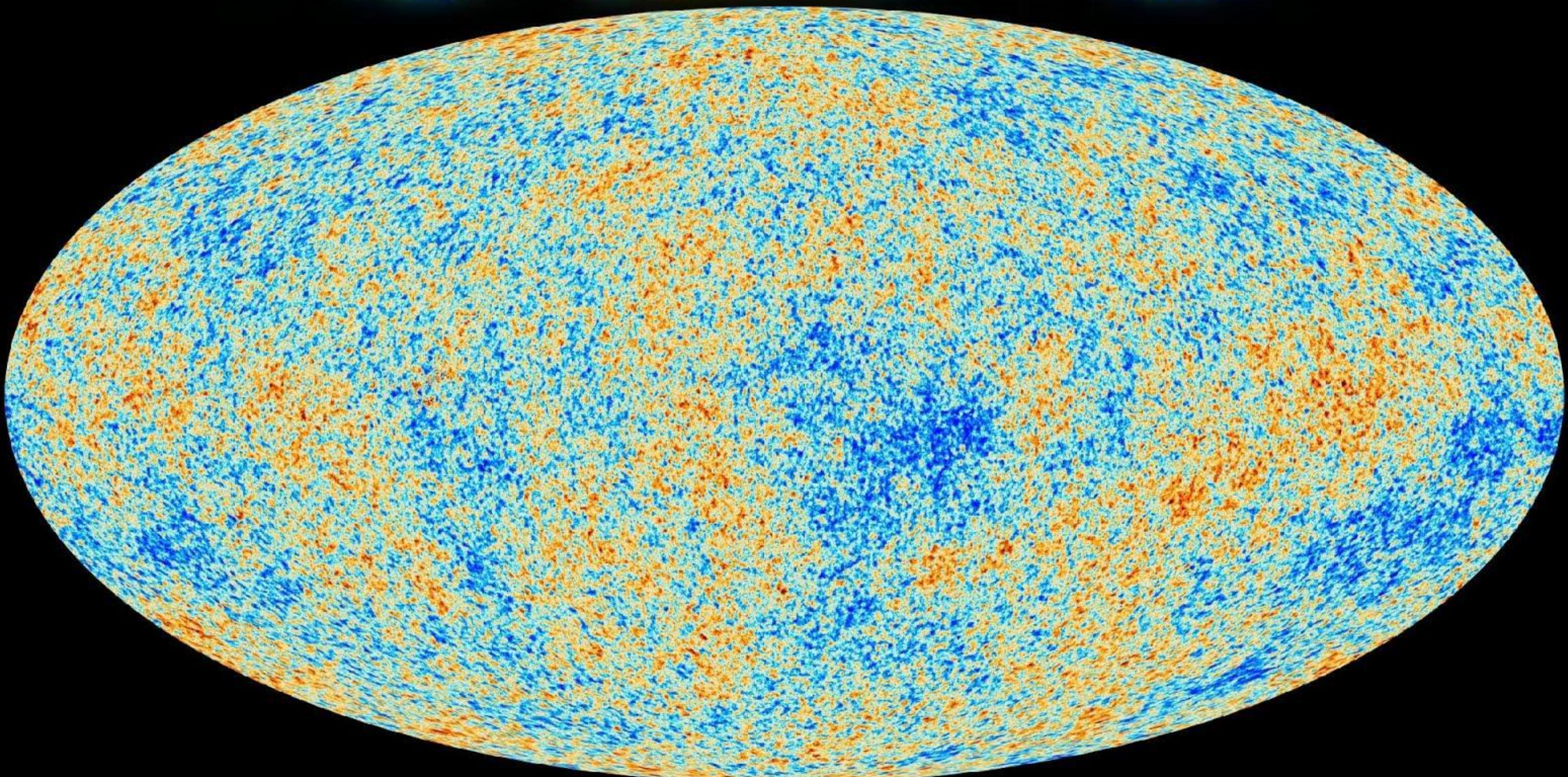
PLANCK



Planck – First Cosmology Release
March 21st, 2013

"Have no fear of perfection - you'll never reach it." Dali
"Imperfection is beauty, ..." Marilyn Monroe

For more information and to obtain all Planck papers to date:

http://planck.caltech.edu

www.deepspace.ucsb.edu

http://sci.esa.int/planck

http://www.sciops.esa.int/index.php?project=planck&page=Planck

UCSB has been involved in Planck since 1996

UCSB Experimental Cosmology Group
Planck team:

Professor Philip Lubin, Planck Co-Investigator

Dr. Peter Meinhold, LFI Core Team Scientist

Dr. Andrea Zonca, LFI Core Team Scientist

Dr. Jatila van der Veen, Education Project Manager

for Planck, USA

Dr. Gregory Dobler (KITP), LFI Core Team Scientist

Planck launch, May 14, 2009, Kouru, French Guiana
Photo: Dr. Charles R. Lawrence, Chief Scientist for Planck, USA

