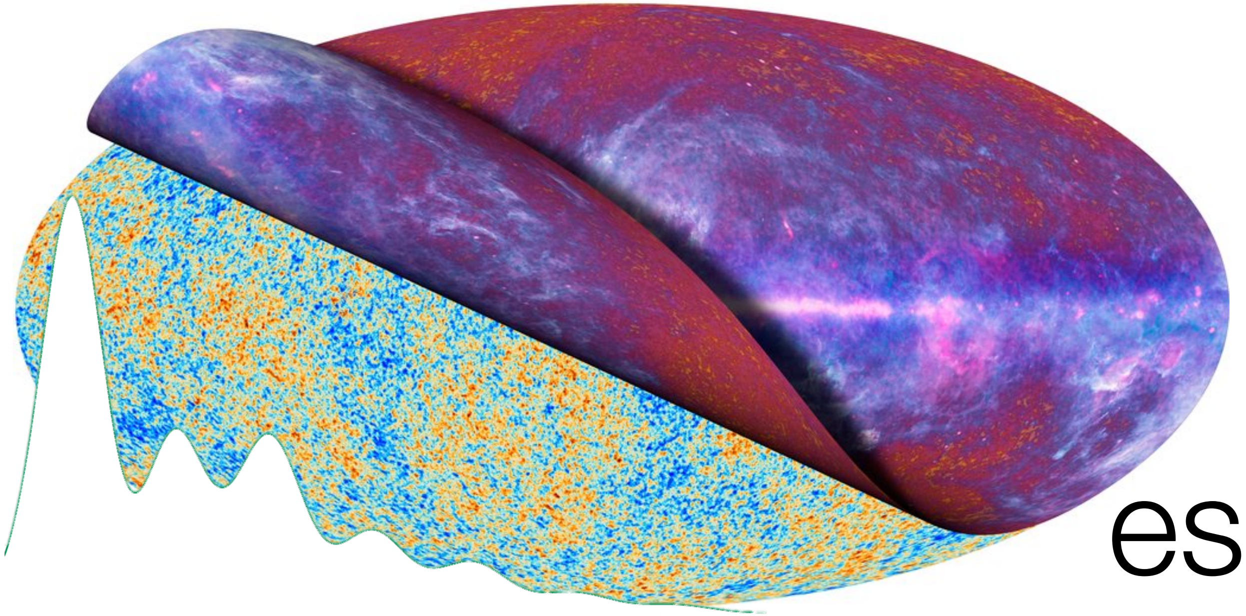


Pourquoi
la nuit
est-elle noire ?
Qu'en a vu Planck ?
Quelle est l'origine de l'Univers ?

Hervé Dole

Institut d'Astrophysique Spatiale, Orsay, France
Université Paris Sud, CNRS & université Paris-Saclay
http://www.ias.u-psud.fr/dole/

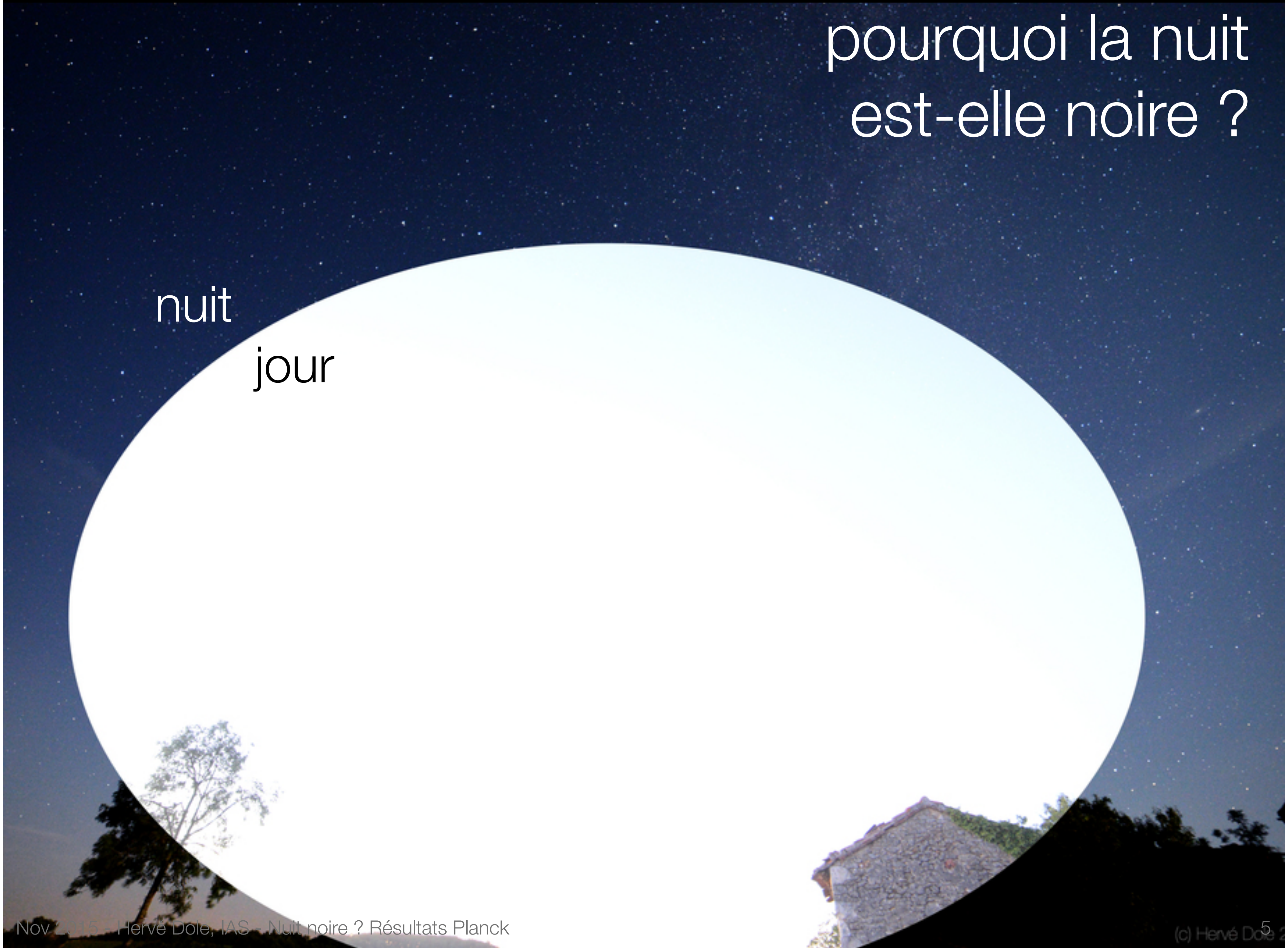
pourquoi la nuit est-elle noire ?

1. Pourquoi la nuit est-elle noire ?
2. Petite histoire de l'univers
3. Les vibrations et le rythme dans l'univers jeune et l'apport de Planck
4. Des galaxies à l'unisson dans des proto-amas ?

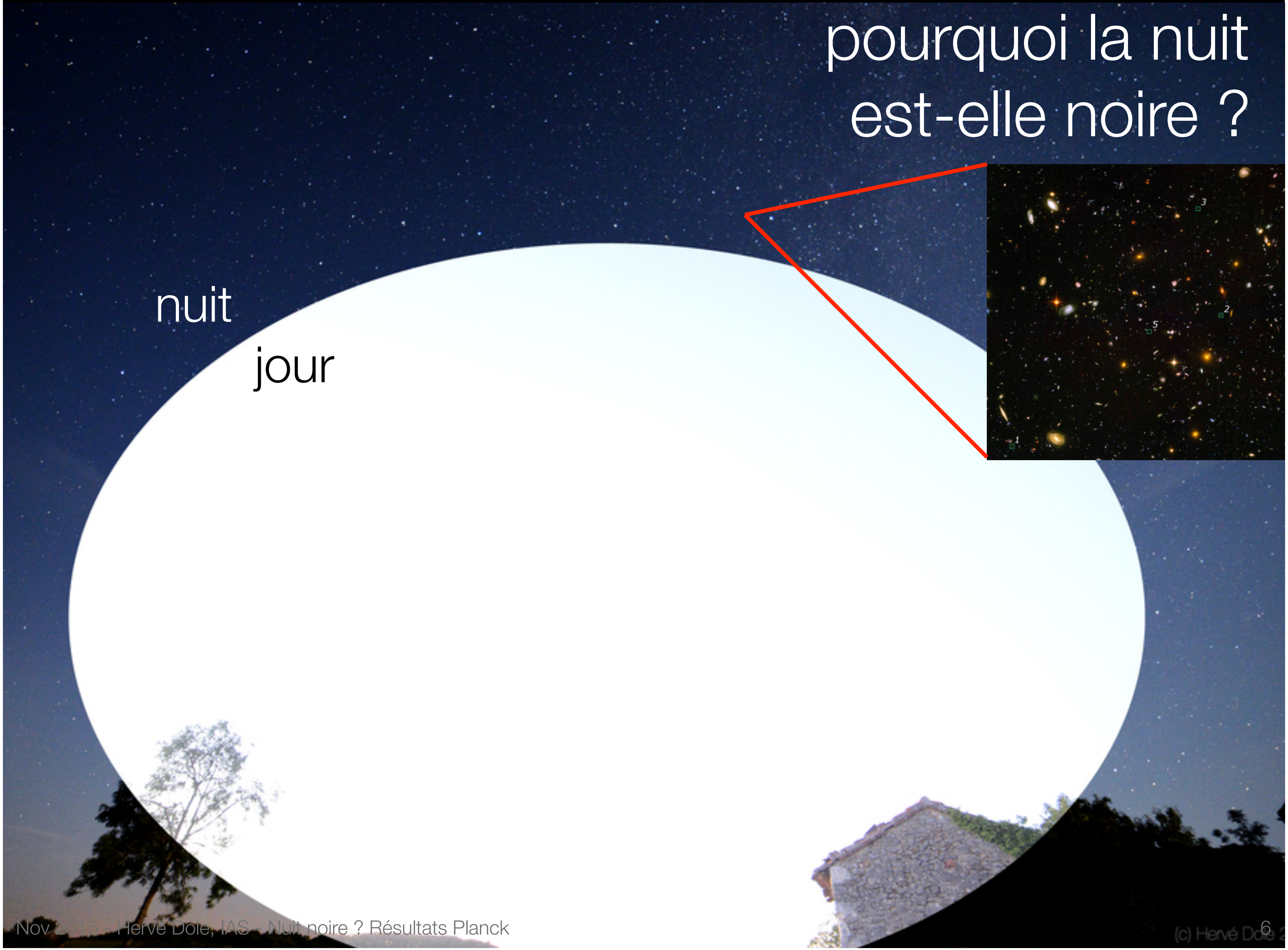
pourquoi la nuit est-elle noire ?

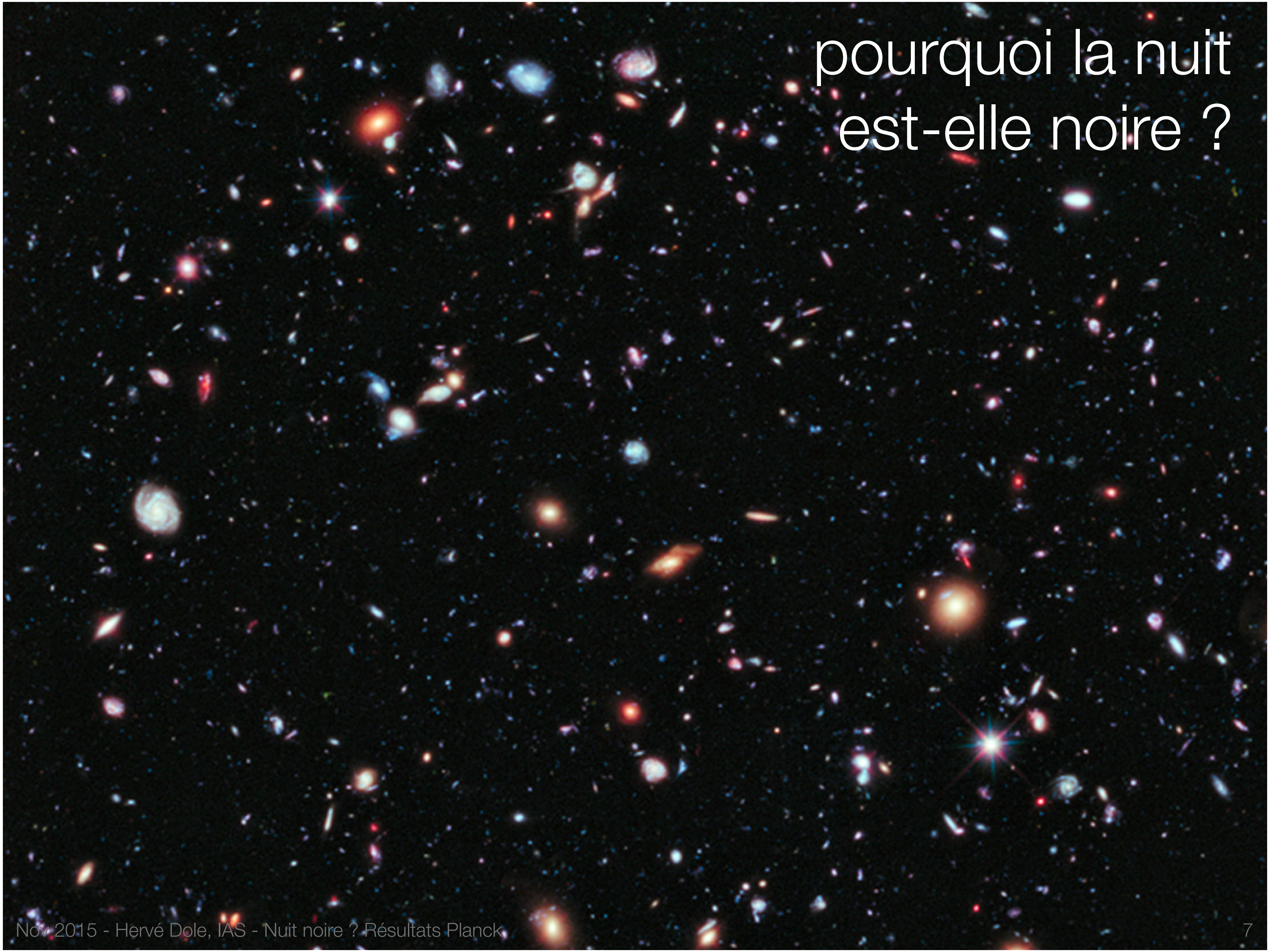
pourquoi la nuit est-elle noire ?

pourquoi la nuit est-elle noire ?



pourquoi la nuit est-elle noire ?



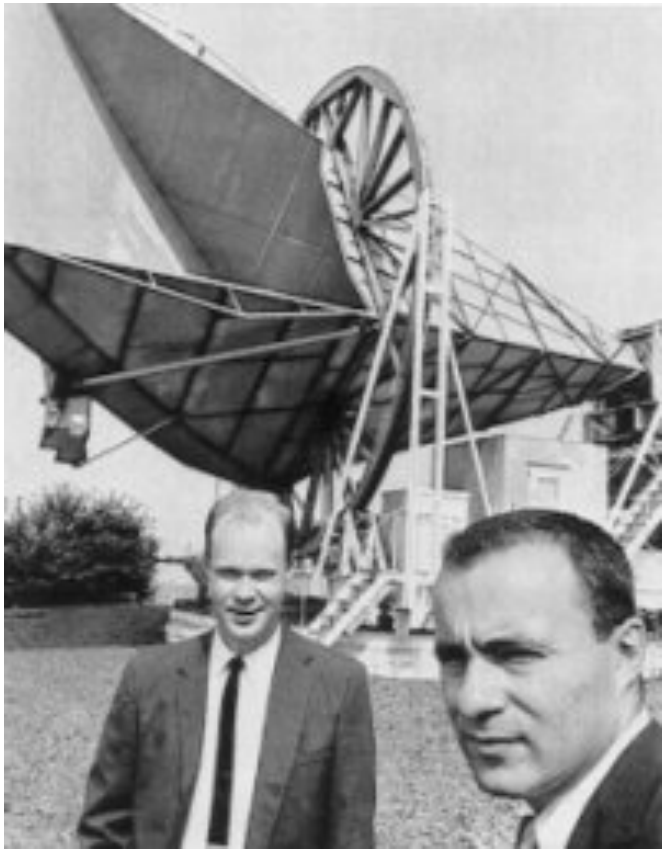


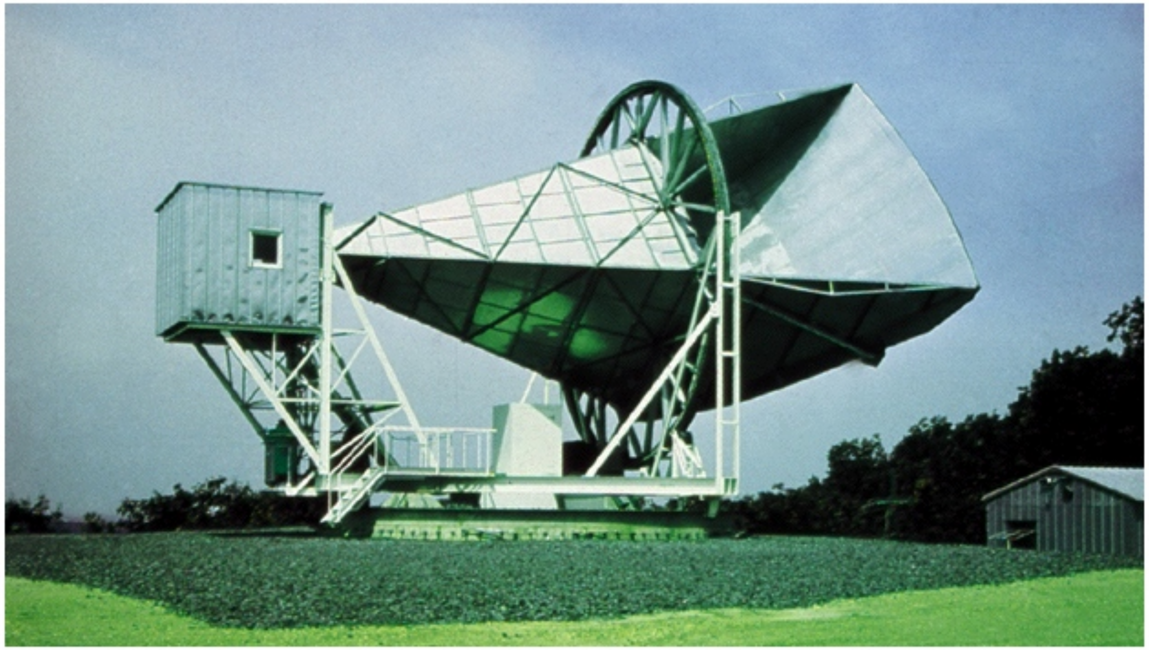
pourquoi la nuit est-elle noire ?

pourquoi la nuit est-elle noire ?

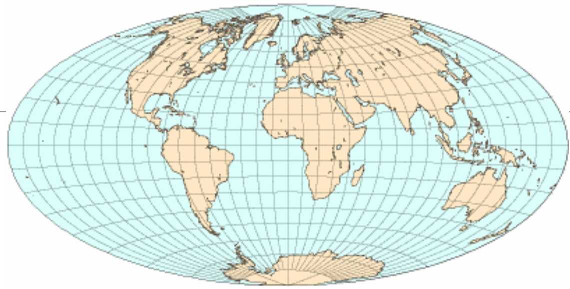
Digges (XVIè), **Chéseaux** (XVIIè), Halley (XVIIIè), **Olbers** (XIXè)
Herschel, Kant, Proctor, Fournier d'Albe, Charlier
Poe (XIXè), **Kelvin** (XIXè)
Hubble (1931)
Gamov (1949)
Penzias & Wilson (1965)
Wesson (1987, 1991)

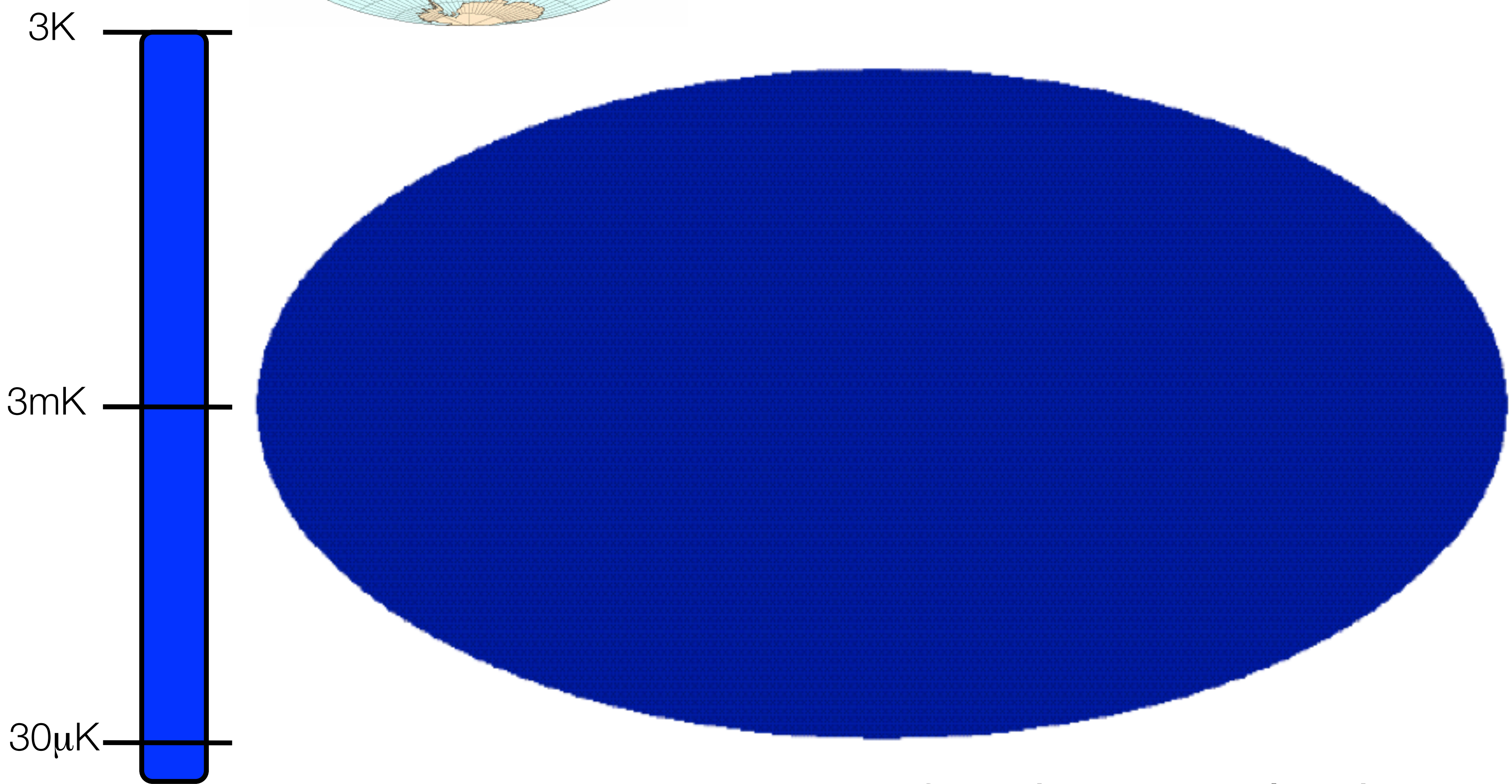
pourquoi la nuit est-elle noire ?





pourquoi la nuit est-elle noire ?

