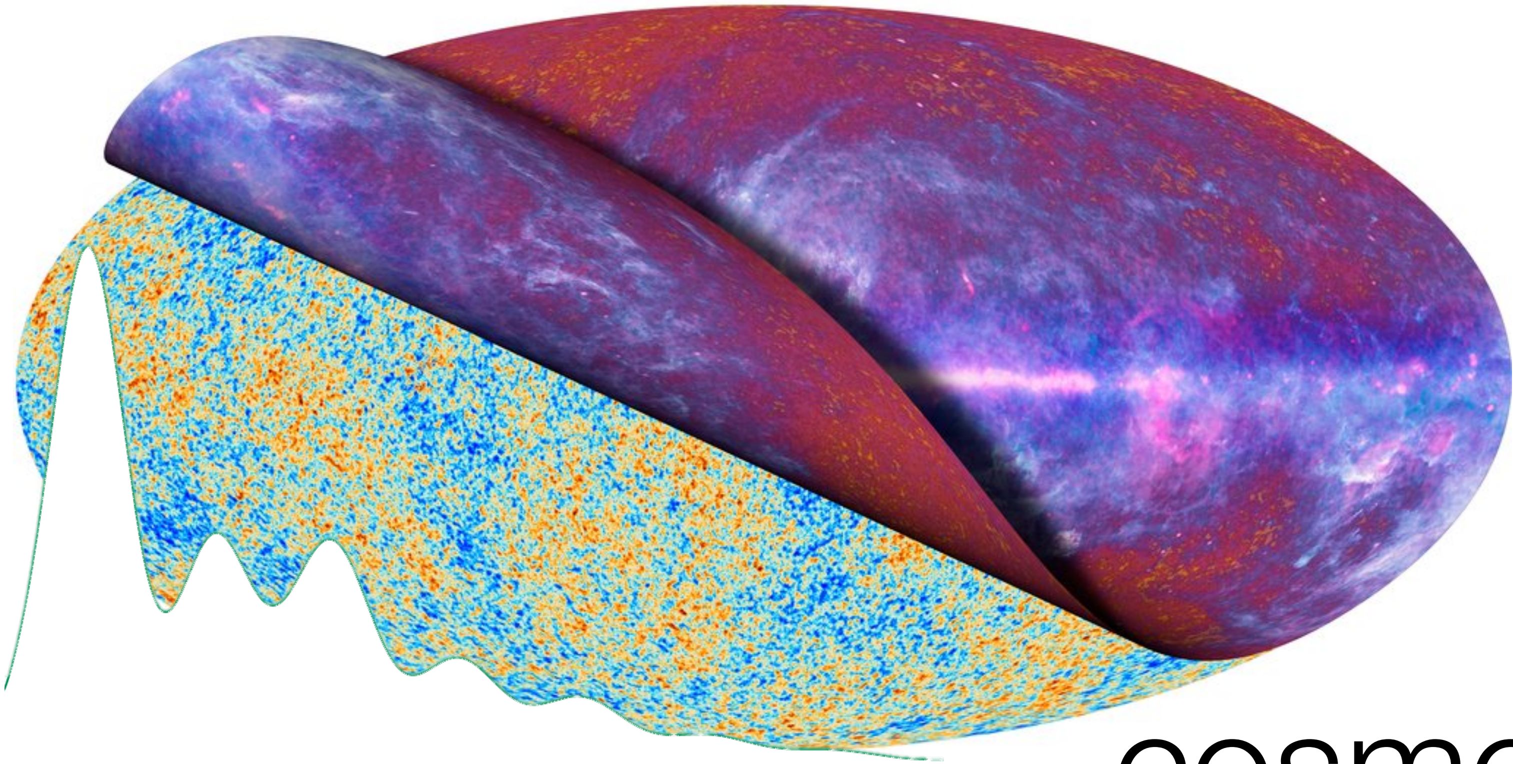

cosmological results from Planck

Hervé Dole
on behalf of the Planck collaboration

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

IAS Institut d'Astrophysique Spatiale Orsay

IUF

UNIVERSITÉ PARIS SUD
Comprendre le monde, construire l'avenir®

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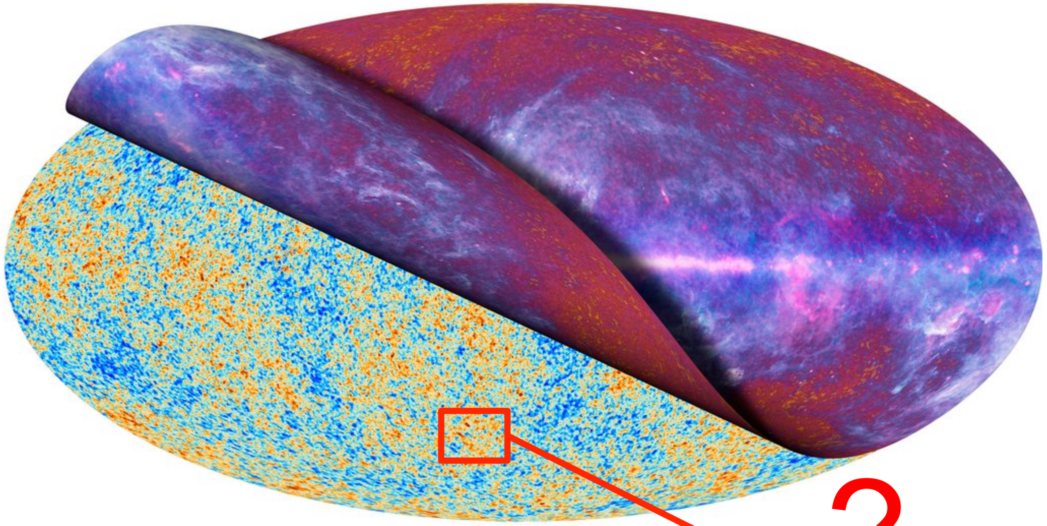
université PARIS-SACLAY

DÉPARTEMENT Sciences de la Planète et de l'Univers

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

the two outstanding questions in cosmology



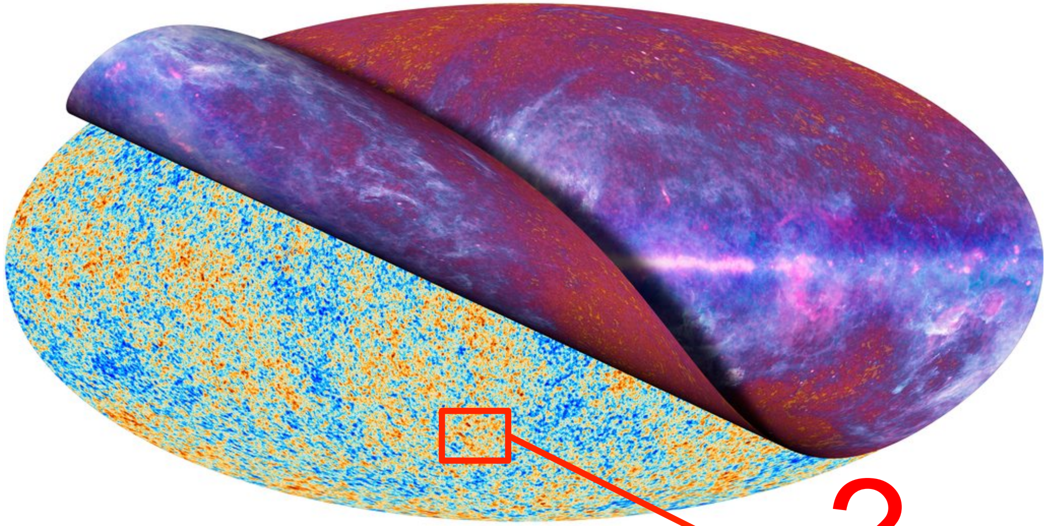
?

homogeneous universe

?

structured, inhomogeneous universe

the two outstanding questions in cosmology



?

homogeneous universe

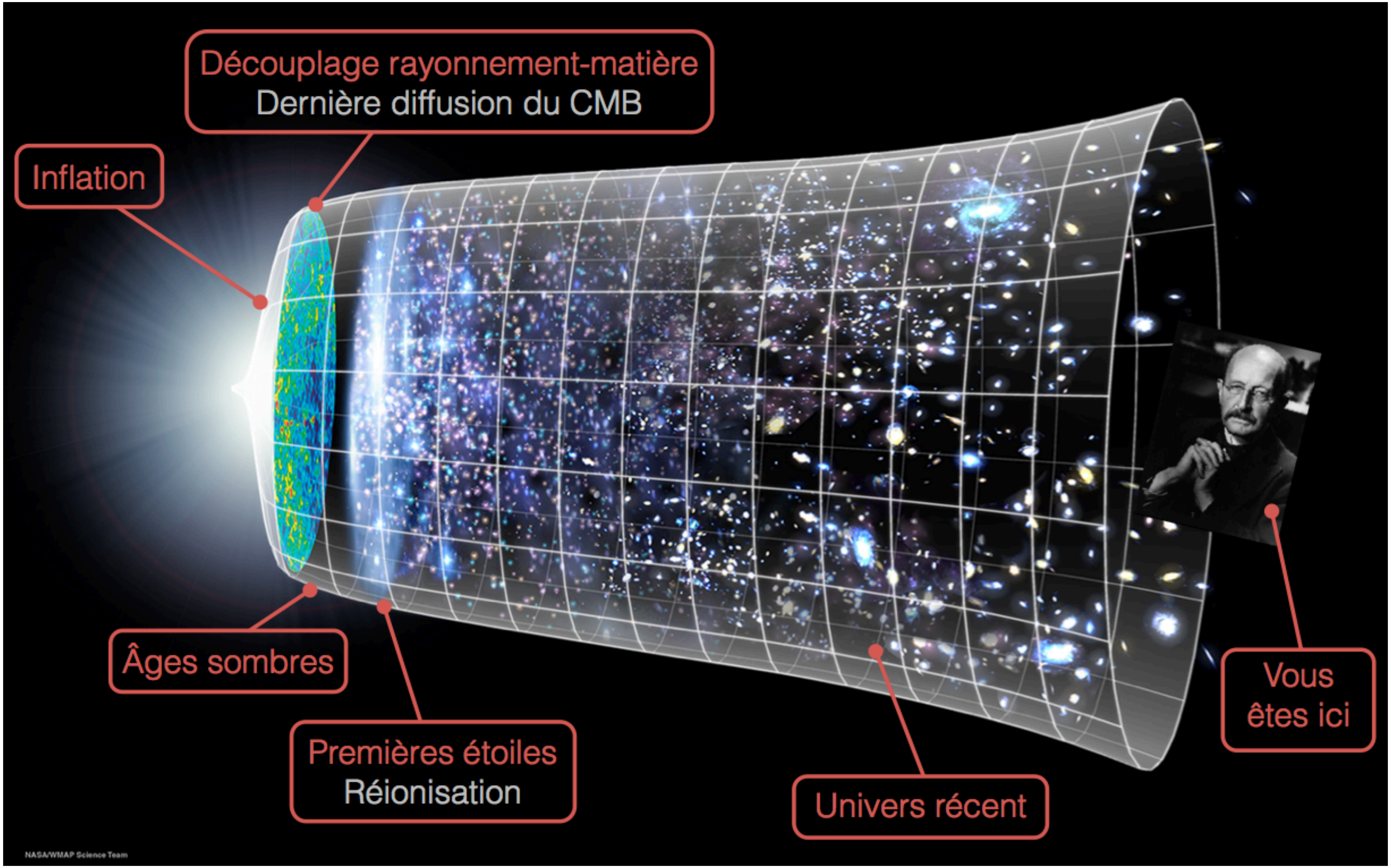
inflation models ?

?

structured, inhomogeneous universe

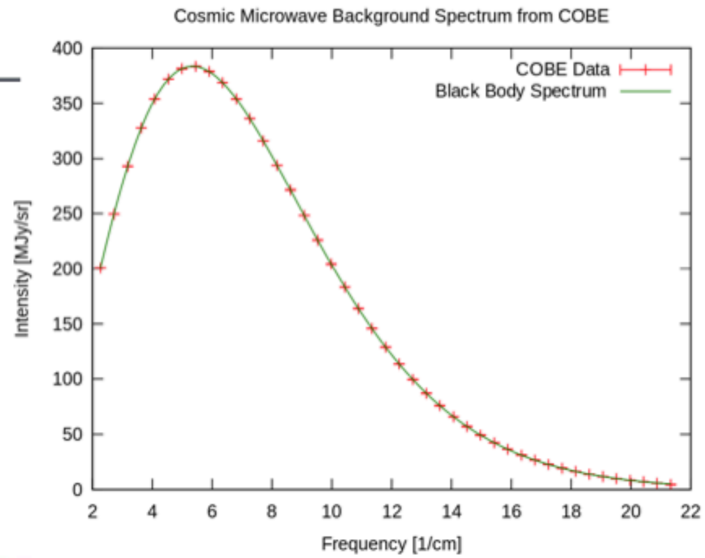
structure formation, ΛCDM

a short history of the 13.8b yr old universe

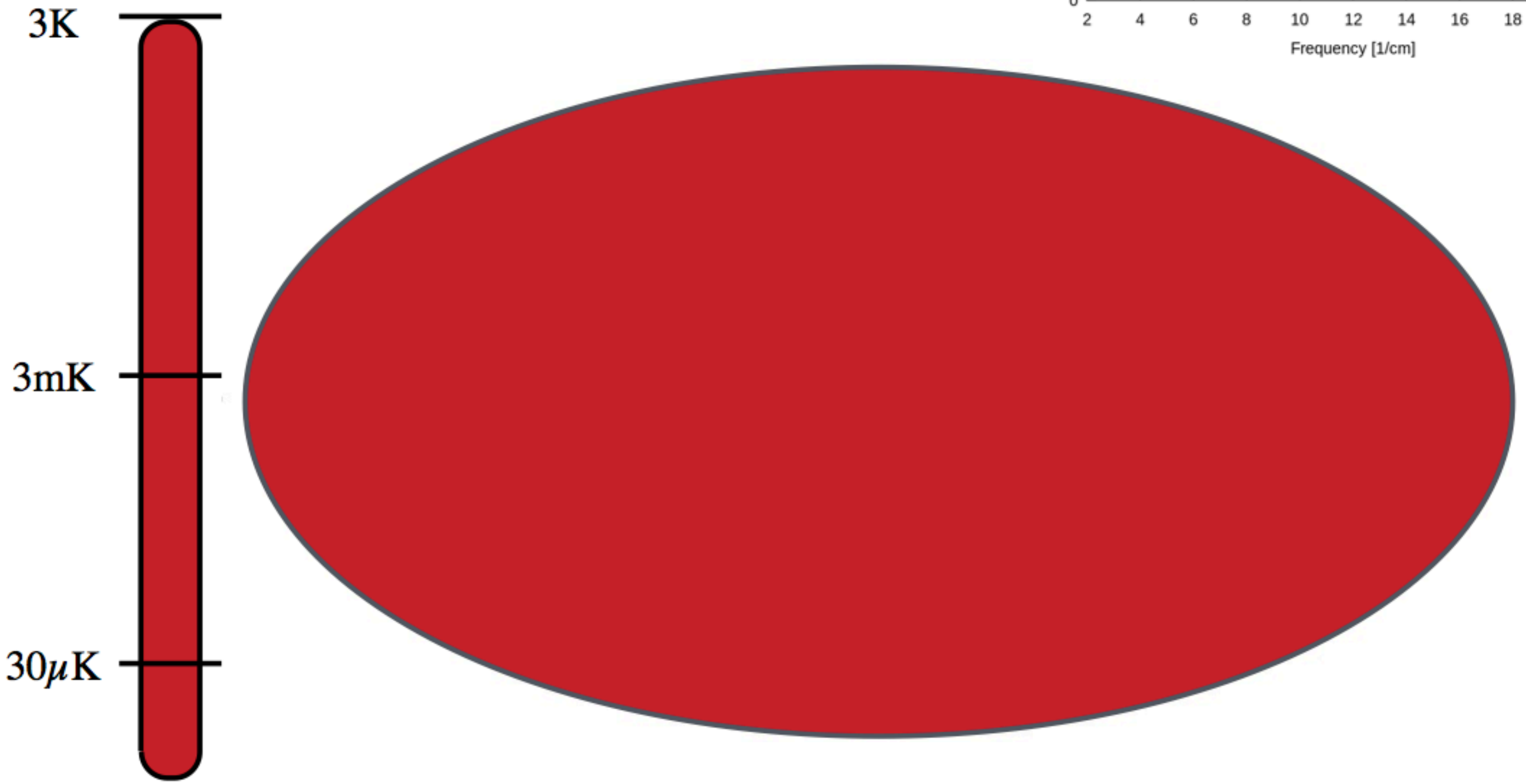


courtesy WMAP, Planck, J. Aumont

Le Fond Diffus Cosmologique (CMB)



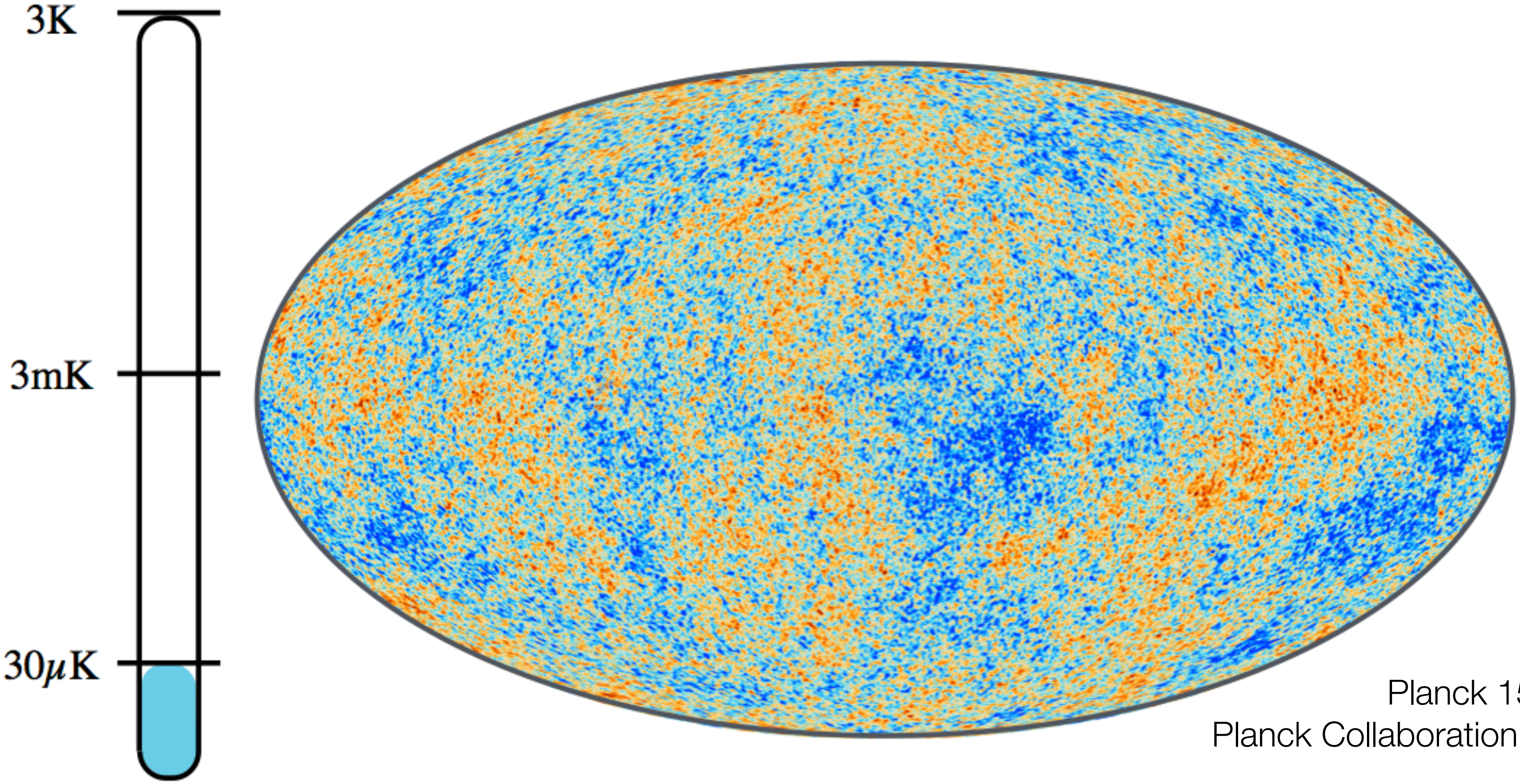
★ Rayonnement découvert par [Penzias et Wilson 1965]
★ En première approximation homogène et isotrope,
$T = 2.725 \pm 0.001$ K



courtesy J. Aumont

Le Fond Diffus Cosmologique (CMB)

- ★ Rayonnement découvert par [Penzias et Wilson 1965]
- ★ En première approximation homogène et isotrope, $T = 2.725 \pm 0.001$ K
- ★ … mais il existe des anisotropies qui sont les empreintes des fluctuations de densité primordiales



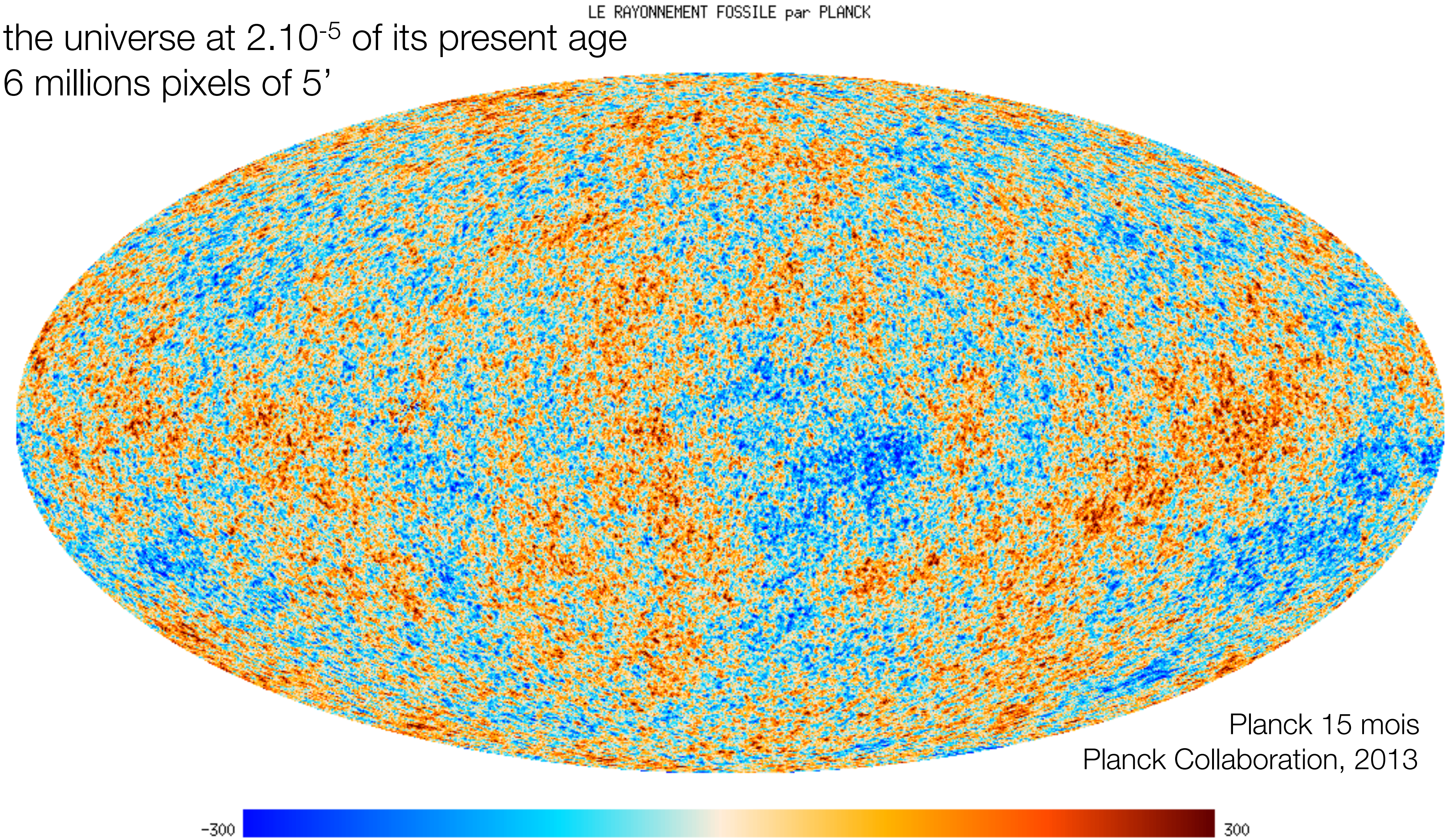
Planck 15 mois
Planck Collaboration, 2013

courtesy J. Aumont

CMB temperature anisotropies

the universe at 2.10^{-5} of its present age

6 millions pixels of 5’



Planck 15 mois

Planck Collaboration, 2013

and a fairly wide coverage

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

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

The infant universe

Once rarity, women

COLLECTION LE MONDE EST MATHÉMATIQUE

CRISE CHYPRIOTE : L'ULTIMATUM DE FRANCFORT

Le Monde

En Tunisie, le drame des disparus de la révolution

LE MONDE DES LIVRES

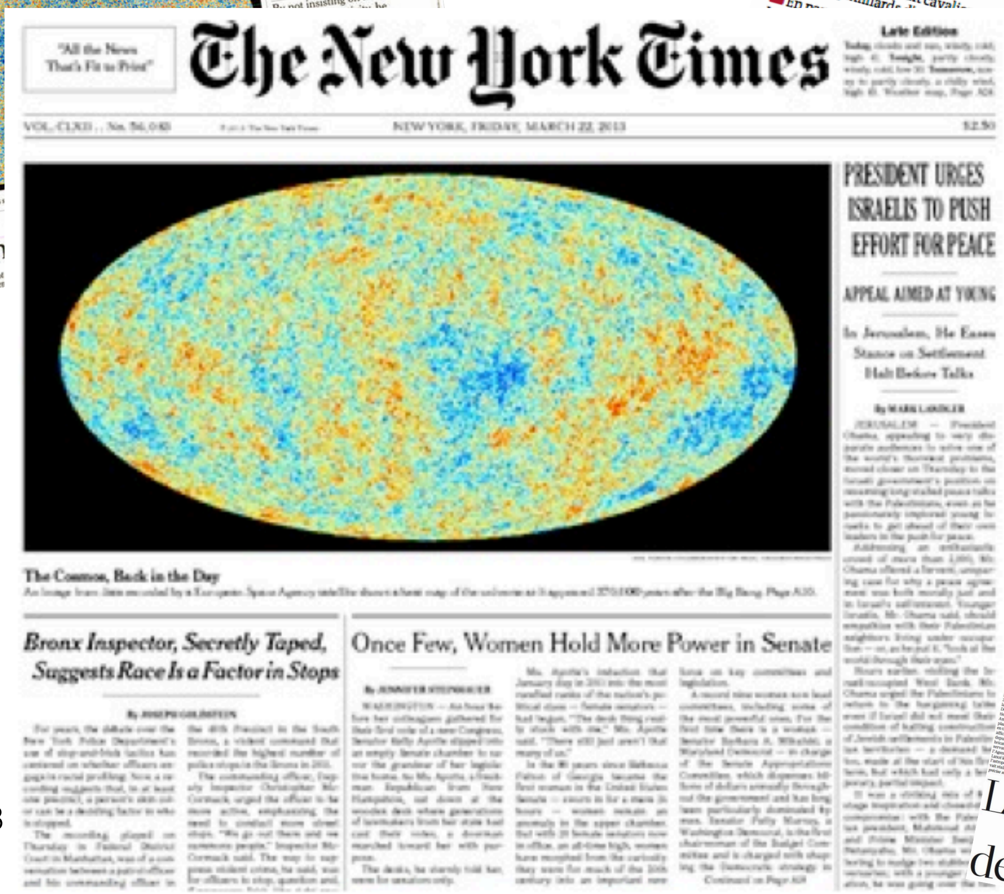
DES GTI POUR ROULER DES MÉCANIQUES

Moins d'impôts et plus d'austérité, Londres persiste

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

AUJOURD'HUI



The New York Times

NEW YORK, FRIDAY, MARCH 22, 2013

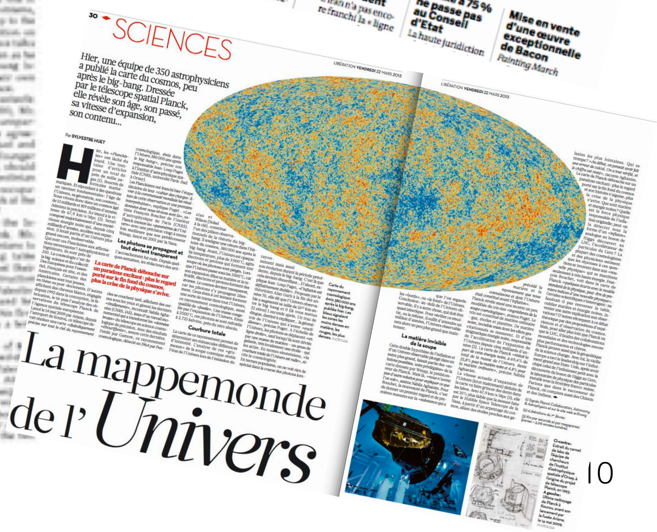
PRESIDENT URGES ISRAELIS TO PUSH EFFORT FOR PEACE

APPEAL AIMED AT YOUNG

The Cosmos, Back in the Day

Bronx Inspector, Secretly Taped, Suggests Race Is a Factor in Stops

Once Few, Women Hold More Power in Senate

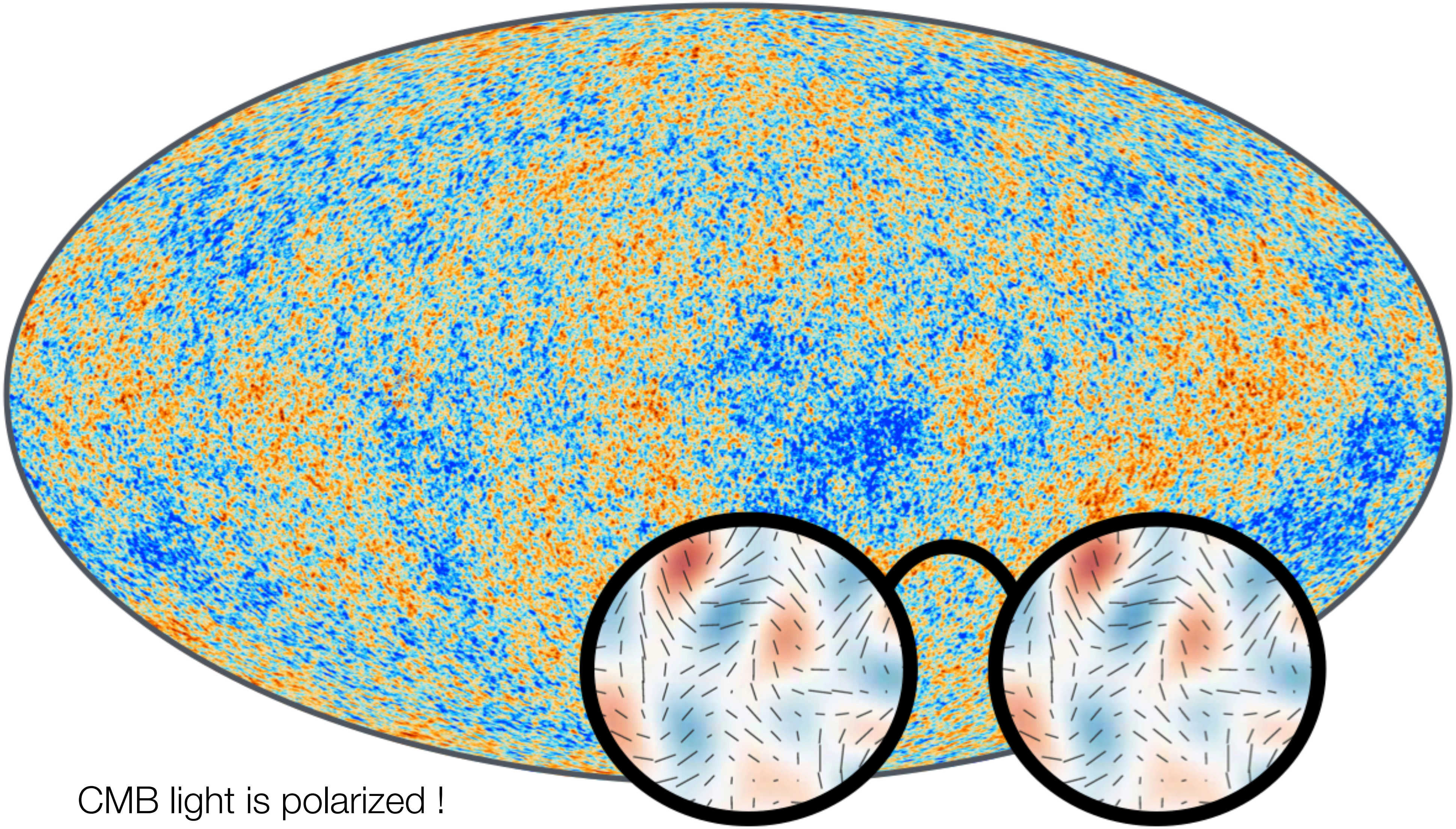


SCIENCES

La mappemonde de l'Univers

March 21st or 22nd, 2013

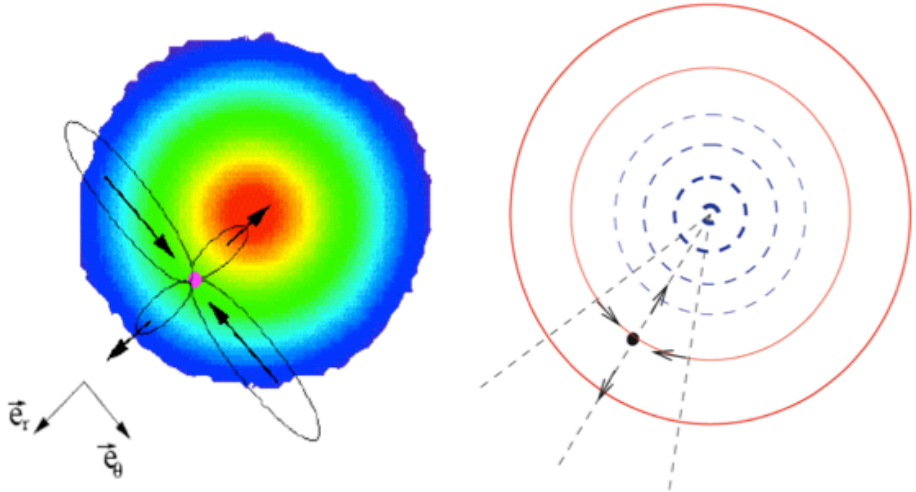
but there is more in CMB light: polarization



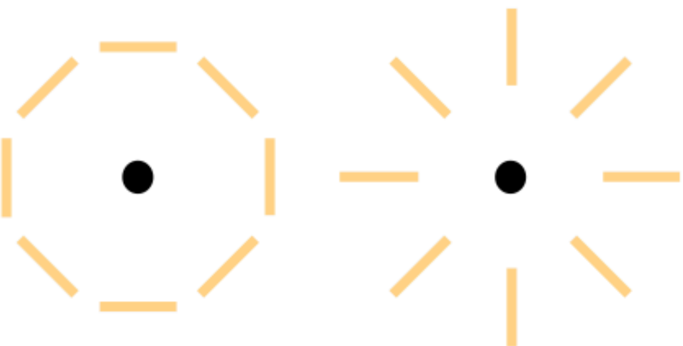
CMB light is polarized !