Four CMB orbital missions

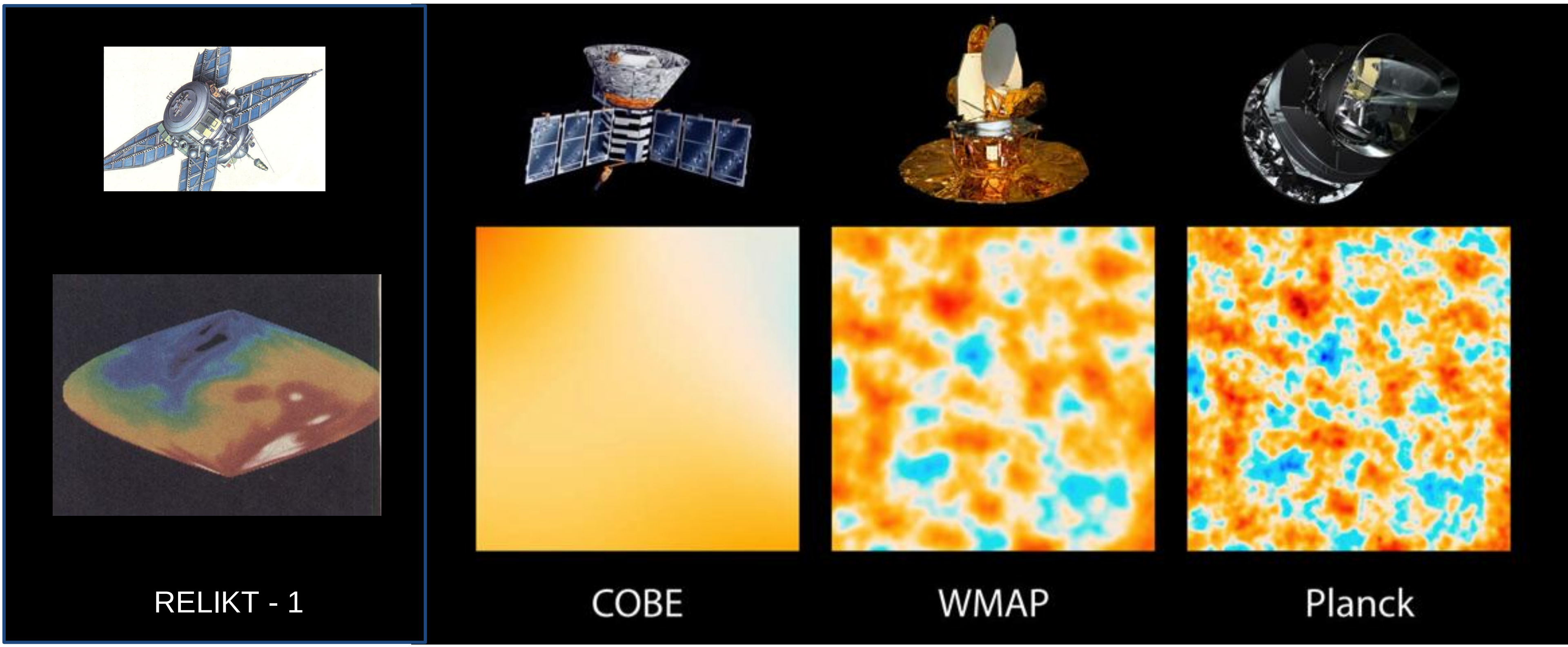
RELIKT-1 (РЕЛИКТ-1), COBE, WMAP and Planck

