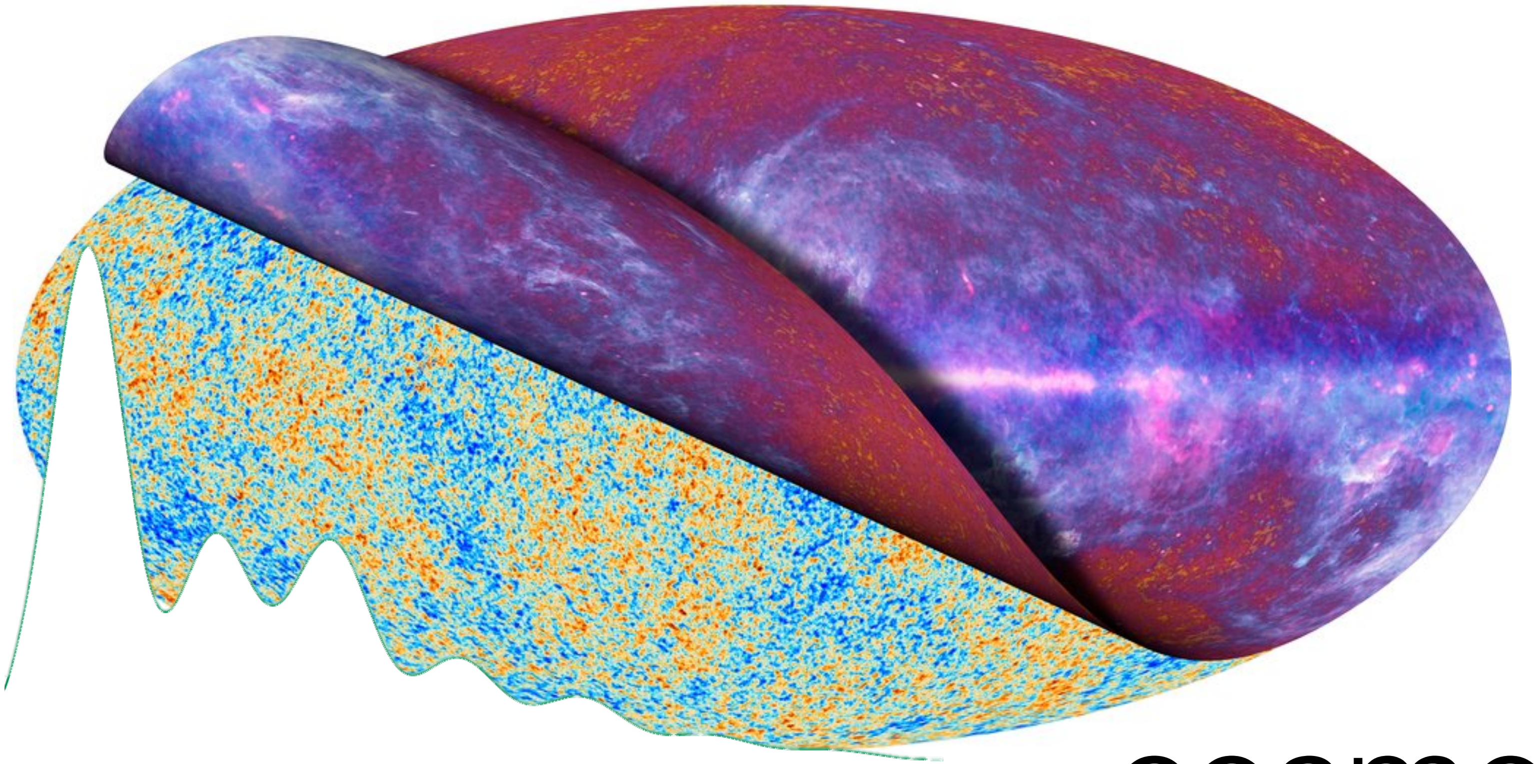


cosmological results from Planck

Hervé Dole

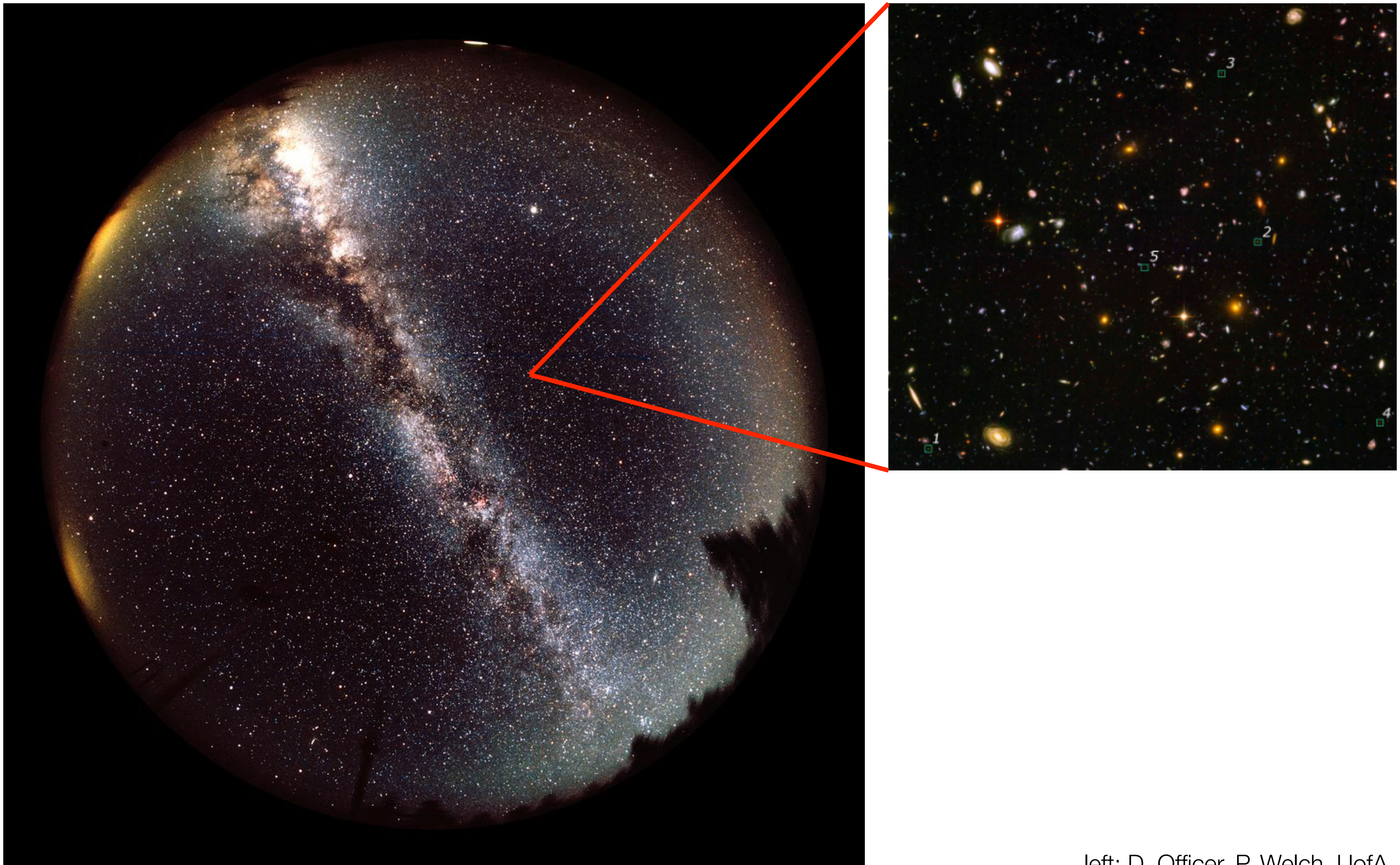
on behalf of the Planck collaboration

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

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

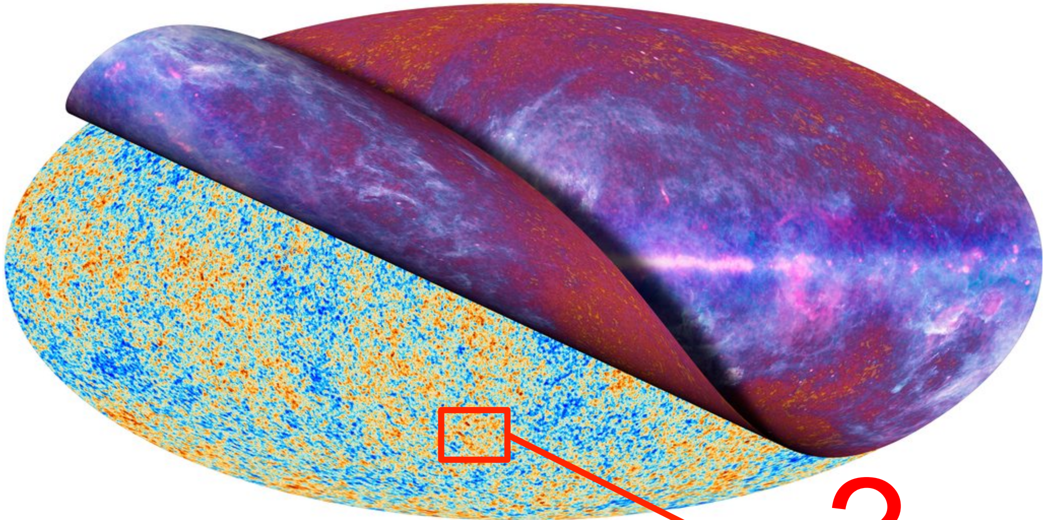
Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific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

why is the night sky ... dark ?



left: D. Officer, P. Welch, UofA
right: NASA, HST

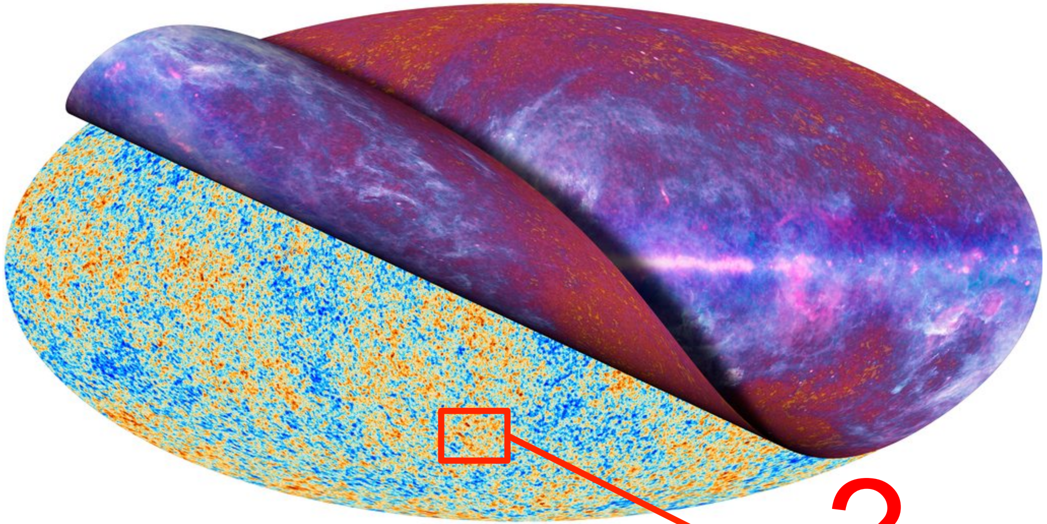
the two outstanding questions



homogeneous universe

structured, inhomogeneous universe

the two outstanding questions



?

homogeneous universe

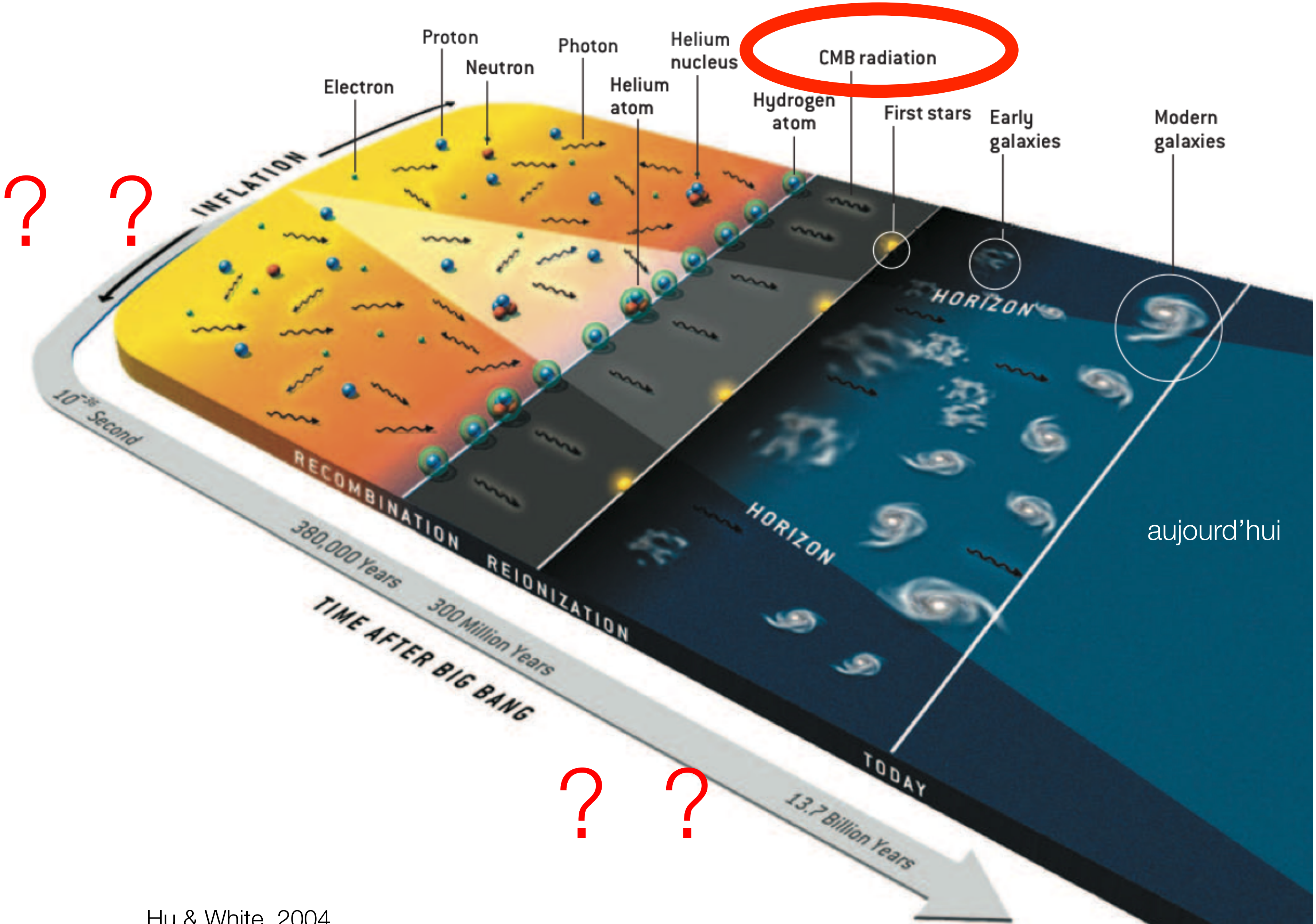
inflation models ?

?

structured, inhomogeneous universe

structure formation, ΛCDM

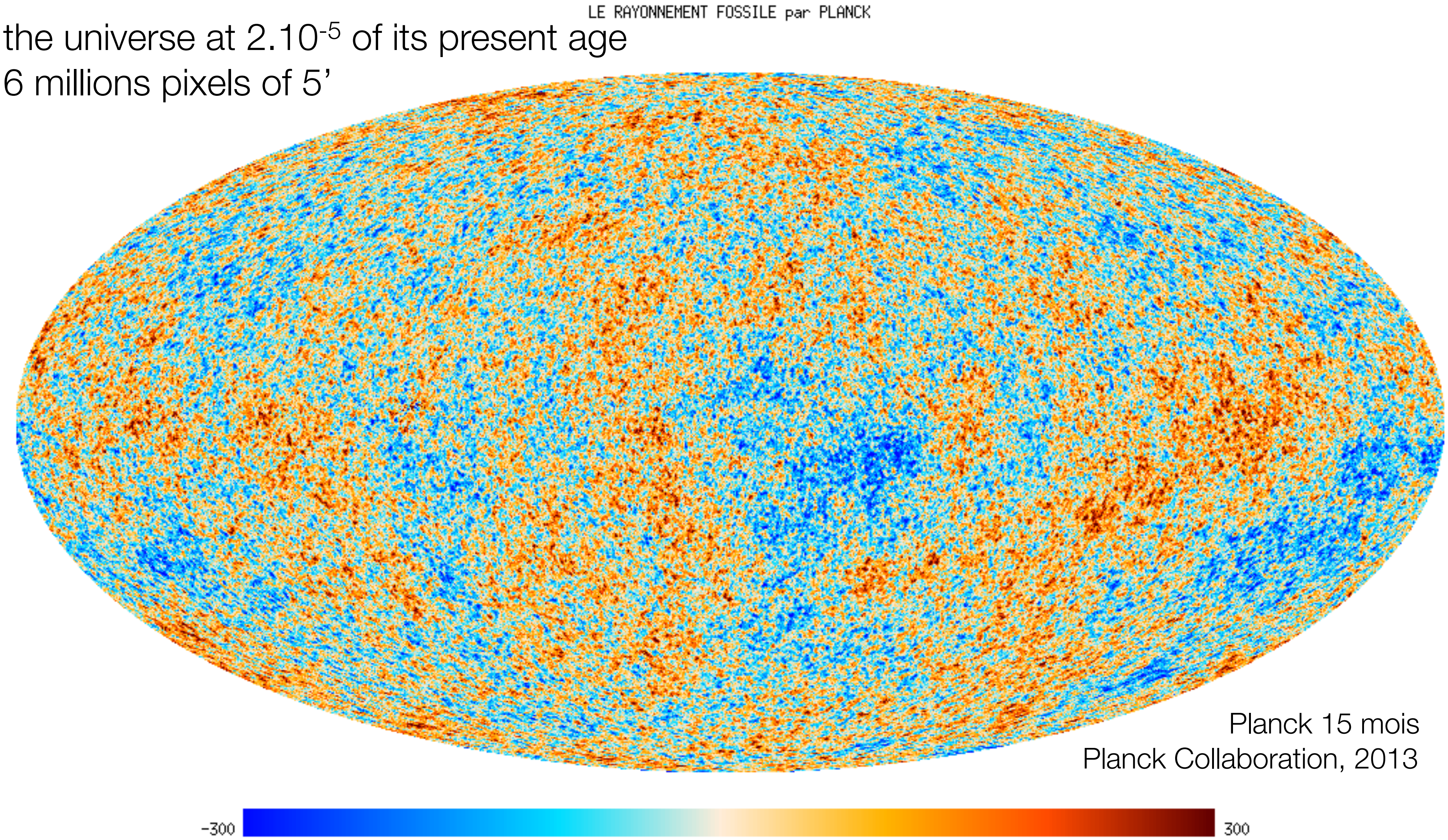
how large scale structures form ?



Hu & White, 2004

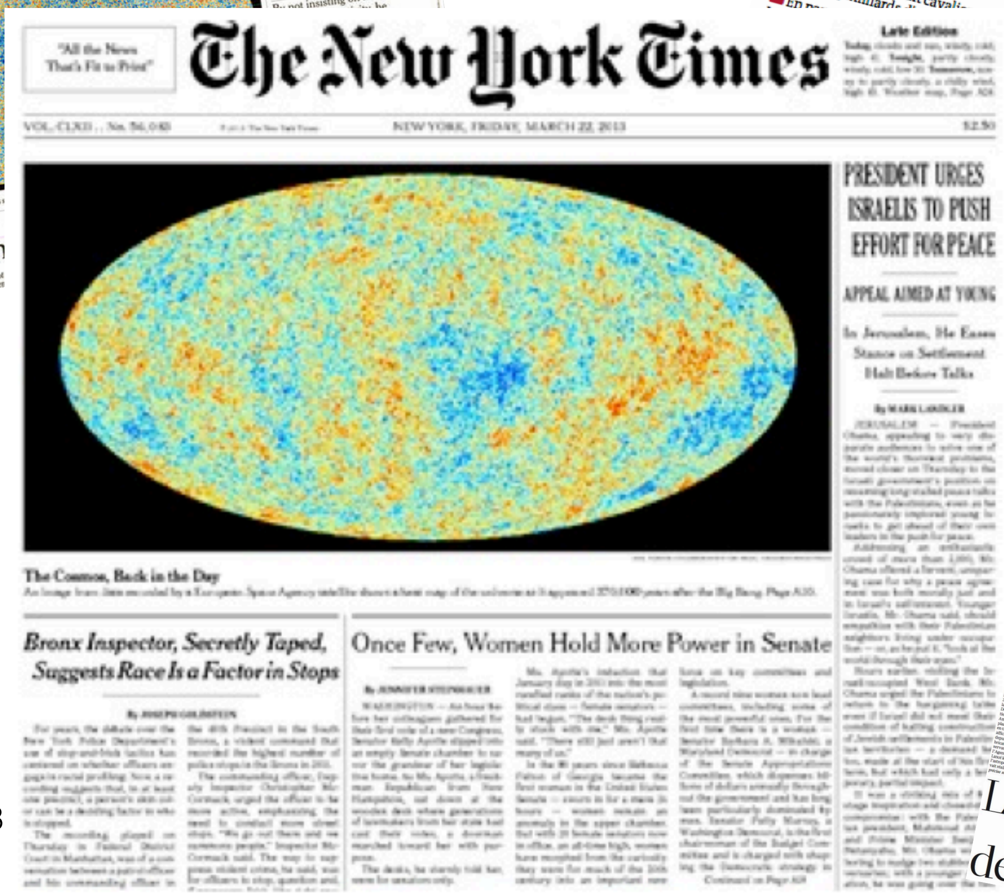
CMB temperature anisotropies

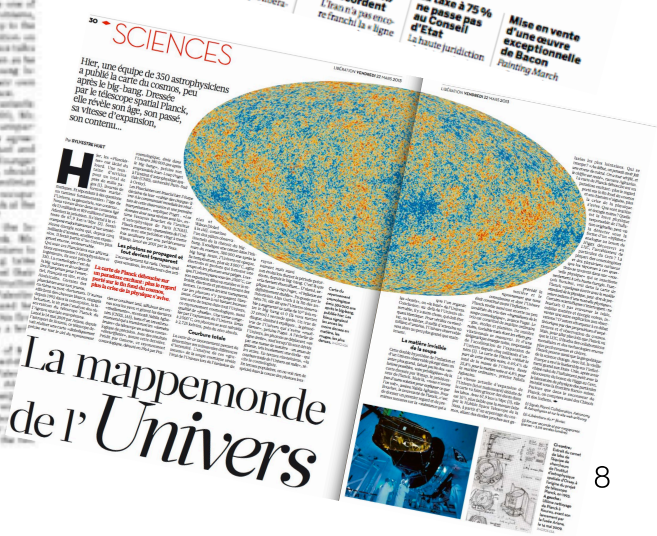
the universe at 2.10^{-5} of its present age
6 millions pixels of 5’



Planck 15 mois
Planck Collaboration, 2013

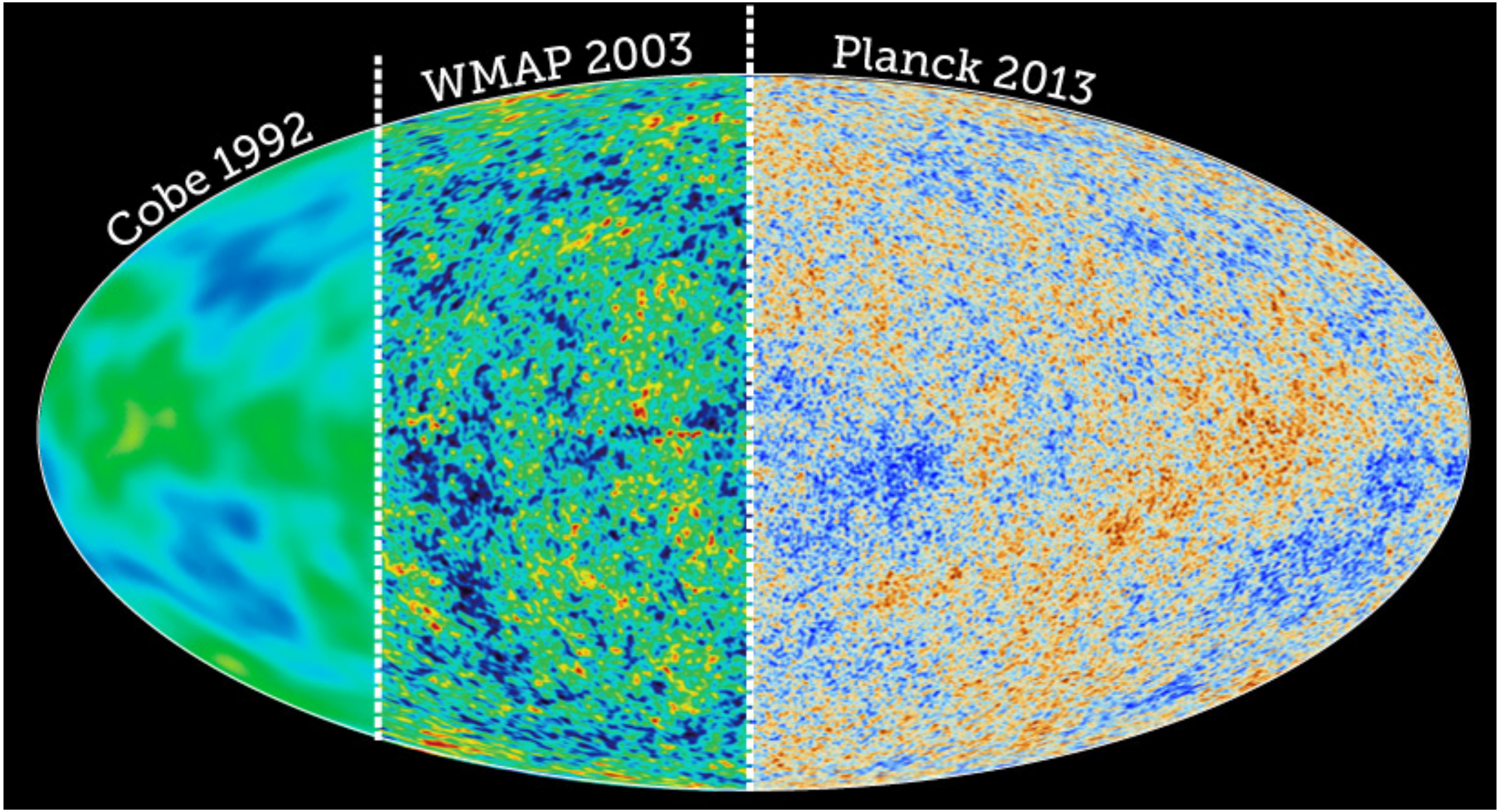
and a fairly wide coverage





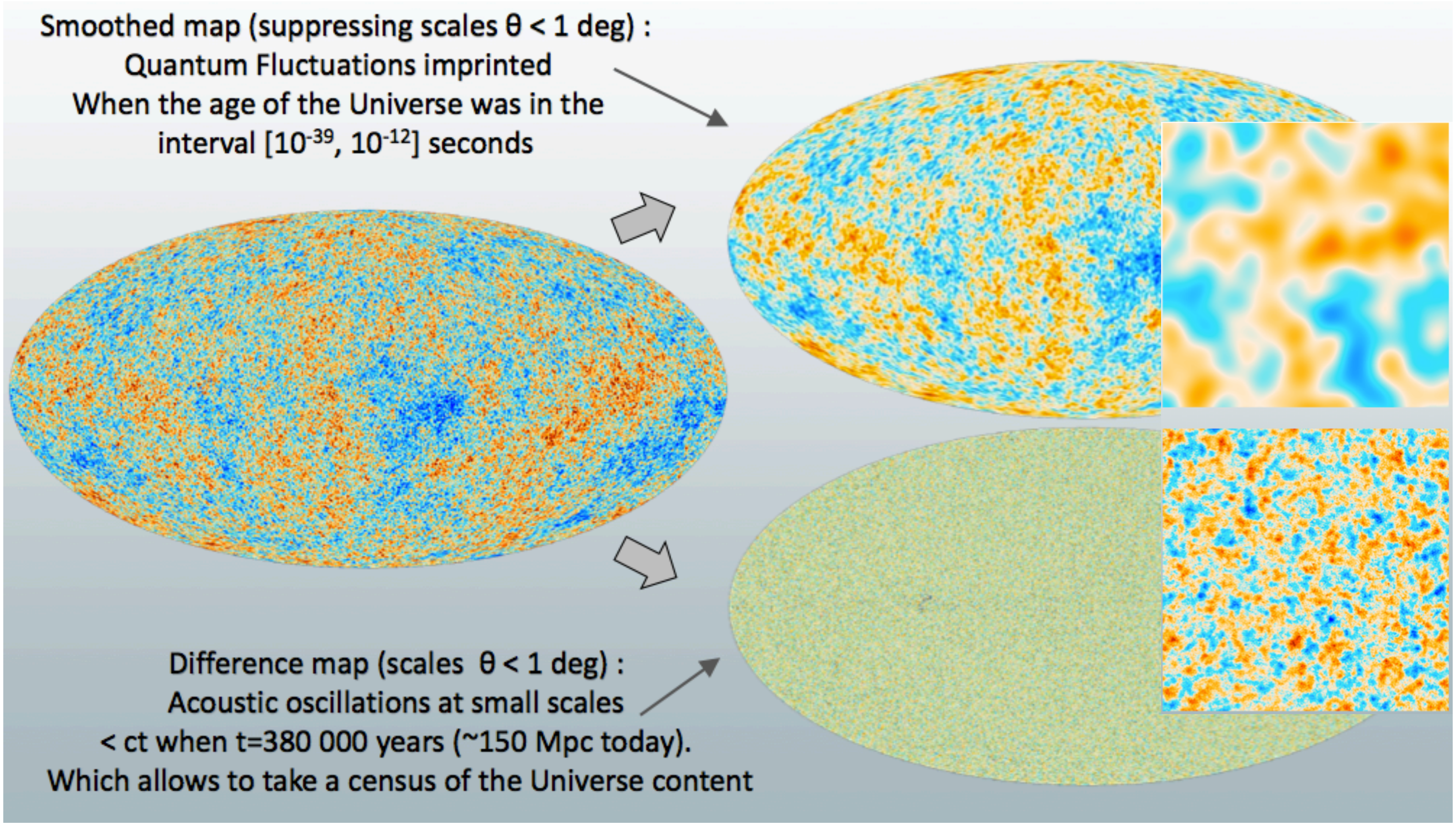
March 21st or 22nd, 2013

improvements with time & technology



Planck sensitivity in 1yr ~ 1000 years of WMAP

1. why Planck ?



the key is to measure both large and small angular scales

outline

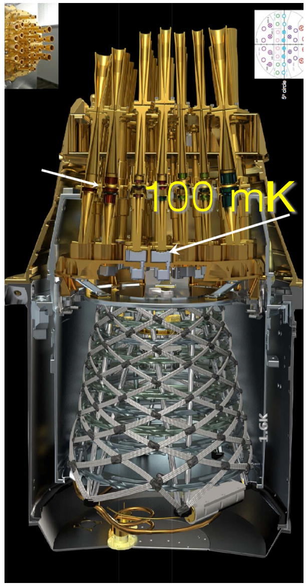
1. why Planck ?
2. the Cosmic Microwave Background (CMB) and the astrophysical components, incl galaxies
3. analysis of the CMB: angular power spectra
4. cosmological implications
5. a word about inflation
6. a clumpy Universe
    1. dark matter
    2. galaxy clusters via SZ
7. digging into the Cosmic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