courtesy J. Aumont

CMB polarization

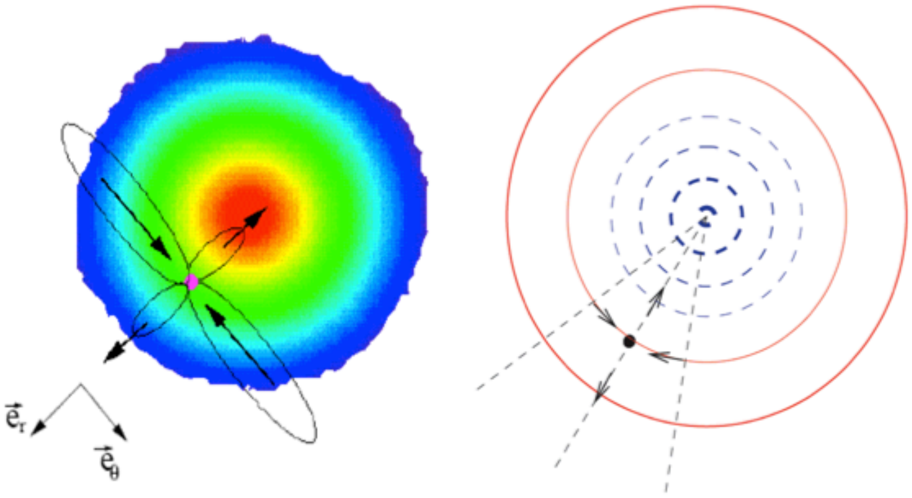


Perturbations scalaires
Perturbations de densité
Génèrent de la polarisation Q_r

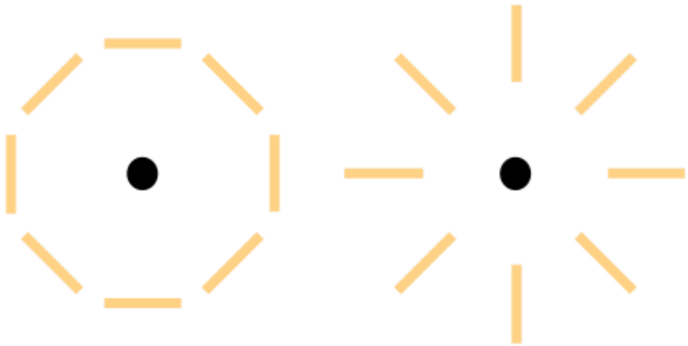


courtesy J. Aumont

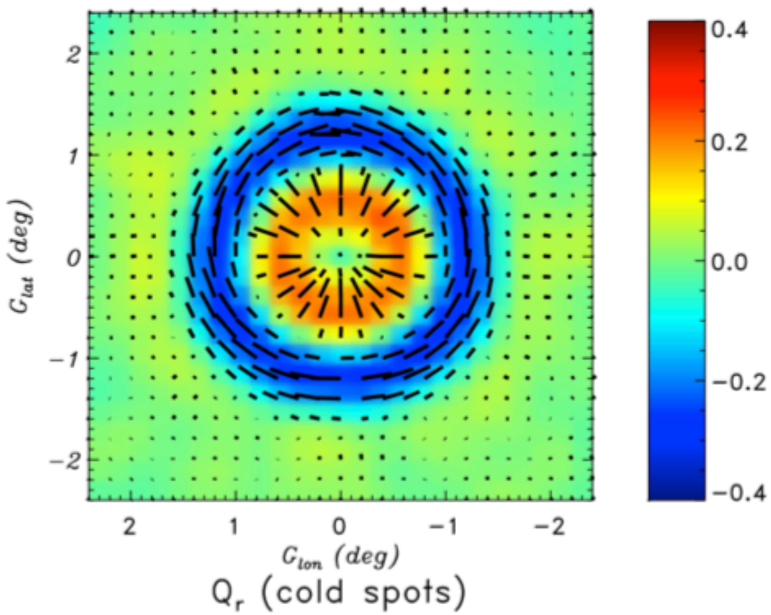
CMB polarization



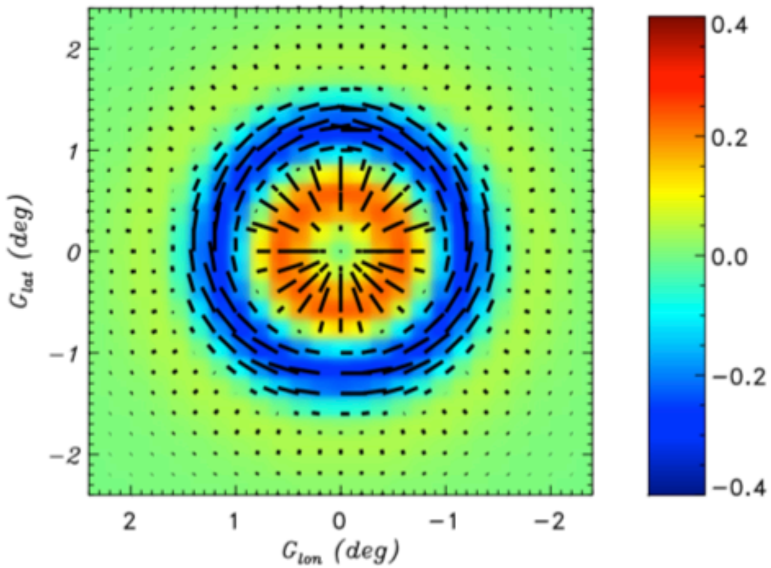
Perturbations scalaires
Perturbations de densité
Génèrent de la polarisation Q_r



Données Planck

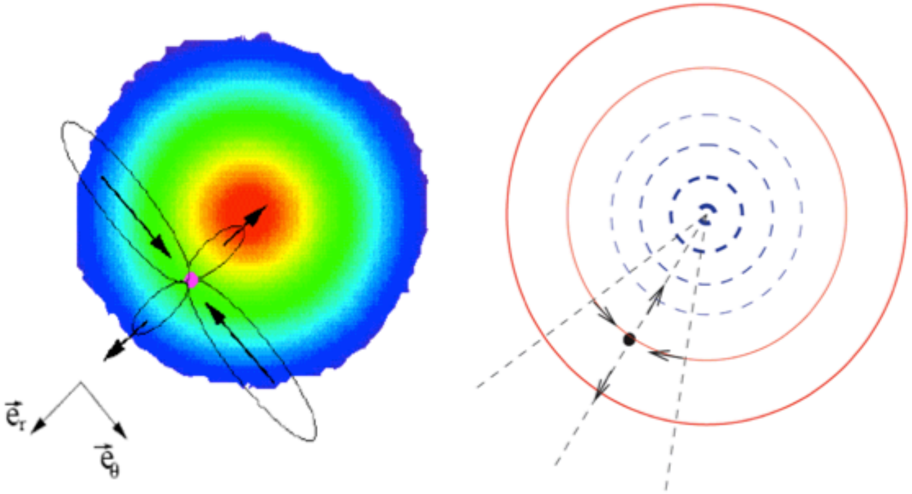


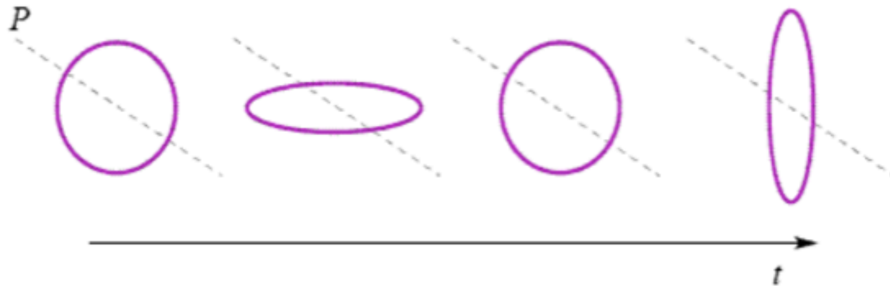
Simulations



courtesy J. Aumont

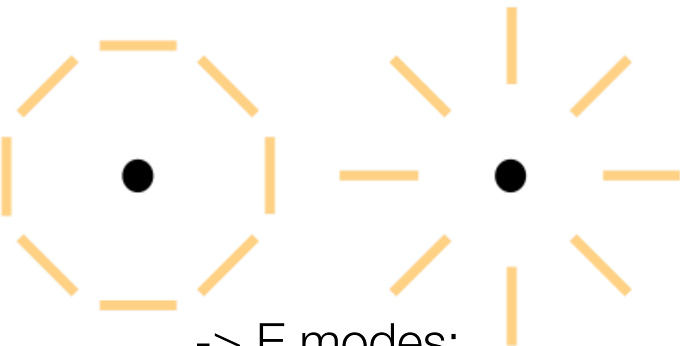
CMB polarization



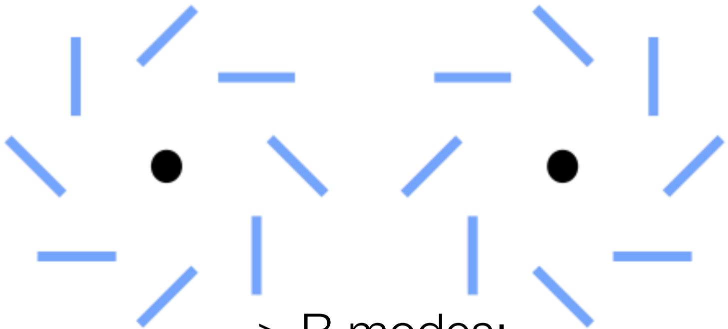


Perturbations scalaires
Perturbations de densité
Génèrent de la polarisation Q_r

Perturbations tensorielles
Ondes gravitationnelles primordiales
Génèrent de la polarisation Q_r et U_r



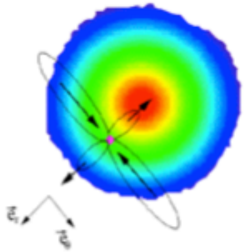
-> E modes:
origin of large-scale structure



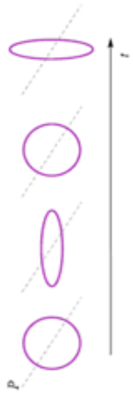
-> B modes:
signature of inflation

courtesy J. Aumont

CMB polarization: E and B modes



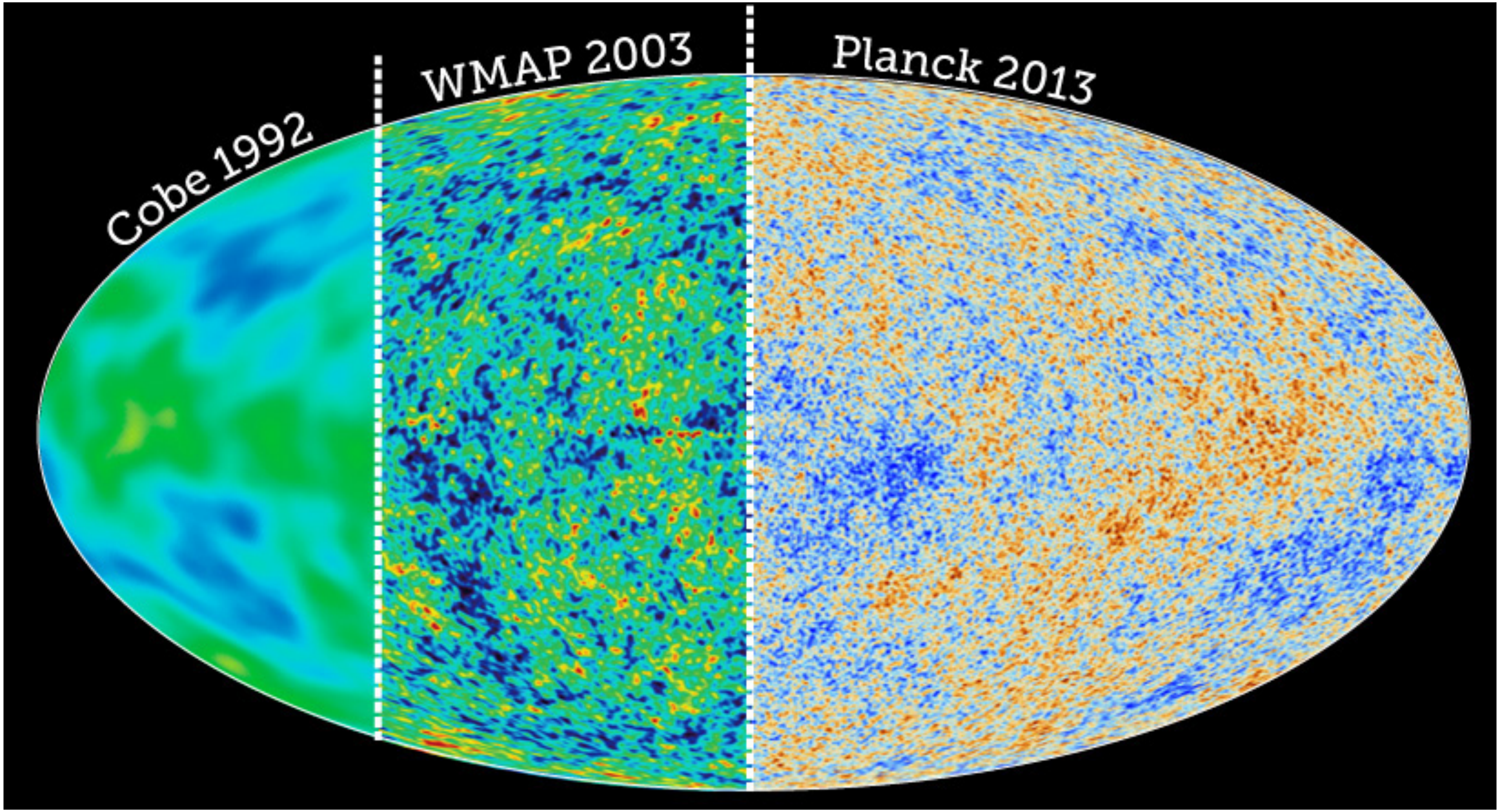
Perturbations scalaires
Génèrent Q_r,
donc E



Perturbations tensorielles
Génèrent Q_r et U_r,
donc E et B

courtesy J. Aumont

1. improvements with time & technology



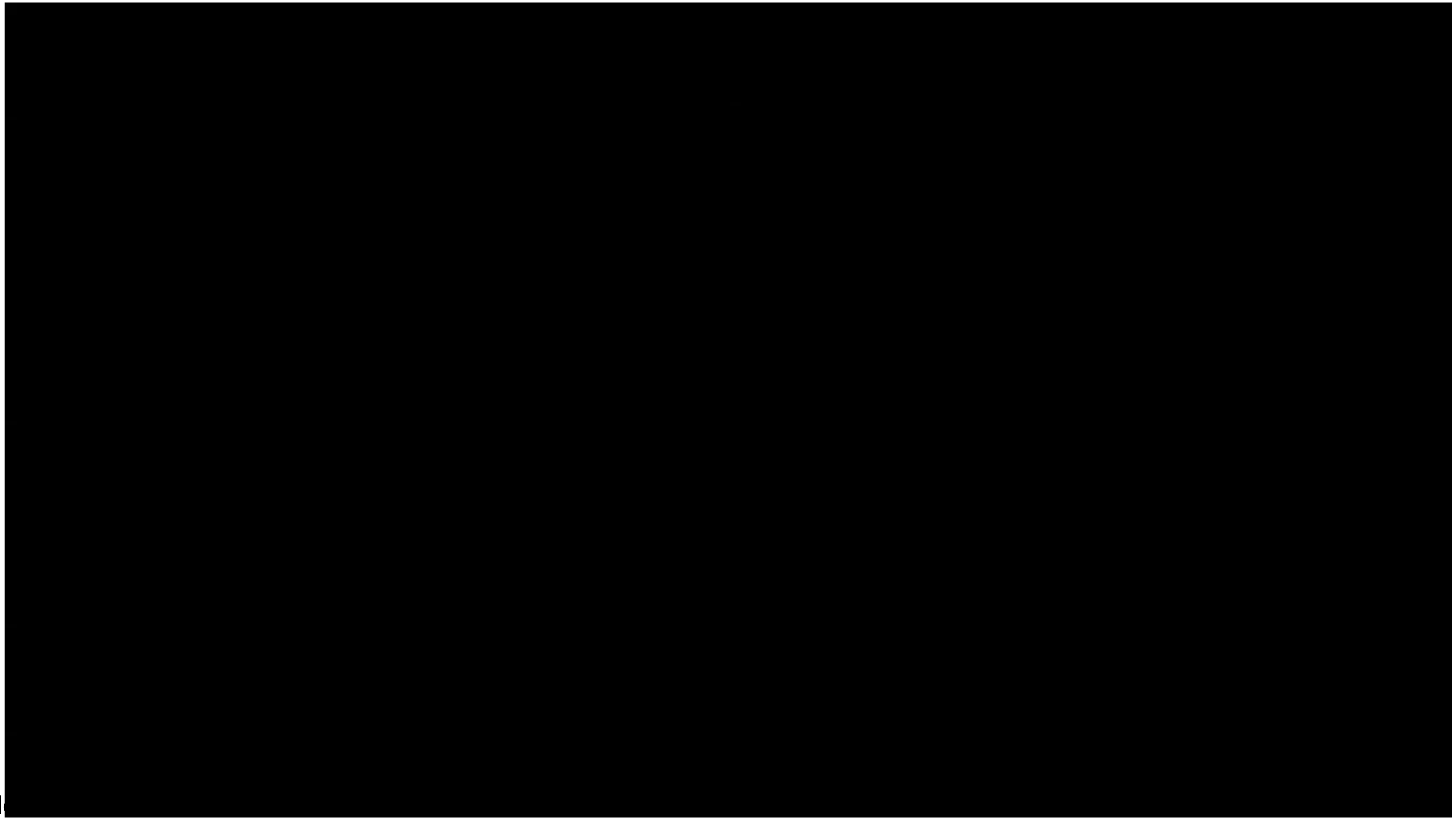
Planck sensitivity (in T) in 1yr ~ 1000 years of WMAP

outline

1. why Planck ? why the CMB ?
2. the Cosmic Microwave Background (CMB) and the astrophysical components, incl galaxies
3. analysis of the CMB: angular power spectra
4. cosmological implications
5. a word about inflation
6. a clumpy Universe
   1. dark matter
   2. galaxy clusters via SZ
7. digging into the Cosmic Infrared Background
   1. overdensities: clusters of dusty galaxies ?
   2. the brightest lensed sources in the sky

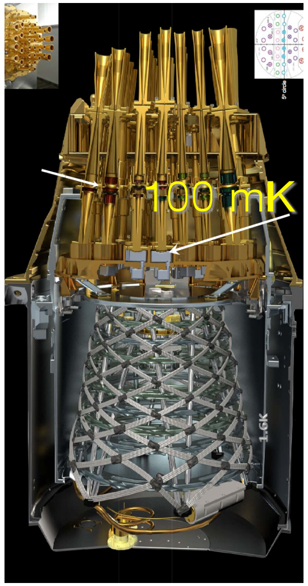
Planck goals and key facts

- selected in 1996 by ESA – launched in 2009
- HFI cooled at 100 mK -> bolometer technology
- 29 months of operation (goal was 12: nominal mission)
  - 5 all-sky surveys instead of 2 (nominal mission, this data release)



a technological success

stability: 0.1mK !



Cryostat:
dilution He3/He4

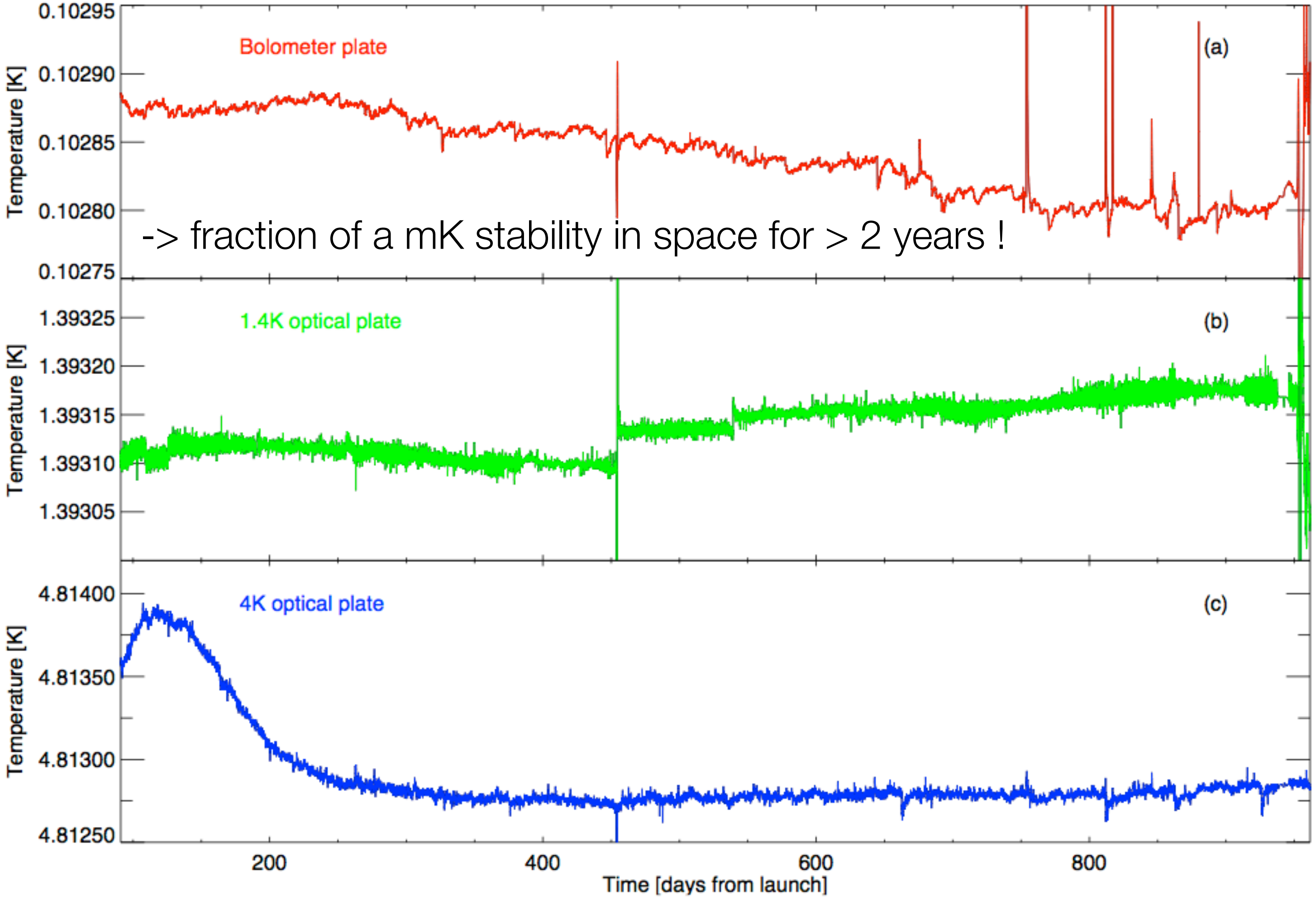
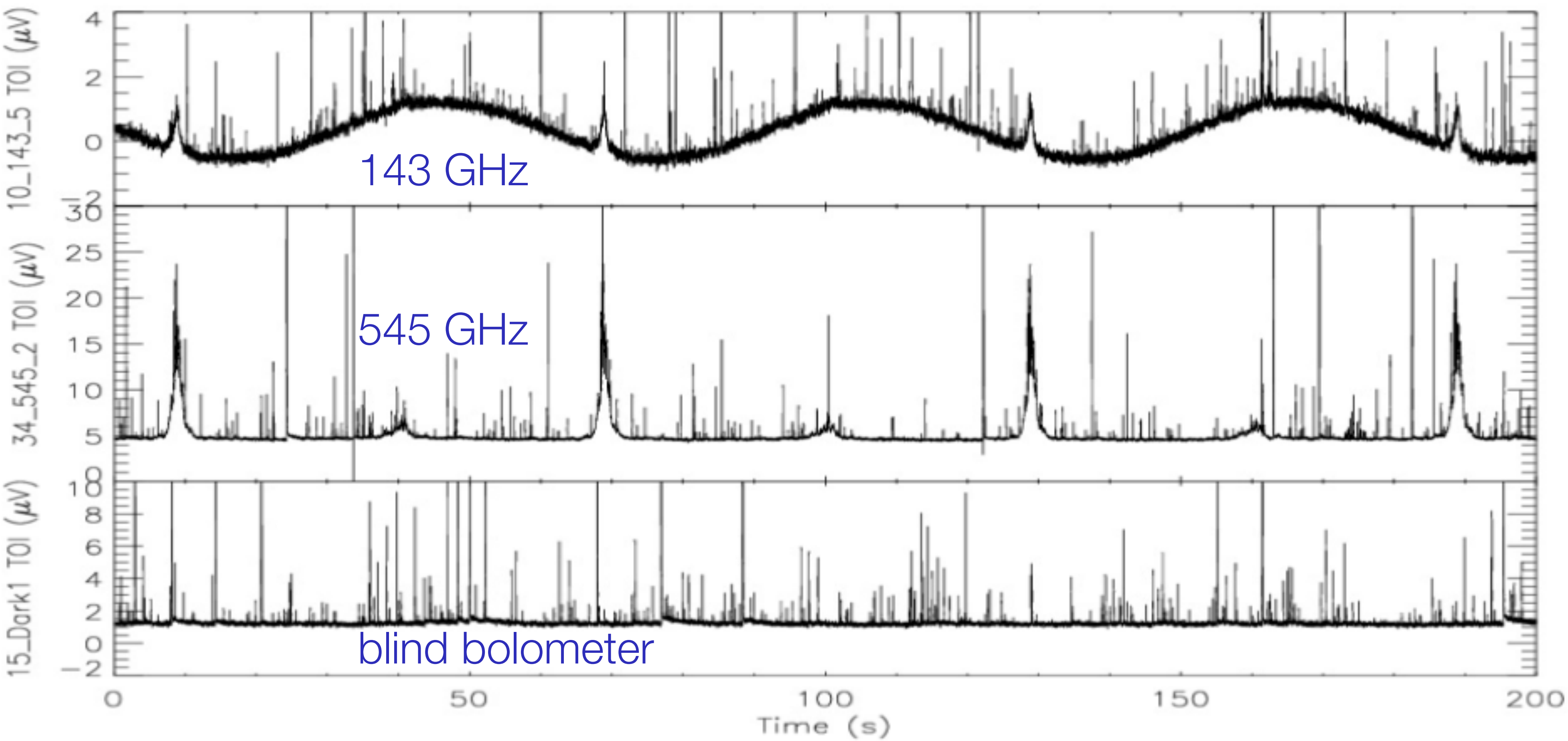


Fig. 7. The impressive stability of the HFI thermal stages during operations. Shown is the temperature evolution of the bolometer stage (*top*), the 1.6 K optical filter stage (*middle*) and the 4-K cooler reference load stage (*bottom*). The horizontal axis displays days since the beginning of the nominal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

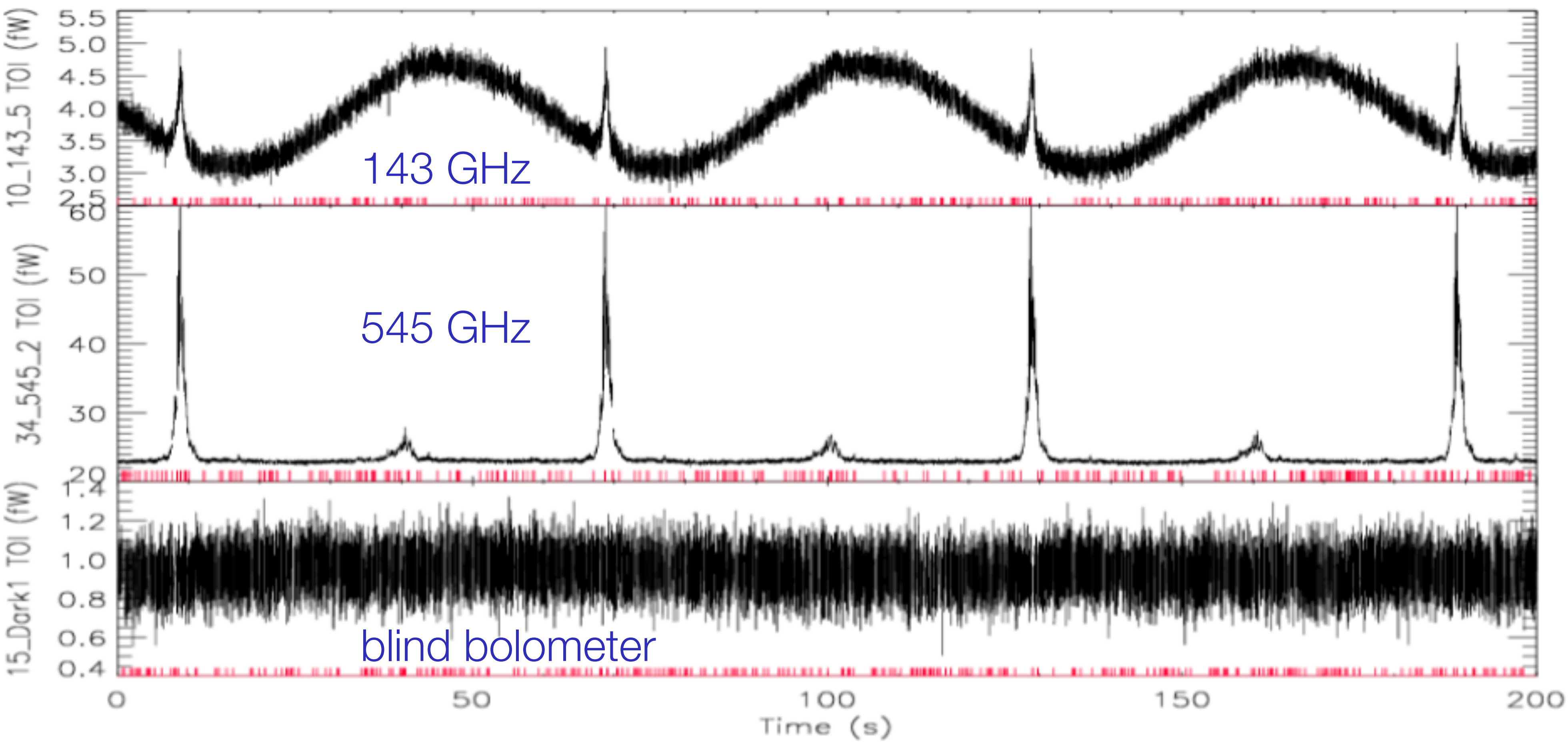
Planck Collab, 2013, 1

a challenging analysis success



Planck-HFI Core Team, 2011

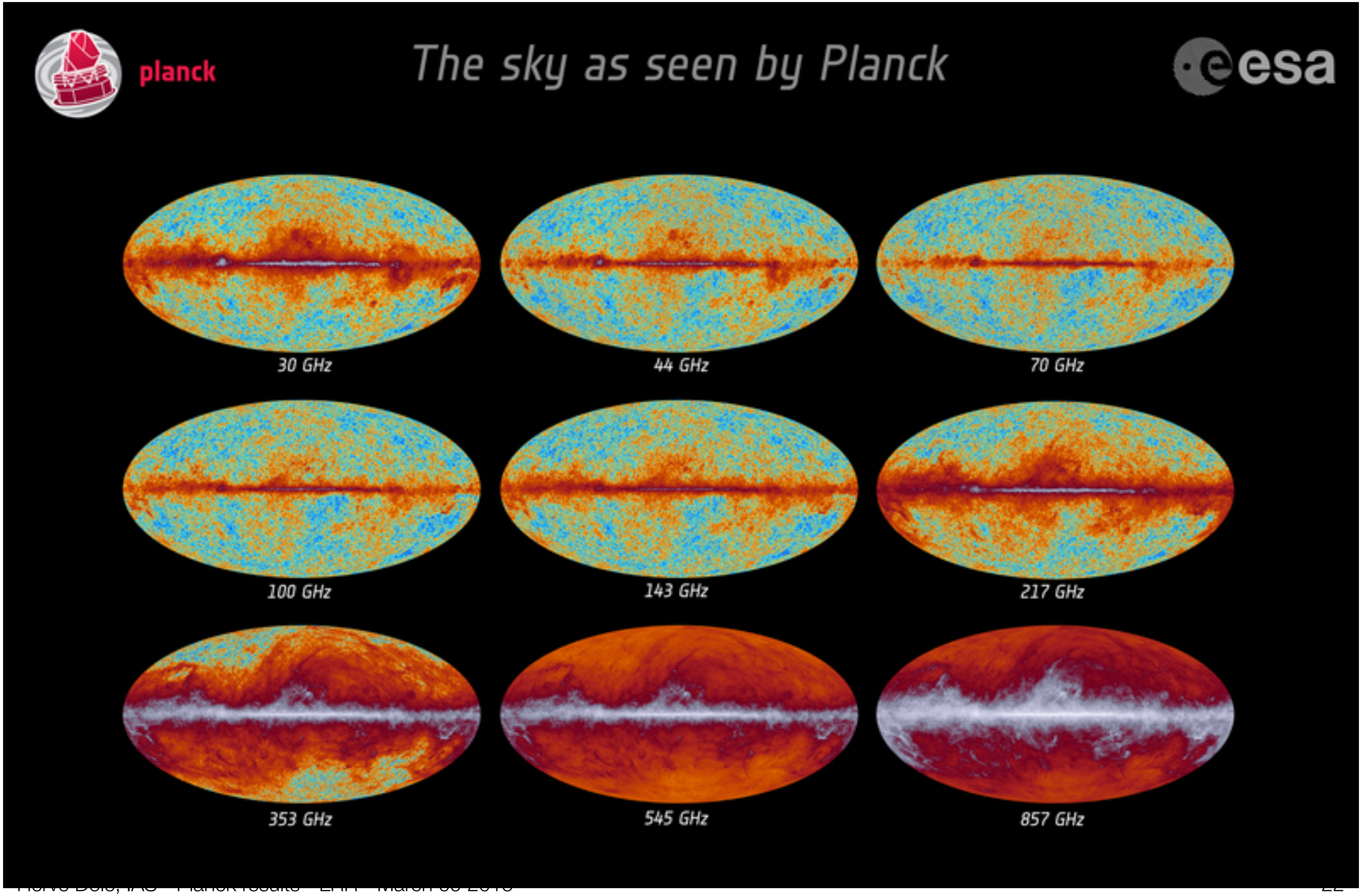
a challenging analysis success



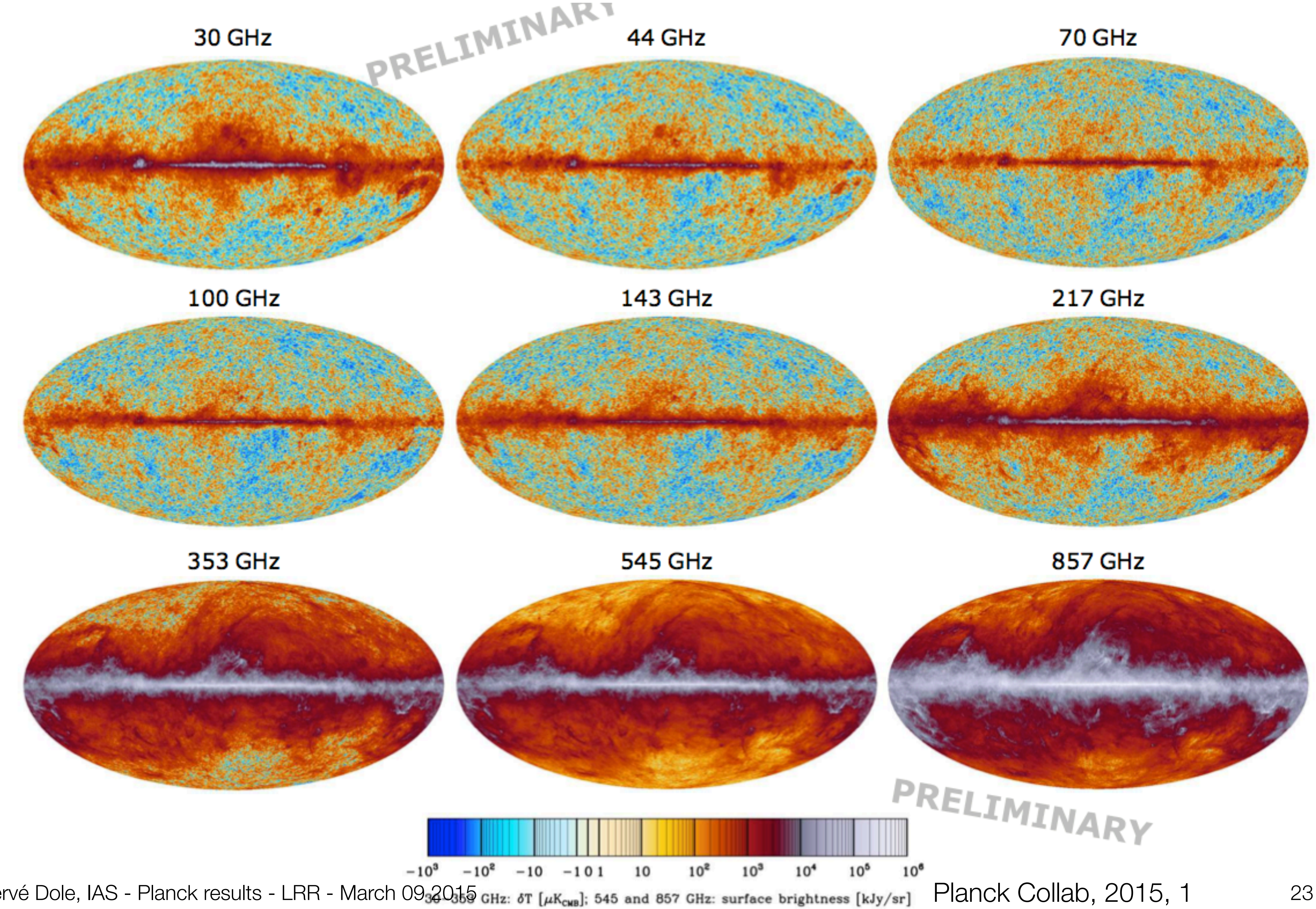
de <20% de données perdues à cause des glitches

