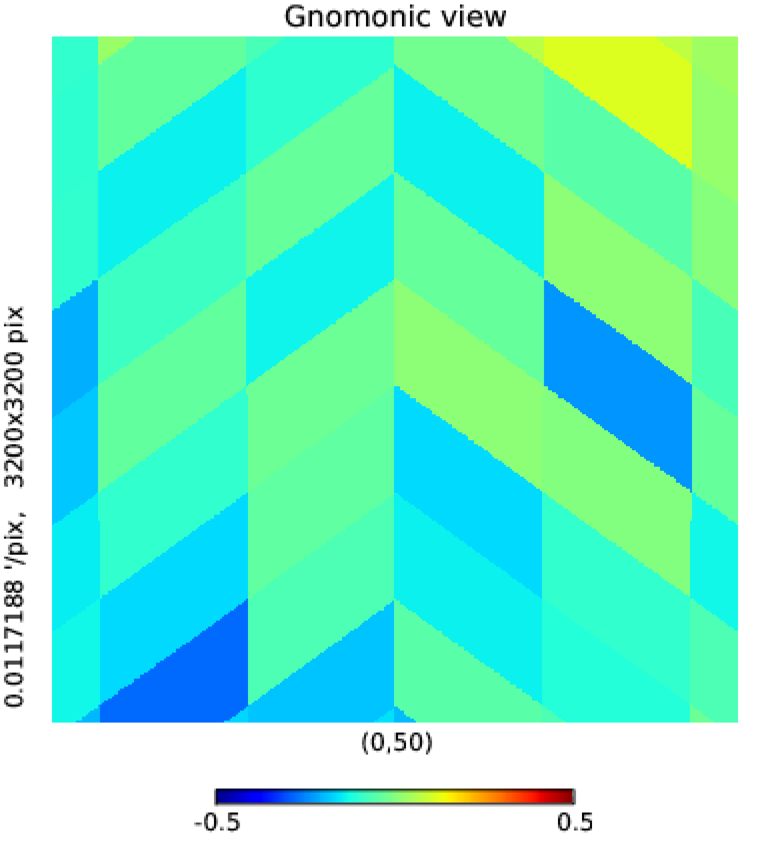


Planck (gauche) vs. WMAP (droite)

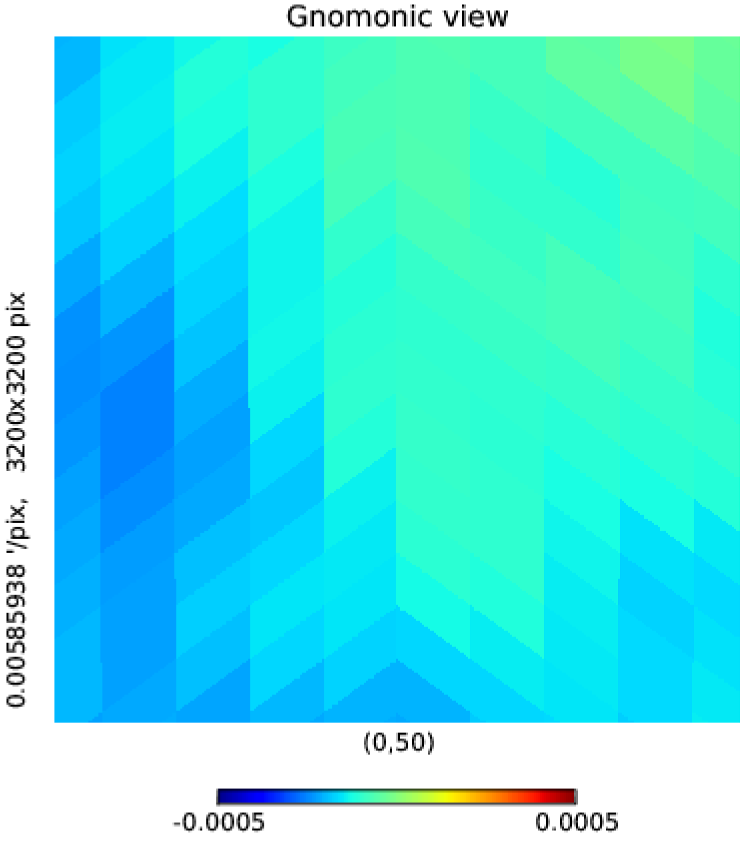


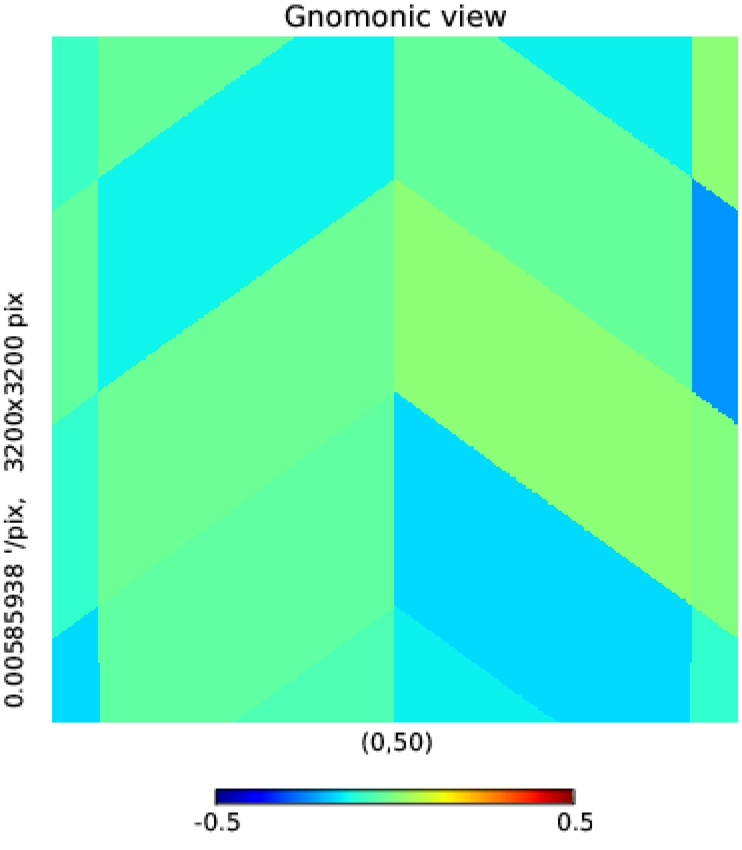
Planck (gauche) vs. WMAP (droite)

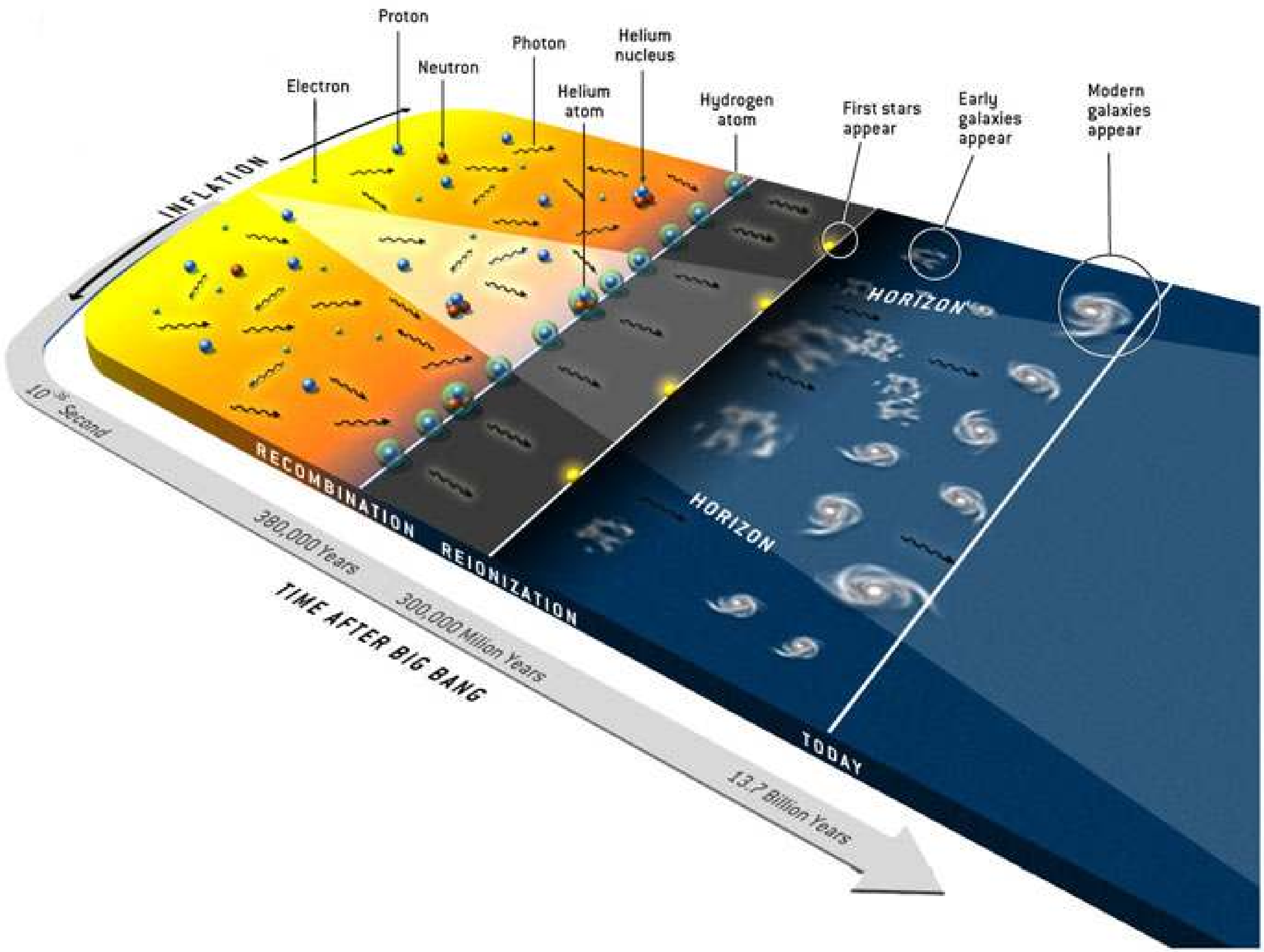




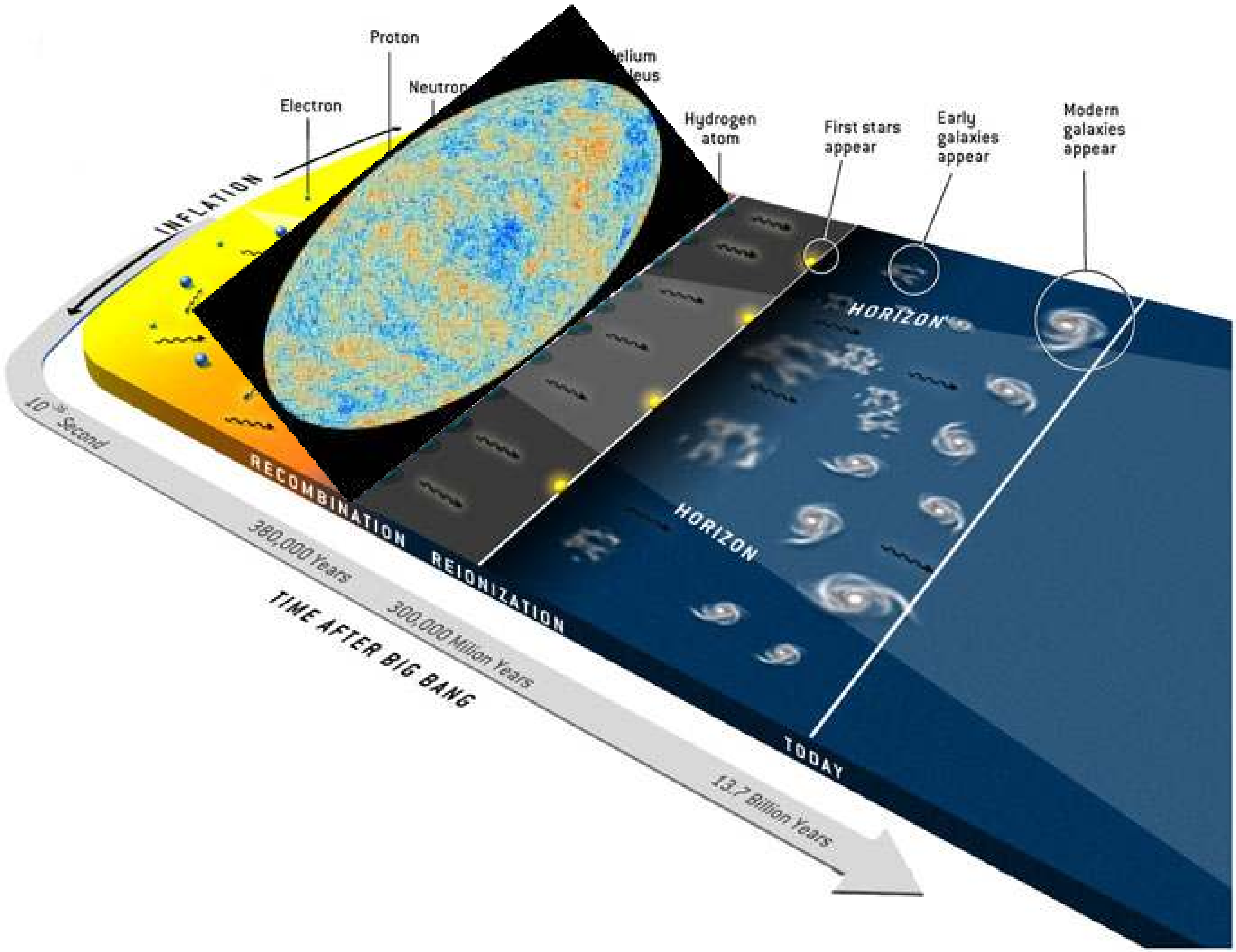
Planck (gauche) vs. WMAP (droite)



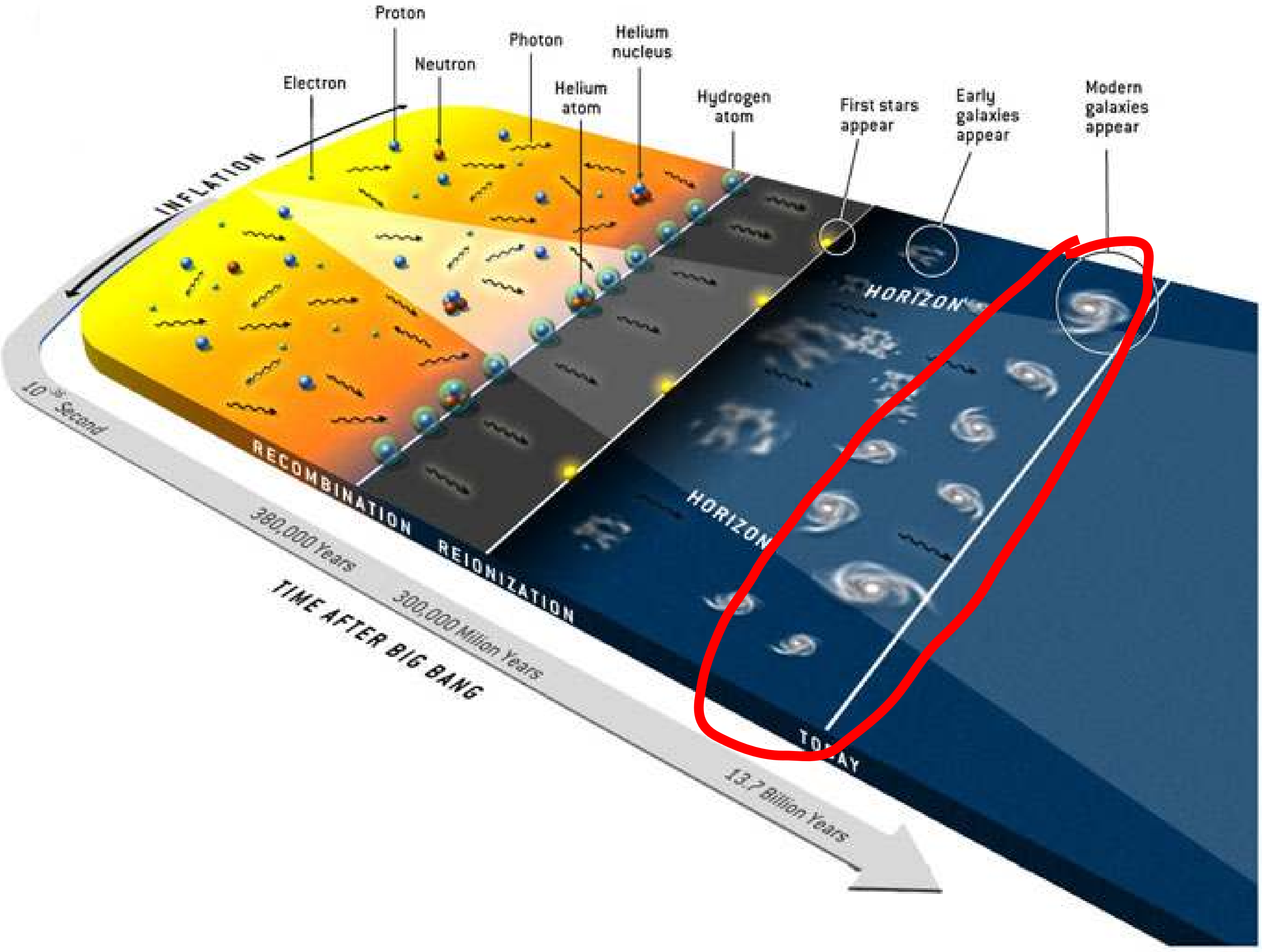




Proton
Neutron
Photon
Helium nucleus
Electron
Helium atom
Hydrogen atom
First stars appear
Early galaxies appear
Modern galaxies appear
INFLATION
HORIZON
RECOMBINATION
REIONIZATION
HORIZON
TODAY
10
Second
380,000 Years
300,000 Million Years
TIME AFTER BIG BANG
13.7 Billion Years



Proton
Electron
Hydrogen atom
First stars appear
Early galaxies appear
Modern galaxies appear
INFLATION
HORIZON
RECOMBINATION
REIONIZATION
HORIZON
TODAY
10⁻³⁵ Second
380,000 Years
300,000 Million Years
13.7 Billion Years
TIME AFTER BIG BANG