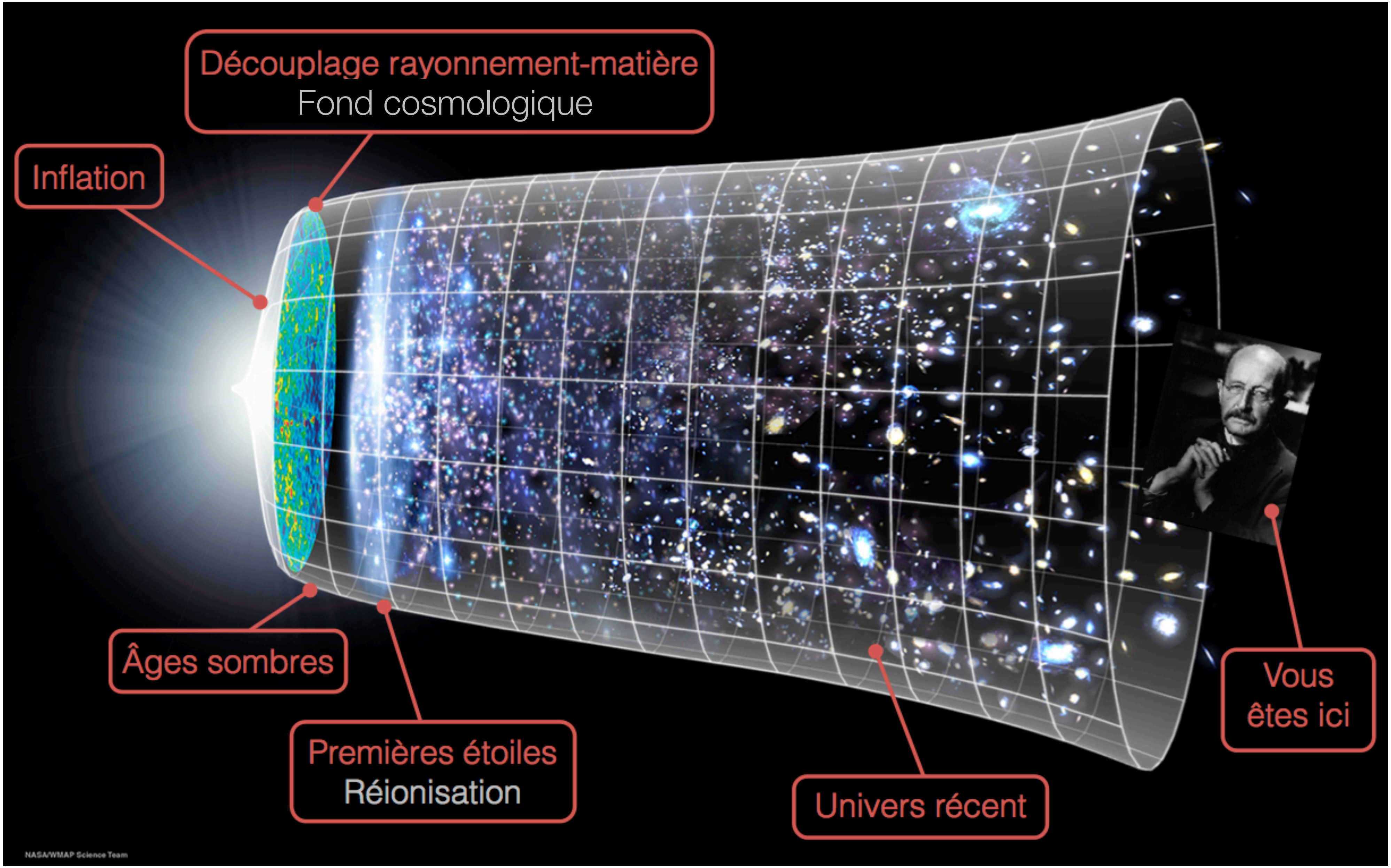




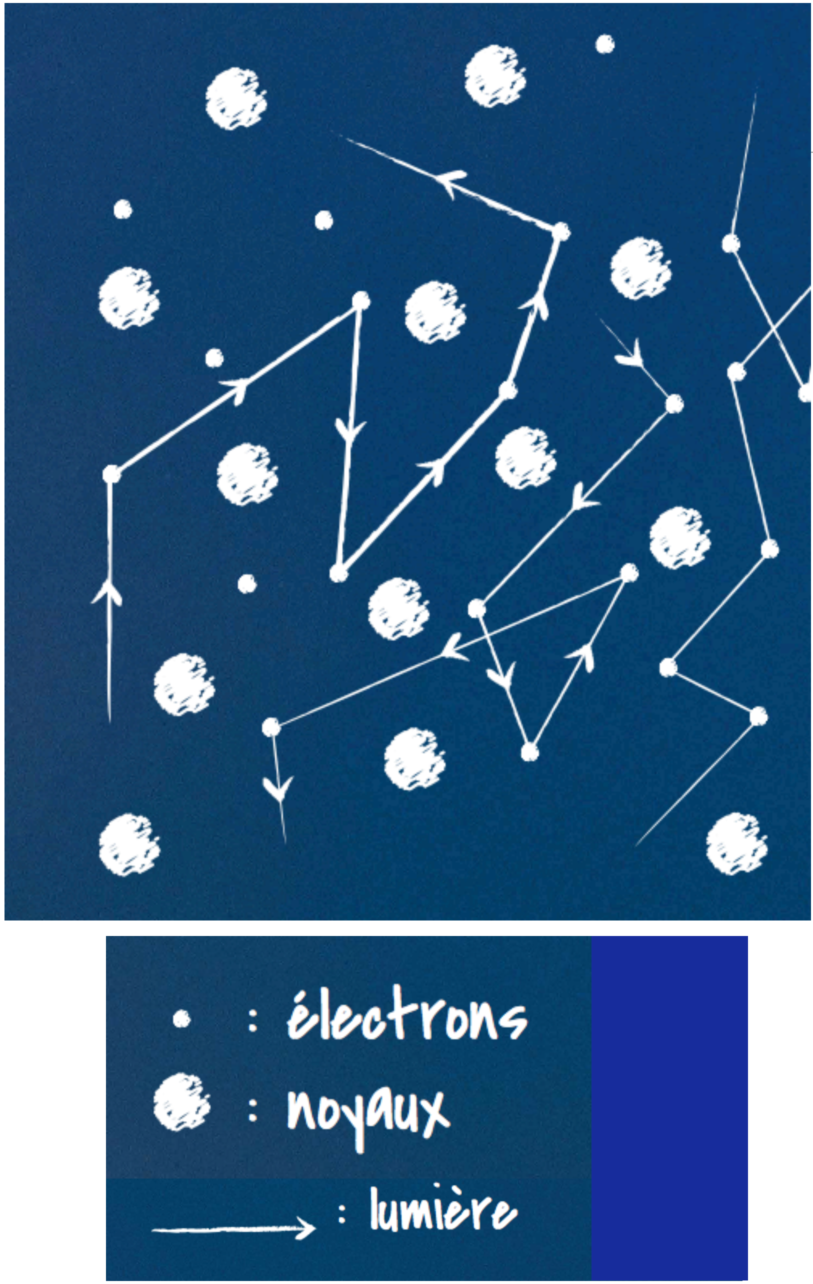
fond cosmologique

courtesy J. Aumont

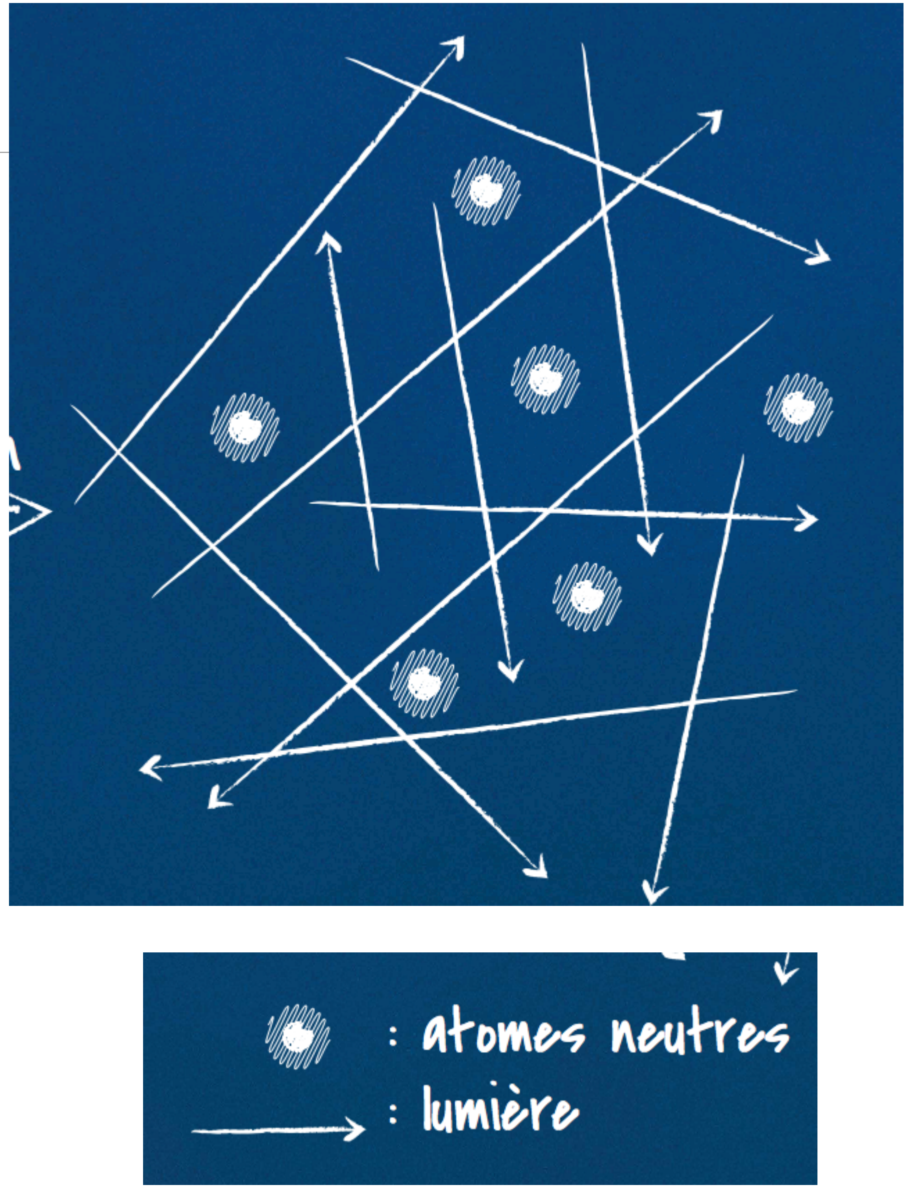
2. univers: 13.8 milliards d’années d’histoire



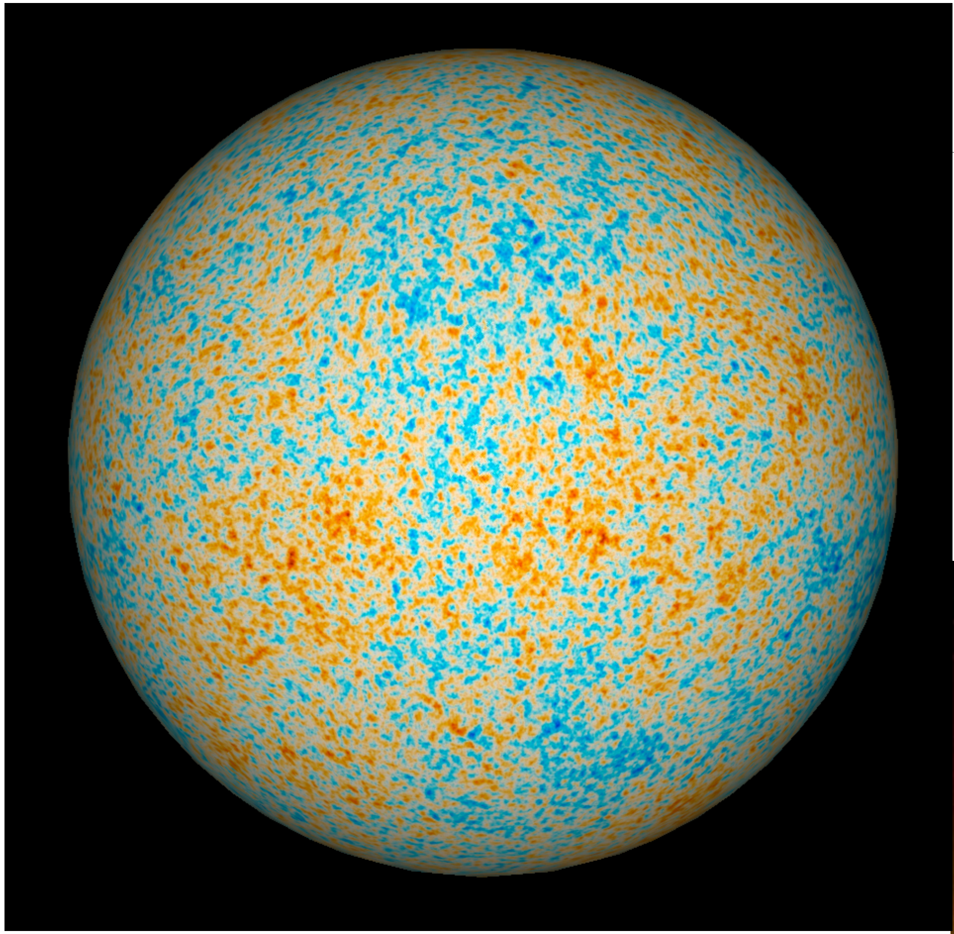
courtesy WMAP, Planck, J. Aumont



univers opaque

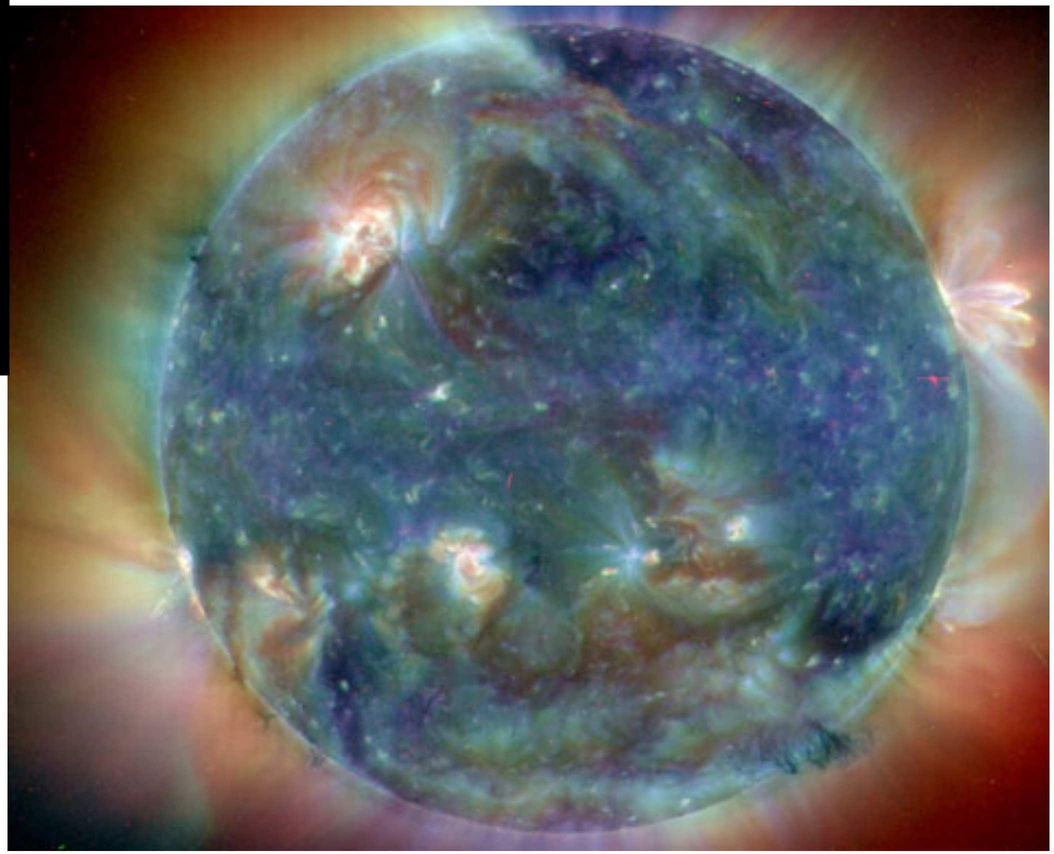


univers transparent

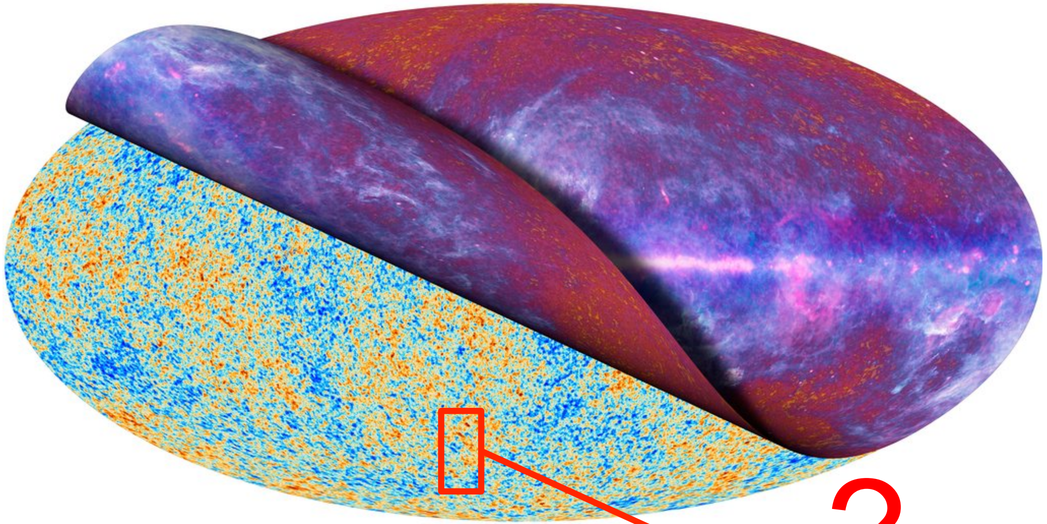


fond cosmologique

Soleil



les deux grandes questions



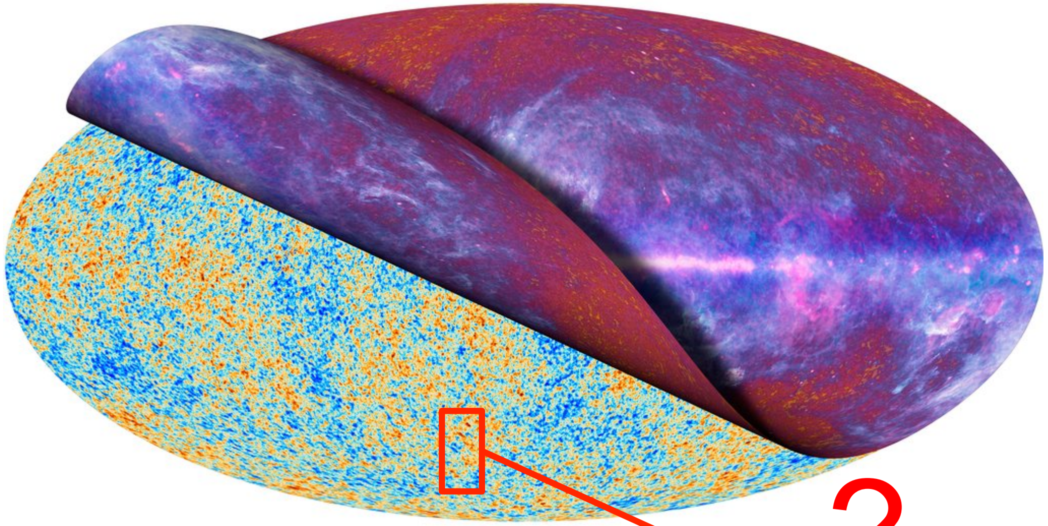
?

univers homogène

?

univers inhomogène,
structuré

les deux grandes questions



?

univers homogène

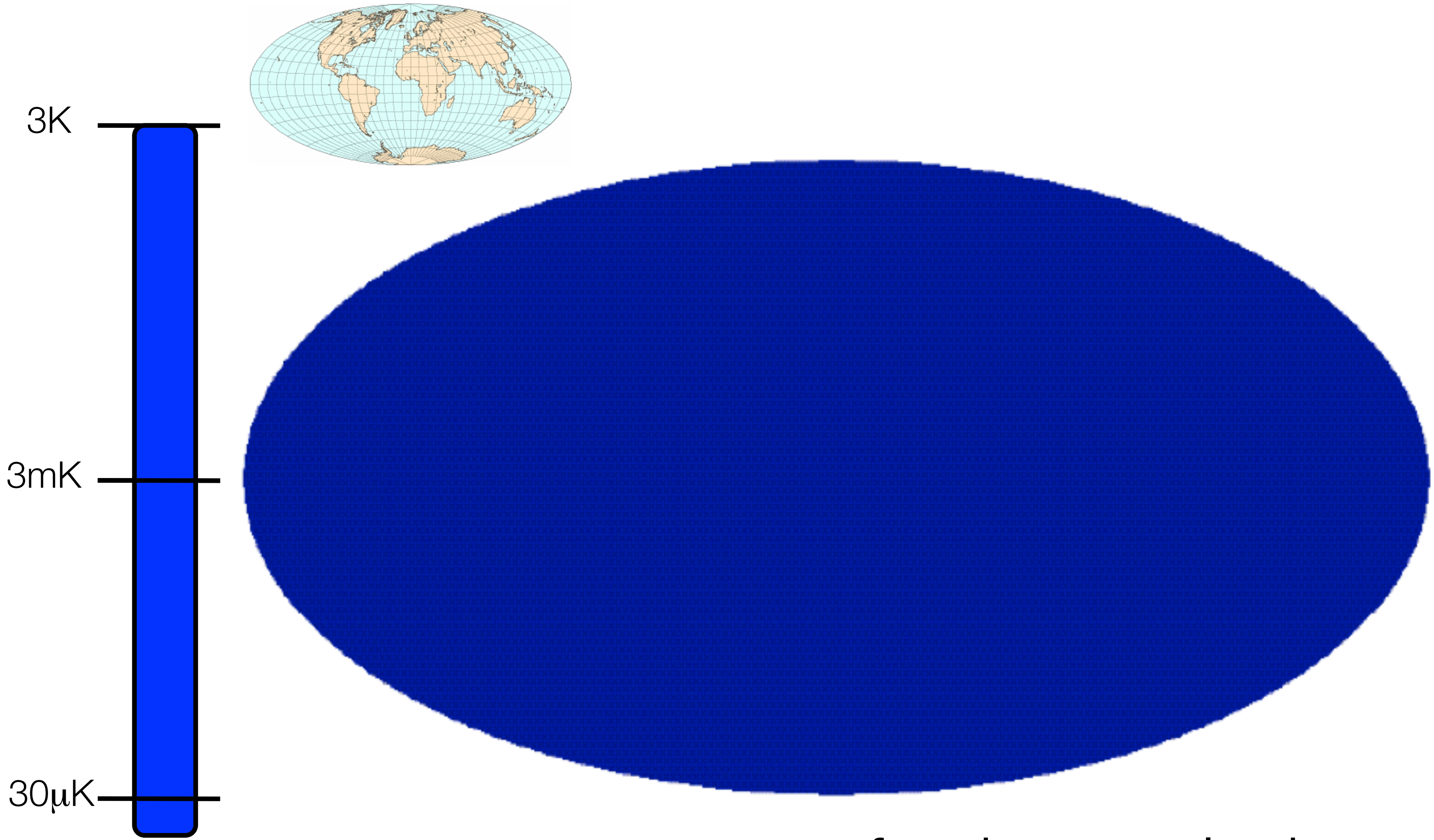
modèles d'inflation ?