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

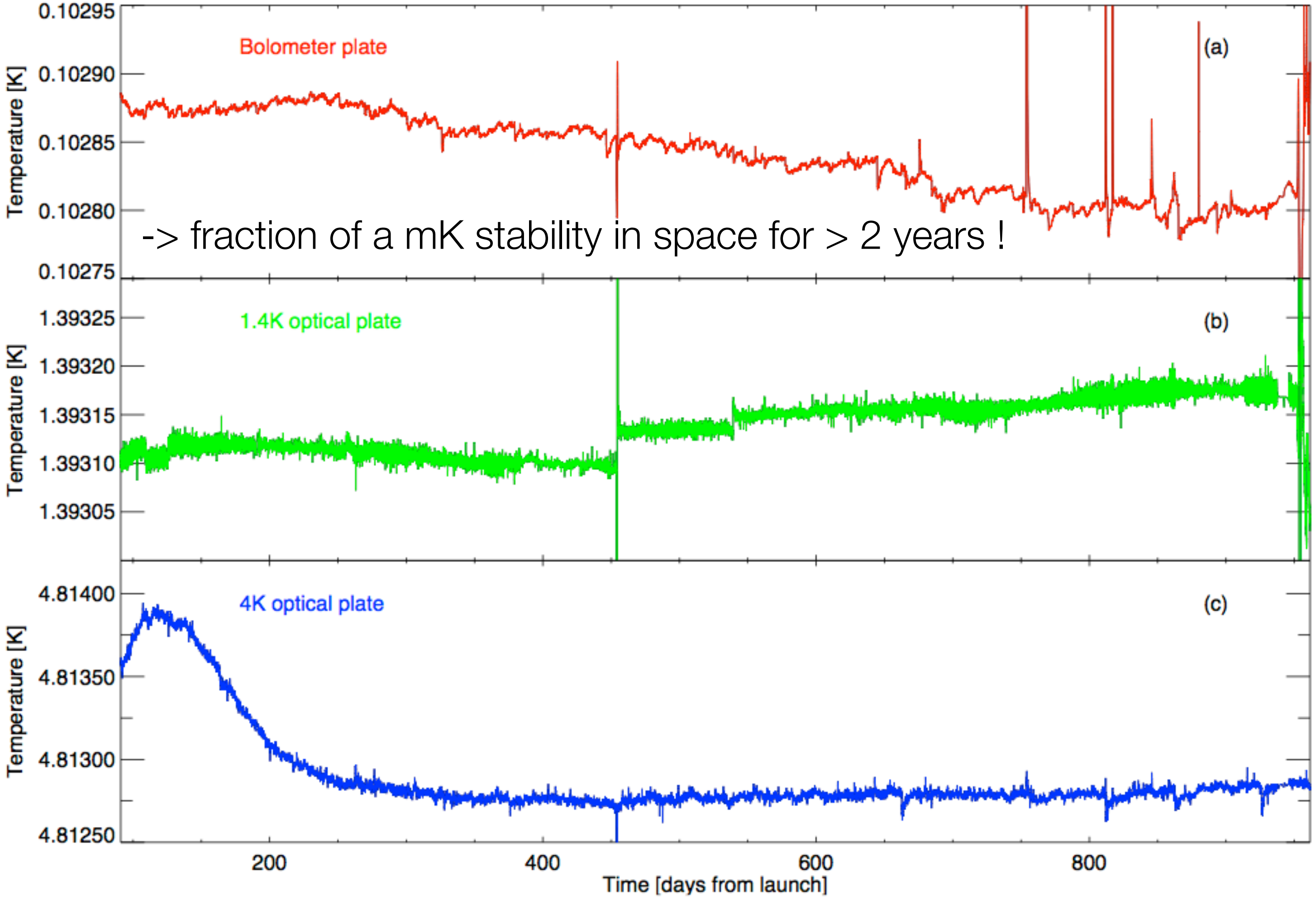
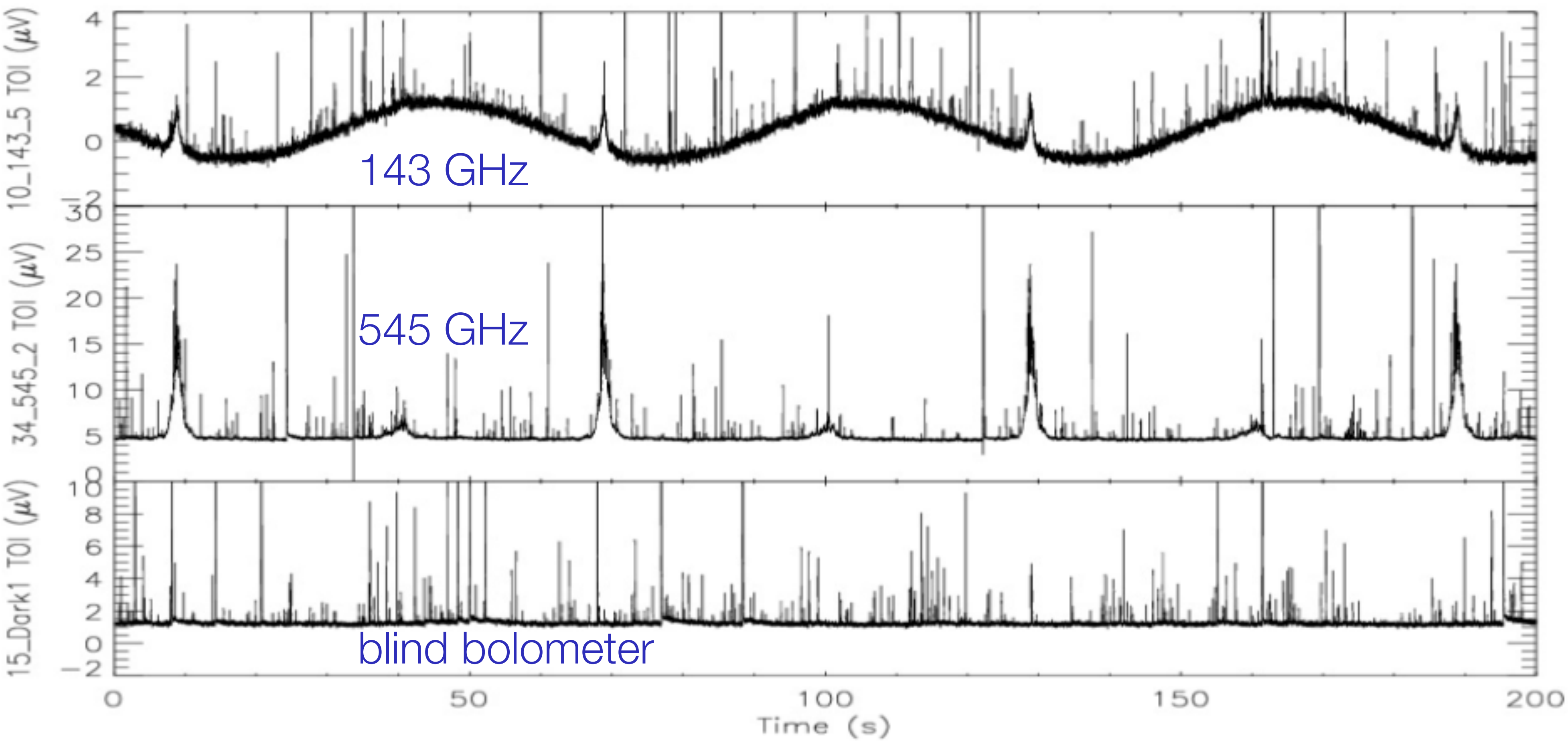


Fig. 7. The impressive stability of the HFI thermal stages during operations. Shown is the temperature evolution of the bolometer stage (*top*), the 1.6 K optical filter stage (*middle*) and the 4-K cooler reference load stage (*bottom*). The horizontal axis displays days since the beginning of the nominal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

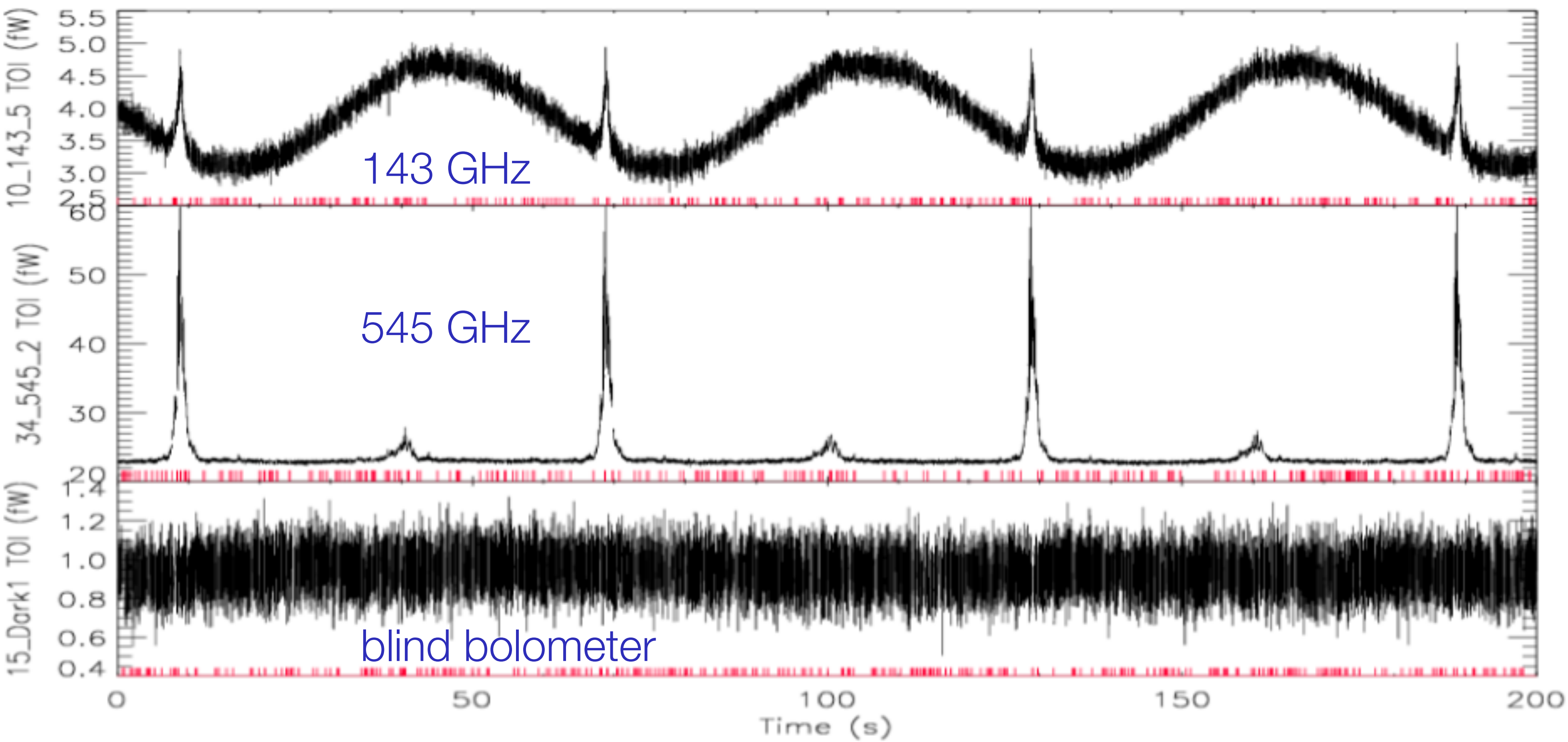
Planck Collab, 2013, 1

a challenging analysis success



Planck-HFI Core Team, 2011

a challenging analysis success

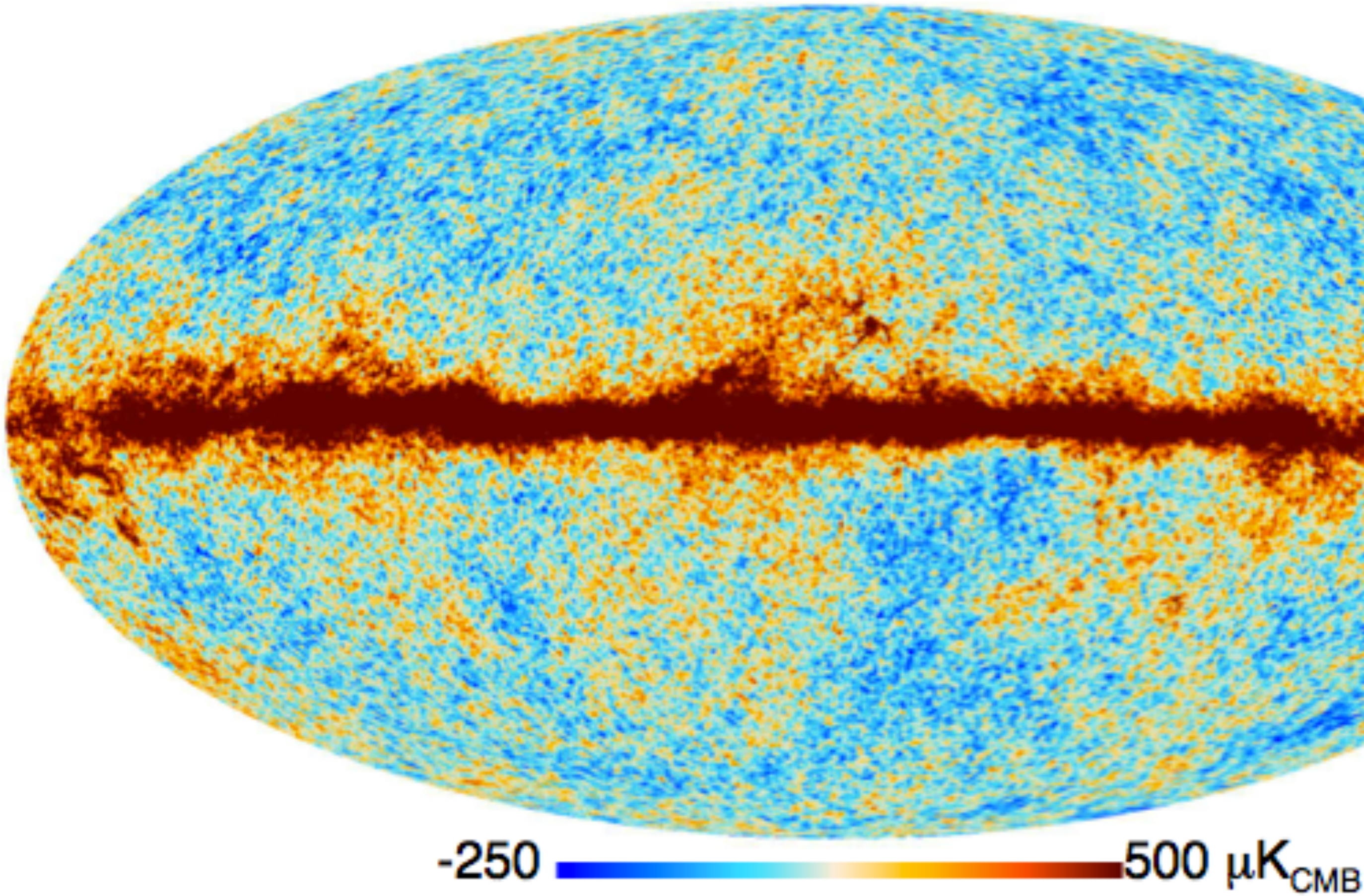


de <20% de données perdues à cause des glitches

Planck-HFI Core Team, 2011

many intermediate products for jacknifes

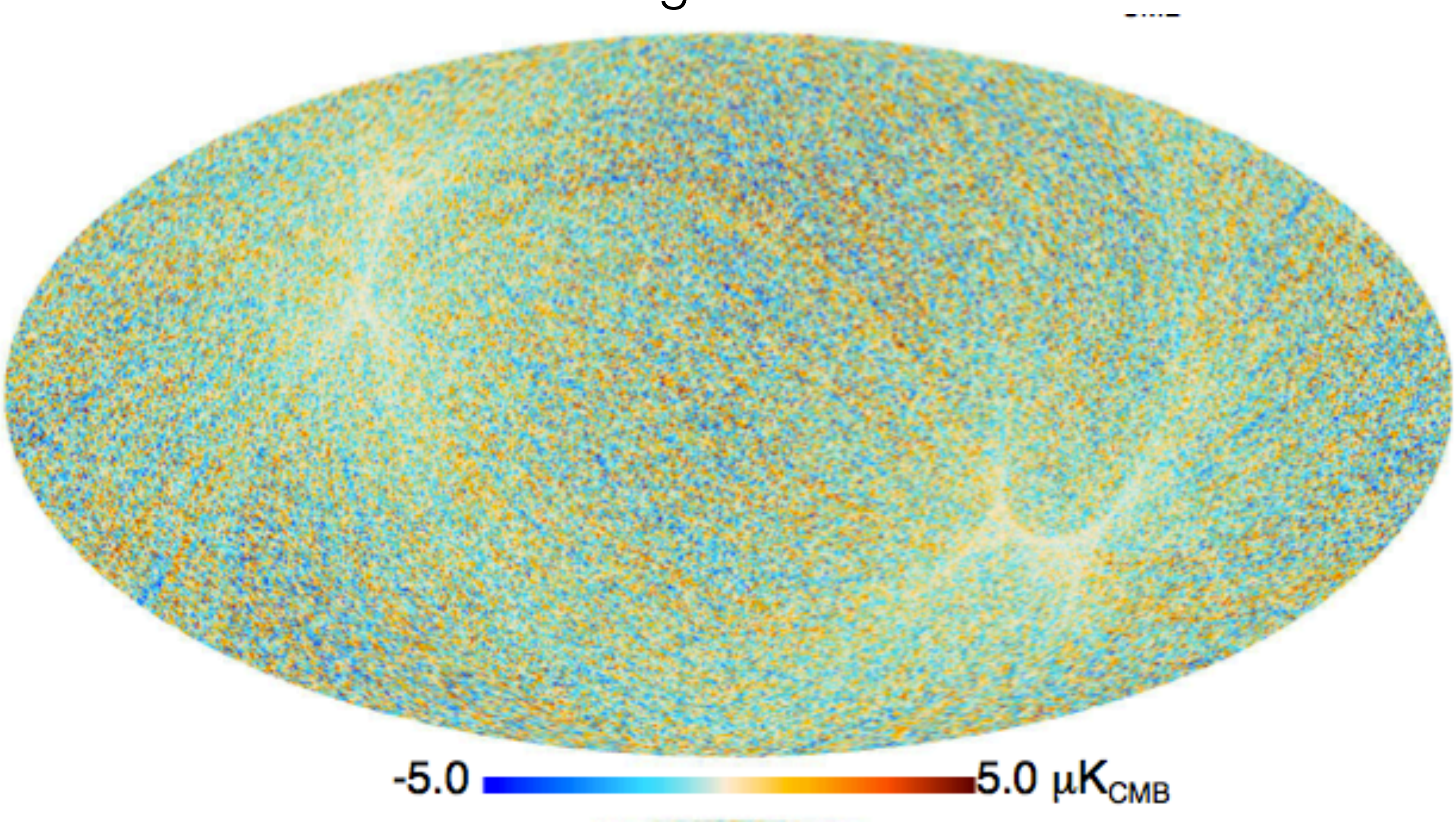
143 GHz map



Planck Collaboration, 2013, 6

many intermediate products for jacknifes

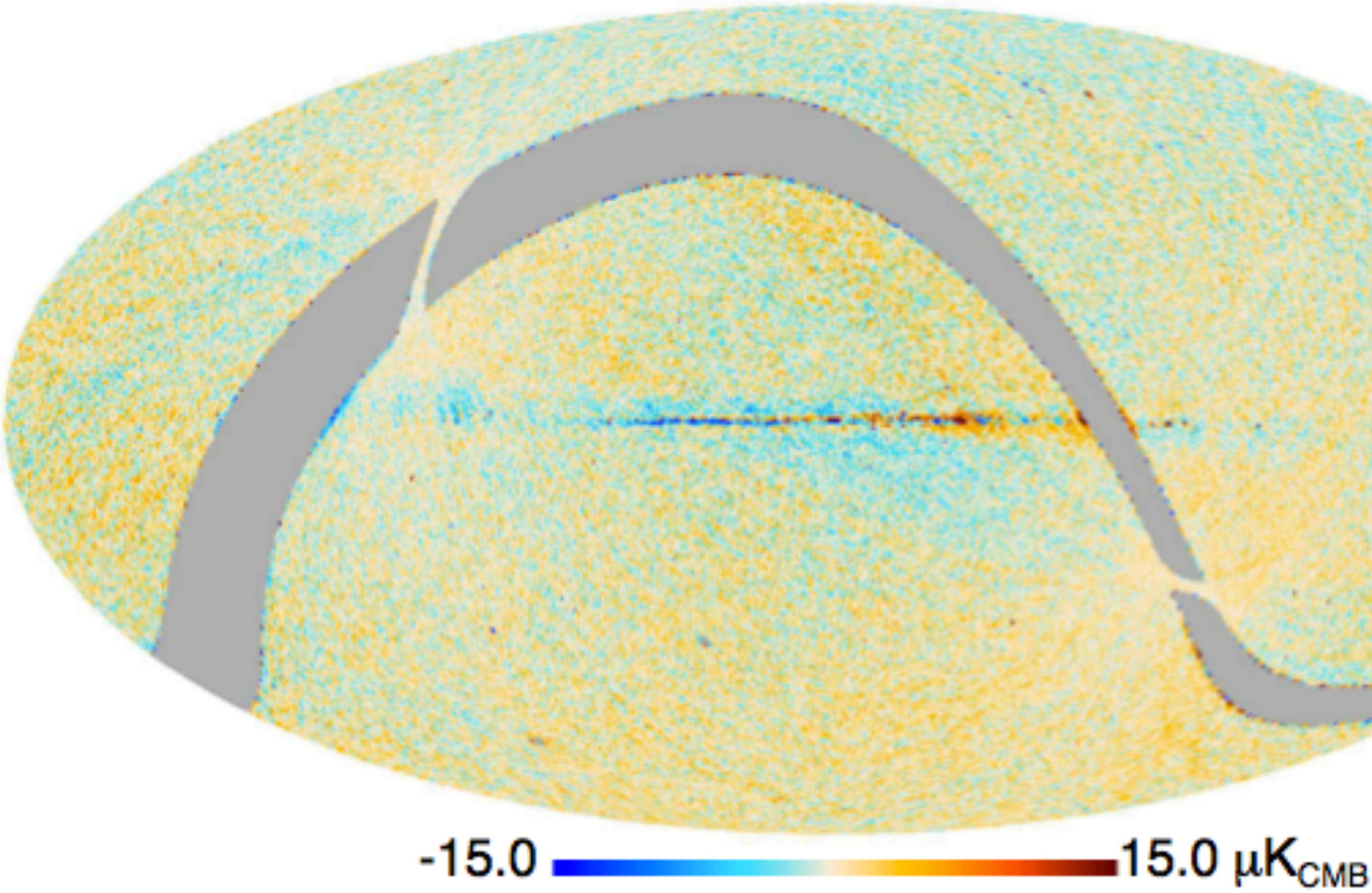
half ring difference



Planck Collaboration, 2013, 6

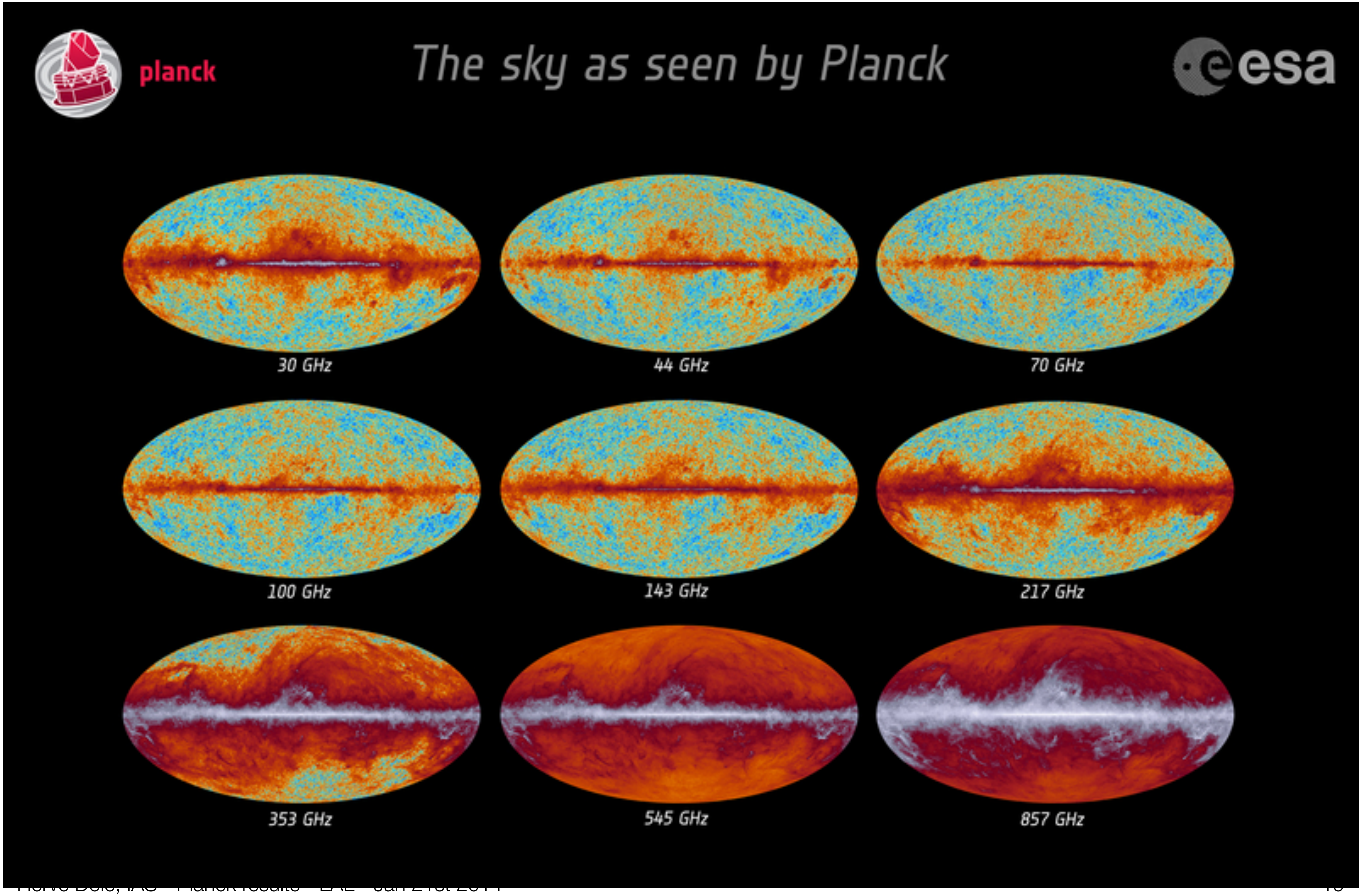
many intermediate products for jacknifes

survey 1 – survey 2 difference



Planck Collaboration, 2013, 6

Planck all-sky maps



Planck 2013 papers

instrument: calibration, processing, systematics
11 papers:

- Planck 2013 results. I. Overview of products and results
- Planck 2013 results. II. Low Frequency Instrument data processing
- Planck 2013 results. III. LFI systematic uncertainties
- Planck 2013 results. IV. LFI beams
- Planck 2013 results. V. LFI calibration
- Planck 2013 results. VI. High Frequency Instrument data processing
- Planck 2013 results. VII. HFI time response and beams
- Planck 2013 results. VIII. HFI calibration and mapmaking
- Planck 2013 results. IX. HFI spectral response
- Planck 2013 results. X. HFI energetic particle effects
- Planck 2013 results. XI. Consistency of the data

3 papers:
component separation

- Planck 2013 results. XII. Component separation
- Planck 2013 results. XIII. Galactic CO emission
- Planck 2013 results. XIV. Zodiacal emission

2 papers:
cosmological parameters, p. spectra, likelihood

- Planck 2013 results. XV. CMB power spectra and likelihood
- Planck 2013 results. XVI. Cosmological parameters

3 papers:
line of sight effects: lensing, CIB, ISW

- Planck 2013 results. XVII. Gravitational lensing by large-scale structure
- Planck 2013 results. XVIII. The gravitational lensing-infrared background correlation
- Planck 2013 results. XIX. The integrated Sachs-Wolfe effect

2 papers:
SZ clusters and map

- Planck 2013 results. XX. Cosmology from Sunyaev-Zeldovich cluster counts
- Planck 2013 results. XXI. All-sky Compton-parameter map and characterization

6 papers:
cosmology, constraints

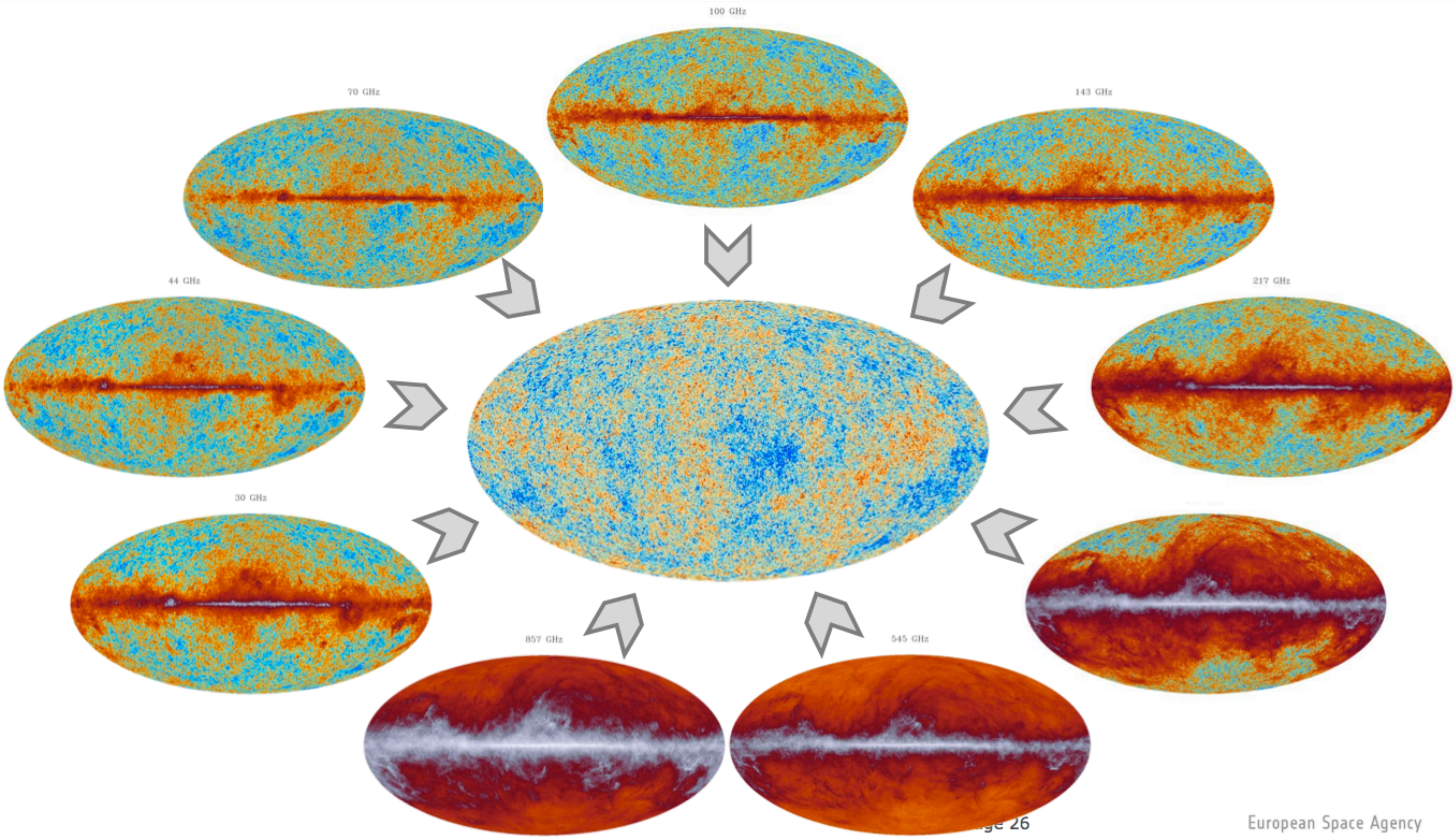
- Planck 2013 results. XXII. Constraints on inflation
- Planck 2013 results. XXIII. Isotropy and statistics of the CMB
- Planck 2013 results. XXIV. Constraints on primordial non-Gaussianity
- Planck 2013 results. XXV. Searches for cosmic strings and other topological defects
- Planck 2013 results. XXVI. Background geometry and topology of the Universe
- Planck 2013 results. XXVII. Special relativistic effects on the CMB dipole

3 papers: products (catalog), XS

- Planck 2013 results. XXVIII. The Planck Catalogue of Compact Sources
- Planck 2013 results. XXIX. The Planck catalogue of Sunyaev-Zeldovich sources
- Planck 2013 results. Explanatory supplement