Proton
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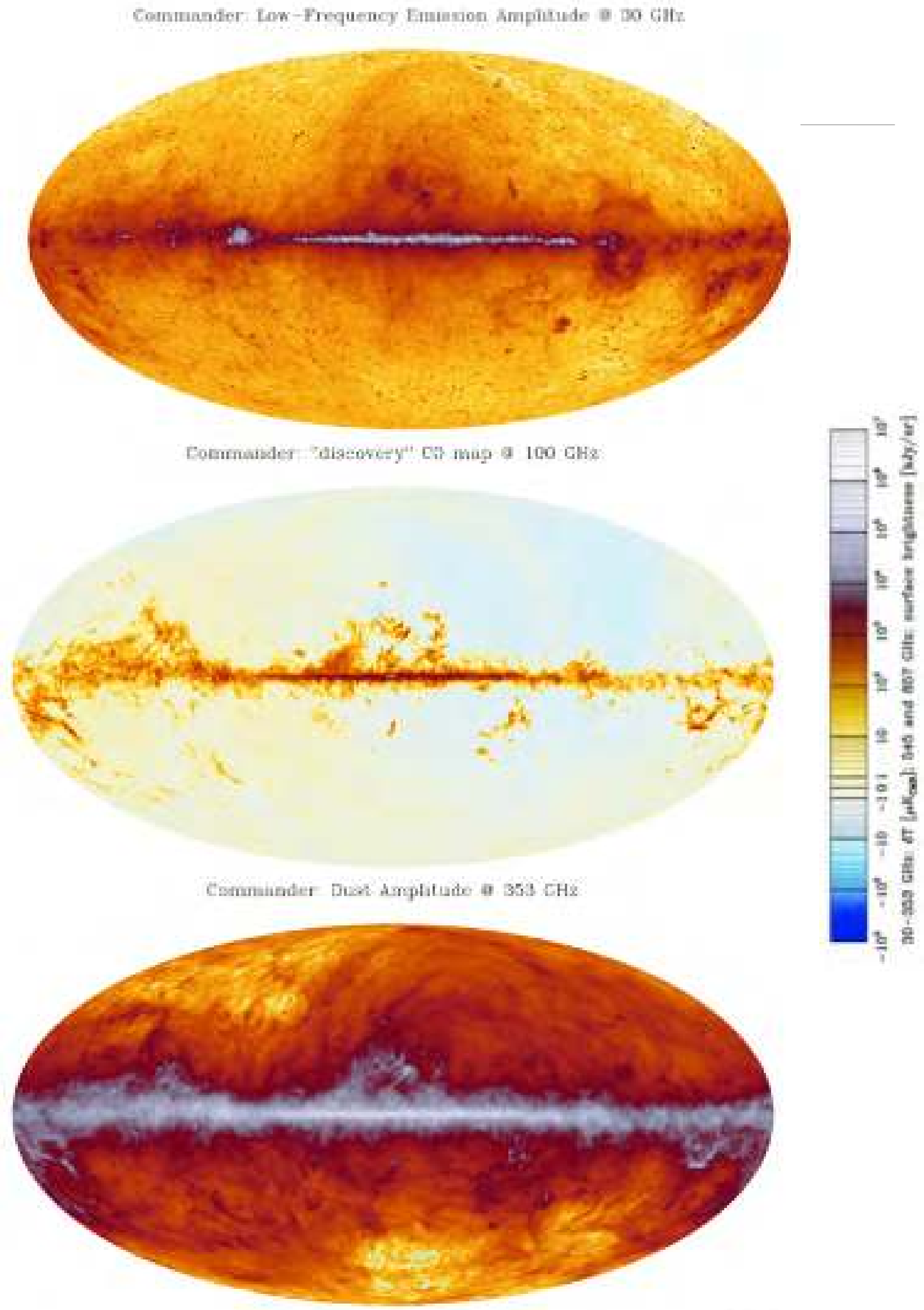
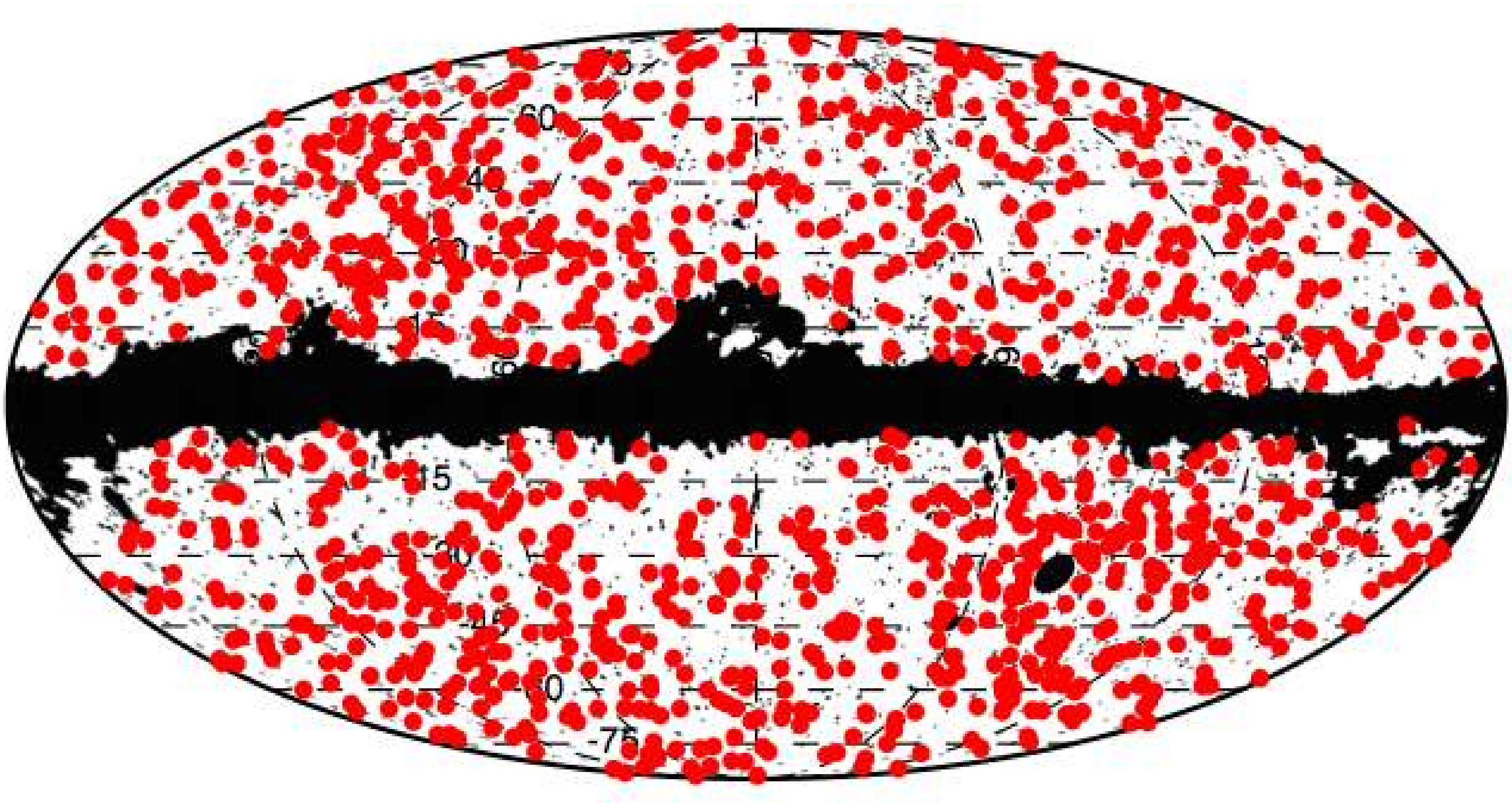
HORIZON
HORIZON
RECOMBINATION
REIONIZATION
TODAY
10 Second
380,000 Years
300,000 Million Years
13.7 Billion Years
TIME AFTER BIG BANG

Univers “proche”