Progress has been in angular resolution and sensitivity

Planck is effectively CMB photon noise limited

Mapping speed: Planck:WMAP:COBE:Relikt ~ $1:10^{-3}:10^{-6}:>10^{-6}$

1 year of Planck = 1000 years of WMAP = 1,000,000 years of COBE

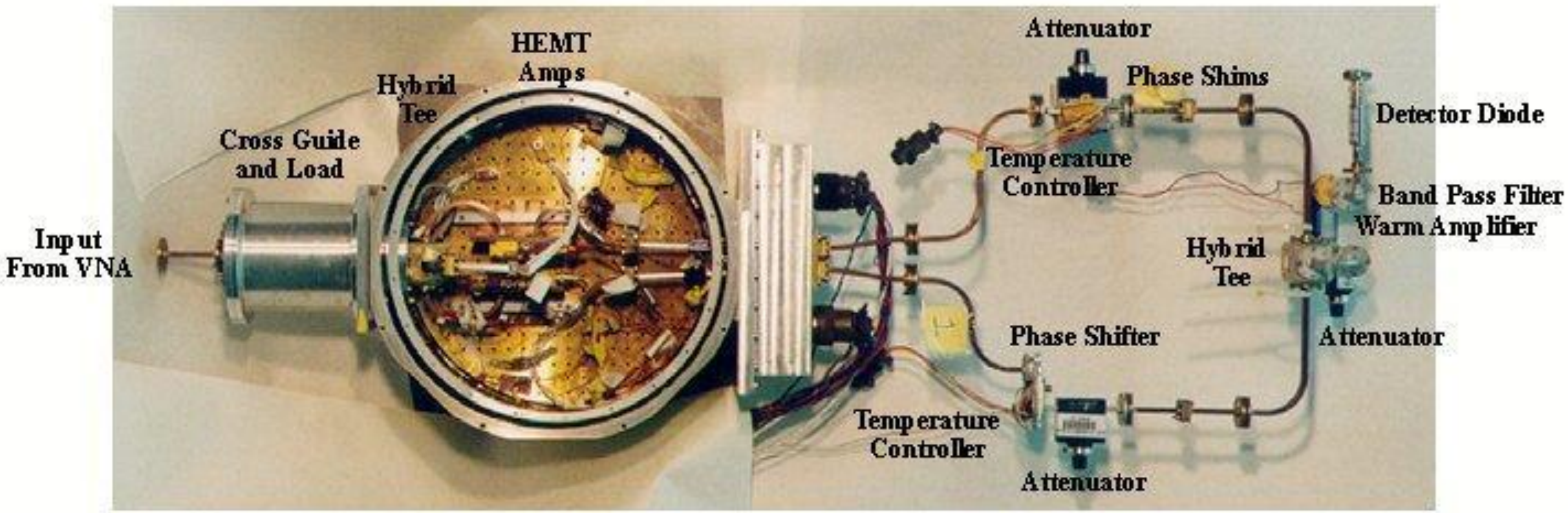


1983 **1989** **2001** **2009**

Highlights

- **Planck firmly establishes a deviation from scale invariance for primordial matter perturbations, consisten with Inflation**
- **Planck detects lensing of the CMB by intervening matter with high significance, providing evidence for dark energy from the CMB alone**
- **Planck finds no evidence for significant deviations from Gaussianity in the statistics of CMB anisotropies**
- **Planck finds a low value of the Hubble constant, in tension with the value derived from the standard distance ladder**
- **Planck finds a deficit of power at low-ell with respect to our best-fit model**
- **Planck establishes anomalies at large angular scales**
- **Planck establishes the number of neutrino species at three**

LFI UCSB 44GHz Test Radiometer

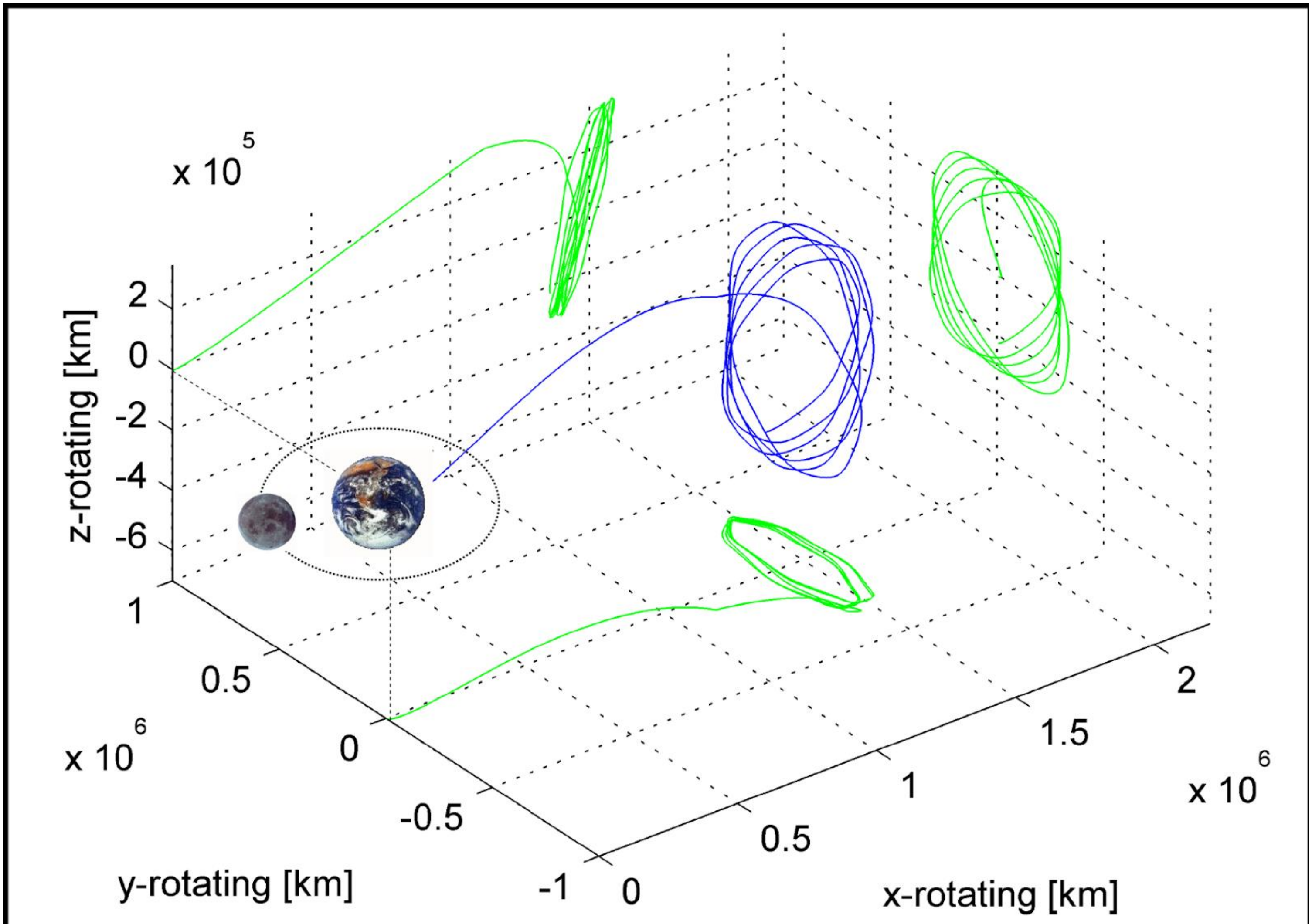


LFI Circa 1999

A few days before mating to Ariane 5 Rocket

Planck was launched May 14, 2009 from the ESA launch site in French Guiana

Planck is in a Lissajous orbit at L2



PLANCK Data released today
15.5 months of data
The full power of Planck has yet to be applied to cosmology