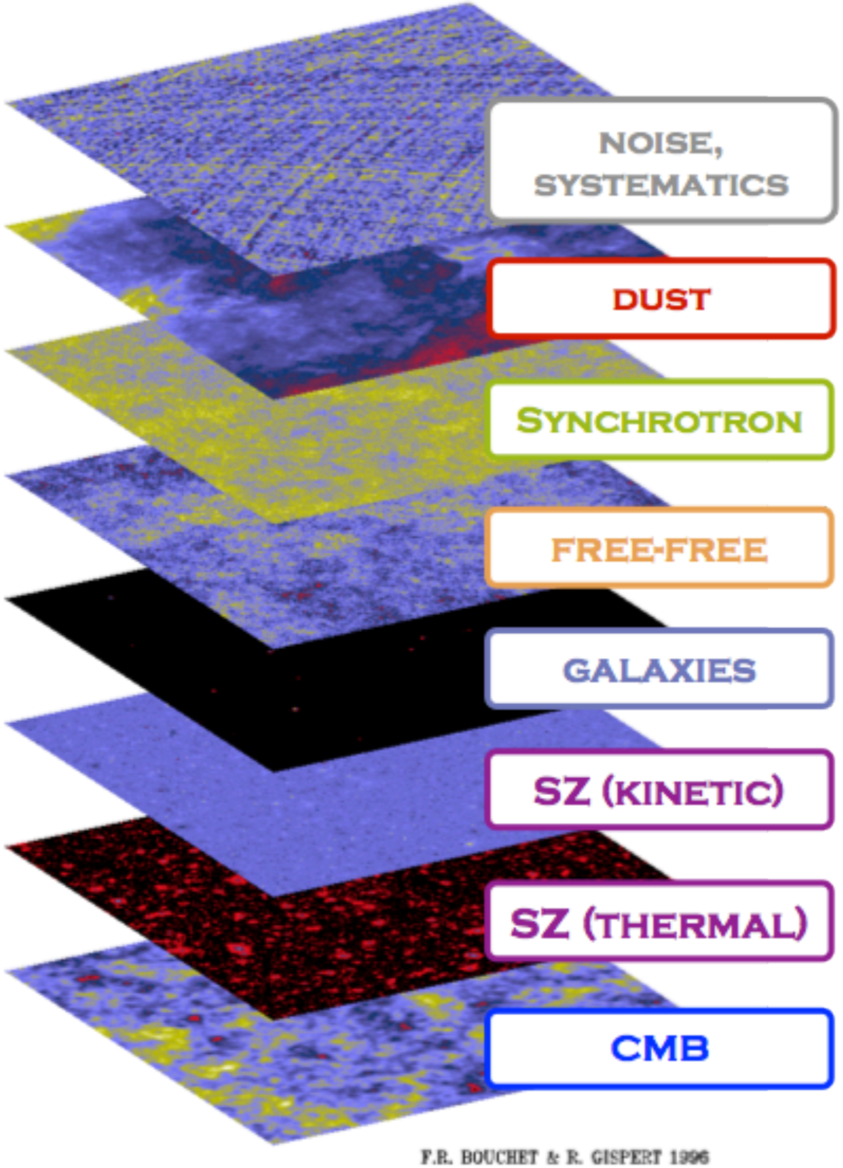
29 papers (+1 to come on CIB) ; 800+ pages
1 Explanatory Supplement
all products available online

2. component separation

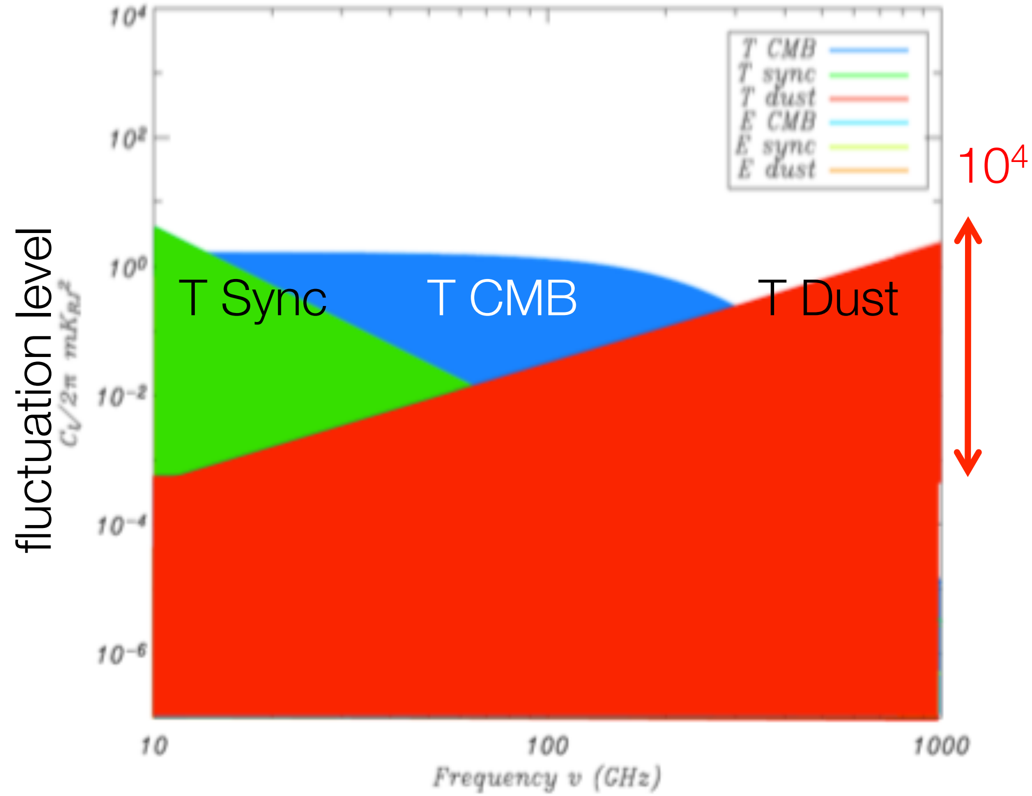


various components

different spectral and spatial behavior



level of fluctuations



observed frequency

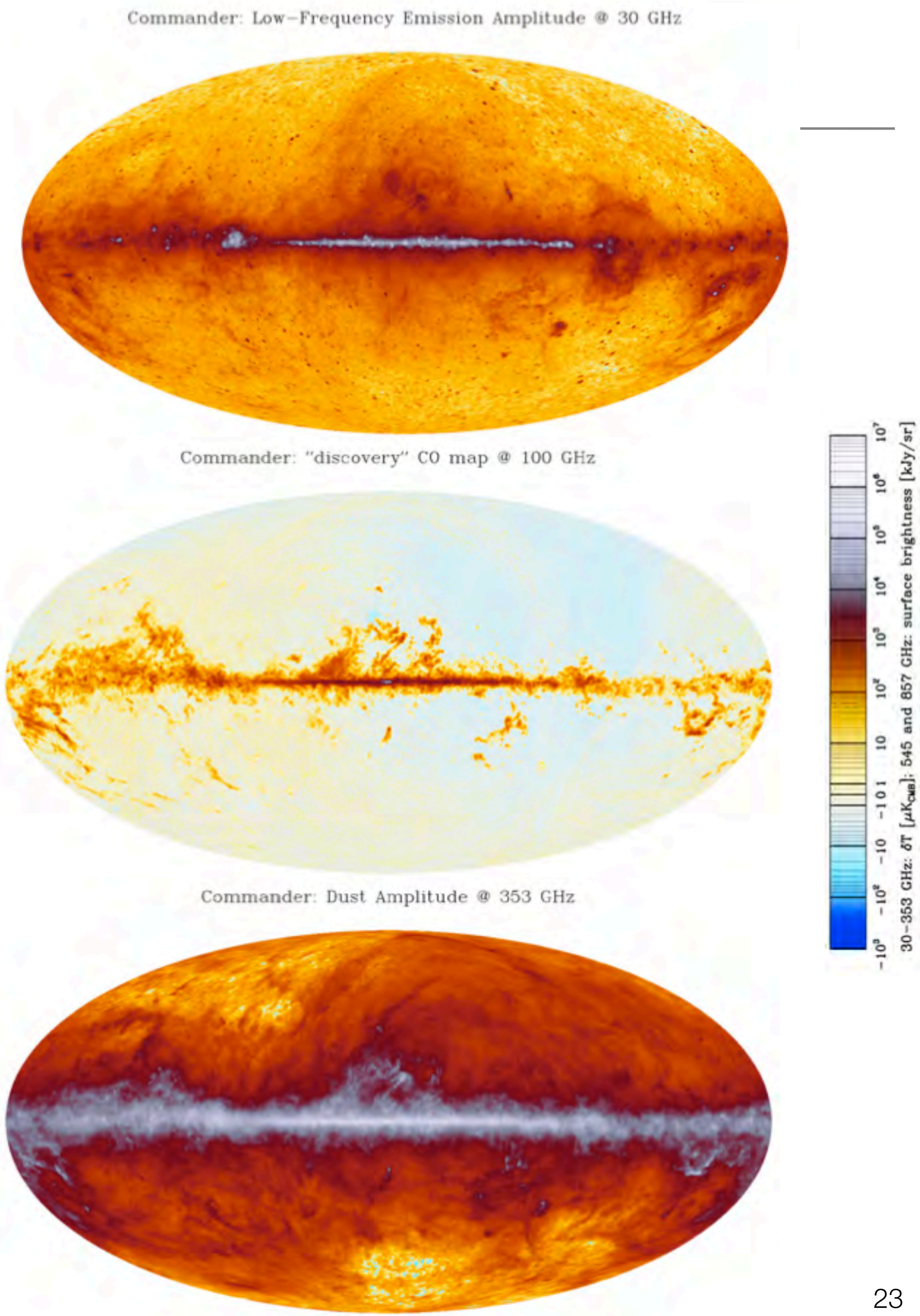
some components

low frequency emission

CO map

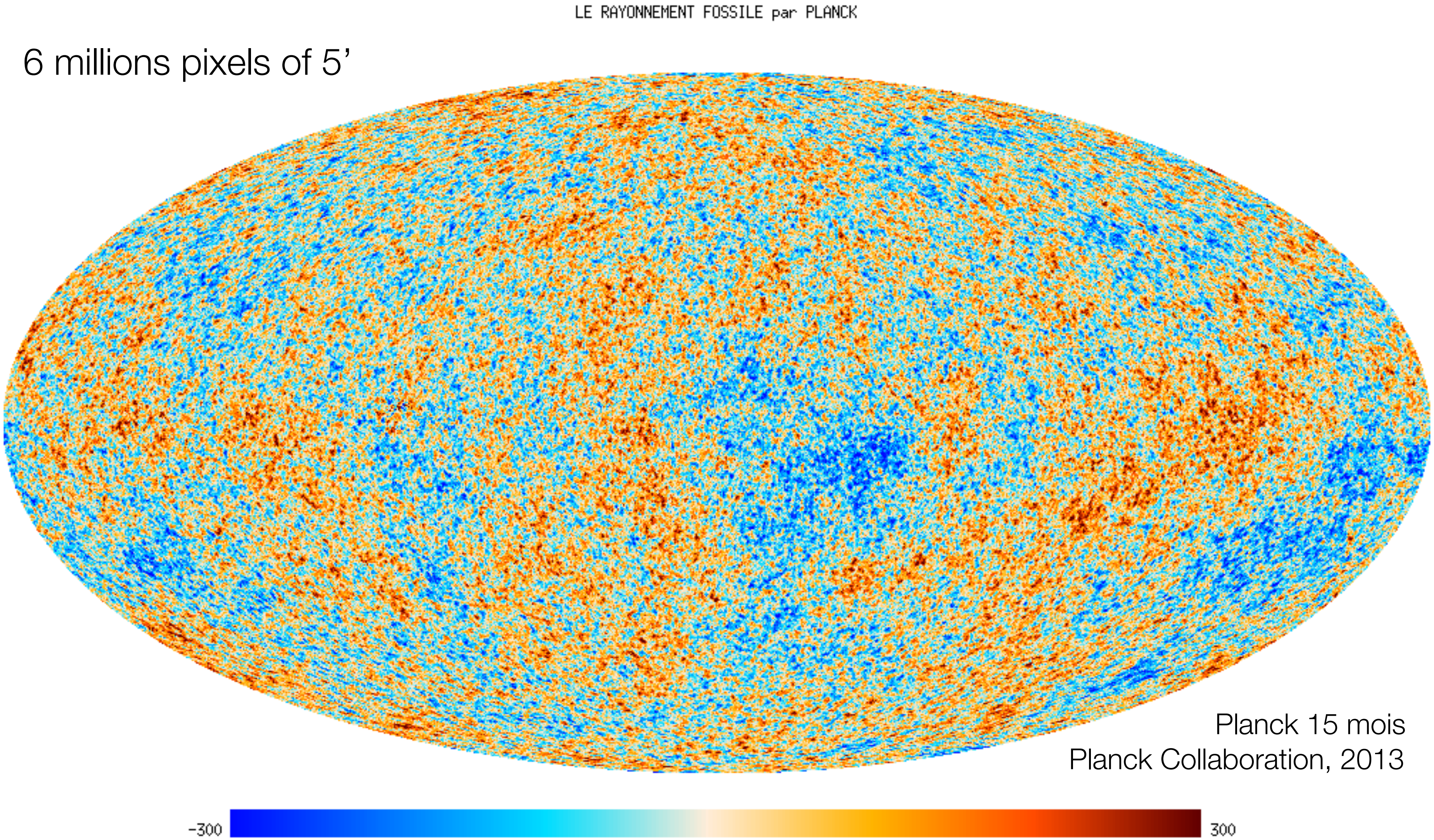
dust at high frequency

Planck Collab, 2013, 1, 12, 13, 14



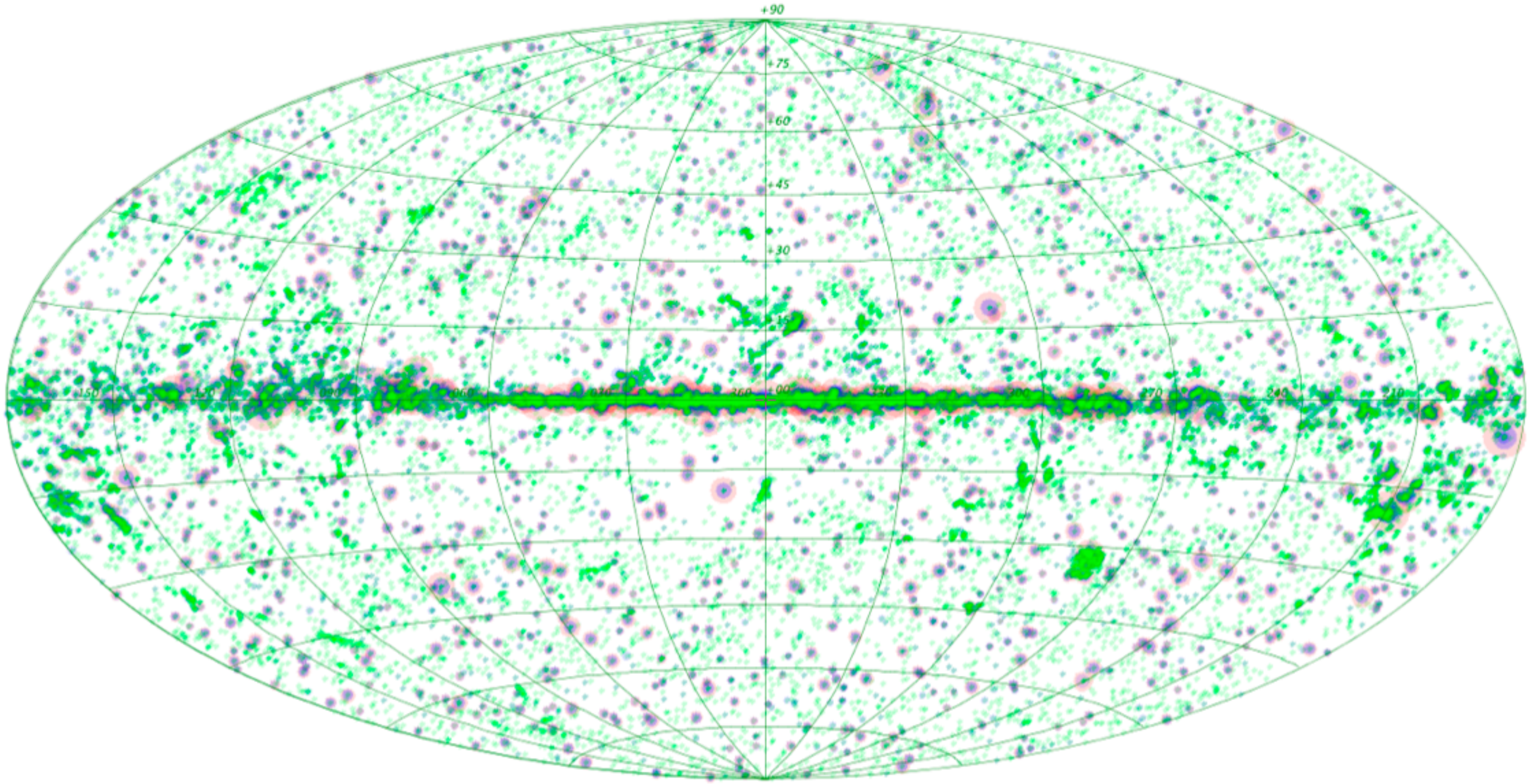
temperature anisotropies

6 millions pixels of 5’



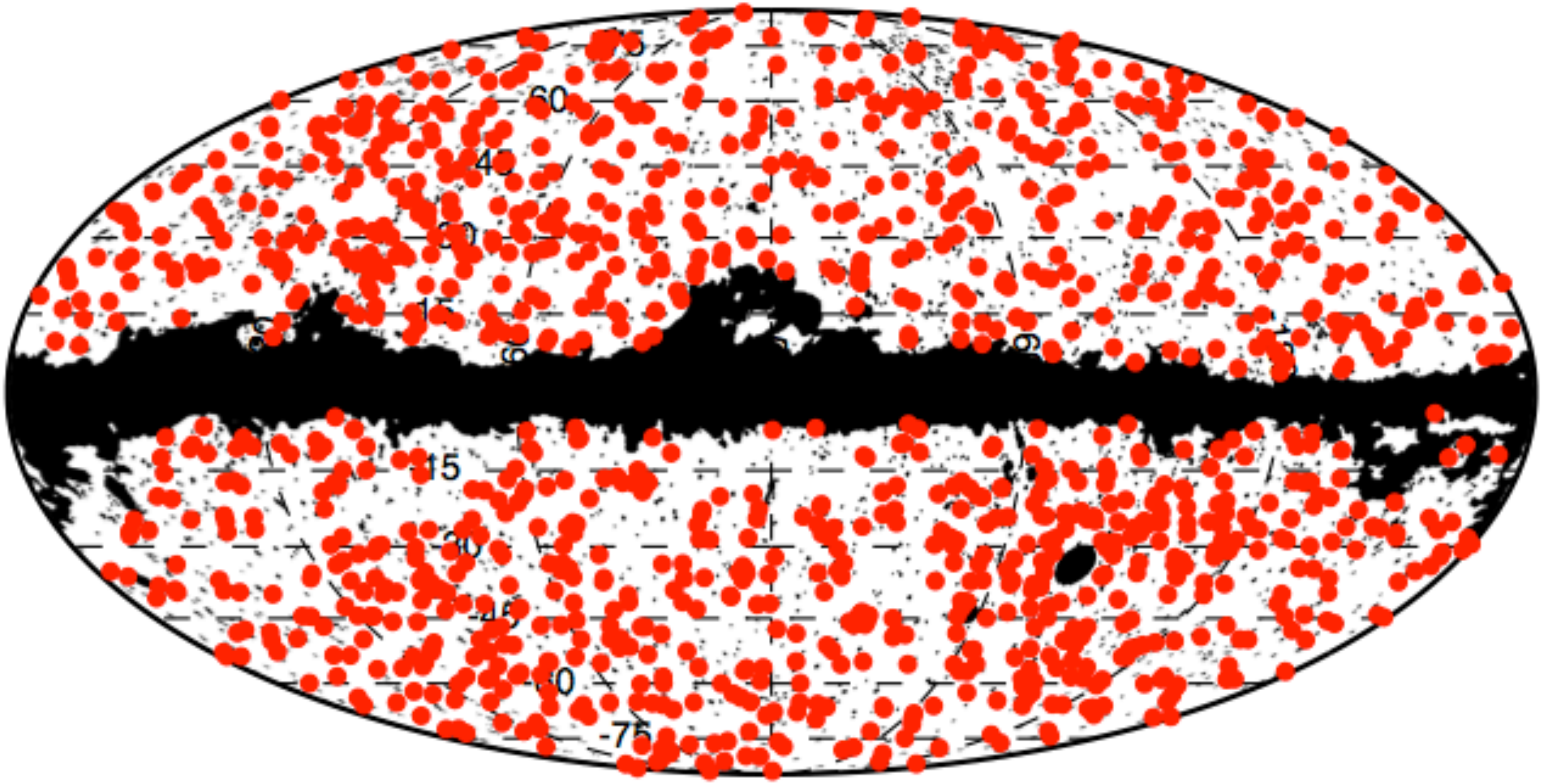
Planck 15 mois
Planck Collaboration, 2013

Planck Catalogue of Compact Sources [PCCS]



Planck Collab, 2013, 28

galaxy clusters: Sunyaev-Zeldovich effect

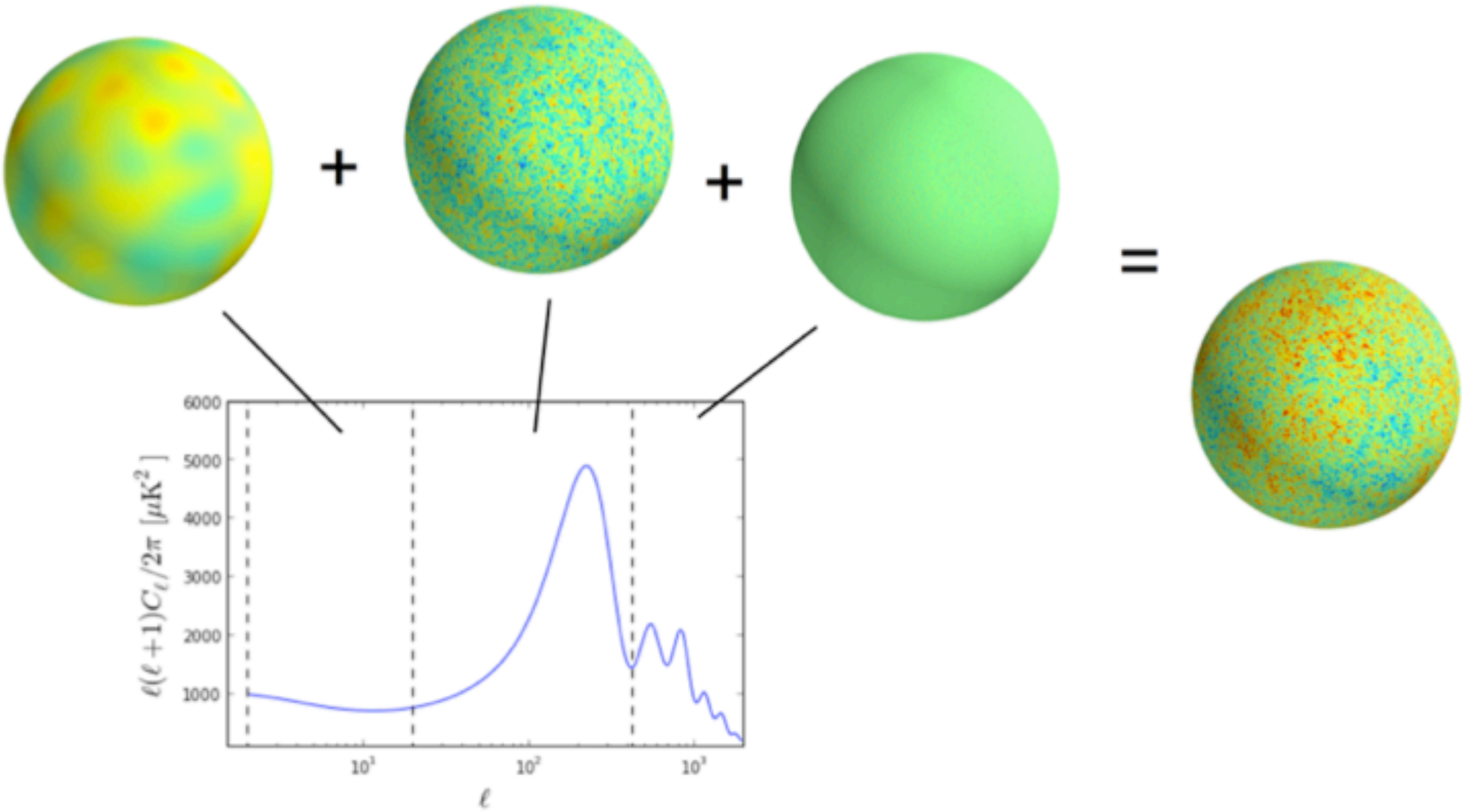


1227 SZ clusters -> including 366 brand new cluster candidates

Planck Collab, 2013, 29

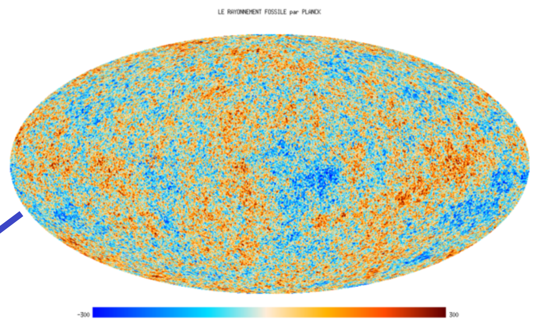
3. angular power spectra

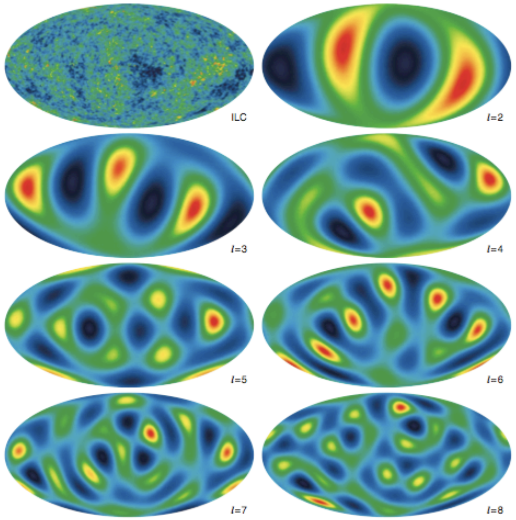
$$\langle a^*_{lm} a_{lm} \rangle = C_l$$



courtesy Olivier Doré

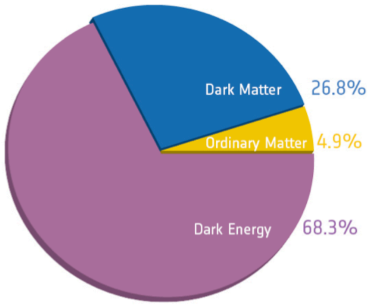
from maps to 6 cosmological parameters

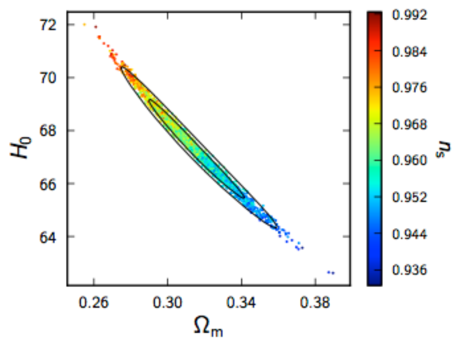


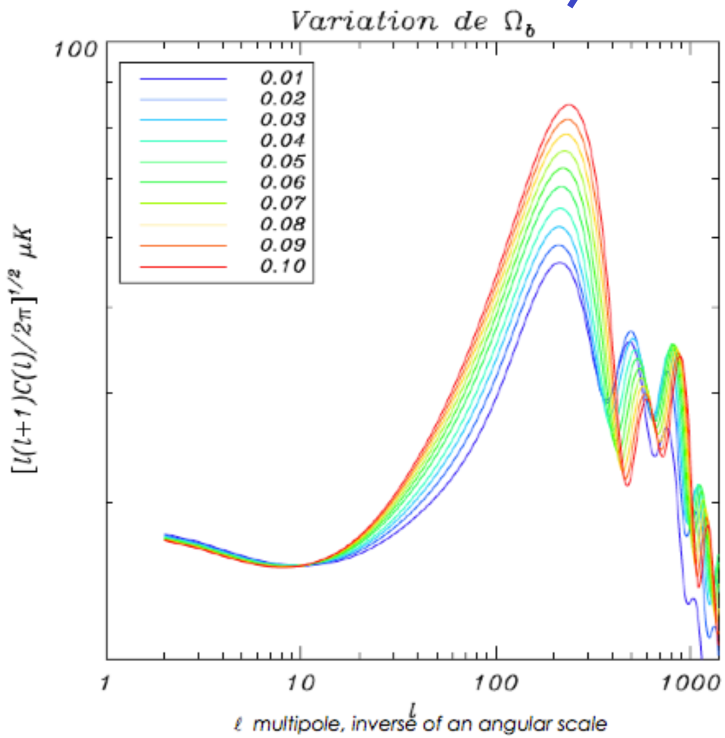


$$\frac{\Delta T(\mathbf{n})}{T_0} = \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m}^{T} Y_{\ell m}(\mathbf{n})$$

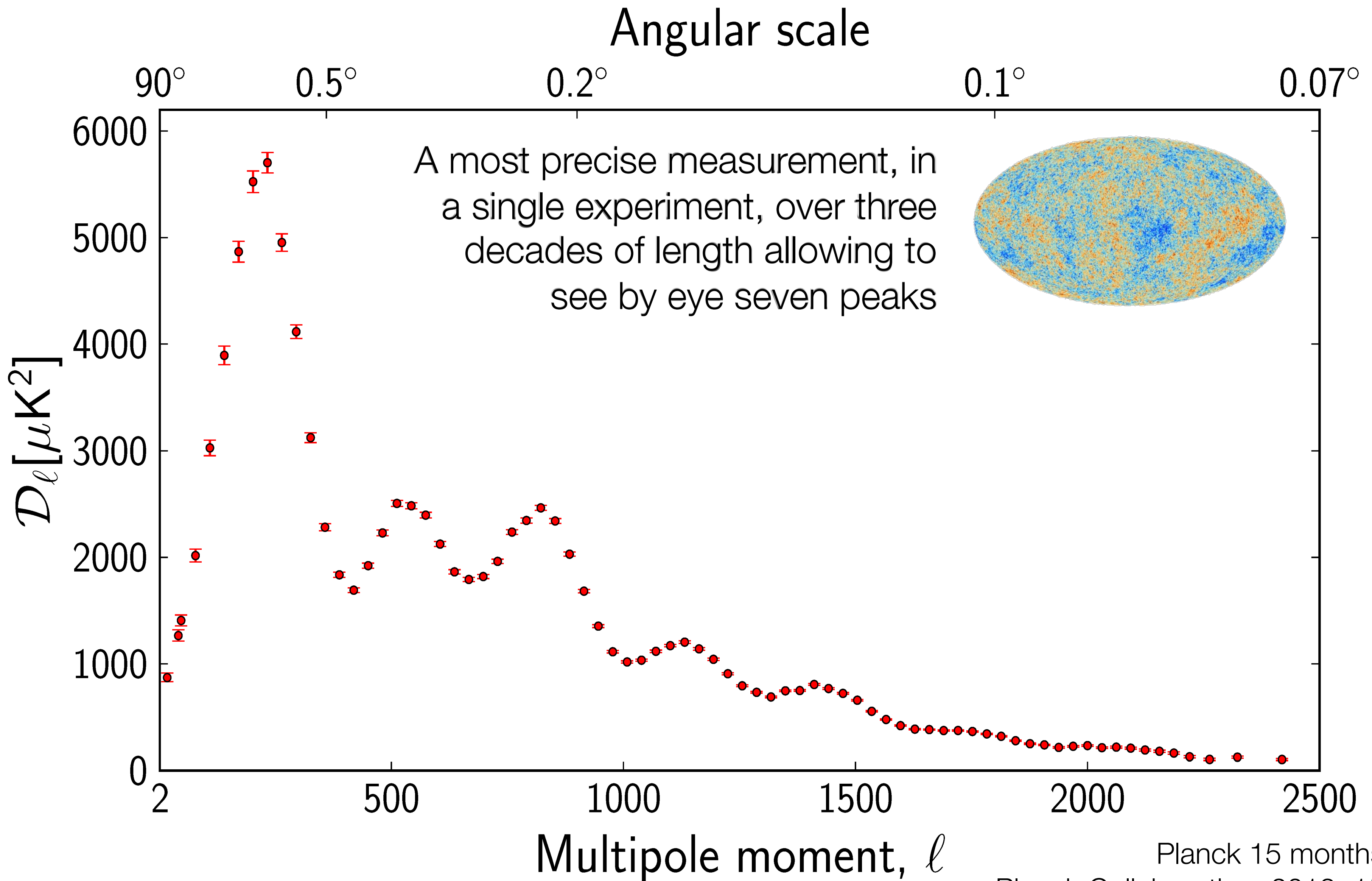
$$C_\ell^{TT} = \langle a_{\ell m}^{T} \cdot a_{\ell m}^{T\star} \rangle$$