?

univers inhomogène,
structuré

formation
des structures

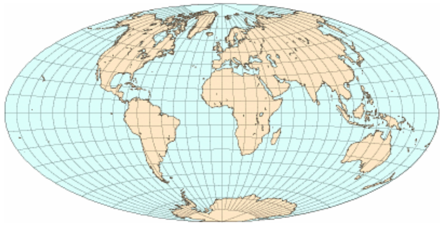
3. les vibrations de l’univers jeune



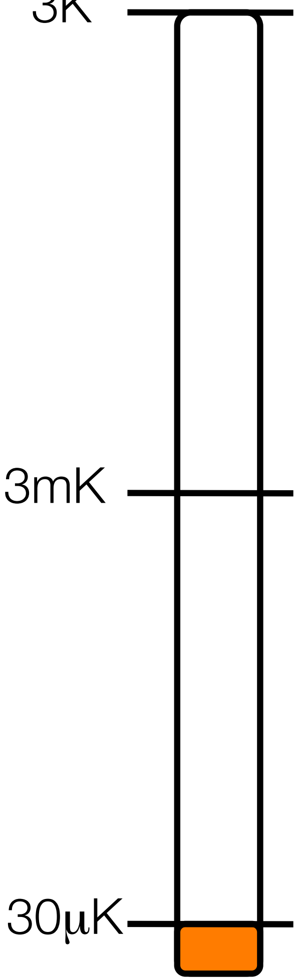
fond cosmologique

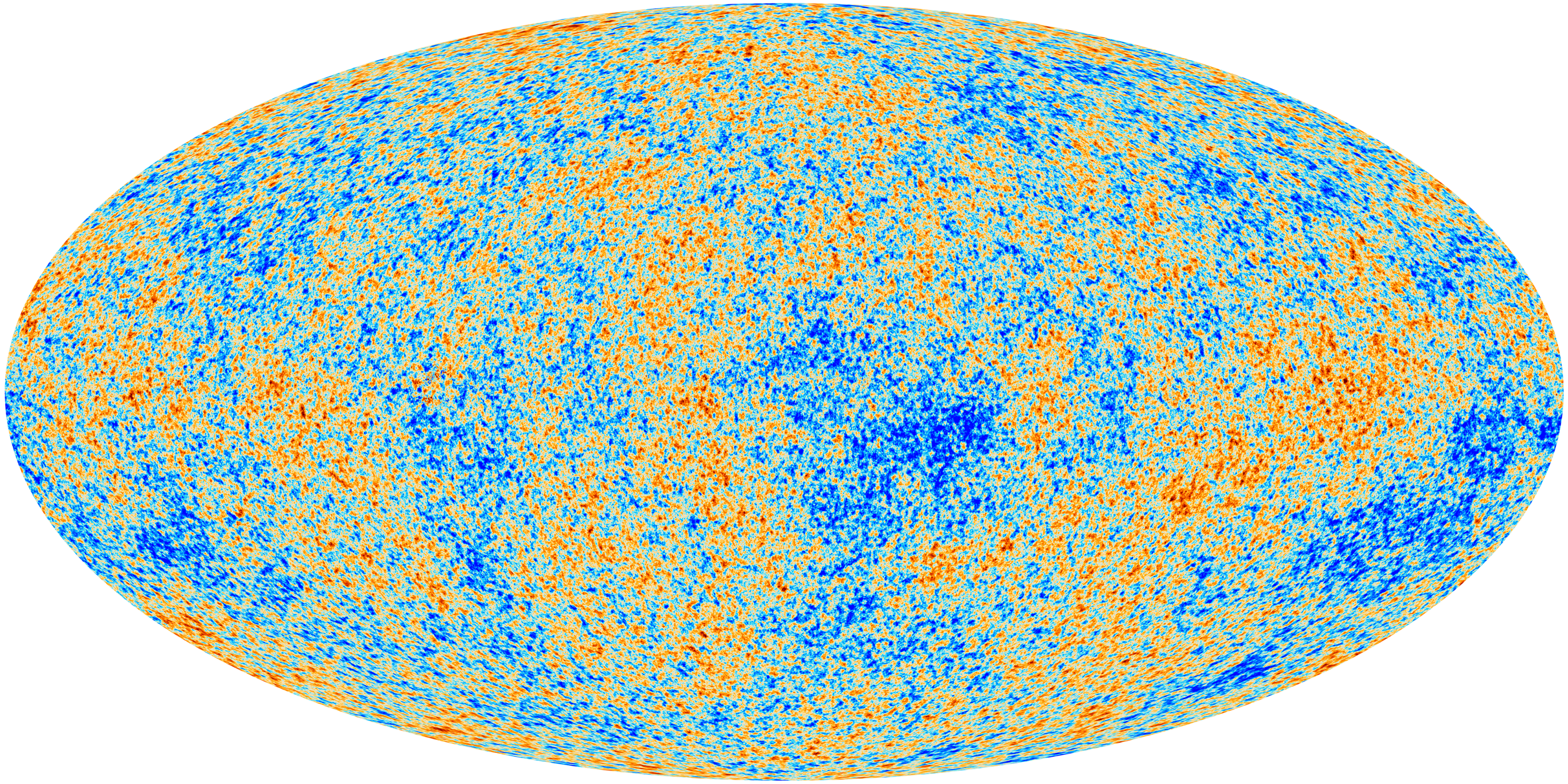
courtesy J. Aumont

3. les vibrations de l'univers jeune



the universe at 2.10^{-5} of its present age
6 millions pixels of 5'