Carte de la “poussière”
dans notre galaxie



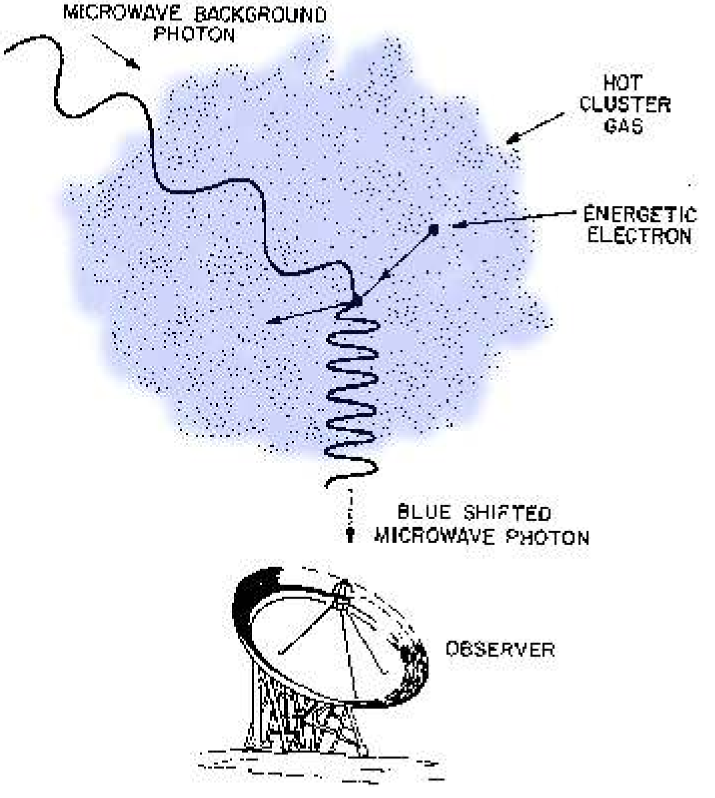
Amas par effet Sunyaev Zel'dovich



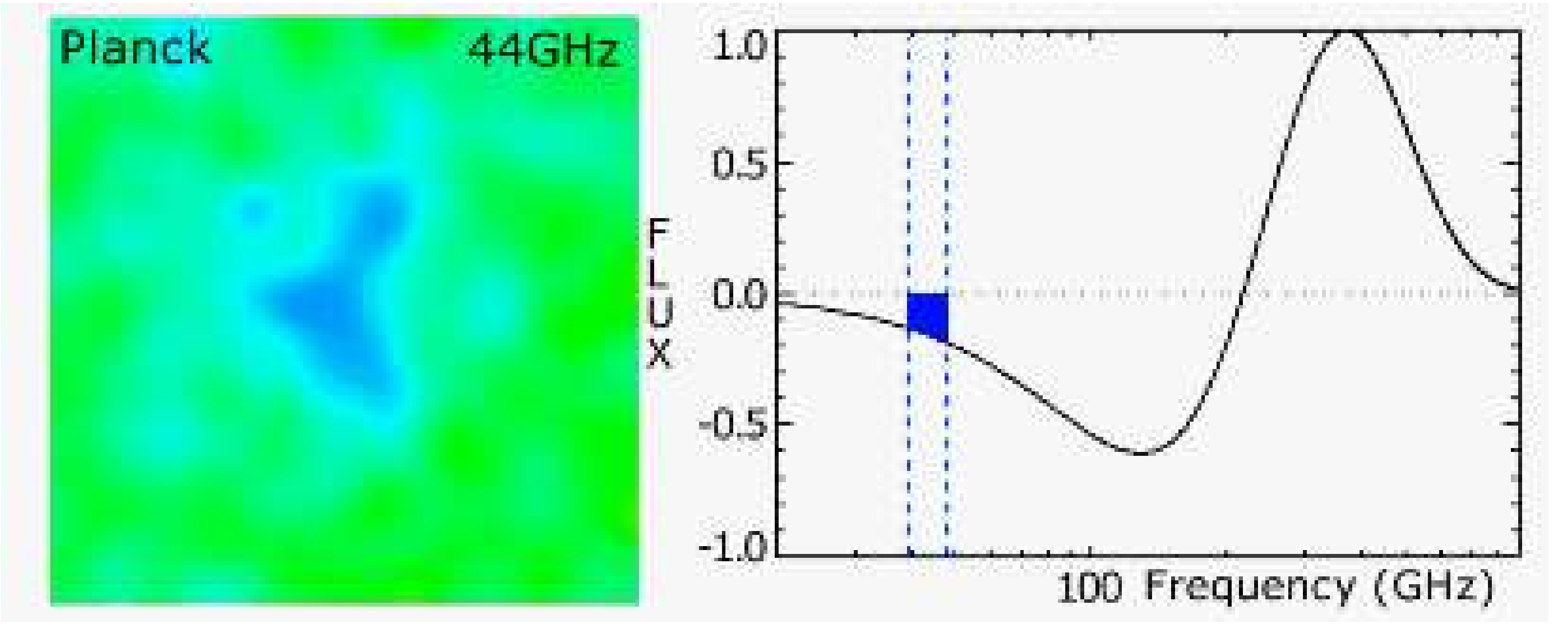
1227 amas détectés -> dont 366 inédits

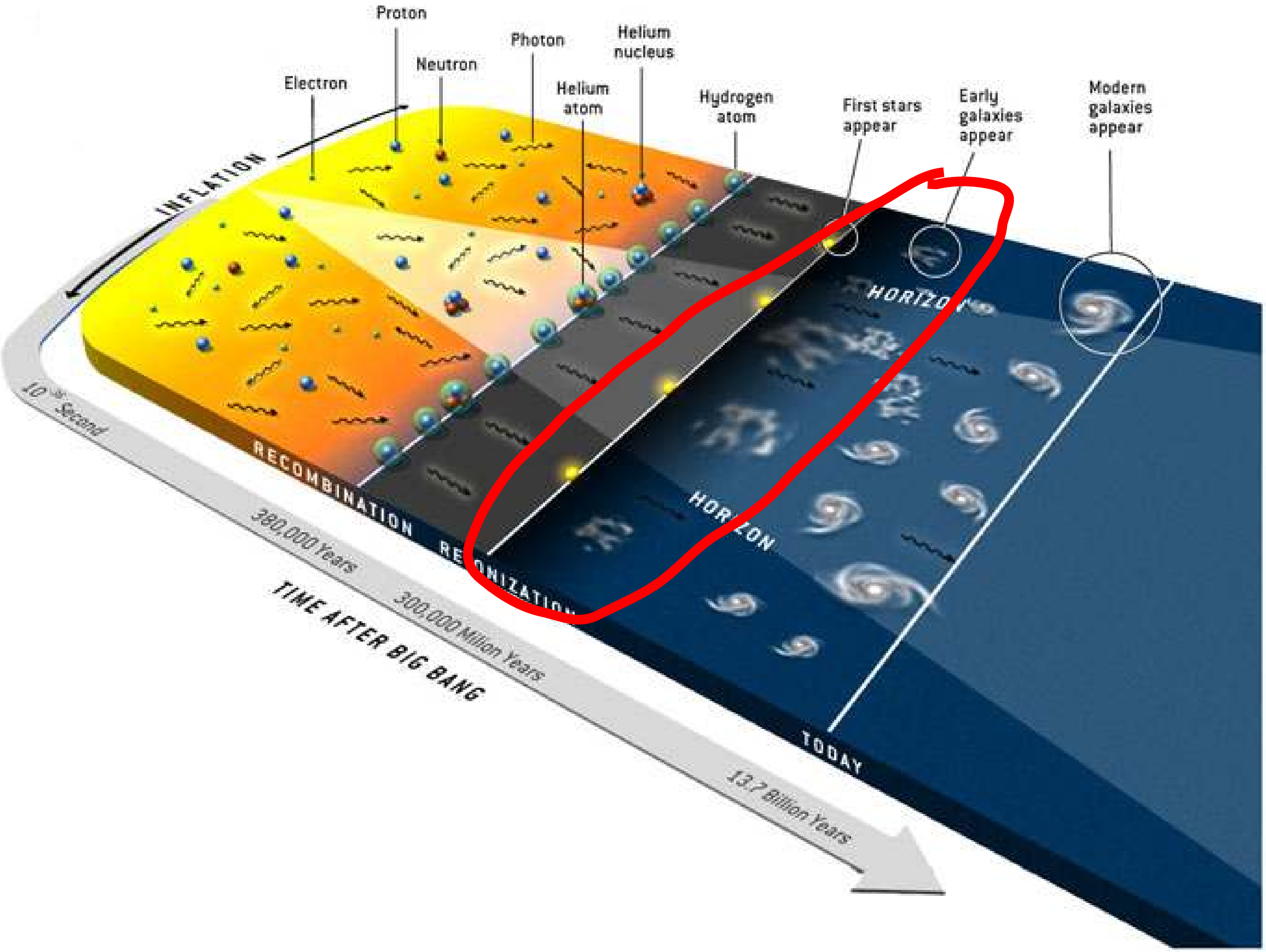
Planck Collab, 2013, 29

Effet Sunyaev Zel'dovich

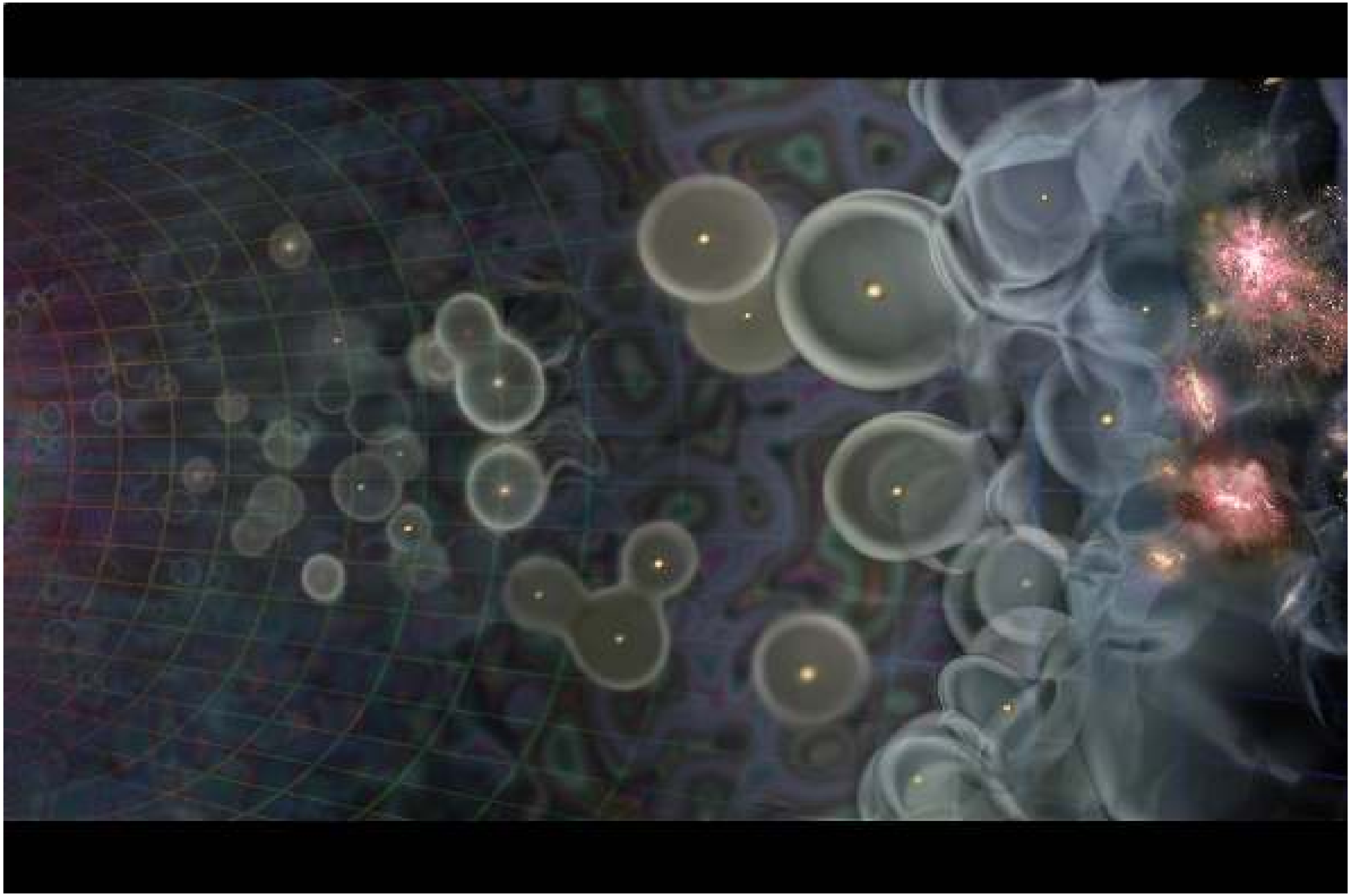


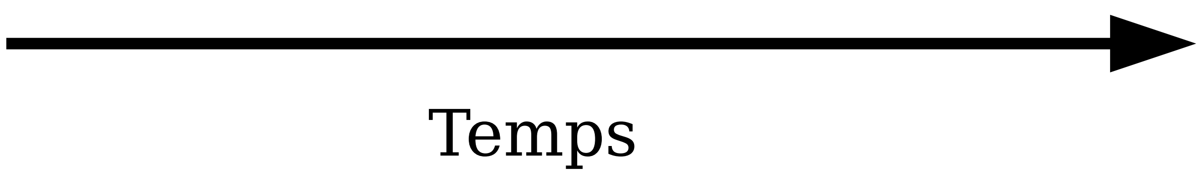
Effet Sunyaev Zel'dovich

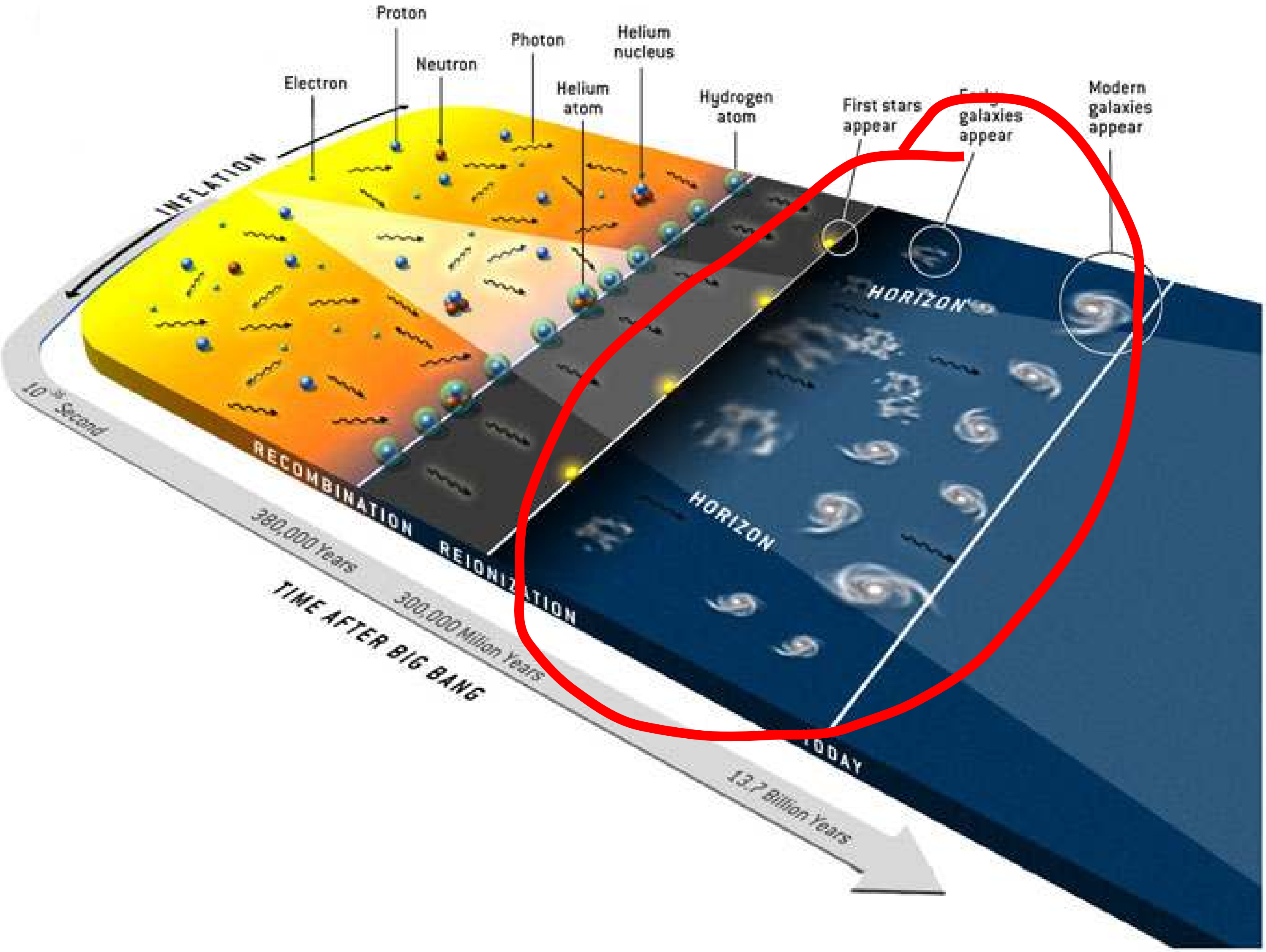



Proton
Neutron
Electron
Photon
Helium nucleus
Helium atom
Hydrogen atom
First stars appear
Early galaxies appear
Modern galaxies appear
INFLATION
RECOMBINATION
REIONIZATION
HORIZON
HORIZON
TODAY
10^{-35} Second
380,000 Years
300,000 Million Years
13.7 Billion Years
TIME AFTER BIG BANG

Sonder la réionisation



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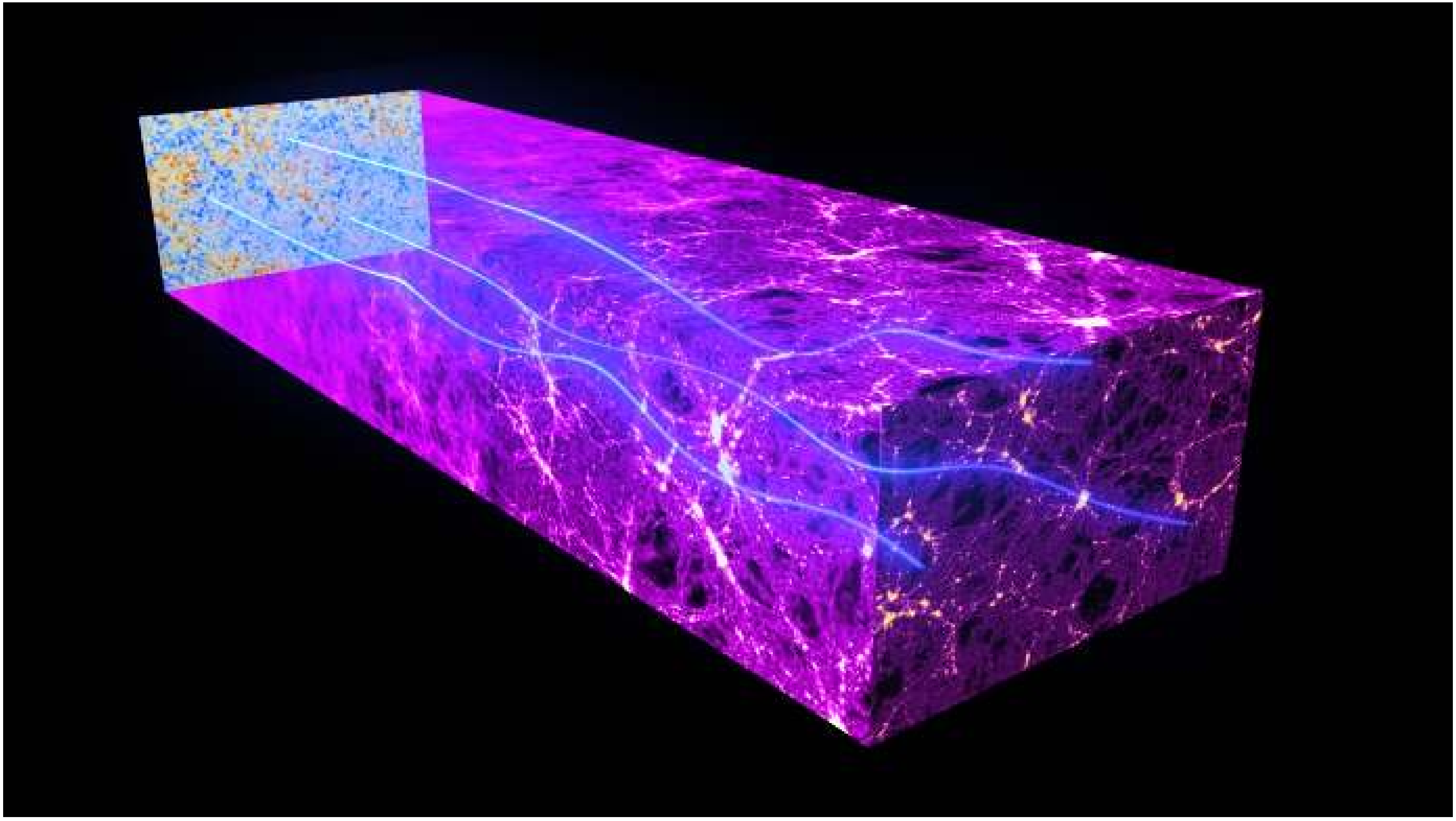
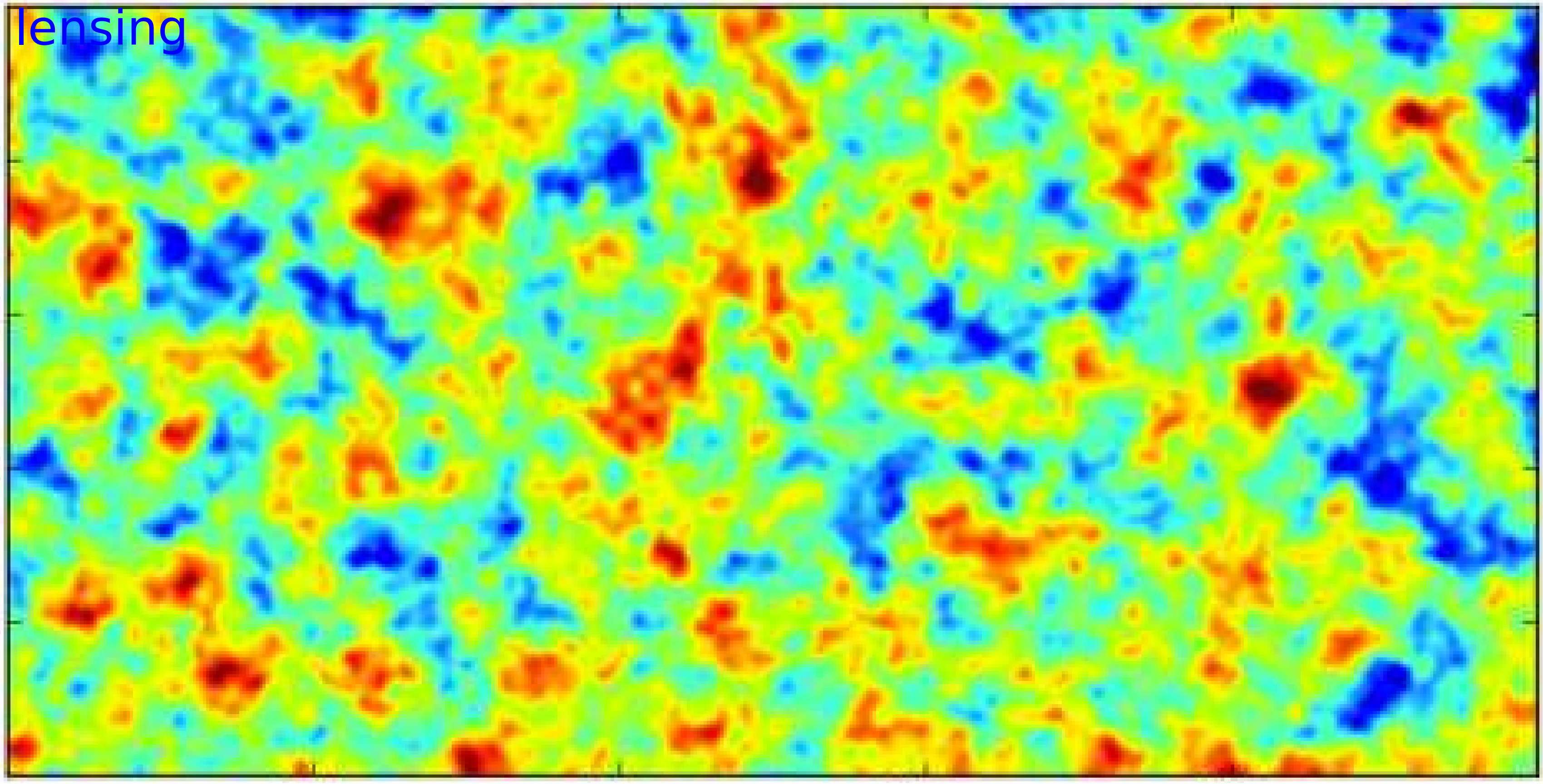
Lentillage gravitationnel