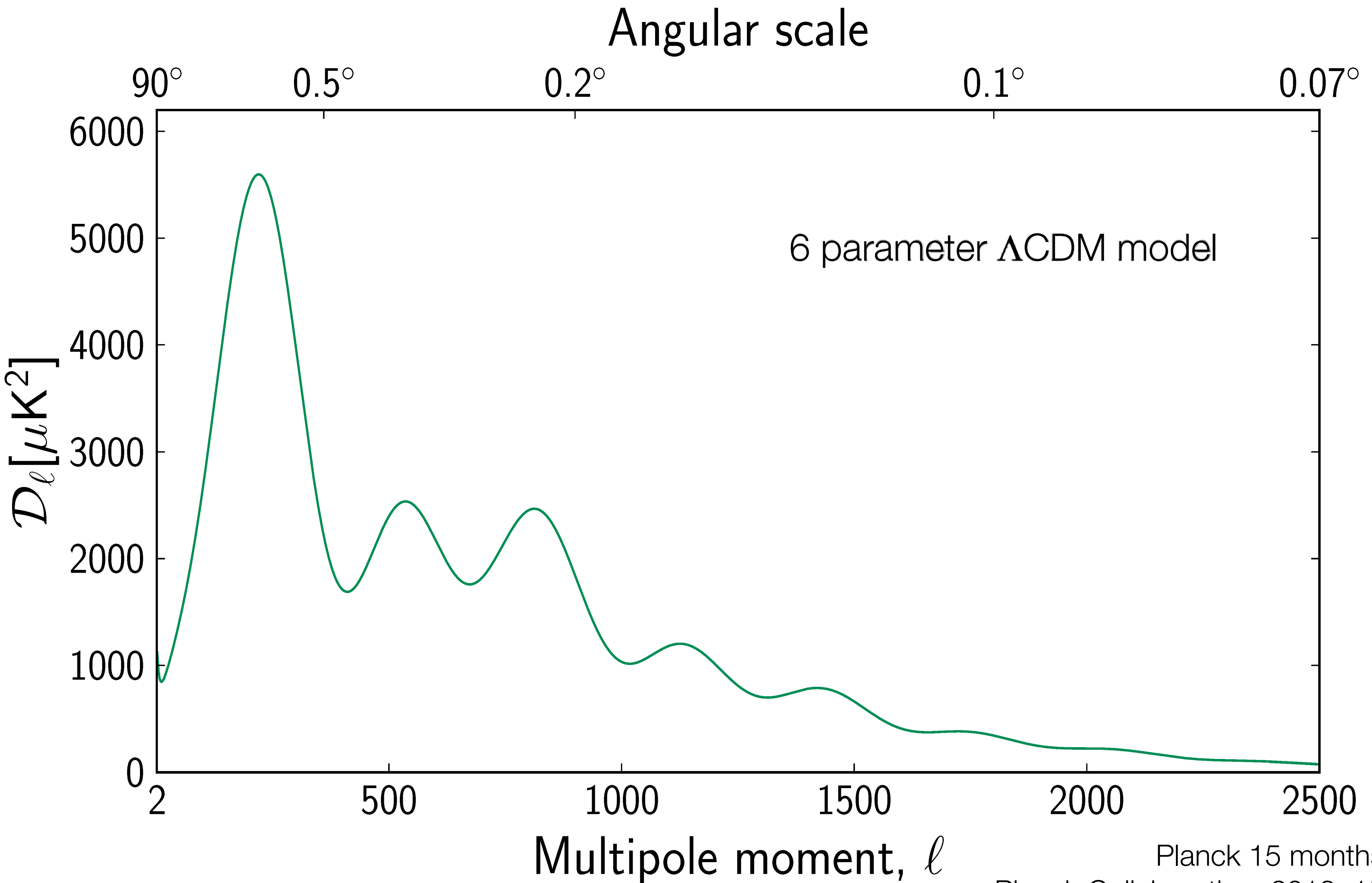
the Planck spectrum of temperature anisotropies



Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

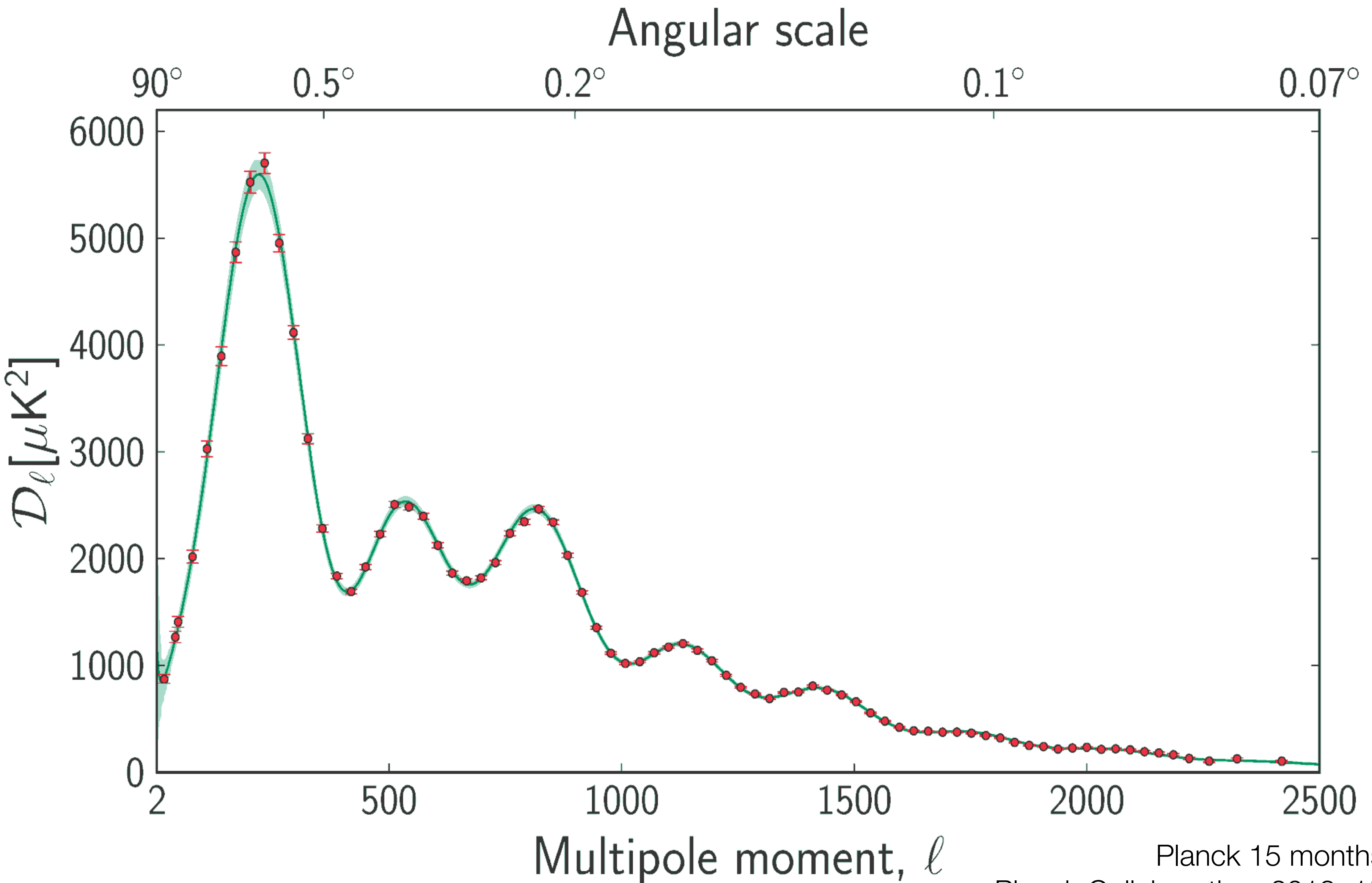
Planck best fitting theoretical model



Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

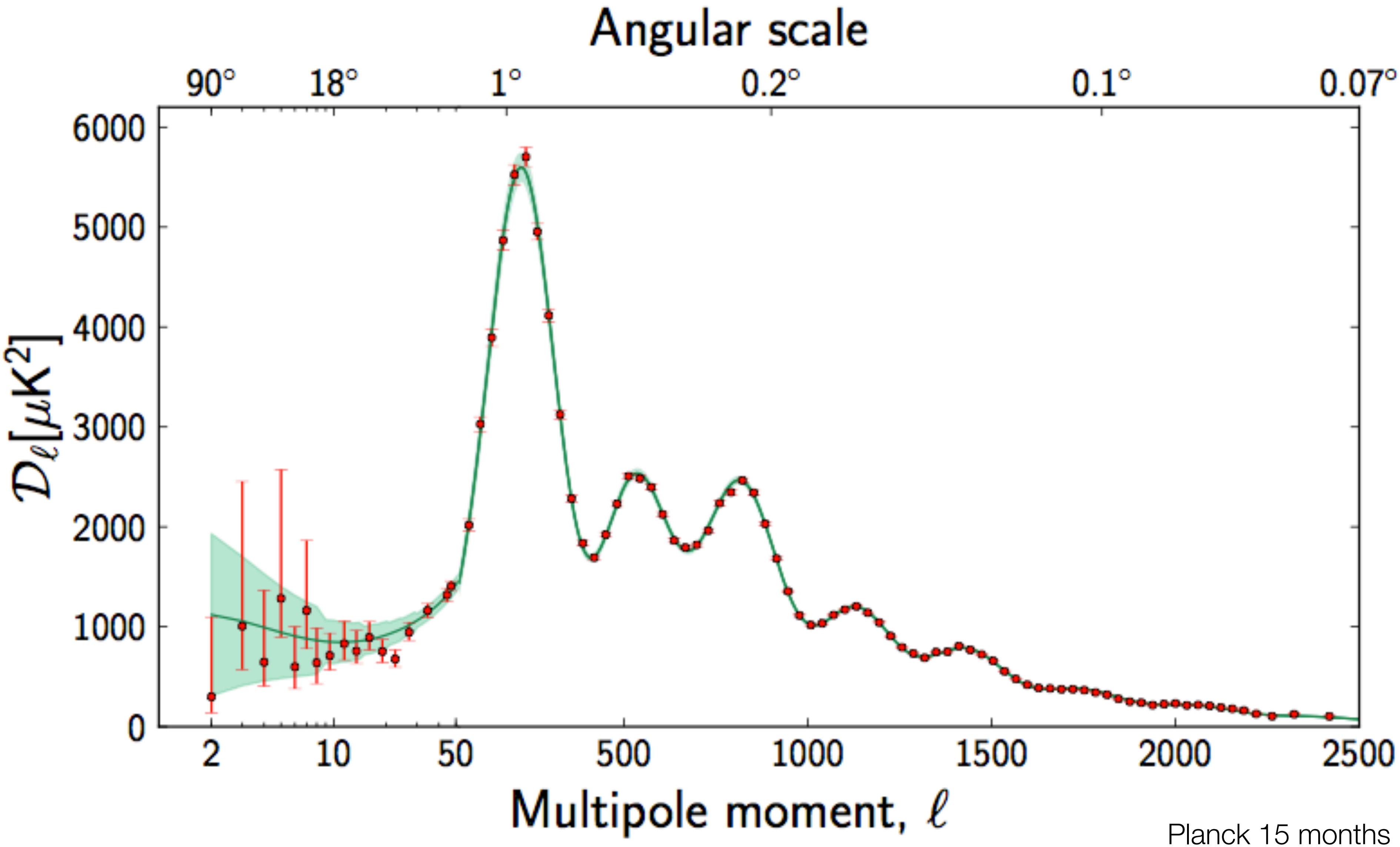
theory confronts data – 1



Planck 15 months
Planck Collaboration, 2013, 15

courtesy François Bouchet

theory confronts data – 2



Planck 15 months
Planck Collaboration, 2013, 15

theory confronts data – 3 – polarization

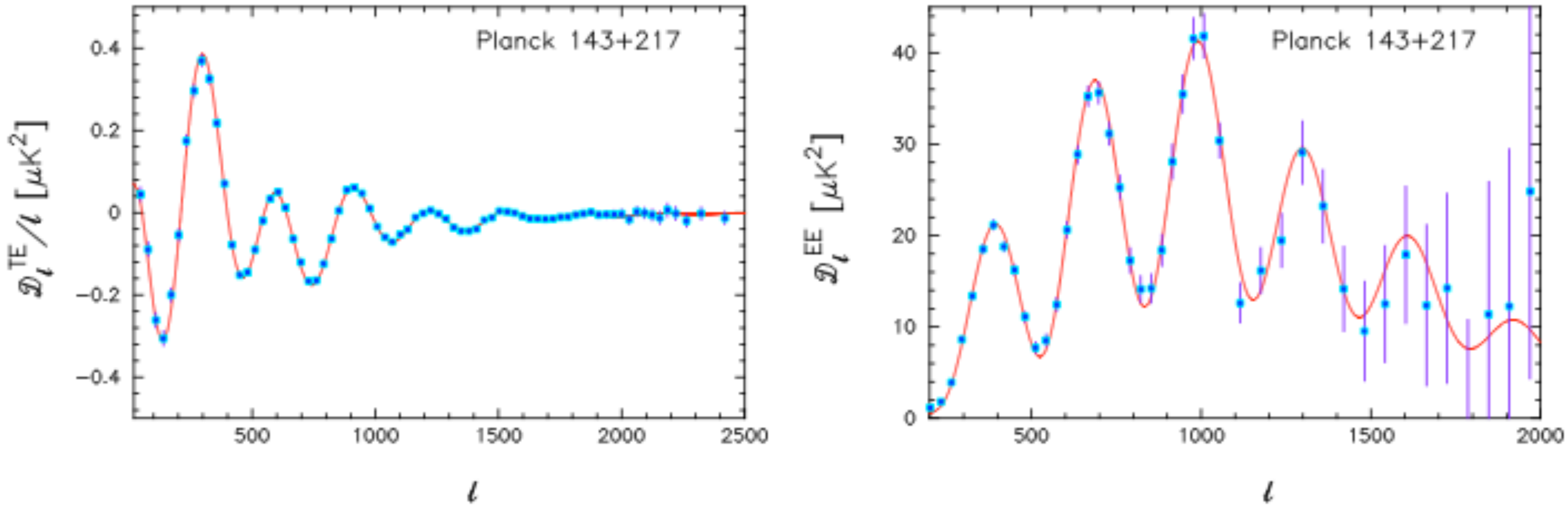
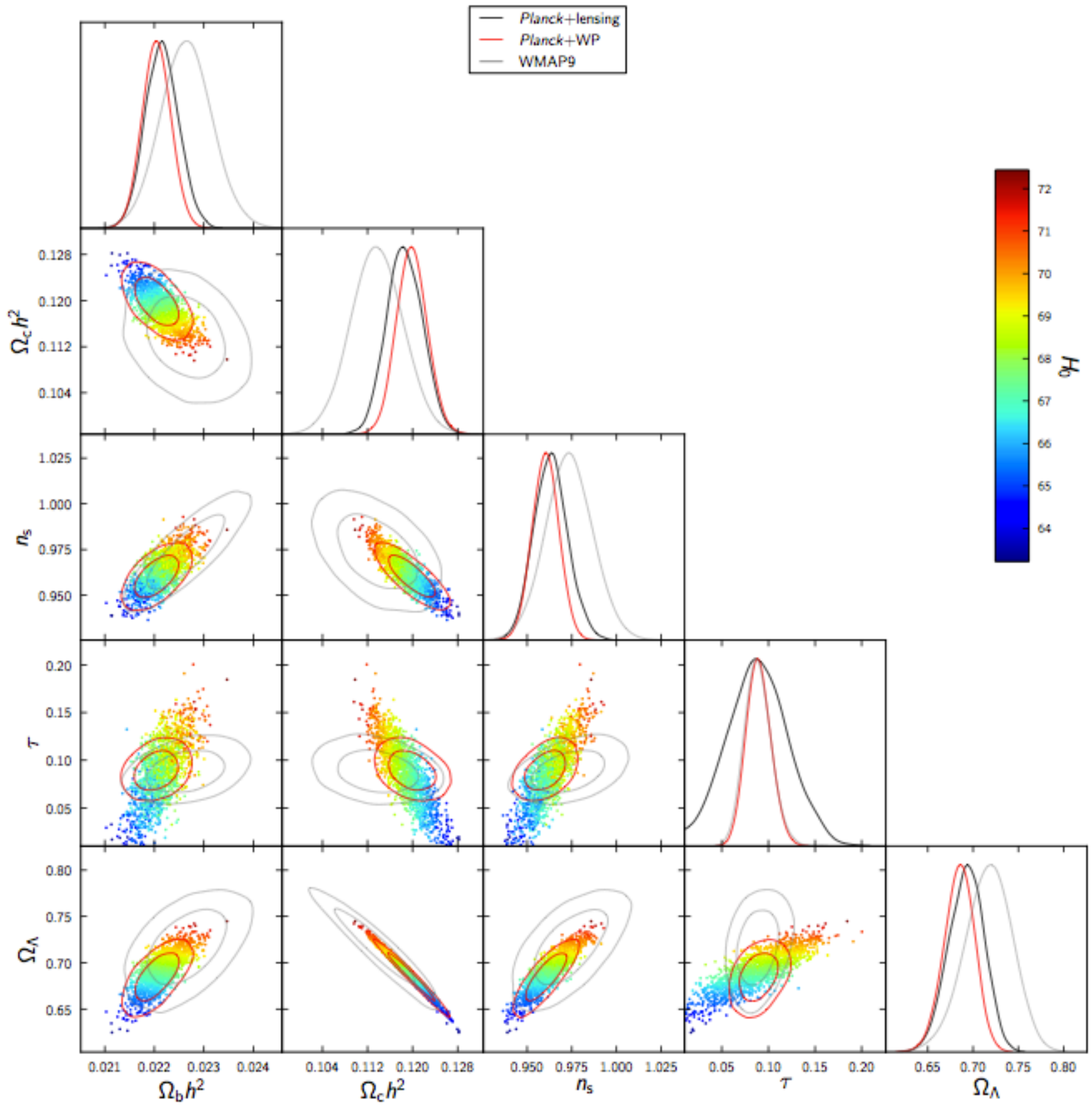


Fig. 11. *Planck TE* (left) and *EE* spectra (right) computed as described in the text. The red lines show the polarization spectra from the base ΛCDM *Planck*+WP+highL model, *which is fitted to the TT data only*.

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

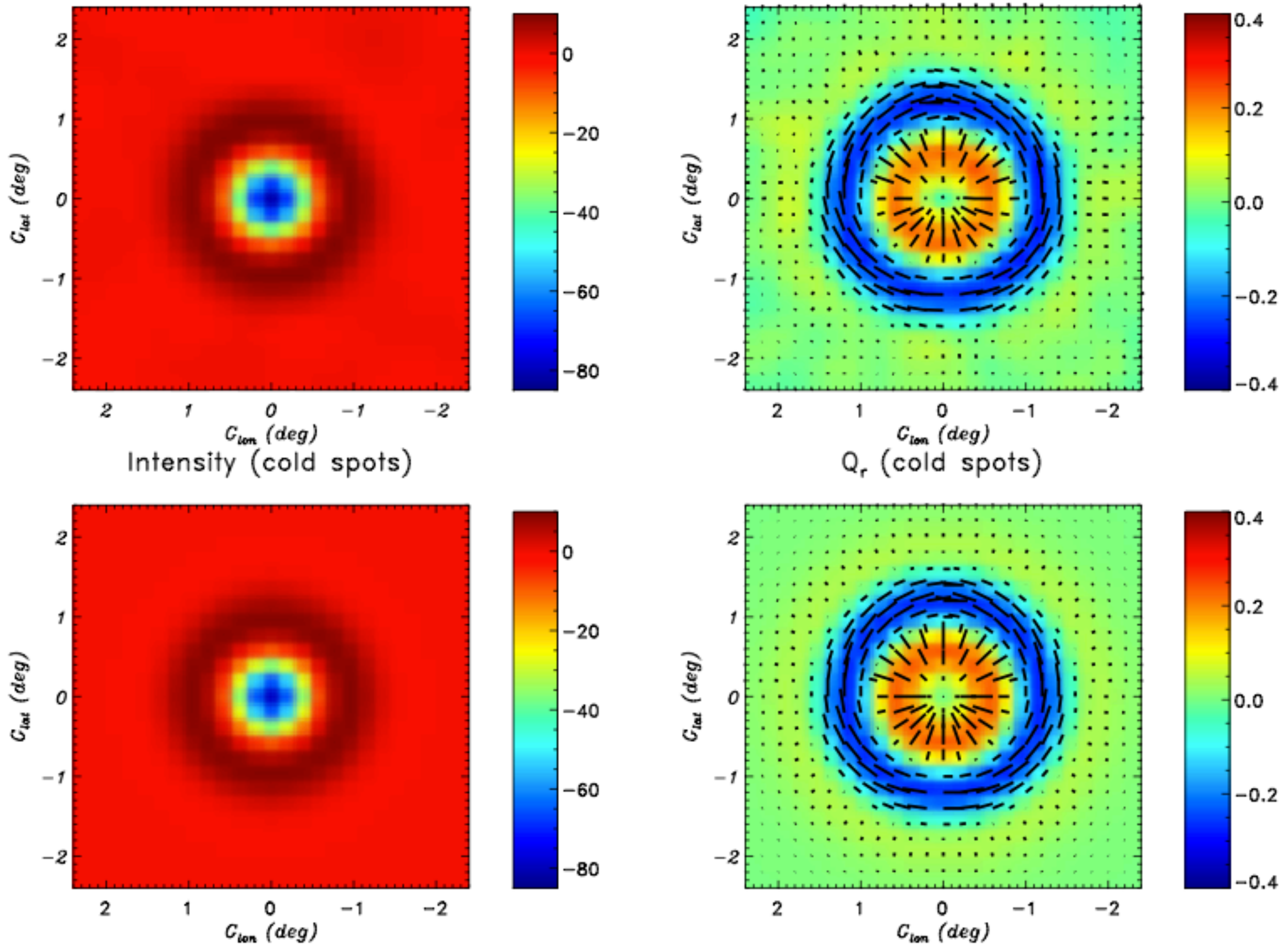
Planck 15 months
Planck Collaboration, 2013, 15

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

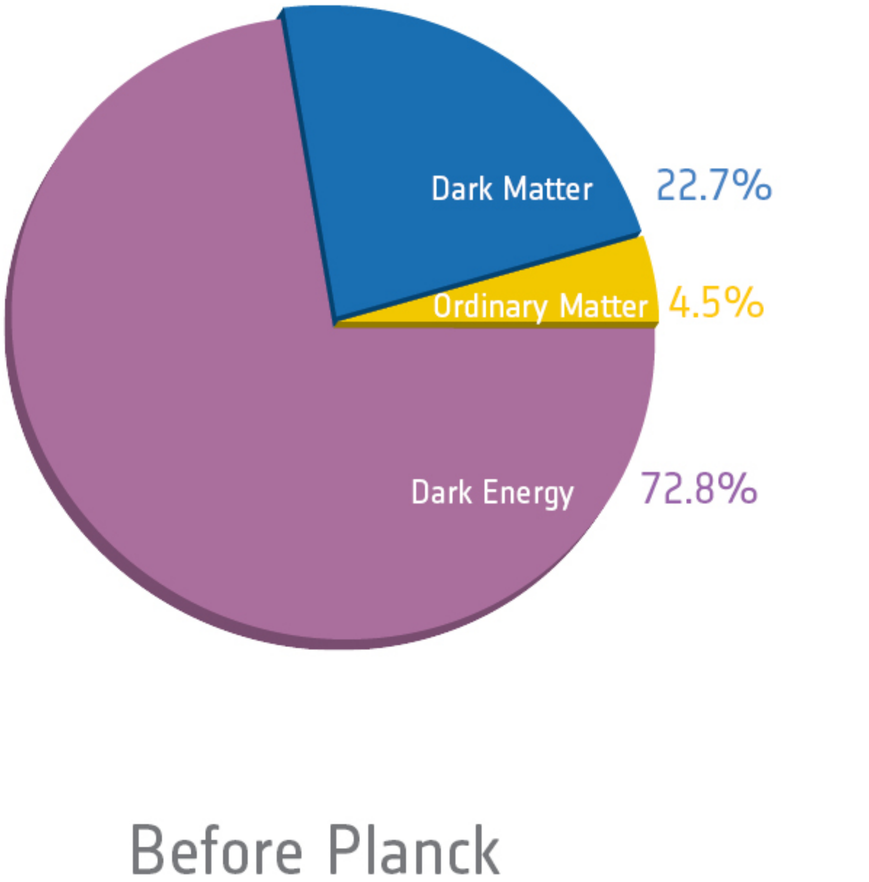
4. standard Λ-CDM model

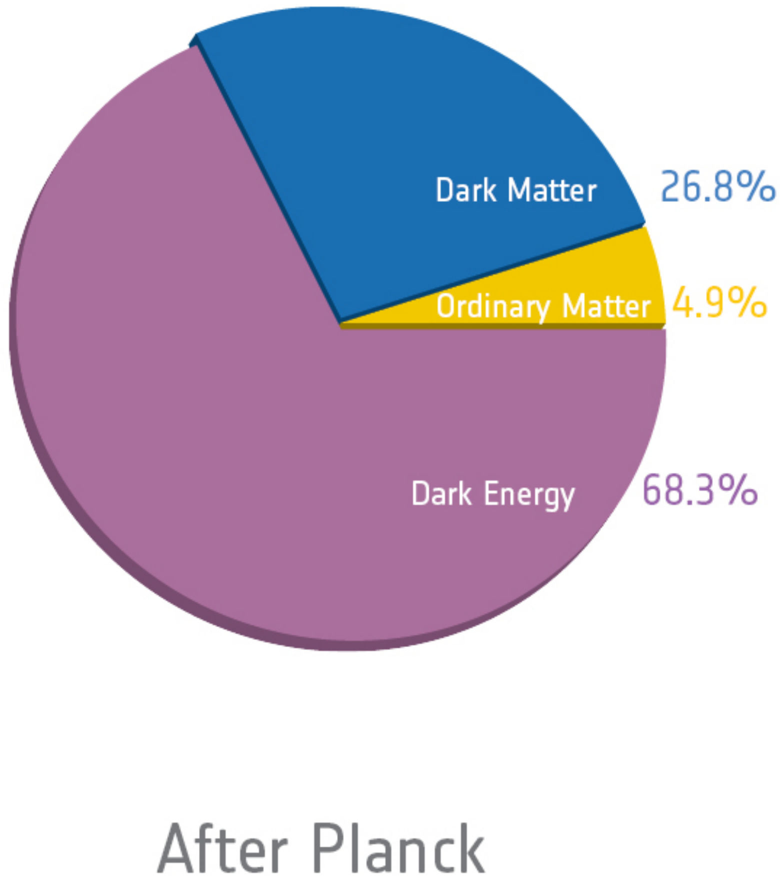
Unviers plat, avec constante cosmologique et matière noire froide

Seulement 6 paramètres…..

	Parameter	Best fit	68% limits
Quantité d'atomes	$\Omega_b h^2$	0.022068	0.02207 ± 0.00033
Quantité de matière noire	$\Omega_c h^2$	0.12029	0.1196 ± 0.0031
Lié à la distance que parcourt le son	$100\theta_{MC}$	1.04122	1.04132 ± 0.00068
Fraction de diffusion récente	τ	0.0925	0.097 ± 0.038
Variation d'échelles de la granulosité	n_s	0.9624	0.9616 ± 0.0094
Force de la granulosité	$\ln(10^{10} A_s)$	3.098	3.103 ± 0.072
Et quelques paramètres dérivés	H_0	67.11	67.4 ± 1.4
	Ω_Λ	0.6825	0.686 ± 0.020
	Ω_m	0.3175	0.314 ± 0.020

4. the Universe gets heavier...





La quantité de matière ordinaire et de matière noire doit être augmentée de 10% par rapport aux estimations précédentes.