Planck-HFI Core Team, 2011

Planck all-sky maps 2013

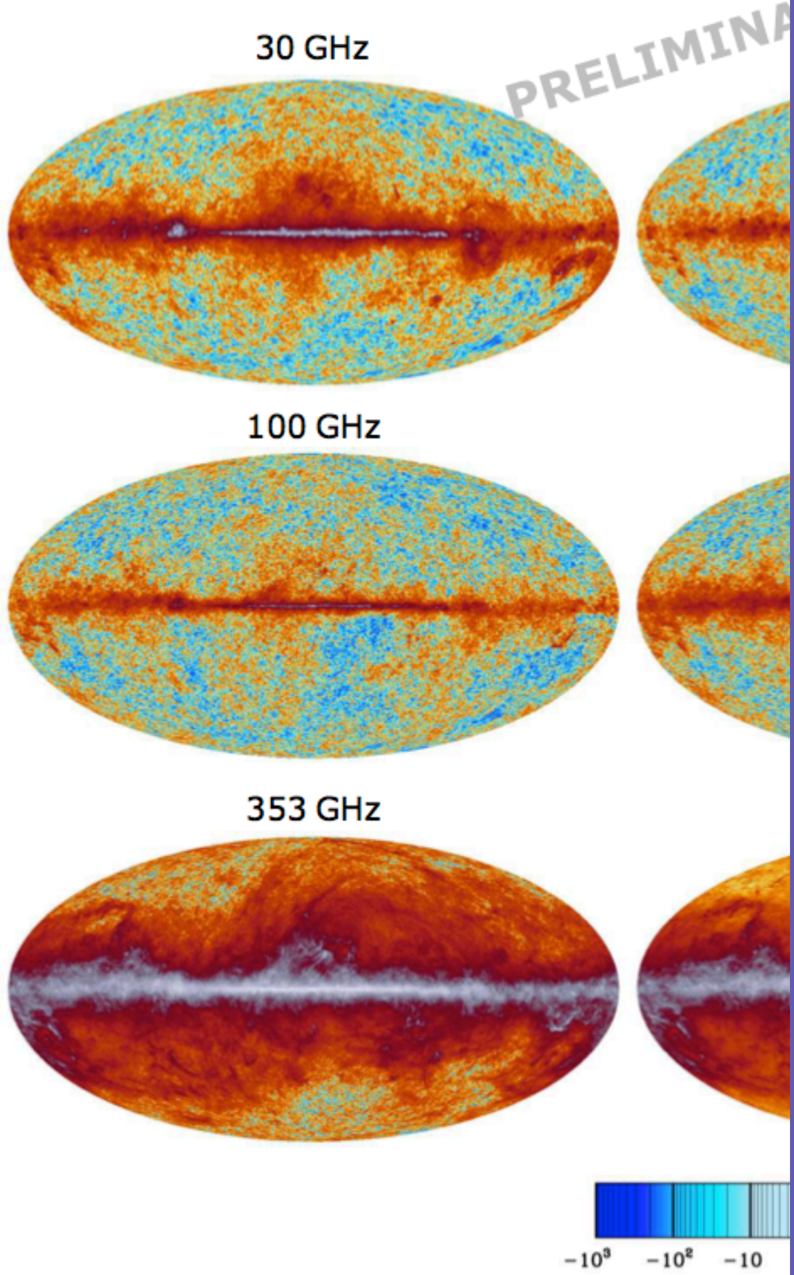


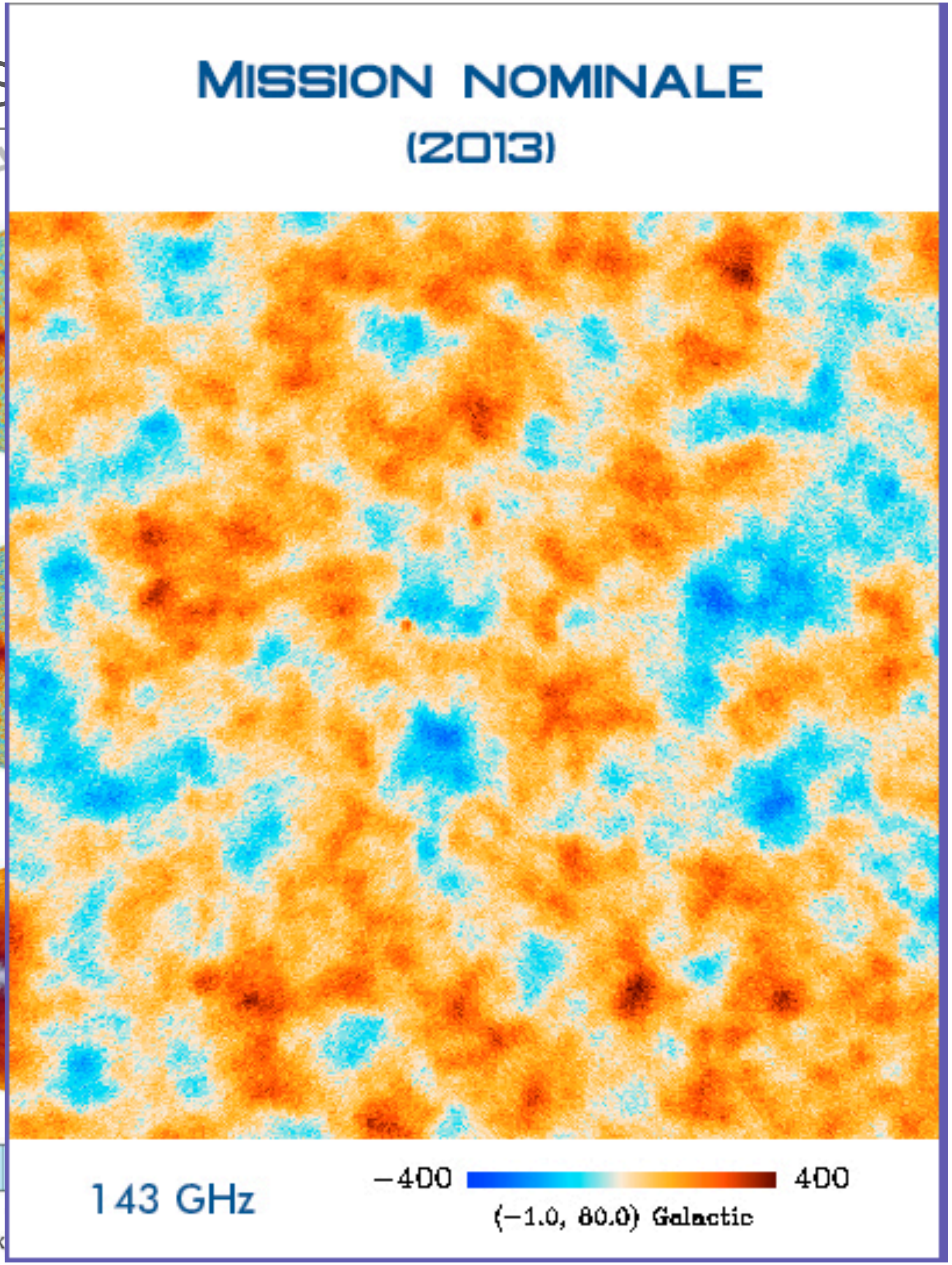
Planck all-sky maps 2015



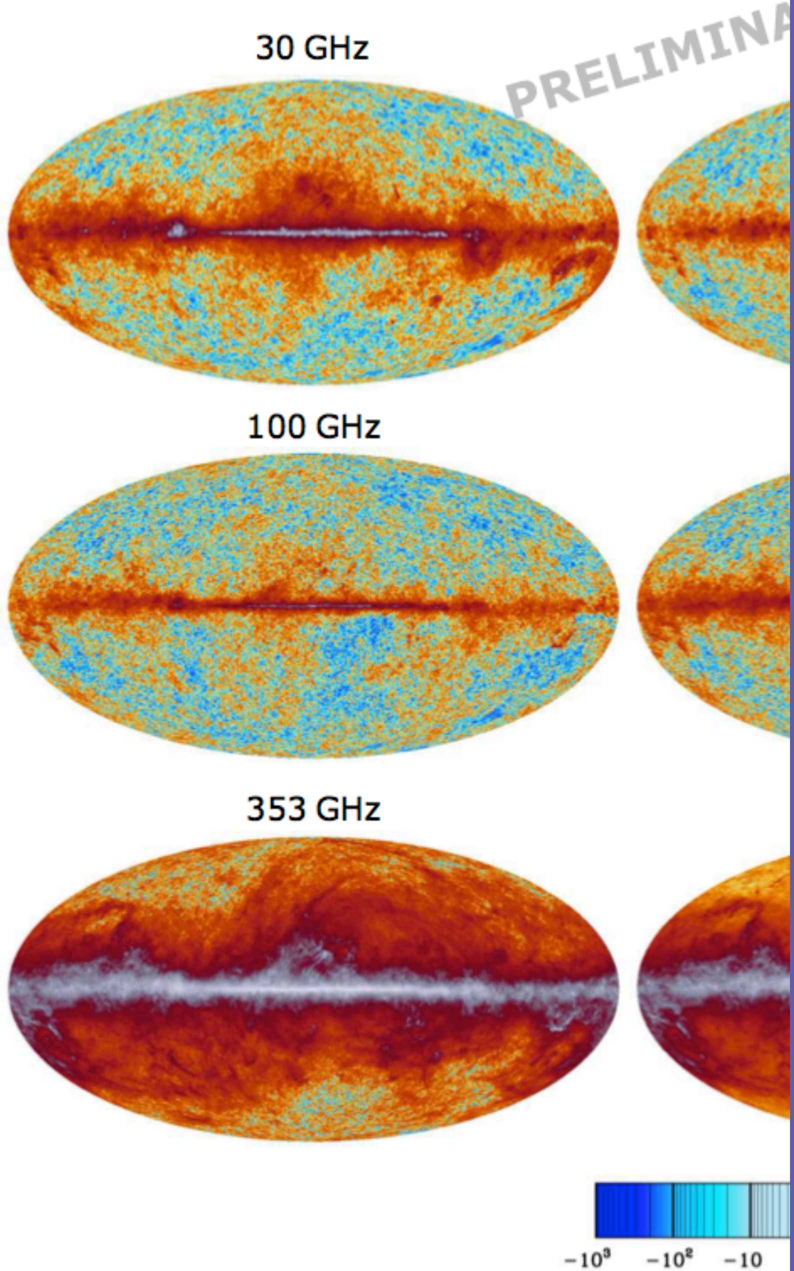
Planck Collab, 2015, 1

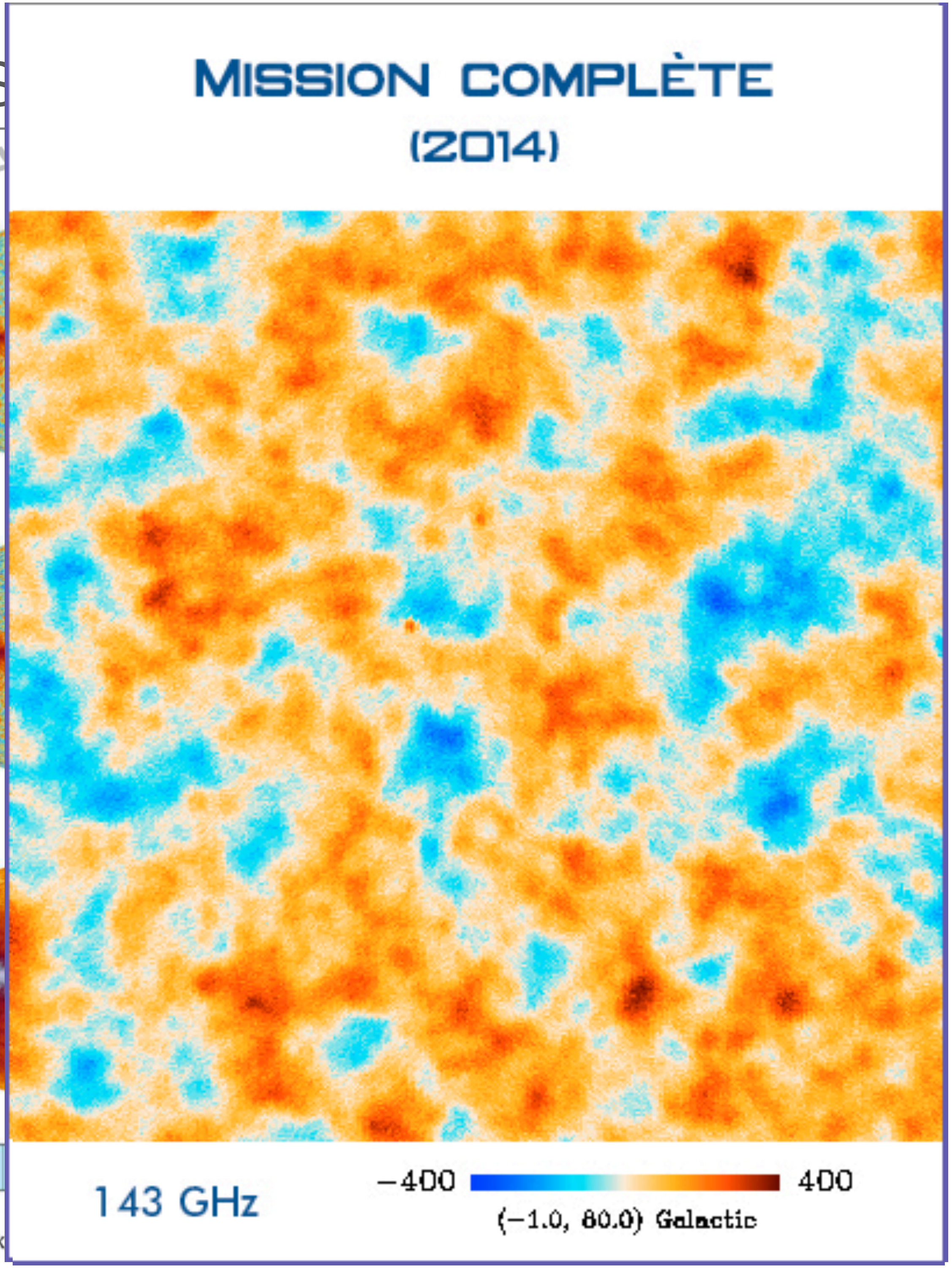
Planck all-sky maps





Planck all-sky maps

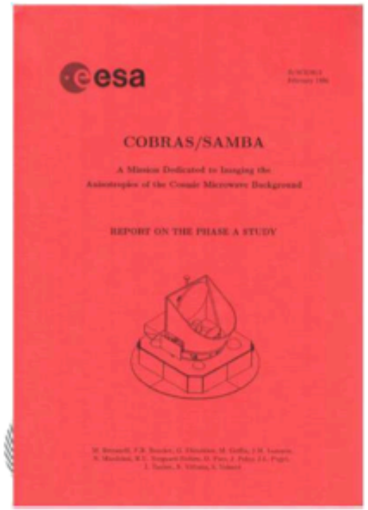


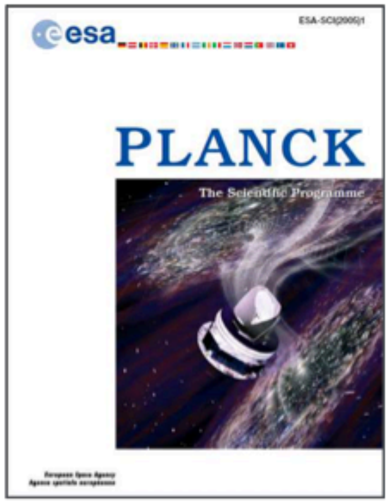


Planck impressive sensitivity

Noise **measured in-flight**, full mission (CMB channels)

	30GHz	44GHz	70GHz	100GHz	143GHz	217GHz	353GHz
Angular resolution [arcmin]	33.2	28.1	13.1	9.7	7.3	5.0	4.9
Noise sensitivity [μK_{CMB} $s^{1/2}$]	148.5	173.2	151.9	41.3	17.4	23.8	78.8
NOISE/PIXEL							
From detector sensitivity [μK_{CMB}]	9.2	12.7	23.9	9.6	5.4	10.7	36.5
Measured from maps [μK_{CMB}]	9.2	12.5	23.2	11.2	6.6	12.0	43.2
Extended mission [months]	*48*	*48*	*48*	*29*	*29*	*29*	*29*
End-of-missioni [μK_{CMB}]	5.2	7.1	13.2	8.2	4.8	8.8	31.6
Measured End-of-Mission [$\Delta T/T$, $\mu K/K$]	**1.9**	**2.6**	**4.8**	**3.0**	**1.8**	**3.2**	**11.6**
2005: Blue book GOAL [$\Delta T/T$, $\mu K/K$]	**2.0**	**2.7**	**4.7**	**2.5**	**2.2**	**4.8**	**14.7**
1996: Red book GOAL [$\Delta T/T$, $\mu K/K$]				**~ 2**			

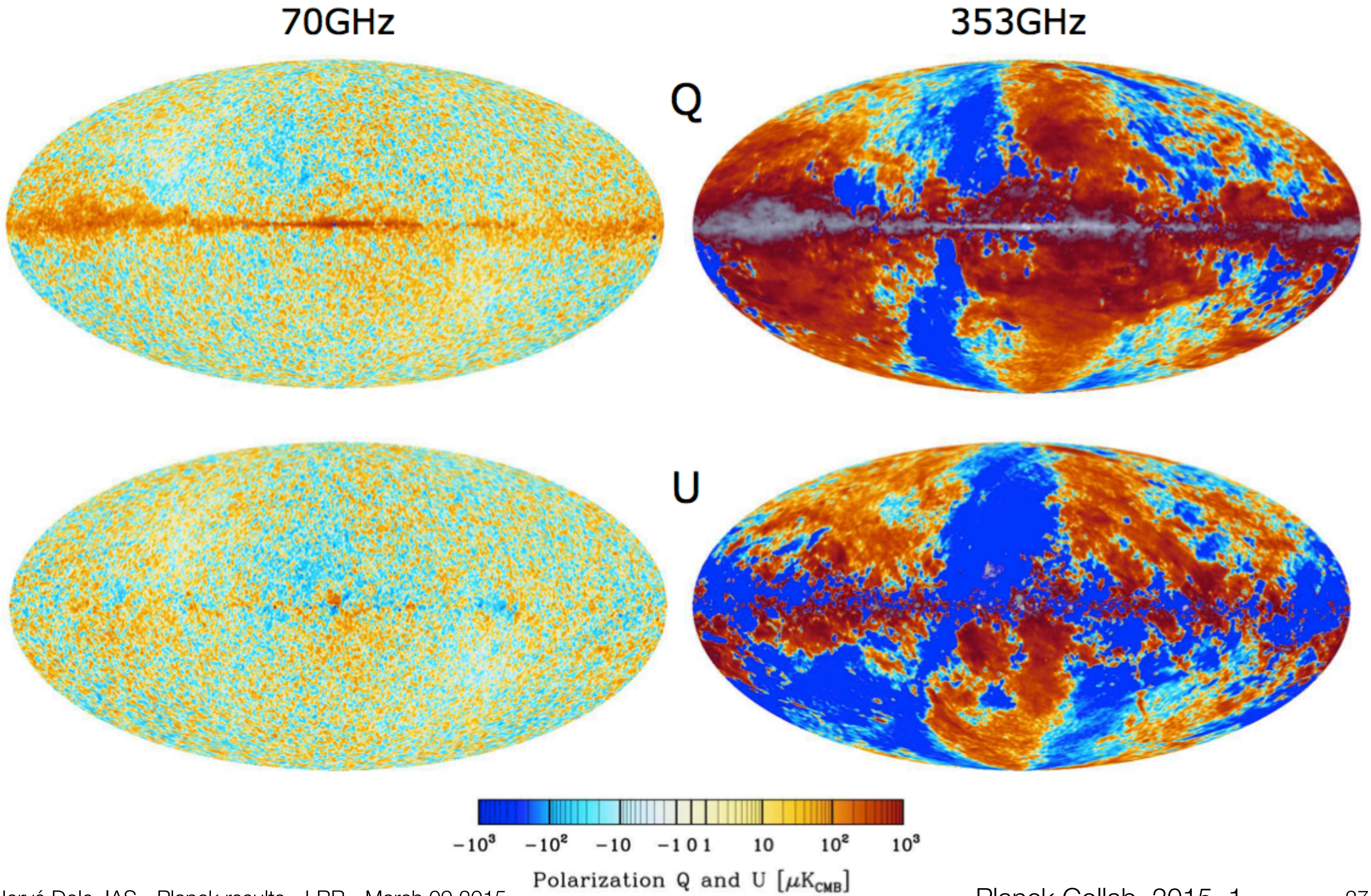




At end of mission Planck fulfills completely the very ambitious sensitivity goals proposed in the design phase several years ago