Lentillage gravitationnel

A simulated patch of CMB sky – before lensing



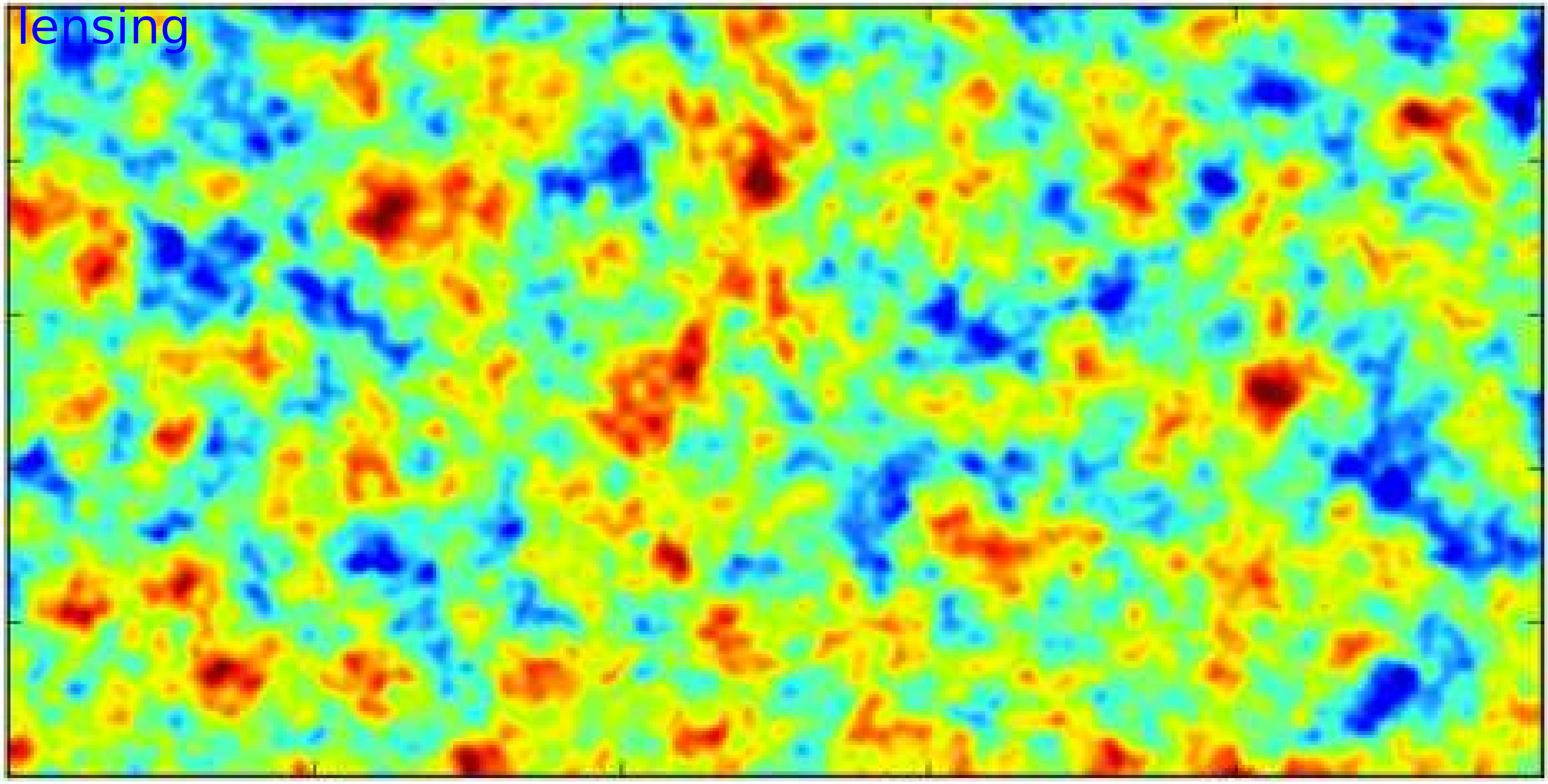
10º

typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

Lentillage gravitationnel

A simulated patch of CMB sky – after lensing

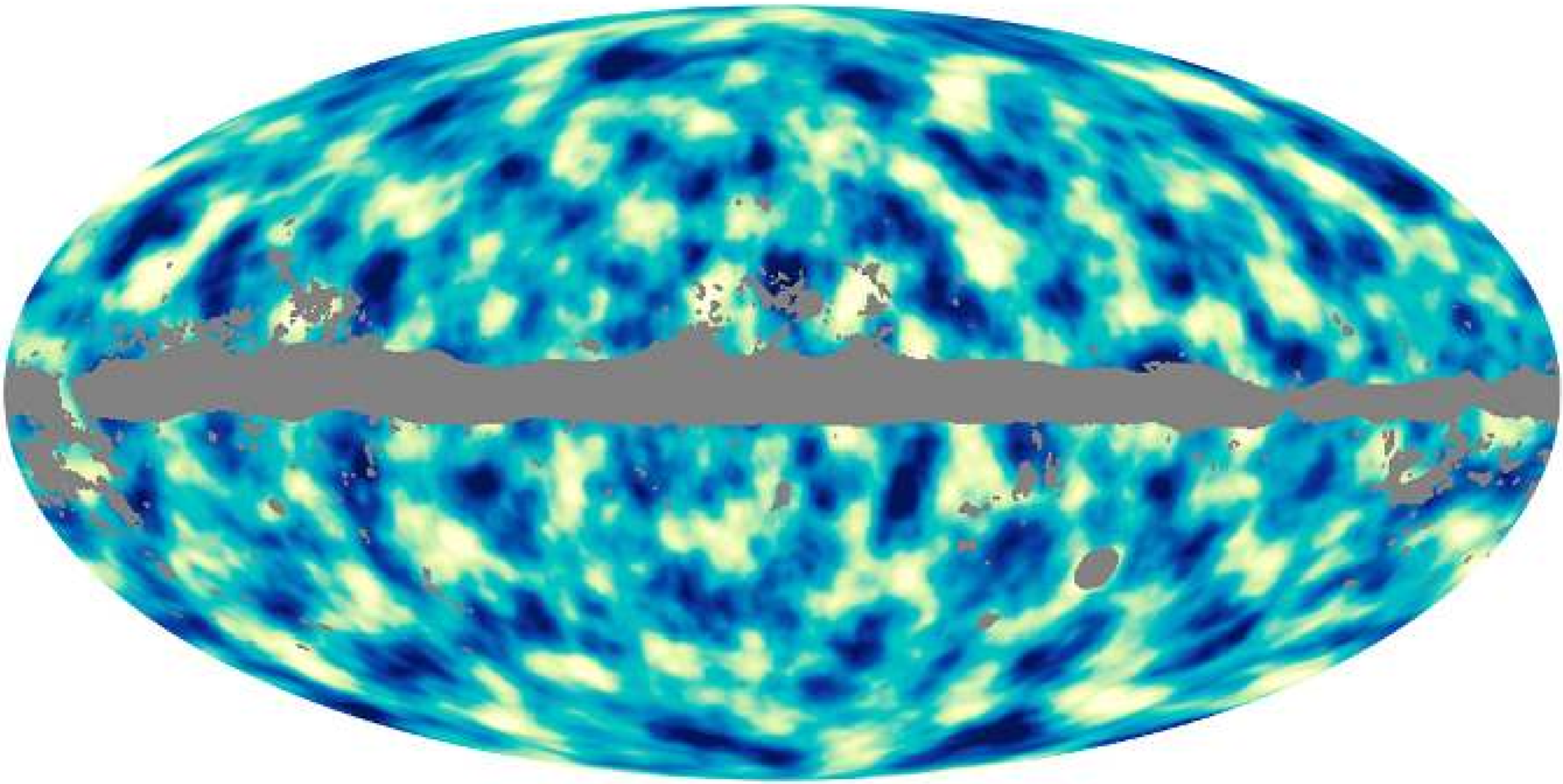


10º

typical deflection: 2.4 arcmin

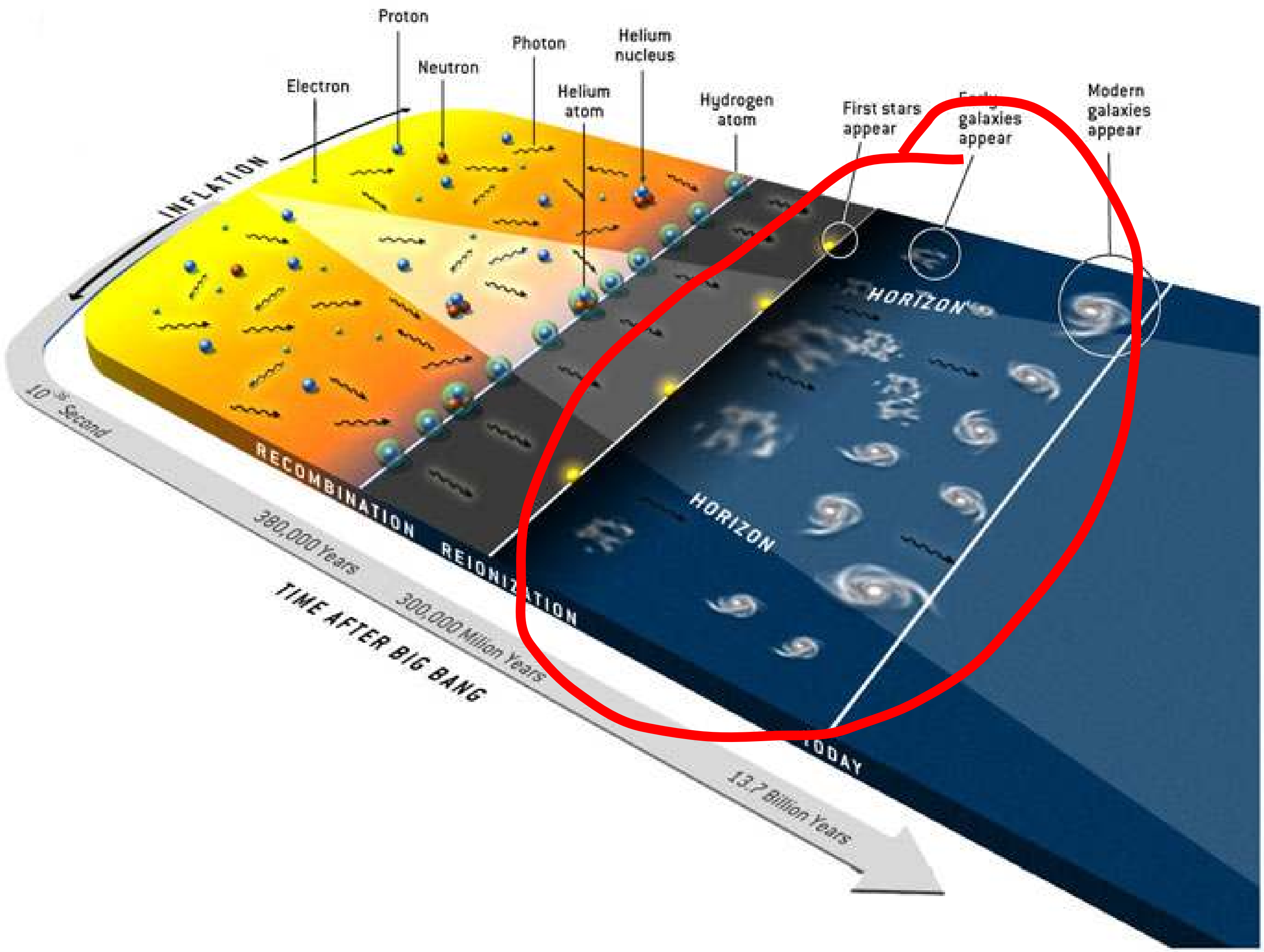
Planck 15 months
Planck Collaboration, 2013, 17

La matière sombre révélée



= carte de la masse de matière projetée sur la ligne de visée

Planck 15 months
Planck Collaboration, 2013, 17



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HORIZON
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REIONIZATION
TODAY
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13.7 Billion Years
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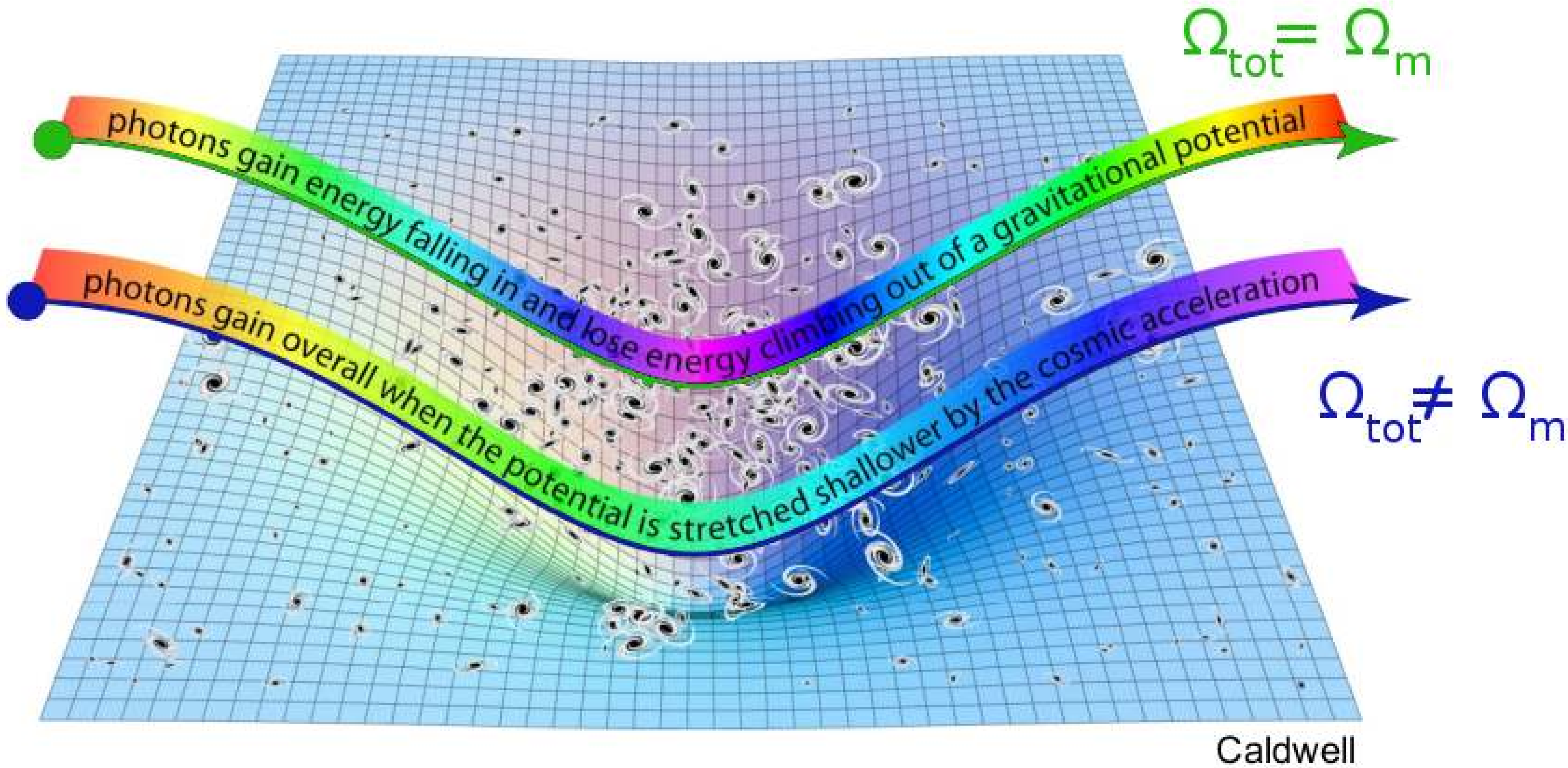
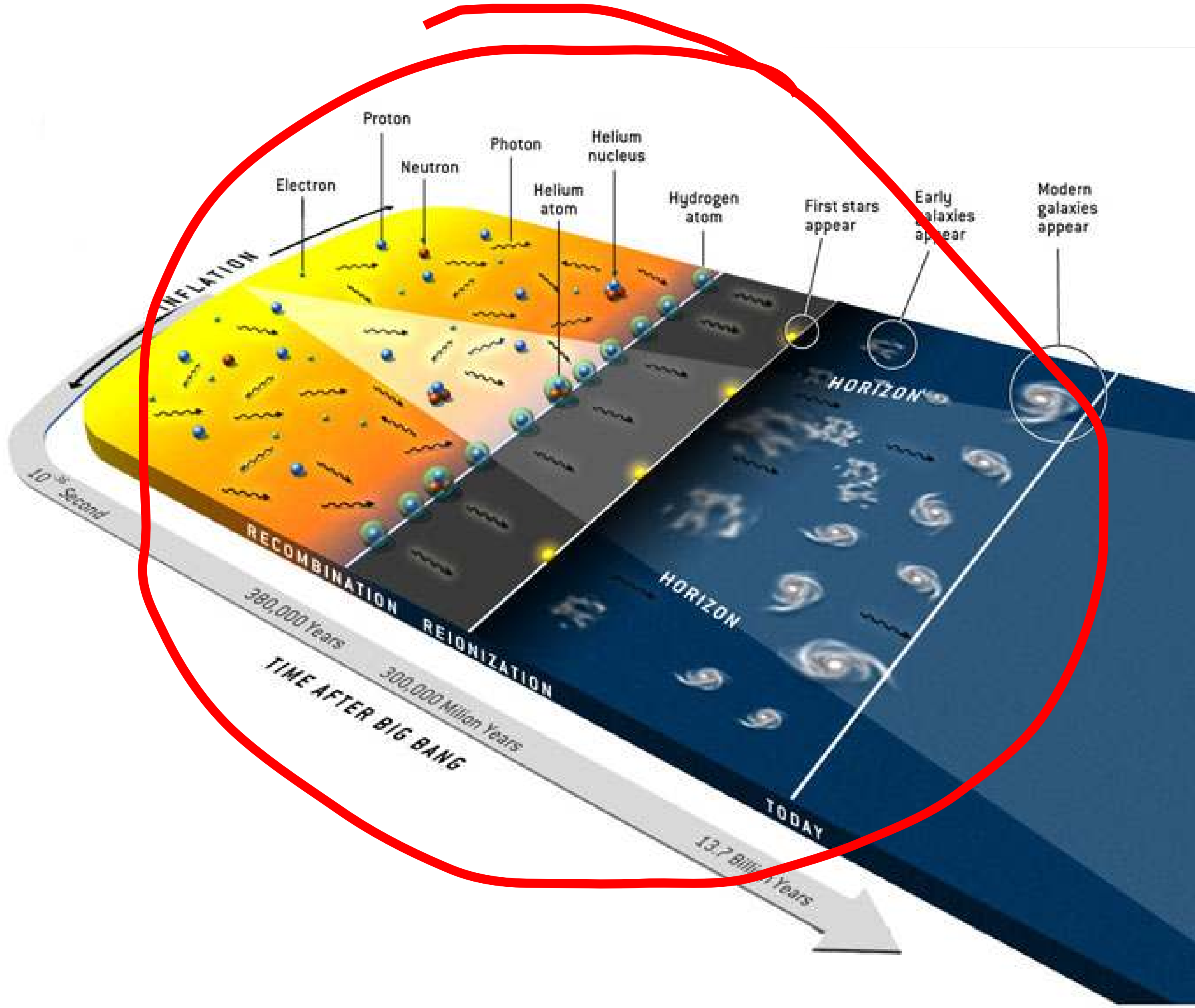
Effet Sachs-Wolfe intégré



L'énergie sombre “applatit” les potentiels gravitationnels
→ Les photons du FDC sont affectés