Planck 15 months

Planck Collaboration, 2013, 16

... and older

Parameter	*Planck*+WP Best fit	*Planck*+WP 68% limits	*Planck*+WP+highL Best fit	*Planck*+WP+highL 68% limits	*Planck*+lensing+WP+highL Best fit	*Planck*+lensing+WP+highL 68% limits	*Planck*+WP+highL+BAO Best fit	*Planck*+WP+highL+BAO 68% limits
$\Omega_b h^2$	0.022032	0.02205 ± 0.00028	0.022069	0.02207 ± 0.00027	0.022199	0.02218 ± 0.00026	0.022161	0.02214 ± 0.00024
$\Omega_c h^2$	0.12038	0.1199 ± 0.0027	0.12025	0.1198 ± 0.0026	0.11847	0.1186 ± 0.0022	0.11889	0.1187 ± 0.0017
$100\theta_{MC}$	1.04119	1.04131 ± 0.00063	1.04130	1.04132 ± 0.00063	1.04146	1.04144 ± 0.00061	1.04148	1.04147 ± 0.00056
τ	0.0925	$0.089^{+0.012}_{-0.014}$	0.0927	$0.091^{+0.013}_{-0.014}$	0.0943	$0.090^{+0.013}_{-0.014}$	0.0952	0.092 ± 0.013
n_s	0.9619	0.9603 ± 0.0073	0.9582	0.9585 ± 0.0070	0.9624	0.9614 ± 0.0063	0.9611	0.9608 ± 0.0054
$\ln(10^{10} A_s)$	3.0980	$3.089^{+0.024}_{-0.027}$	3.0959	3.090 ± 0.025	3.0947	3.087 ± 0.024	3.0973	3.091 ± 0.025
A^{PS}_{100}	152	171 ± 60	209	212 ± 50	204	213 ± 50	204	212 ± 50
A^{PS}_{143}	63.3	54 ± 10	72.6	73 ± 8	72.2	$72 \pm$ [illegible]	[illegible]	[illegible]
A^{PS}_{217}	117.0	107^{+20}_{-10}	59.5	59 ± 10	60.2	$58 \pm$ [illegible]	[illegible]	[illegible]
A^{CIB}_{143}	0.0	< 10.7	3.57	3.24 ± 0.83	3.25	$3.24 \pm$ [illegible]	[illegible]	[illegible]
A^{CIB}_{217}	27.2	29^{+6}_{-9}	53.9	49.6 ± 5.0	52.3	$50.0 \pm$ [illegible]	[illegible]	[illegible]
A^{tSZ}_{143}	6.80	...	5.17	$2.54^{+1.1}_{-1.9}$	4.64	2.51 [illegible]	[illegible]	[illegible]
$r^{PS}_{143\times217}$	0.916	> 0.850	0.825	$0.823^{+0.069}_{-0.077}$	0.814	$0.825 \pm$ [illegible]	[illegible]	[illegible]
$r^{CIB}_{143\times217}$	0.406	0.42 ± 0.22	1.0000	> 0.930	1.0000	> 0.9[illegible]	[illegible]	[illegible]
γ^{CIB}	0.601	$0.53^{+0.13}_{-0.12}$	0.674	0.638 ± 0.081	0.656	$0.643 \pm$ [illegible]	[illegible]	[illegible]
$\xi^{tSZ\times CIB}$	0.03	...	0.000	< 0.409	0.000	< 0.389	0.000	< 0.410
A^{kSZ}	0.9	...	0.89	$5.34^{+2.8}_{-1.9}$	1.14	$4.74^{+2.6}_{-2.1}$	1.58	$5.34^{+2.8}_{-2.0}$
Ω_Λ	0.6817	$0.685^{+0.018}_{-0.016}$	0.6830	$0.685^{+0.017}_{-0.016}$	0.6939	0.693 ± 0.013	0.69[illegible]4	0.692 ± 0.010
σ_8	0.8347	0.829 ± 0.012	0.8322	0.828 ± 0.012	0.8271	0.8233 ± 0.0097	0.8288	0.826 ± 0.012
z_{re}	11.37	11.1 ± 1.1	11.38	11.1 ± 1.1	11.42	11.1 ± 1.1	11.52	11.3 ± 1.1
H_0	67.04	67.3 ± 1.2	67.15	67.3 ± 1.2	67.94	67.9 ± 1.0	67.77	67.80 ± 0.77
Age/Gyr	13.8242	13.817 ± 0.048	13.8170	13.813 ± 0.047	13.7914	13.794 ± 0.044	13.7965	13.798 ± 0.037
$100\theta_*$	1.04136	1.04147 ± 0.00062	1.04146	1.04148 ± 0.00062	1.04161	1.04159 ± 0.00060	1.04163	1.04162 ± 0.00056
r_{drag}	147.36	147.49 ± 0.59	147.35	147.47 ± 0.59	147.68	147.67 ± 0.50	147.611	147.68 ± 0.45

km/s/Mpc

67.80 ± 0.77

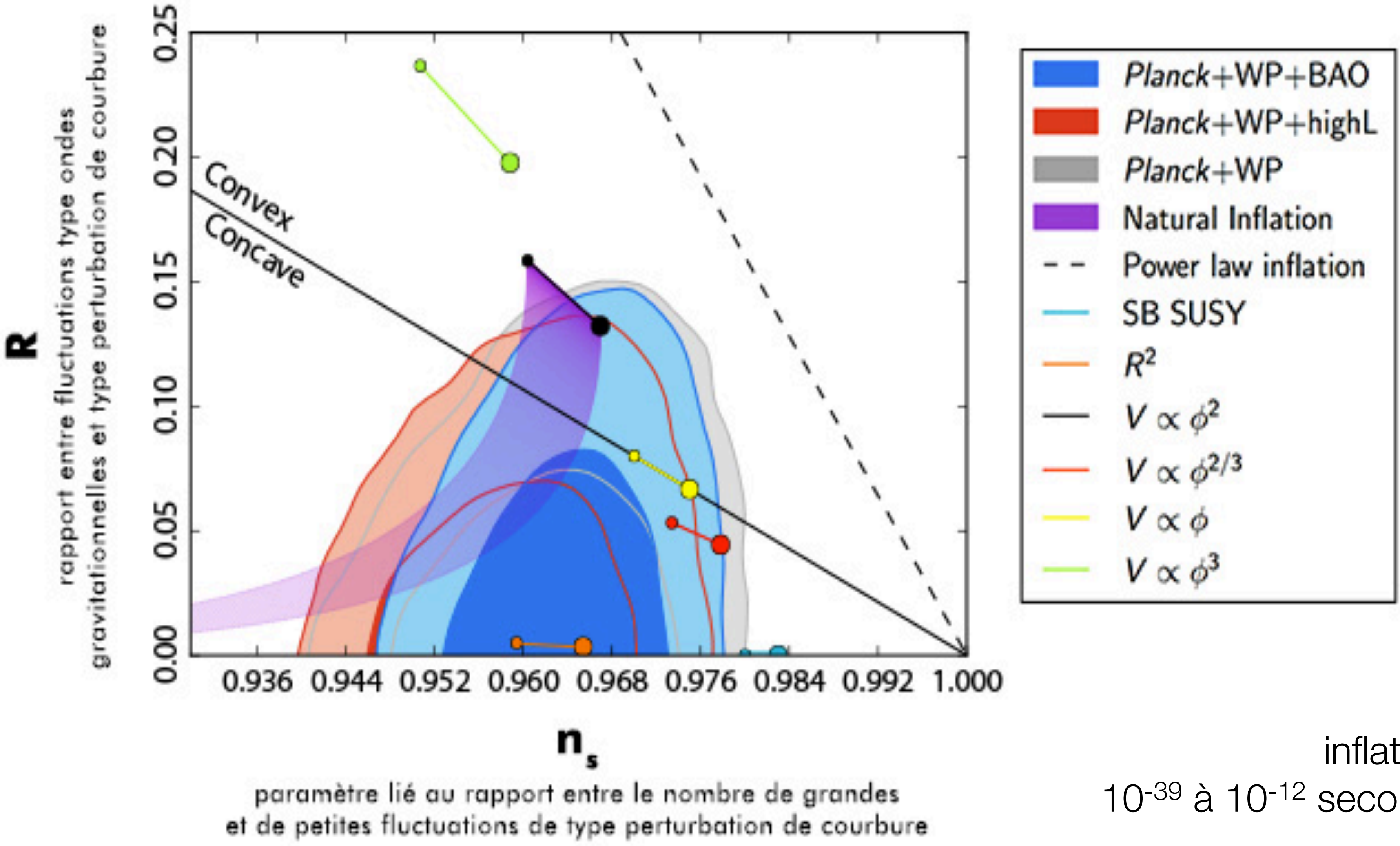
Gyr

13.798 ± 0.037

Planck 15 months

Planck Collaboration, 2013, 16

5. some inflation models excluded



inflation:
10^{-39} à 10^{-12} seconde

Planck 15 months
Planck Collaboration, 2013, 22

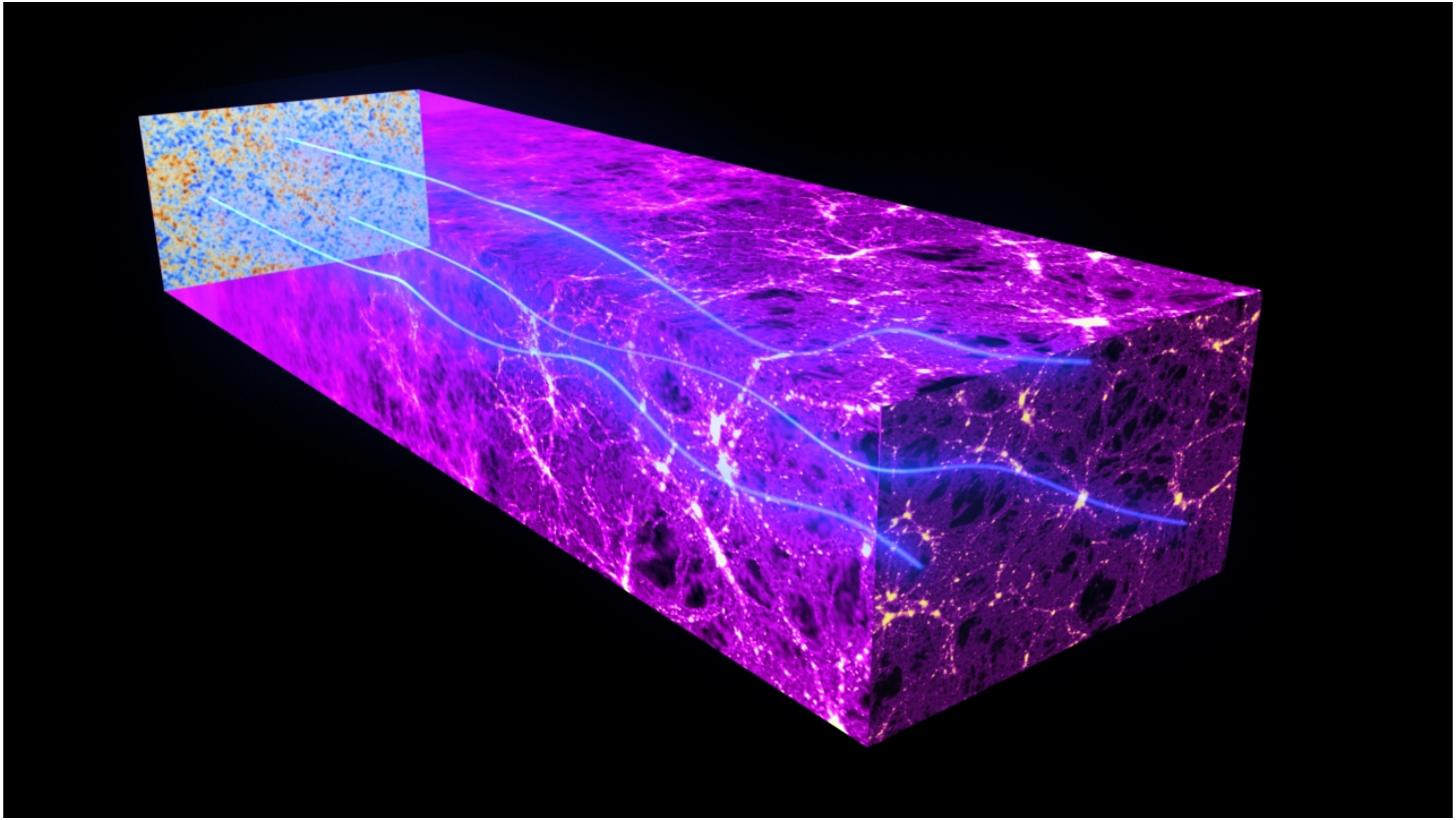
more implications

	Planck+WP+highL+BAO
θ: sound horizon is determined by the position of the 7 peaks, and now measured at 0.05% precision	1.04147 ± 0.00056
n_s: exact scale invariance of the primordial fluctuations is ruled out, at more than 7σ (as predicted by base inflation models)	0.9608 ± 0.0054
upper limit on neutrino masses	$\sum m_\nu < 0.23\,\text{eV}$ (95%; *Planck*+
3 neutrinos species favored by Planck	$N_{\text{eff}} = 3.30^{+0.54}_{-0.51}$ (95%; *Pla*

- no evidence for dynamical dark energy
- non gaussiannities

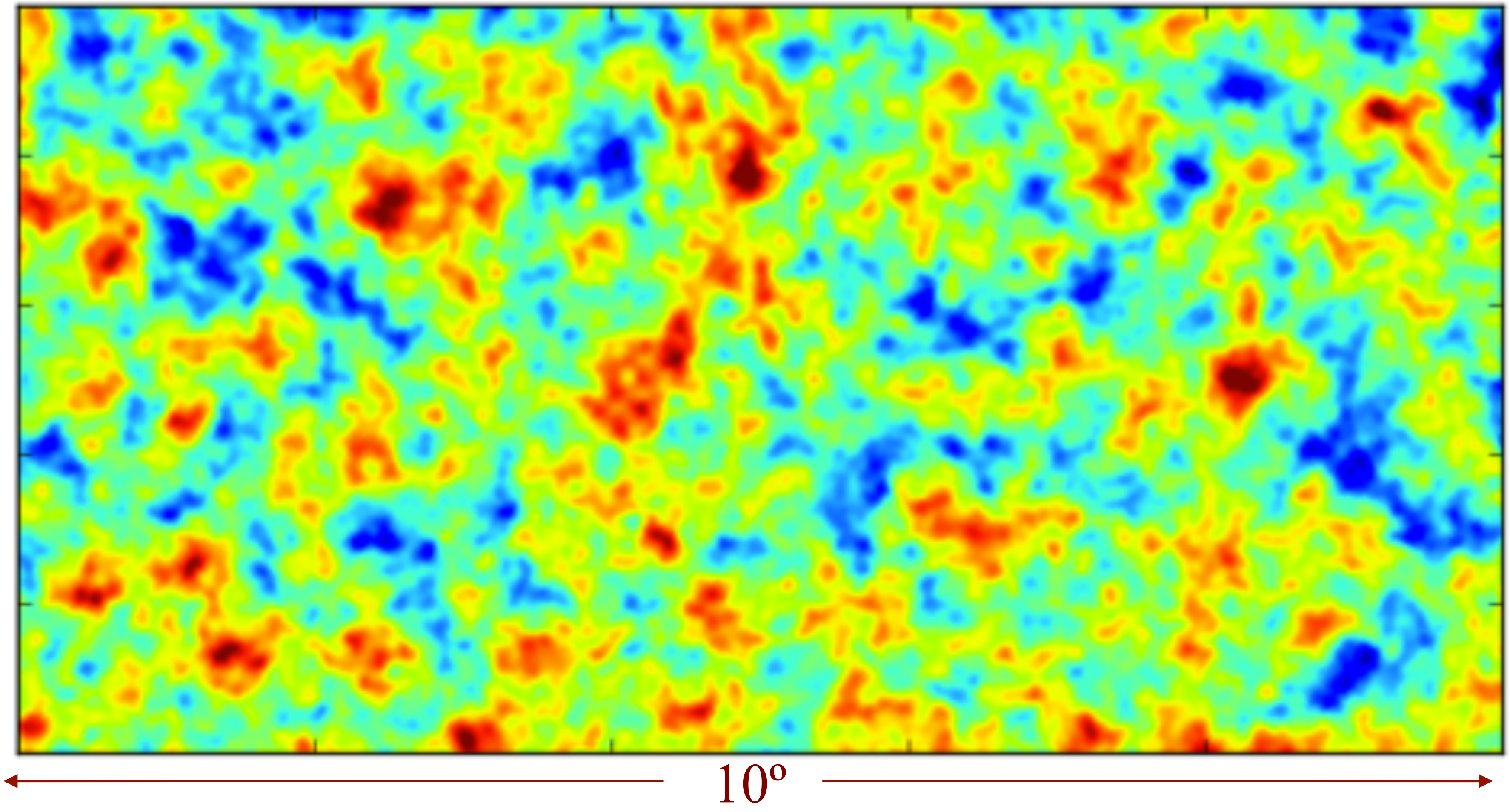
Planck 15 months
Planck Collaboration, 2013, 16

6. between CMB and us: structures



gravitational lensing of the CMB

A simulated patch of CMB sky – before lensing

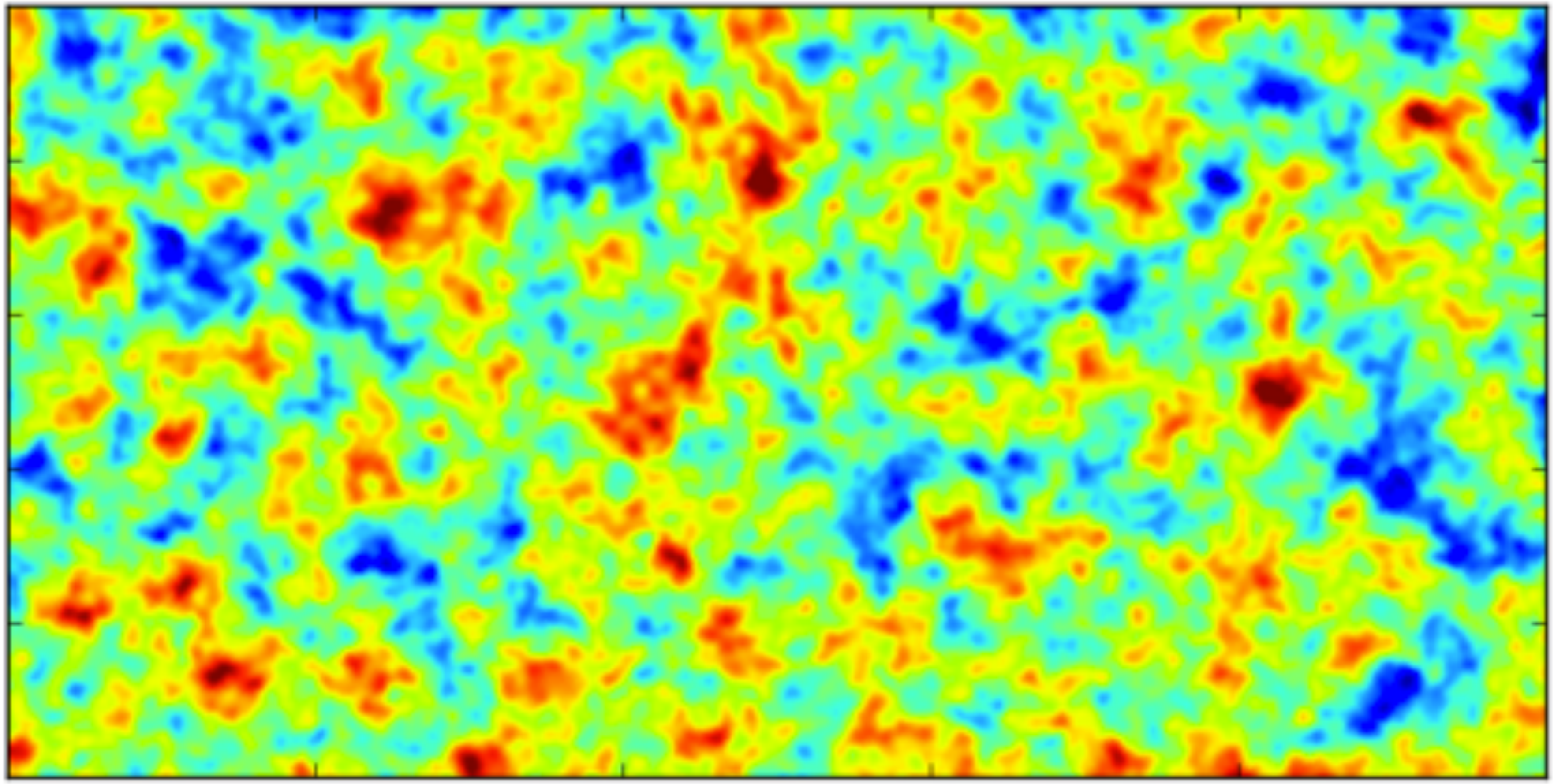


typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

gravitational lensing of the CMB

A simulated patch of CMB sky – after lensing

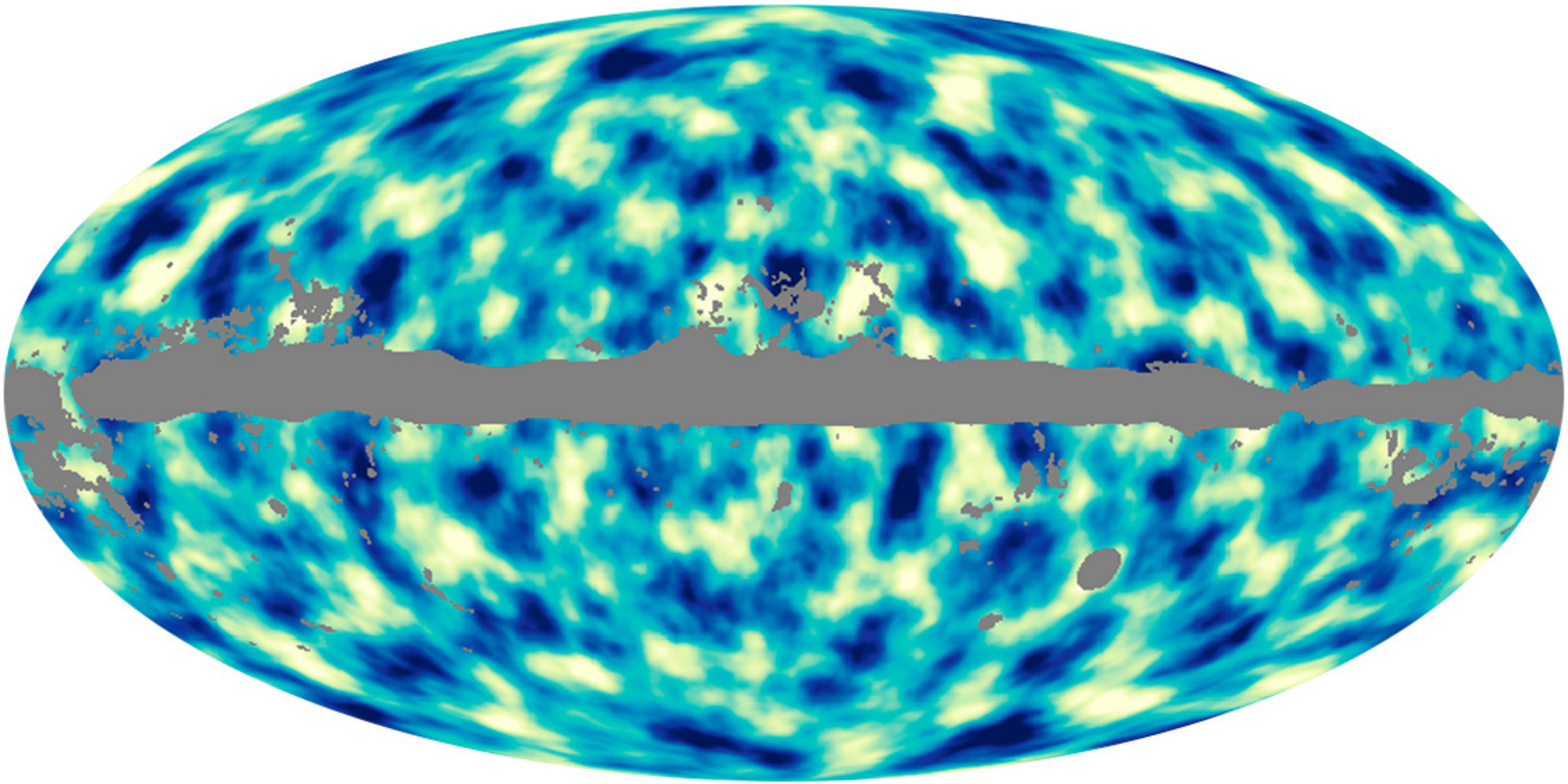


10º

typical deflection: 2.4 arcmin

Planck 15 months
Planck Collaboration, 2013, 17

Planck all-sky map of the dark matter

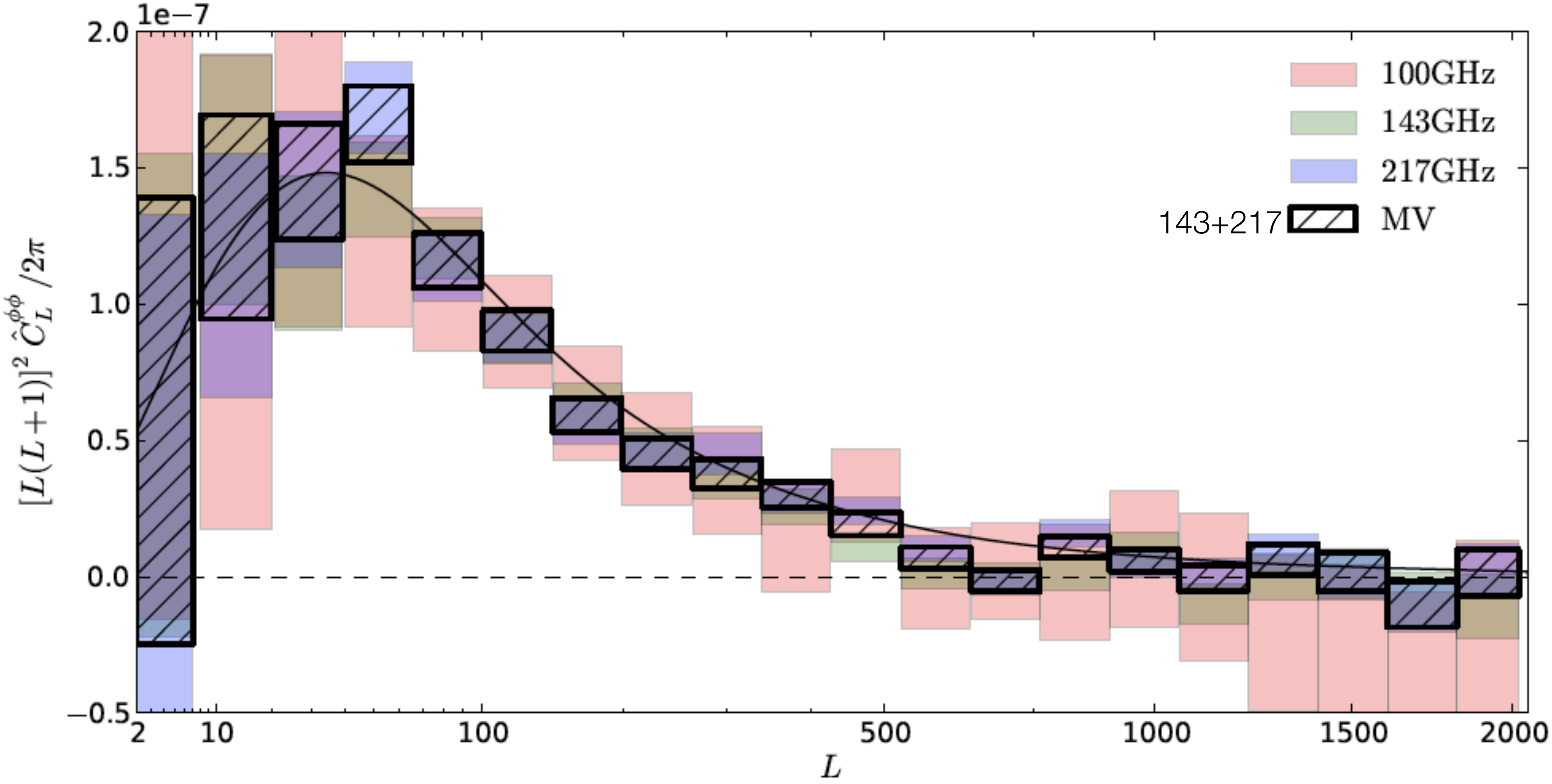


= Carte de la masse projetée sur la ligne de visée

Planck 15 months
Planck Collaboration, 2013, 17

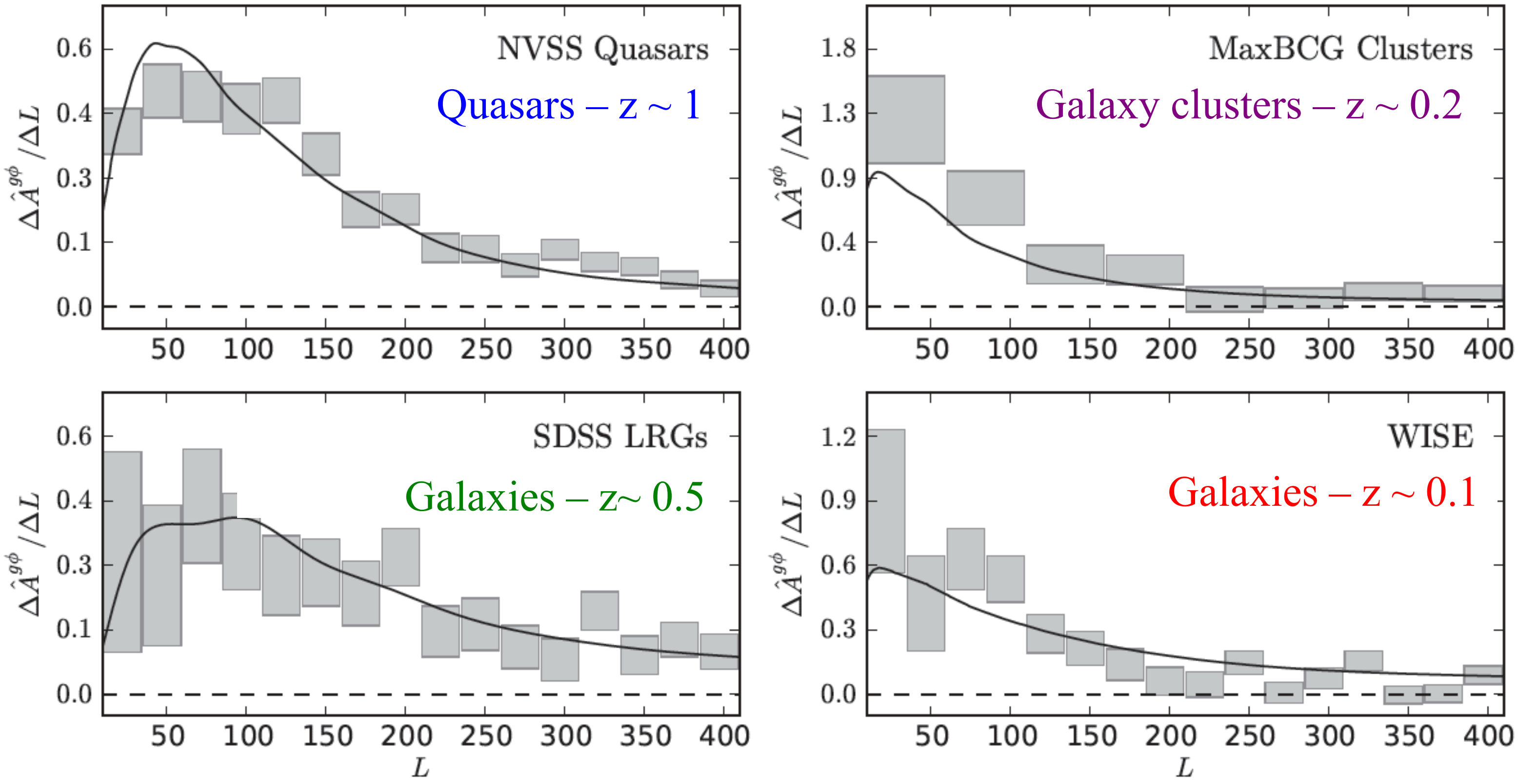
clumpiness of the Planck mass map

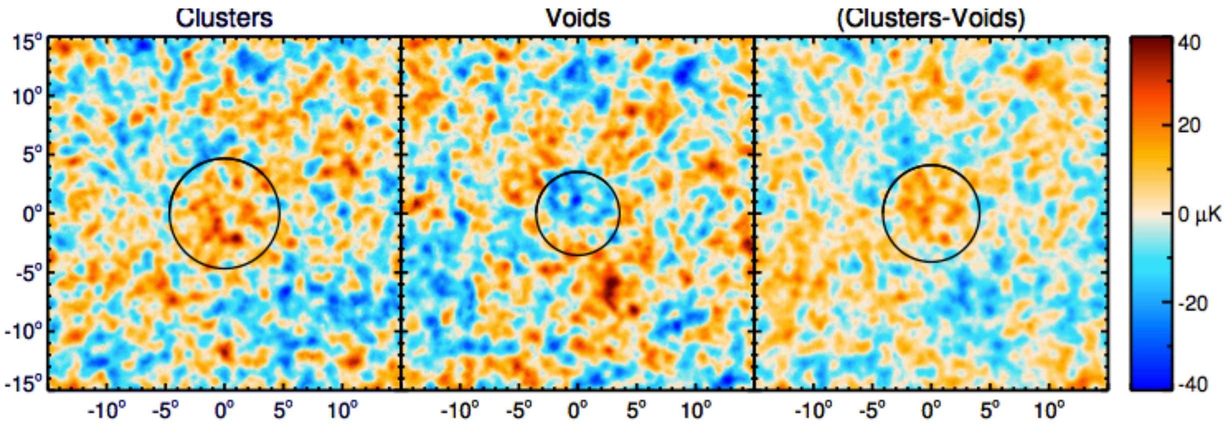
aka clumpiness now and at z<1090



Planck 15 months
Planck Collaboration, 2013, 17

galaxies mirror the Planck mass map + ISW





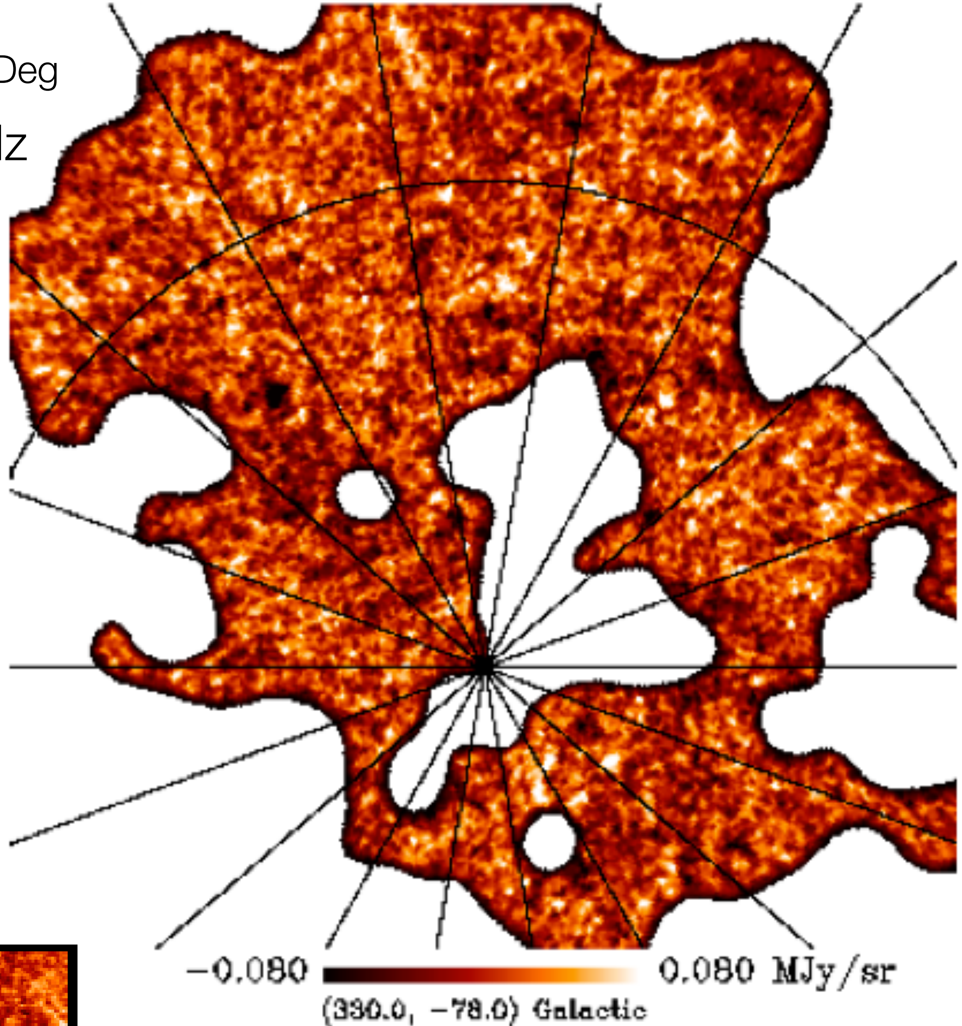
Stacking the Planck CMB at the location of clusters and voids.
2.5 sigma detection.