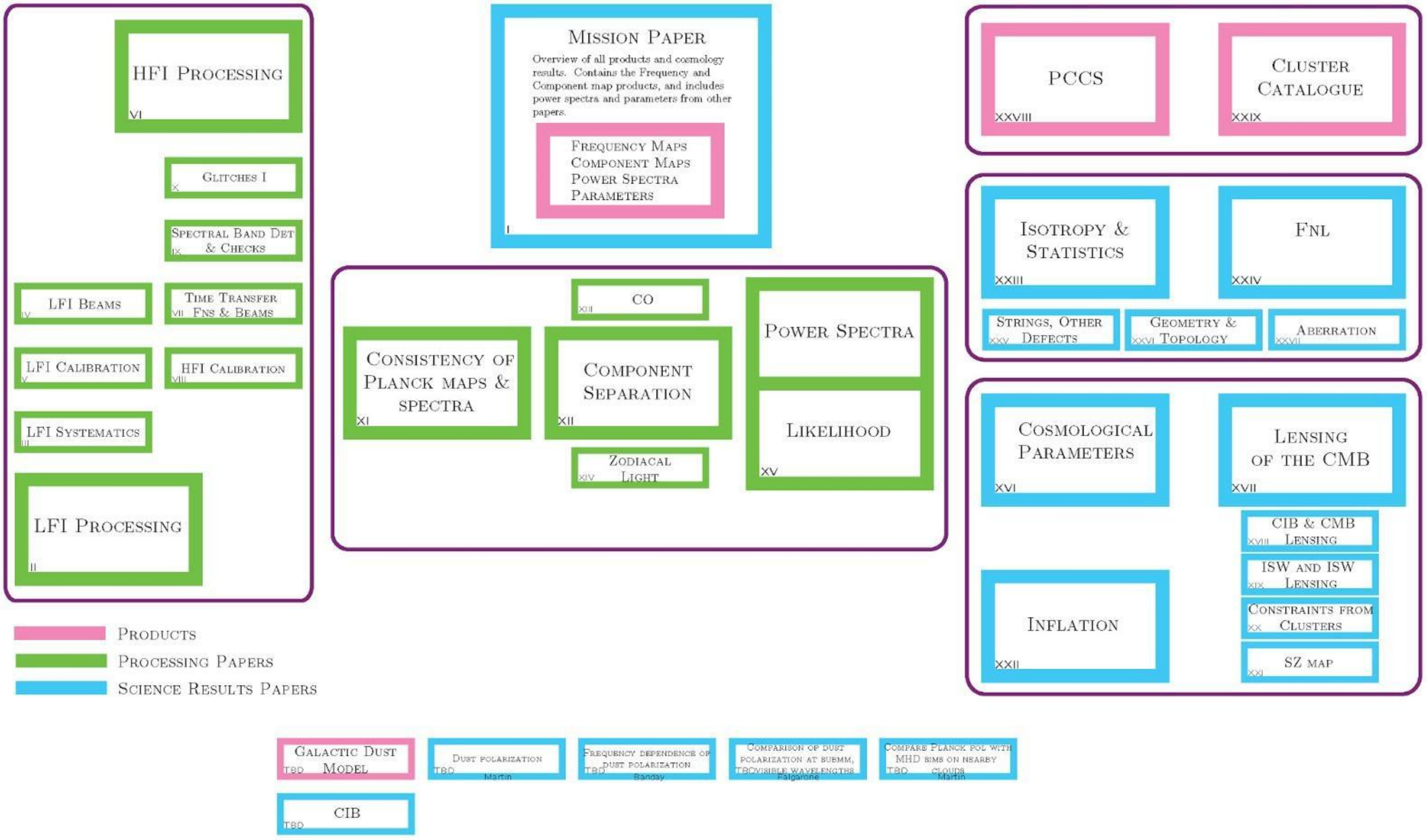
- **Full sky maps for 9 frequencies, surveys 1-2, ‘halfrings’**
- **Component separation maps:**
  - **CMB-only, full sky**
  - **thermal dust + residual CIB**
  - **CO**
  - **synchrotron + free-free + spinning dust**
  - **dust temperature / opacity**
- **low-resolution CMB map used in low ell likelihood (+ likelihood code, with lensing)**
- **Catalog of Compact Sources (PCCS)**
- **Catalog of Sunyaev-Zeldovich Sources (PSZ)**

I. Overview of products and results (*this paper*)
II. Low Frequency Instrument data processing
III. LFI systematic uncertainties
IV. LFI beams
V. LFI calibration
VI. High Frequency Instrument data processing
VII. HFI time response and beams
VIII. HFI calibration and mapmaking
IX. HFI spectral response
X. HFI energetic particle effects
XI. Consistency of the data
XII. Component separation
XIII. Galactic CO emission
XIV. Zodiacal emission
XV. CMB power spectra and likelihood
XVI. Cosmological parameters
XVII. Gravitational lensing by large-scale structure
XVIII. Gravitational lensing by star-forming galaxies
XIX. The integrated Sachs-Wolfe effect
XX. Cosmology from Sunyaev-Zeldovich cluster counts
XXI. All-sky Compton-parameter map and characterization
XXII. Constraints on inflation
XXIII. Isotropy and statistics of the CMB
XXIV. Constraints on primordial non-Gaussianity
XXV. Searches for cosmic strings and other topological defects
XXVI. Background geometry and topology of the Universe
XXVII. Special relativistic effects on the CMB dipole
XXVIII. The Planck Catalogue of Compact Sources
XXIX. The Planck catalogue of Sunyaev-Zeldovich sources