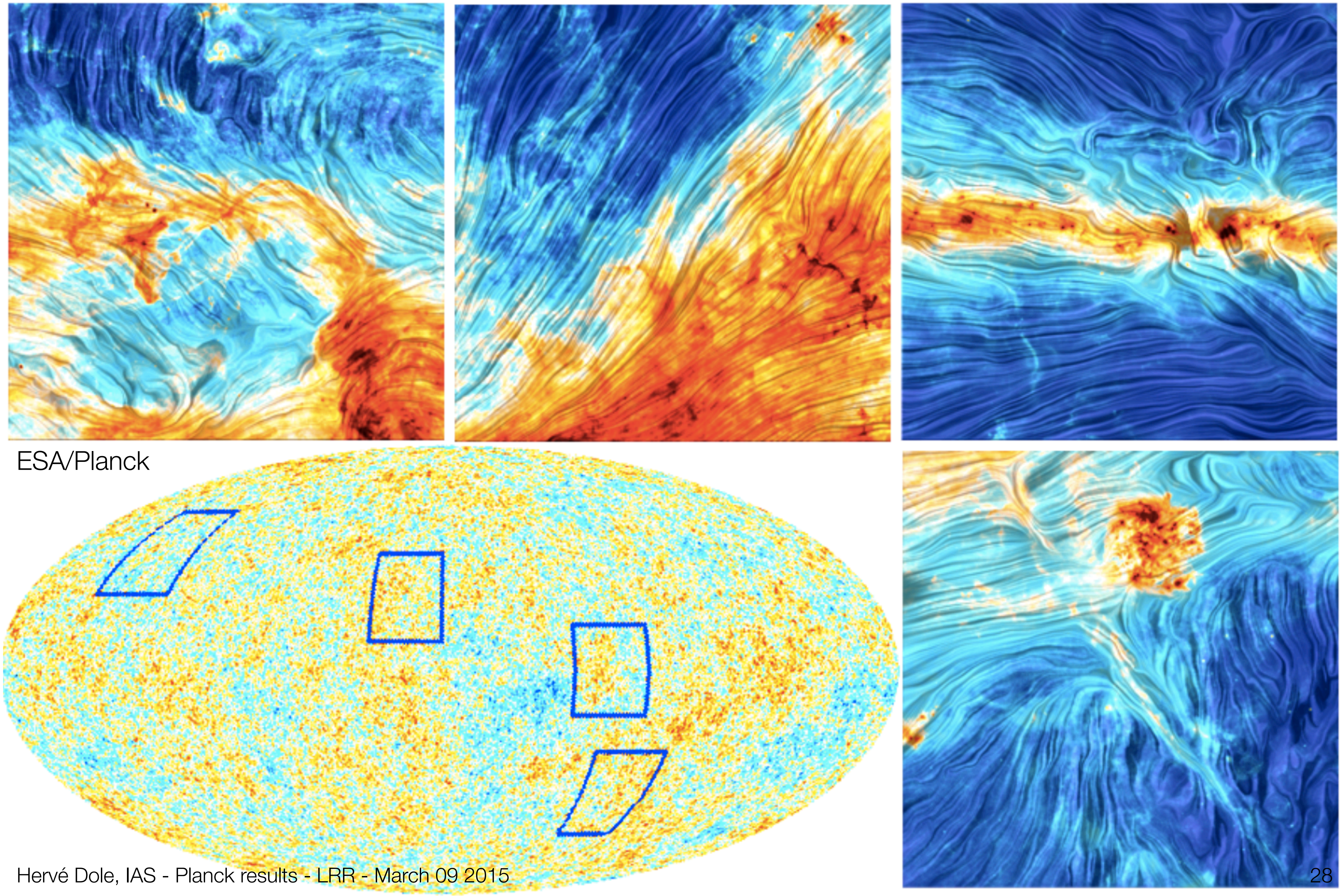
Courtesy M. Bersanelli

new results 2015: polarization



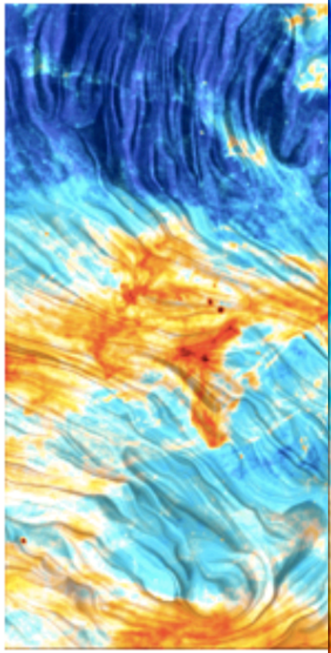
Planck Collab, 2015, 1

new results 2015: polarization and mag. field

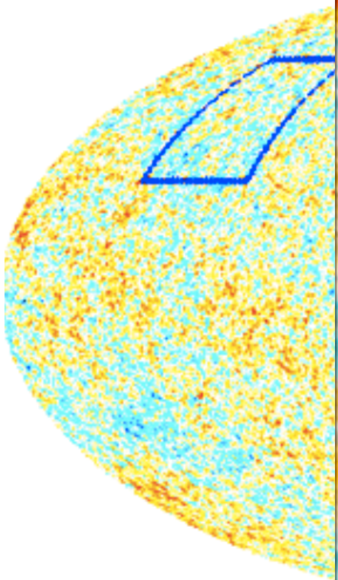


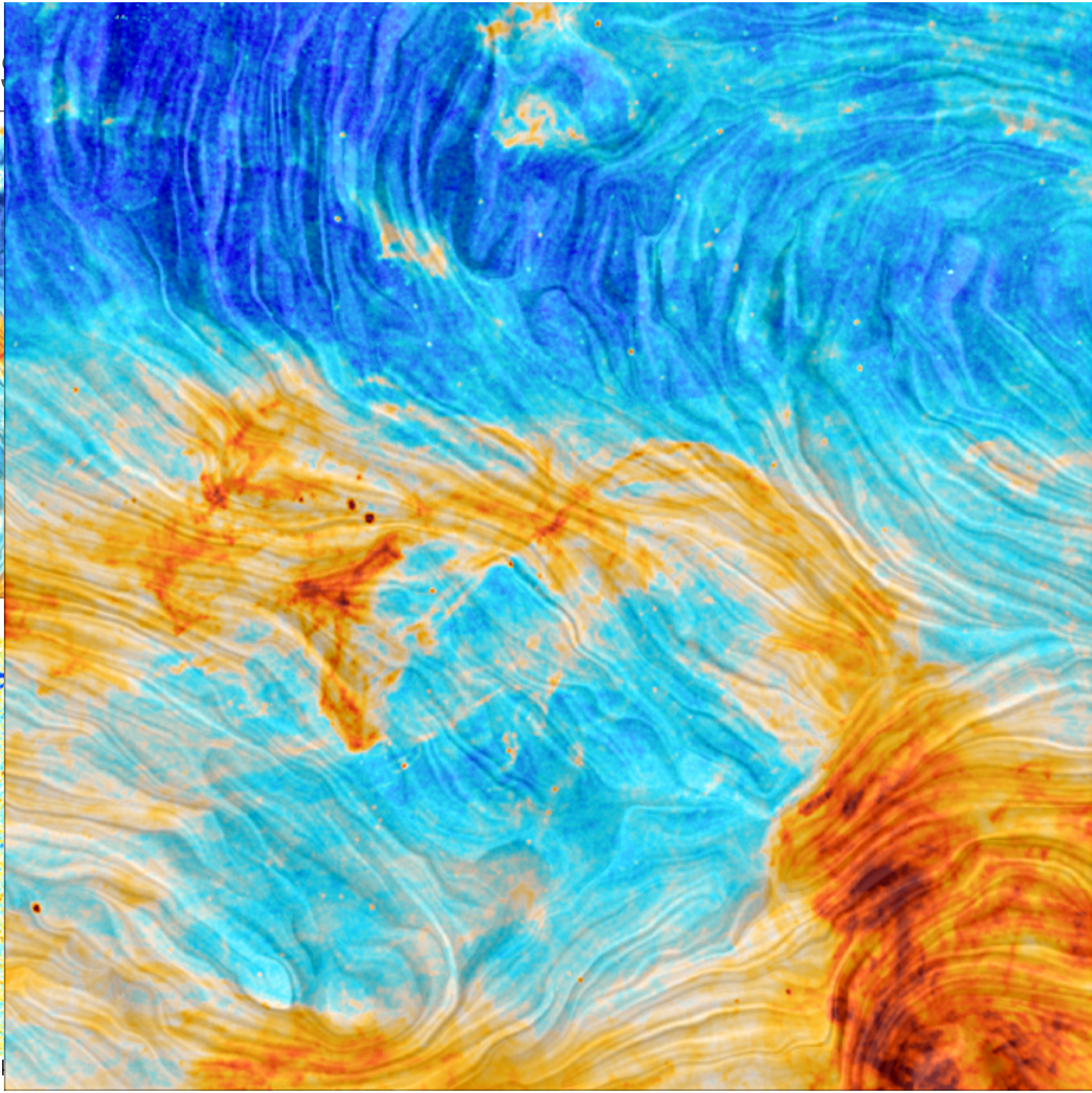
ESA/Planck

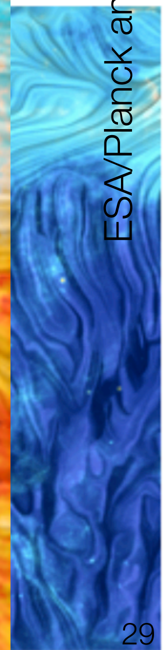
new res eld



ESA/Planck

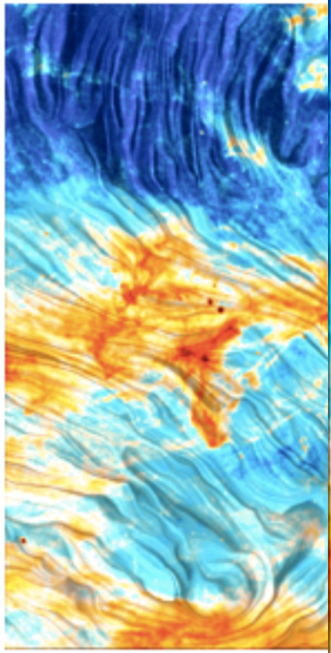




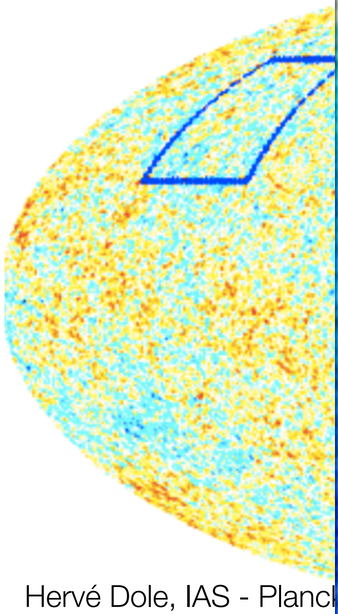


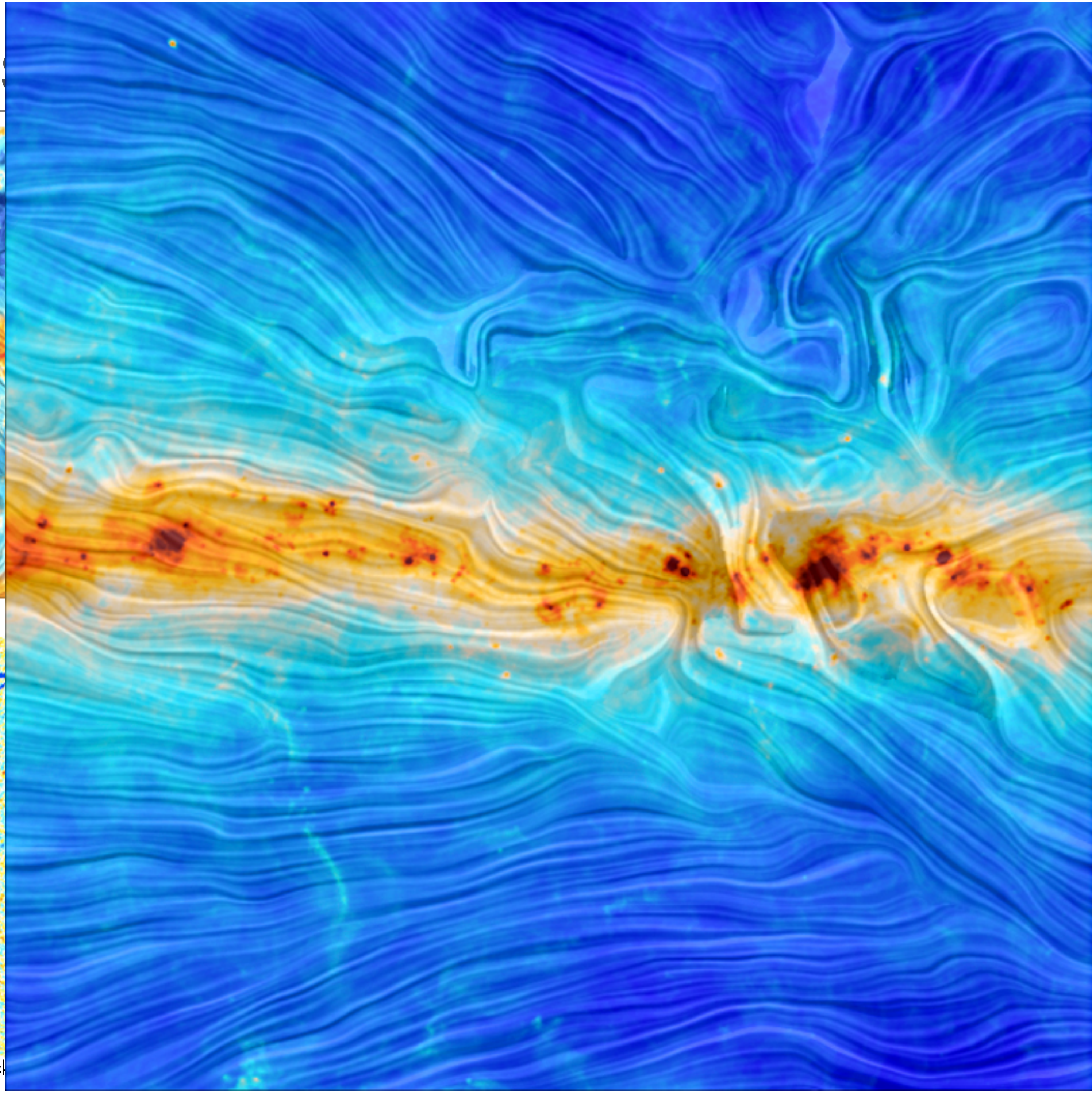
ESA/Planck and M-A Miville-Deschênes

new res… …eld

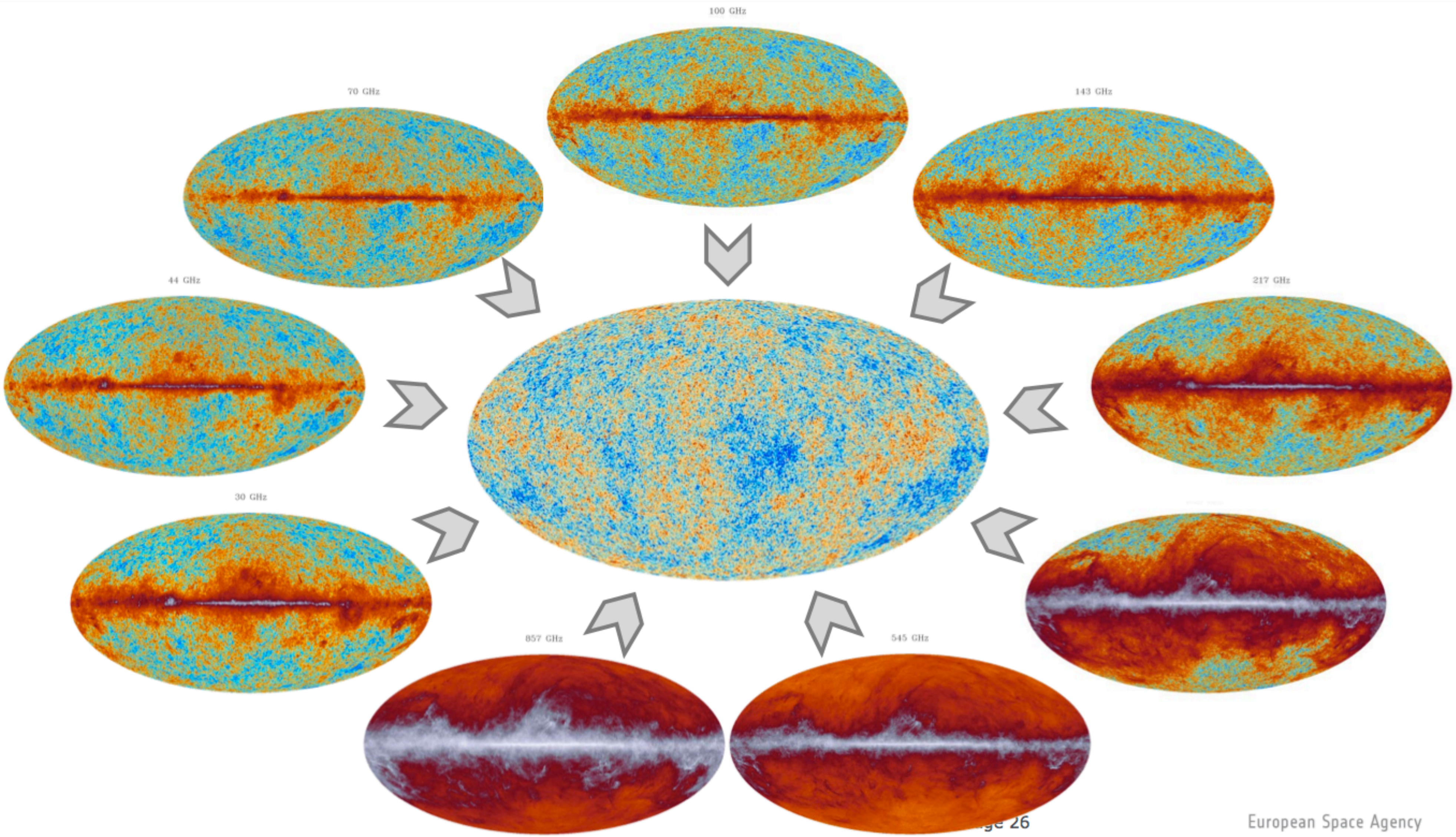


ESA/Planck





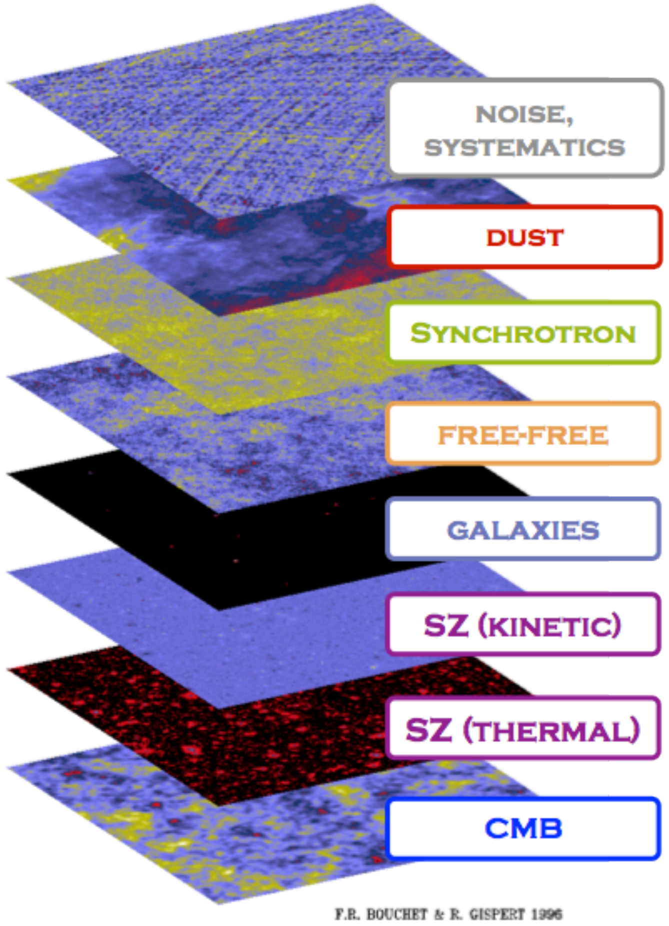
2. component separation

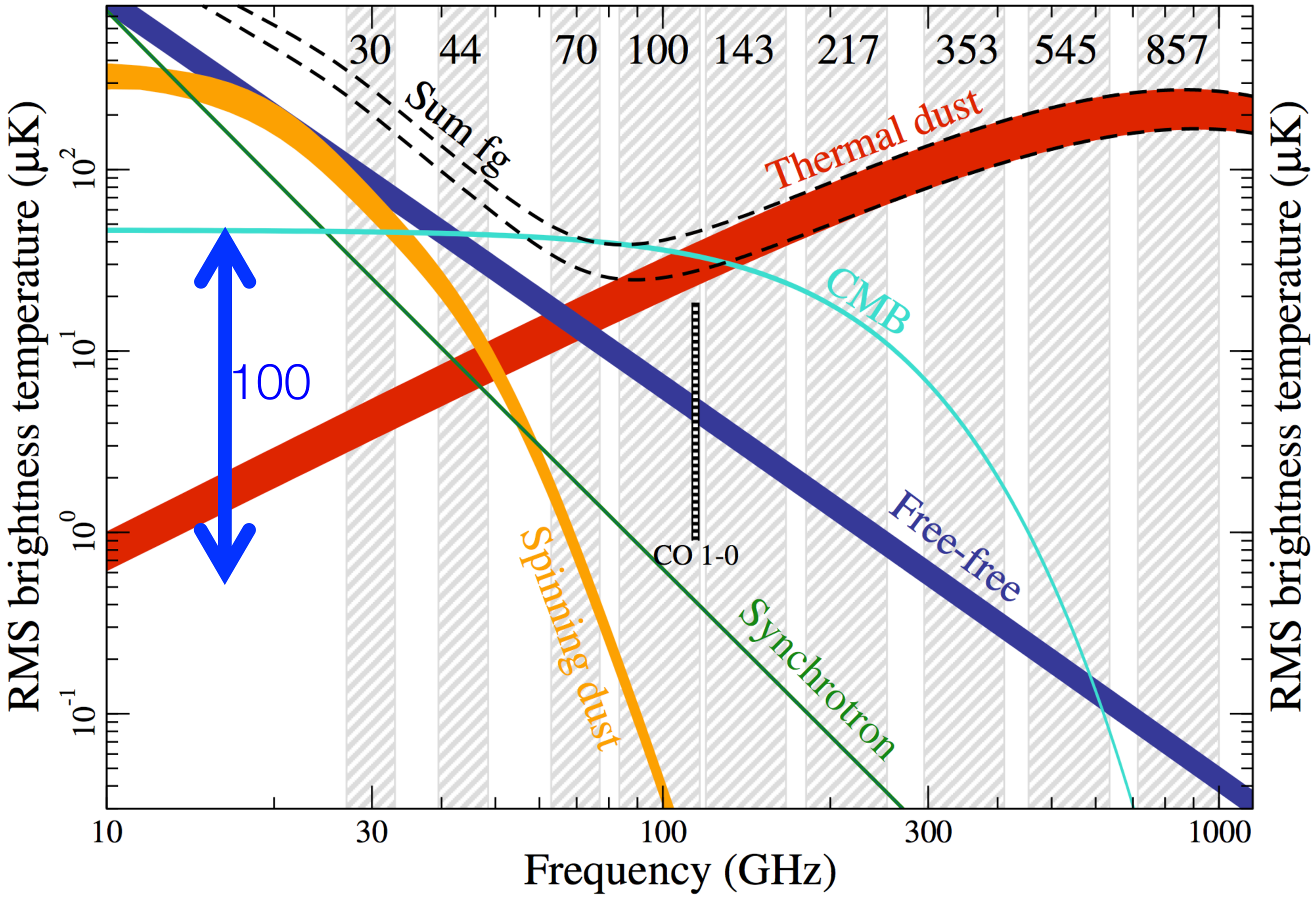


various components

different spectral and spatial behavior

sky temperature



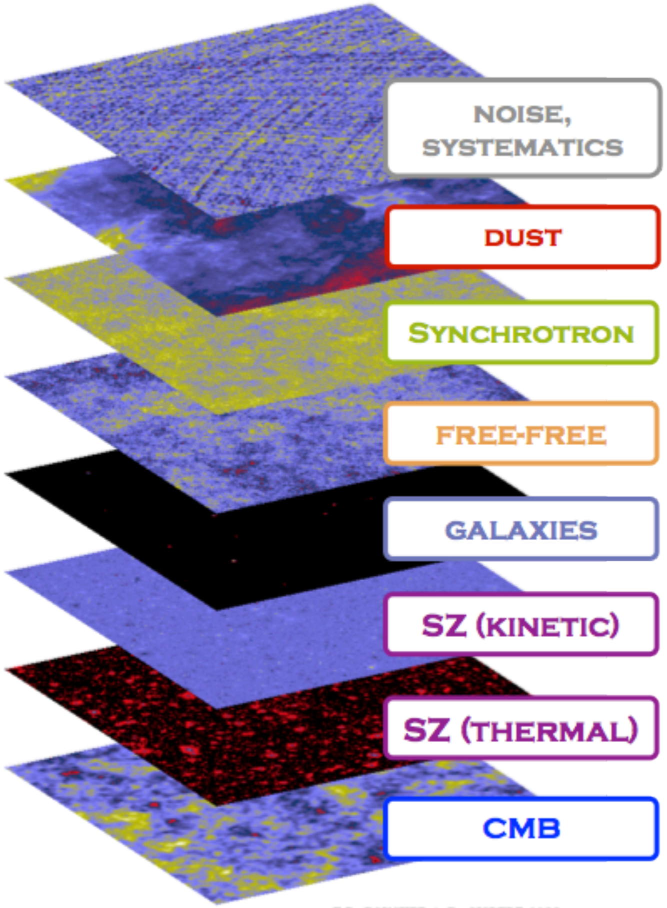


Planck Collab, 2015, 1

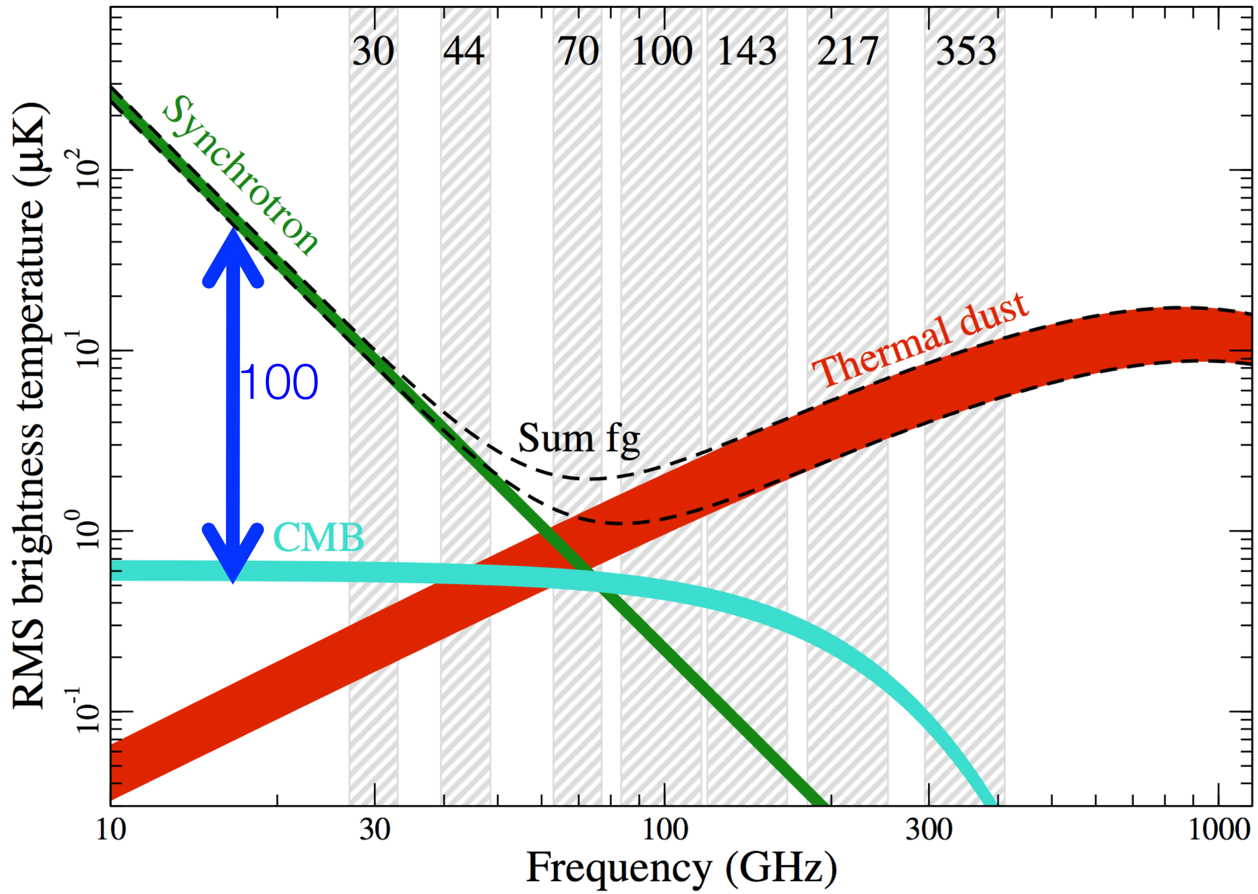
various components

different spectral and spatial behavior

sky polarization



F.R. BOUCHET & R. GISPERT 1996



Planck Collab, 2015, 1

2015 Planck sky components

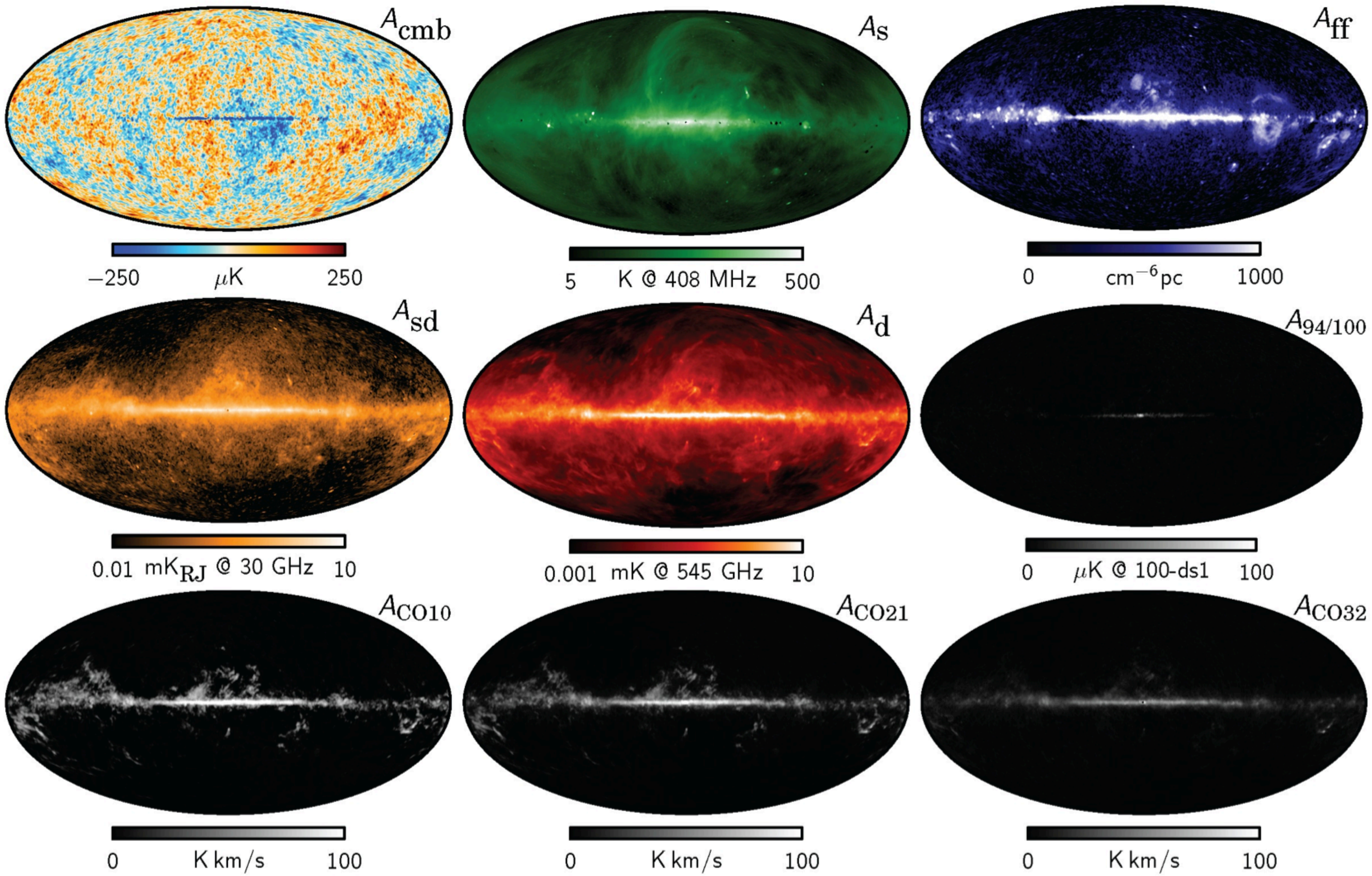
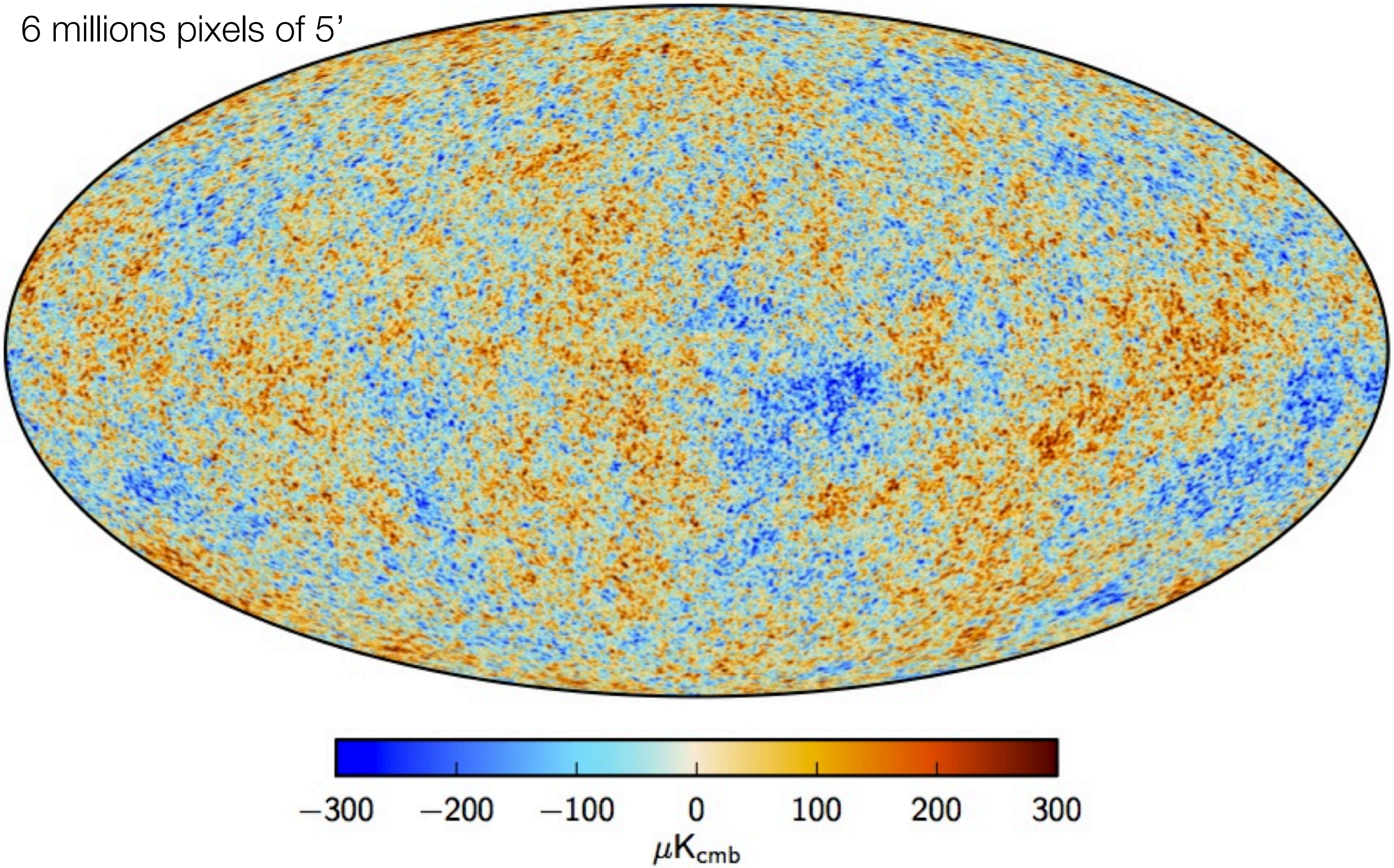


Fig. 14. Maximum posterior intensity maps derived from the joint analysis of *Planck*, WMAP, and 408 MHz observations (Planck Collaboration X 2015). From left to right, top to bottom: CMB; synchrotron; free-free; spinning dust; thermal dust; line emission around 90 GHz; CO $J = 1 \rightarrow 0$; CO $J = 2 \rightarrow 1$, and CO $J = 3 \rightarrow 2$.

Planck Collab, 2015, 1

temperature anisotropies

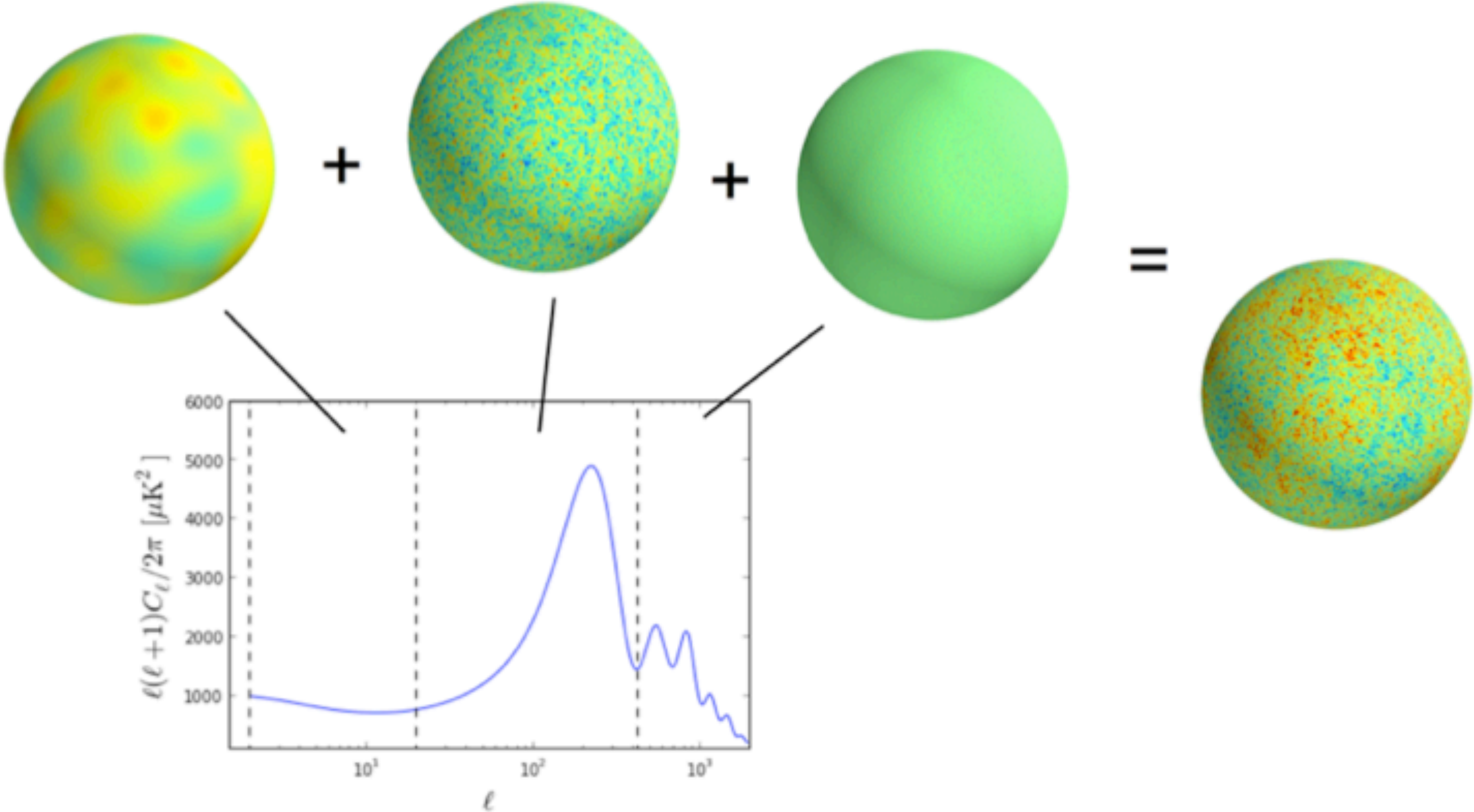
6 millions pixels of 5’



Planck Collab, 2015, 1

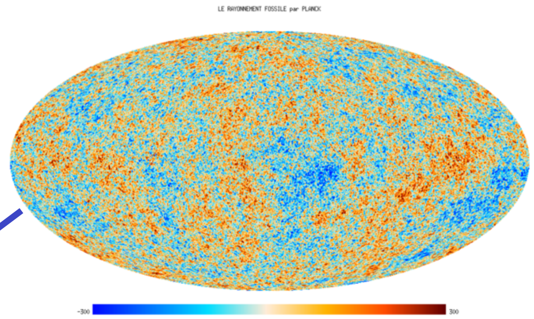
3. angular power spectra

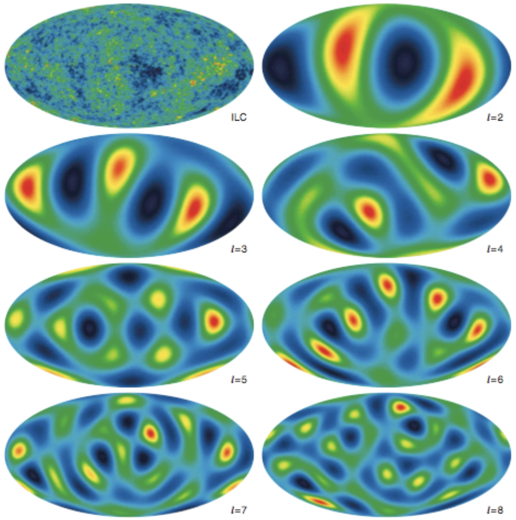
$$\langle a^*_{lm} a_{lm} \rangle = C_l$$



courtesy Olivier Doré

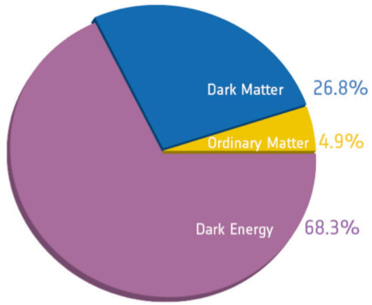
from maps to 6 cosmological parameters

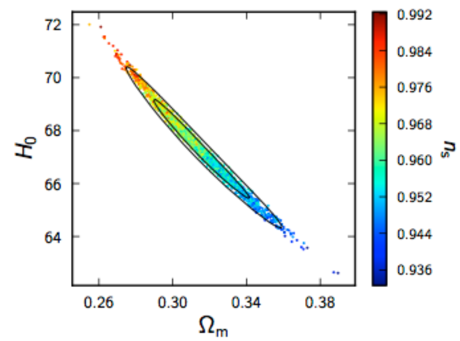


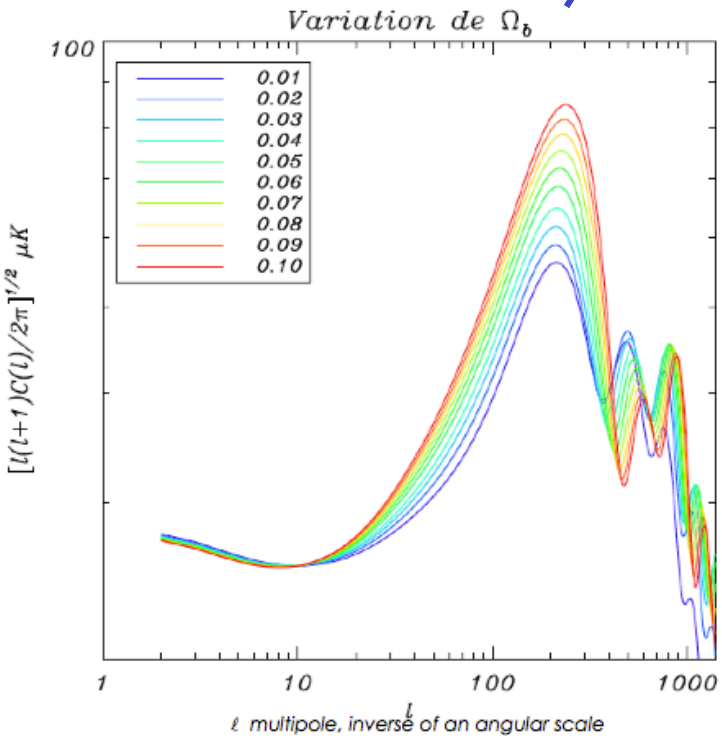


$$\frac{\Delta T(\mathbf{n})}{T_0} = \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m}^{T} Y_{\ell m}(\mathbf{n})$$

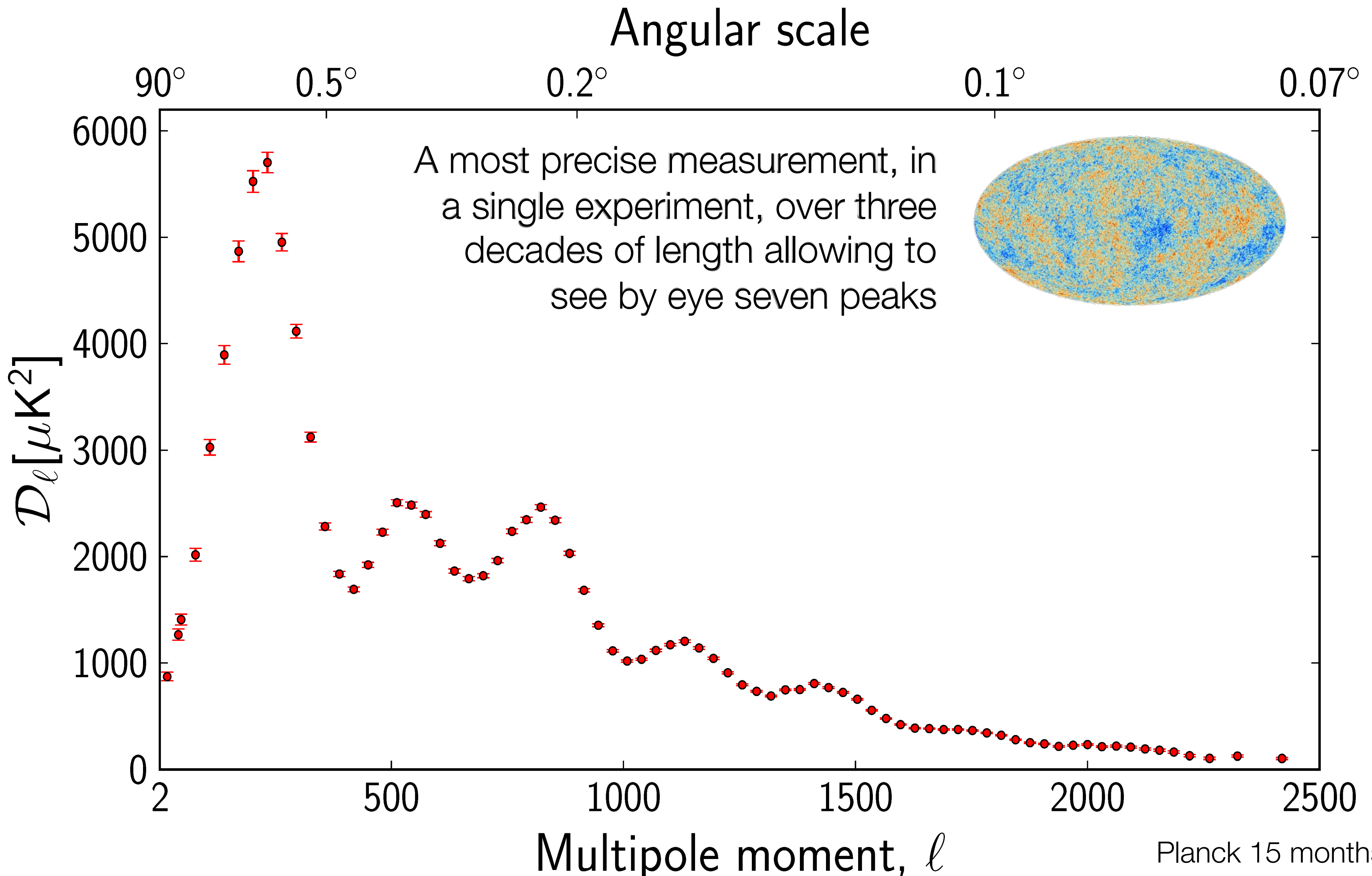
$$C_\ell^{TT} = \langle a_{\ell m}^{T} \cdot a_{\ell m}^{T\star} \rangle$$







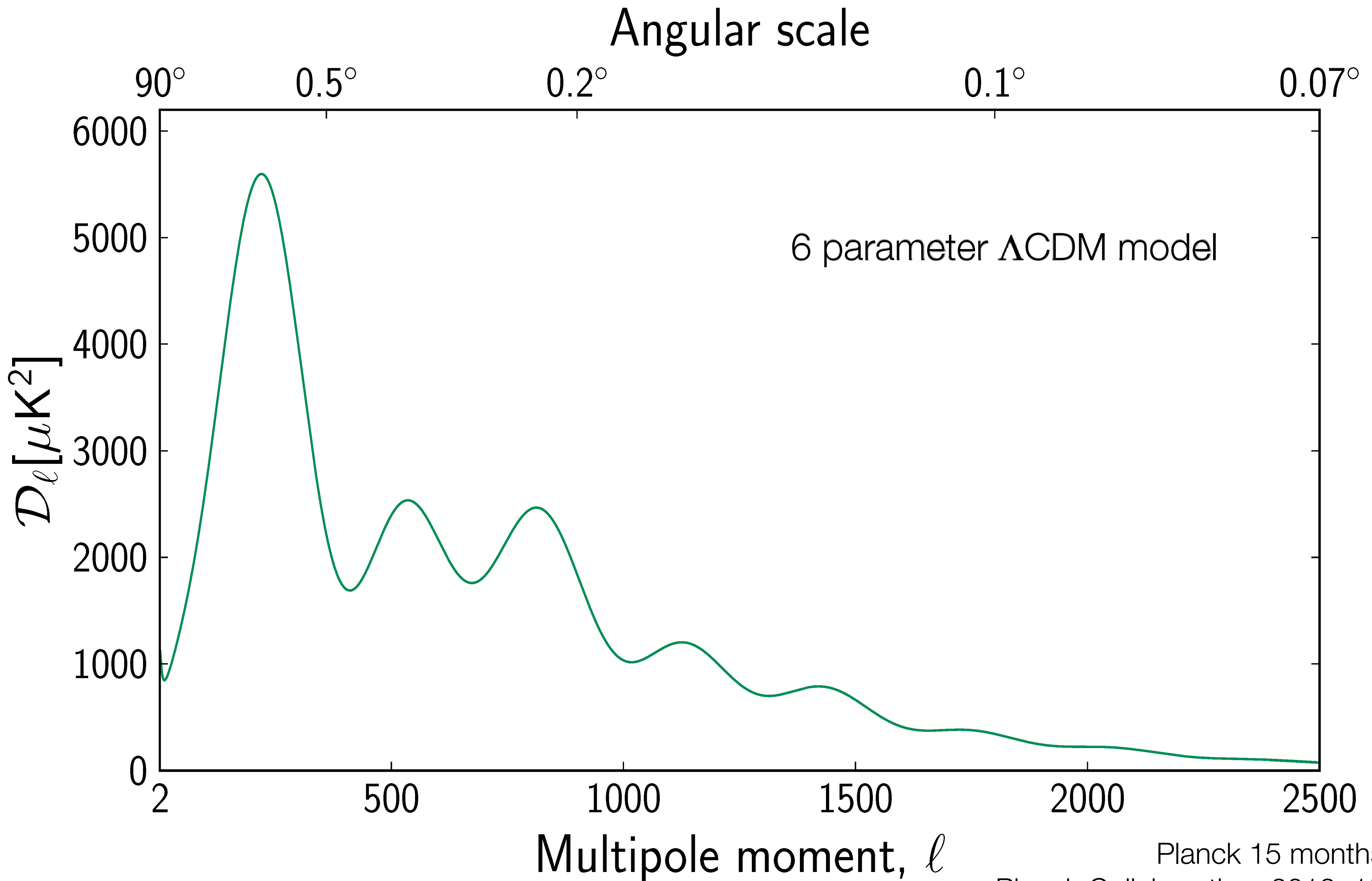
the Planck spectrum of temperature anisotropies



Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

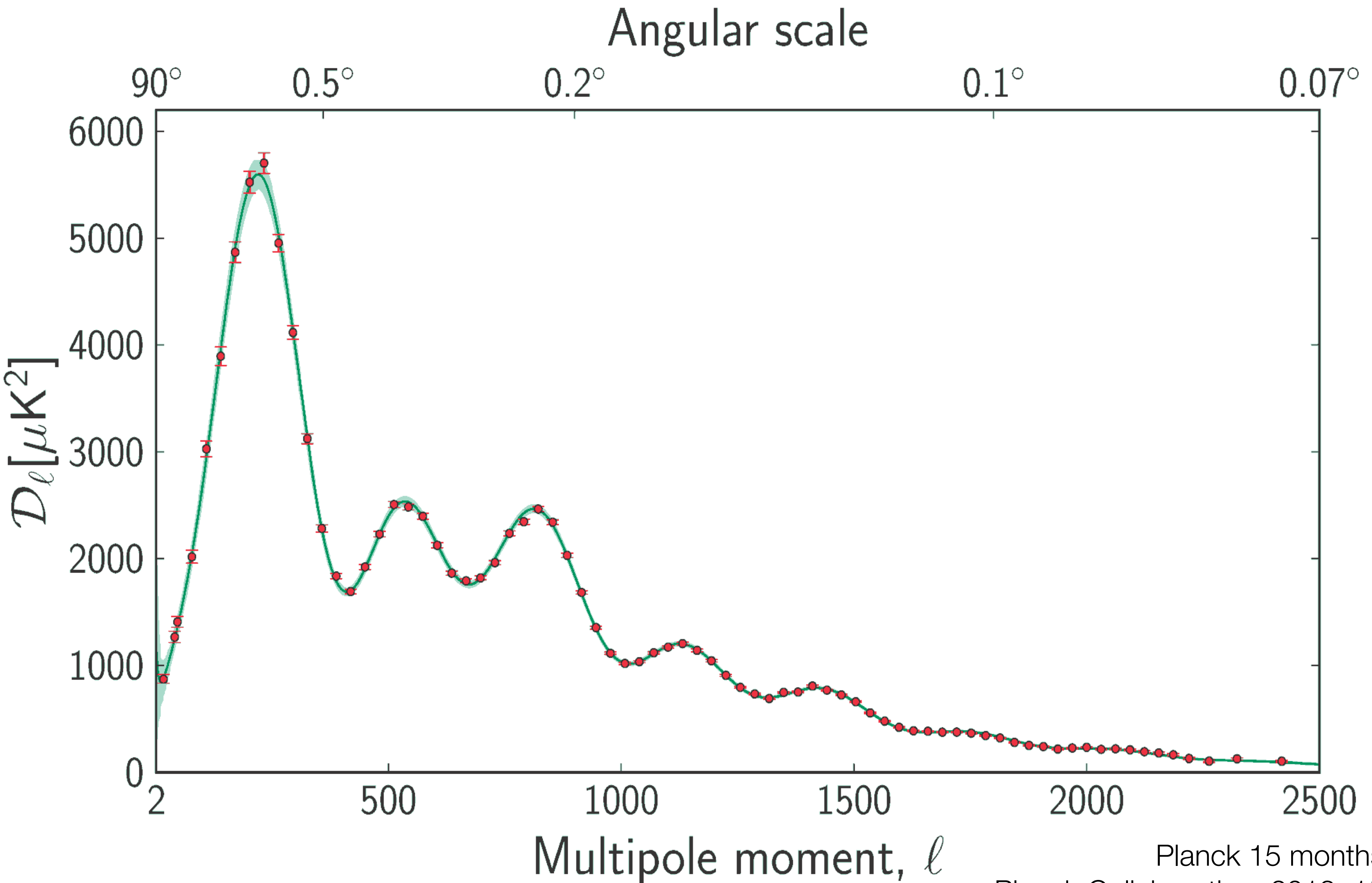
Planck best fitting theoretical model



Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

theory confronts data



Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

theory confronts data – polarization 2013

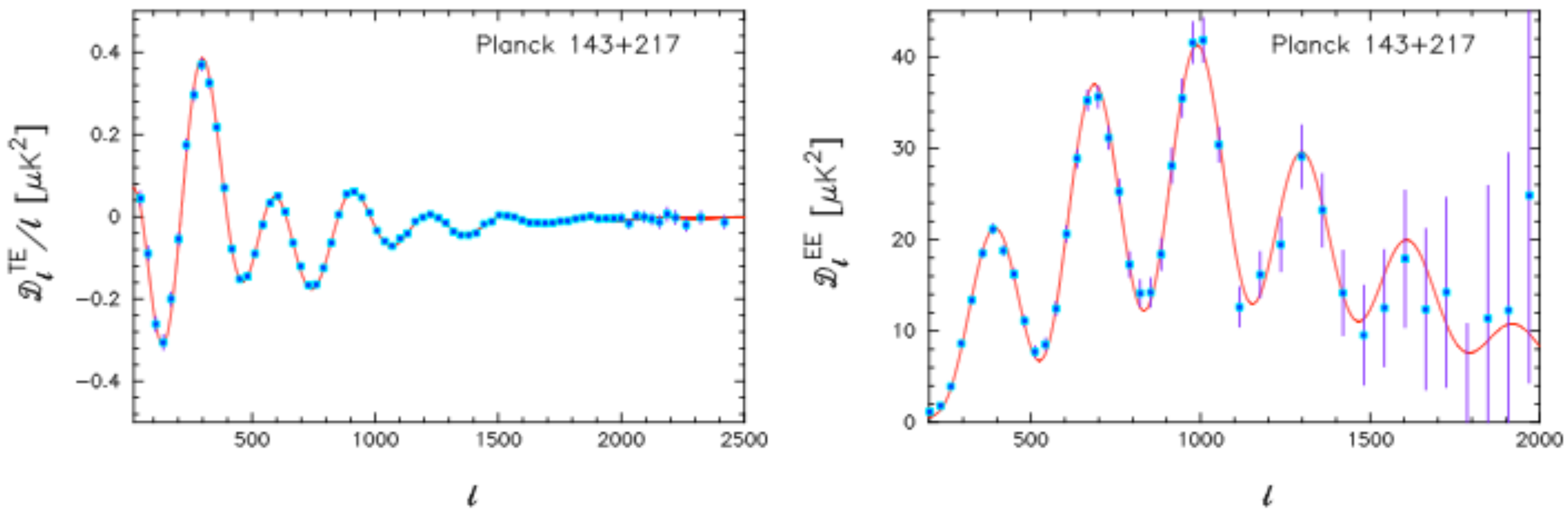


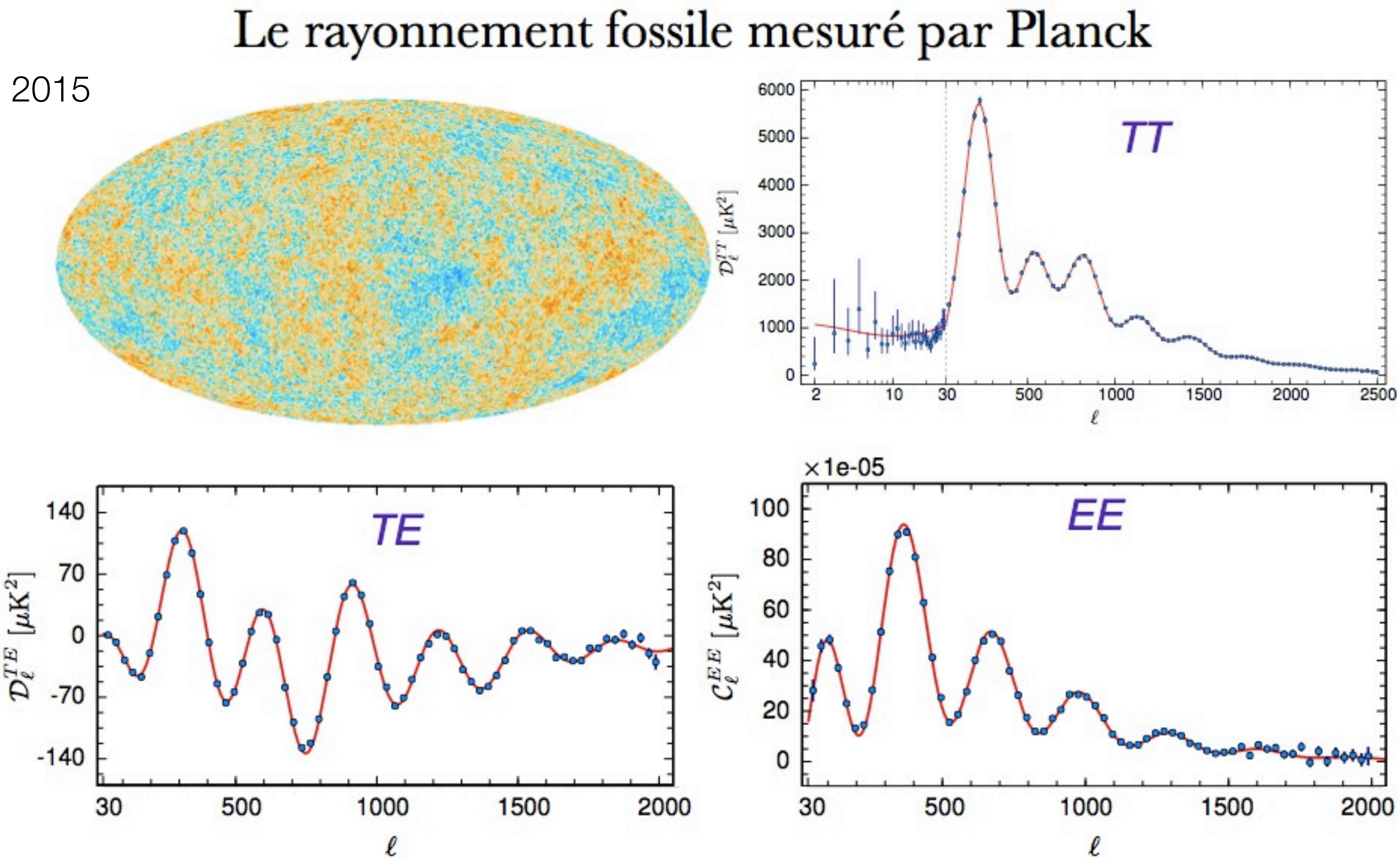
Fig. 11. *Planck TE* (left) and *EE* spectra (right) computed as described in the text. The red lines show the polarization spectra from the base ΛCDM *Planck*+WP+highL model, *which is fitted to the TT data only*.

-> NOT a fit to TE and EE, just an overplot at higl-ell

Planck 15 months
Planck Collaboration, 2013, 15

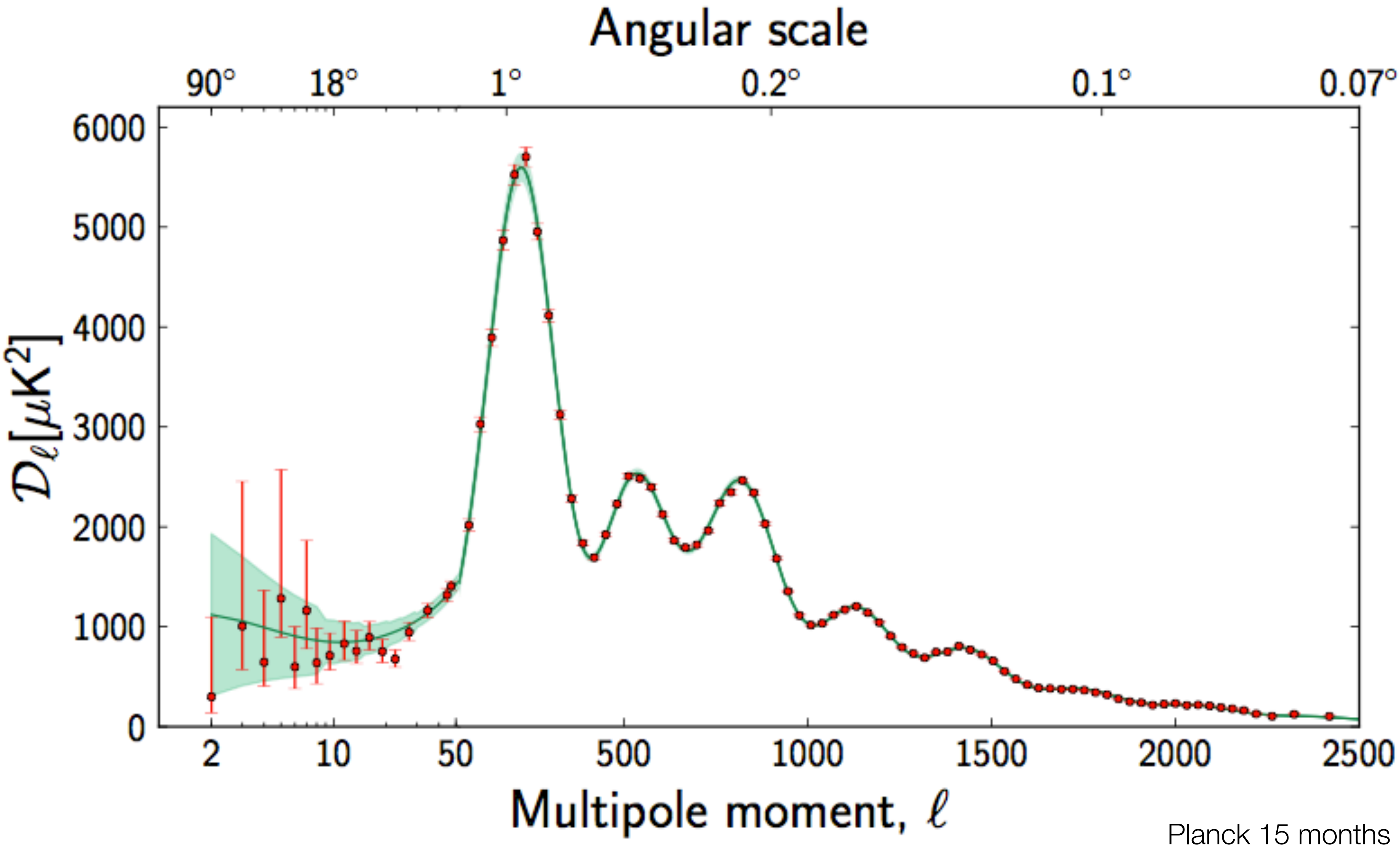
theory confronts data – from 7 to 19 peaks

2015



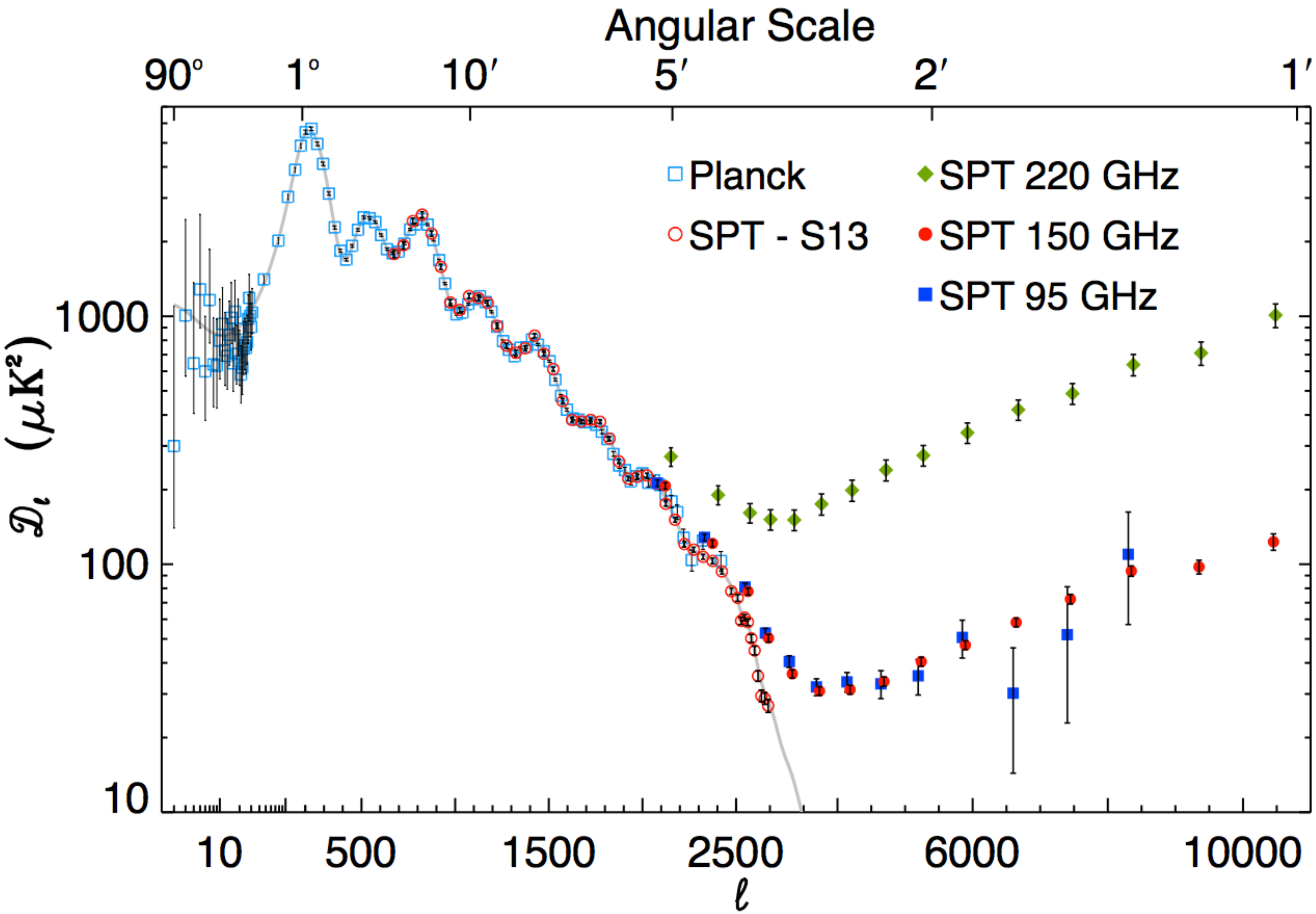
Planck 2015

theory confronts data



Planck 15 months
Planck Collaboration, 2013, 15

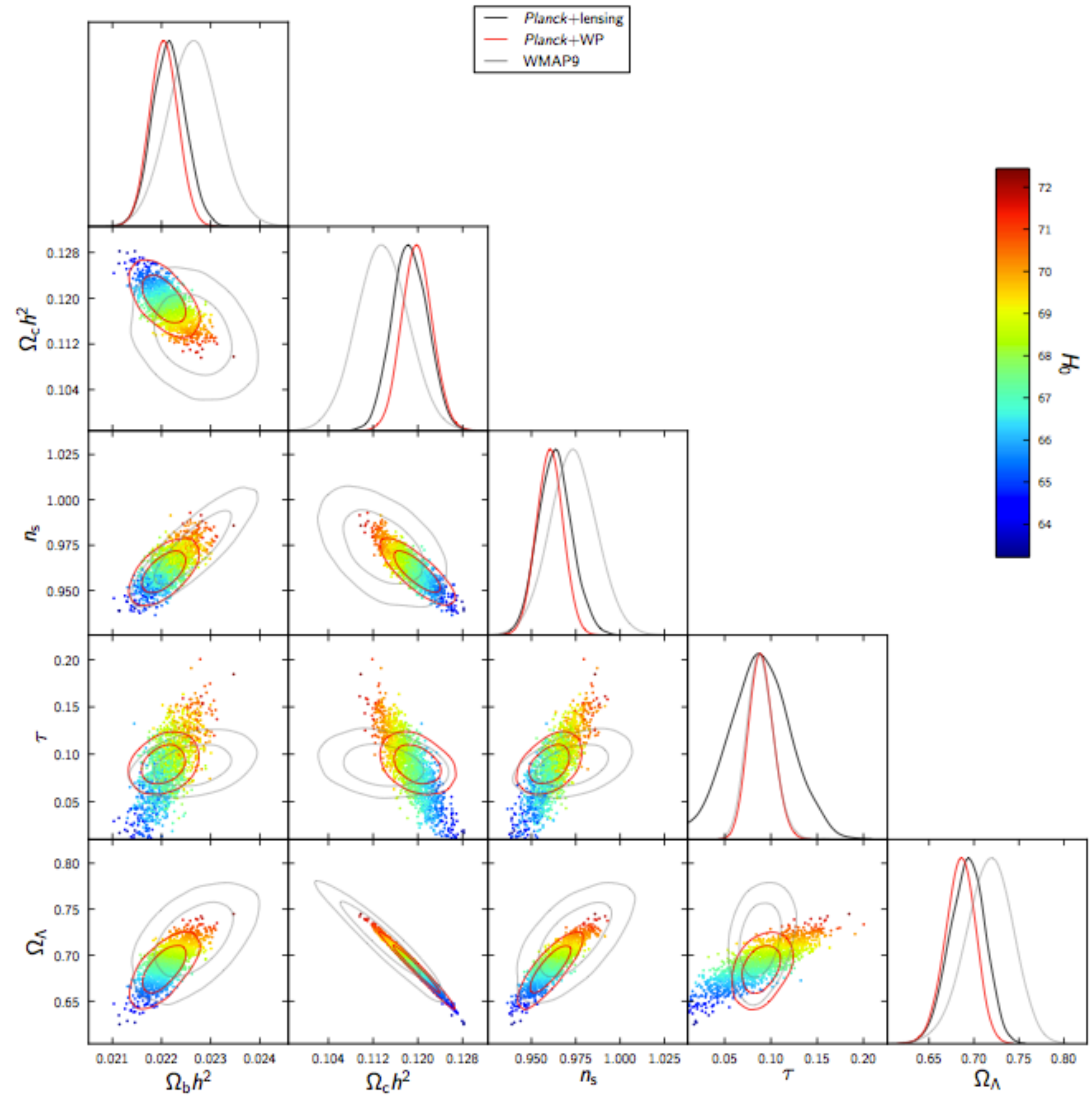
independant datasets



George+ 2014

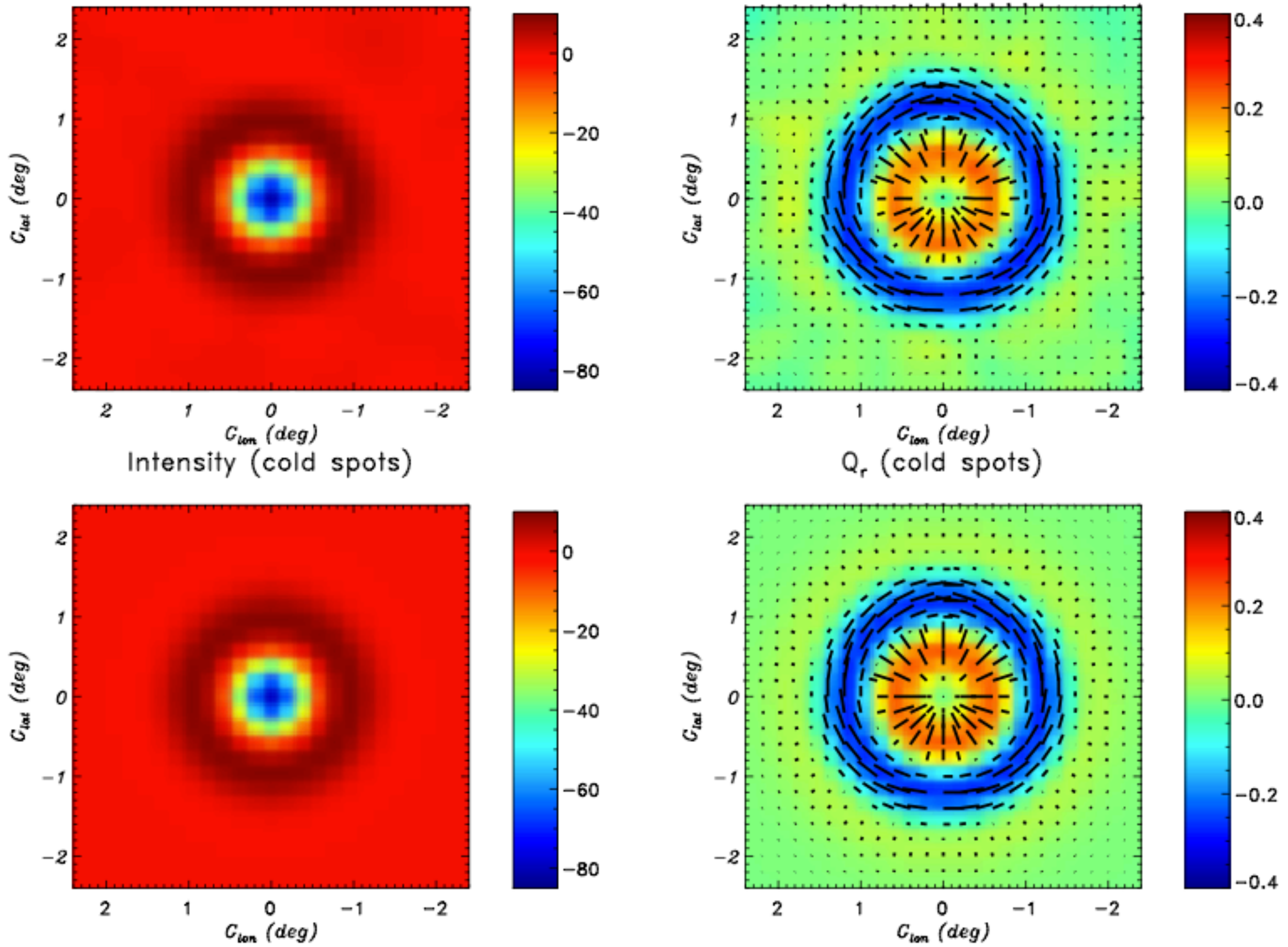
FIG. 2.— The SPT and *Planck* bandpowers. The *Planck* and S13 bandpowers (open squares and circles) are primary CMB only, and agree well on all angular scales. The grey line is the lensed ΛCDM CMB theory spectrum. We also show bandpowers at 95, 150, and 220 GHz (filled squares, circles and diamonds) measured with the SPT in this work. On large scales, the primary CMB anisotropy is dominant at all frequencies. On smaller scales, contributions from the CIB, radio sources, and secondary CMB anisotropies (tSZ and kSZ) dominate the observed power. The observed differences between frequency bands are due to these other sources of power. The CIB dominates the power spectrum at small scales at 150 and 220 GHz; radio galaxies are more important at 95 GHz.

cosmological parameters estimates



Planck 15 months
Planck Collaboration, 2013, 16

matter density and velocity at recombination



Data (top) versus expectation (bottom) of stacked cold spots

➔ Planck “sees” precisely the dynamics of fluctuations, at ~380 000 years

Planck 15 months
Planck Collaboration, 2013, 1

4. 2015 cosmological parameters

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

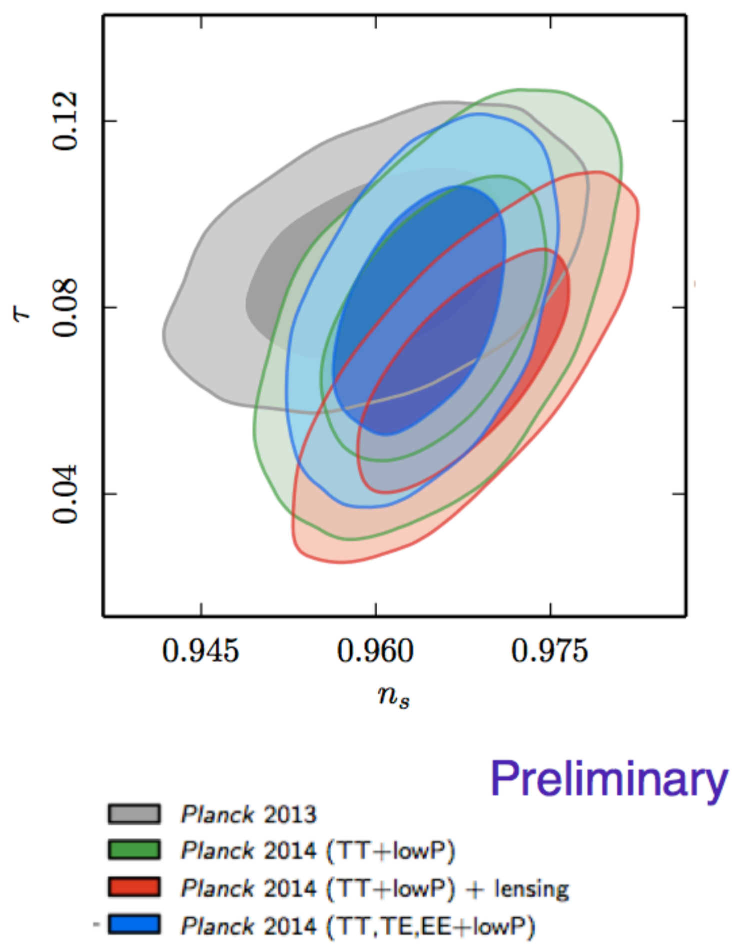
6 cosmological parameters

0.3% uncertainty !

Planck Collab, 2015, 1

5. inflation 2015

Planck 2014 n_s



$$\mathcal{P}_{\mathcal{R}}(k) = A_s \left(\frac{k}{k_*}\right)^{n_s - 1}$$

$$n_s = 0.9652 \pm 0.0062 \quad (68\,\%\mathrm{CL}\,, \mathit{Planck}\;\mathrm{TT}+\mathrm{lowP})$$

$$\tau = 0.078 \pm 0.019 \quad (68\,\%\mathrm{CL}\,, \mathit{Planck}\;\mathrm{TT}+\mathrm{lowP})$$

Compare with Planck 2013 results:

$$n_s = 0.9603 \pm 0.0073 \quad (68\,\%\mathrm{CL}\,, \mathit{Planck}\;2013)$$

The polarization results reported here and in the folllowing slides are preliminary, because we do not yet have confidence that all systematic and foreground uncertainties have been properly characterized, and the results may therefore be subject to revision.

courtesy Finelly

5. inflation 2015

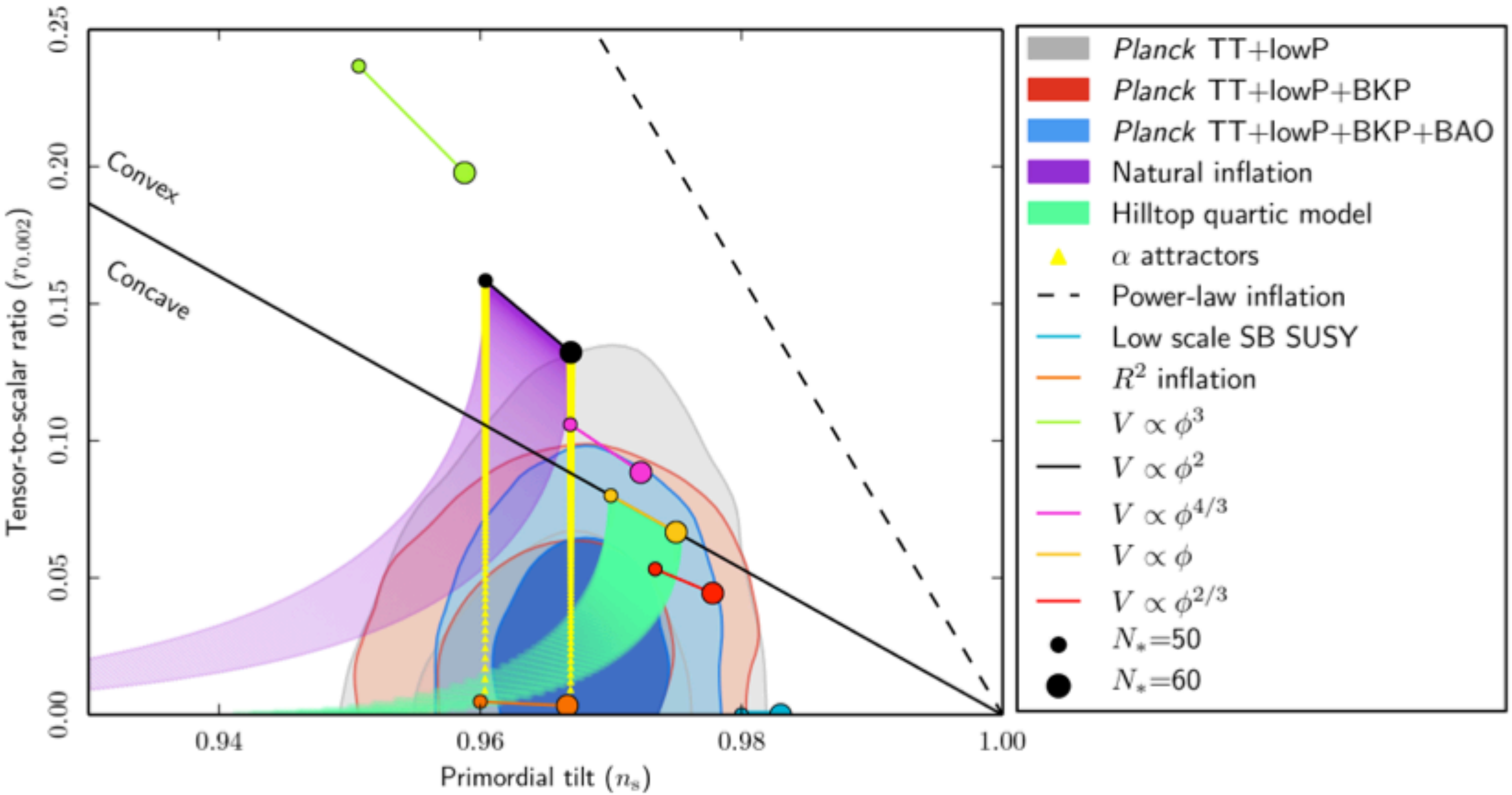


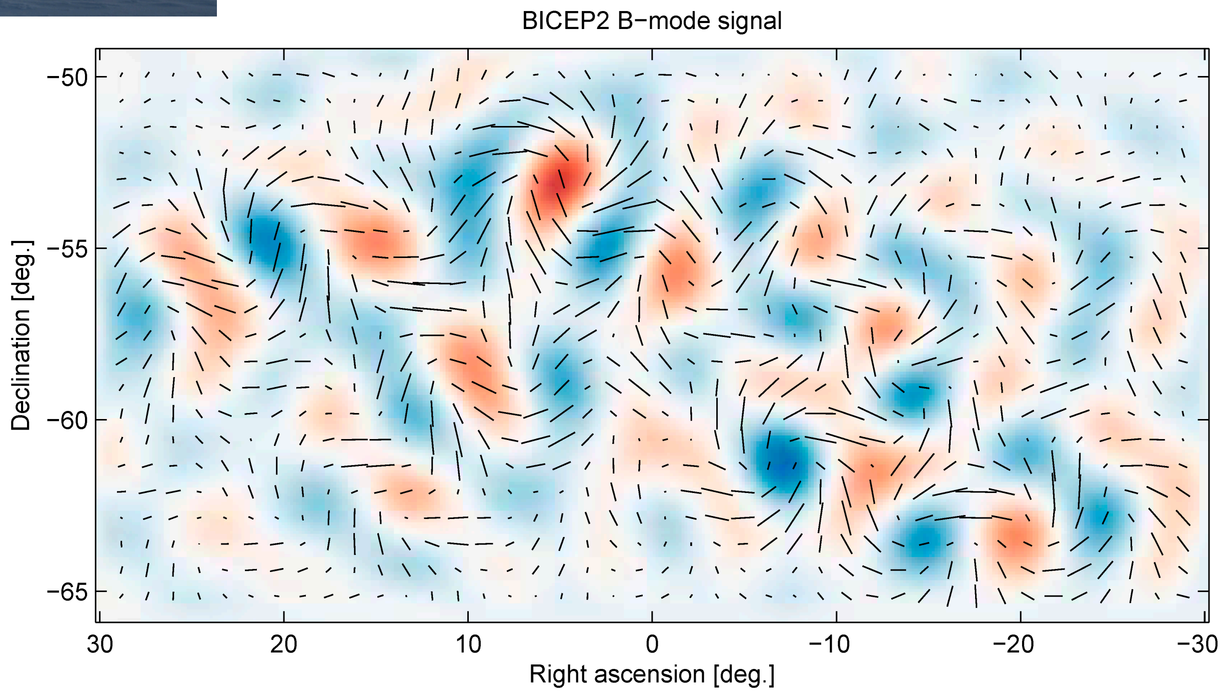
Fig. 54. Marginalized joint 68 % and 95 % CL regions for n_s and $r_{0.002}$ from *Planck* alone and in combination with its cross-correlation with BICEP2/Keck Array and/or BAO data compared with the theoretical predictions of selected inflationary models.

cosmic inflation < 10^{-35} second

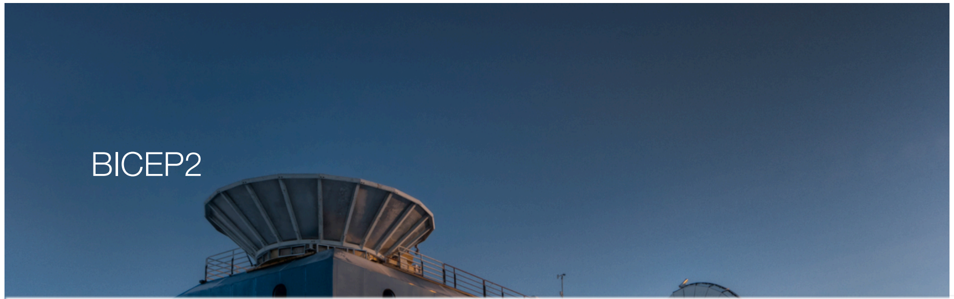
Planck 2015, 20

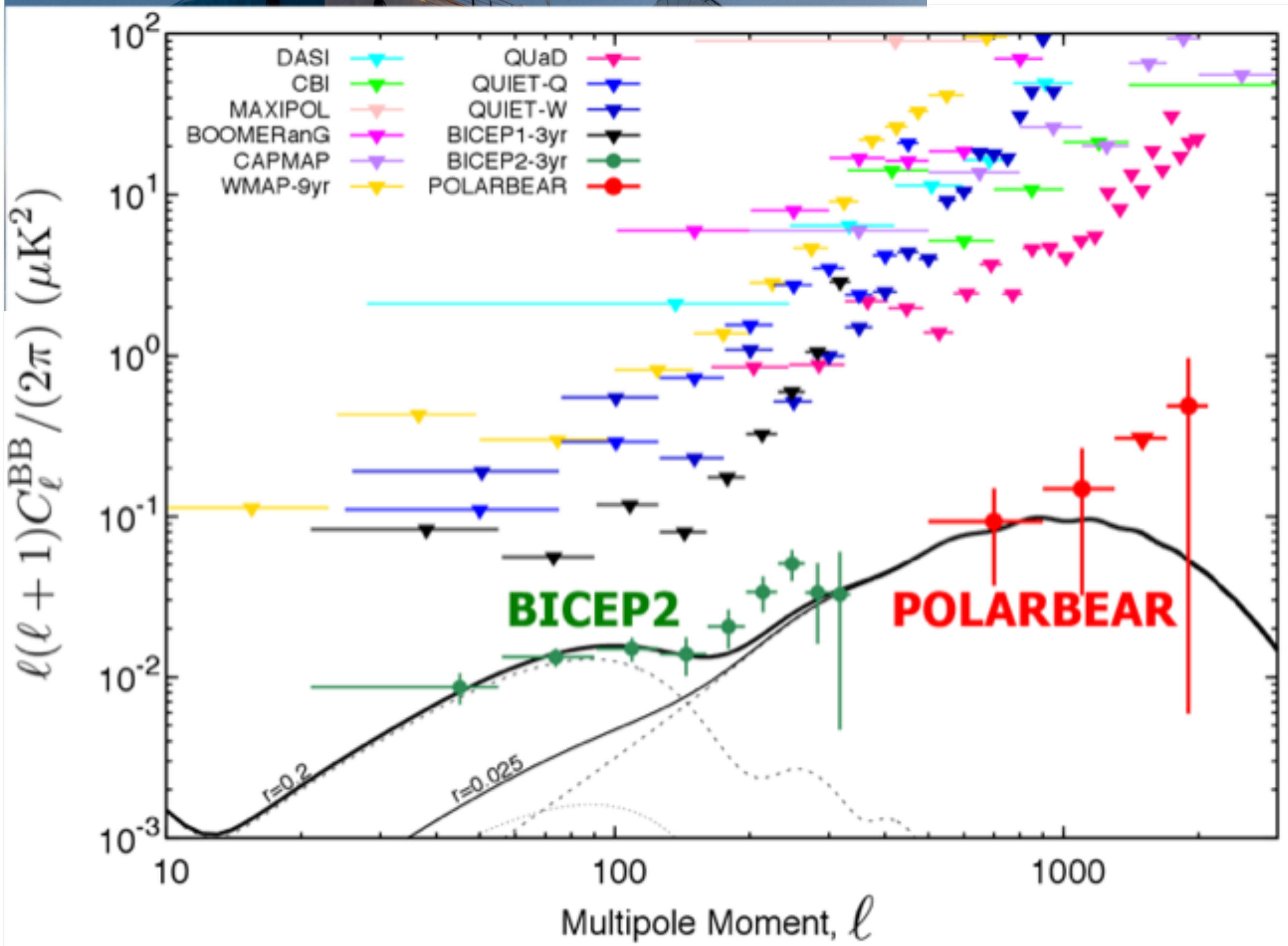
inflation and primordial B-modes ?

détection des modes B primordiaux ?
un débat vif !