Planck 15 months
Planck Collaboration, 2013, 17, 19

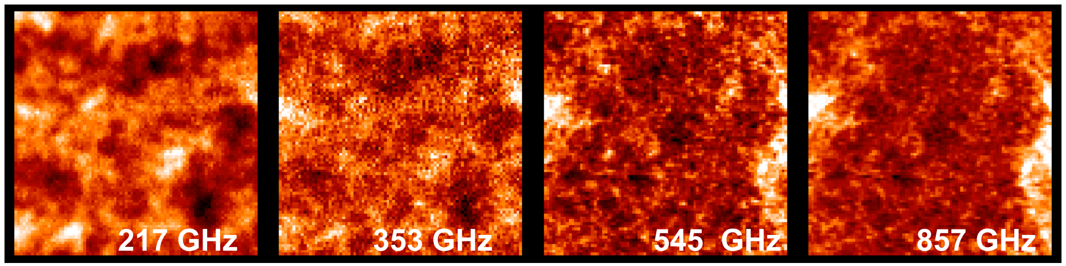
Cosmic IR Background maps probe high-z SFR

~2000 Sq. Deg

545 GHz



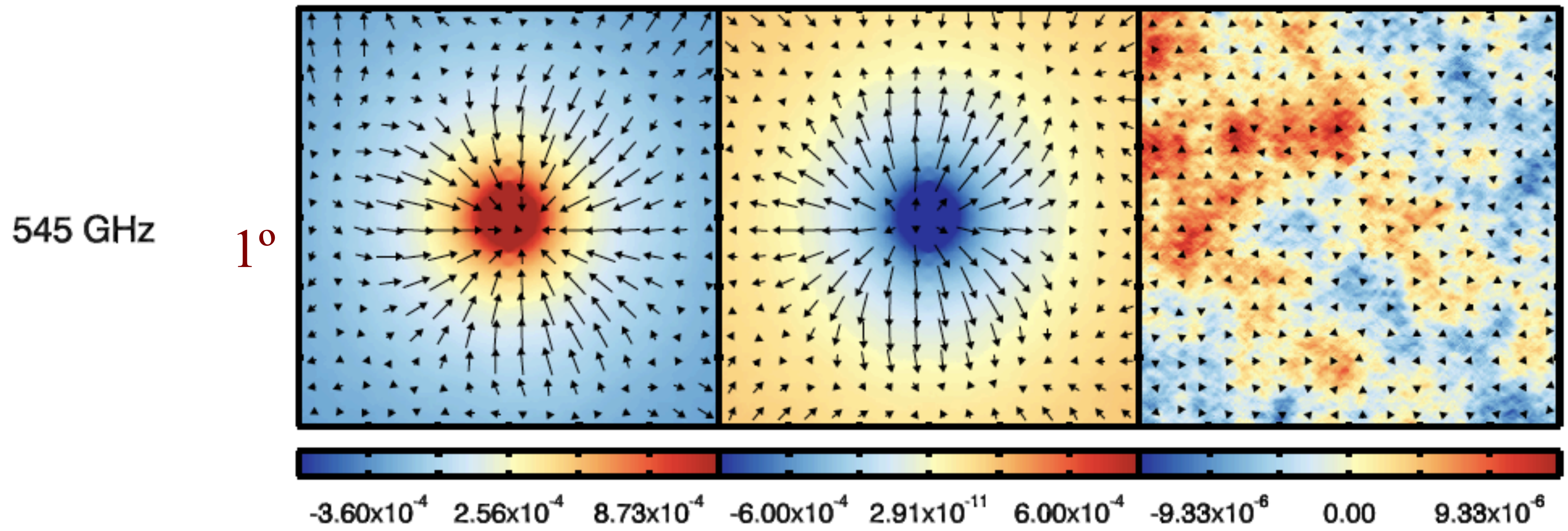
Planck Collab., 2013, 30



few 10 Sq Deg fields in 2011

CIB peaks correspond to mass peaks

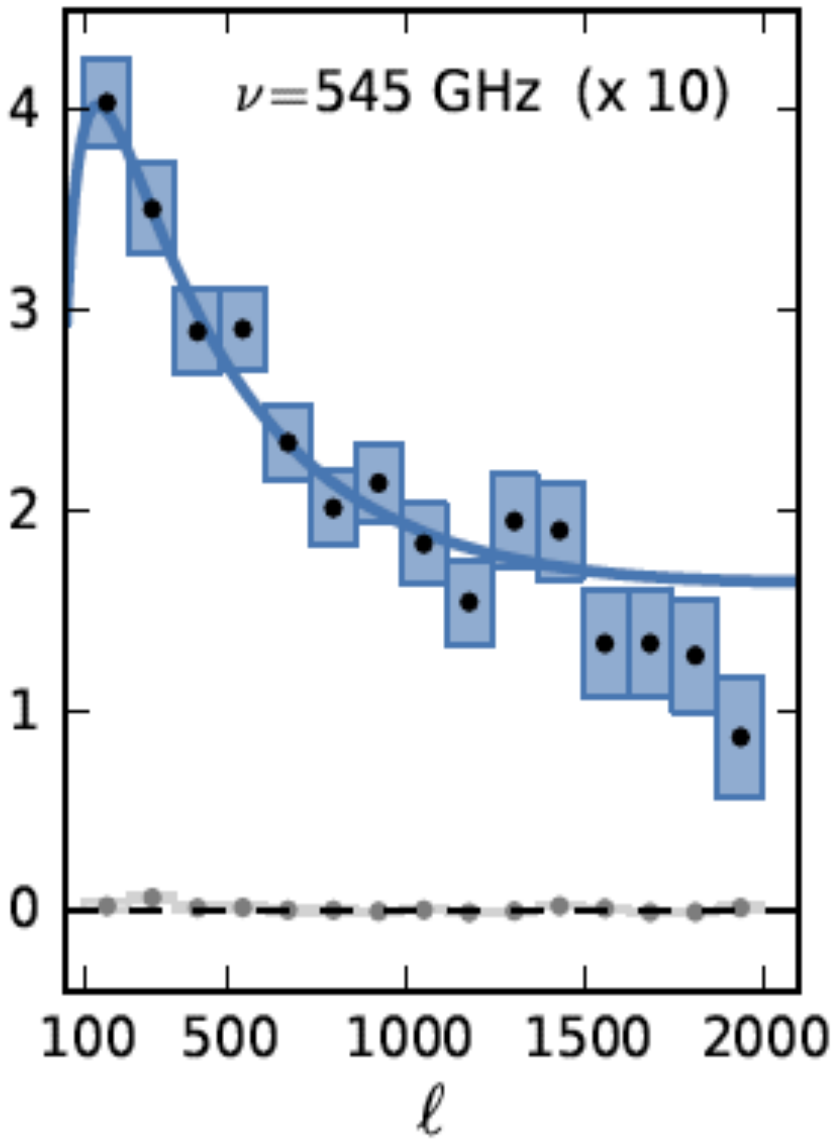
Stacking the Planck mass maps at the positions of peaks and troughs of Cosmic Infrared Background leads to a strong detection of the mass associated with these distant star forming galaxies. This is mostly Dark Matter.



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

Planck 15 months
Planck Collaboration, 2013, 18

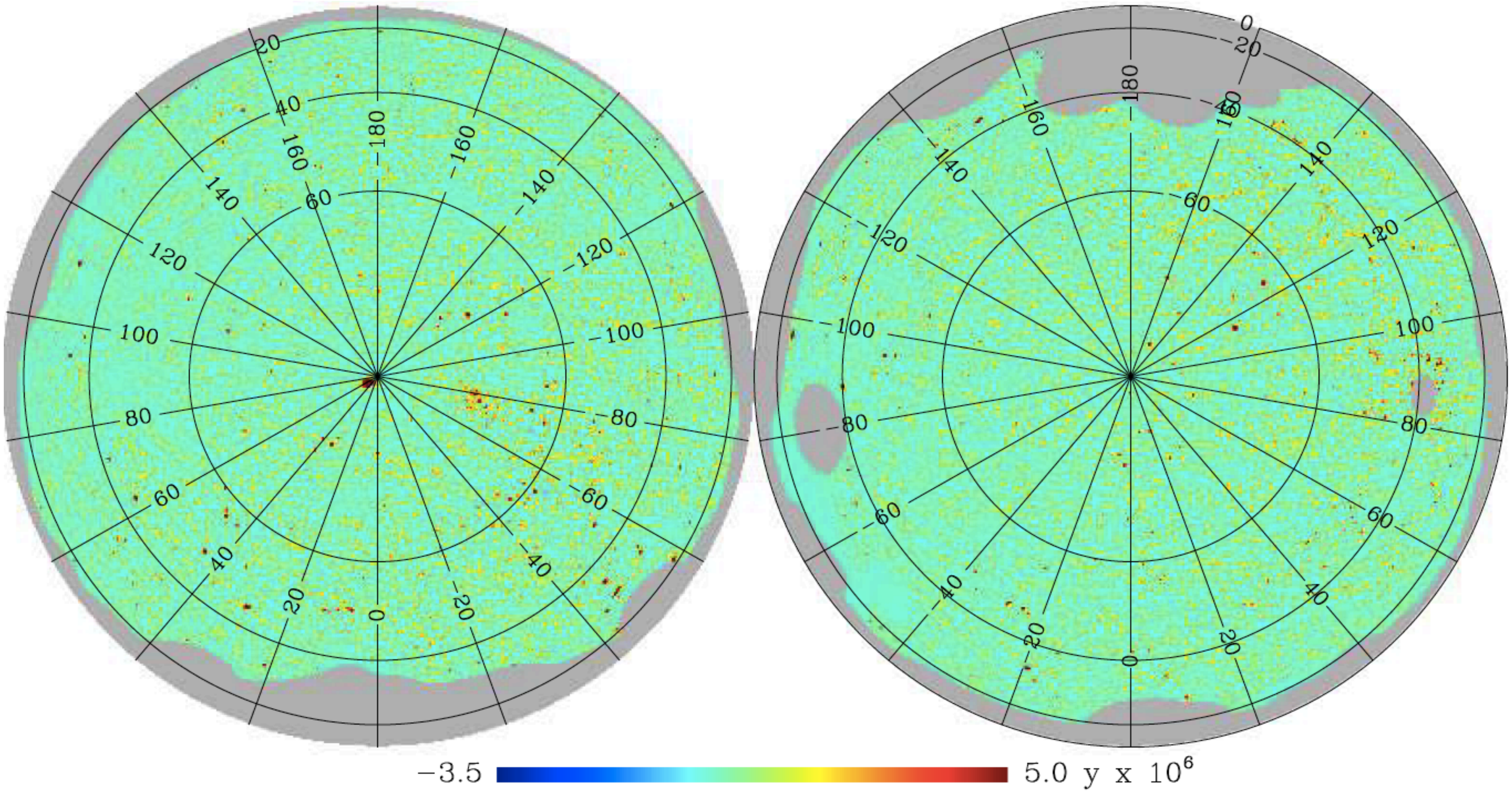
mass and CIB maps correspond closely



Planck 15 months
Planck Collaboration, 2013, 18

Planck map of the baryon distribution

Planck can also image the gas (baryon) distribution in the low-redshift Universe using scattering of CMB photons off the electrons. This SZ (Sunyaev-Zeldovich) effect causes a change in the shape of the CMB spectrum

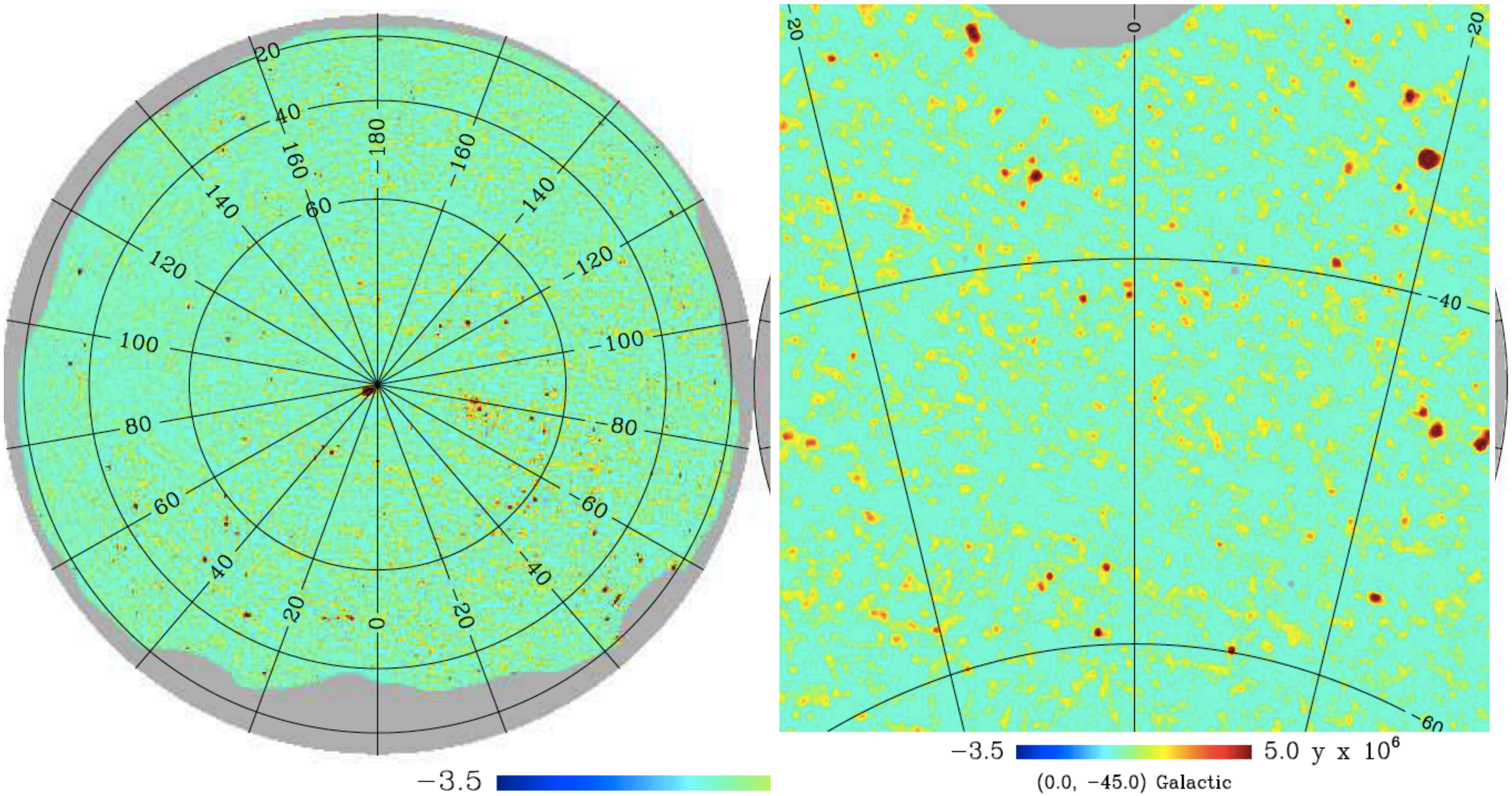


Planck 15 months

Planck Collaboration, 2013, 21

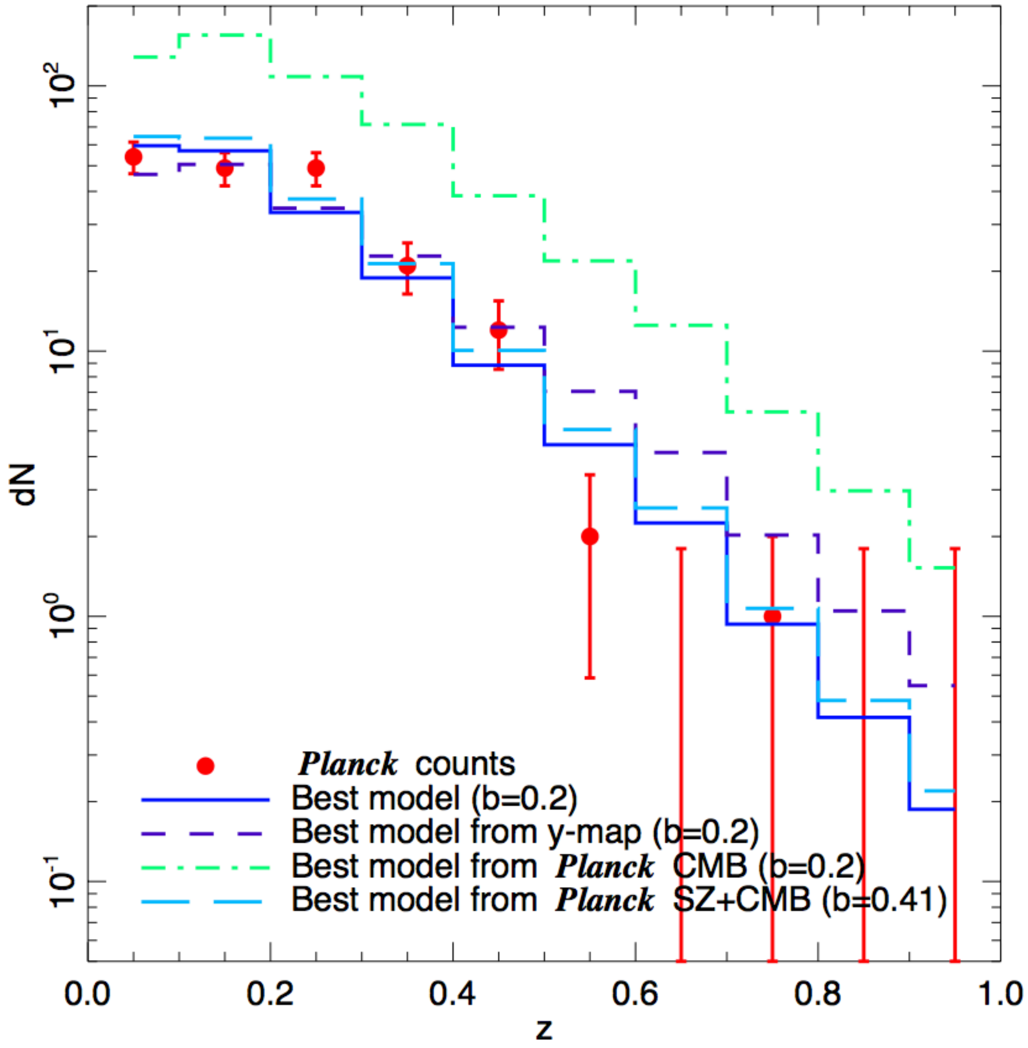
Planck map of the baryon distribution

Planck can also image the gas (baryon) distribution in the low-redshift Universe using scattering of CMB photons off the electrons. This SZ (Sunyaev-Zeldovich) effect causes a change in the shape of the CMB spectrum



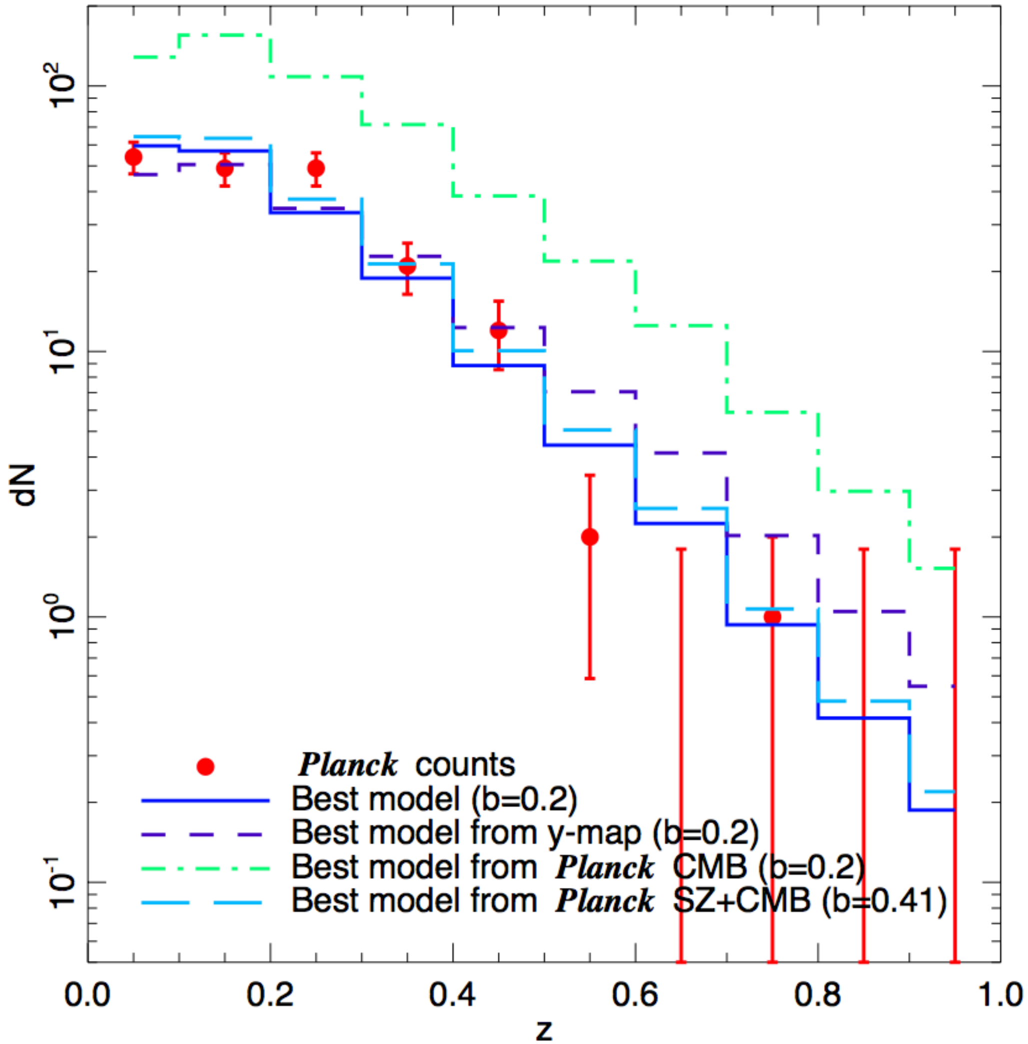
Planck 15 months
Planck Collaboration, 2013, 21

cluster counts – on 188 clusters



Courtesy Marian Douspis

cluster counts – on 188 clusters



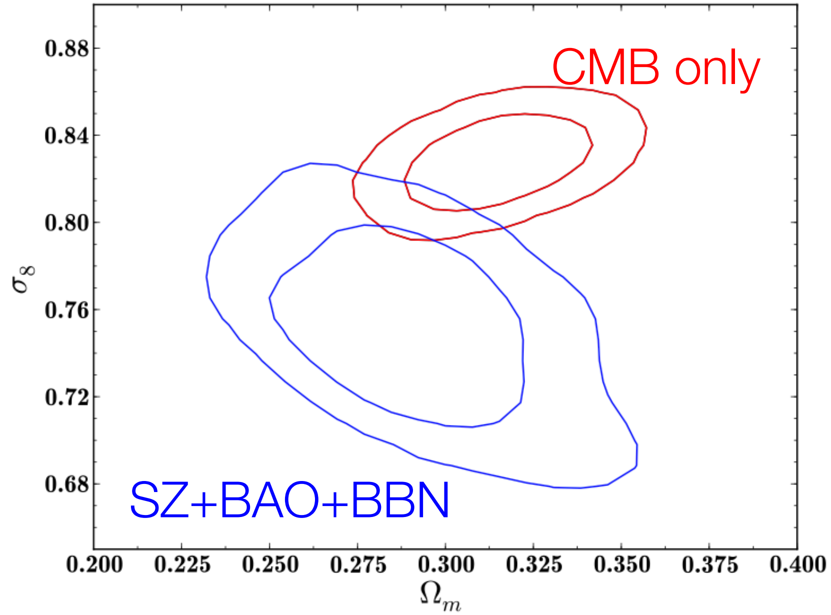


Fig. 11. 2D Ω_m–σ_8 likelihood contours for the analysis with *Planck* CMB only (red); *Planck* SZ + BAO + BBN (blue) with $(1 - b)$ in [0.7, 1].

tension w/ CMB

physics of the baryons ? bias ?

massive neutrino ?

Courtesy Marian Douspis

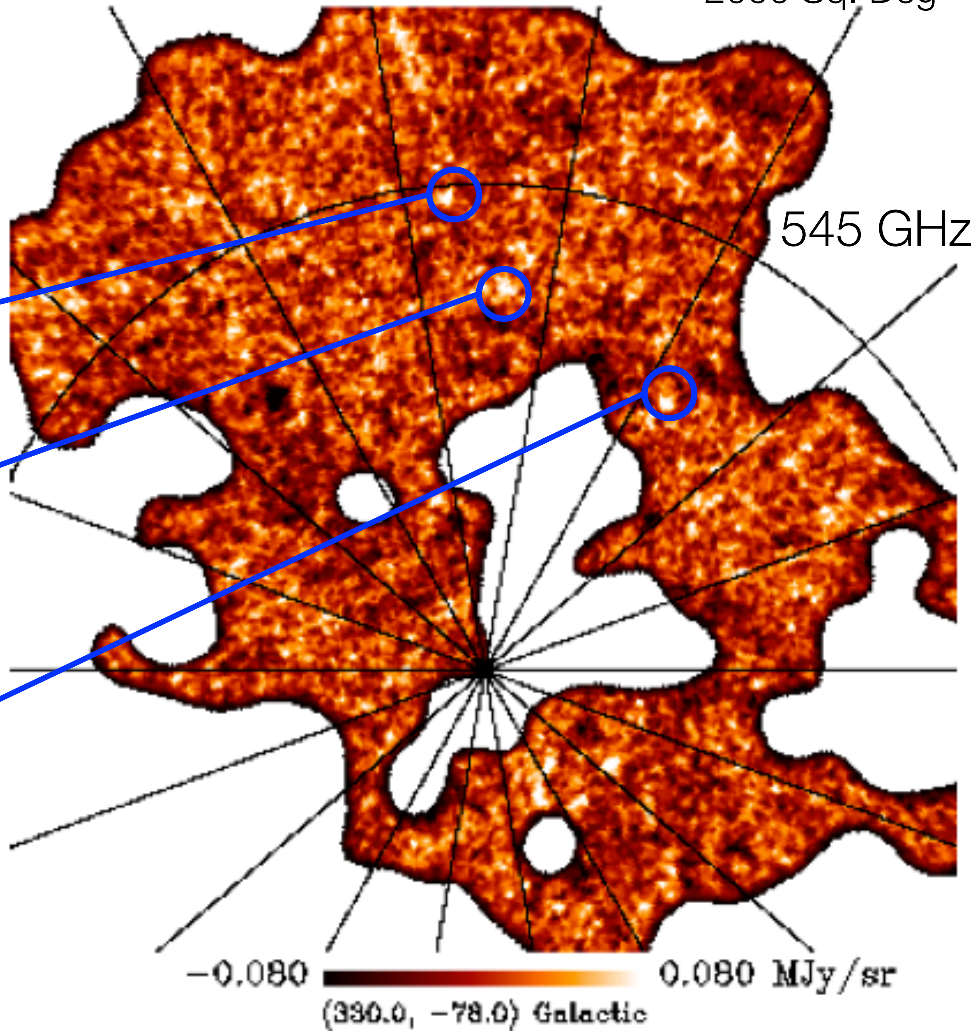
7. digging into the Cosmic IR Background

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

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

~2000 Sq. Deg

545 GHz

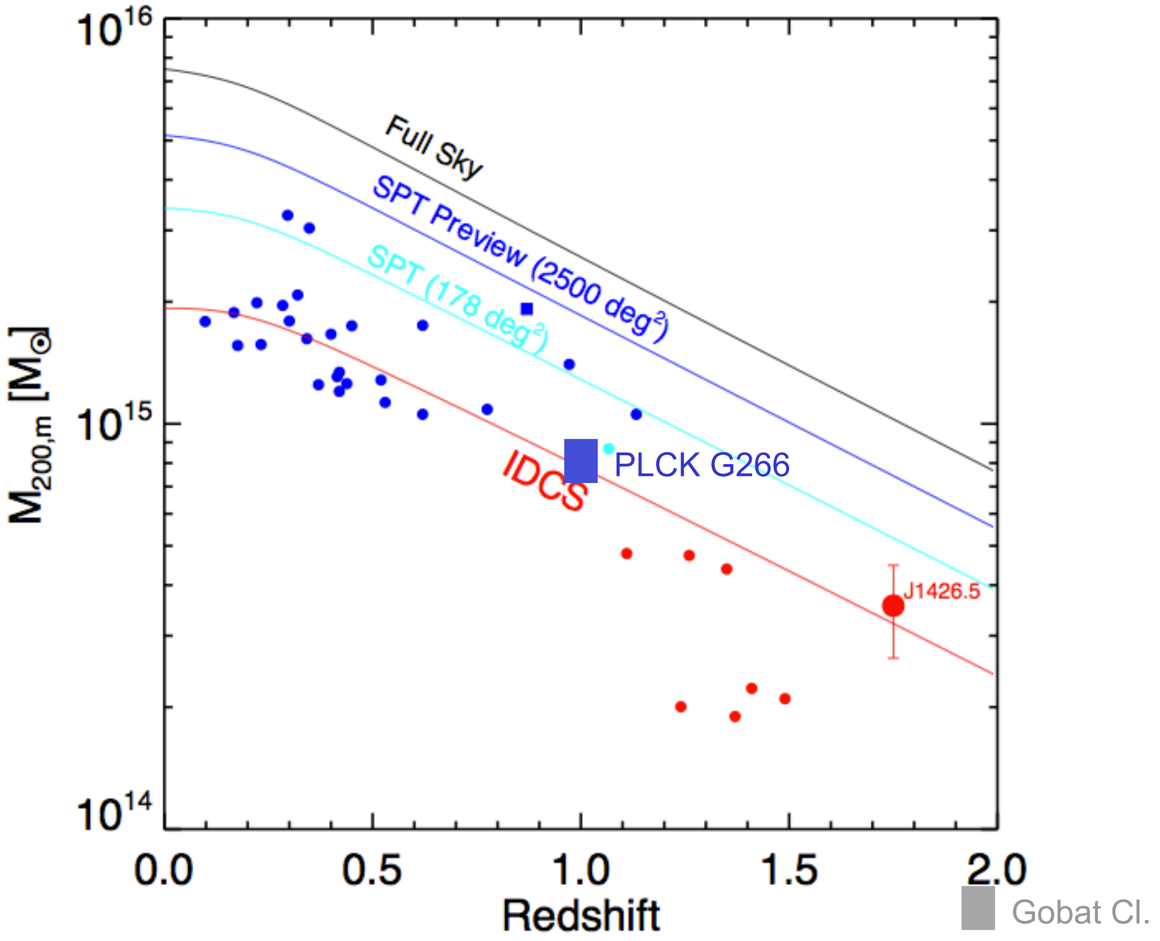


Planck Collab., 2013, 30

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

finding z>1.5 galaxy clusters ?