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REIONIZATION
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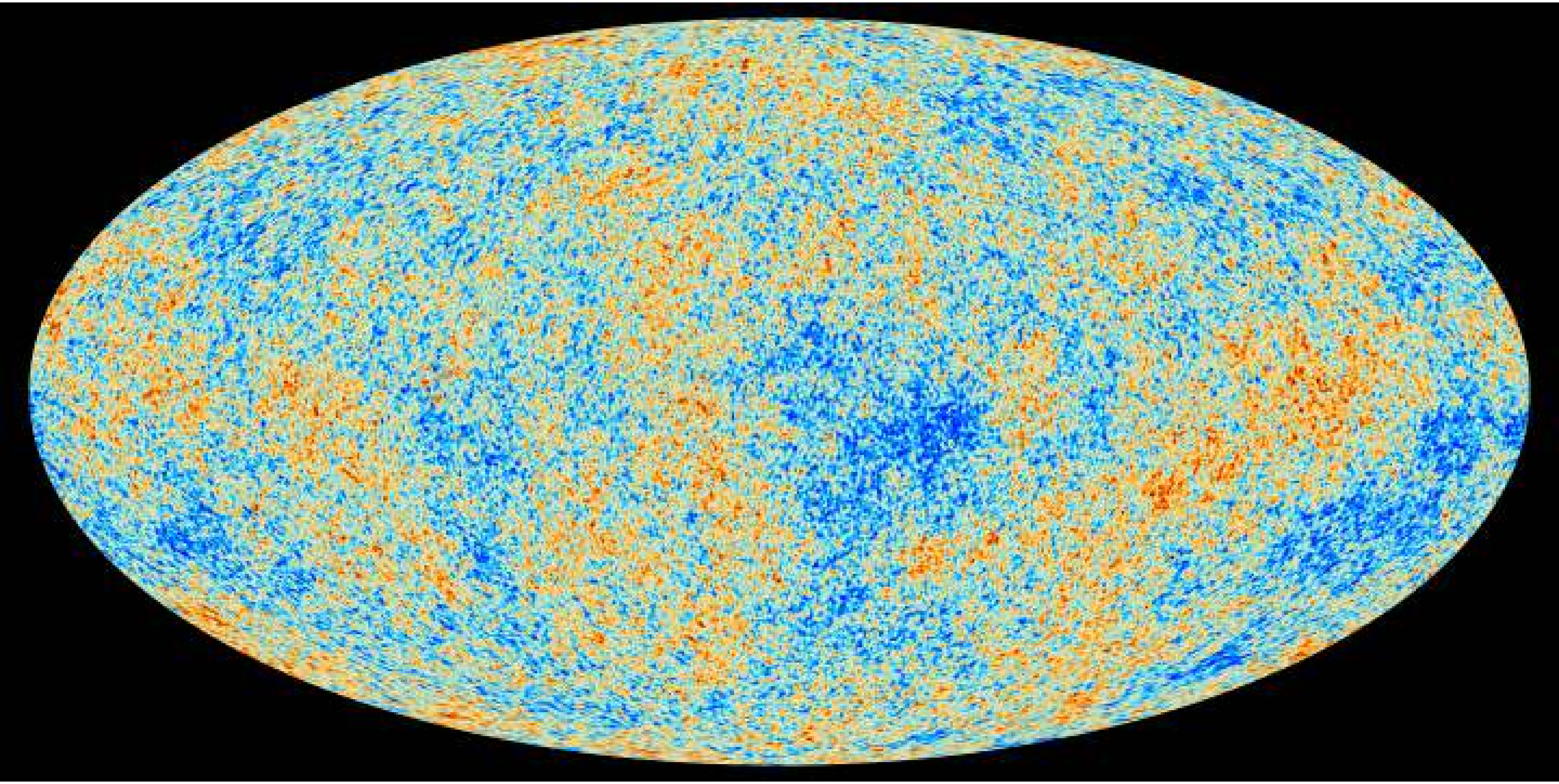
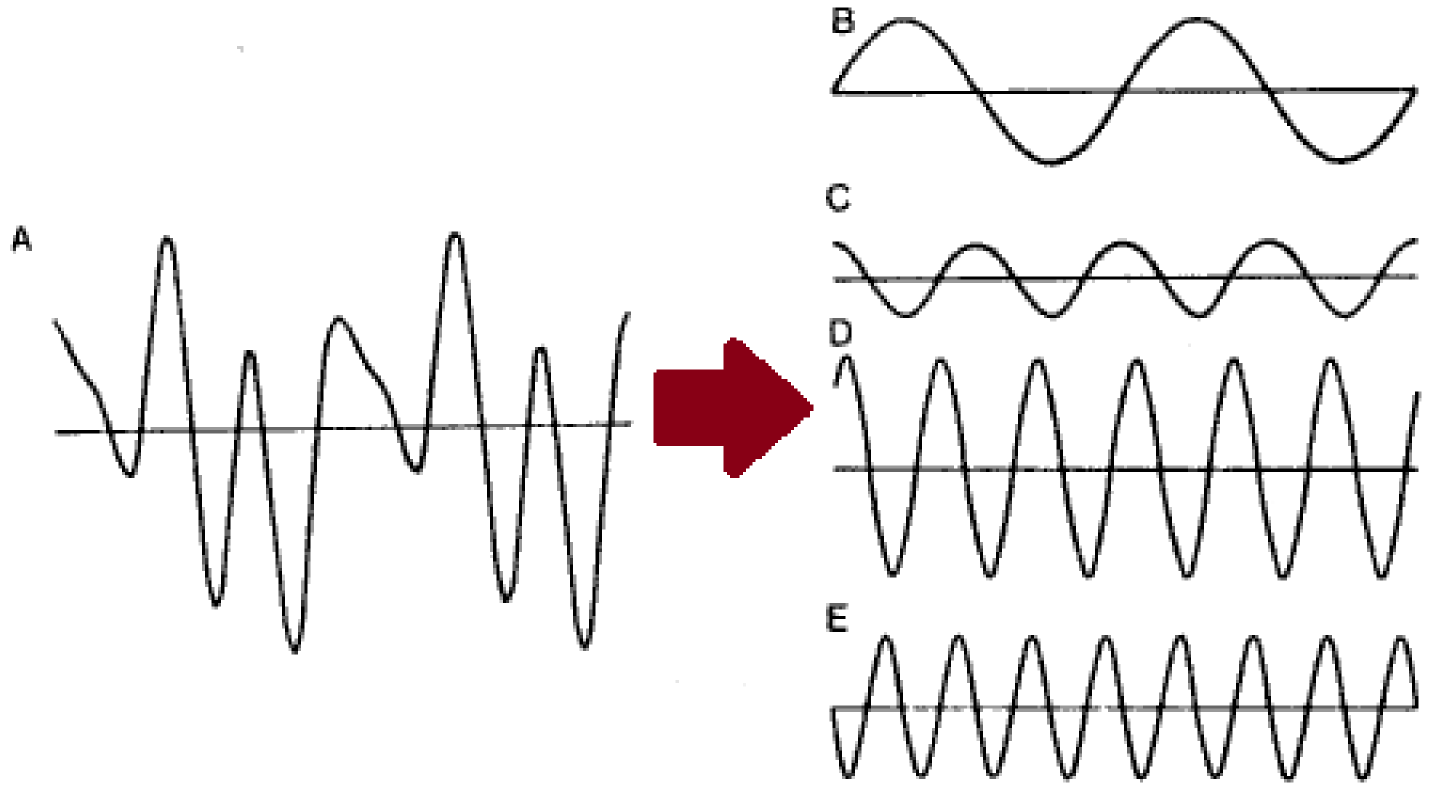
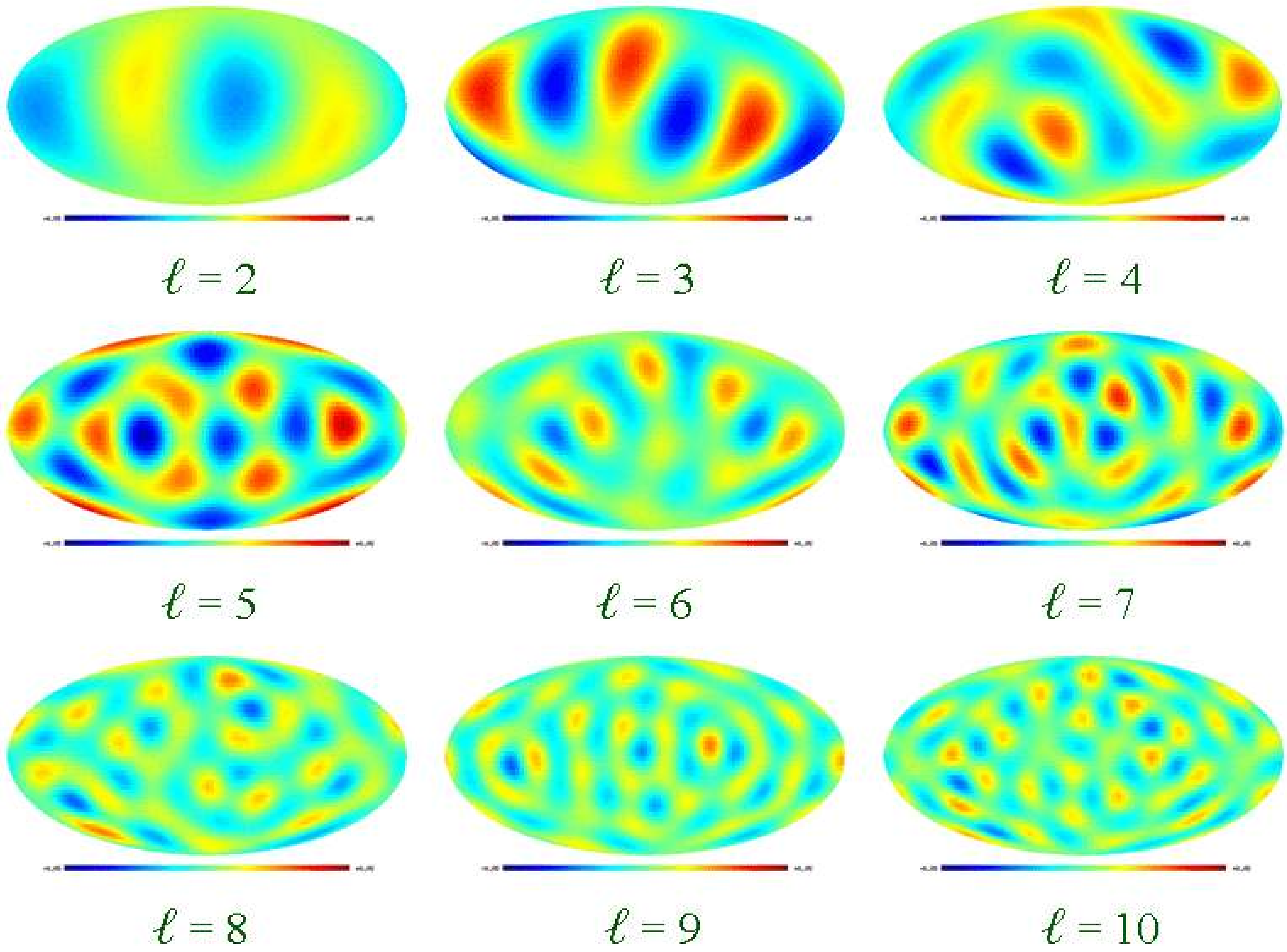
Comment on analyse ça ???



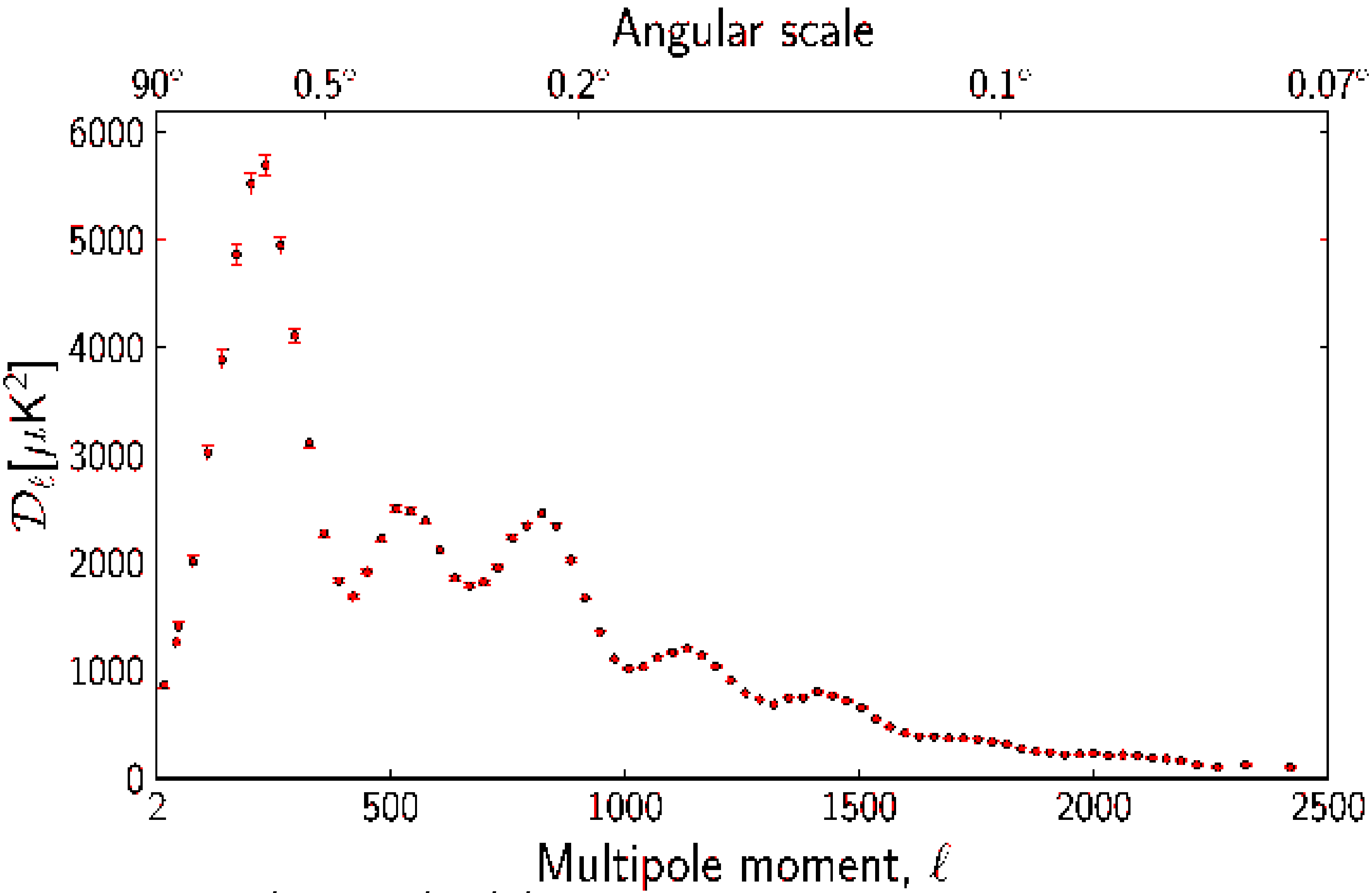
Décomposition de Fourier



Harmoniques sphériques



Le spectre de puissance par Planck

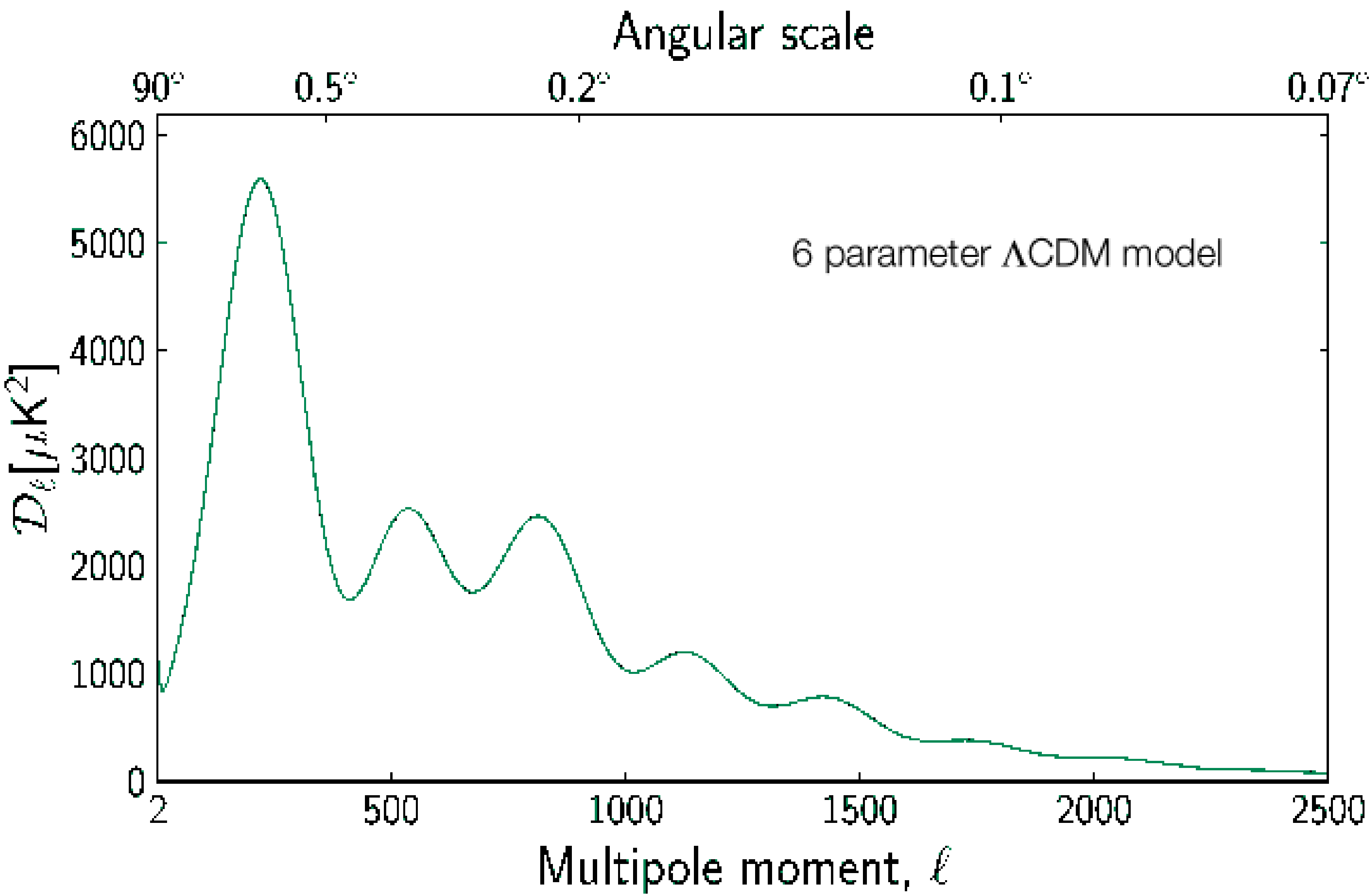


Puissance du signal

« mode » sur le ciel, ou
inverse de l'échelle angulaire

Le spectre de puissance par théorie

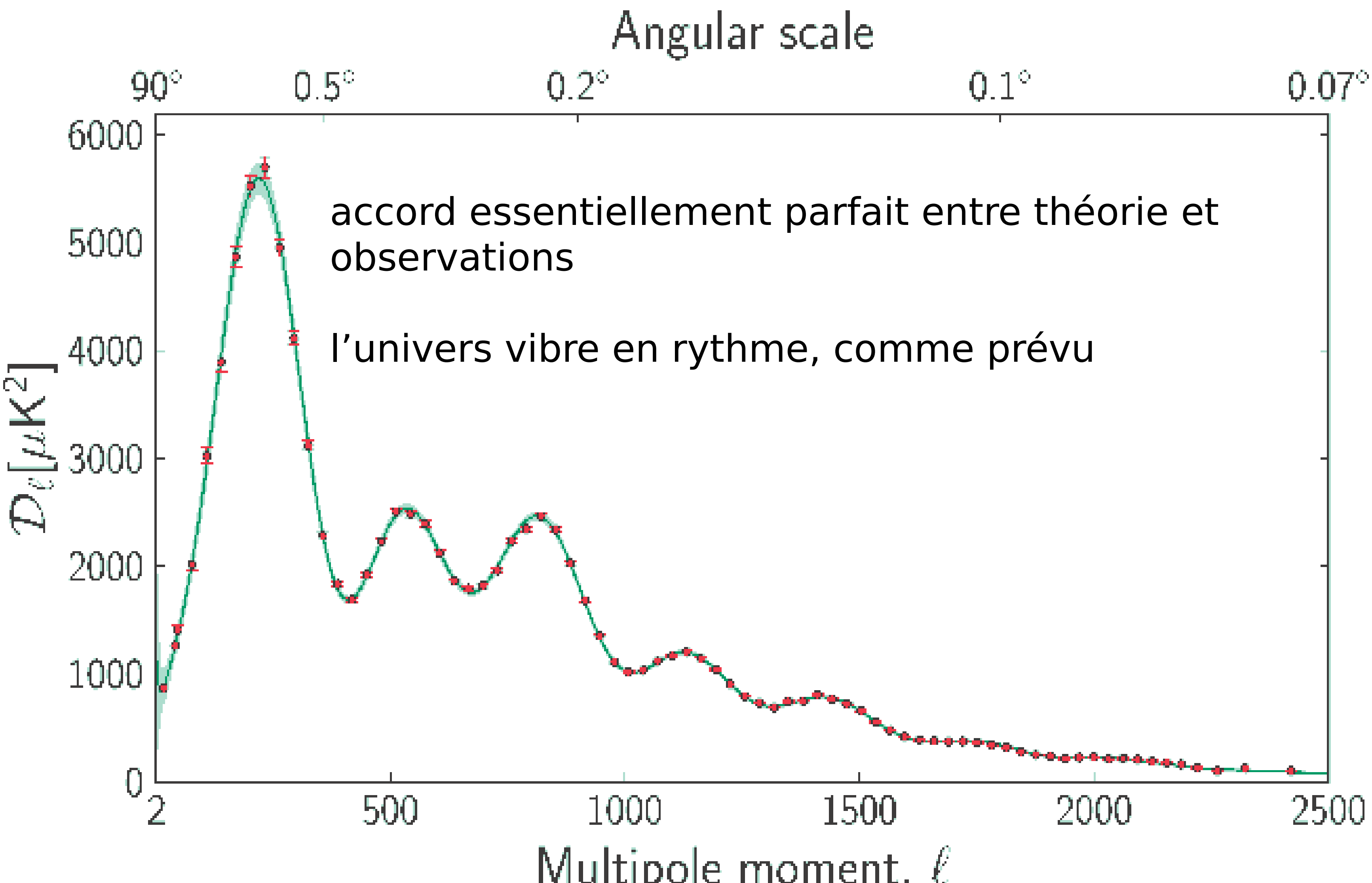
Puissance du signal



« mode » sur le ciel, ou
inverse de l’échelle angulaire

La comparaison…

Puissance du signal



accord essentiellement parfait entre théorie et observations

l’univers vibre en rythme, comme prévu

« mode » sur le ciel, ou
inverse de l’échelle angulaire

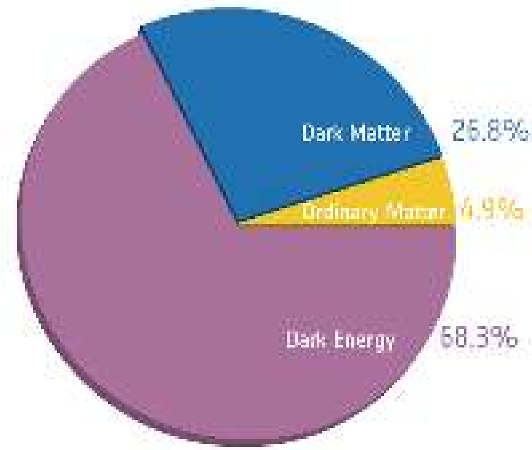
Les paramètres du modèle standard

Table 9. Parameter 68 % confidence levels for the base ΛCDM cosmology computed from the *Planck* CMB power spectra, in combination with the CMB lensing likelihood (“lensing”).