Planck Cosmology and Product Papers 2013

will be on Astro-ph tomorrow!
On ESA site right now:
http://sci.esa.int/planck

Organization of the Planck Cosmology and Product Papers, 2013



Planck Sensitivity

All are linear polarization sensitive except 545 and 857 GHz Coverage is 25-1000 GHz

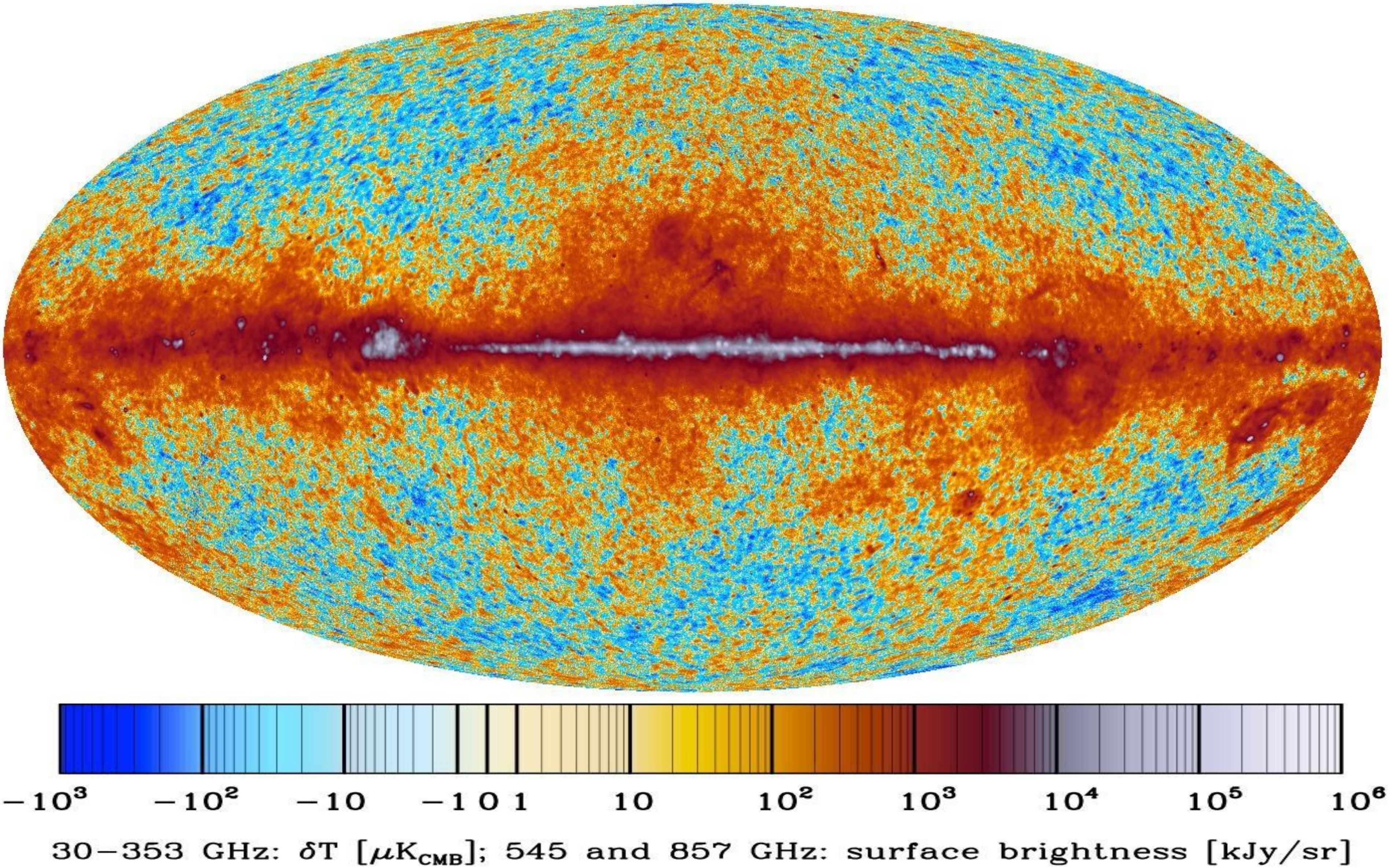
545 and 857 “CMB” is actually MJy/st-s$^{1/2}$