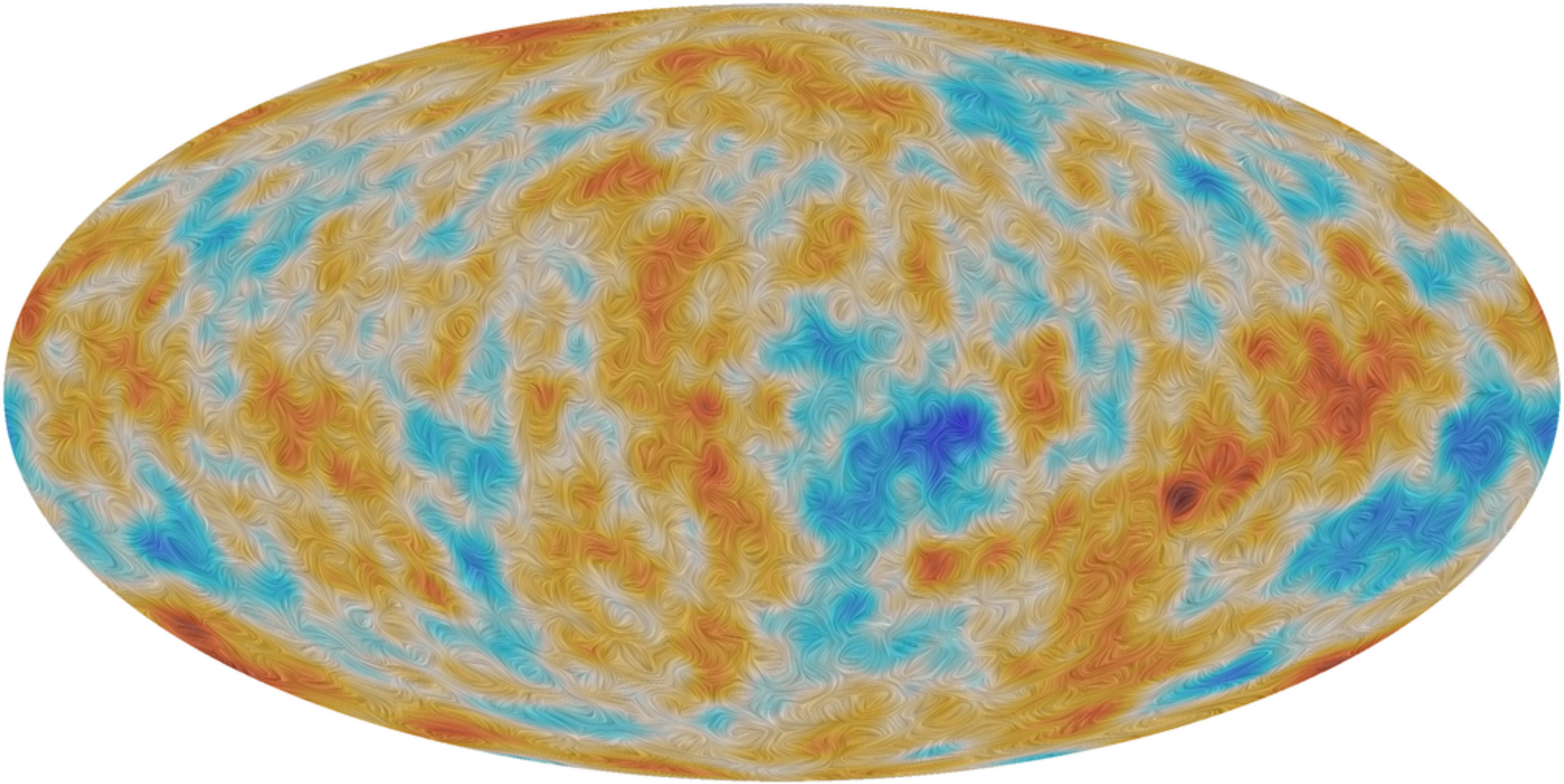
fluctuations du fond cosmologique

Planck 15 mois

courtesy J. Aumont Planck Collaboration, 2013

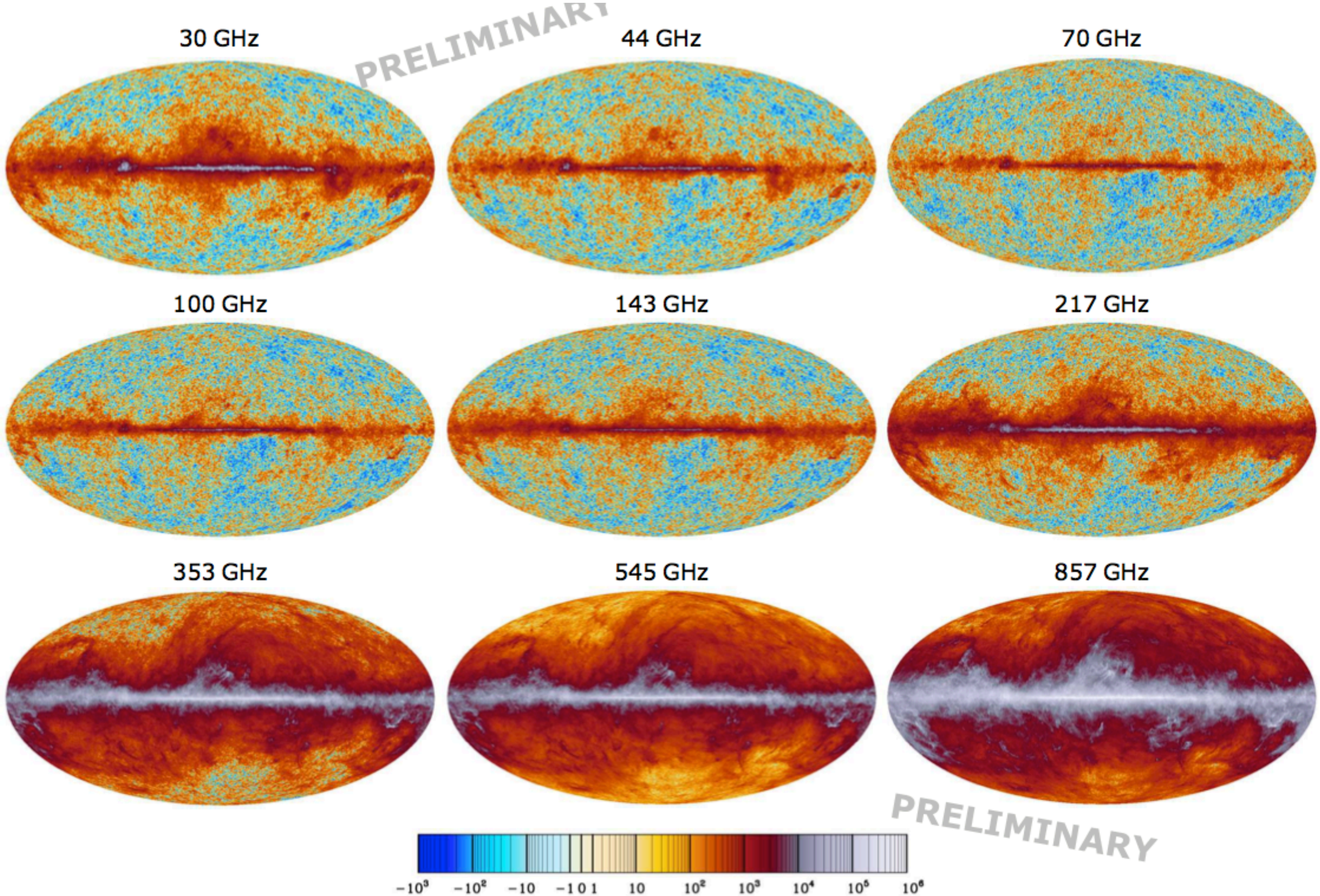
3. les vibrations de l'univers jeune

fluctuations de polarisation du rayonnement



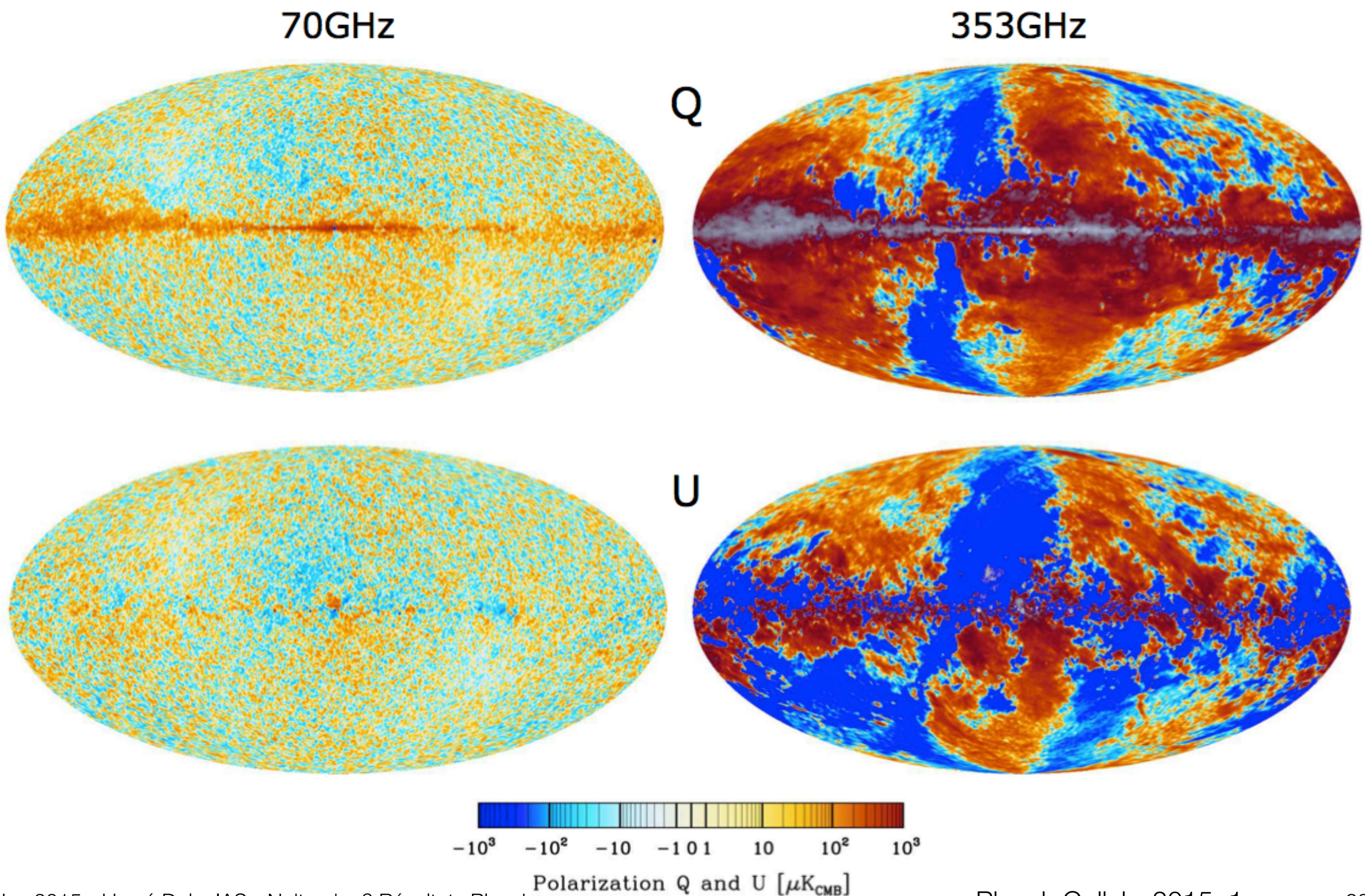
Planck Collab, 2015, 1

3.1 observations: Planck all-sky maps 2015



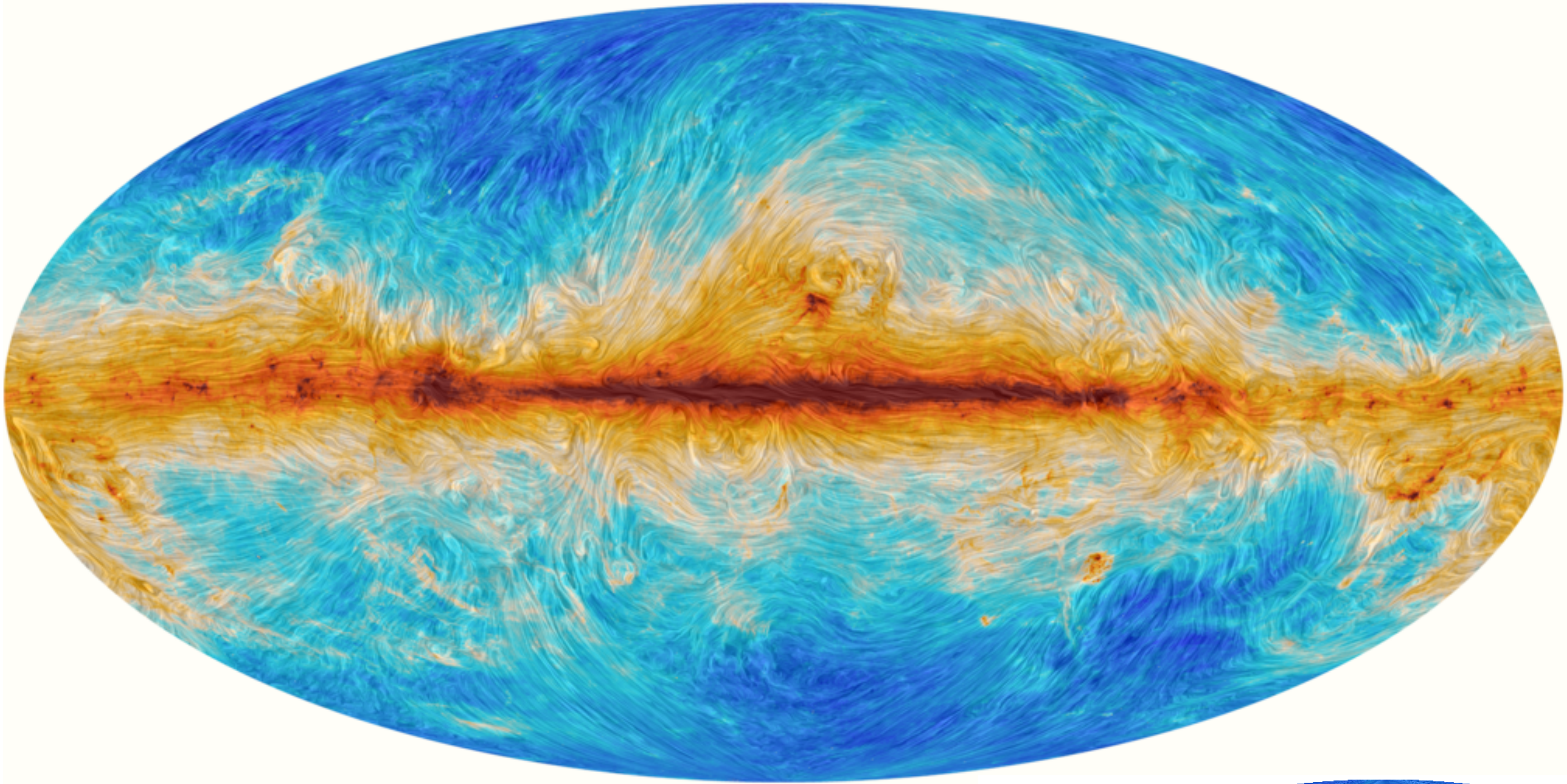
Planck Collab, 2015, 1

3.1 observations: polarisation 2015

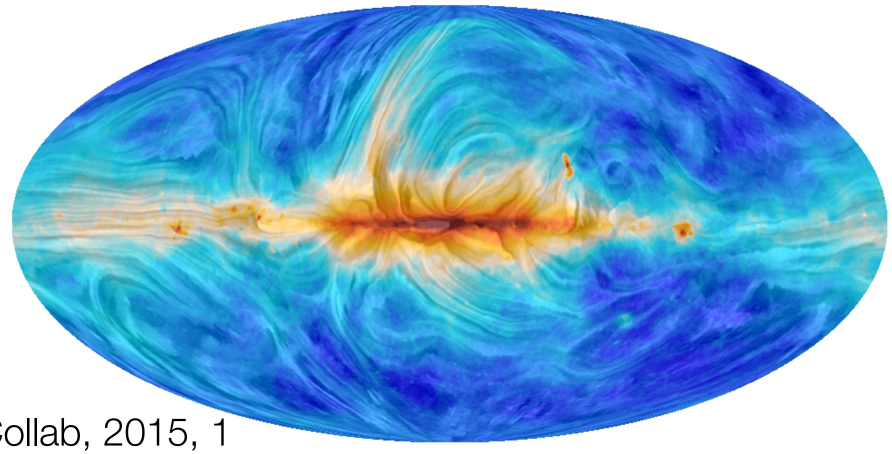


Planck Collab, 2015, 1

3.1 fantastiques vues du champ magnétique

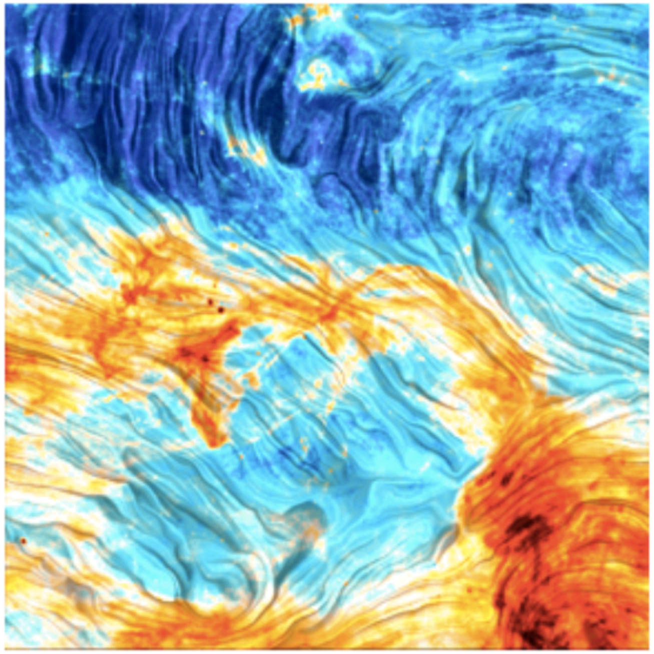


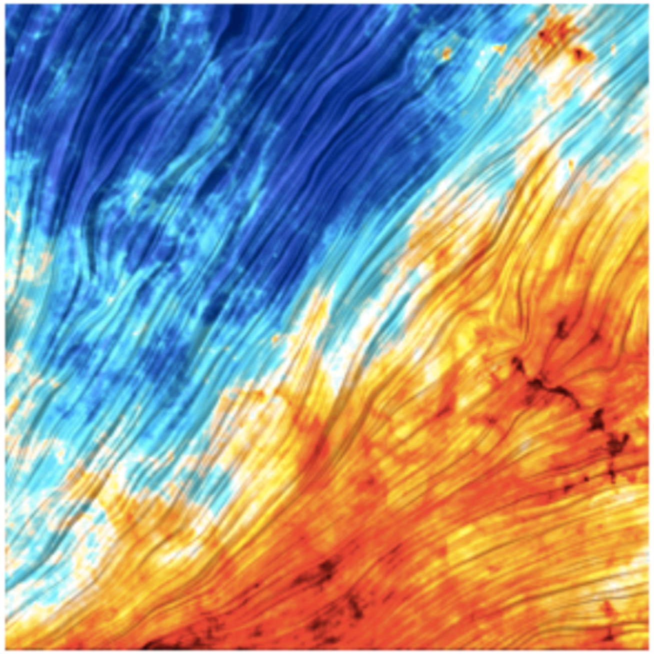
B field.
top: dust @ 353 GHz
right: synchrotron @ 30 GHz

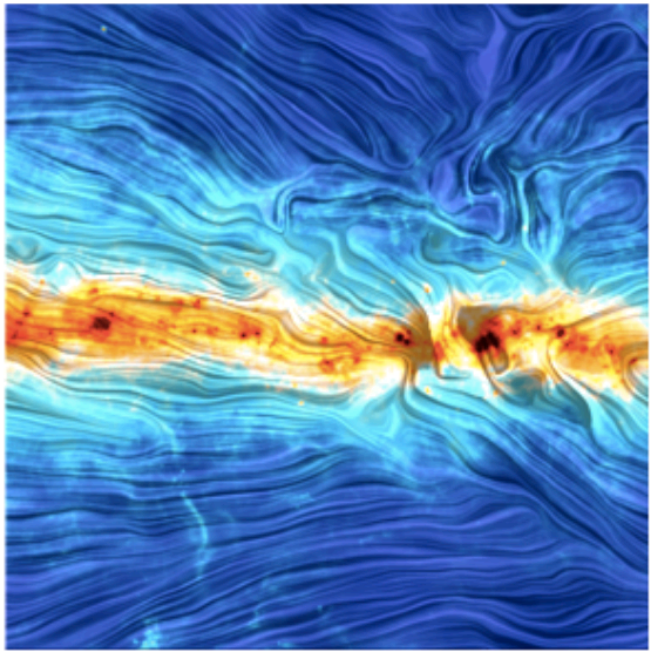


Planck Collab, 2015, 1

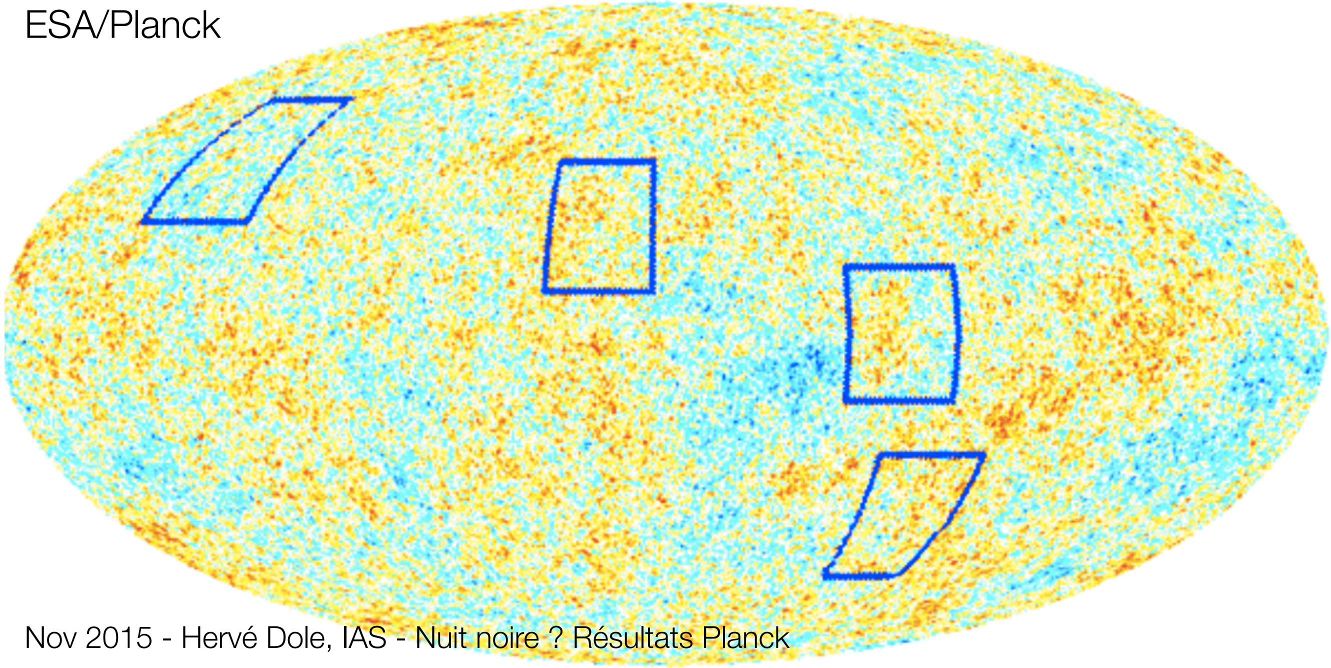
3.1 observations: polarisation 2015 et B