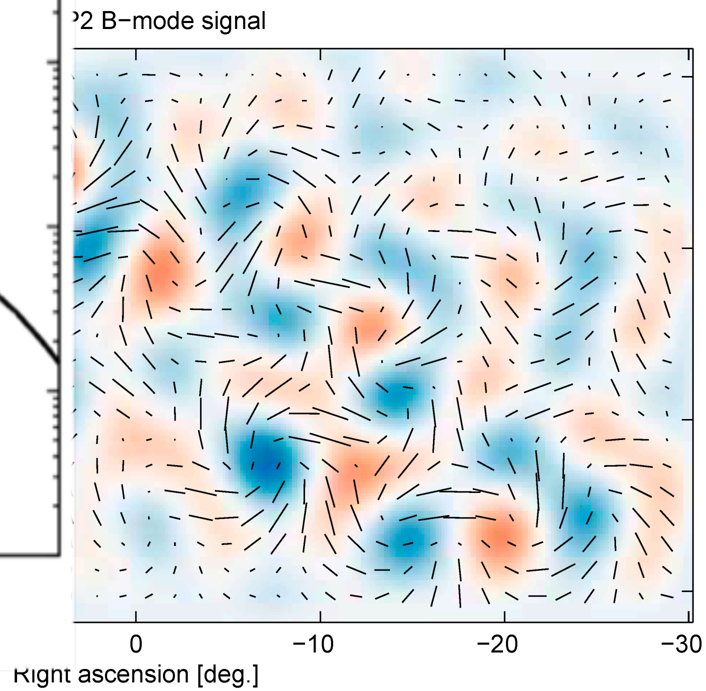


inflation and primordial B-modes ?

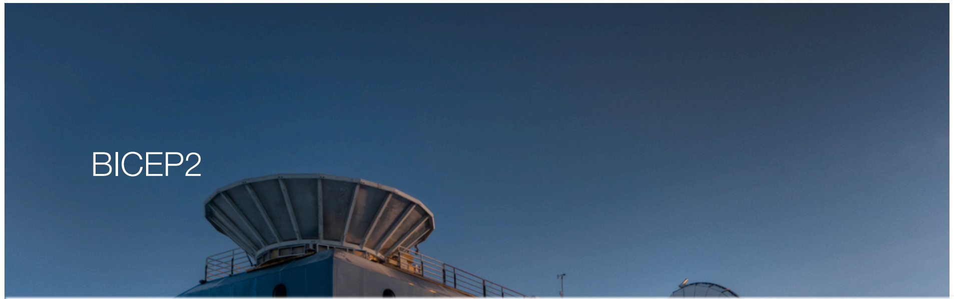


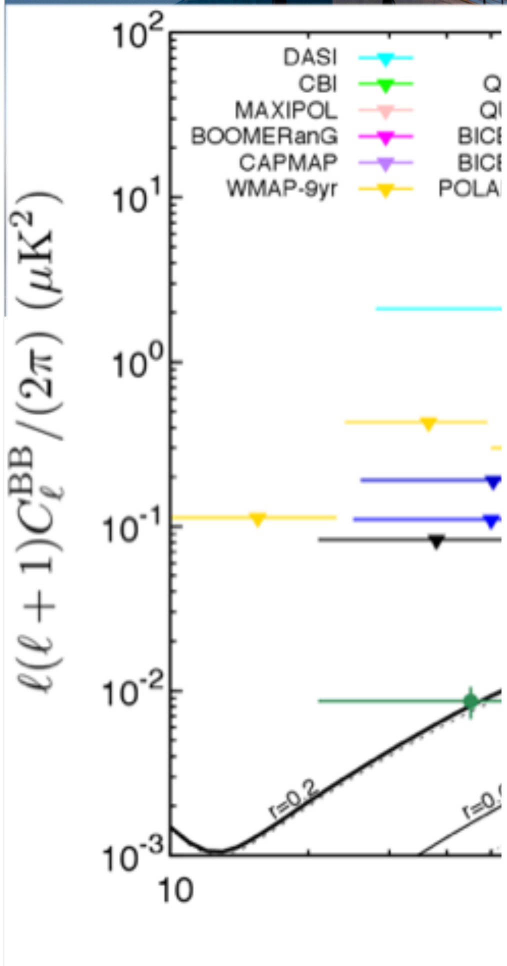


détection des modes B primordiaux ?
un débat vif !



inflation and primordial B-modes ?





détection des modes B primordiaux ?
un débat vif !

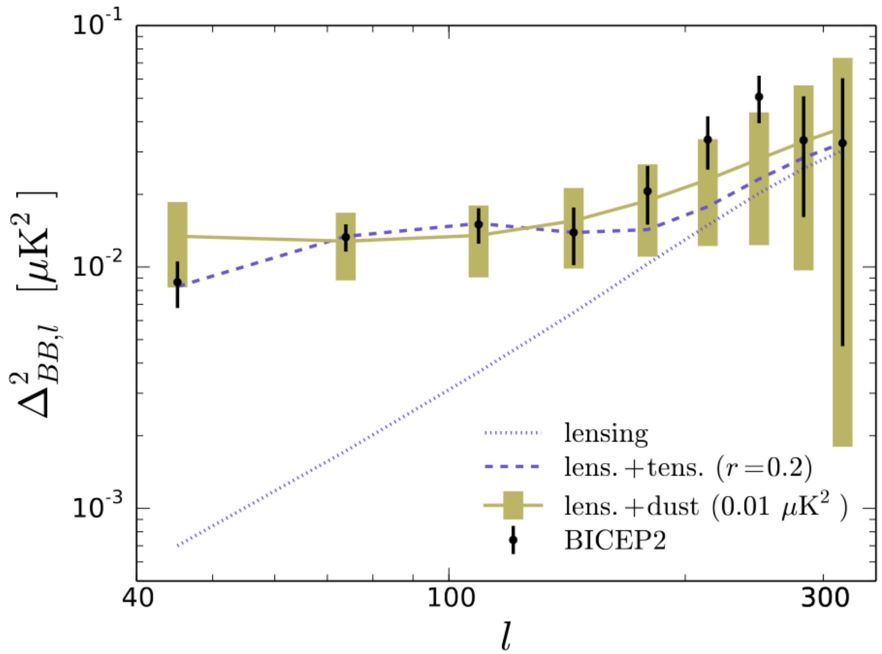


Figure 3. *B* mode spectrum predictions compared with BICEP2 data (black points with error bars, showing measurement uncertainty only). Each model curve shows the expected signal in the 9 BICEP2 bandpowers. The dashed curve is the sum of a gravity wave component with $r = 0.2$ and the lensing spectrum (dotted curve); the solid curve assumes $r = 0$ and adds to the lensing spectrum a dust polarization spectrum $\Delta^2_{BB,\mathrm{dust},l} = (0.01\,\mu\mathrm{K}^2)\,(l/100)^{-0.3}$. 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

inflation and primordial B-modes ?

ection des modes B primordiaux ?
débat vif !

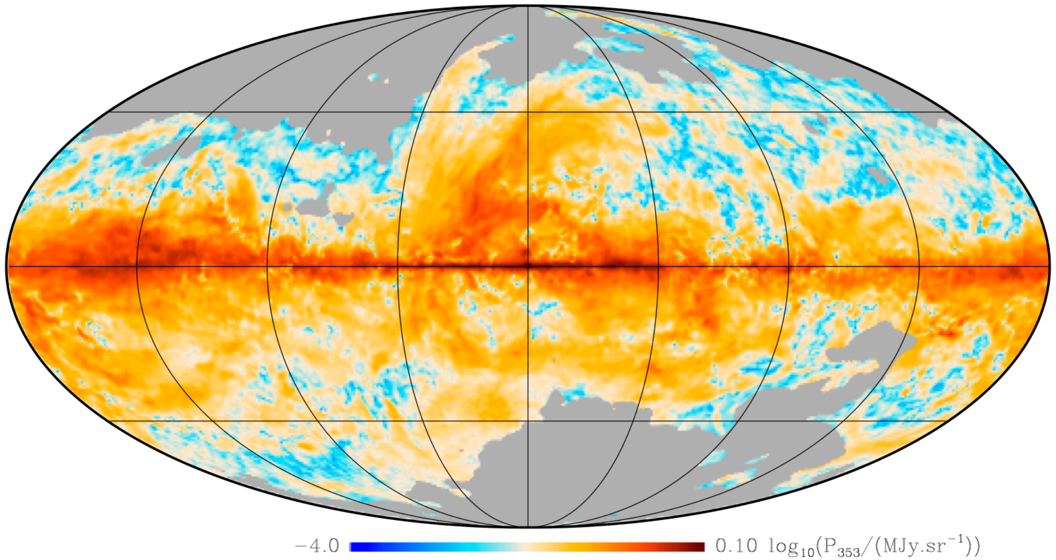
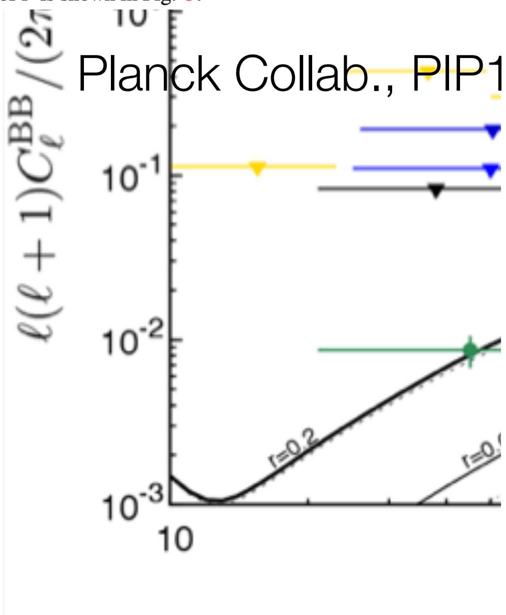


Fig. 2. *Planck* 353 GHz polarized intensity (*P*) map at 1° resolution in $\log_{10}$ scale. The values shown have been bias corrected as described in Sect. 2.3. The same mask as in Fig. 1 is applied. The full sky map of the unpolarized intensity *I* entering the calculation of *P* is shown in Fig. 5.



Planck Collab., PIP19, 2014

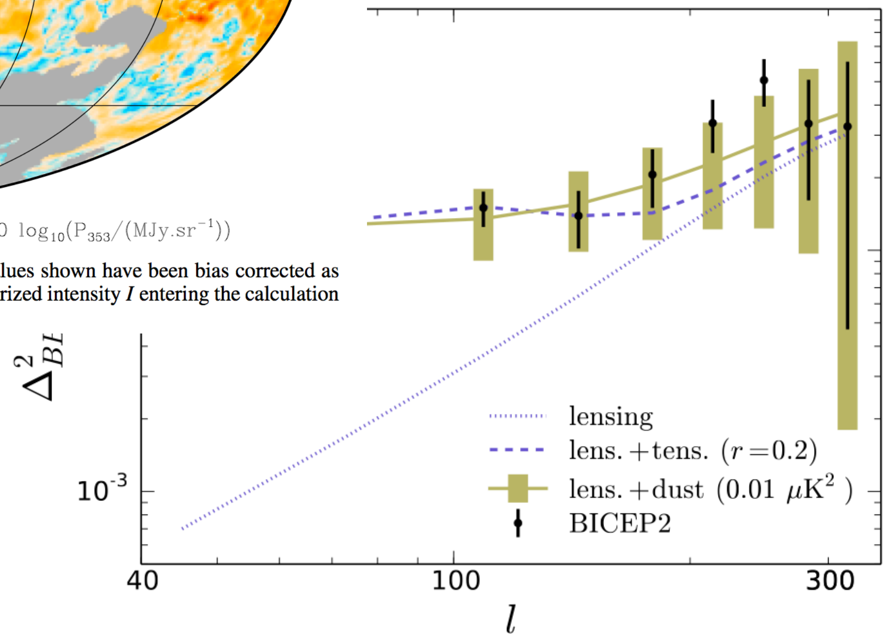


Figure 3. *B* mode spectrum predictions compared with BICEP2 data (black points with error bars, showing measurement uncertainty only). Each model curve shows the expected signal in the 9 BICEP2 bandpowers. The dashed curve is the sum of a gravity wave component with $r = 0.2$ and the lensing spectrum (dotted curve); the solid curve assumes $r = 0$ and adds to the lensing spectrum a dust polarization spectrum $\Delta^2_{BB,\mathrm{dust},l} = (0.01\,\mu\mathrm{K}^2)\,(l/100)^{-0.3}$. 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

inflation and primordial B-modes ?

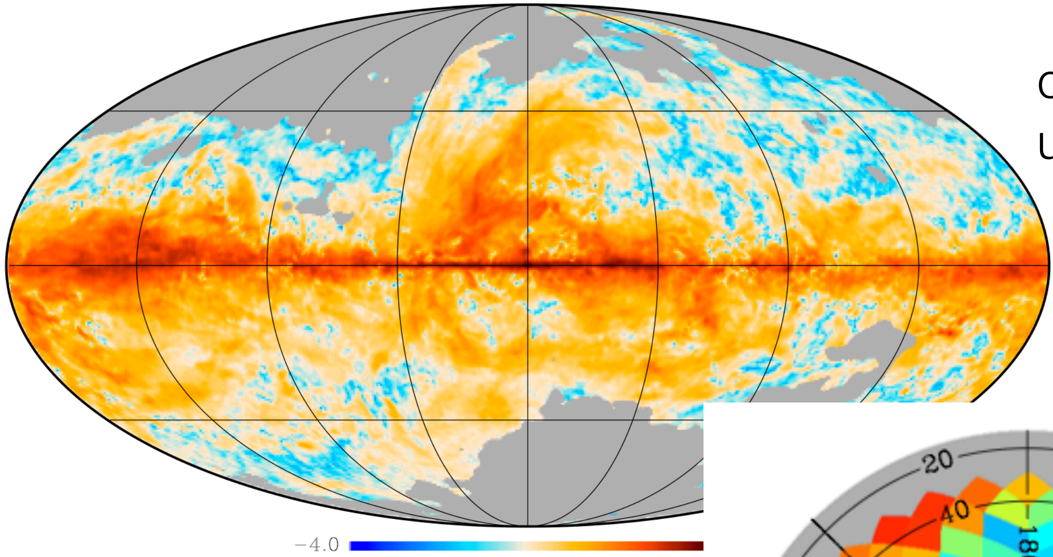
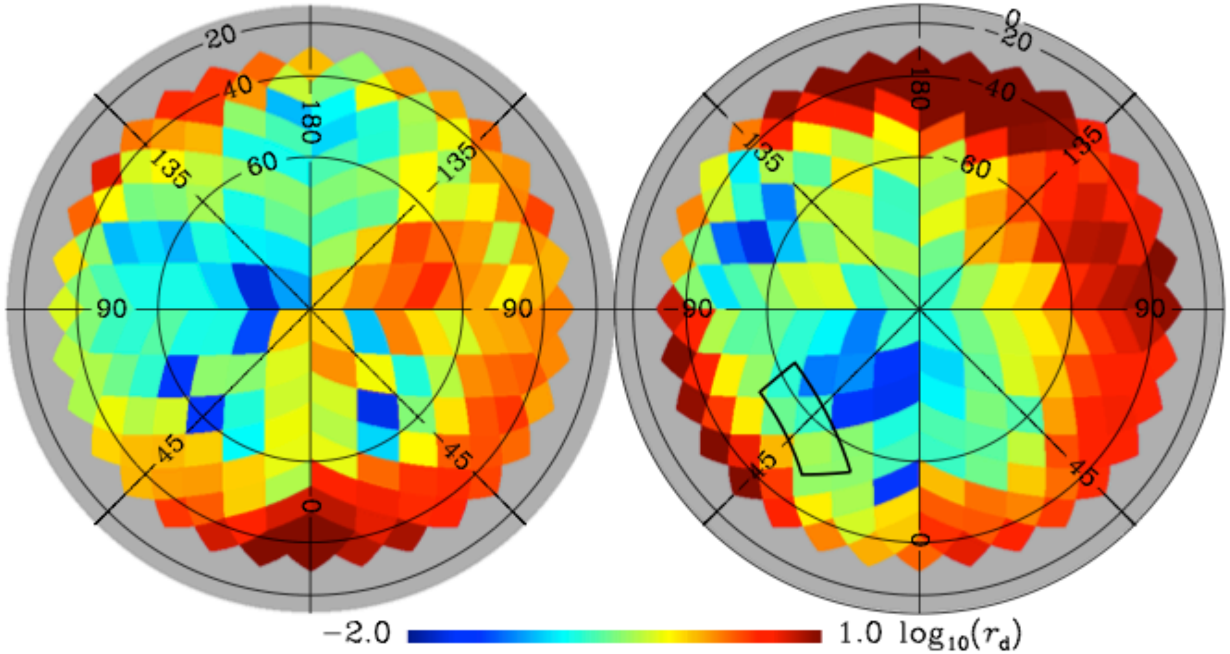


Fig. 2. *Planck* 353 GHz polarized intensity (P) map at 1° resolution in $\log_{10}$ scale. T
described in Sect. 2.3. The same mask as in Fig. 1 is applied. The full sky map of the u
of P is shown in Fig. 5.

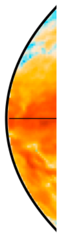
Planck Collab., PIP19, 2014

détection des modes B primordiaux ?
un débat vif !



Planck Collab., PIP30, 2014

inflation and primordial B-modes ?



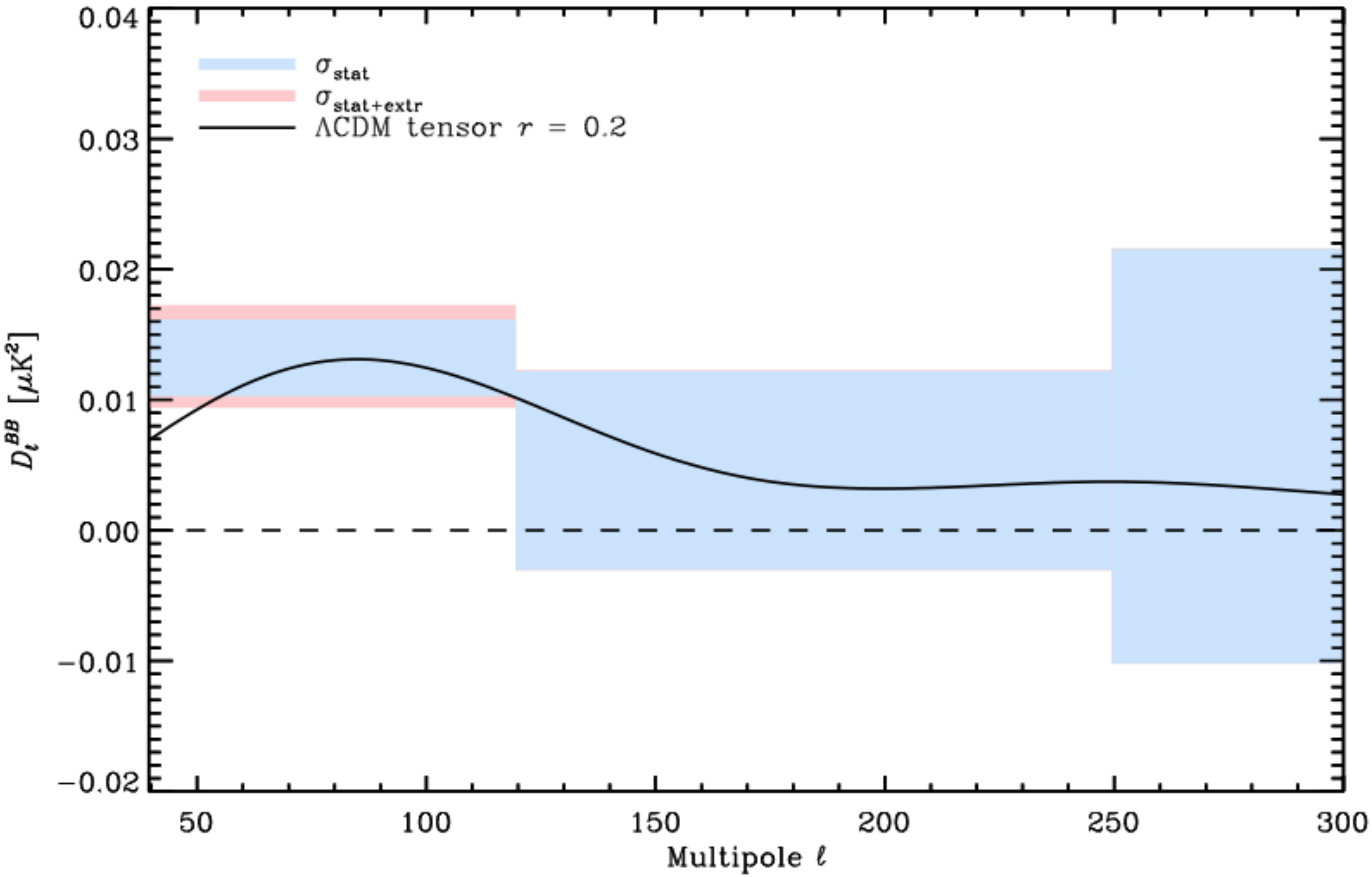
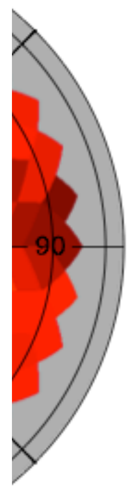
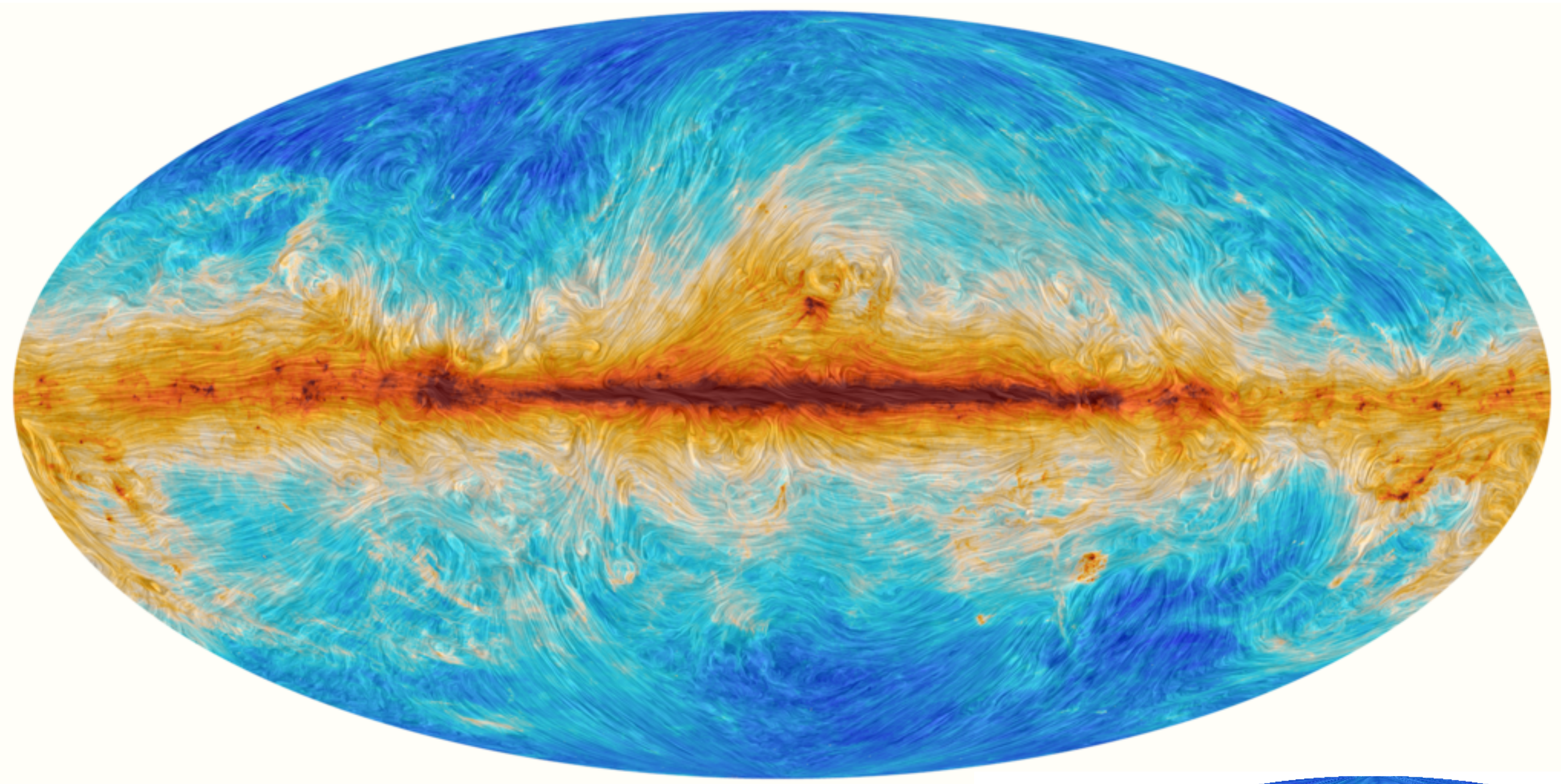


Fig. 2. *Pl*
described
of *P* is sho

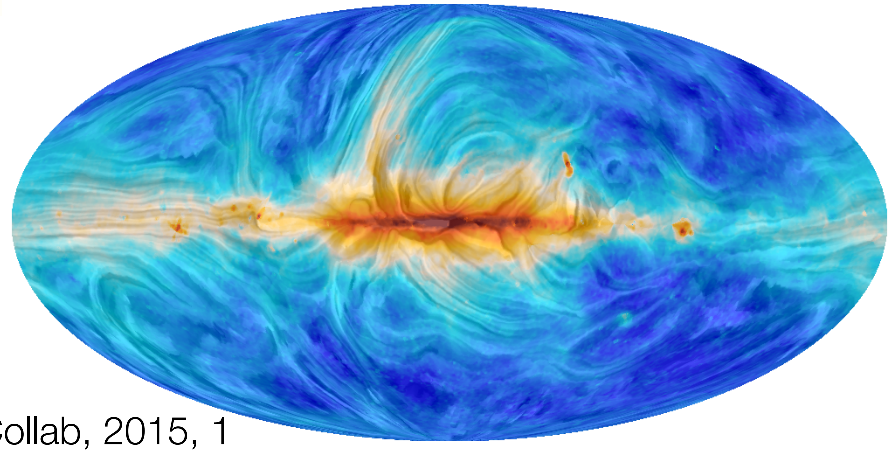


Planck Collab., PIP30, 2014

key foreground polarization maps



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



Planck Collab, 2015, 1

inflation and pri...