Lowest noise channel is ~ 100/1000 times lower than WMAP/COBE

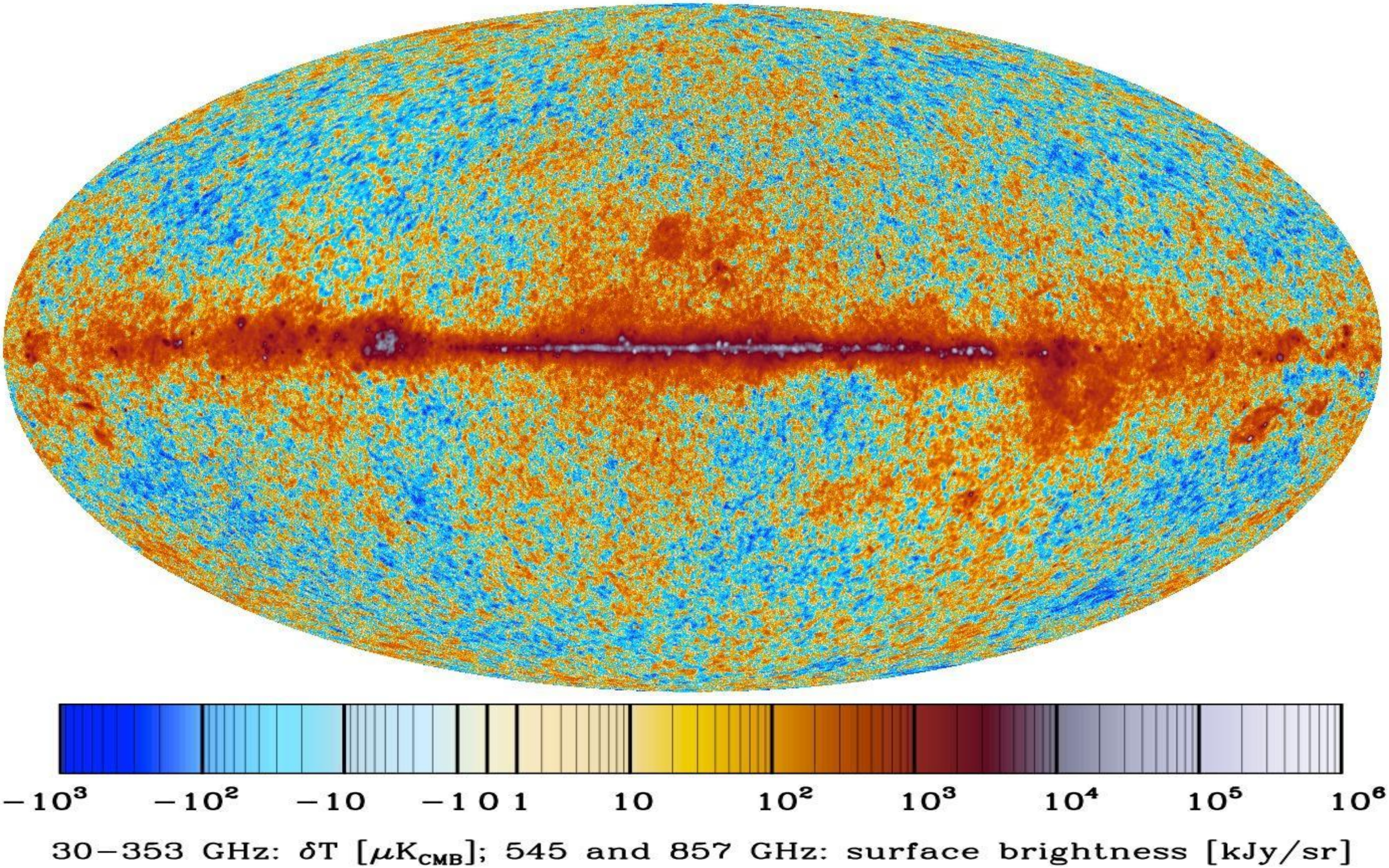
Channel	$N_{detectors}$[a]	ν_{center}[b] [GHz]	Scanning Beam[c] FWHM [arcm]	Ellipticity	Noise[d] Sensitivity [μK_{RJ} s$^{1/2}$]	[μK_{CMB} s$^{1/2}$]
30 GHz	4	28.4	33.16	1.37	145.4	148.5
44 GHz	6	44.1	28.09	1.25	164.8	173.2
70 GHz	12	70.4	13.08	1.27	133.9	151.9
100 GHz	8	100	9.59	1.21	31.52	41.3
143 GHz	11	143	7.18	1.04	10.38	17.4
217 GHz	12	217	4.87	1.22	7.45	23.8
353 GHz	12	353	4.7	1.2	5.52	78.8
545 GHz	3	545	4.73	1.18	2.66	0.0259[d]
857 GHz	4	857	4.51	1.38	1.33	0.0259[d]