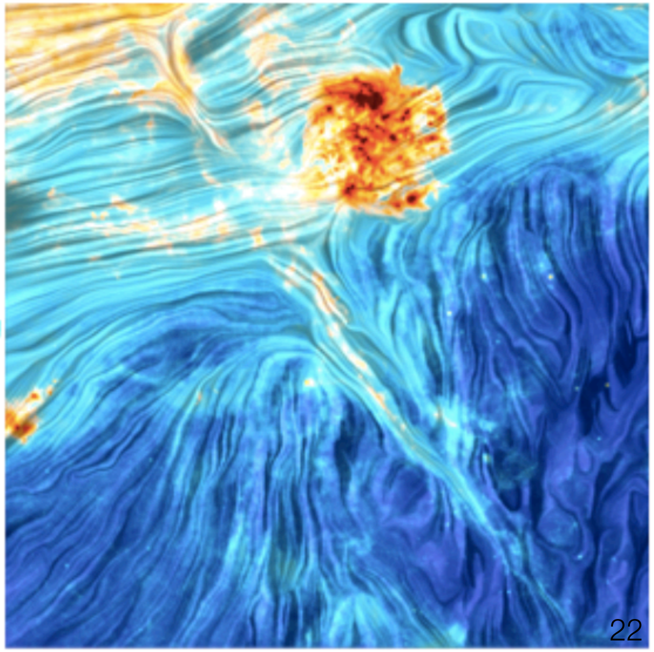




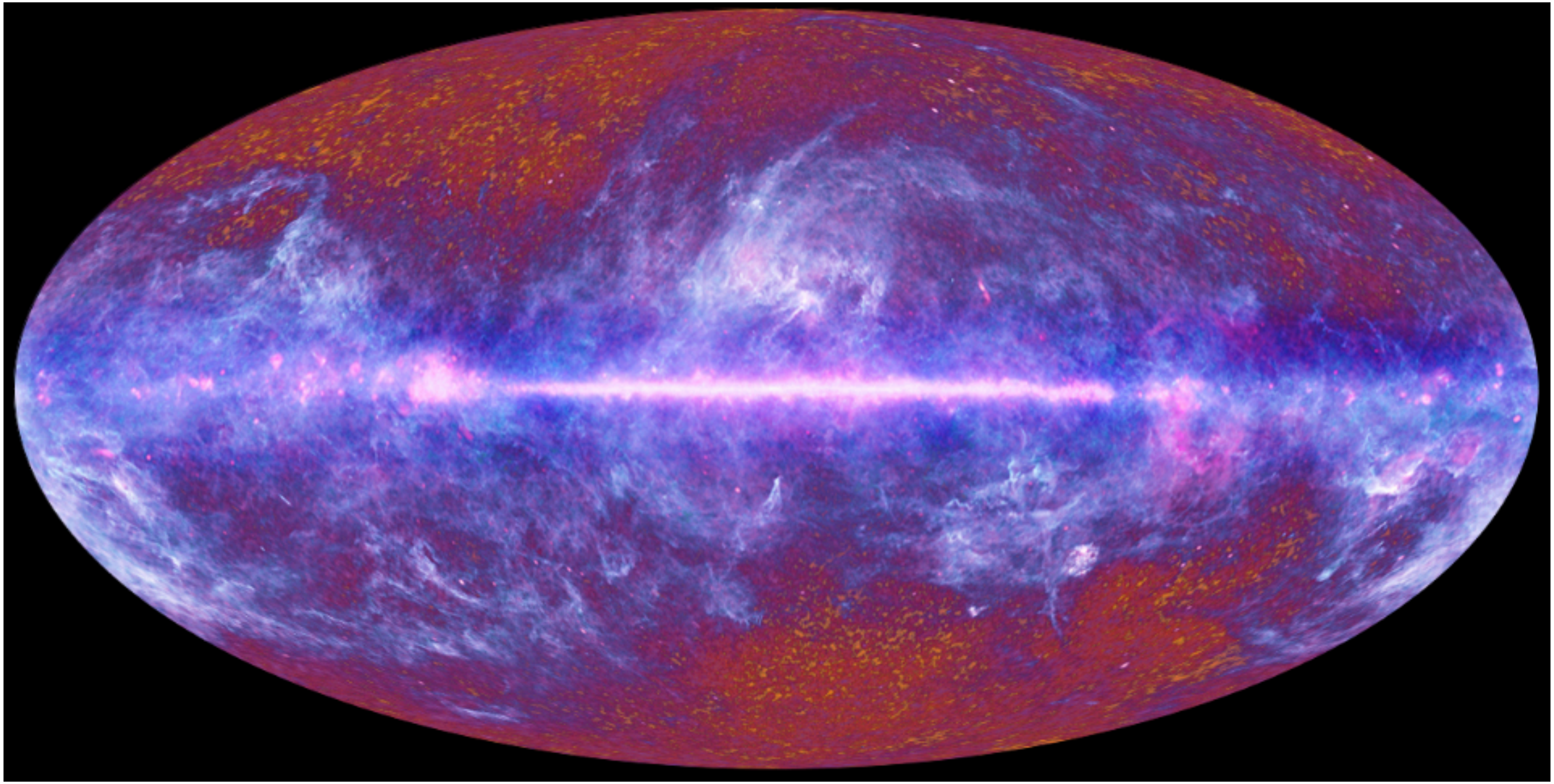


ESA/Planck



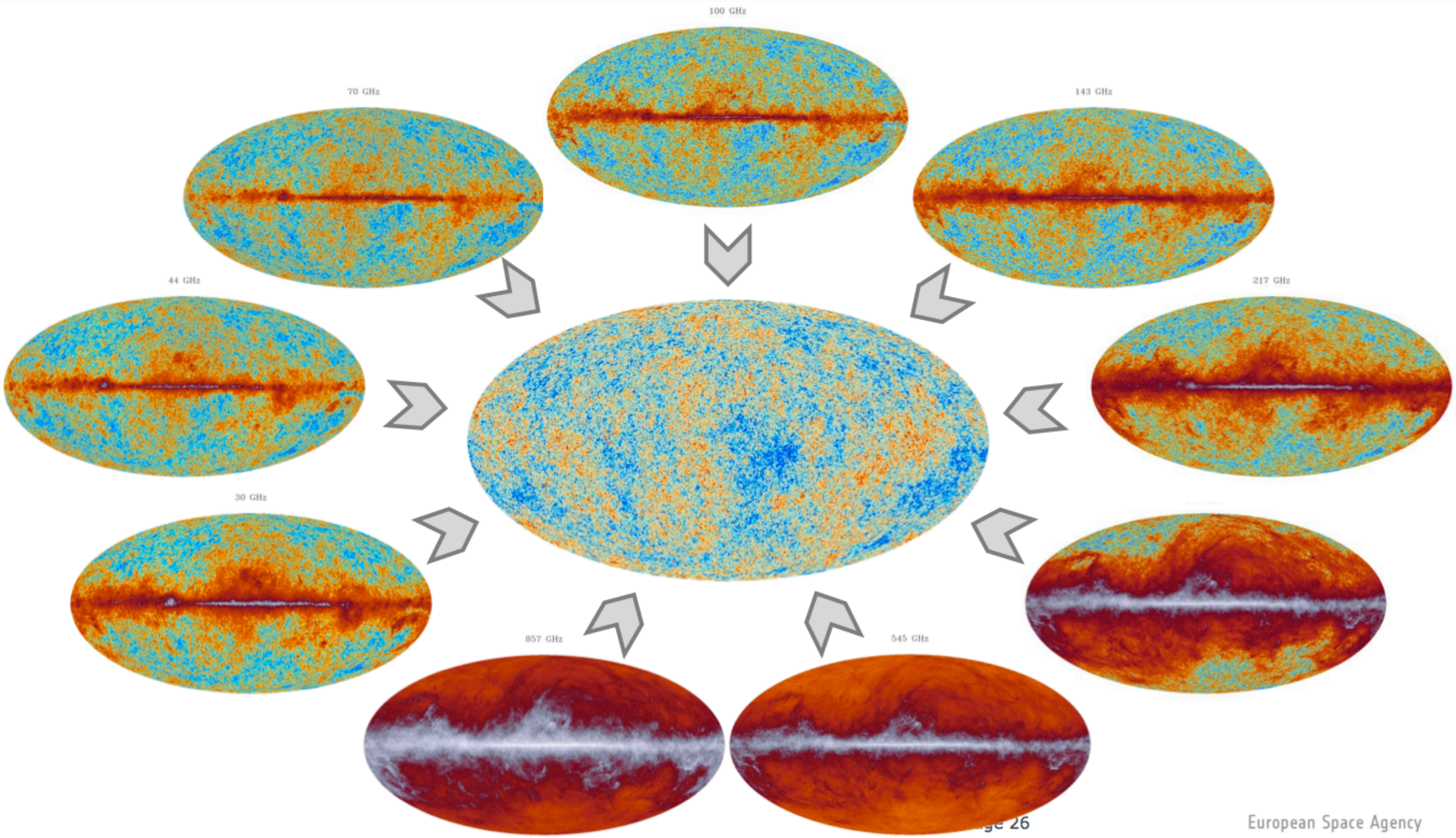


3.2 séparation de composantes

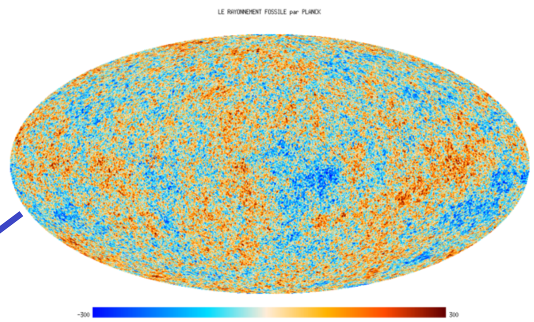


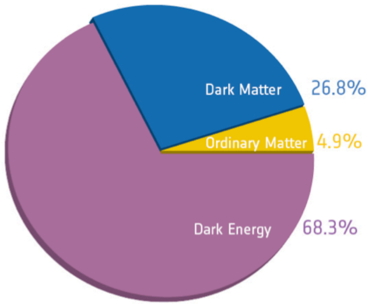
The PLANCK one-year all-sky survey esa

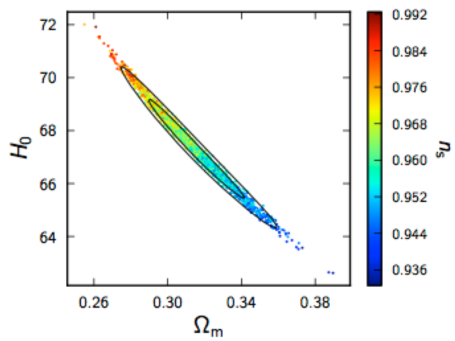
3.2 séparation de composantes

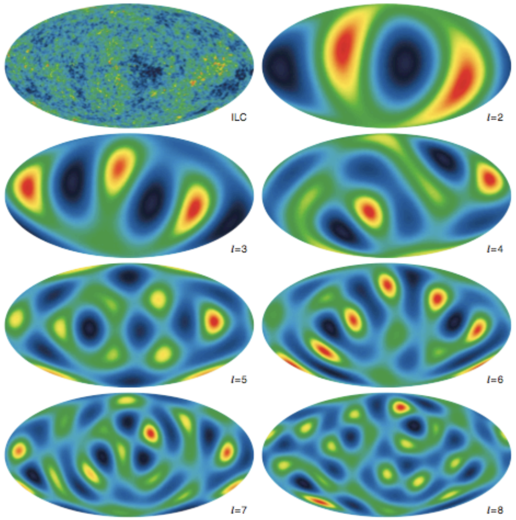


3.3 des cartes aux 6 param. cosmologiques



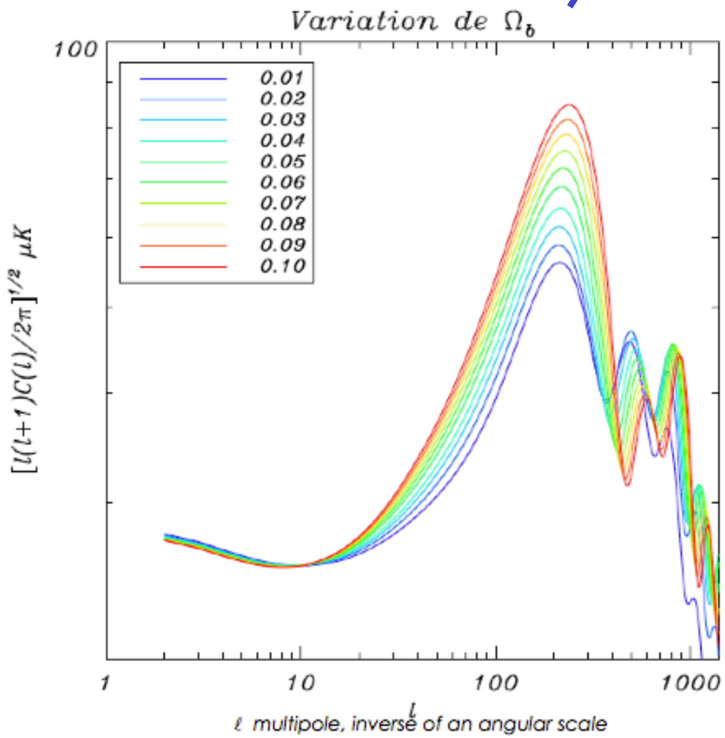




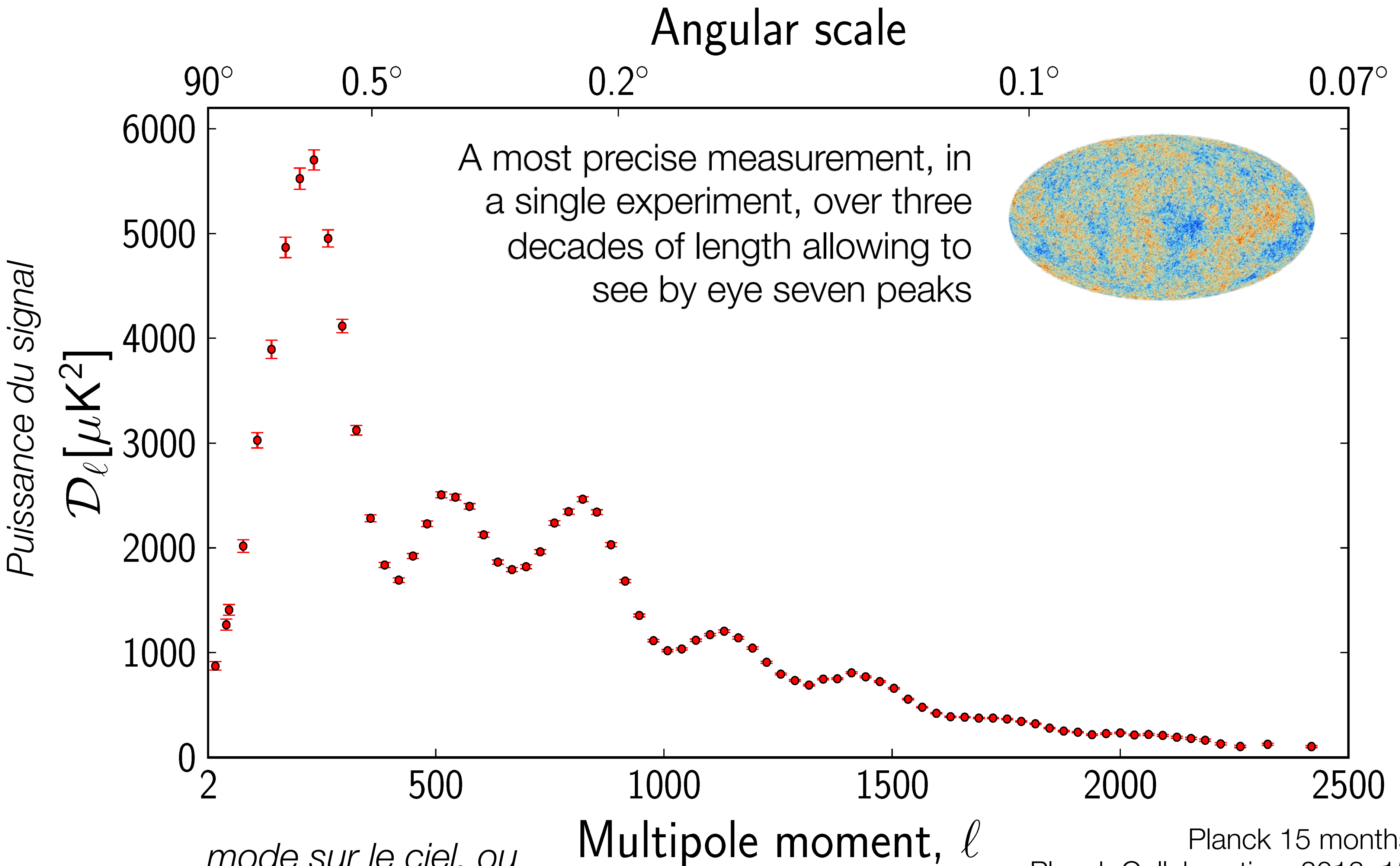


$$\frac{\Delta T(\mathbf{n})}{T_0} = \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} a^T_{\ell m} Y_{\ell m}(\mathbf{n})$$

$$C_\ell^{TT} = \langle a^T_{\ell m} \cdot a^{T\star}_{\ell m} \rangle$$



the Planck power spectrum of temp. anisotropies

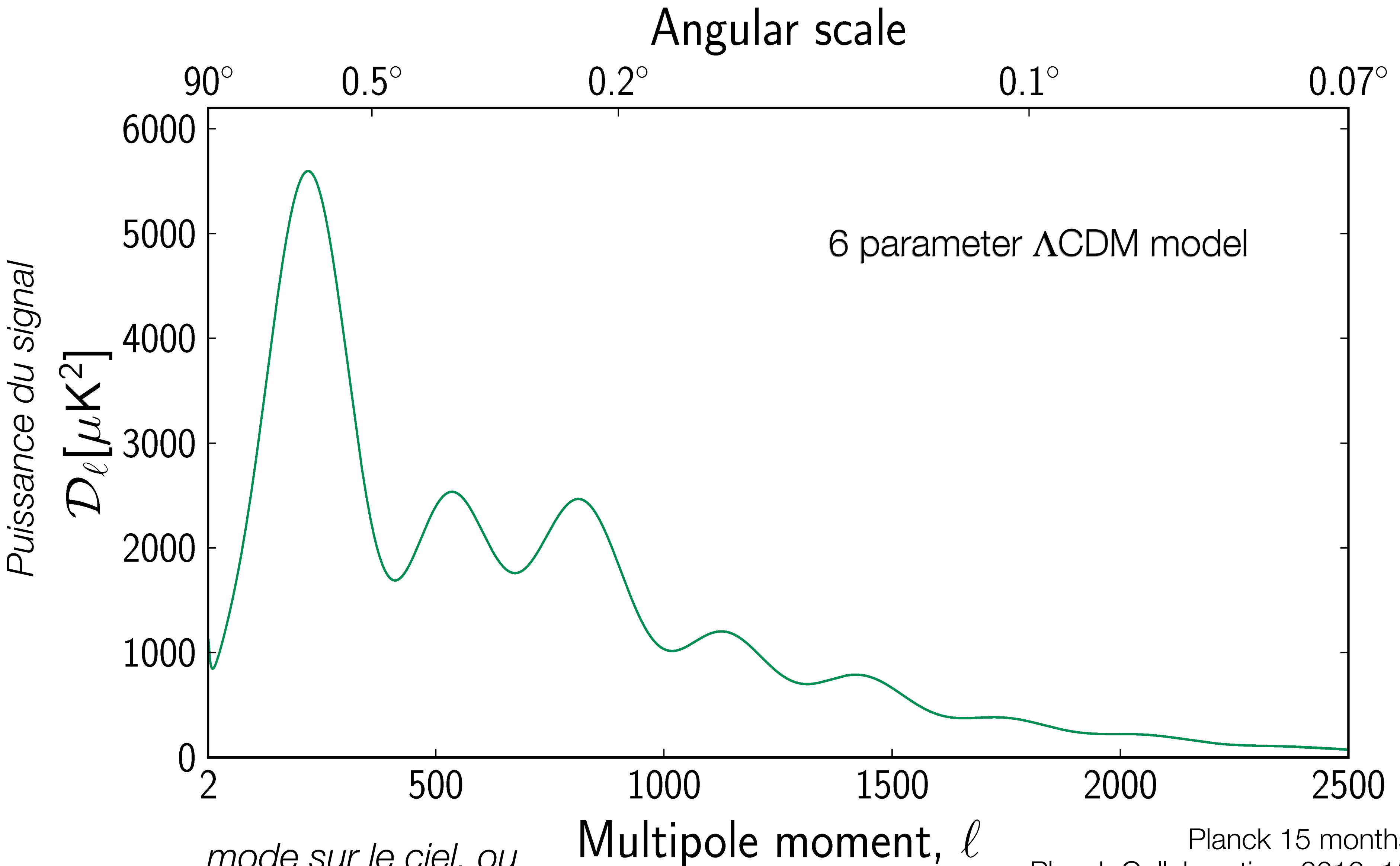


mode sur le ciel, ou inverse de l'échelle angulaire

Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

Planck best fitting theoretical model

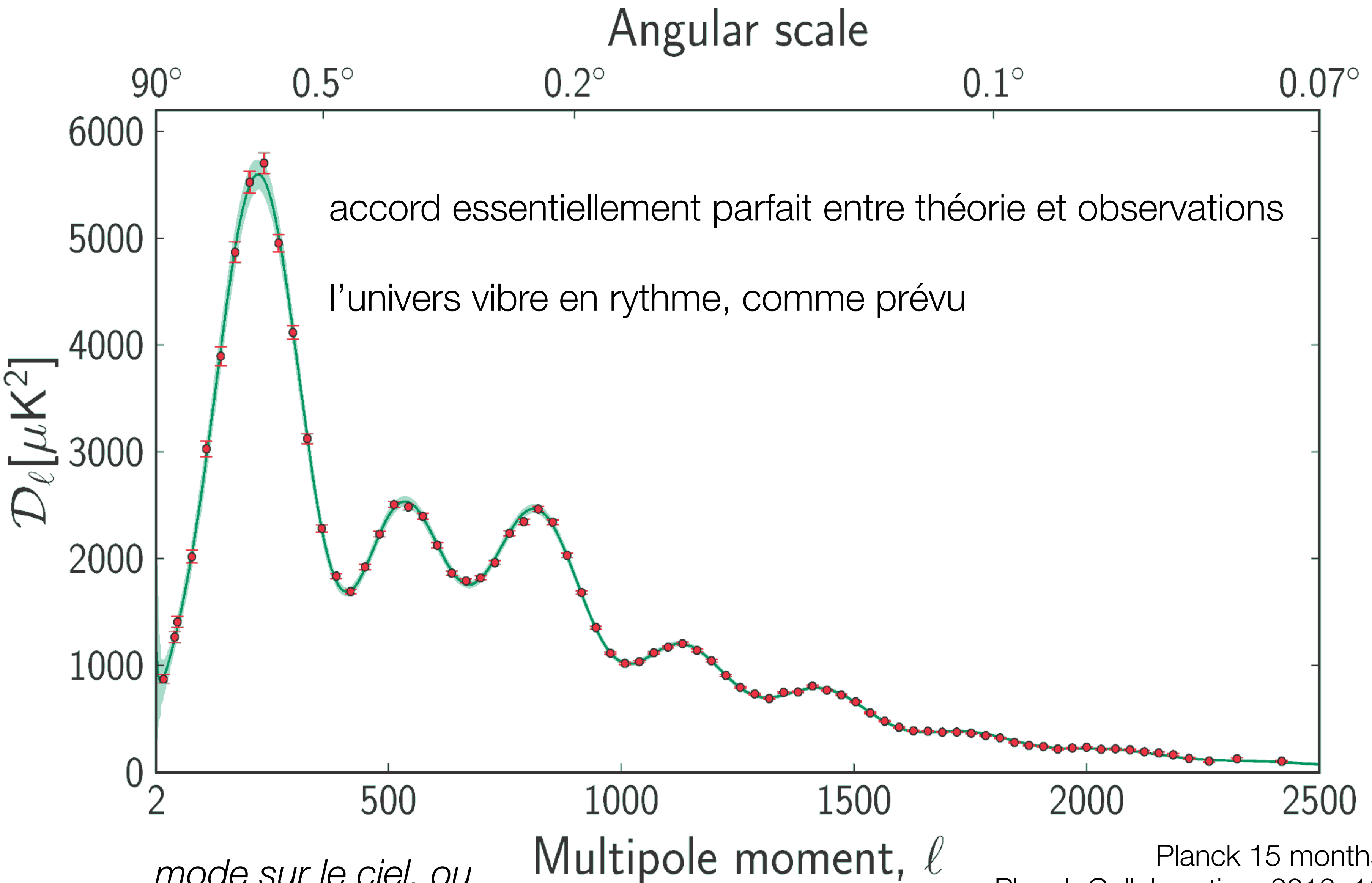


mode sur le ciel, ou
inverse de l'échelle angulaire

Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

theory confronts data



Puissance du signal

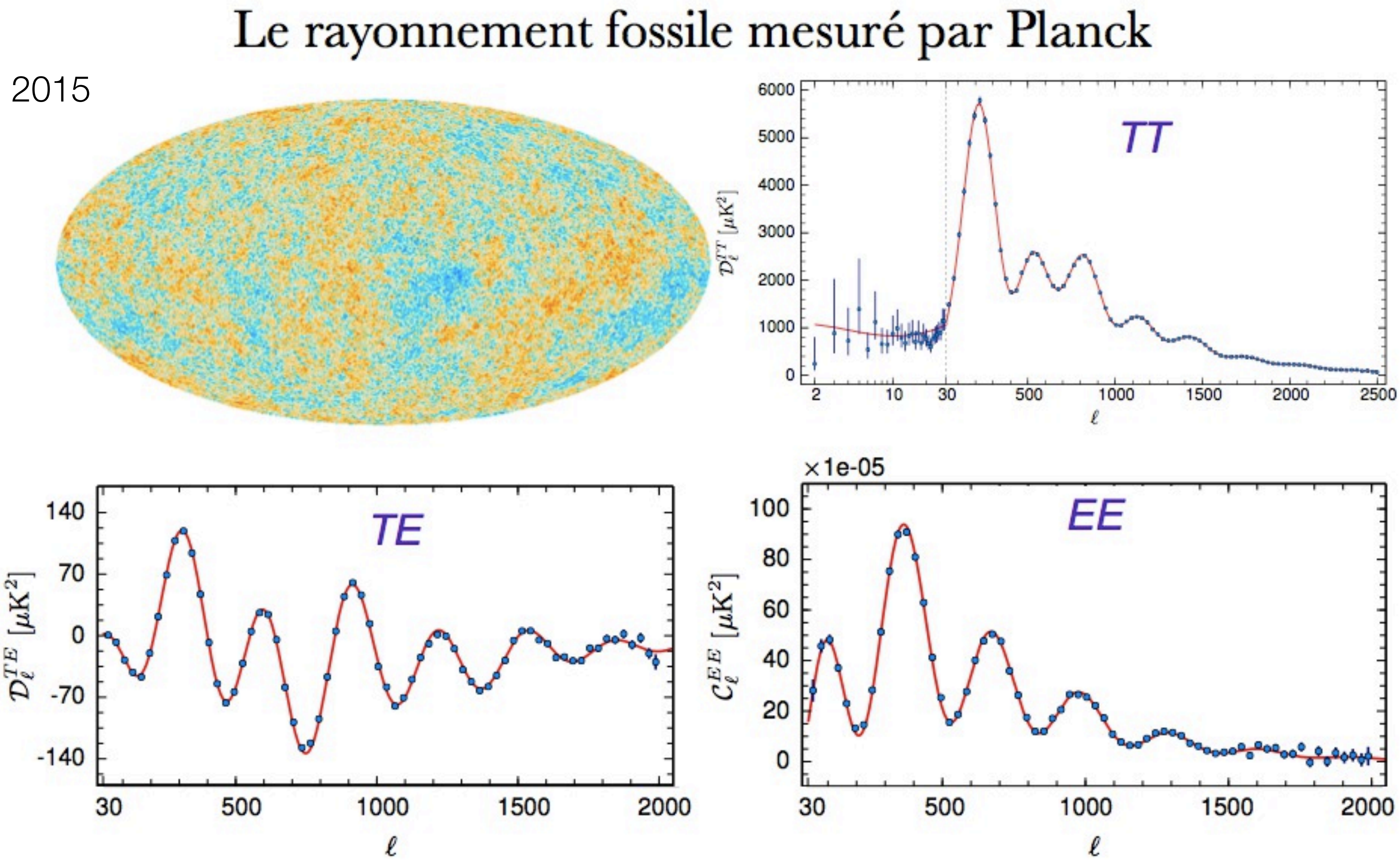
mode sur le ciel, ou inverse de l'échelle angulaire

Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

theory confronts data – from 7 to 19 peaks

2015



Planck 2015

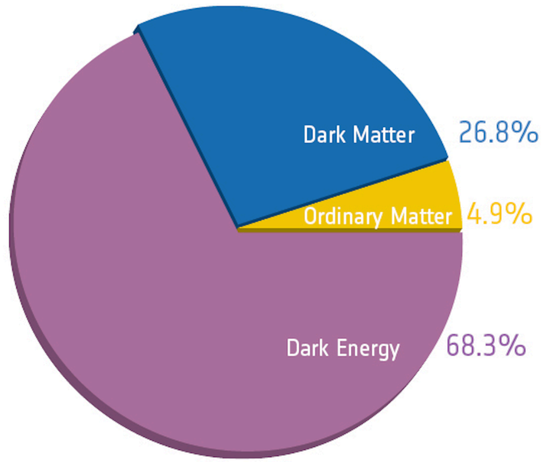
paramètres cosmologiques les plus précis

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	13.799 ± 0.038
r_{drag}	147.60 ± 0.43
k_{eq}	0.01027 ± 0.00014

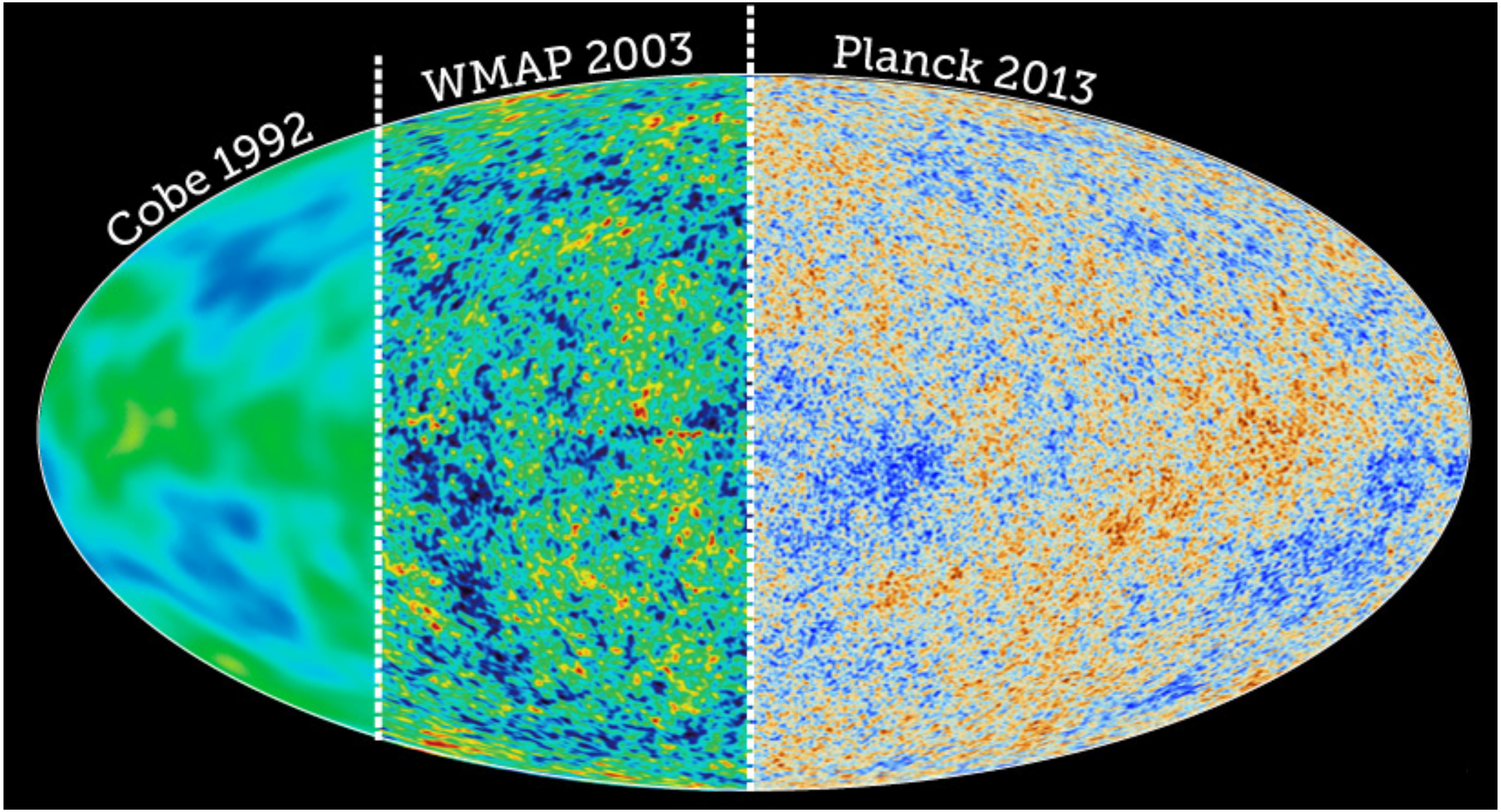
6 cosmological parameters

0.3% incertitude !