The Washington Post

Achenblog

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

nature | Home | News & Comment

News & Comment > News

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

Le Monde Sciences

SCIENCES | Vidéos | Archéologie | Biologie | Cosmos | Géologie | Grandes idées de la science

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

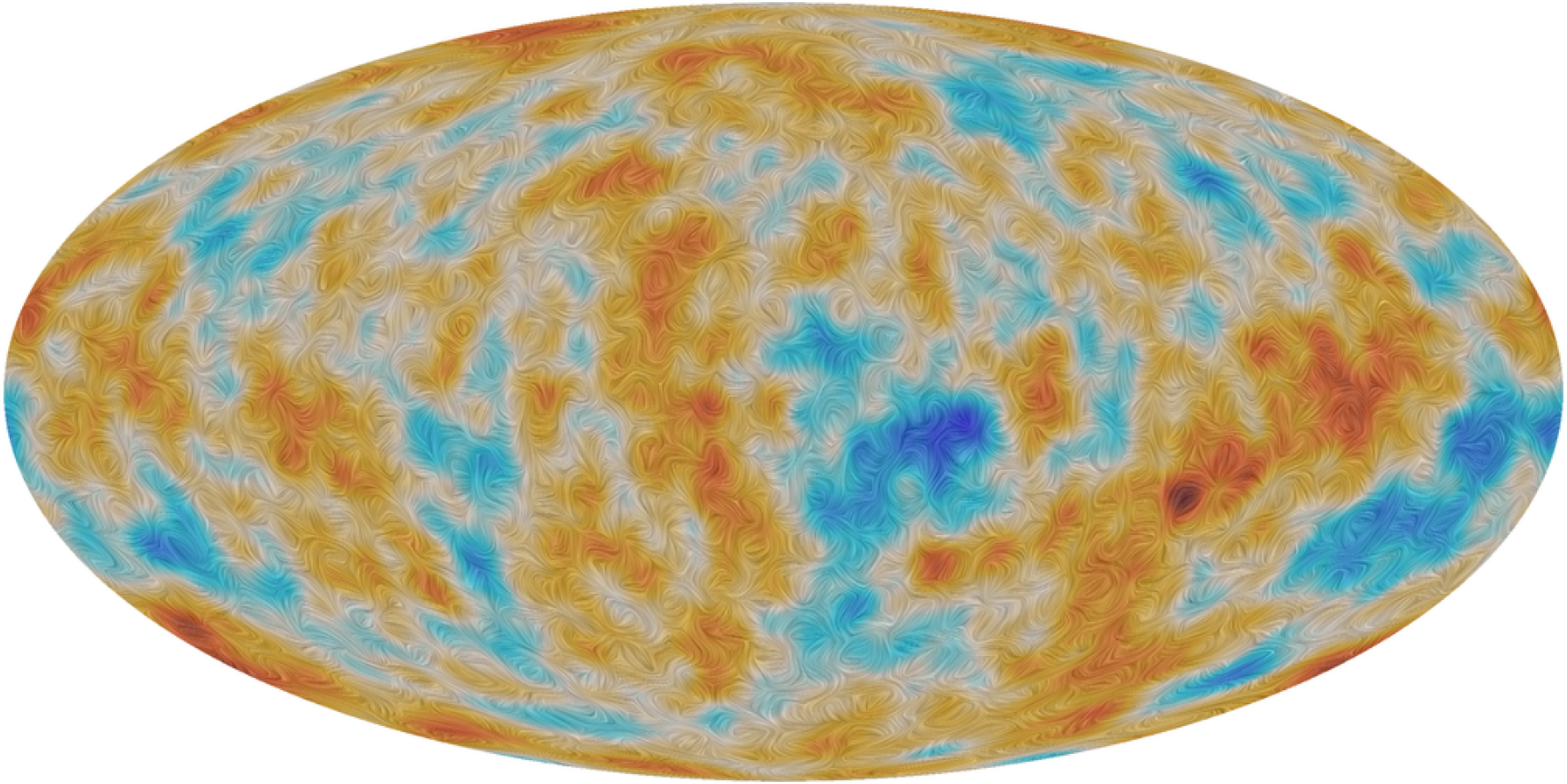
Criticism of Study Detecting Ripples From Big Bang Continues to Expand

Libération {SCIENCES²}

Par Sylvestre Huet
Journaliste à Libération

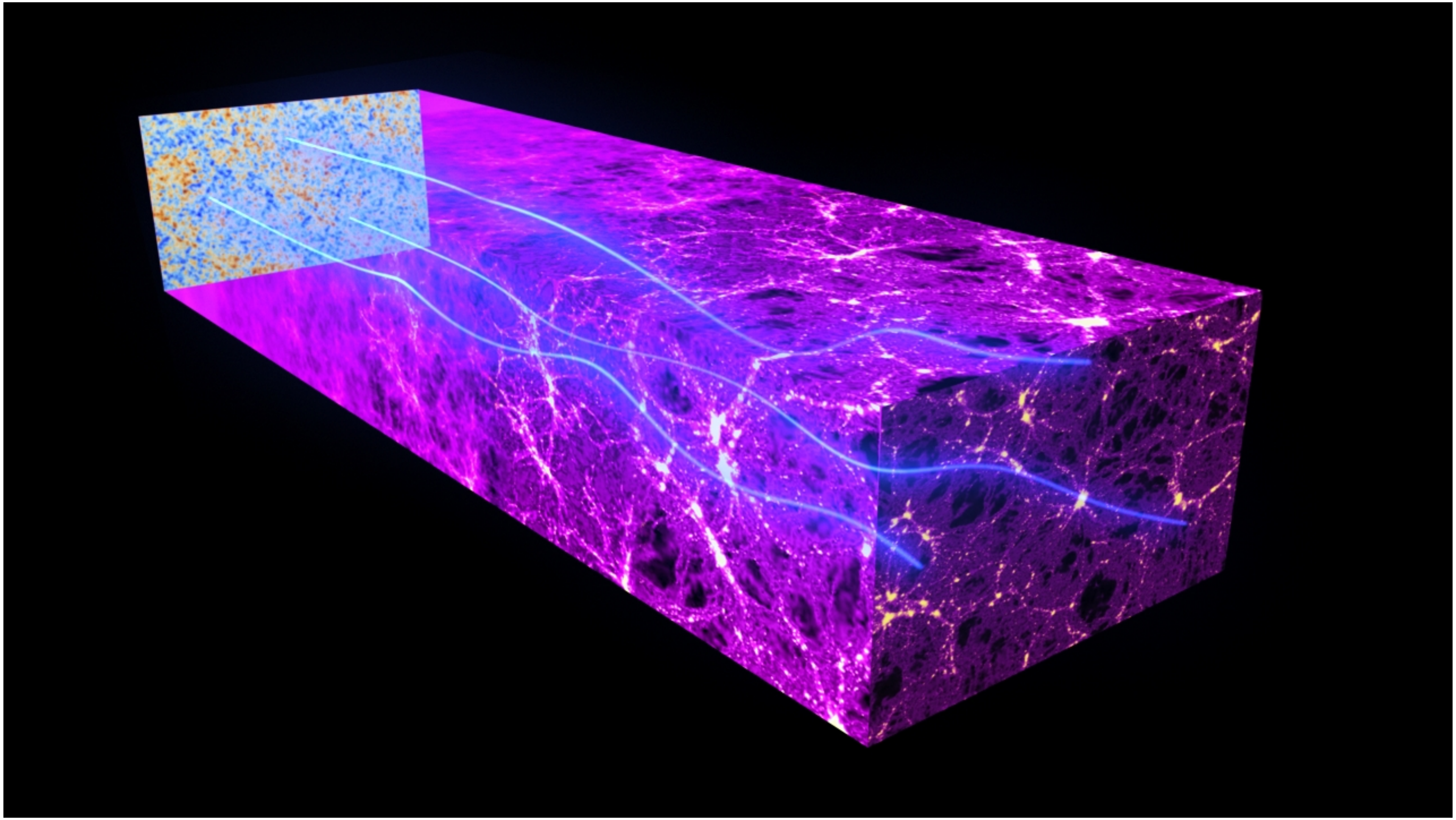
ONDES GRAVITATIONNELLES: L'ÉNIGME PERSISTE

Planck 2015 all sky CMB polarization



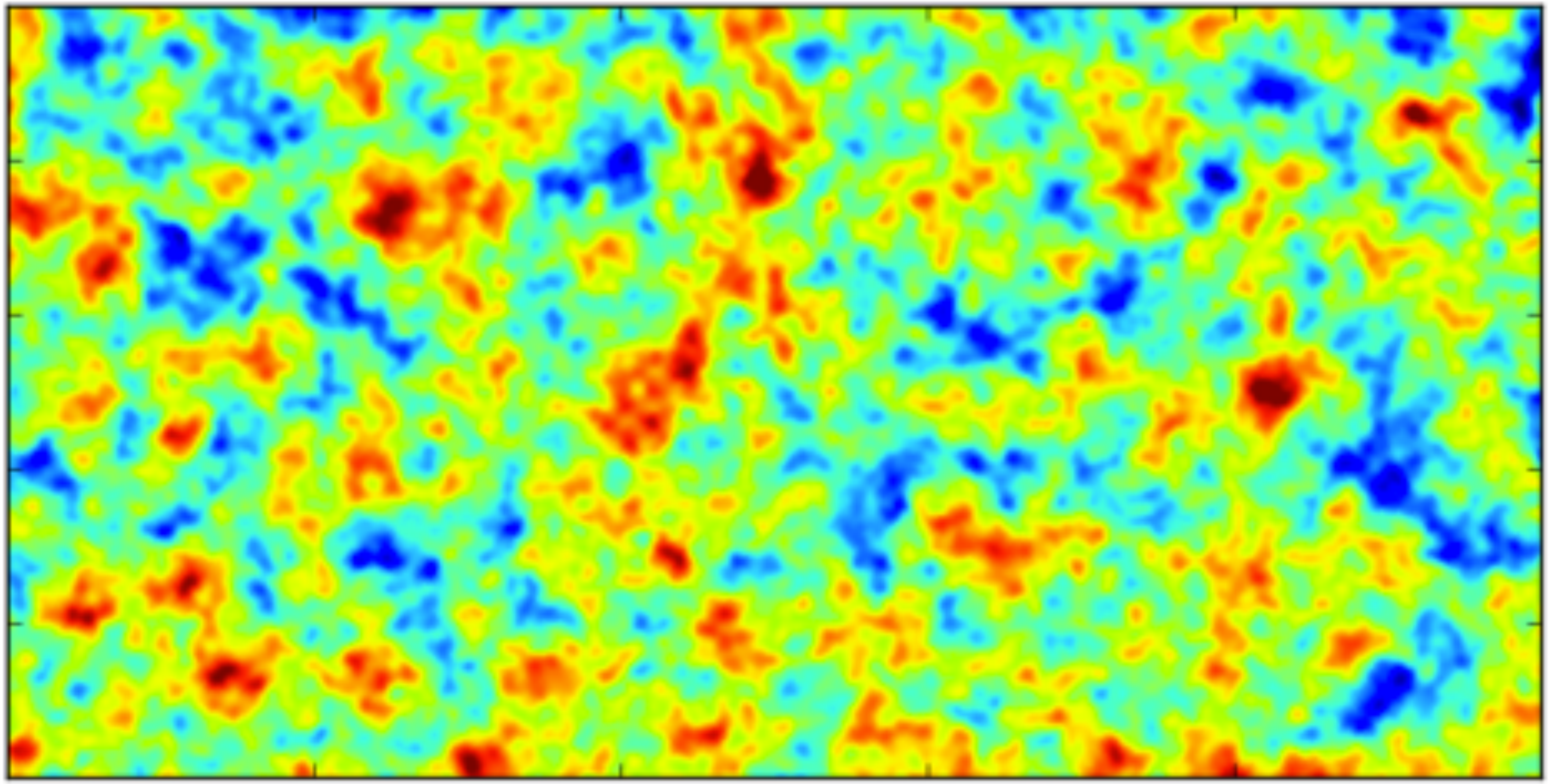
Planck Collab, 2015, 1

6. between CMB and us: structures



gravitational lensing of the CMB

A simulated patch of CMB sky – before lensing



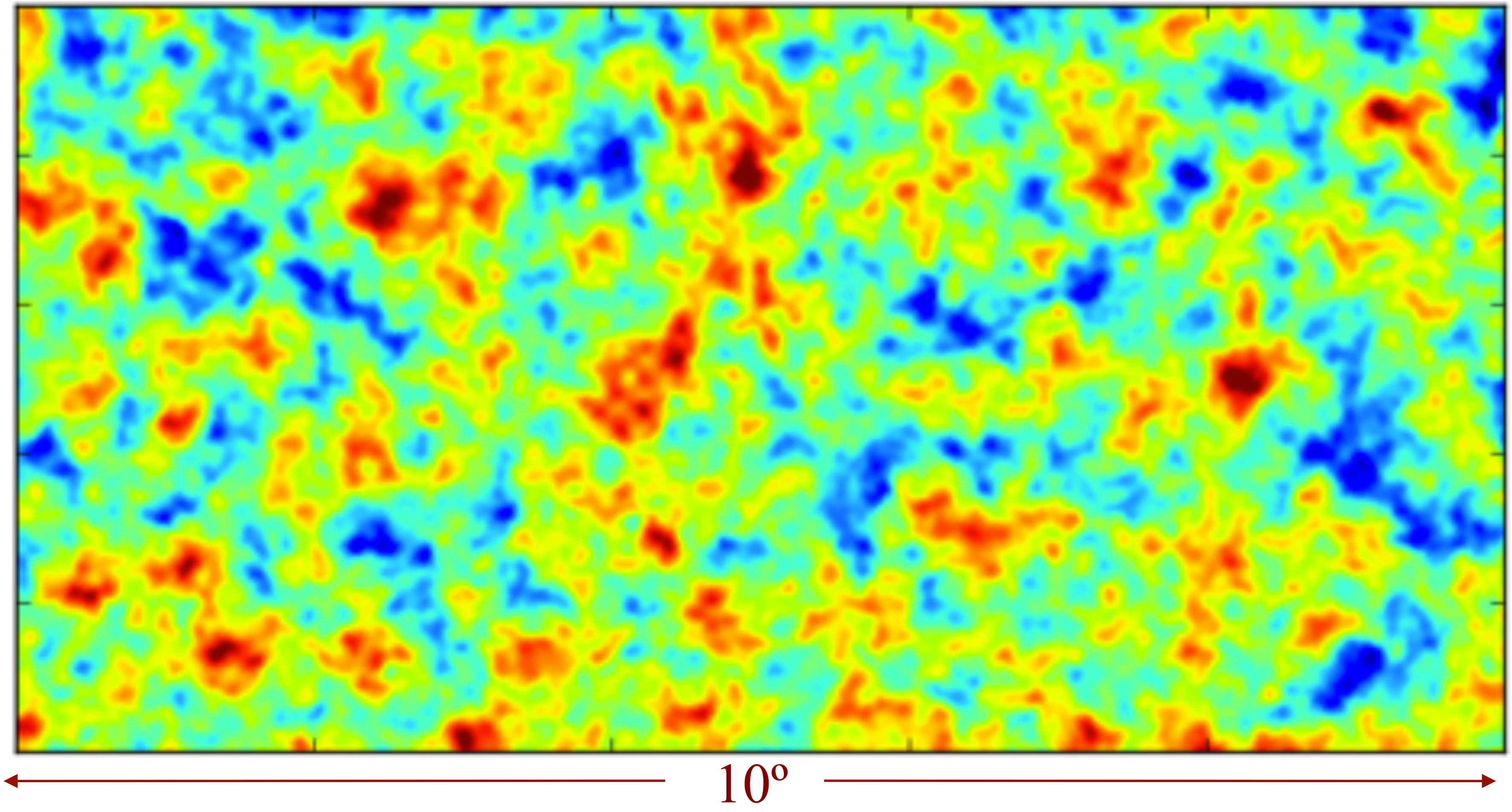
←— 10° —→

typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

gravitational lensing of the CMB

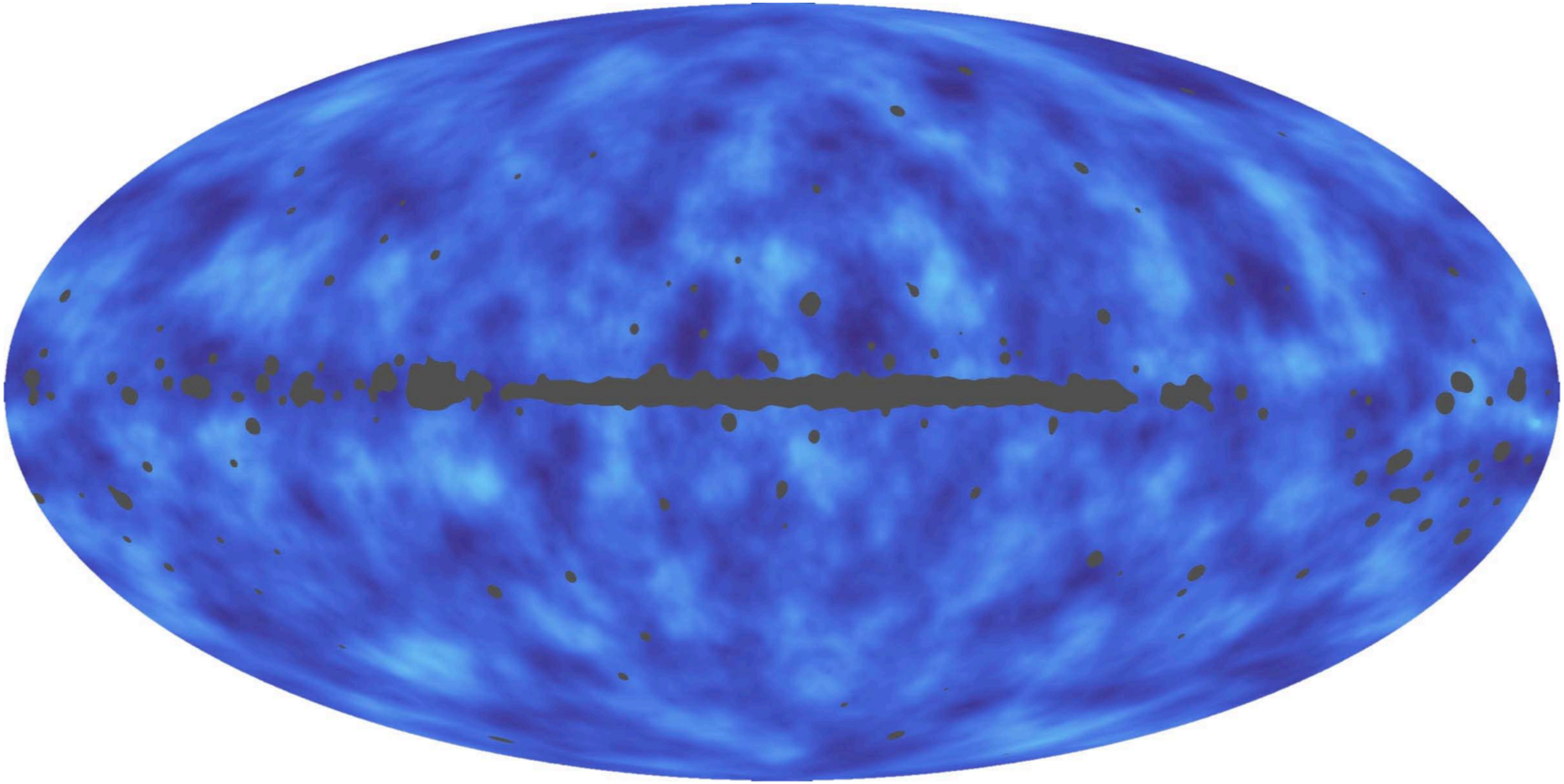
A simulated patch of CMB sky – after lensing



typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

Planck all-sky map of the dark matter



= Carte de la masse projetée sur la ligne de visée

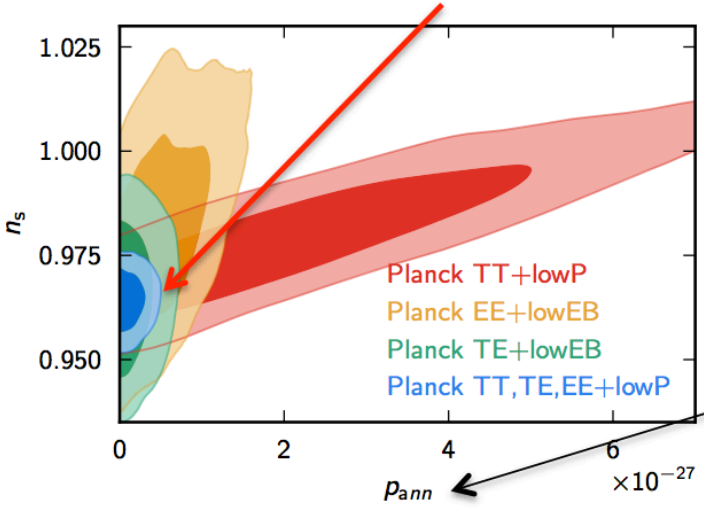
Planck 2015

nature de la matière noire – 2015

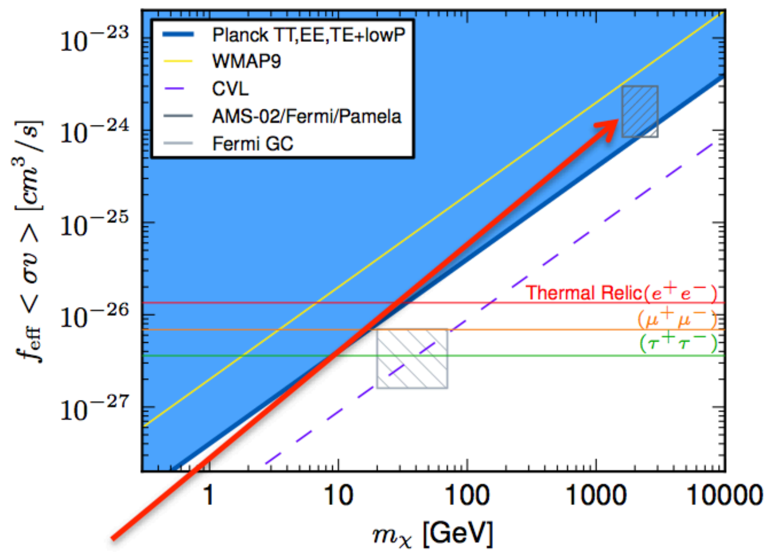
Les observations de Planck montrent qu'il n'est pas nécessaire de faire appel à l'existence d'une forte annihilation matière noire - antimatière noire pour expliquer la dynamique des débuts de l'univers.

En effet, un tel mécanisme produirait une quantité d'énergie qui influerait sur l'évolution du fluide lumière-matière, en particulier aux périodes proches de l'émission du rayonnement fossile. Or, les observations les plus récentes n'en portent pas la trace.

Planck is consistent with no DM annihilation

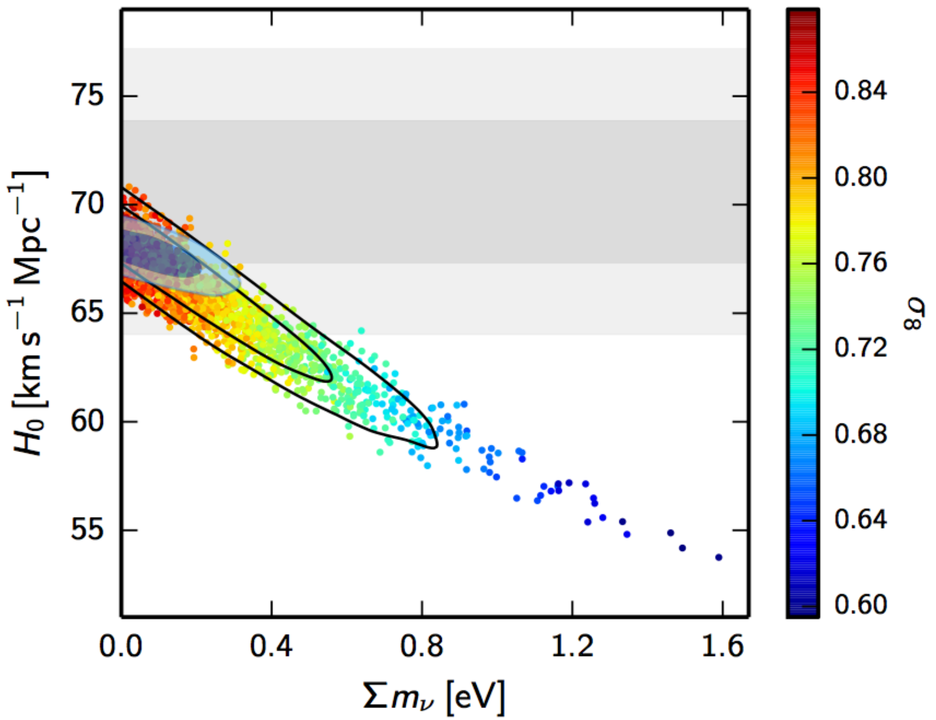


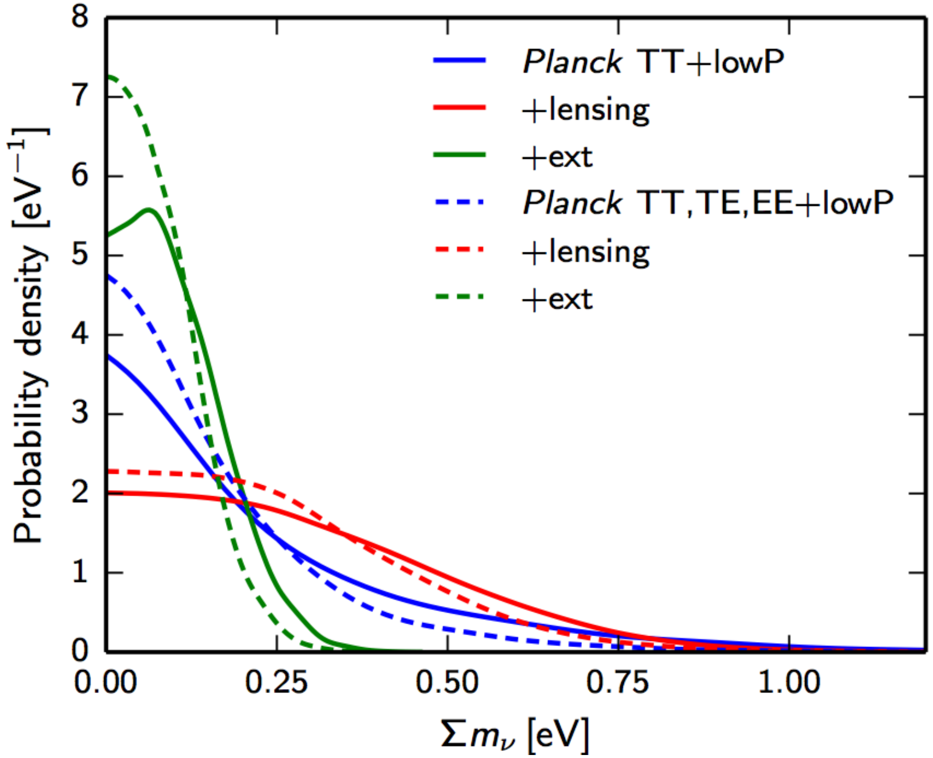
(cross section/ mass) x (efficiency)



Simplest DM interpretation of cosmic ray excesses is excluded

neutrinos – 2015





spectrum. The *Planck* power spectrum (95 %) constraints are

$$\sum m_\nu < 0.72 \text{ eV} \quad \textit{Planck} \text{ TT+lowP}; \tag{54a}$$

$$\sum m_\nu < 0.21 \text{ eV} \quad \textit{Planck} \text{ TT+lowP+BAO}; \tag{54b}$$

$$\sum m_\nu < 0.49 \text{ eV} \quad \textit{Planck} \text{ TT, TE, EE+lowP}; \tag{54c}$$

$$\sum m_\nu < 0.17 \text{ eV} \quad \textit{Planck} \text{ TT, TE, EE+lowP+BAO}. \tag{54d}$$

Planck 2015, 13

neutrinos – 2015

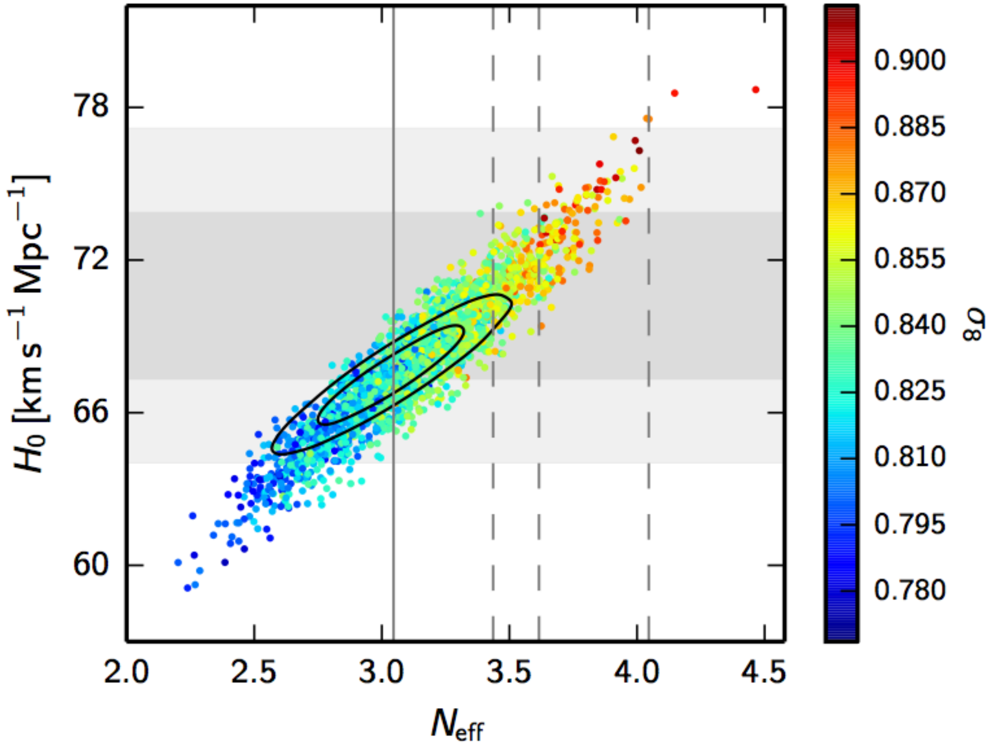
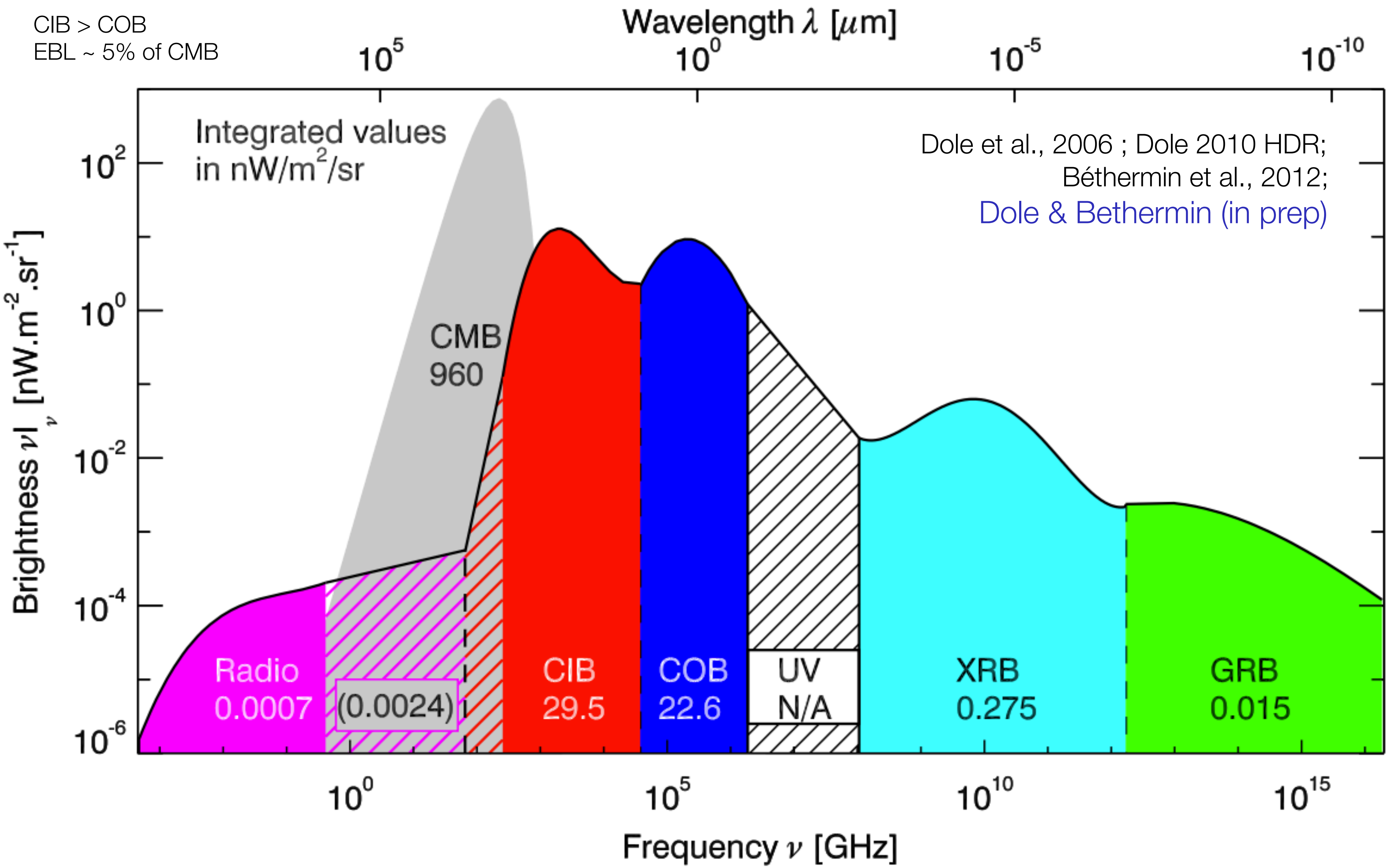


Fig. 31. Samples from *Planck* TT+lowP chains in the $N_{\rm eff}$–H_0 plane, colour-coded by σ_8. The grey bands show the constraint $H_0 = (70.6 \pm 3.3)$ km s^{-1}Mpc^{-1} of Eq. (30). Note that higher $N_{\rm eff}$ brings H_0 into better consistency with direct measurements, but increases σ_8. Solid black contours show the constraints from *Planck* TT,TE,EE+lowP+BAO. Models with $N_{\rm eff} < 3.046$ (left of the solid vertical line) require photon heating after neutrino decoupling or incomplete thermalization. Dashed vertical lines correspond to specific fully-thermalized particle models, for example one additional massless boson that decoupled around the same time as the neutrinos ($\Delta N_{\rm eff} \approx 0.57$), or before muon annihilation ($\Delta N_{\rm eff} \approx 0.39$), or an additional sterile neutrino that decoupled around the same time as the active neutrinos ($\Delta N_{\rm eff} \approx 1$).

Planck 2015, 13

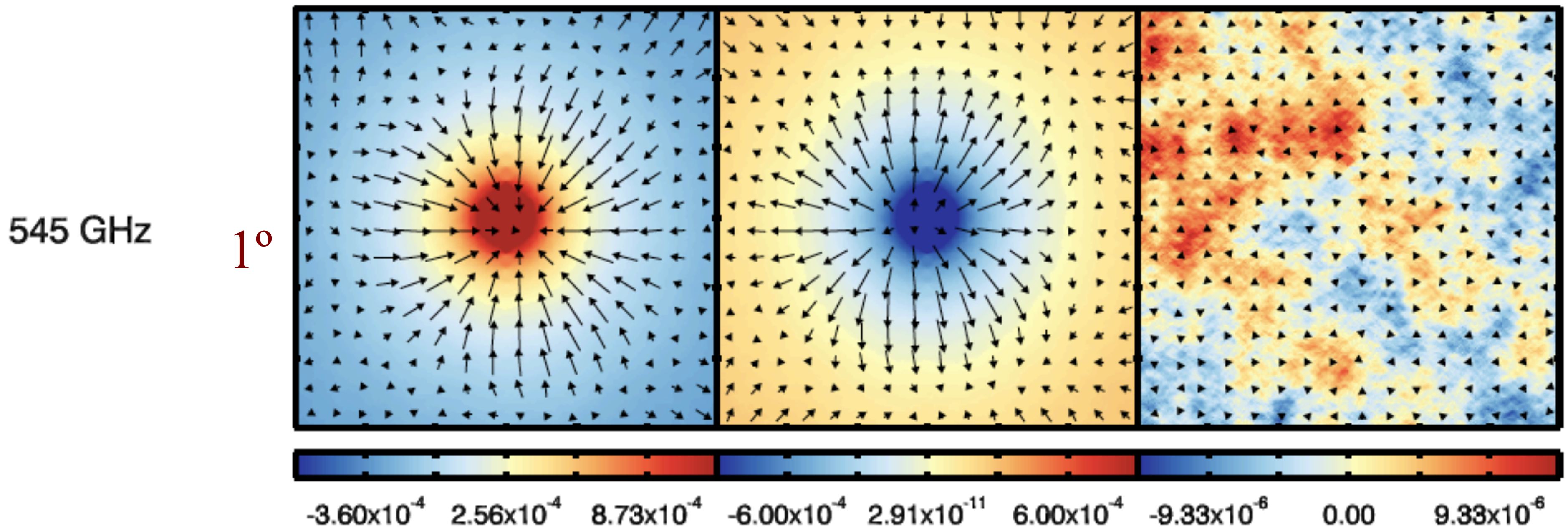
7. Extragalactic Bkg. Light Spectral En. Distrib.

CIB > COB
EBL ~ 5% of CMB



CIB peaks correspond to mass peaks

Stacking the Planck mass maps at the positions of peaks and troughs of Cosmic Infrared Background leads to a strong detection of the mass associated with these distant star forming galaxies. This is mostly Dark Matter.



see also Hanson et al., 2013 about lensing induced B-modes (NOT primordial B-modes !)

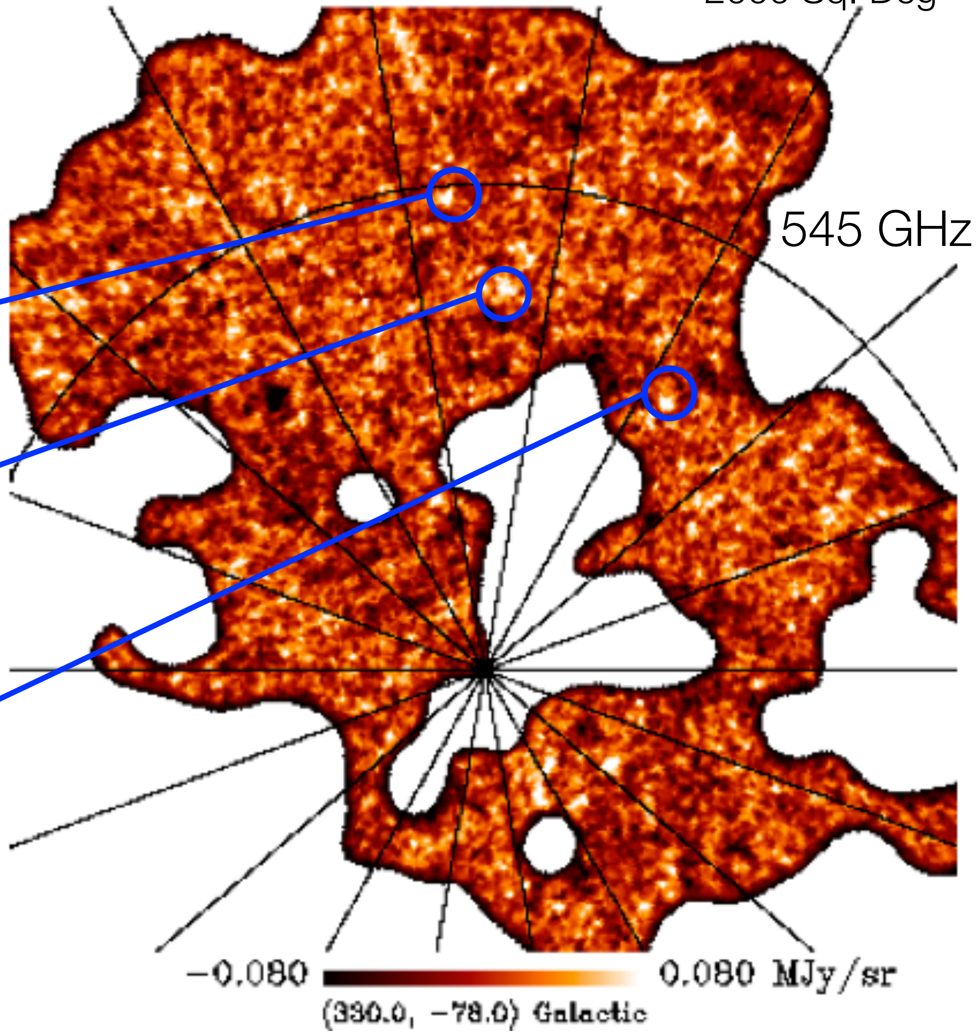
Planck 15 months
Planck Collaboration, 2013, 18

7. digging into the Cosmic IR Background

~2000 Sq. Deg

« cold sources » of the CIB in Planck data (4.5' beam)

545 GHz



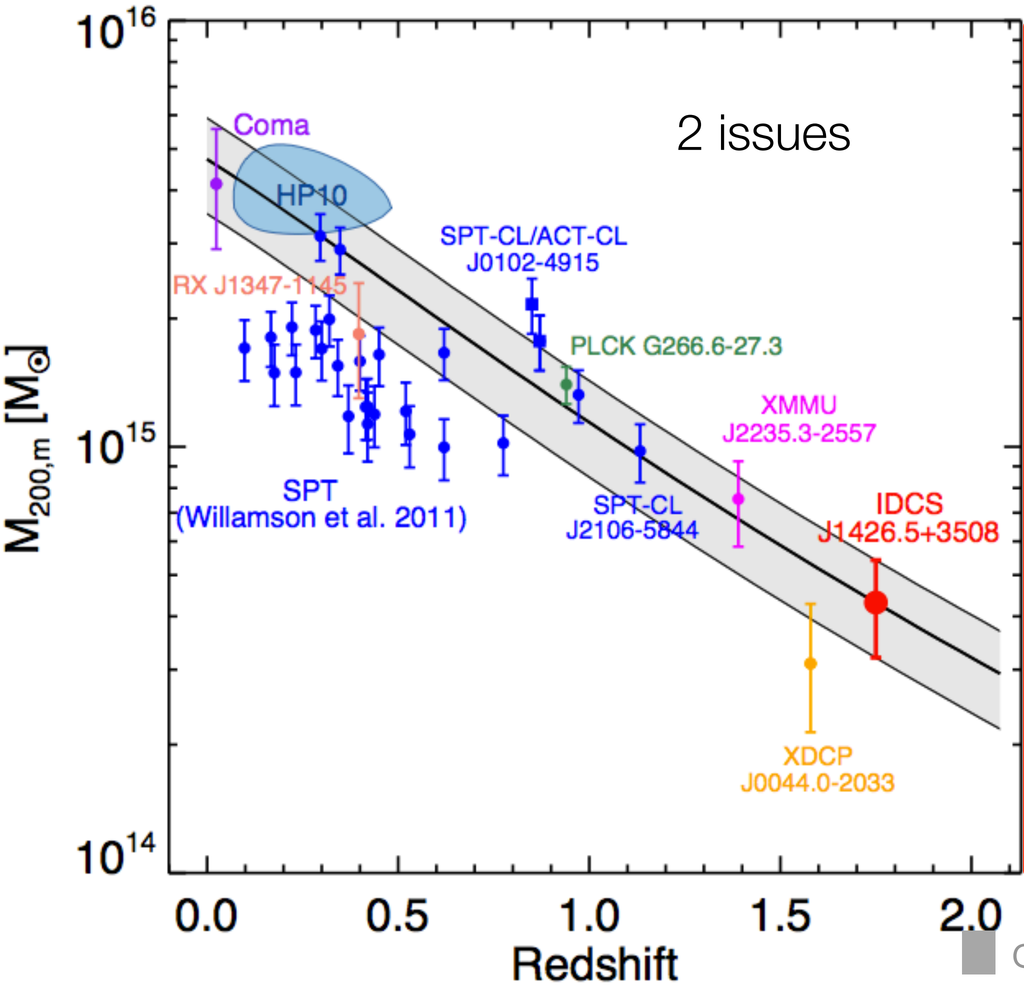
- z >1.5 overdensities of intensely star forming galaxies ?
- z >1.5 extremely bright lensed sources ?
- large scale structure alignments ?
- residual cirrus ?