Parameter	*Planck* TT+lowP+lensing
$\Omega_b h^2$	0.02226 ± 0.00023
$\Omega_c h^2$	0.1186 ± 0.0020
$100\theta_{MC}$	1.04103 ± 0.00046
τ	0.066 ± 0.016
$\ln(10^{10}A_s)$	3.062 ± 0.029
n_s	0.9677 ± 0.0060
H_0	67.8 ± 0.9
Ω_m	0.308 ± 0.012
$\Omega_m h^2$	0.1415 ± 0.0019
$\Omega_m h^3$	0.09591 ± 0.00045
σ_8	0.815 ± 0.009
$\sigma_8 \Omega_m^{0.5}$	0.4521 ± 0.0088
Age/Gyr	$\boxed{13.799 \pm 0.038}$
r_{drag}	147.60 ± 0.43
k_{eq}	0.01027 ± 0.00014

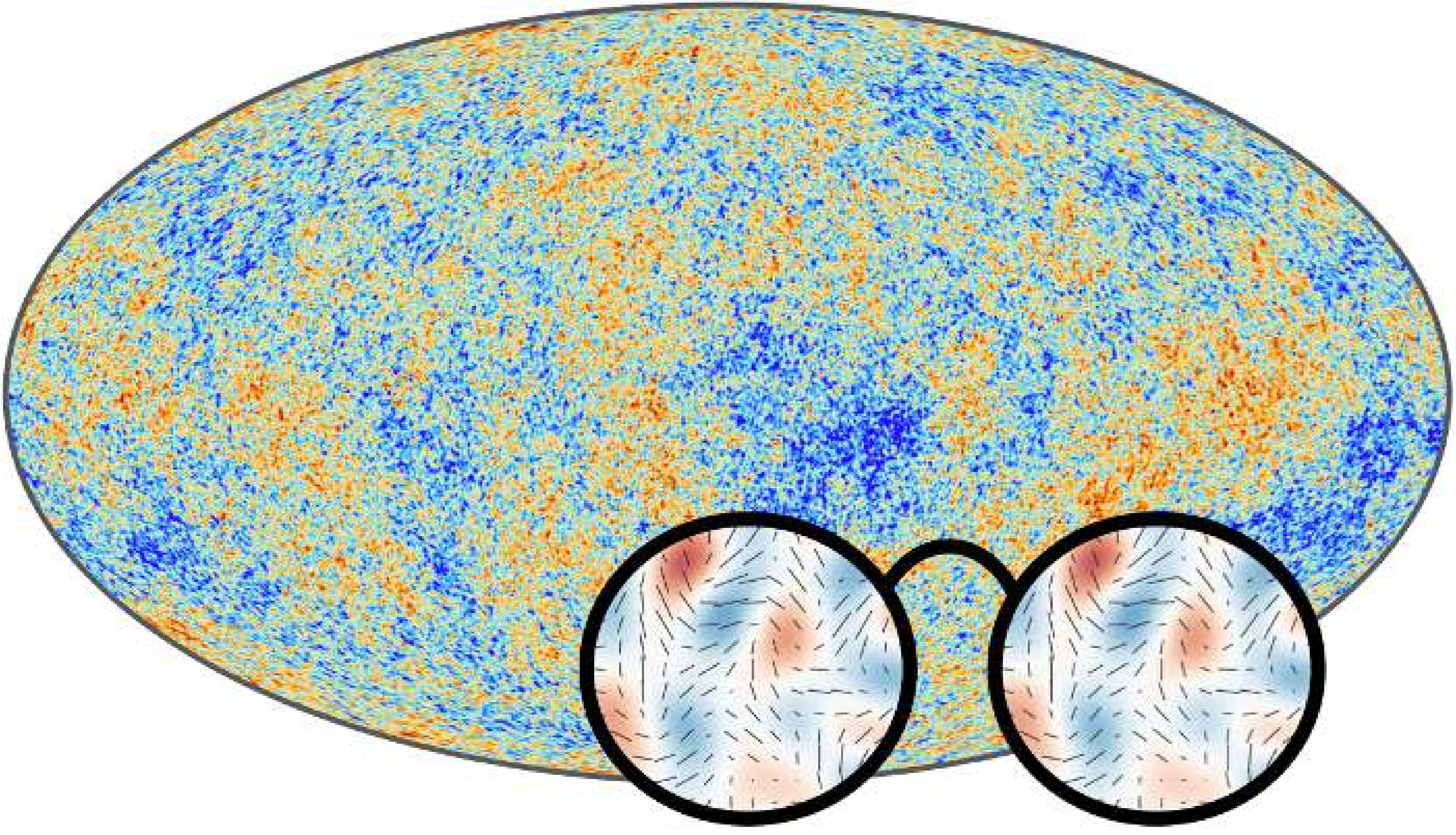
6 paramètres cosmologiques

0.3% d'incertitude !



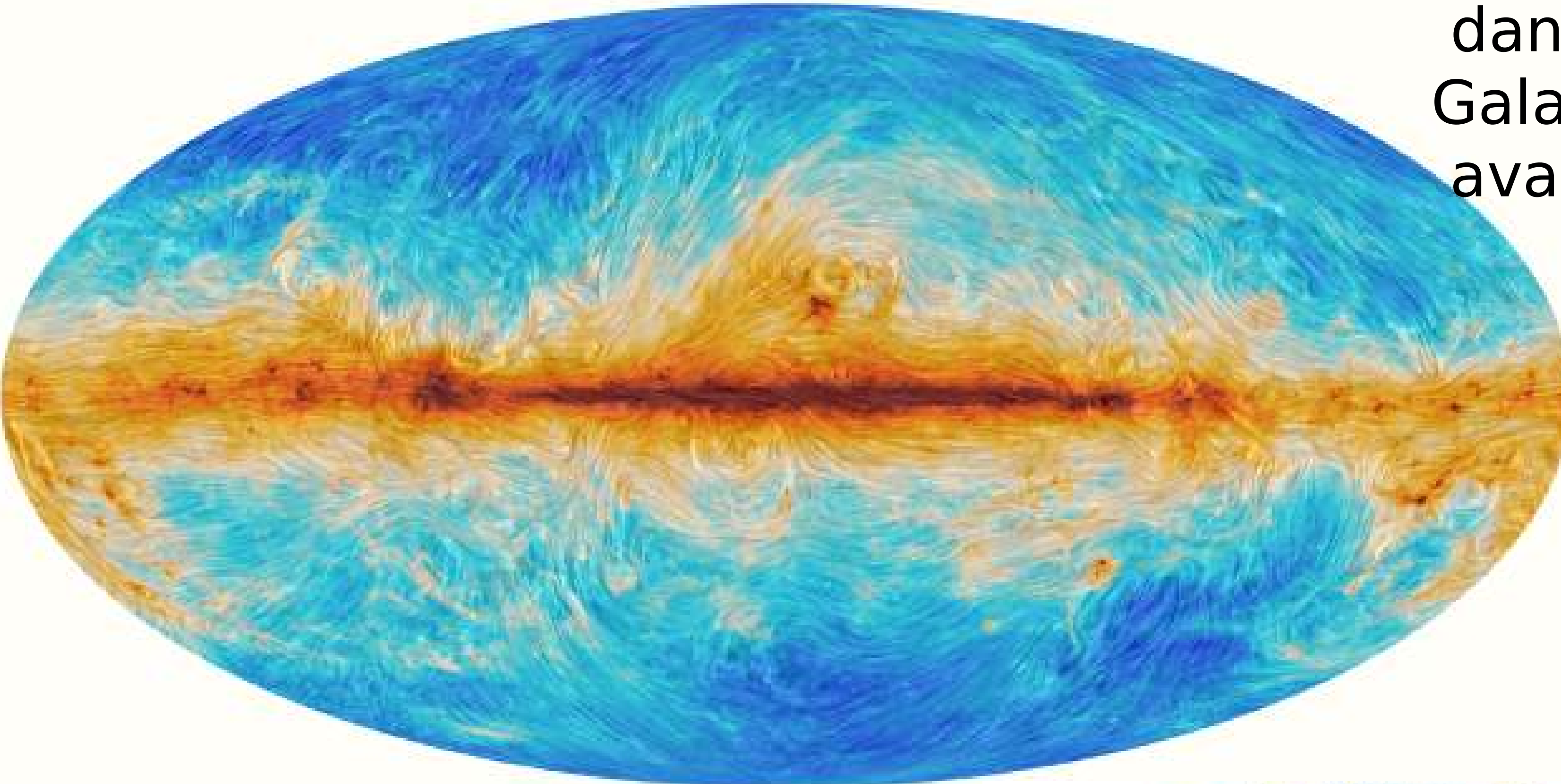
Planck Collab, 2015, 1

Polarisation du FDC



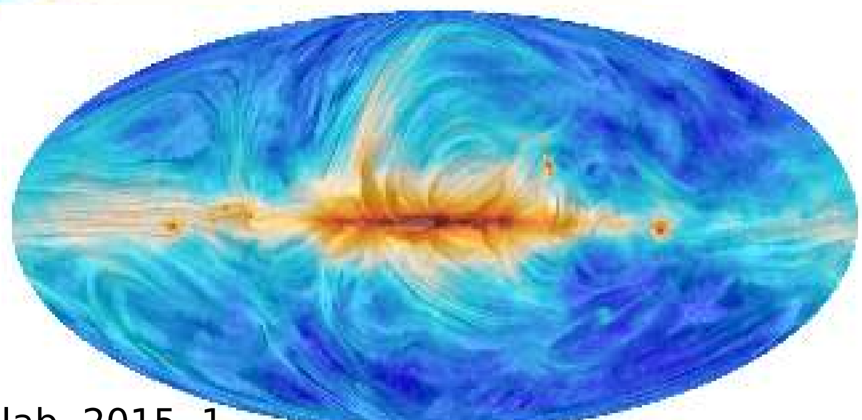
courtesy J. Aumont

Polarisation vue par Planck



dans notre
Galaxie, un
avant-plan

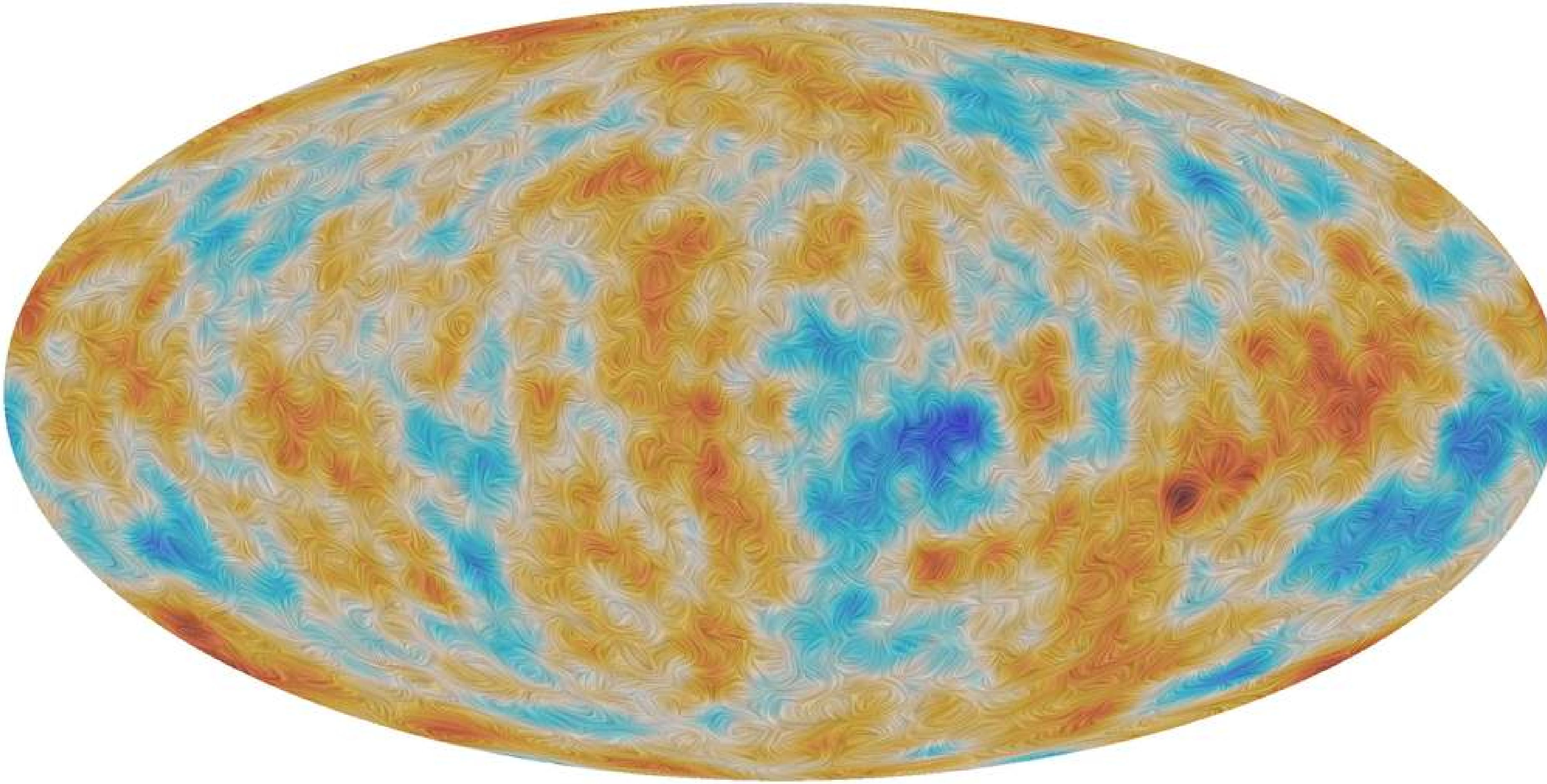
B field.
top: dust @ 353 GHz
right: synchrotron @ 30 GHz