Galactic coordinates

30 GHz

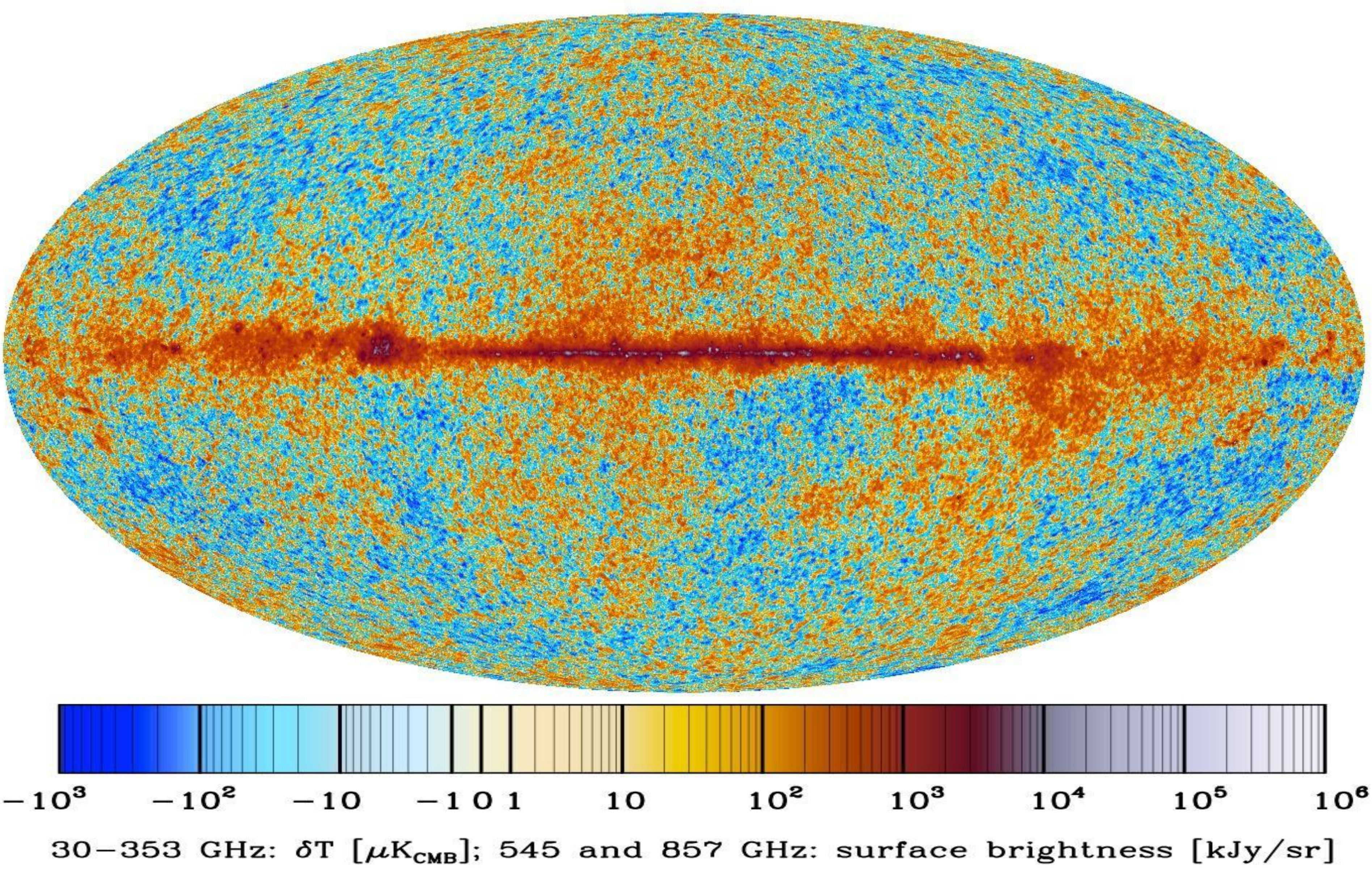


44 GHz



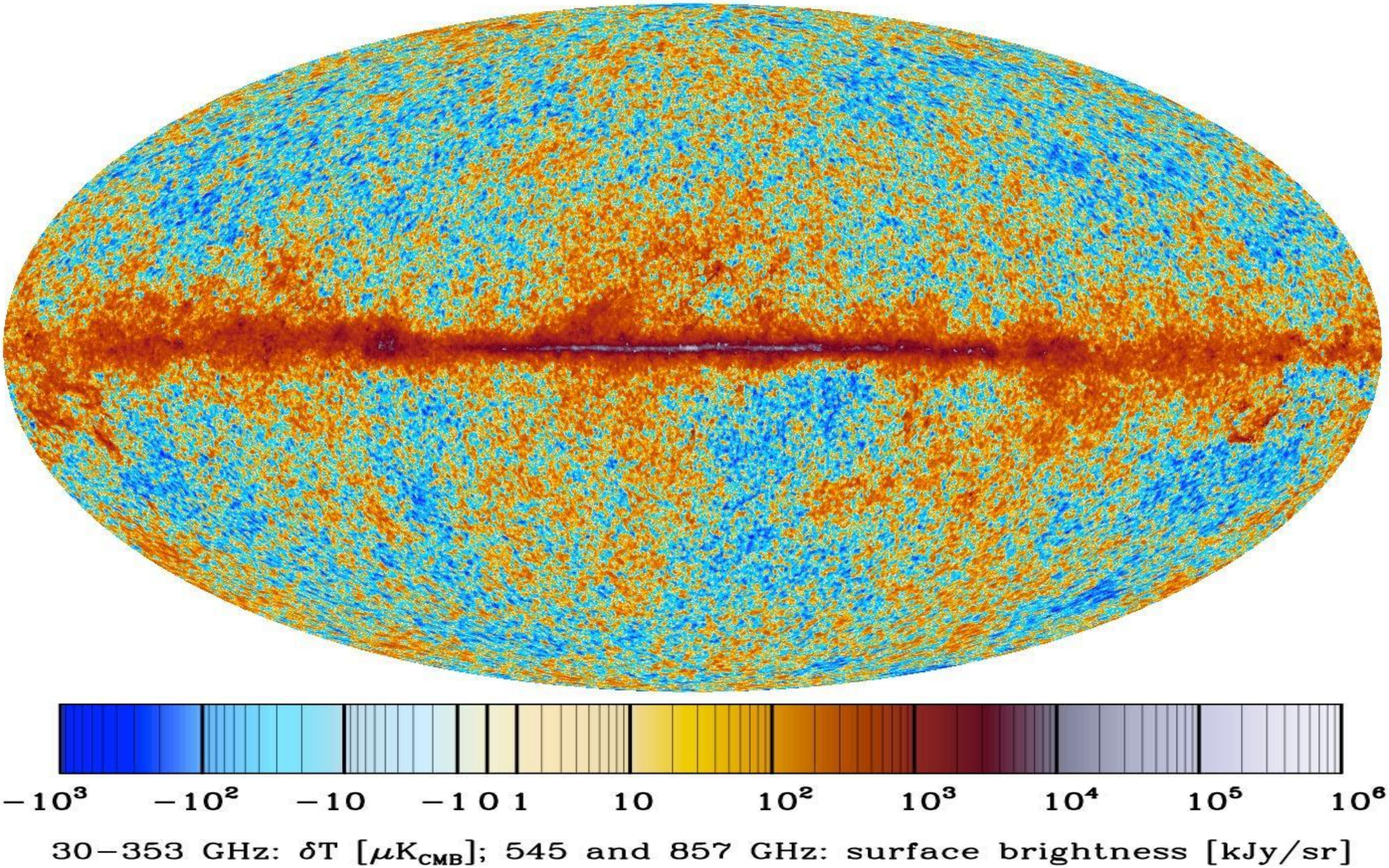
−10³ −10² −10 −1 0 1 10 10² 10³ 10⁴ 10⁵ 10⁶
30−353 GHz: δT [μK_CMB]; 545 and 857 GHz: surface brightness [kJy/sr]