Planck Collab., 2013, 30

predicted number of extragalactic objects :
100 – 1000 (Negrello+2005)

searching for high-z massive structures: probe of DE ?

Predictions / mesurements: massive clusters vs redshift



Gobat Cl.

Q: processes of cluster
- stellar mass assembly
- star formation ?
--> can we find a new way to select **highly star-forming clusters** ?

z > 2

Planck

Herschel, ALMA

then Euclid,

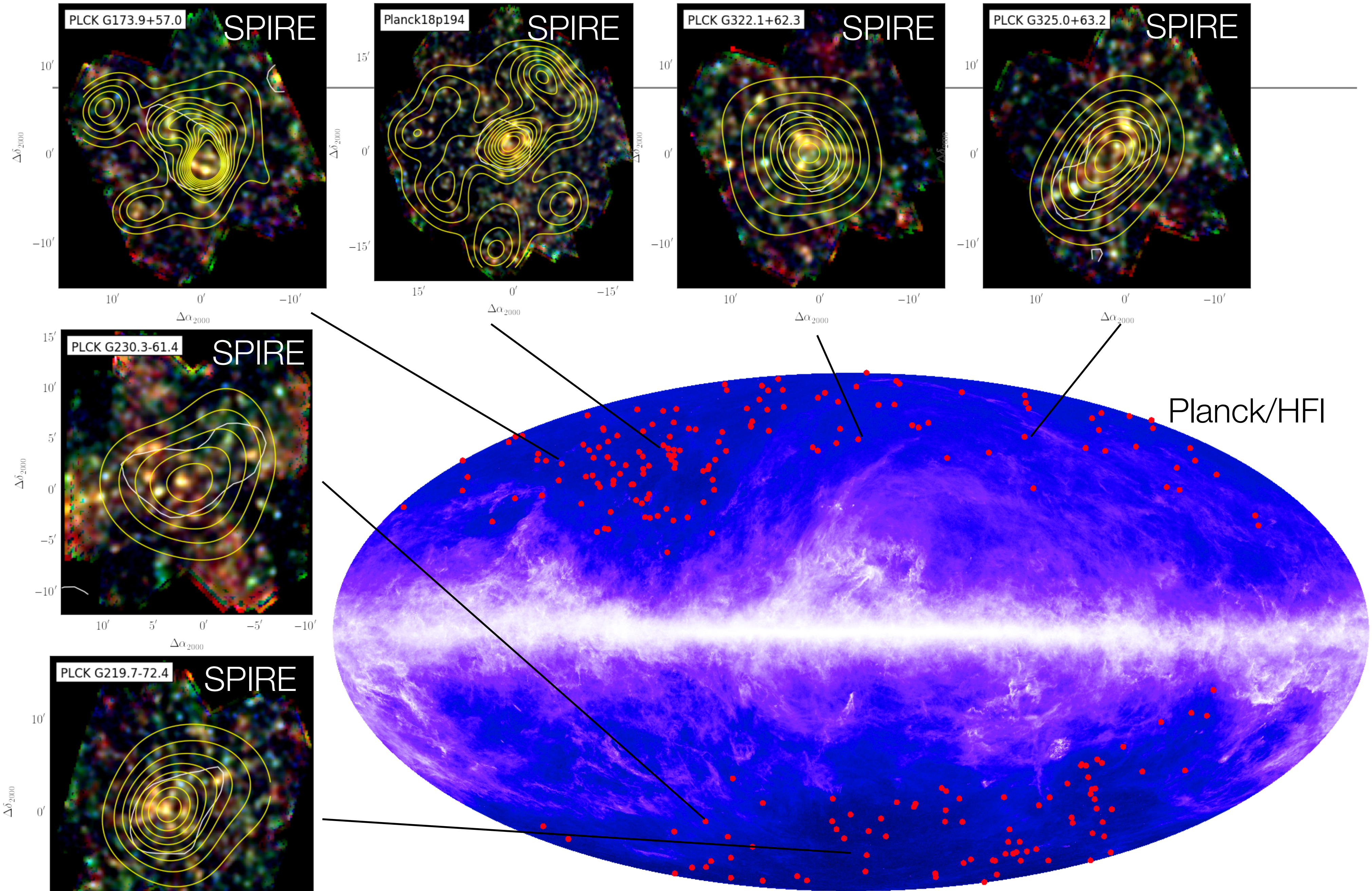
WFIRST, JWST

Brodwin et al, 2012 – Mortonson et al., 2011

how to find z>2 clusters ?

(observationnally) rare objects can be unveiled using all-sky surveys: Planck, Euclid, and further studied with JWST, WFIRST

Galaxy clusters are proxies for massive DM halos

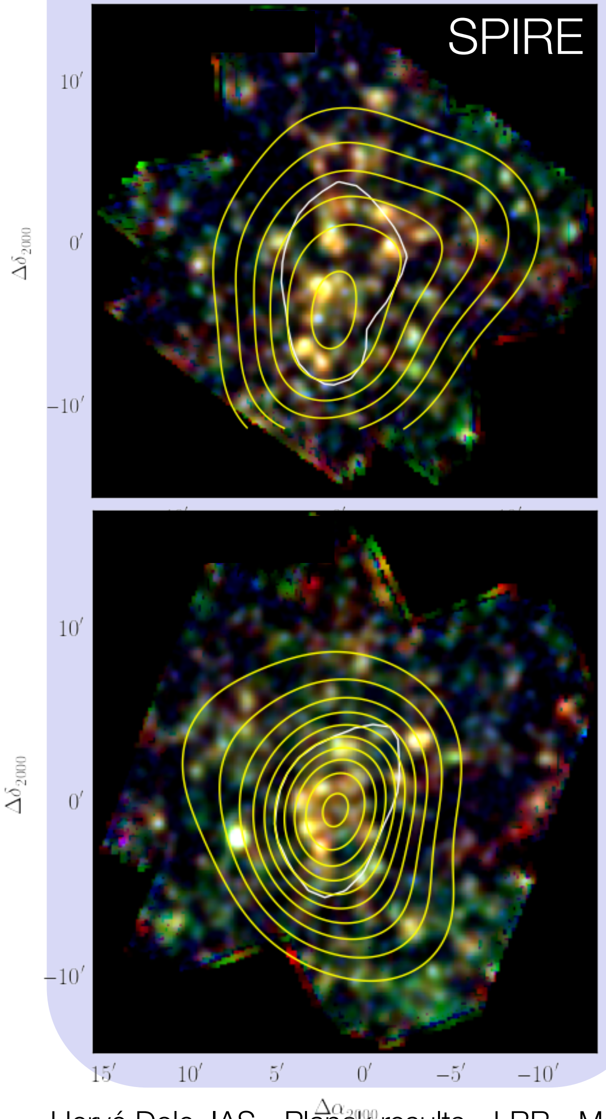


several hundreds of Planck high-z candidates
228 followed-up by Herschel

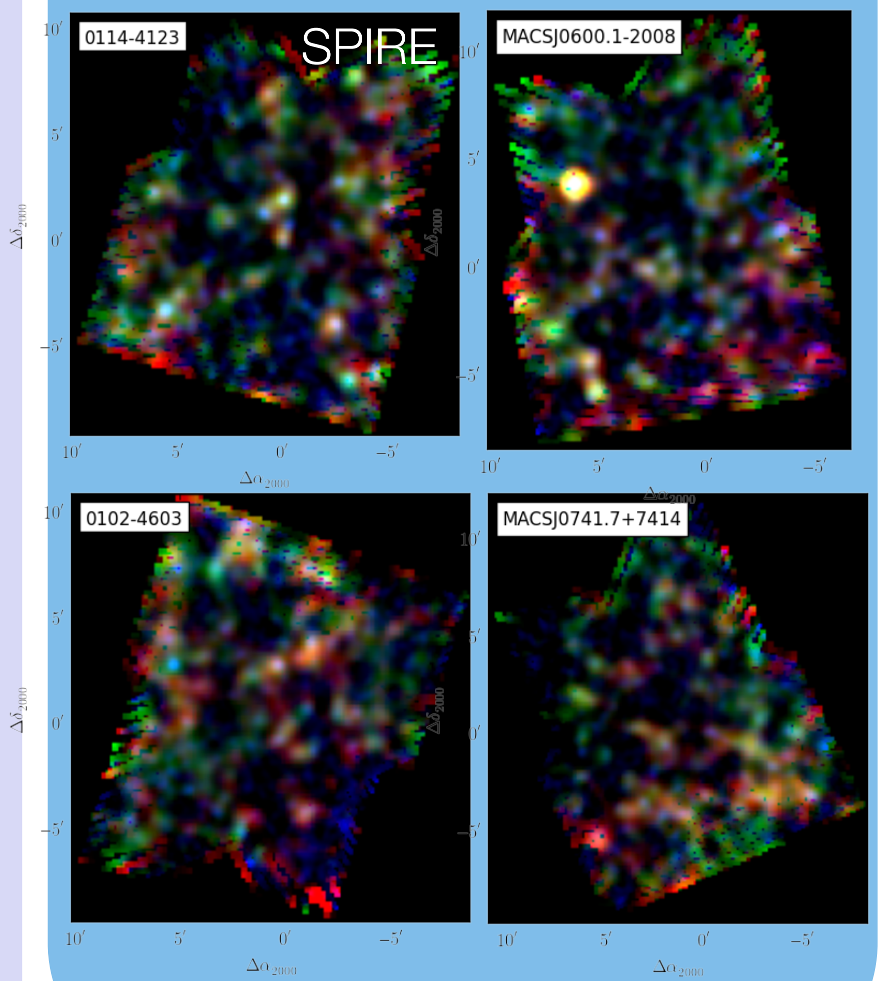
Planck & Herschel
Institut d'Astrophysique Spatiale
H. Dole & Planck collab

a remarkable Planck+Herschel dataset among others

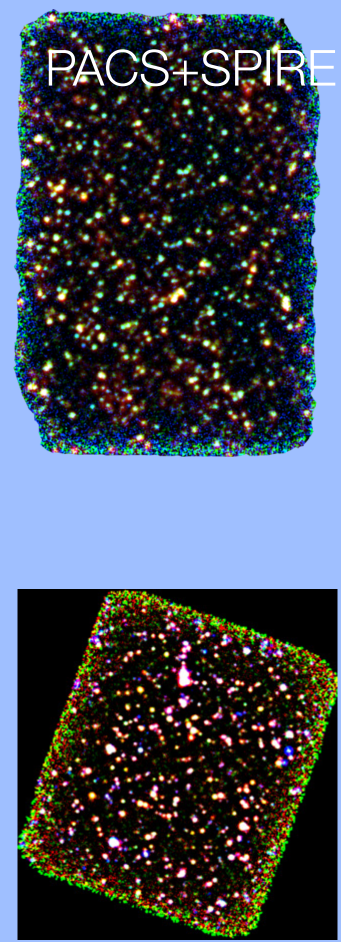
Planck/Herschel HPASSS
30'x 30' (Planck subm)



HLS 20'x 20'
(Egami+2010)

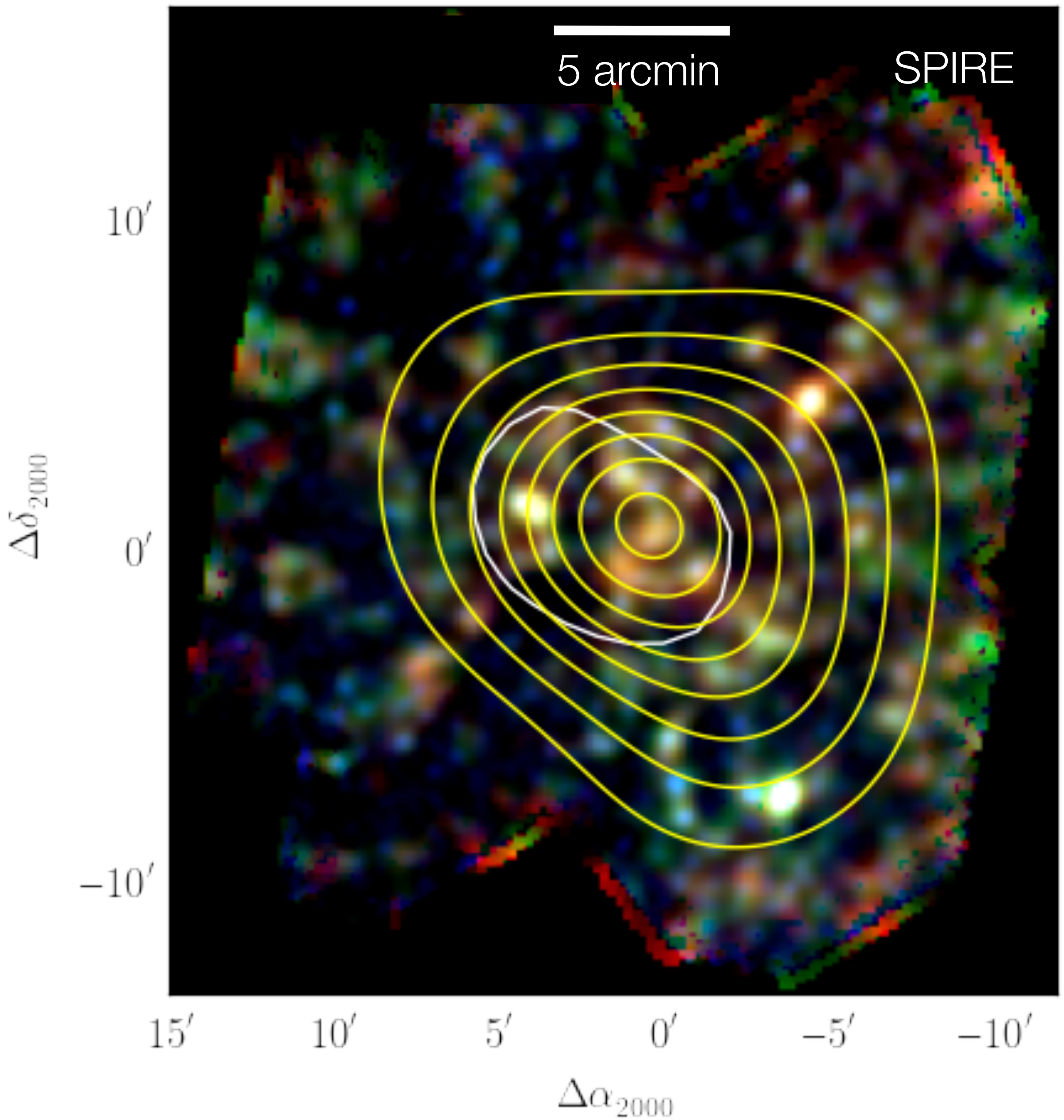


GOODS 16'x 10'
(Elbaz+2011)



the case of one field: Spitzer and VLT

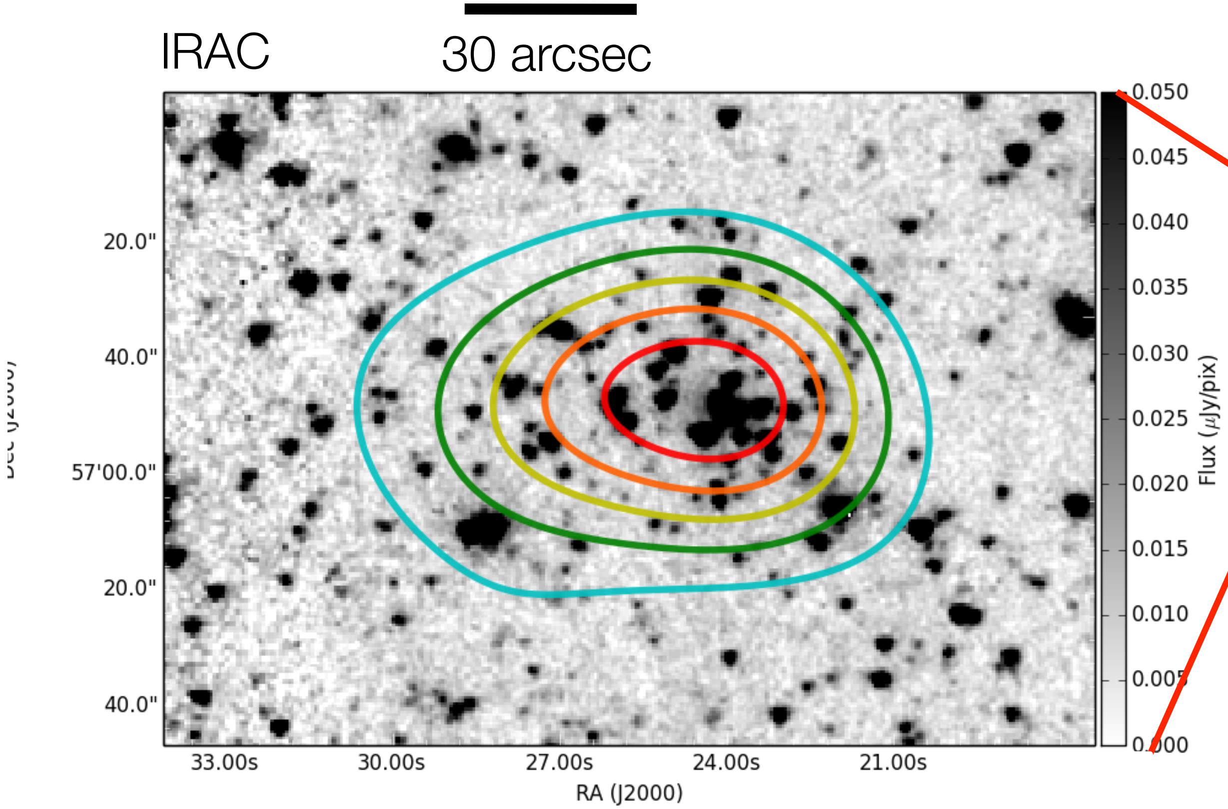
Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um



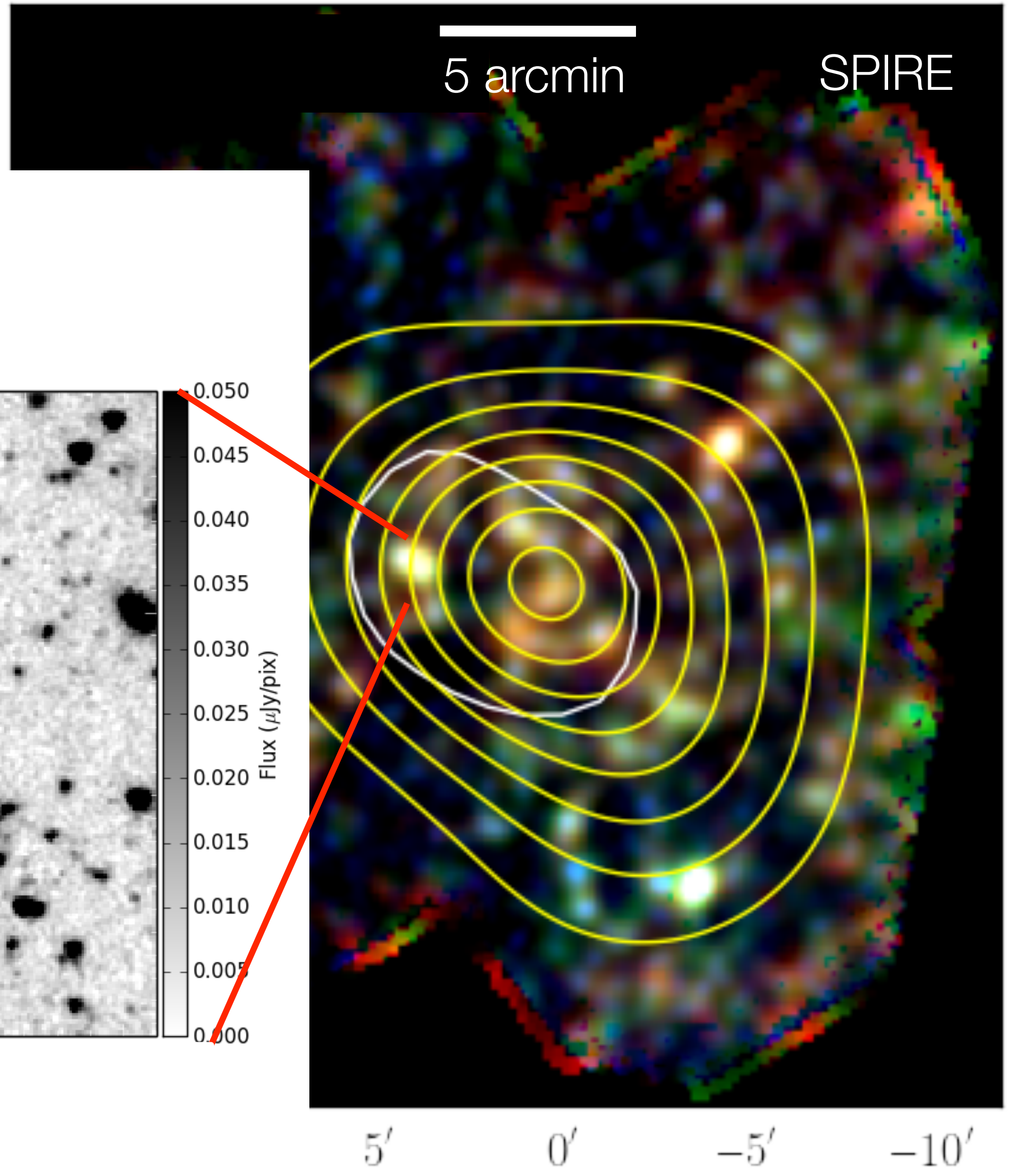
the case of one field: Spitzer and VLT

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 image at 3.6um



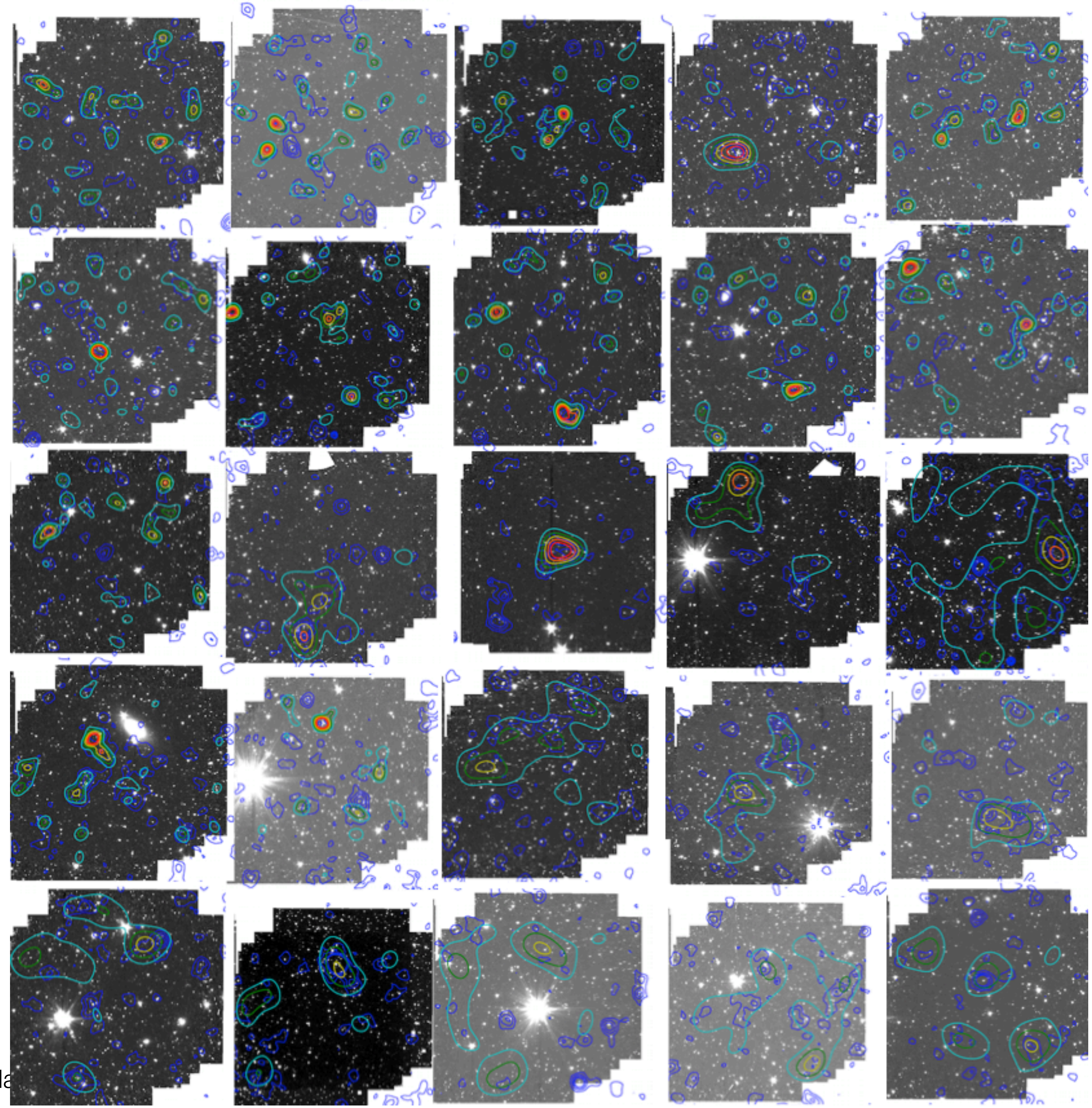
Martinache et al., in prep

25 Spitzer fields having >5σ overdensities

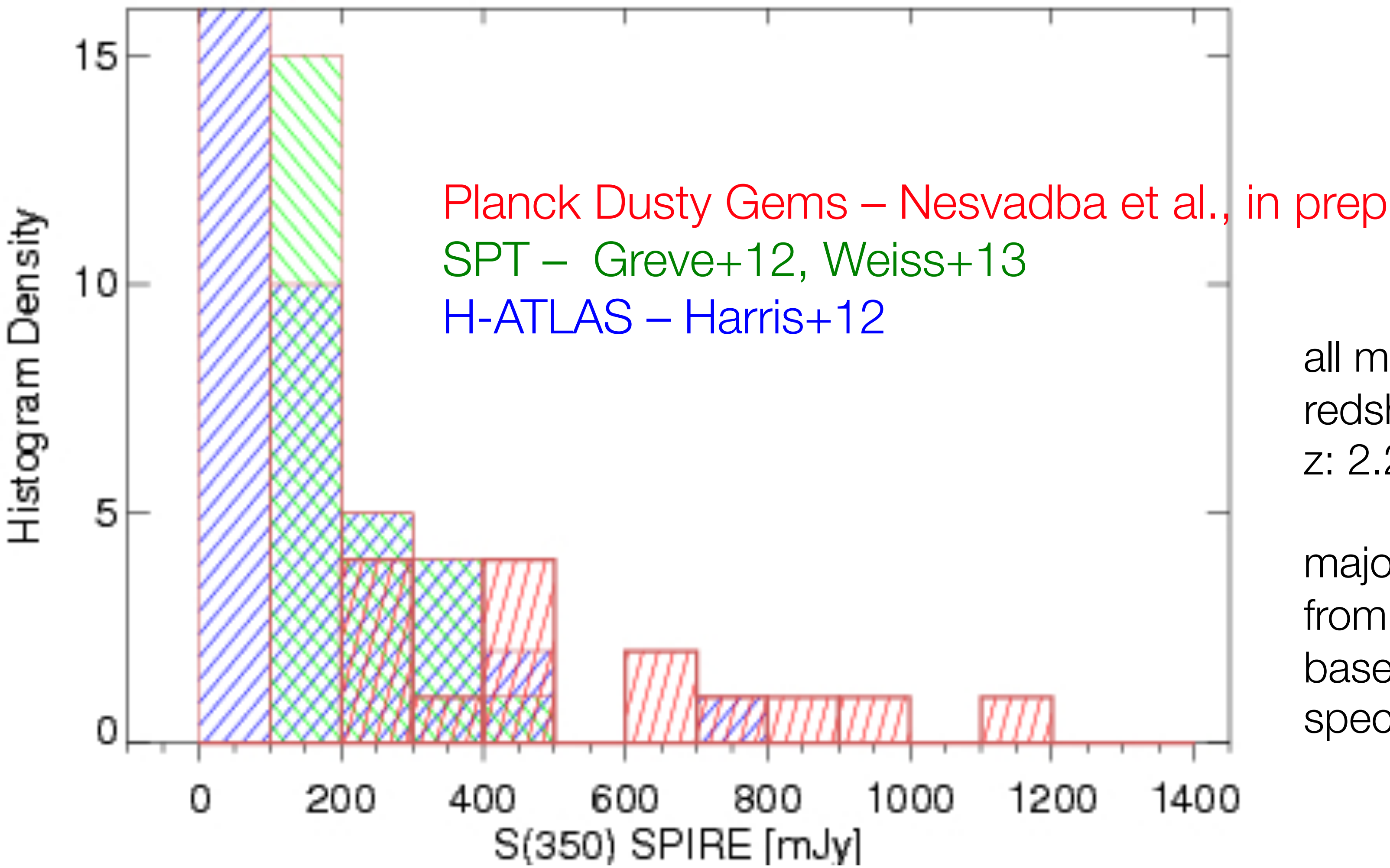
IRAC fields,
about 5’x 5’ each
observed at
3.6 and 4.5um

color contours:
significance of red
IRAC source
overdensity

deep blue contours:
SPIRE 350um



many bright z>2.2 lensed sources



all measured redshifts at IRAM: z: 2.2 – 3.6

major contribution from ground-based mm img/spec

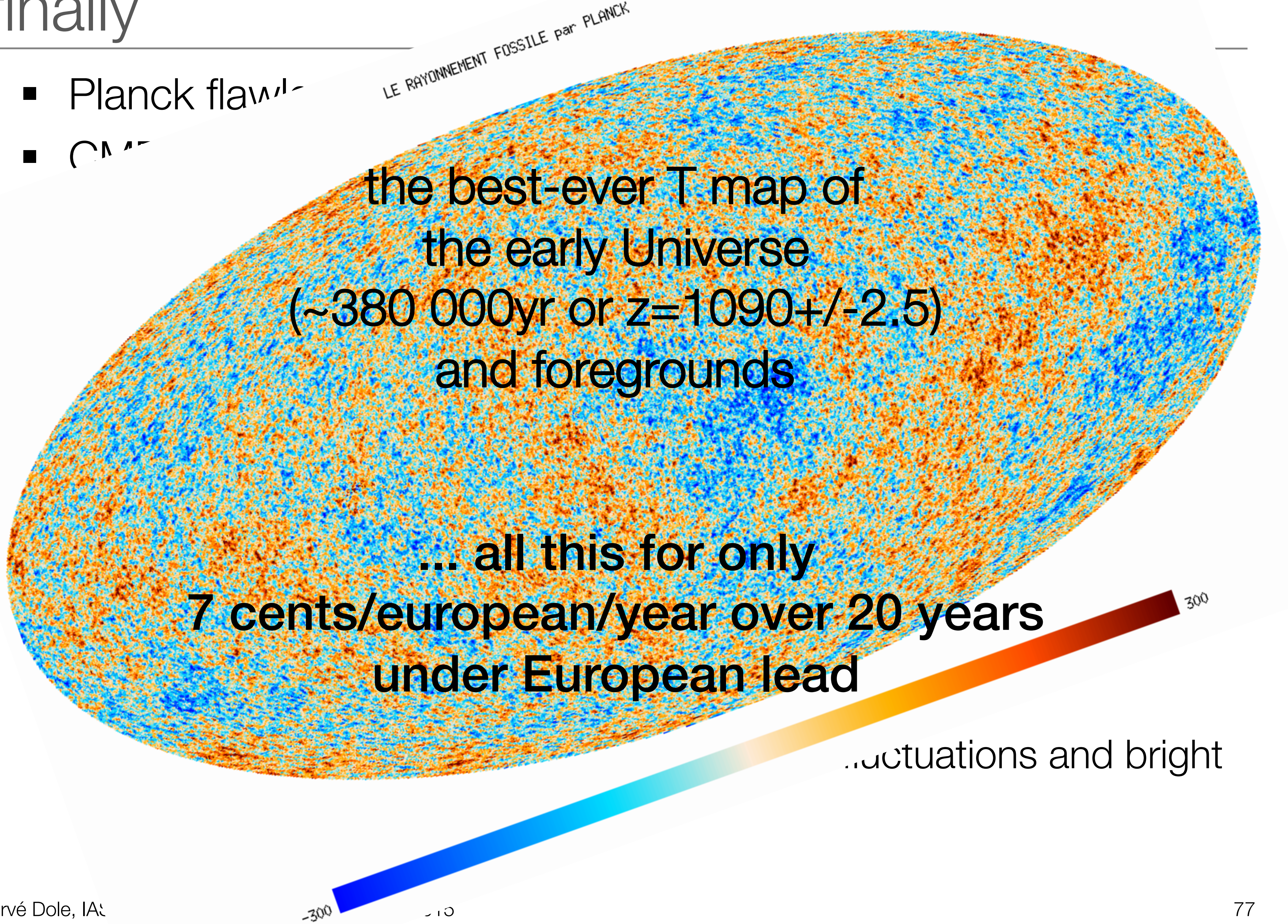
Canameras, Nesvadba et al., subm

finally

- Planck flawlessly worked at 0.1K for ~2 yrs: 5 surveys
- CMB TT ultimate measurement, TE
- Polarization: BB ongoing
- Many results
  - CMB, params, inflation, NG, neutrinos, dark matter, lensing
  - foregrounds, point sources, SZ clusters
  - polarized foregrounds: magnetic field
- Only 6 cosmological parameters perfecly fitting the data
- Some novelties
  - all-sky polarization
  - LSS with all-sky dark matter map
  - search of high-z high-SFR clusters in CIB fluctuations and bright lensed sources

finally

- Planck flawl
- CM



the best-ever T map of
the early Universe
(~380 000yr or z=1090+/-2.5)
and foregrounds

... all this for only
7 cents/european/year over 20 years
under European lead

uctuations and bright