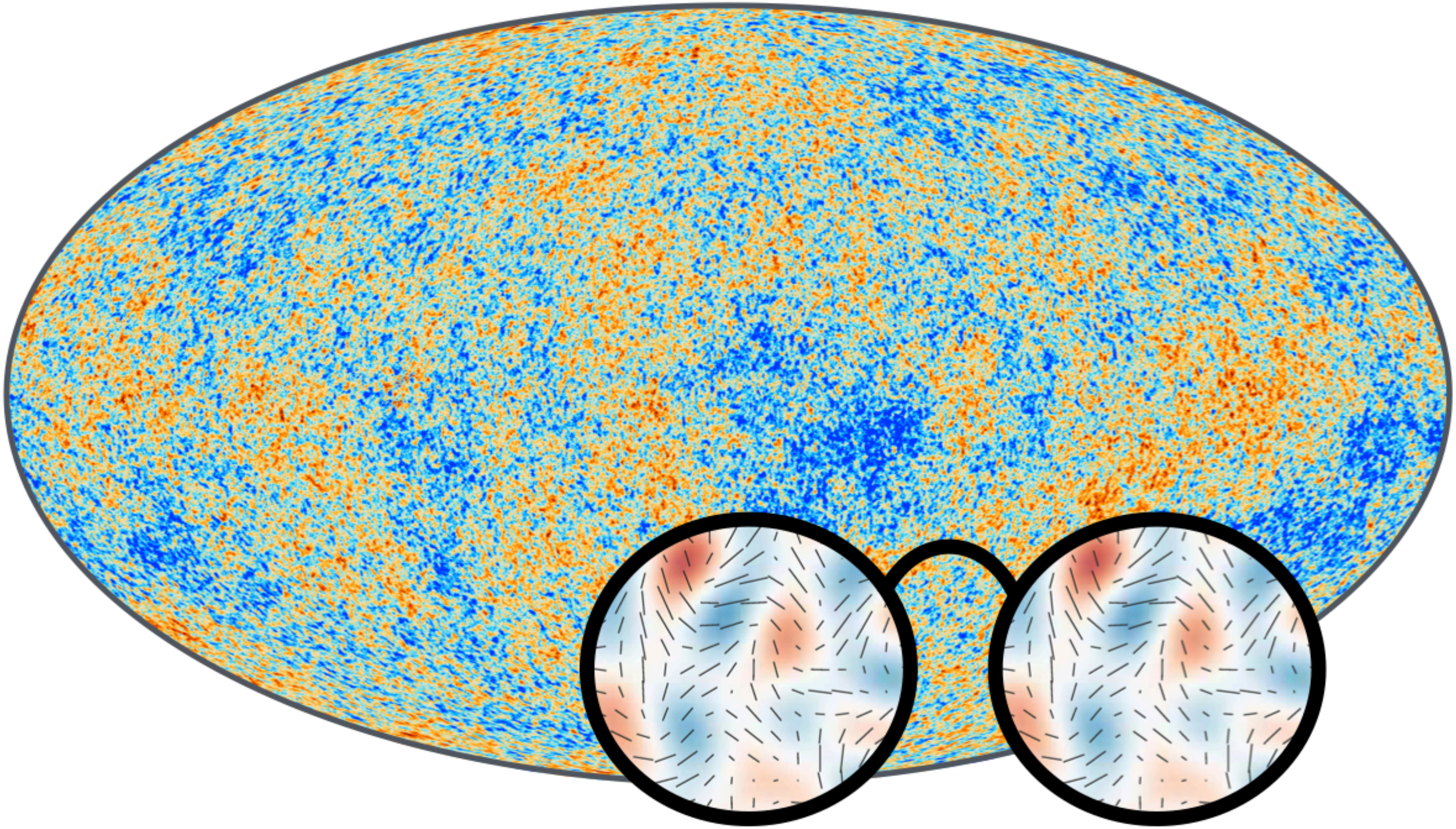


Planck Collab, 2015, 1

3.4 la « révolution » Planck



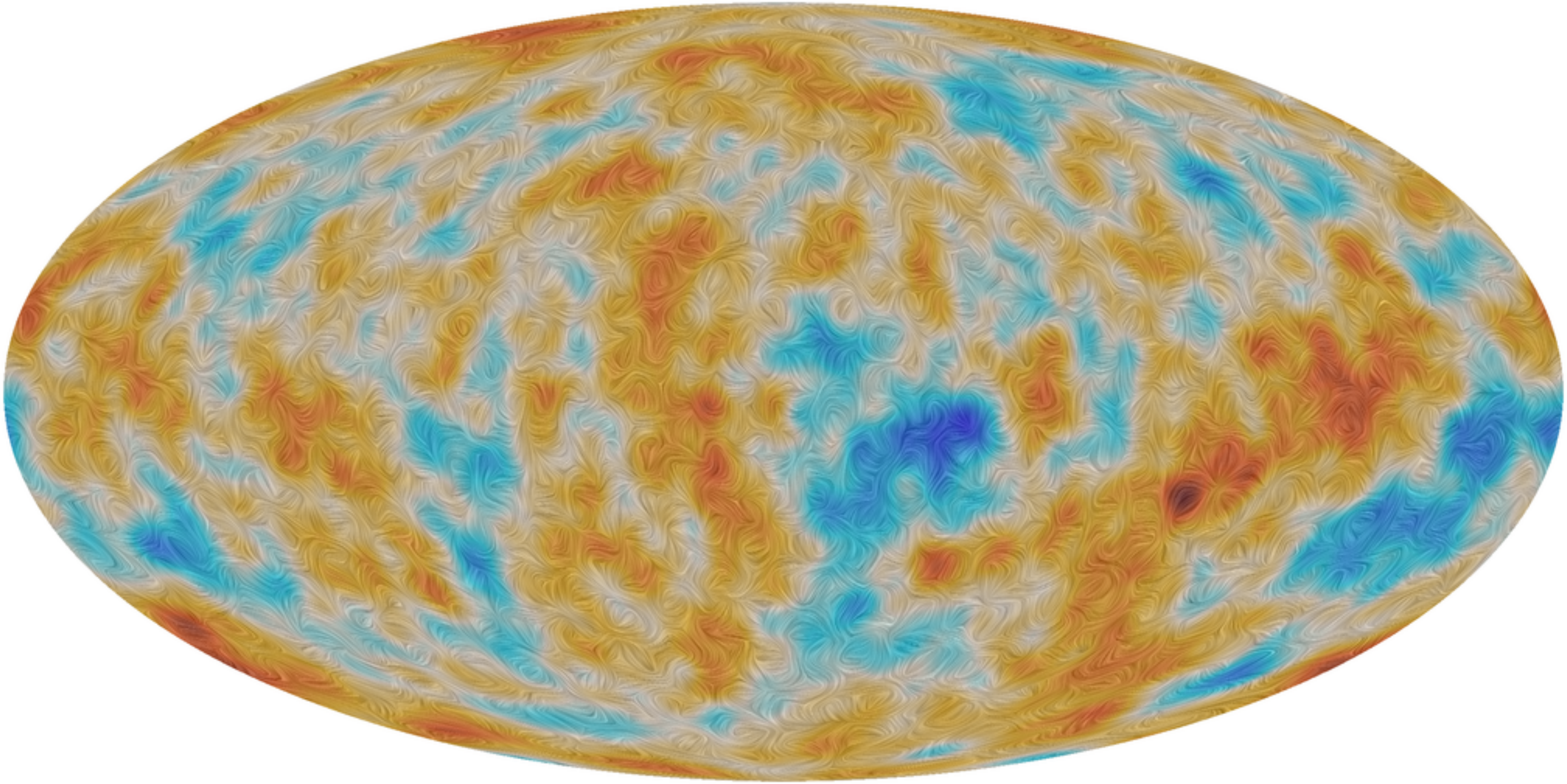
3.5 la polarisation du fond cosmologique



courtesy J. Aumont

les vibrations de l’univers jeune: polarisation

fluctuations de polarisation du rayonnement



Planck Collab, 2015, 1

3.6 inflation 2015

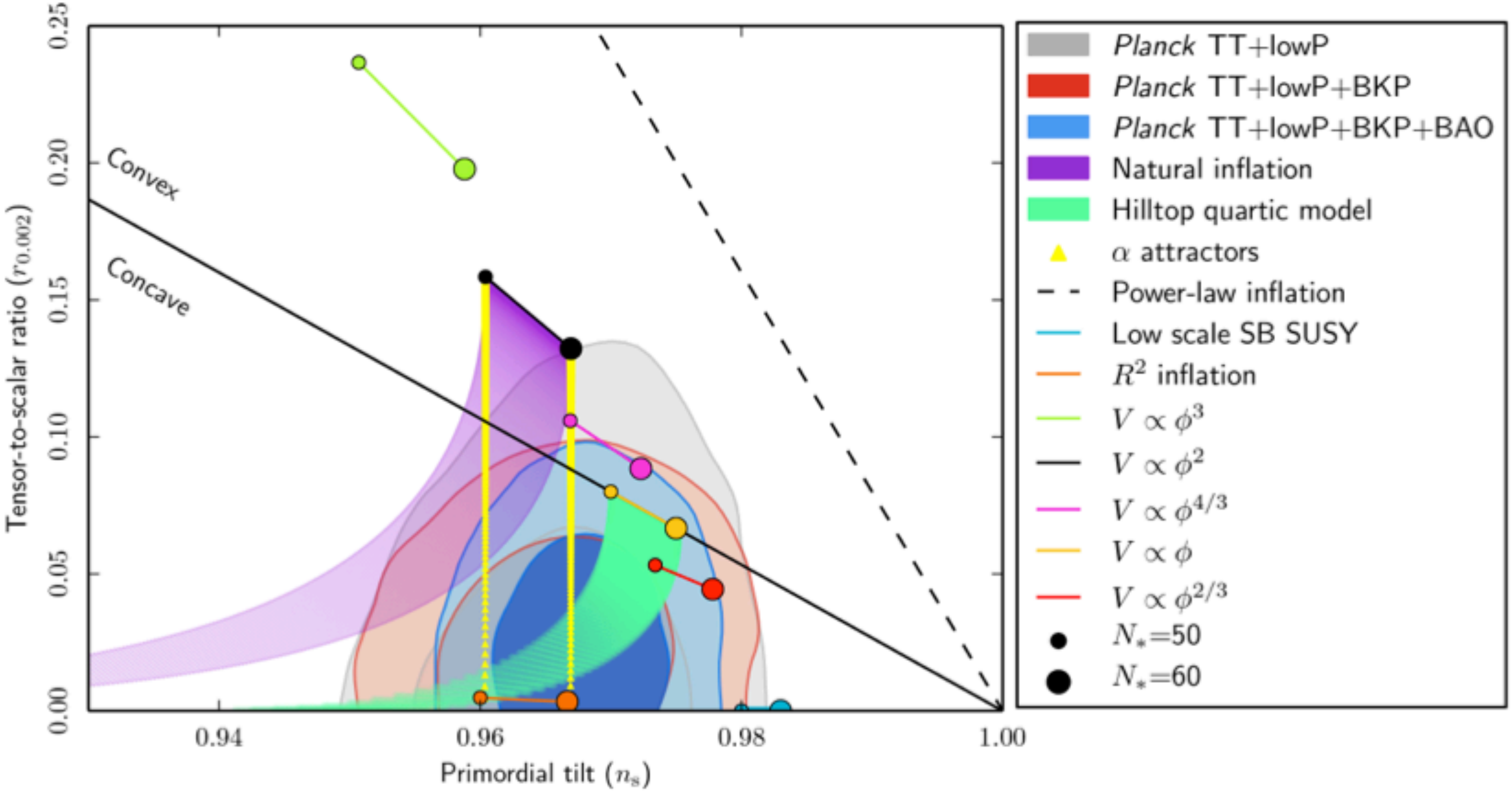
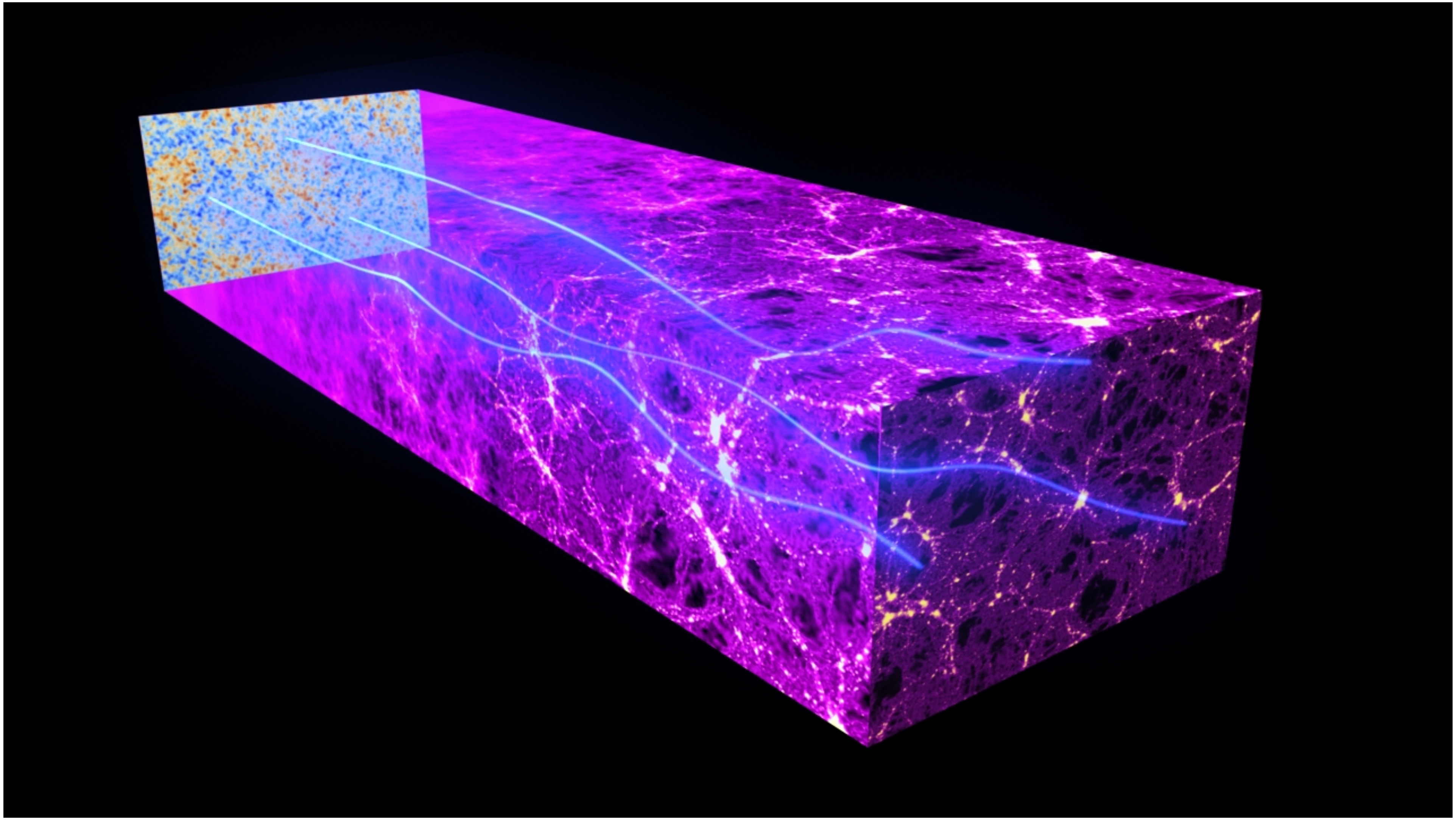


Fig. 54. Marginalized joint 68 % and 95 % CL regions for n_s and $r_{0.002}$ from *Planck* alone and in combination with its cross-correlation with BICEP2/Keck Array and/or BAO data compared with the theoretical predictions of selected inflationary models.

cosmic inflation < 10^{-35} second

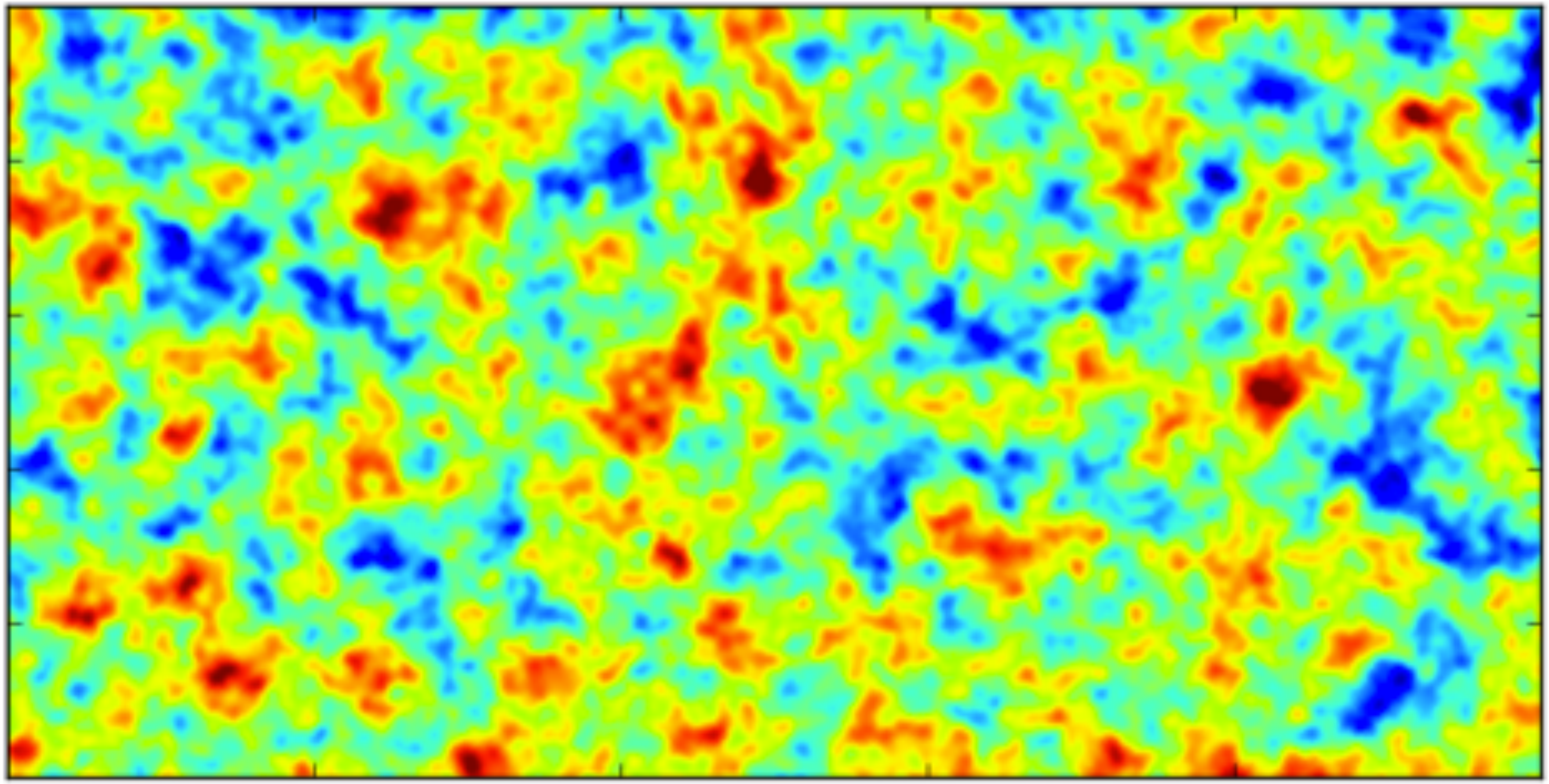
Planck 2015, 20

3.7 Planck révèle l'invisible: la matière noire



3.7 Planck révèle l'invisible: la matière noire

A simulated patch of CMB sky – before lensing



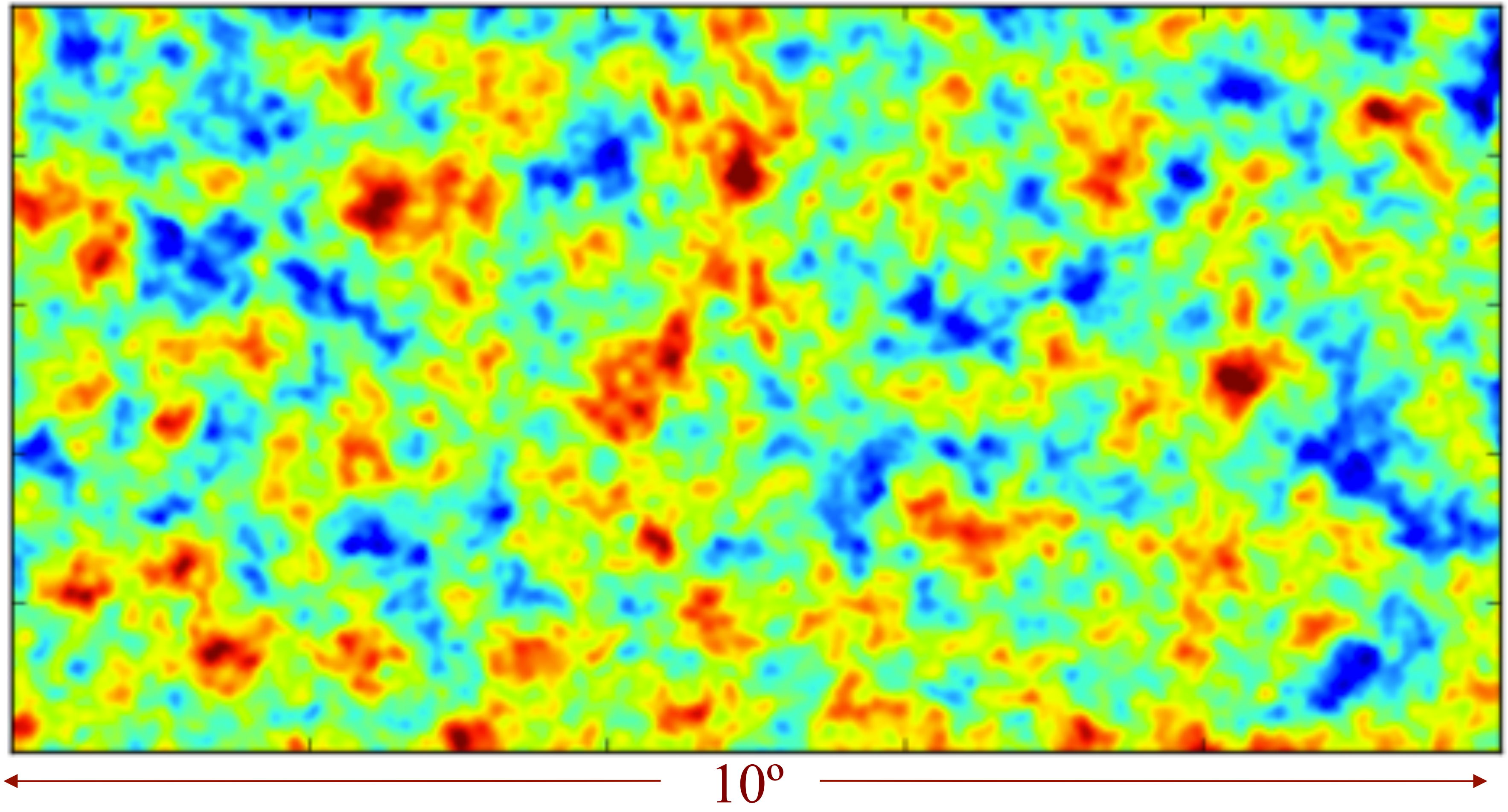
10°

typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

3.7 Planck révèle l'invisible: la matière noire

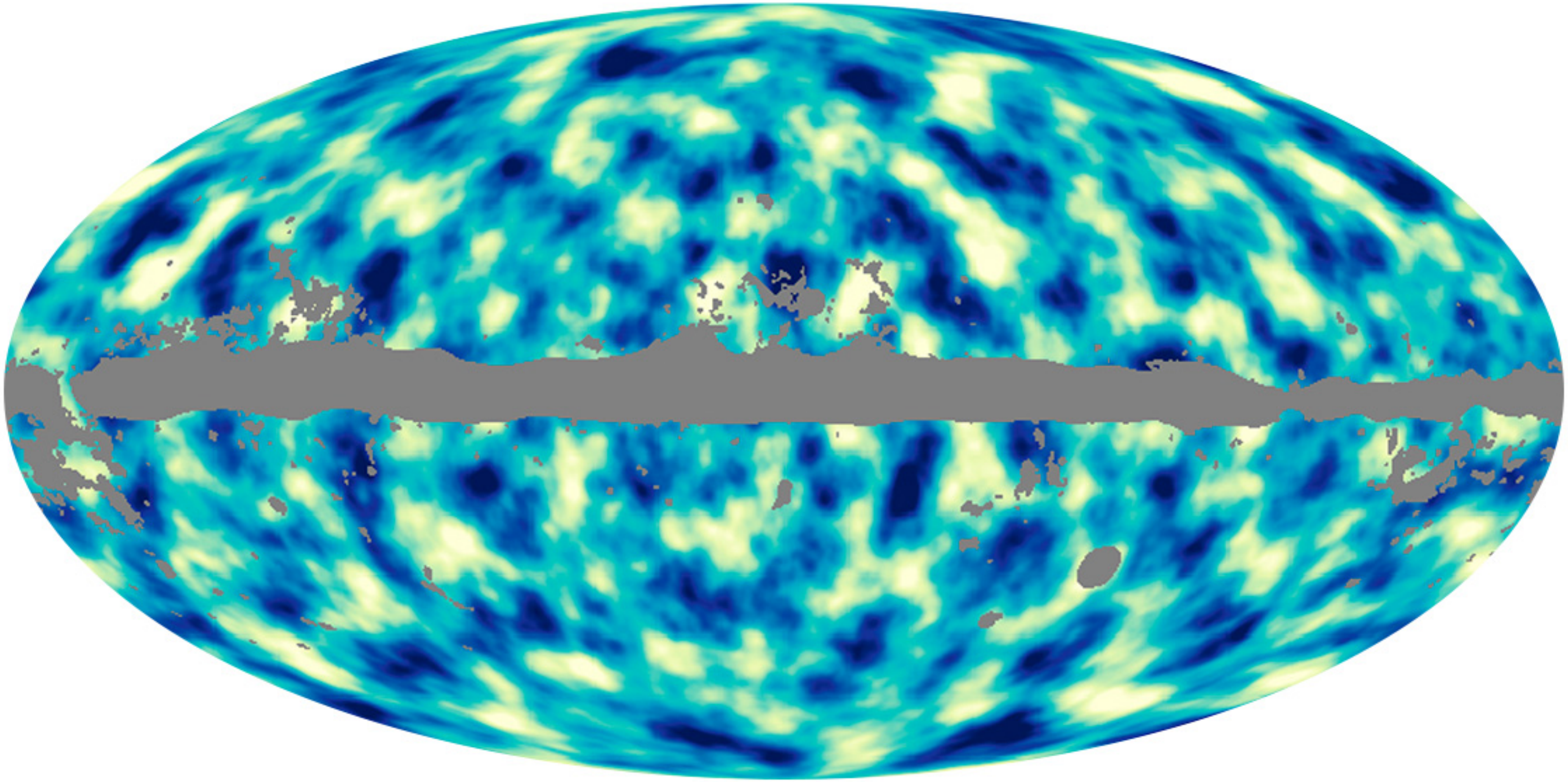
A simulated patch of CMB sky – after lensing



typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

3.7 Planck révèle l'invisible: la matière noire



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

Planck 15 months
Planck Collaboration, 2013, 17


HAVANA DECO
SAVING A CITY'S ARCHITECTURE
PLAYERS UNITED
BIGGER CHECKS ON THE WAY
FLOYD NORRIS
THE FOLLY OF GIANT BANKS
International Herald Tribune
THE GLOBAL EDITION OF THE NEW YORK TIMES
FRIDAY, MARCH 22, 2013
Kurd leader issues a call for cease-fire with Turkey
From jail, Ocalan makes bold move to hasten end of a bitter conflict
Obama asks Israelis and Palestinians to talk again
By not insisting on freeze in settlement activity, he softens his earlier stance
The infant universe
Once rarity, women are U.S. Senate force
THE FEMALE FACTOR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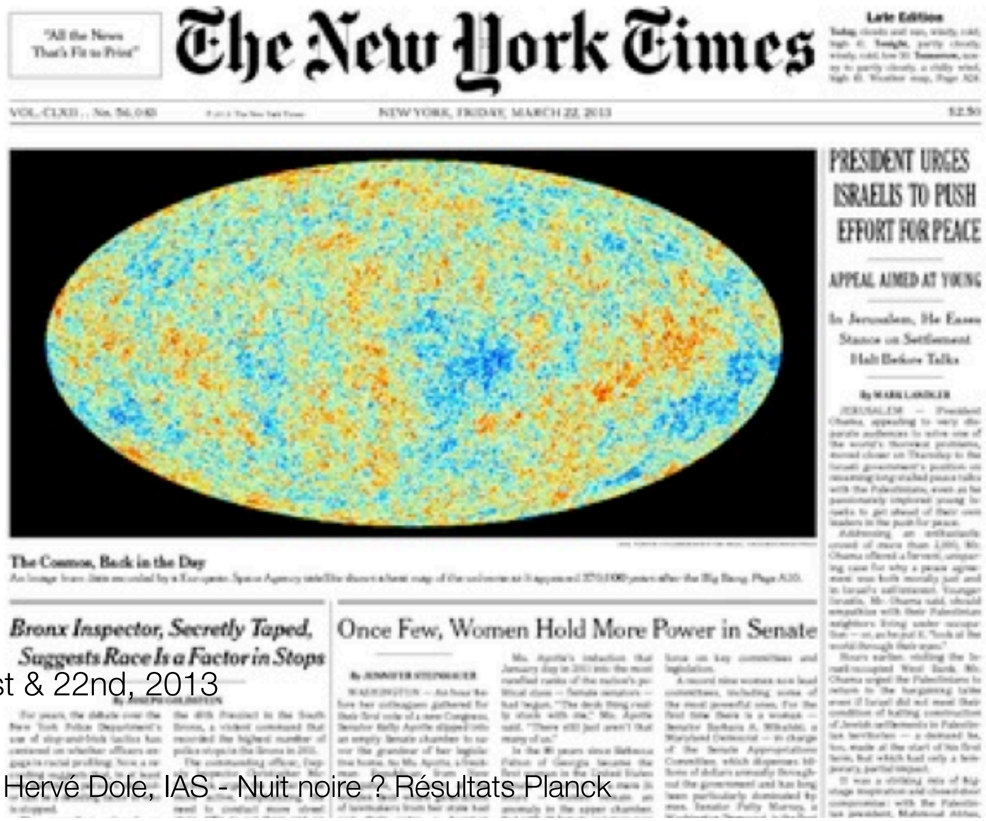
Le Monde
CRISE CHYPRIOTE : L'ULTIMATUM DE FRANCFORT
En Tunisie, le drame des disparus de la révolution
DES GTI POUR ROU DES MÉCANIQUES
Vendredi 22 mars 2013
Moins d'impôts et plus d'austérité, Londres persiste
Le Royaume-Uni fait cavalier seul en matière fiscale et décide 13 milliards d'euros de coupes budgétaires
En panne de croissance comme le reste de l'Europe, Londres mise toujours plus sur la Banque d'Angleterre
L'efficacité des politiques d'austérité en question
C'ÉTAIT L'UNIVERS IL Y A 13,8 MILLIARDS D'ANNÉES
Des images inédites du satellite européen Planck dévoilent l'enfance du monde. Ni étoile ni galaxie, mais des particules microscopiques, des électrons et des protons
LE MONDE DES LIVRES
Spécial Salon du livre de Paris
Le pari de Cameron : politique de l'offre contre récession
AUJOURD'HUI
Image du rayonnement primordial de l'Univers prise par le satellite européen Planck.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NEW YORK, FRIDAY, MARCH 22, 2013
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APPEAL AIMED AT YOUNG
In Jerusalem, He Eases Stance on Settlement Halt Before Talks
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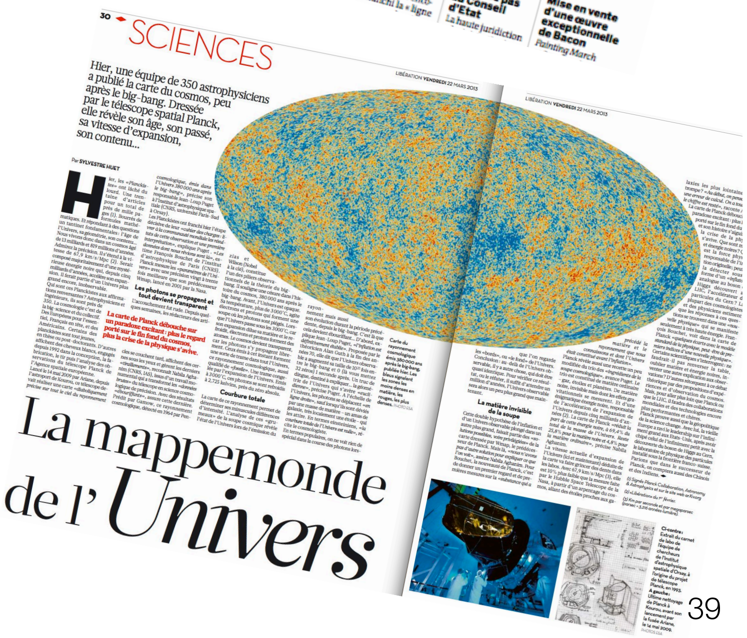
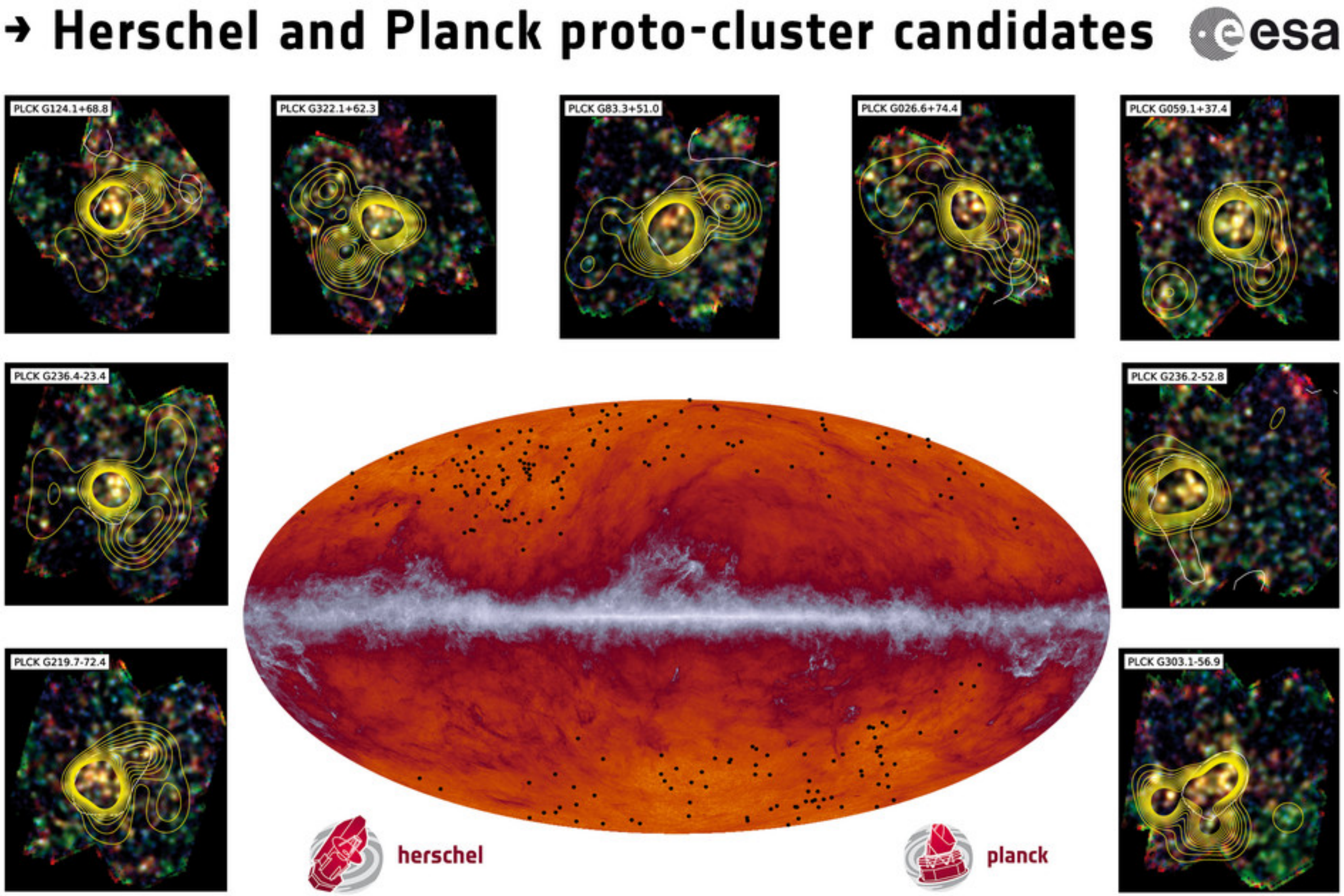
Once Few, Women Hold More Power in Senate


SCIENCES
Hier, une équipe de 350 astrophysiciens a publié la carte du cosmos, peu après le big-bang. Dressée par le télescope spatial Planck, elle révèle son âge, son passé, sa vitesse d'expansion, son contenu...
La mappemonde de l'Univers

March 21st & 22nd, 2013

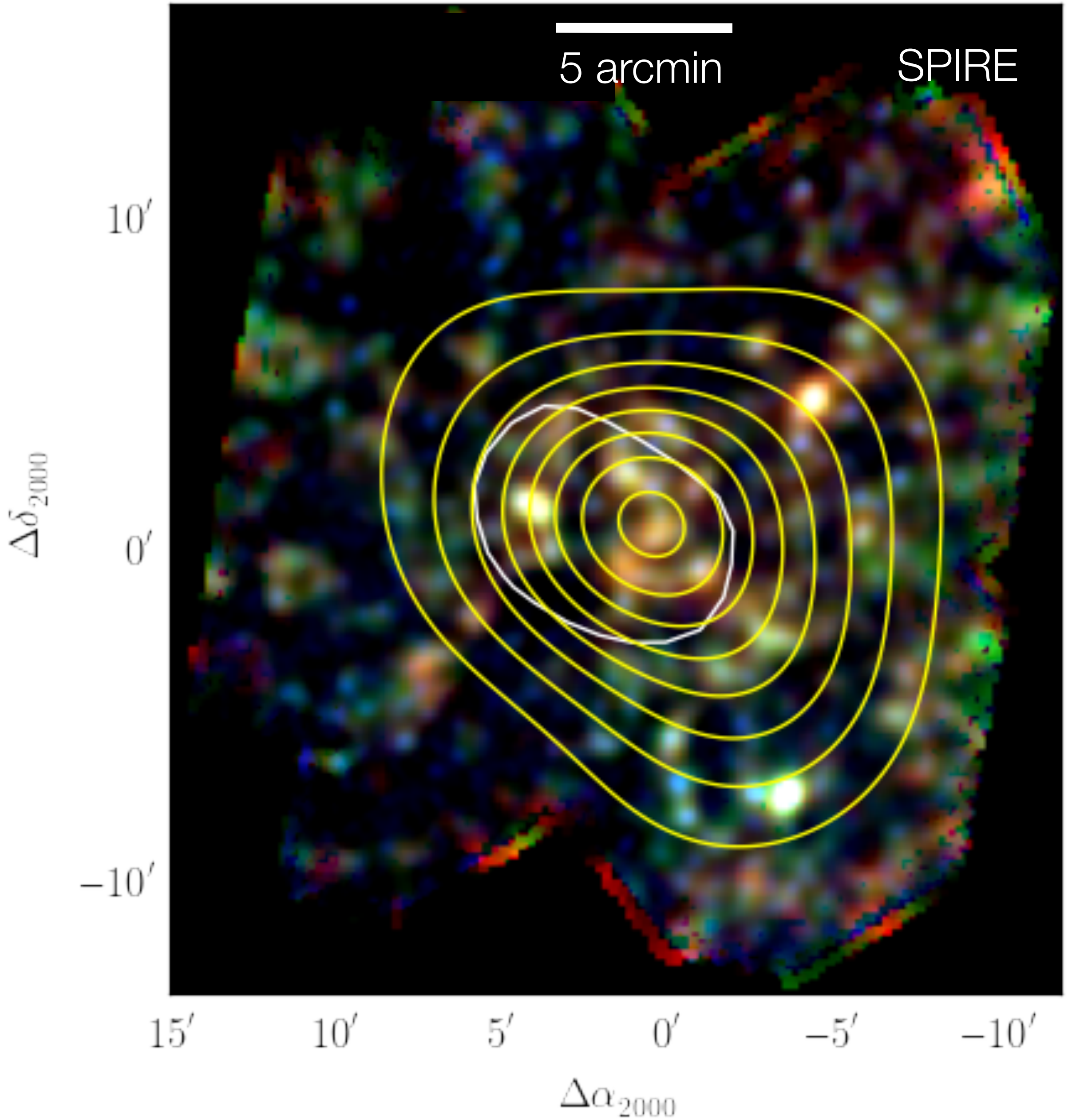
4. des galaxies en rythme et à l'unisson ?



Communiqué de presse ESA, NASA, A&A, INSU 31 mars 2015
Planck Collab. Int., 2015, XXVII

the case of one field: Spitzer

Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um

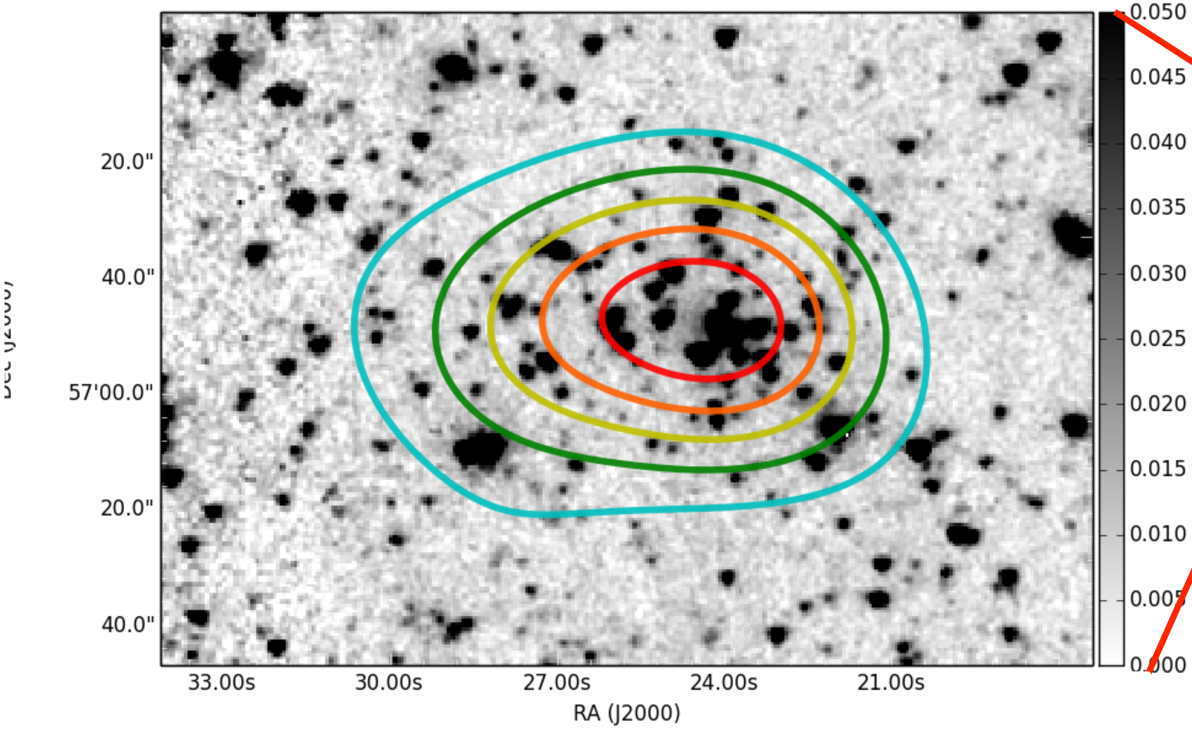


the case of one field: Spitzer

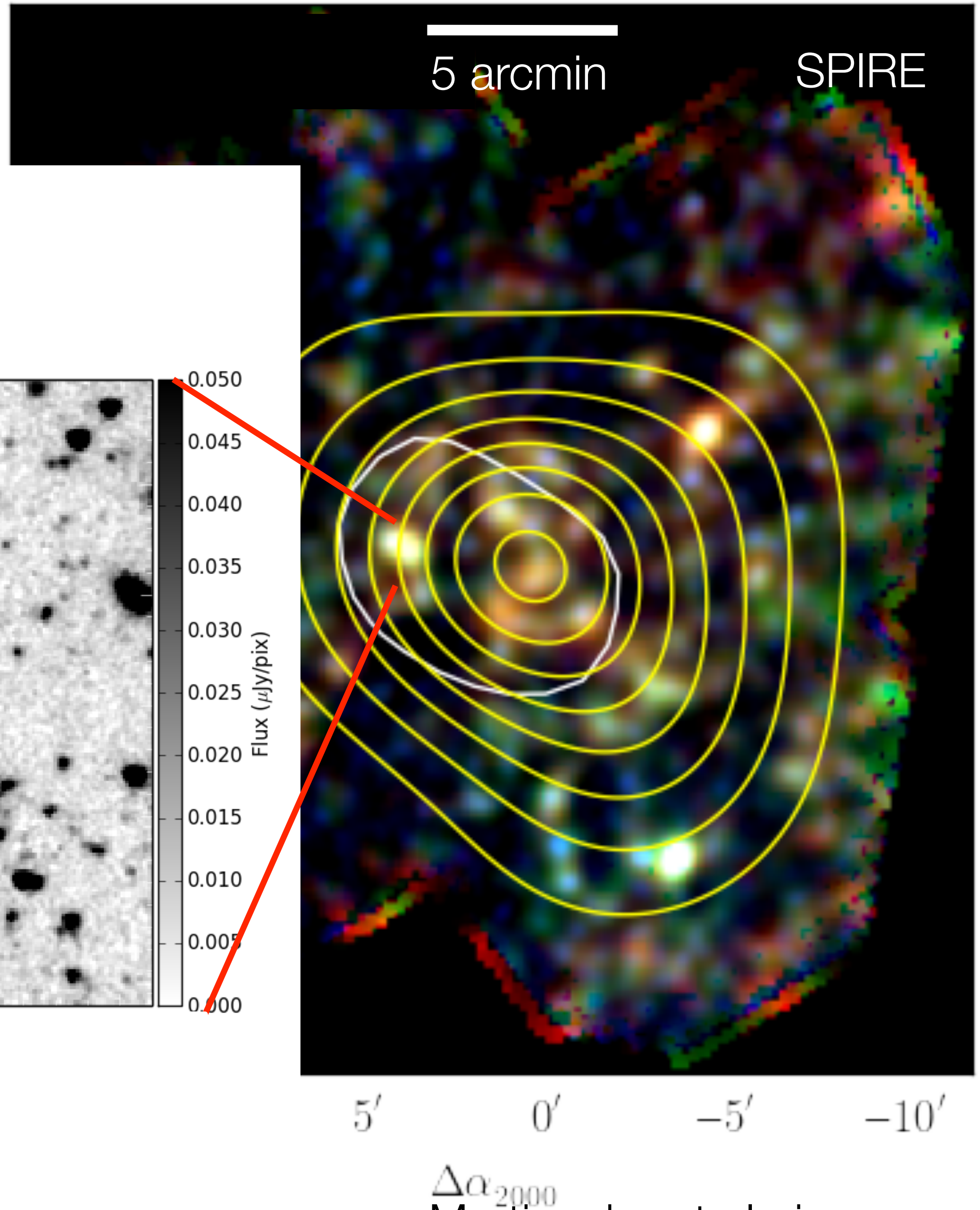
Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um

Euclid will provide this kind of sensitivity over the whole sky !
JWST and WFIRST much better, on smaller sky areas !