Predictions de masse des amas en fonction du redshift (et de la surface)

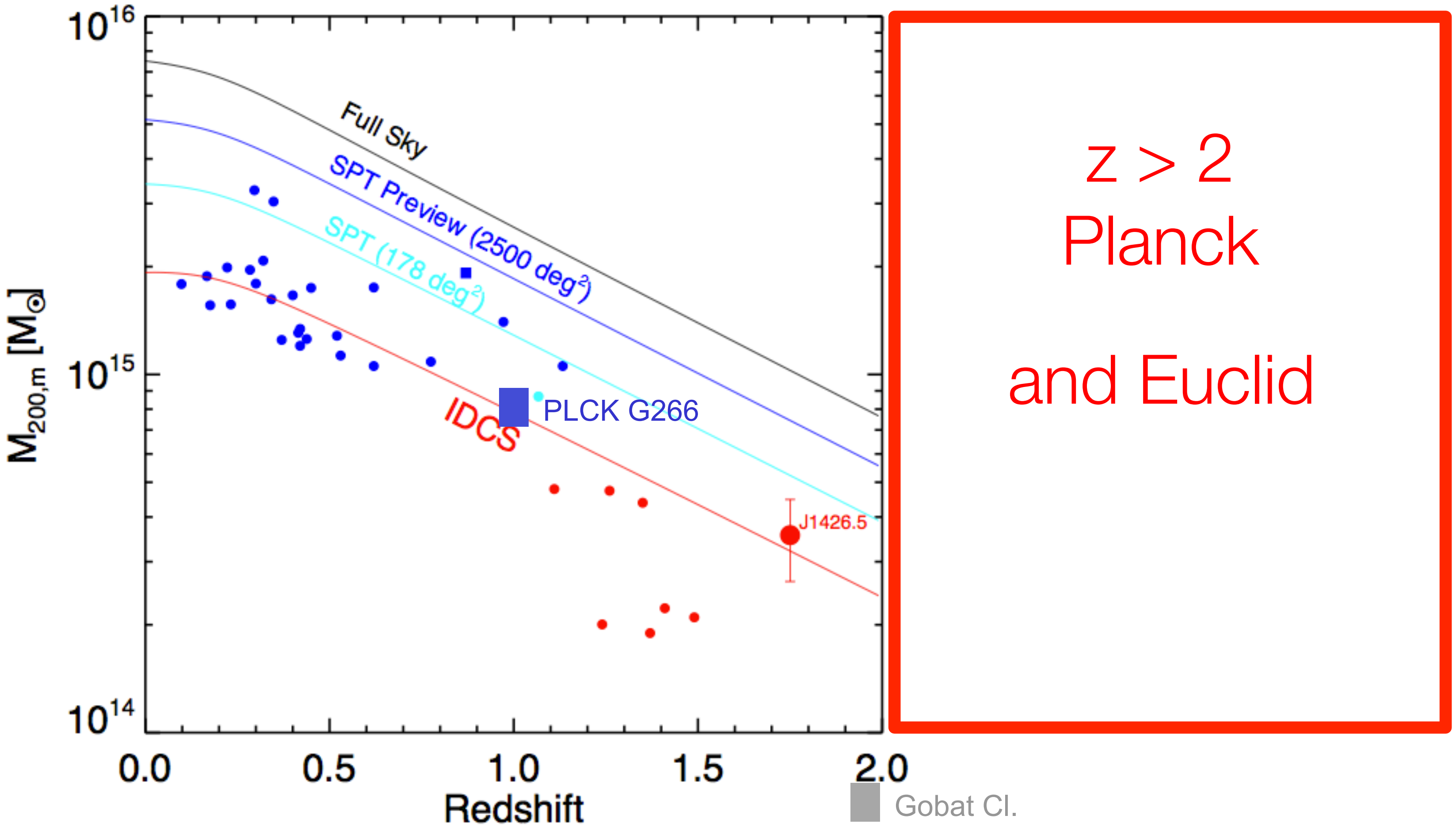


Amas de galaxies à grand redshift: objets très rares sur le ciel.
Necessité d'observer tout le ciel (Planck, Euclid).

Brodwin et al, 2012
Mortonson et al., 2011

finding z>1.5 galaxy clusters ?

Predictions de masse des amas en fonction du redshift (et de la surface)

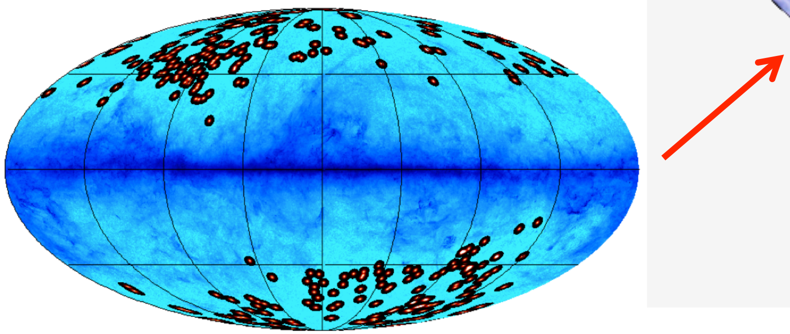


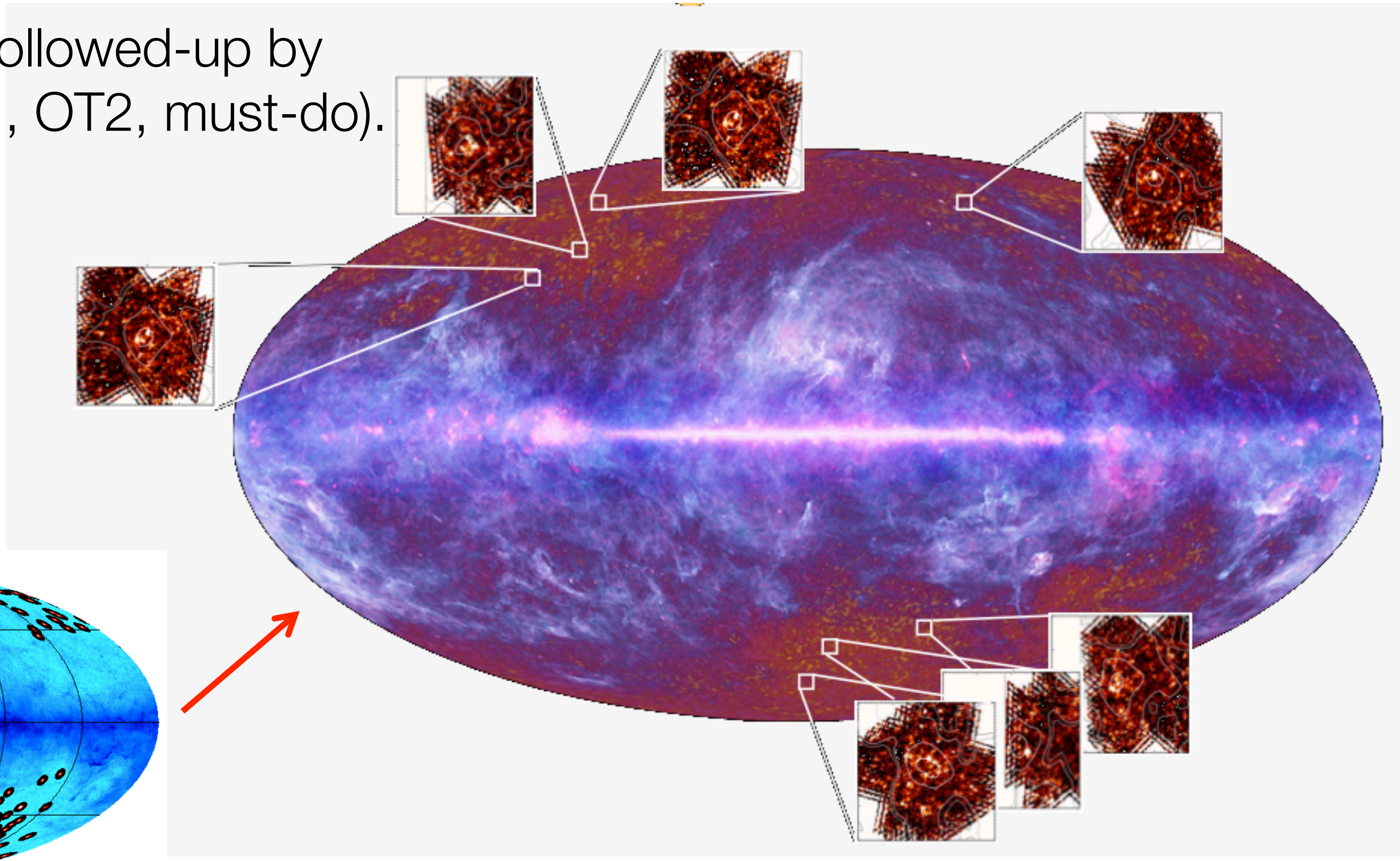
Amas de galaxies à grand redshift: objets très rares sur le ciel.
Necessité d'observer tout le ciel (Planck, Euclid).

Brodwin et al, 2012
Mortonson et al., 2011

several hundred Planck high-z candidates

226 Planck sources followed-up by Herschel/SPIRE (OT1, OT2, must-do).

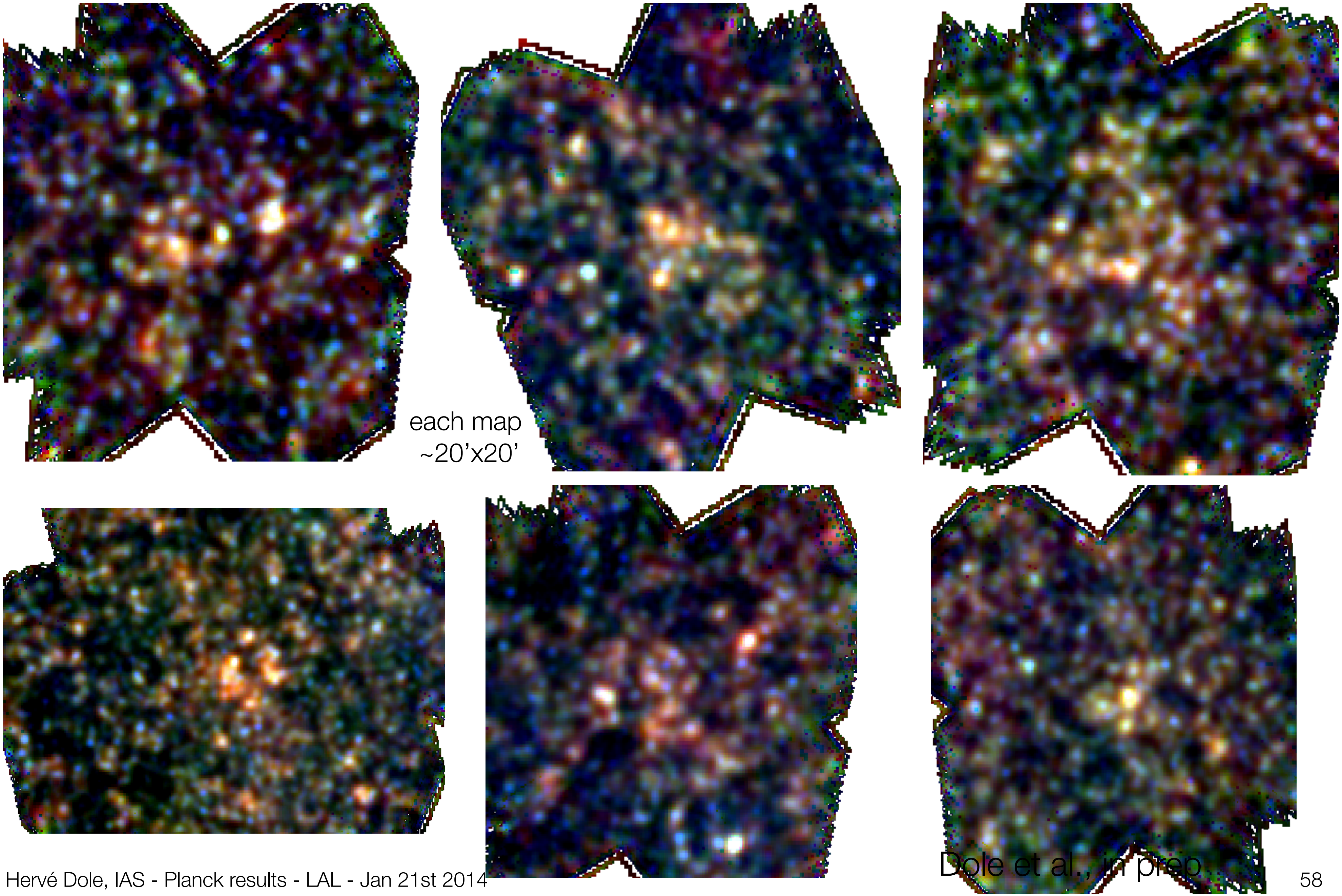




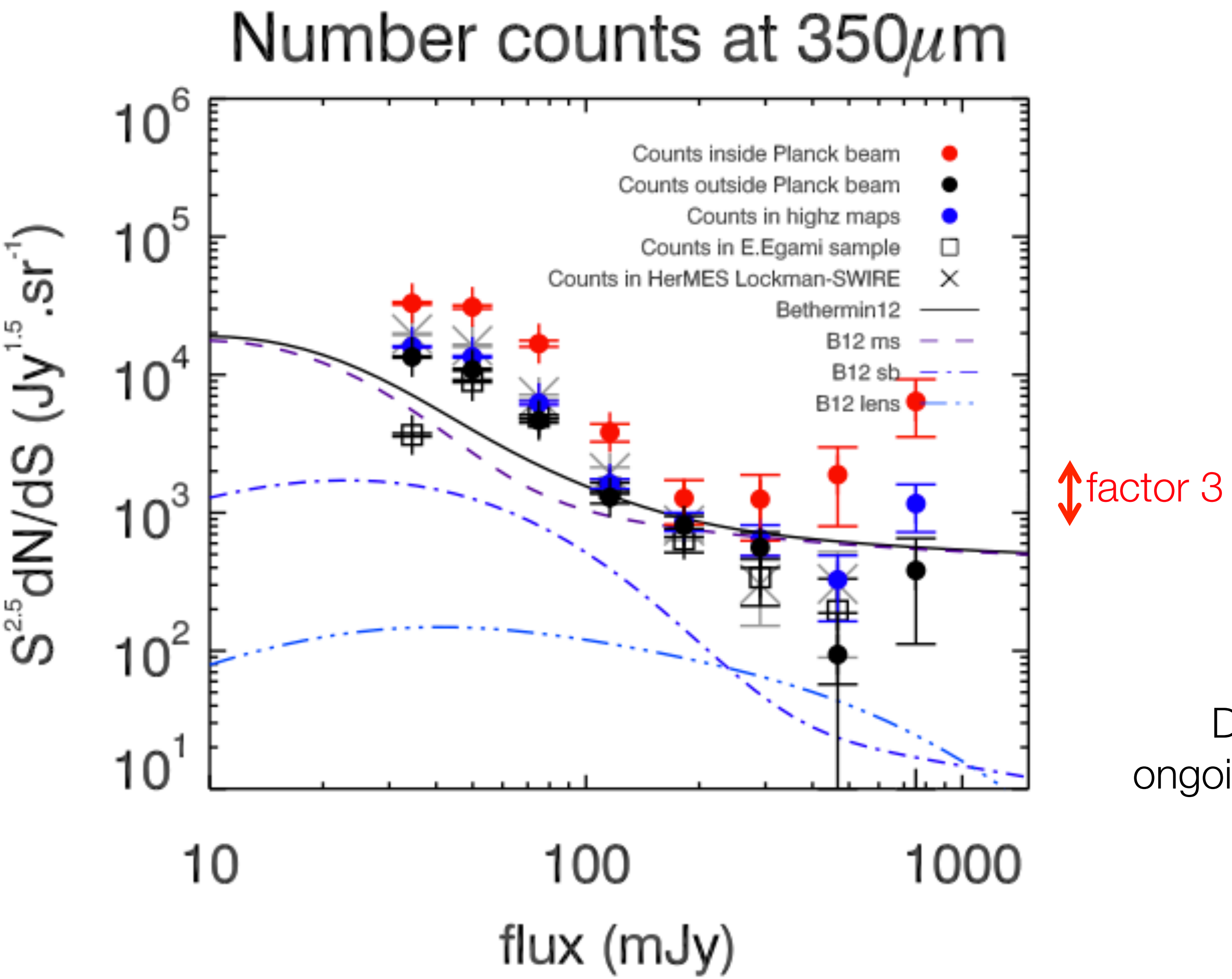
98% success
- either bright lensed candidates
- or overdensities of red galaxies
- 1.4% of the fields were cirrus

Dole et al., in prep

a remarkable dataset



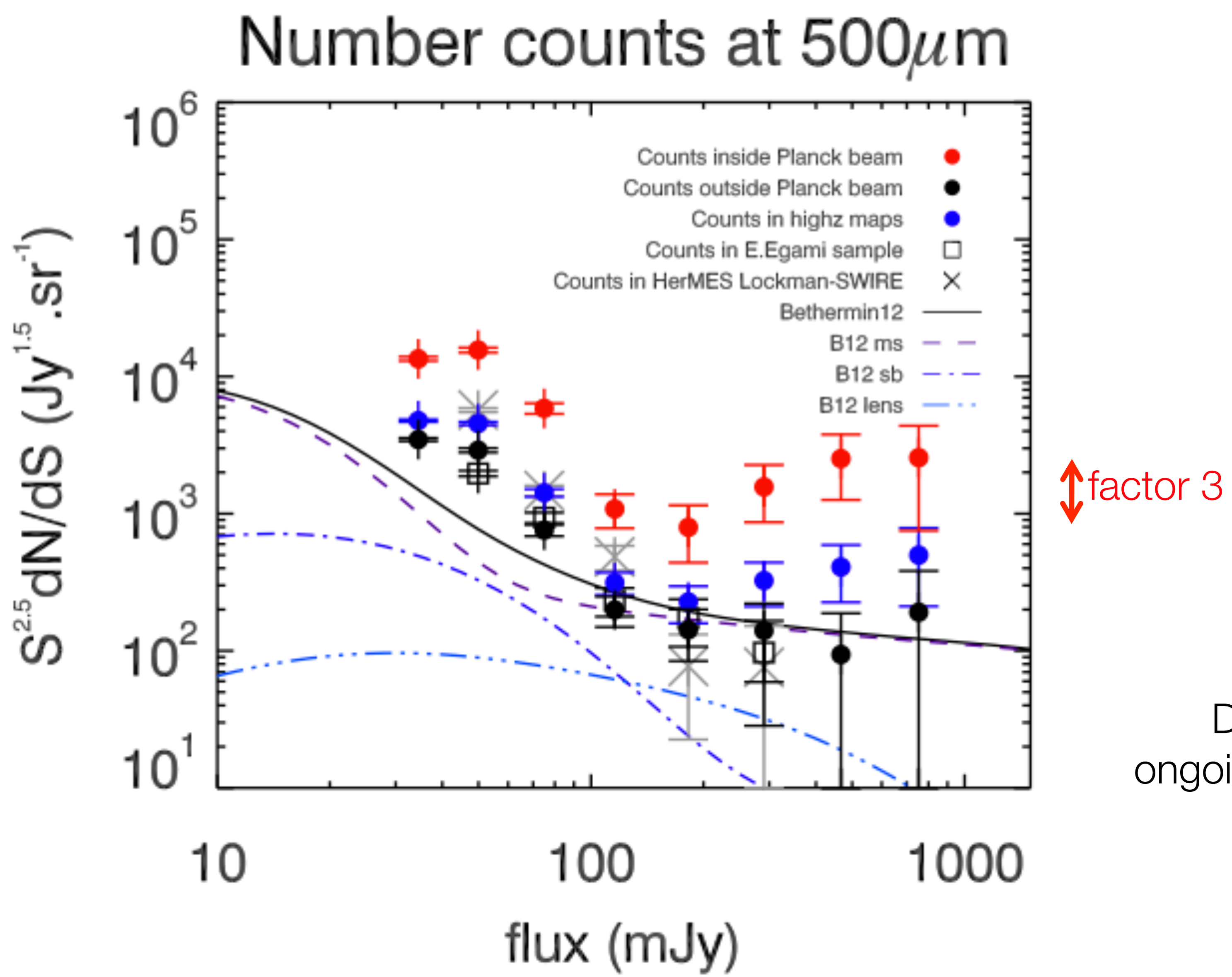
excess of red sources



David Guéry's ongoing thesis peoject

Dole et al., in prep

excess of red sources



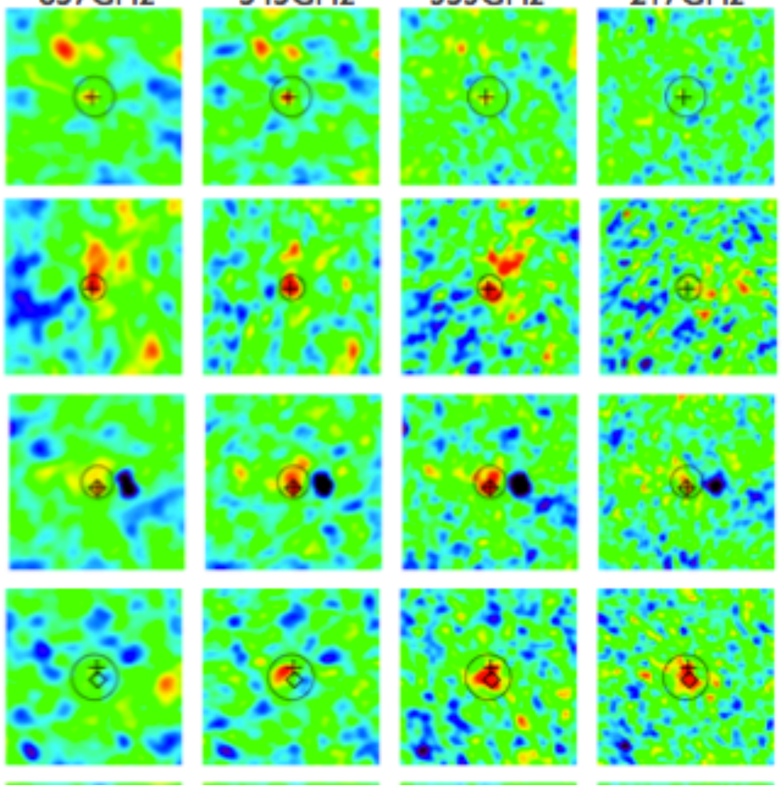
David Guéry's
ongoing thesis peoject

Dole et al., in prep

7.1 first identifications: all at z>1.5

Planck cutouts after cleaning

857GHz 545GHz 353GHz 217GHz



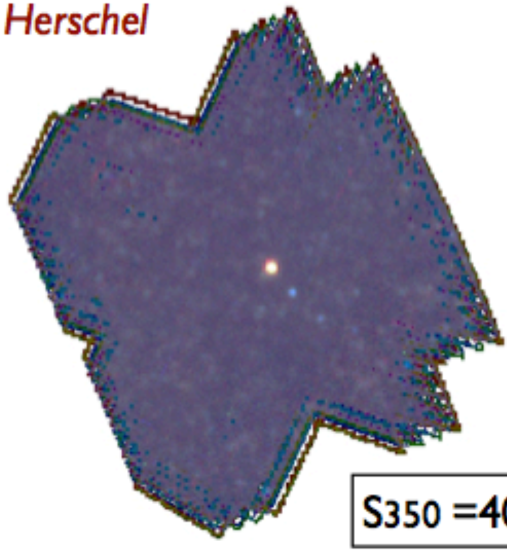
Confirmation	Redshift	Nature
SPT (1)	2.783	Lensed Dusty Galaxy (Greve et al. 2012) (Marrone et al. in prep)
Herschel ATLAS	3.26	Lensed Dusty Galaxy (Herranz et al.2012) (Fu et al. 2012)
SPT (2)	2.738	Lensed Dusty Galaxy behind a Galaxy Cluster (Greve et al. 2012) (Vieira et al. in prep)
Herschel Lensing Survey	5.2	Lensed Dusty Galaxy behind a Galaxy Cluster (Combes et al. 2012)

Courtesy Ludovic Montier

a bright gravitational lens candidate

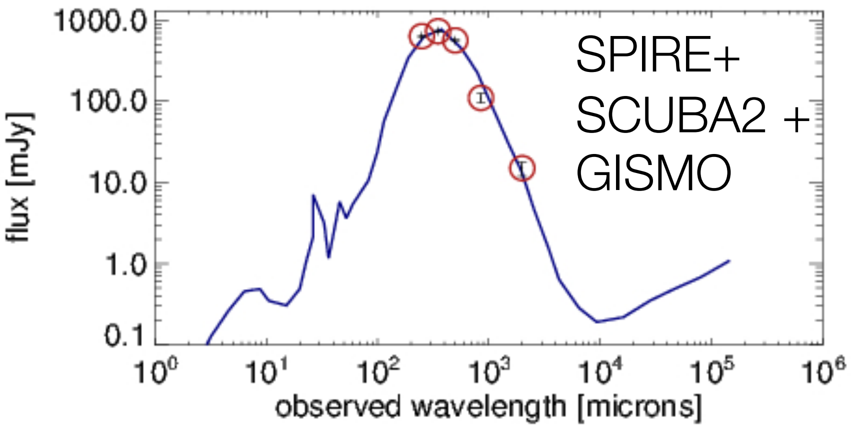

Herschel confirmation of the first *Planck* lensed Galaxy

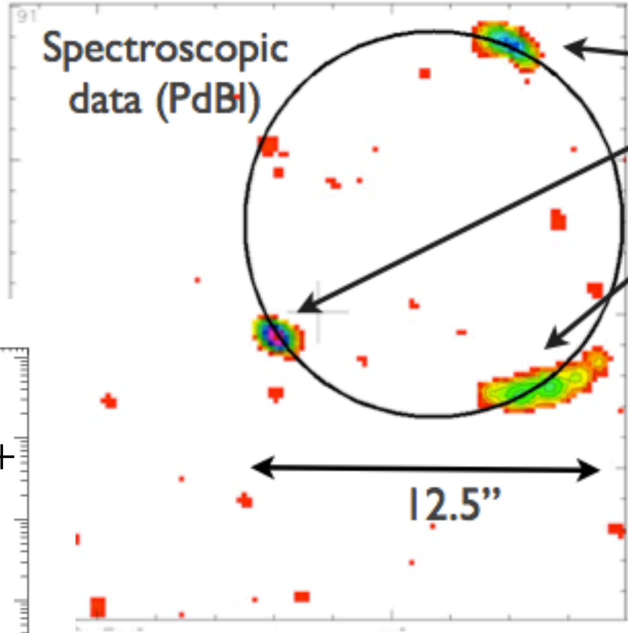
Herschel



S350 =400 mJy

Spectroscopic data (PdBI) CO(3-2) interferometery → z = 2.59





2 images of interacting galaxies

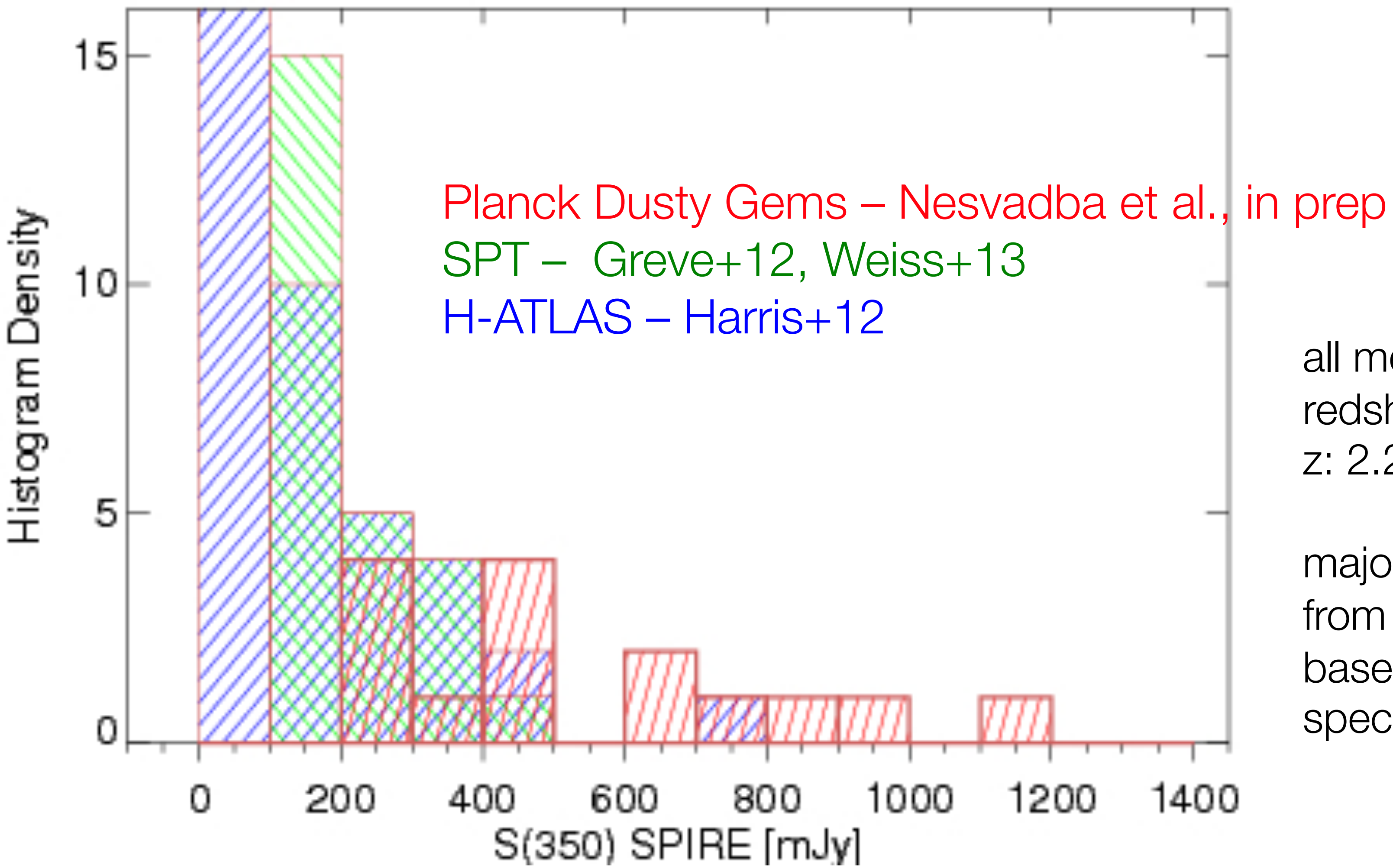
2 merging images of other or same galaxies

Highly magnified (>>10)