Planck Collab, 2015, 1

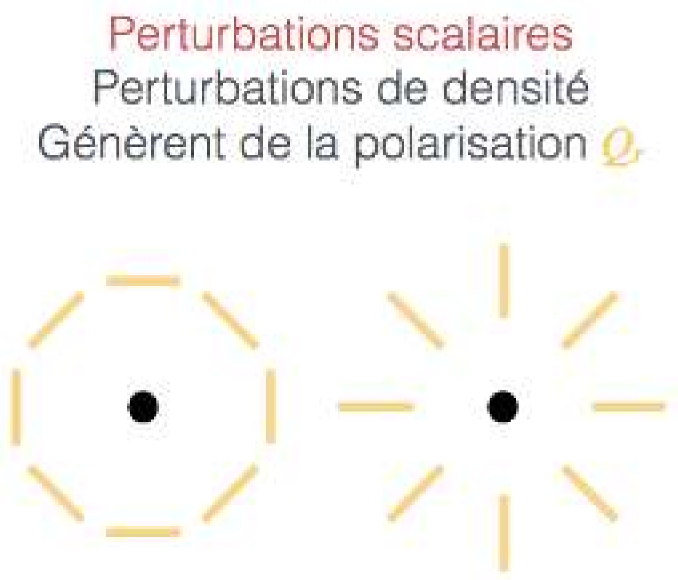
Polarisation vue par Planck

ﬂuctuations de polarisation du FDC seul

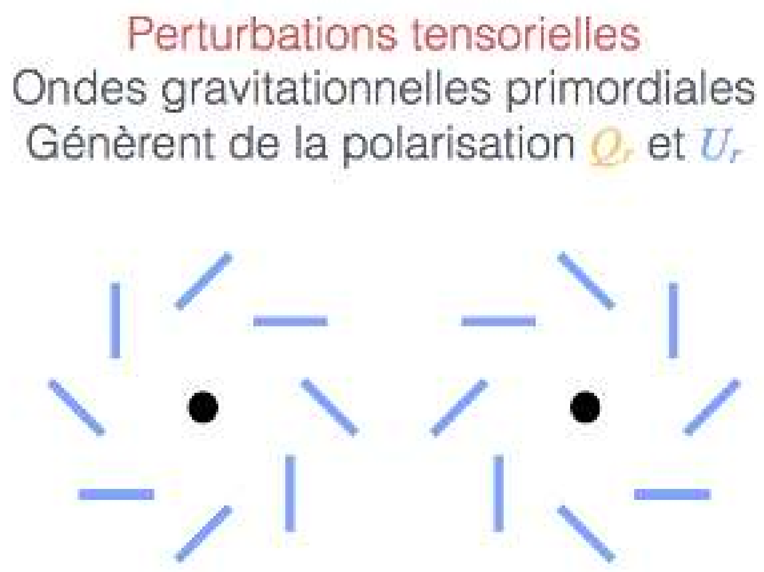


Planck Collab, 2015, 1

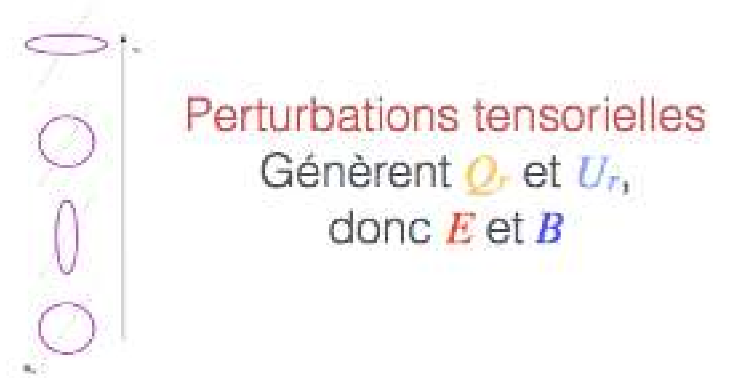
Deux “modes” de polarisation

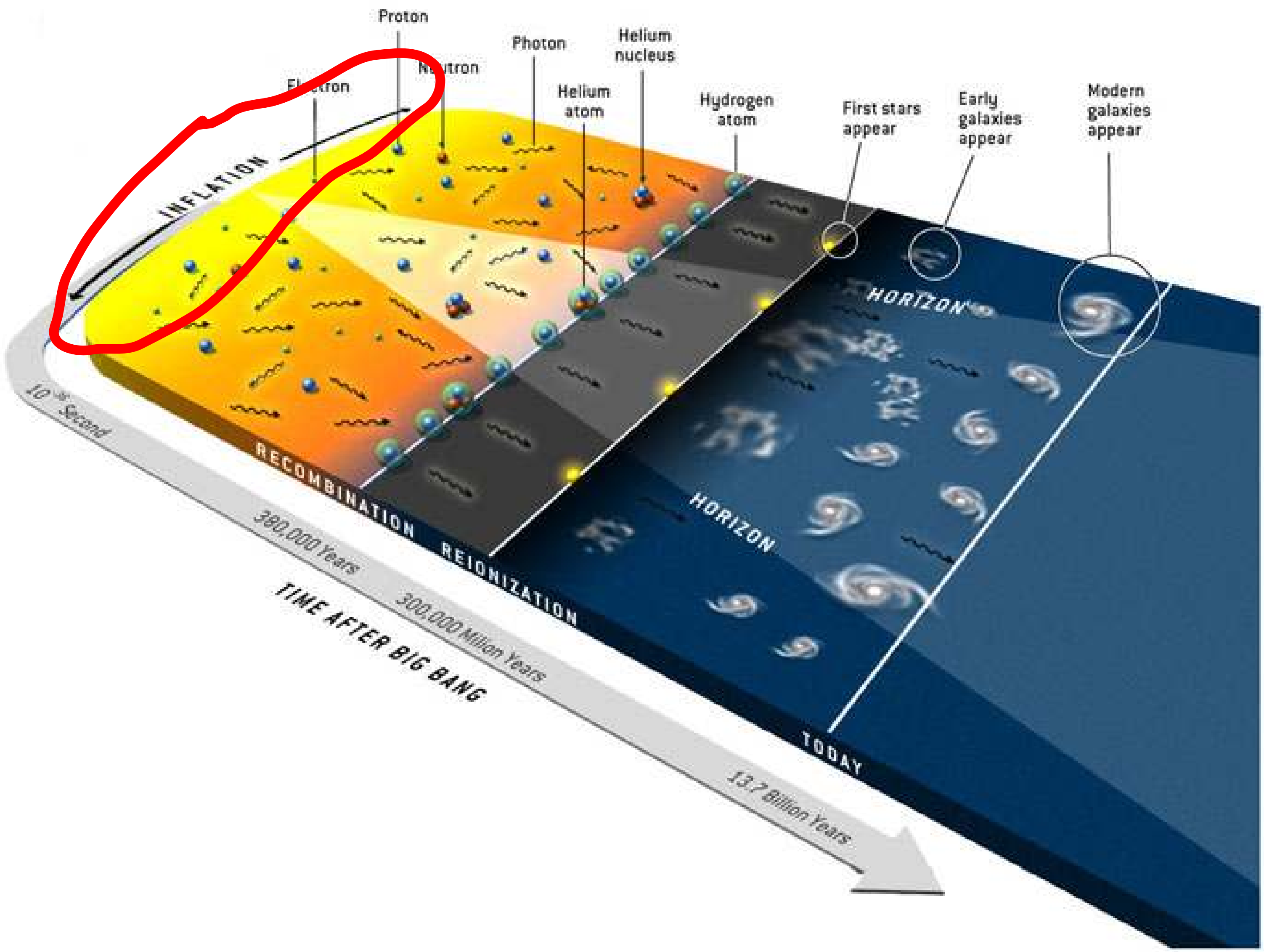


-> E modes:
origin of large-scale structure



-> B modes:
signature of inflation



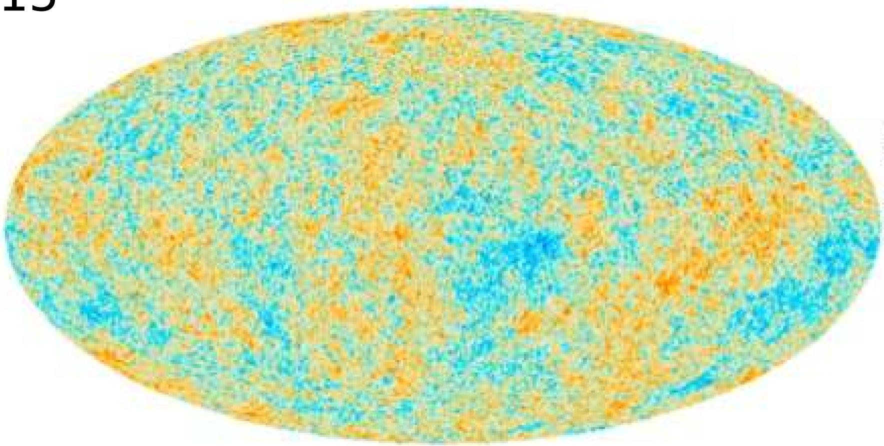


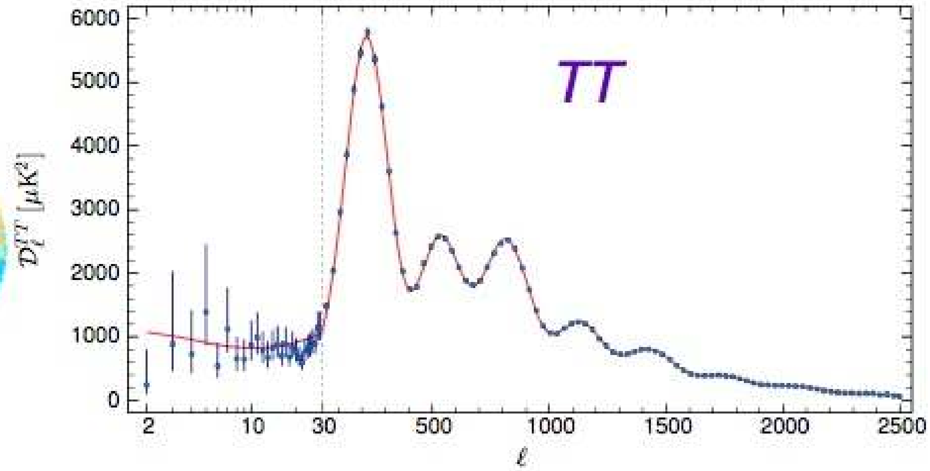
Proton
Photon
Helium nucleus
Helium atom
Hydrogen atom
First stars appear
Early galaxies appear
Modern galaxies appear
INFLATION
RECOMBINATION
REIONIZATION
HORIZON
HORIZON
TODAY
380,000 Years
300,000 Million Years
13.7 Billion Years
TIME AFTER BIG BANG

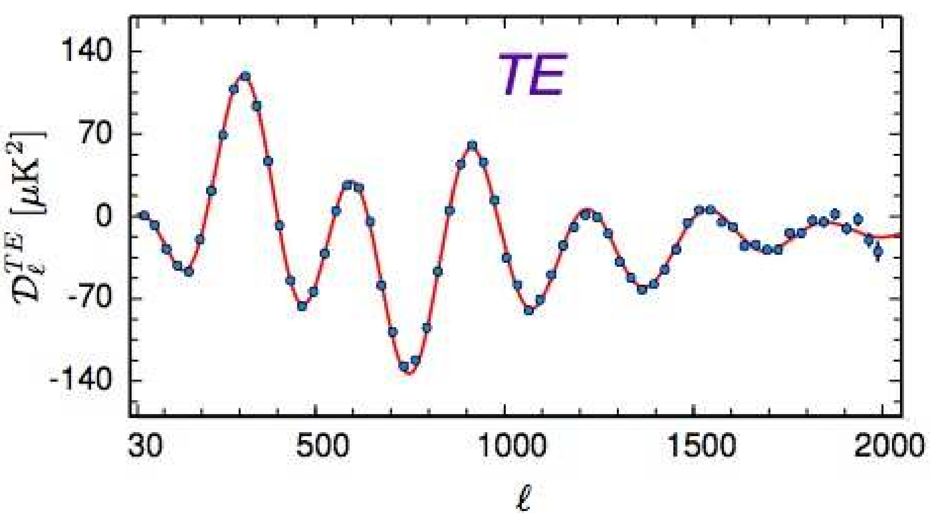
Modes E ? ok !

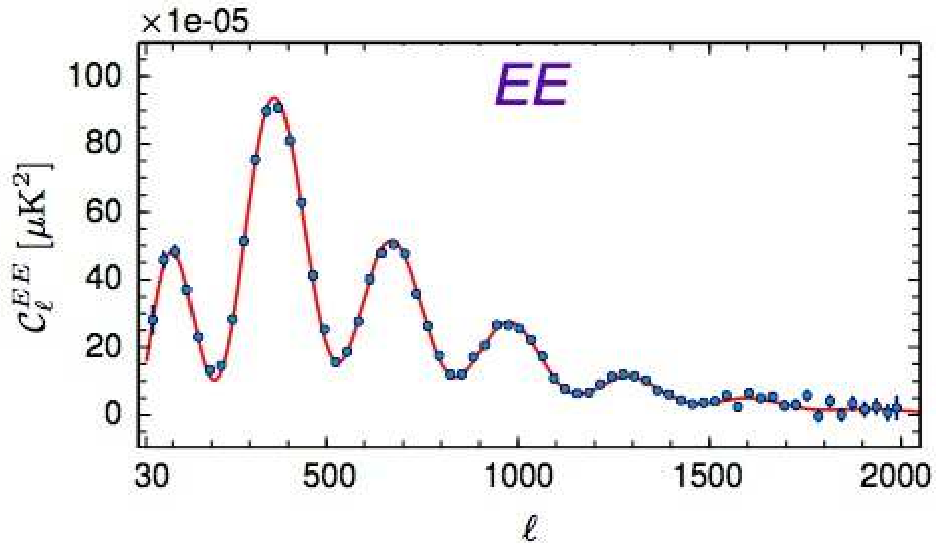
Le rayonnement fossile mesuré par Planck

2015







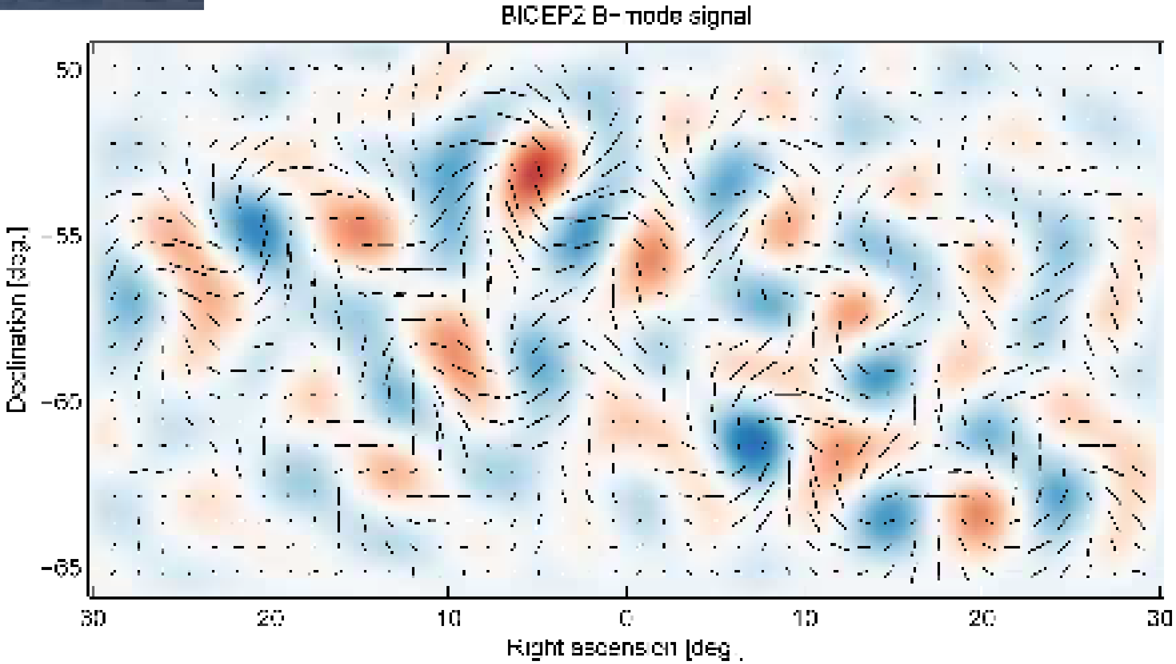


Planck 2015

Modes B ?   pas encore publié

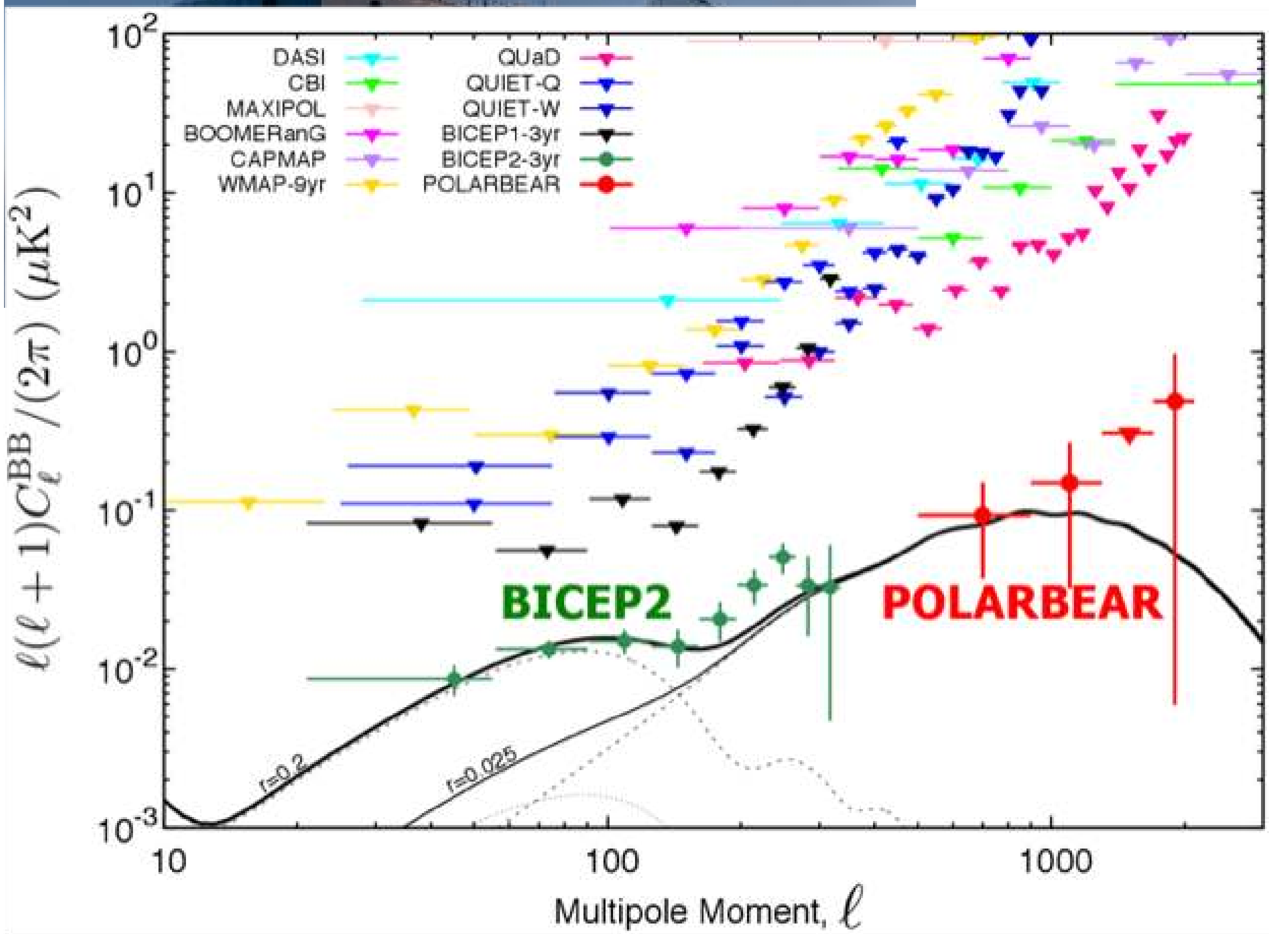
Modes B de polarisation

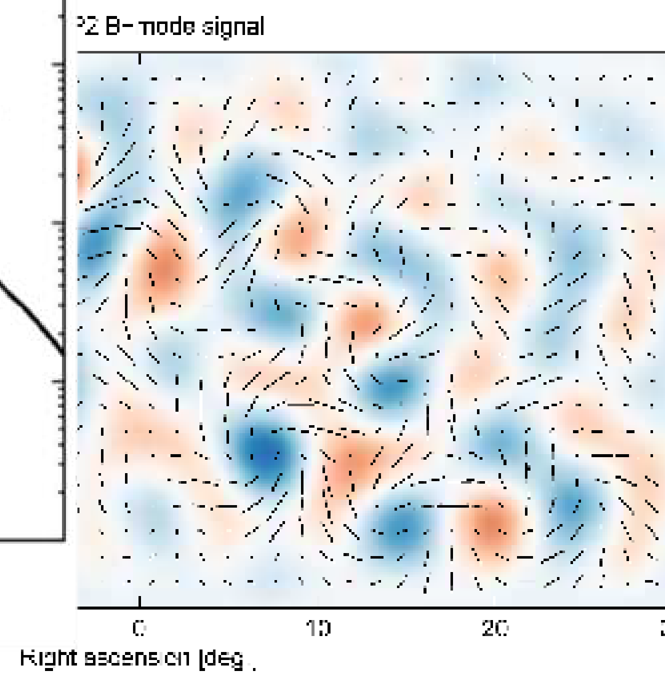
Mars 2014 :
détection des modes B primordiaux ?
un débat vif !



Modes B de polarisation

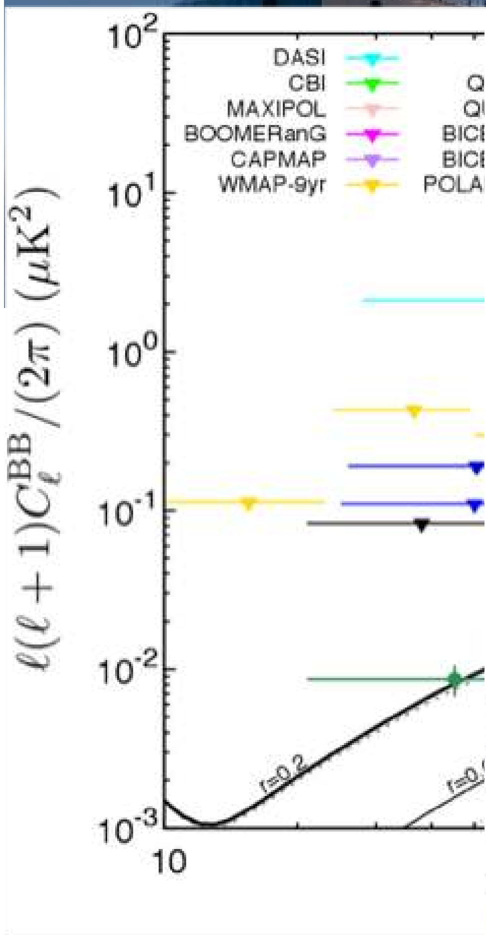
détection des modes B primordiaux
un débat vif !





Modes B de polarisation

détection des modes B primordiaux
un débat vif !