IRAC 30 arcsec



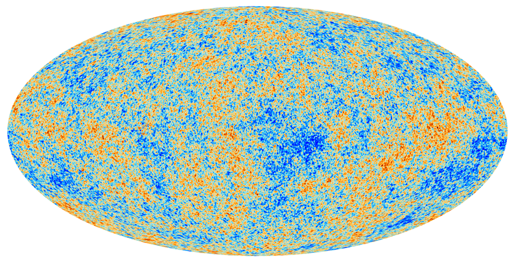
IRAC image at 3.6um

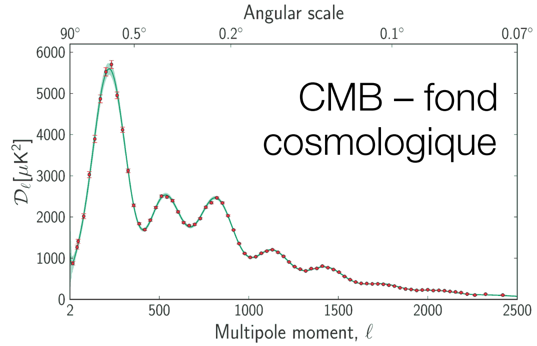


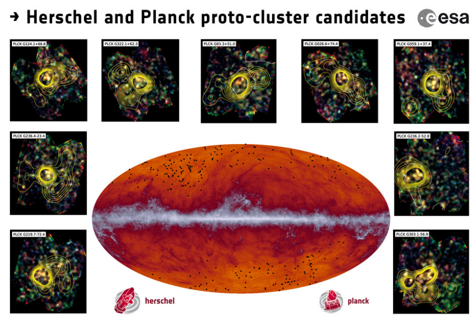
Martinache et al., in prep

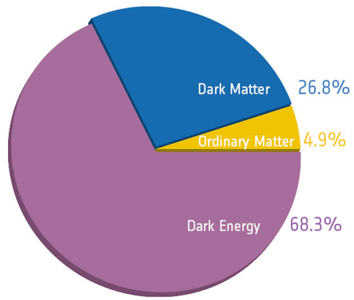
en conclusion: le rythme de l'univers

- L'univers jeune vibre à toutes les échelles, surtout aux grandes
- Les traces de ces vibrations se retrouvent aujourd'hui dans les galaxies
- Prédictions et mesures en accord avec grande précision
- Découverte de galaxies concentrées: la piste des proto-amas de galaxies ?
- De grandes questions demeurent
  - Existence et nature de la matière noire ?
  - Nature de l'énergie sombre ?
  - Scénario de l'inflation cosmique ?
  - Formation des galaxies ?
  - Perspectives: Euclid (ESA) en 2021

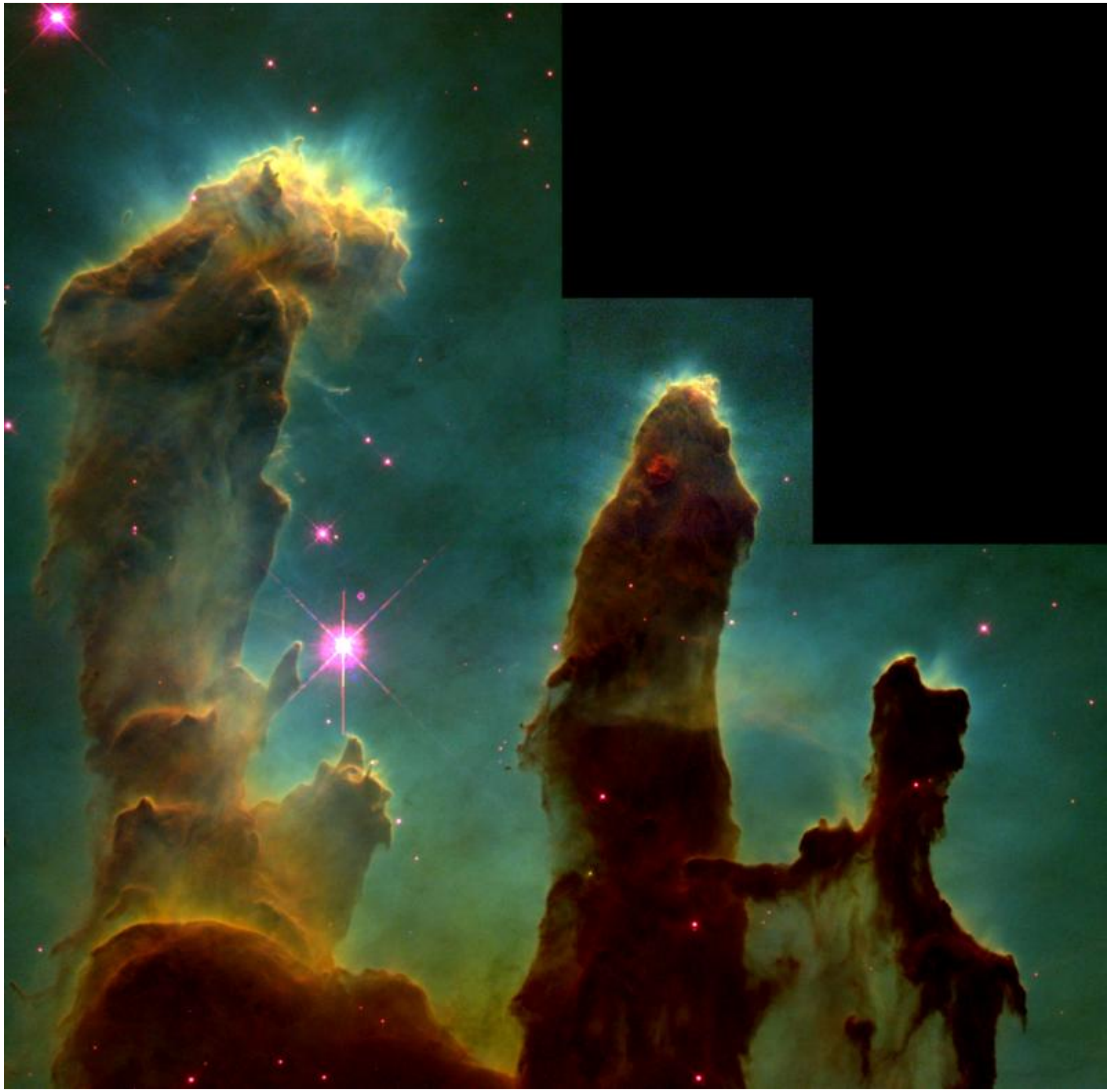






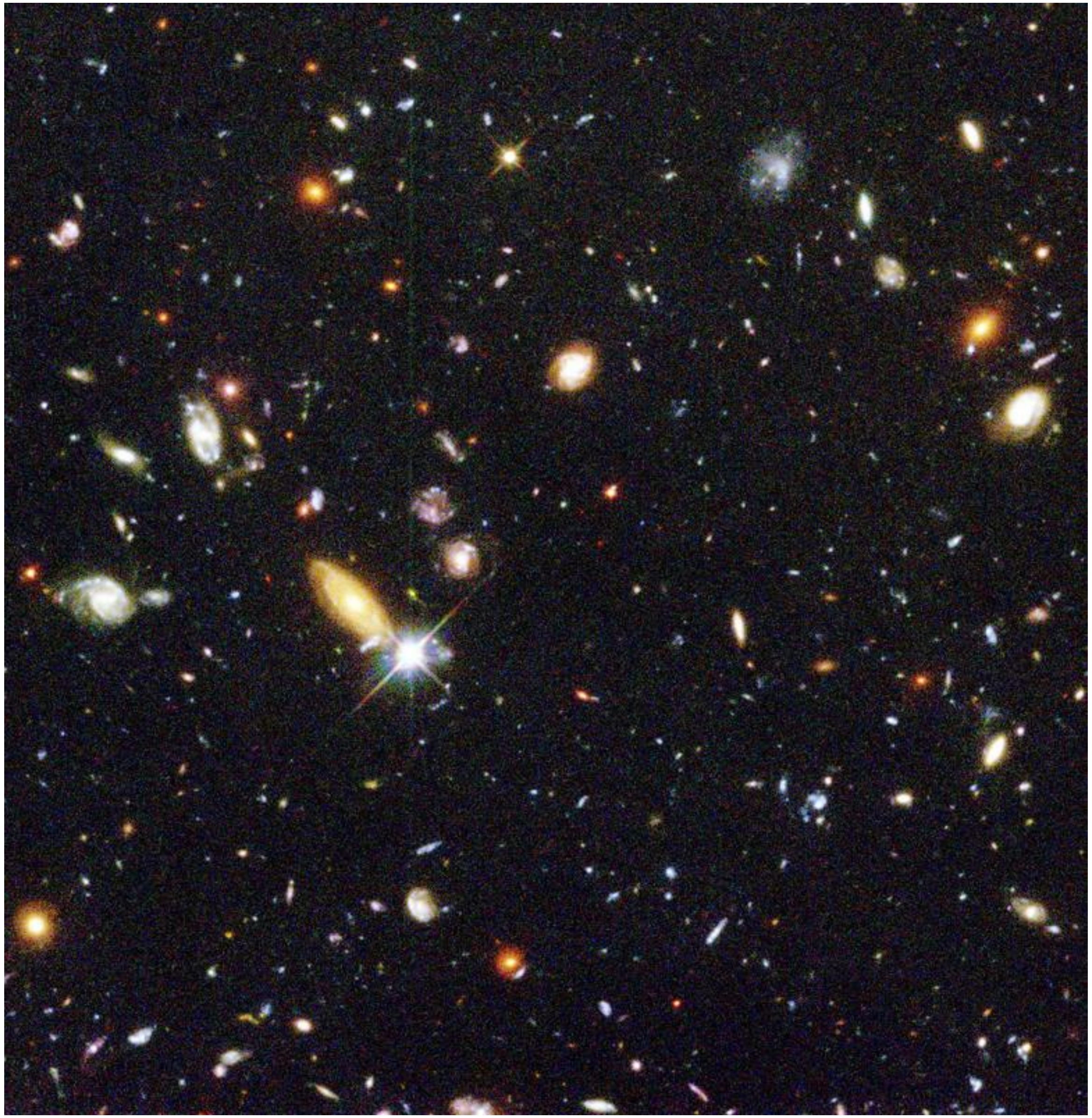


remarques finales



Hubble, 1995

remarques finales



Hubble, 1996

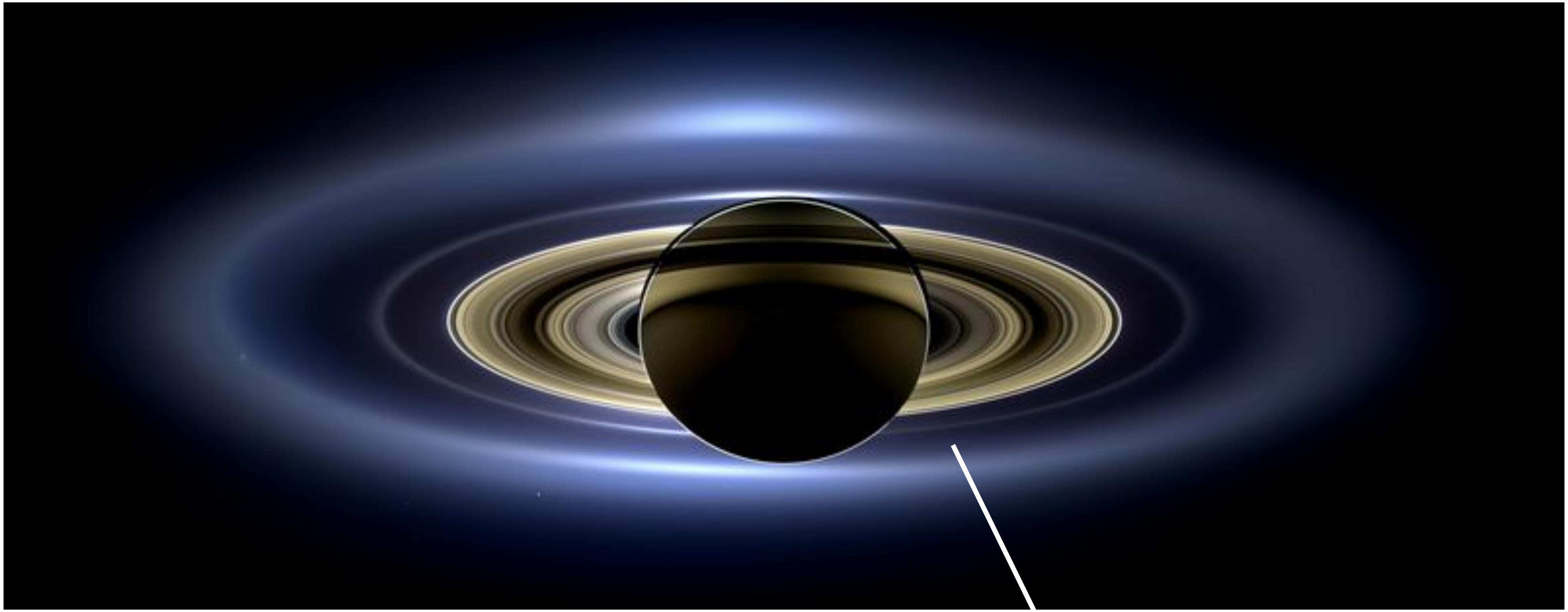
remarques finales

Spirit, mai 2005

remarques finales

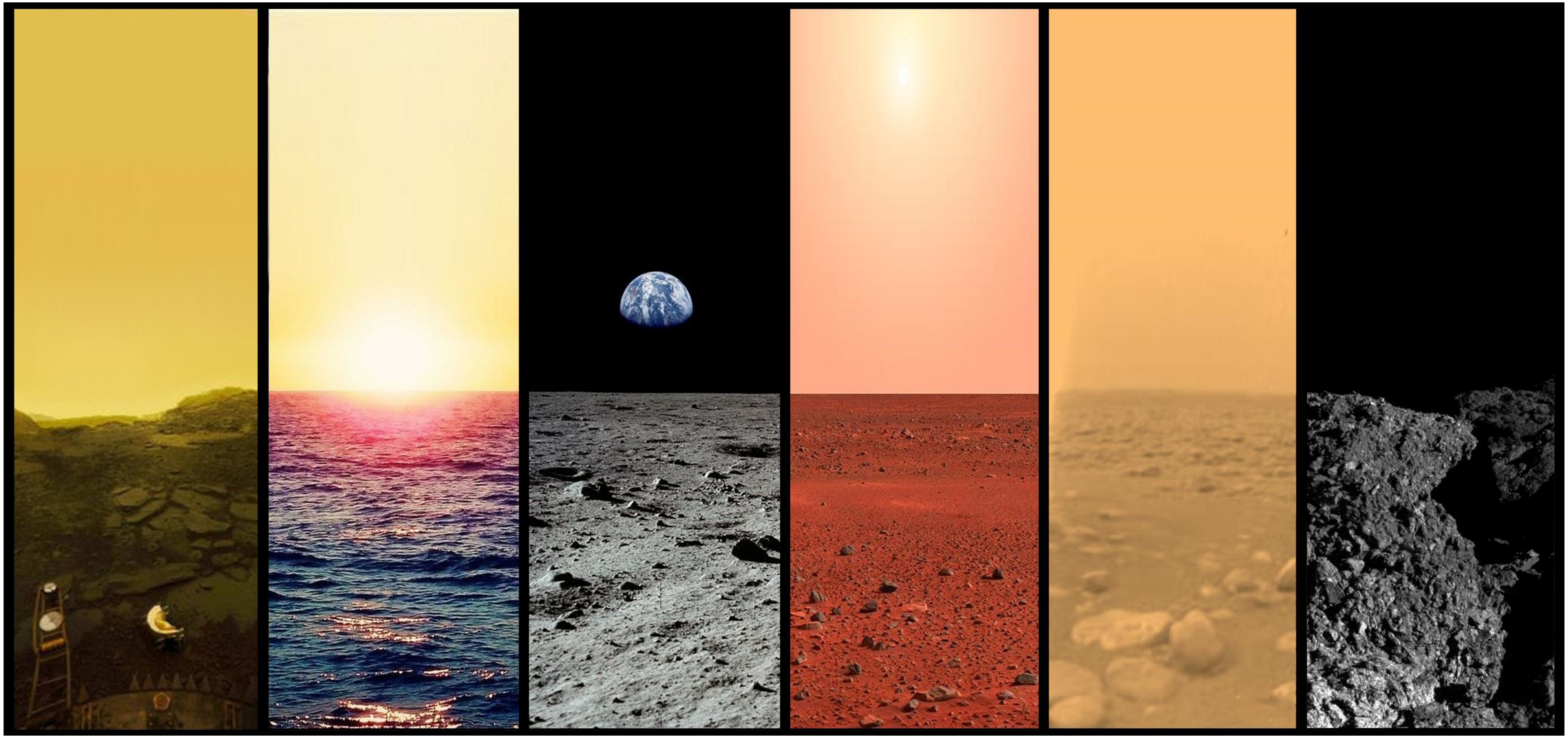
Spirit, mars 2004

remarques finales



Cassini, nov 2013

remarques finales

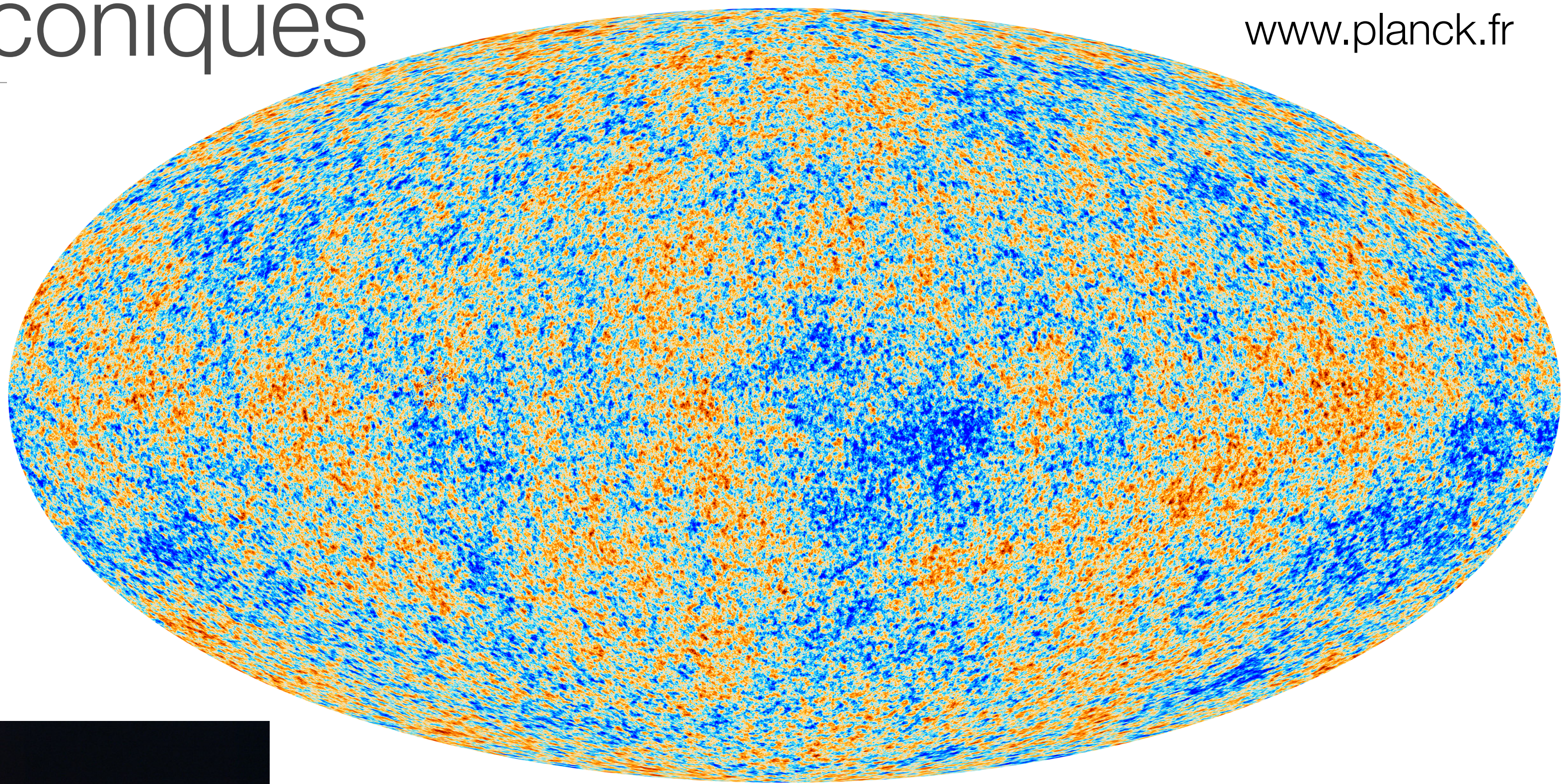


remarques finales

Apollo VIII, Noël
1968- Lovell, Anders,
Borman

images iconiques

www.planck.fr



… nous ramènent environ 13,8 milliards d’années en arrière

… nous permettent de commencer à sonder l’inflation cosmique, une fraction de seconde après le Big Bang

… et nous permettent de penser le monde et d’avoir une vision du monde