Waiting for lens model

Canameras et al., in prep
Nesvadba et al., in prep

many bright high-z lensed sources

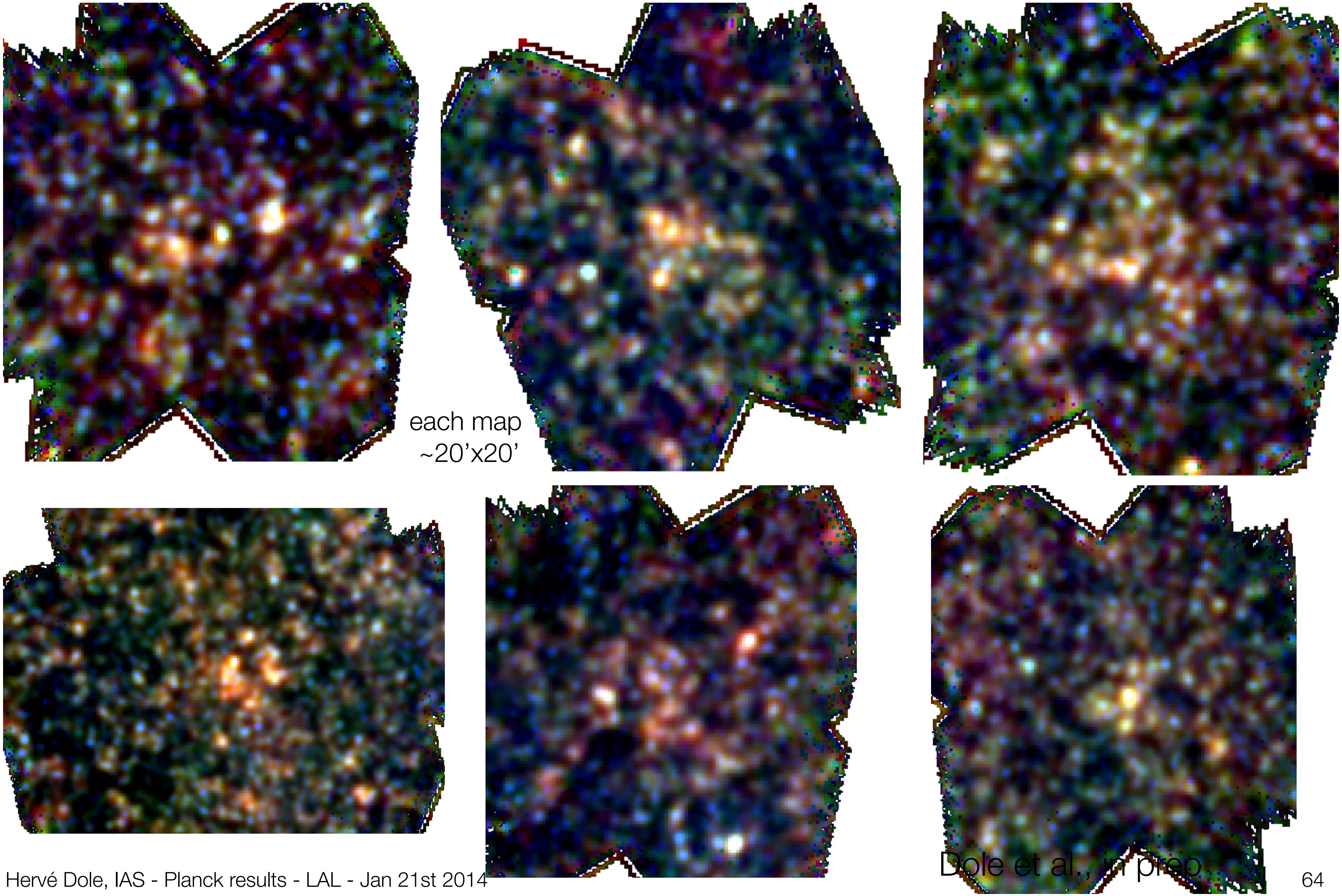


all measured redshifts at IRAM: z: 2.2 – 3.6

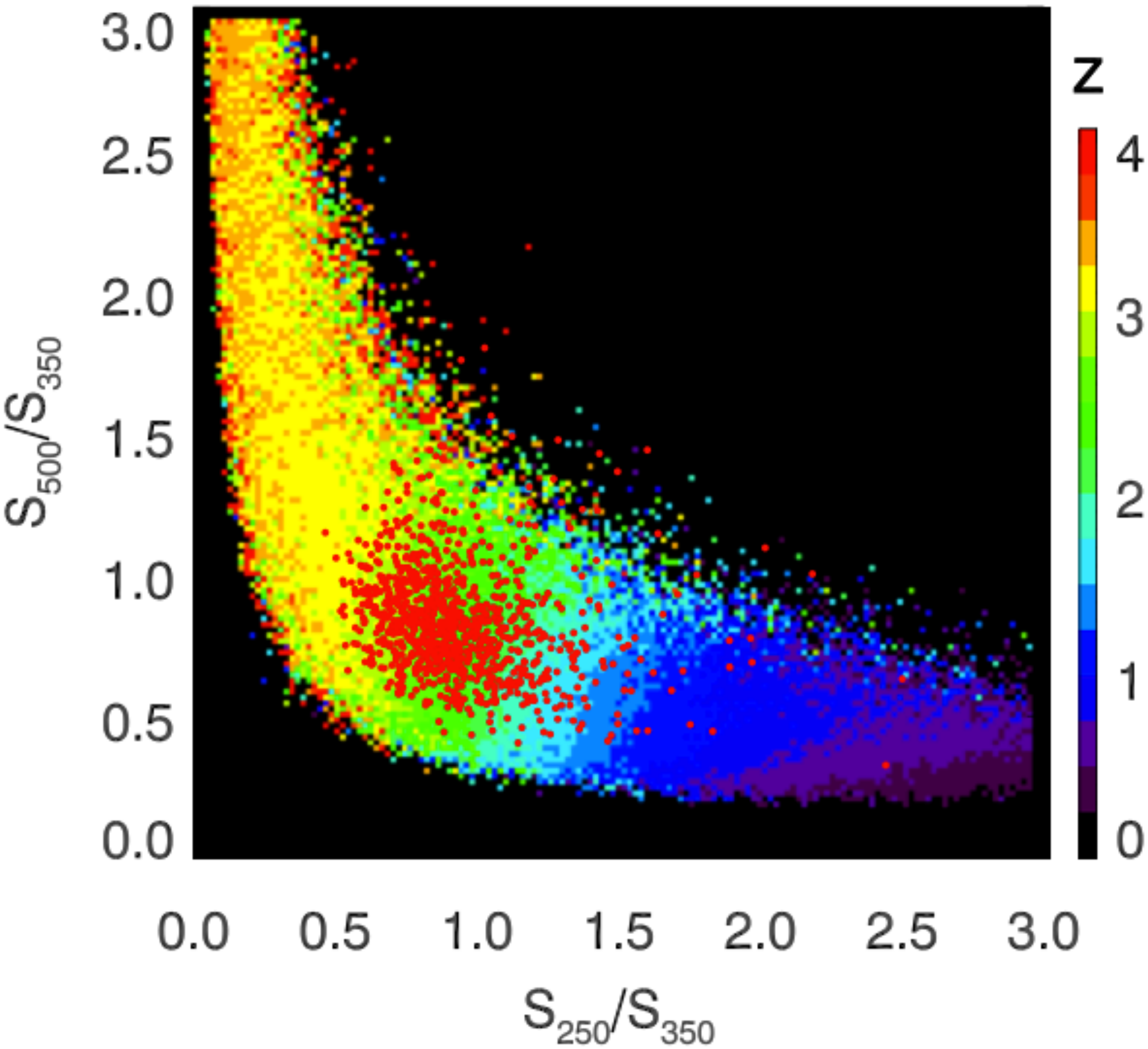
major contribution from ground-based mm img/ spec

Nesvadba et al., in prep

7.2 overdensities ?



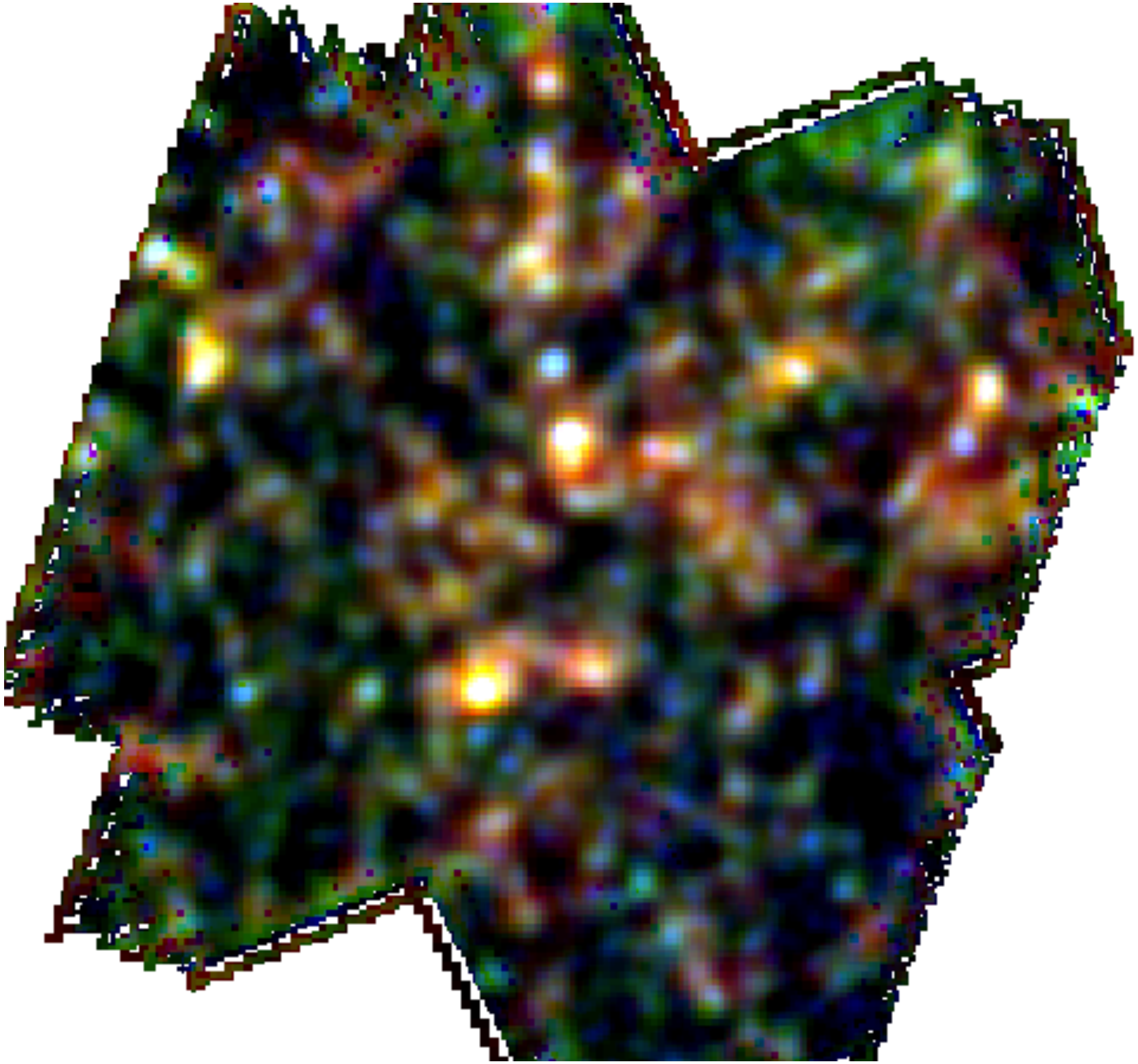
most of the SPIRE sources look z~1.5 – 3



David Guéry's
ongoing thesis peoject

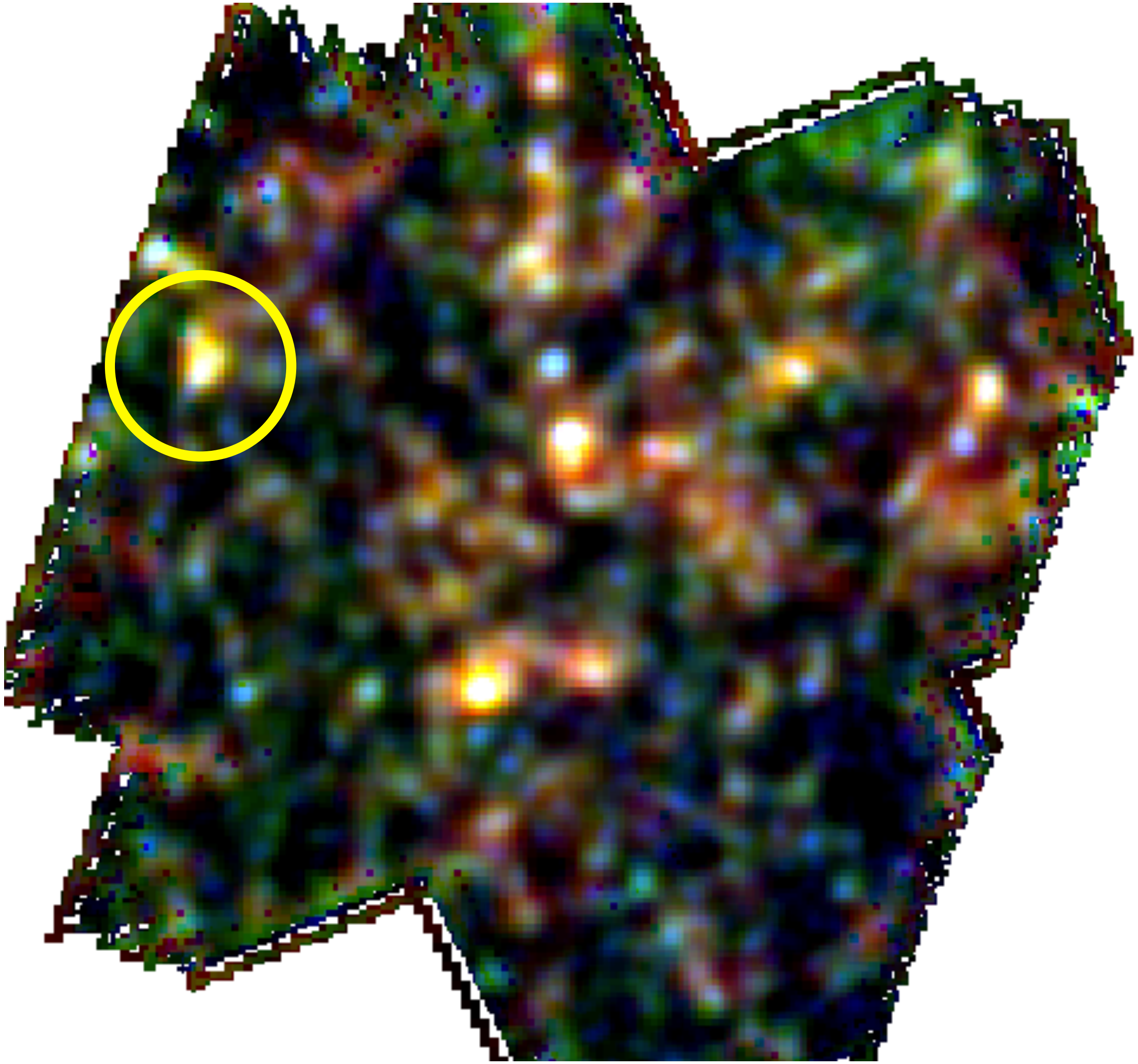
Dole et al., in prep

the case of XMMU J0044.0-2033 @z=1.58



Dole et al., in prep

the case of XMMU J0044.0-2033 @z=1.58



Dole et al., in prep

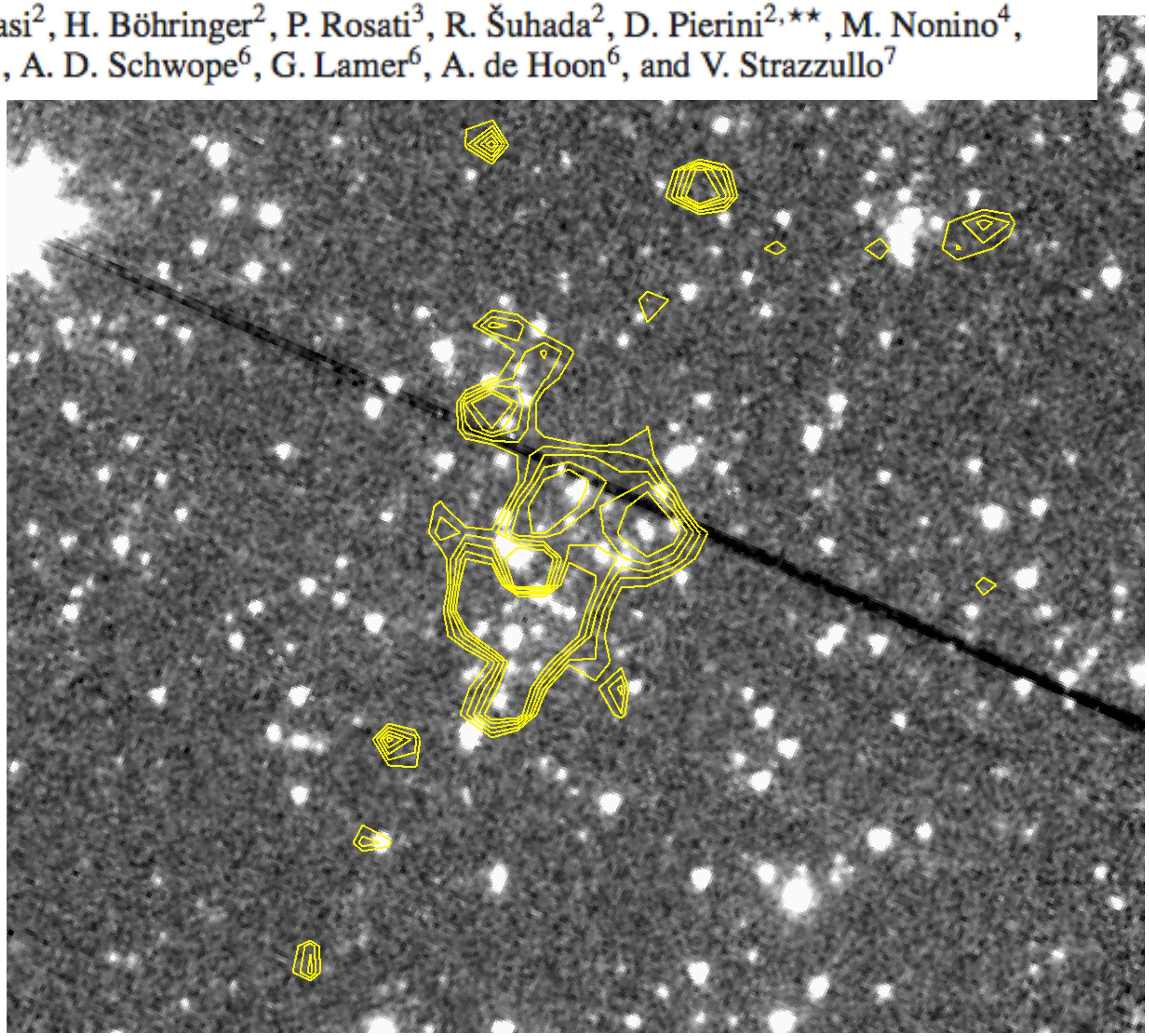
the case of XMMU J0044.0-2033 @z=1.58

Discovery of a massive X-ray luminous galaxy cluster at $z = 1.579^{\star}$

J. S. Santos[1], R. Fassbender[2], A. Nastasi[2], H. Böhringer[2], P. Rosati[3], R. Šuhada[2], D. Pierini[2,★★], M. Nonino[4], M. Mühlegger[2], H. Quintana[5], A. D. Schwope[6], G. Lamer[6], A. de Hoon[6], and V. Strazzullo[7]

We report on the discovery of a very distant galaxy cluster serendipitously detected in the archive of the *XMM-Newton* mission, within the scope of the *XMM-Newton* Distant Cluster Project (XDCP). XMMUJ0044.0-2033 was detected at a high significance level (5σ) as a compact, but significantly extended source in the X-ray data, with a soft-band flux $f(r < 40'') = (1.5 \pm 0.3) \times 10^{-14}$ erg s^{-1} cm^{-2}. Optical/NIR follow-up observations confirmed the presence of an overdensity of red galaxies matching the X-ray emission. The cluster was spectroscopically confirmed to be at $z = 1.579$ using ground-based VLT/FORS2 spectroscopy. The analysis of the $I-H$ colour–magnitude diagram shows a sequence of red galaxies with a colour range $[3.7 < I-H < 4.6]$ within 1′ from the cluster X-ray emission peak. However, the three spectroscopic members (all with complex morphology) have significantly bluer colours relative to the observed red-sequence. In addition, two of the three cluster members have [OII] emission, indicative of on-going star formation. Using the spectroscopic redshift we estimated the X-ray bolometric luminosity, $L_{bol,40''} \sim 5.8 \times 10^{44}$ erg s^{-1}, implying a massive galaxy cluster. This places XMMU J0044.0-2033 at the forefront of massive distant clusters, closing the gap between lower redshift systems and recently discovered proto- and low-mass clusters at $z > 1.6$.

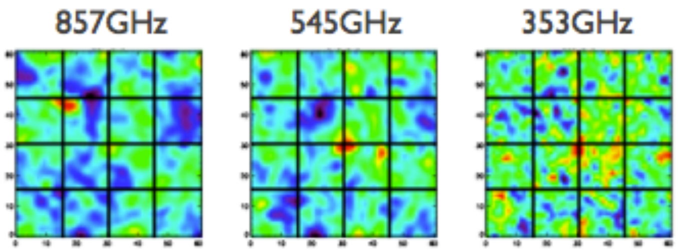
M~3-5 10^{14} Ms



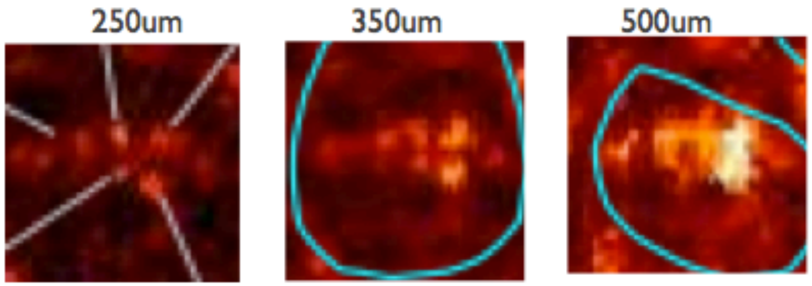
new structure at z>~1.7

Herschel confirmation of the *Planck* proto-cluster candidate

Planck
Detection



Herschel
SPIRE



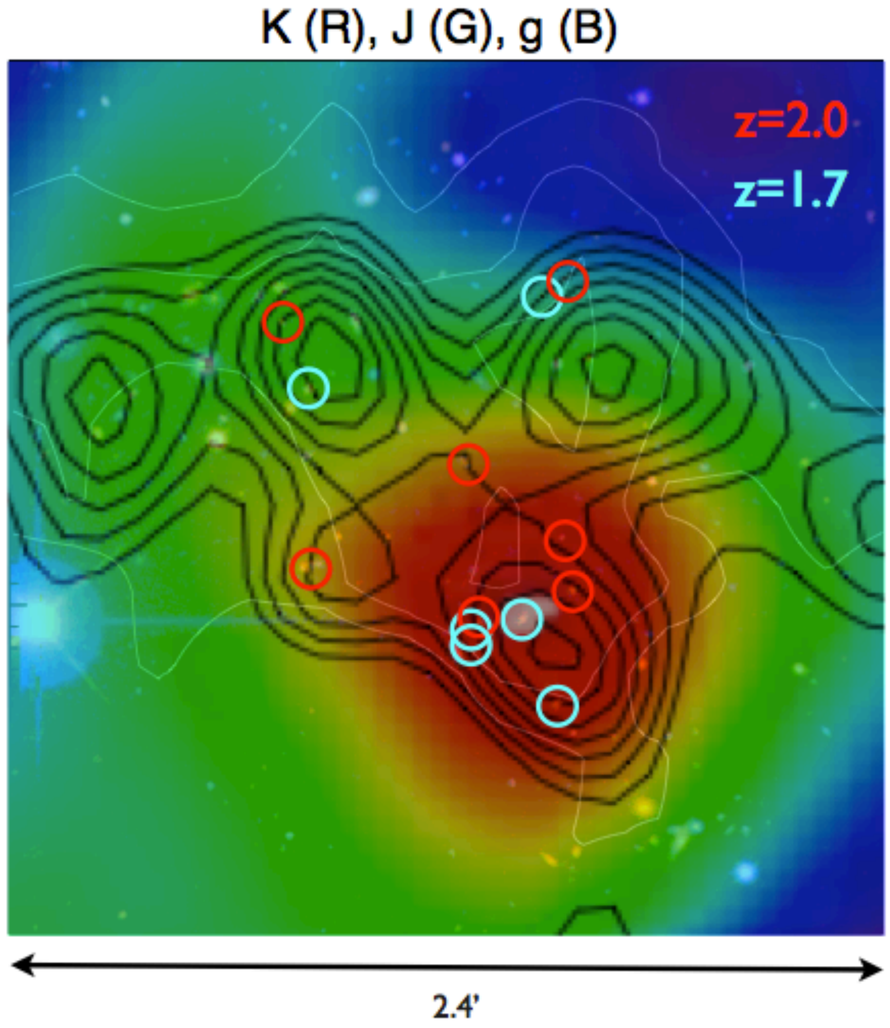
IR observation: CFHT + Spitzer

Overdensity of J-K galaxies

Spectroscopic redshifts (VLT)

2 groups of Galaxies: z=2.0 & z=1.7

(Flores-Cacho et al. in prep)



Courtesy Ludovic Montier

more identifications to go

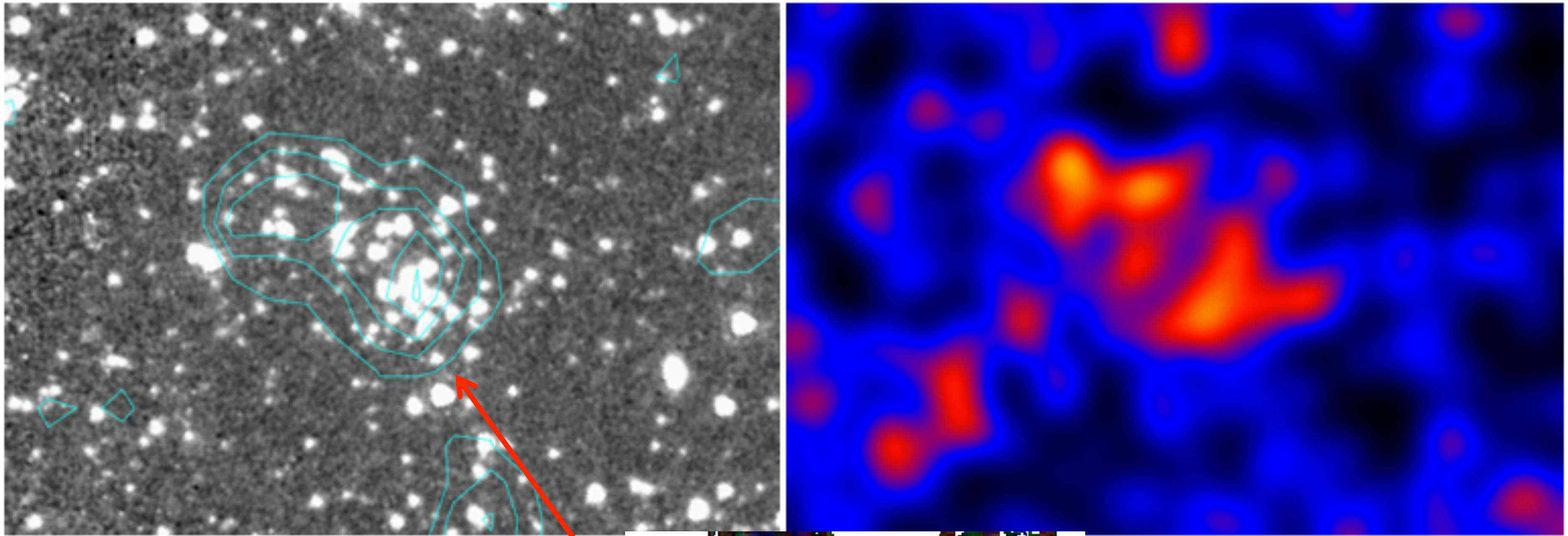
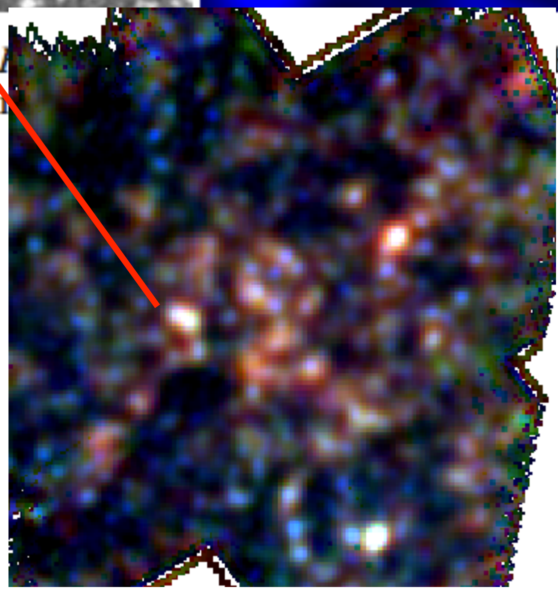


Figure 10. A high-z cluster candidate observed by A… RAC (3.5′ × 2.3′). Left: IRAC channel 2 (4.5 μm) with SPIRE 350 μm contour. Right: color i… ing the red color of the sources within the cluster candidate.



Clément Martinache's ongoing thesis project

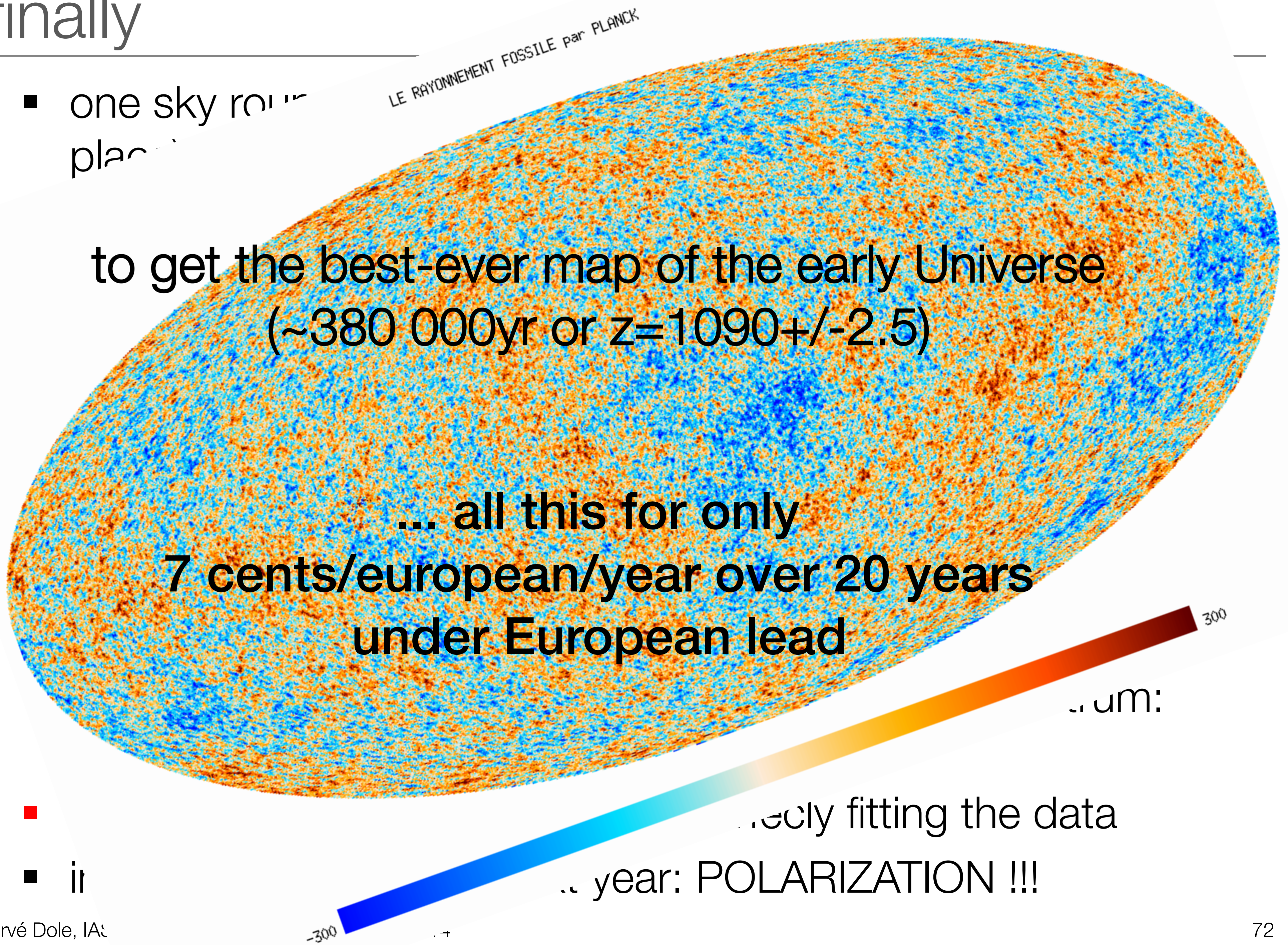
Dole et al., in prep

finally

- one sky round per minute (repeated 50 times at the same place)
- 200 measurements/second par detector, during 30 months at temperature 0.1K at 1.5M km from Earth
- ~1000 billion samples (72 ch., 30 months) and few billion telemetry packets to downlink
- raw data for one detector (Time Ordered Informatio, TOI)
  - 50 Gb (multiply by 52 detectors, eand many versions)
- 1 release: 1 month of processing, 2200 maps generated
- sky maps : 50 millions pixels (6 freq for HFI + 3 LFI)
- Cosmic Microwave Background angular power spectrum: 1000 values
- only 6 cosmological parameters perfecly fitting the data
- inflation, LSS etc; and next year: POLARIZATION !!!

finally

- one sky rou
  plac



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

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

um:

ecly fitting the data

- i year: POLARIZATION !!!