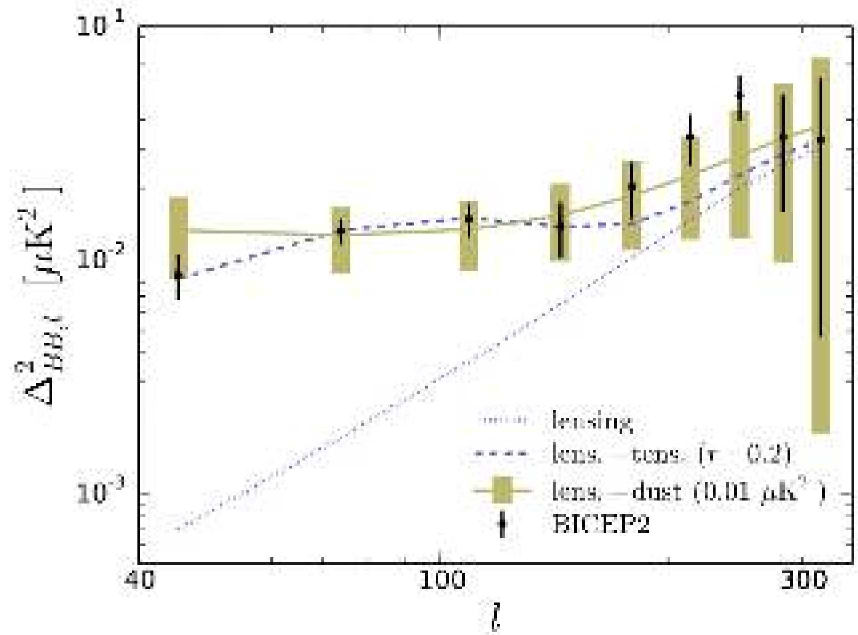


Figure 3. B mode spectrum predictions compared with BICEP2 data (black points with error bars, showing measurement uncertainty only). Each model curve shows the expected signal in the 9 BICEP2 bandpowers. The dashed curve is the sum of a gravity wave component with $r = 0.2$ and the lensing spectrum (dotted curve); the solid curve assumes $r = 0$ and adds to the lensing spectrum a dust polarization spectrum $\Delta^2_{BB,\mathrm{dust},l} = (0.01\ \mu K^2)(l/100)^{-0.3}$. Error bars on the dust model spectrum indicate approximate sampling variance uncertainties; although not shown here, sampling variance on the $r = 0.2$ model is comparable in magnitude.

Mortonson & Seljak, 2014

Modes B de polarisation

ection des modes B primordiaux ?
débat vif !

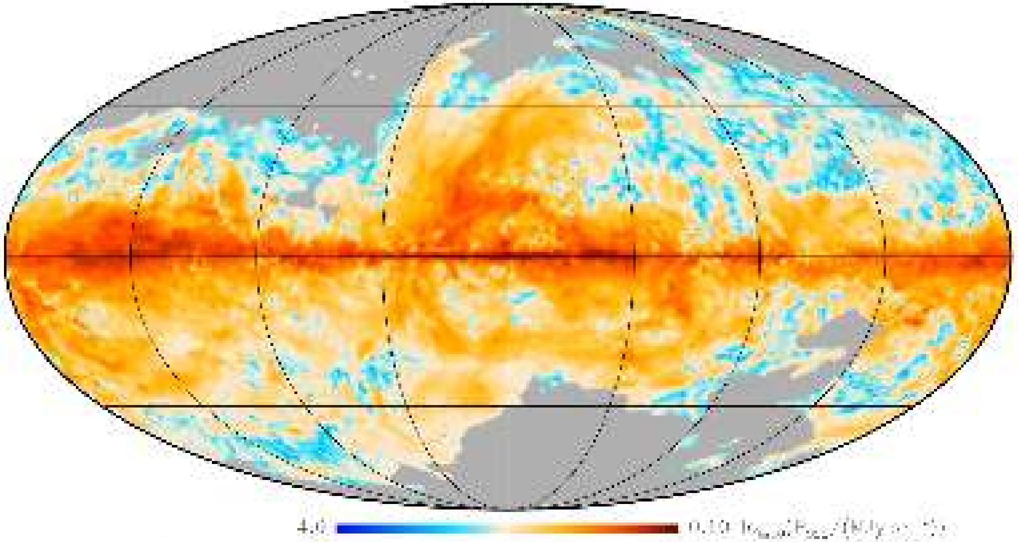
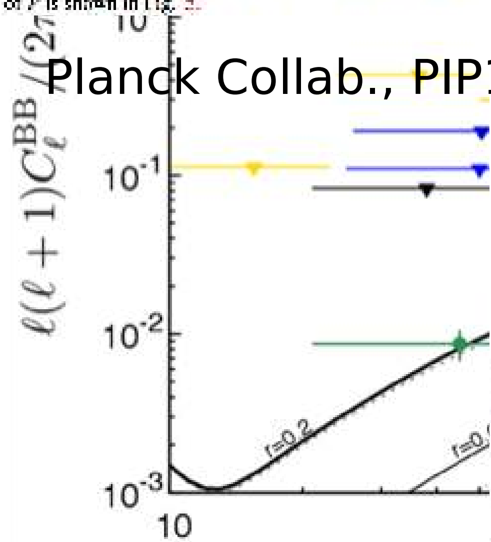
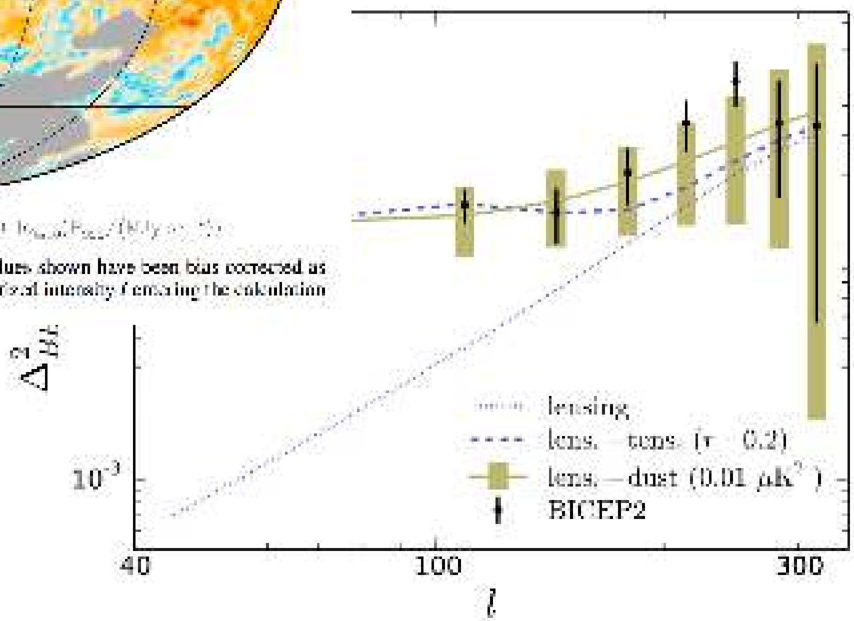


Fig. 2. *Planck* 353 GHz polarized intensity (P) map at 1° resolution in $\log_{10}$ scale. The values shown have been bias corrected as described in Sect. 2.3. The same mask as in Fig. 1 is applied. The full sky map of the unpolarized intensity I entering the calculation of P is shown in Fig. 2.

Planck Collab., PIP19, 2014





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Mortonson & Seljak, 2014

Modes B de polarisation

détection des modes B primordiaux
un débat vif !

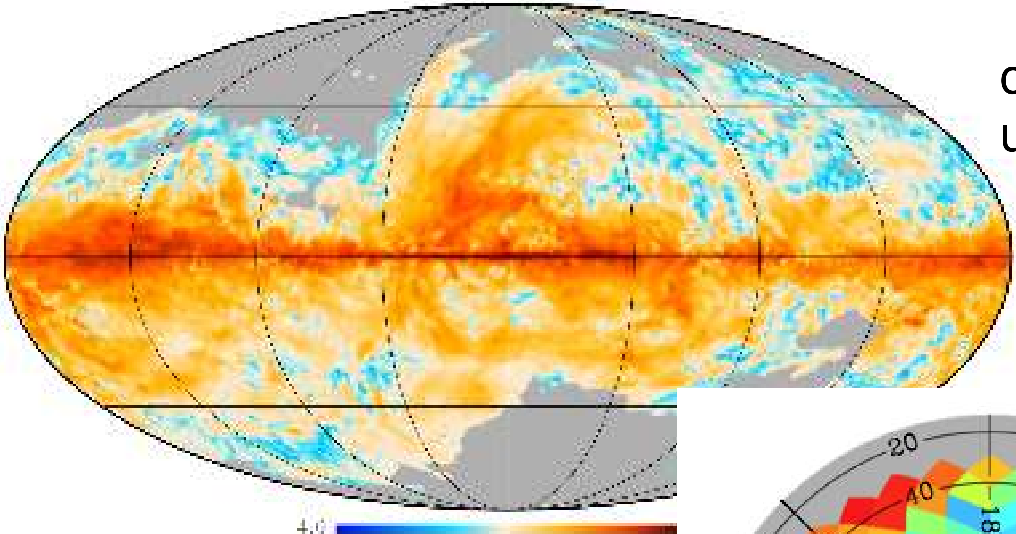

Fig. 2. Planck 353 GHz polarized intensity (P) map at 1° resolution in $\log_{10}$ scale. T
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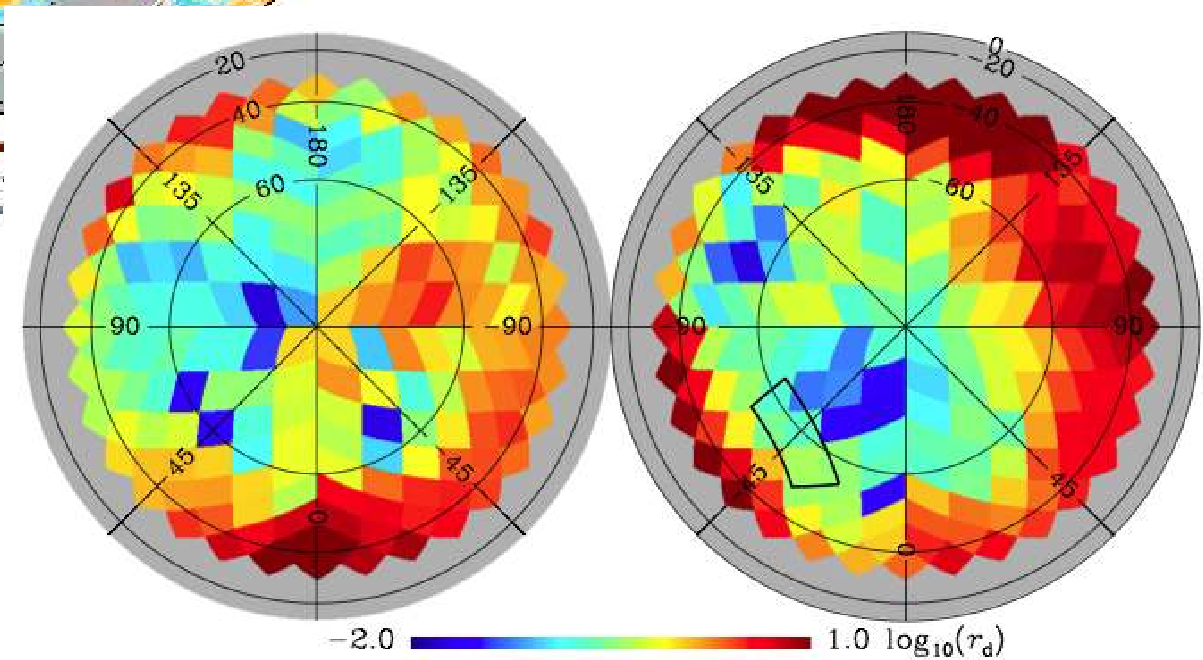
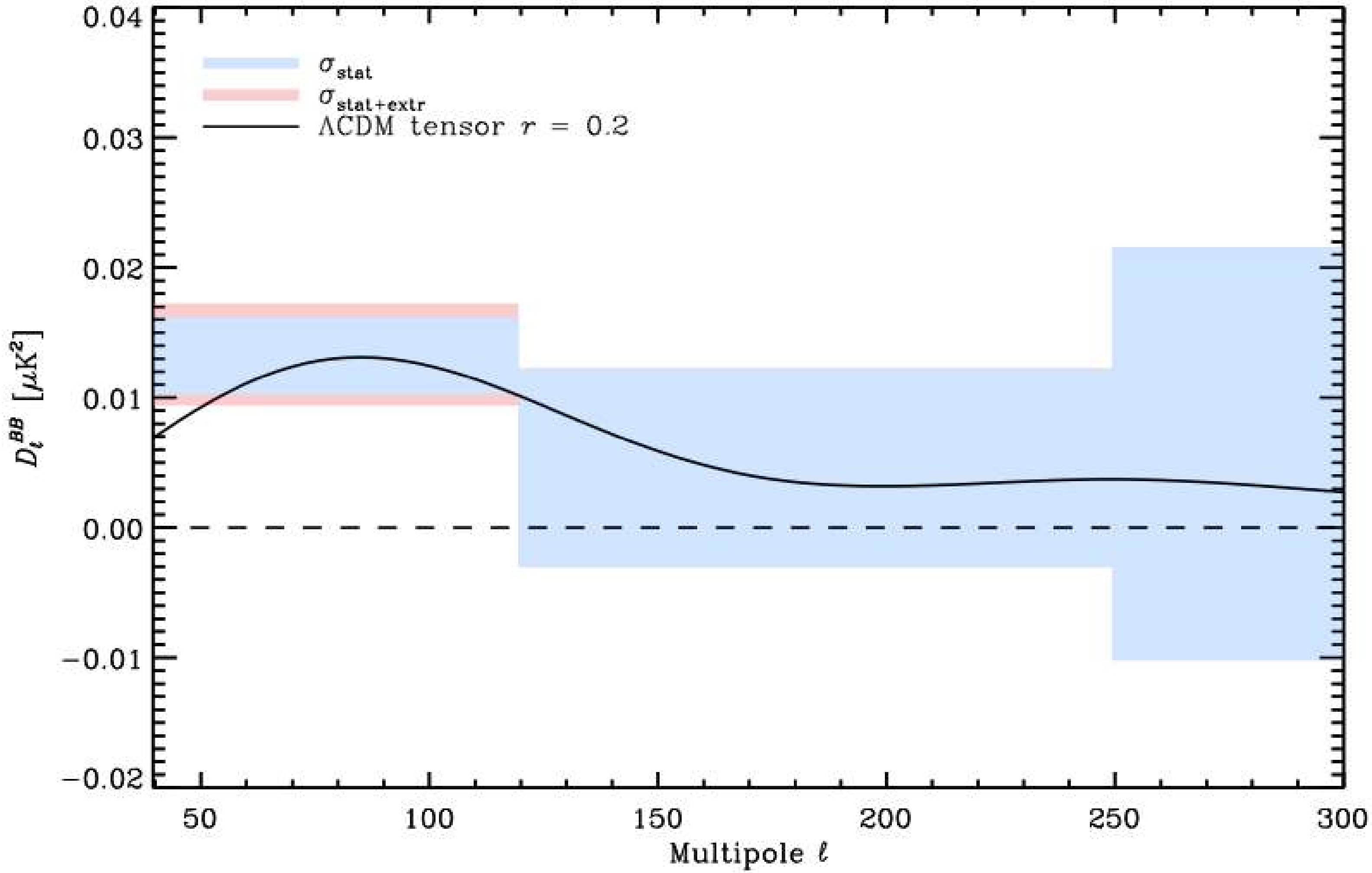
Planck Collab., PIP19, 2014

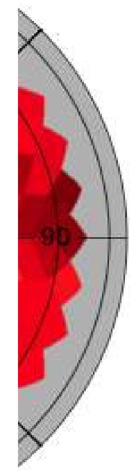


Planck Collab., PIP30, 2014

Modes B de polarisation

aux f





Pl

Planck Collab., PIP30, 2014

Modes B de

The Washington Post

Achenblog

Cosmic smash-up: BICEP2's big bang discovery getting dusted by new satellite data

nature

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NATURE | NEWS

Full-Galaxy dust map muddles search for gravitational waves

Planck probe's survey of polarized light casts further doubt on BICEP2's gravitational-wave discovery claims.

Ron Cowen

M Sciences

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Des poussières brouillent l'écho du Big Bang

Le Monde.fr | 22.09.2014 à 10h34 • Mis à jour le 22.09.2014 à 13h32 |

Par David Larousserie

Criticism of Study Detecting Ripples From Big Bang Continues to Expand

Libération

{SCIENCES²}

Par Sylvestre Huet
Journaliste à Libération

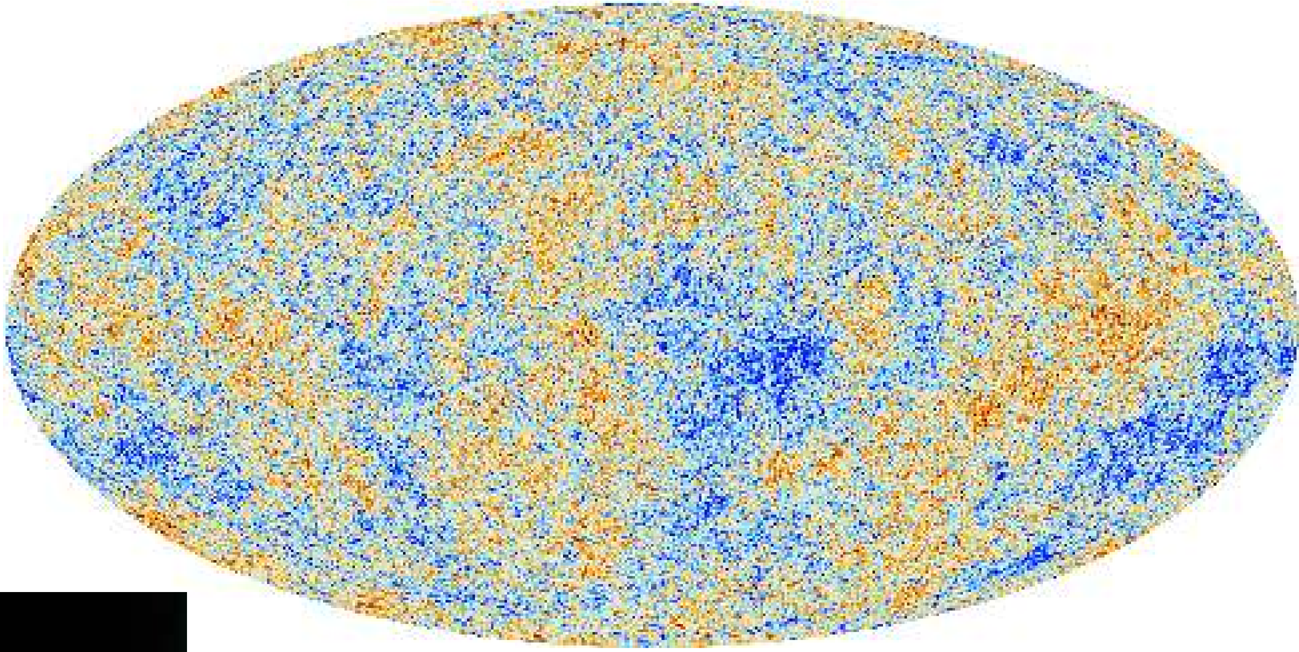
echercher

ONDES GRAVITATIONNELLES: L'ÉNIGME PERSISTE

Aussi avec Planck :

- Nature de la matière noire
- Abondance des éléments primordiaux
- Nombre/masse des neutrinos
- Test des modèles de gravité modifiée
- ...

Remarques finales



Planck collab.
Apollo VIII, Noël 1968- Lovell, Anders, Borman