70 GHz



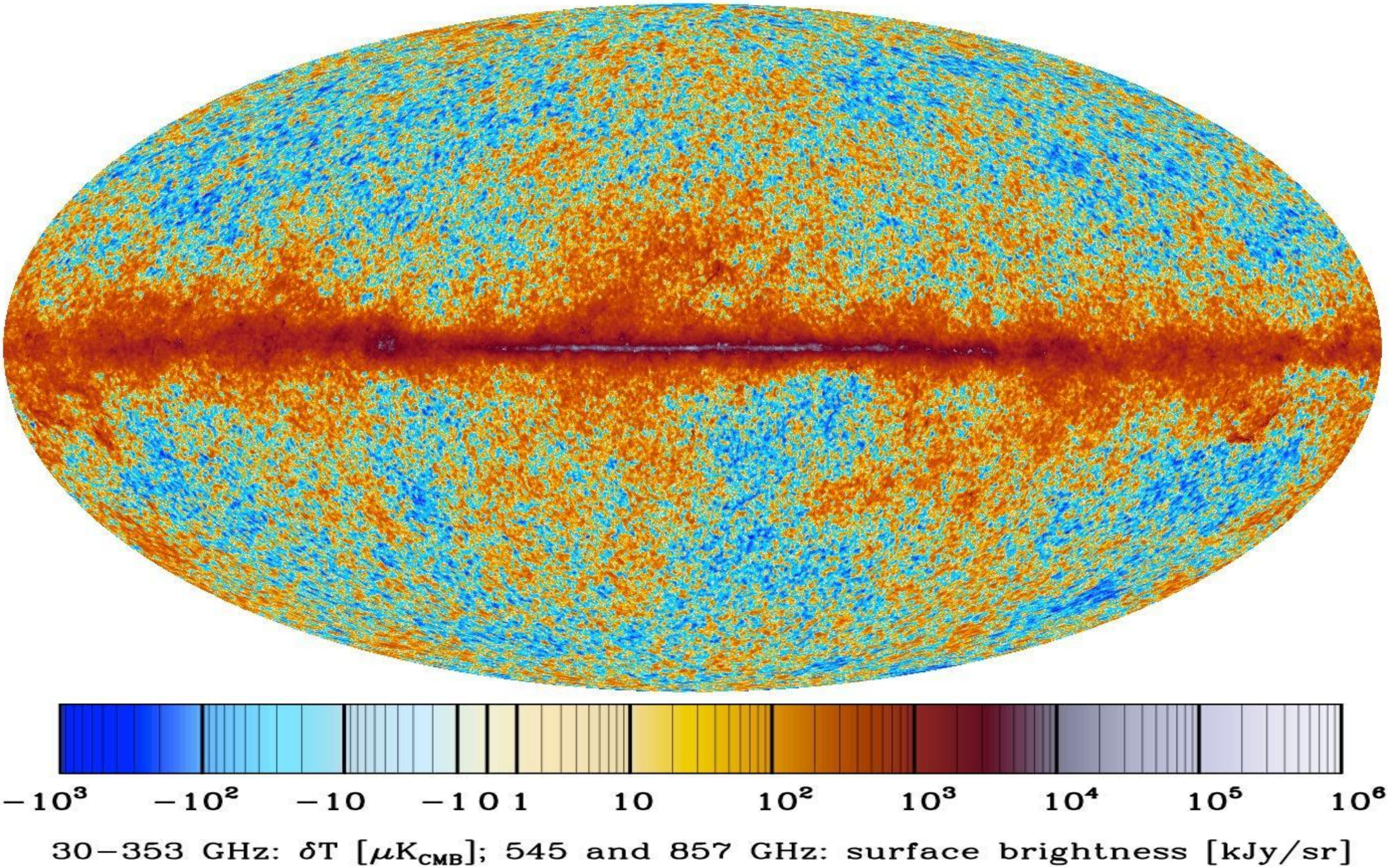
−10³ −10² −10 −1 0 1 10 10² 10³ 10⁴ 10⁵ 10⁶
30−353 GHz: δT [μK_CMB]; 545 and 857 GHz: surface brightness [kJy/sr]

100 GHz



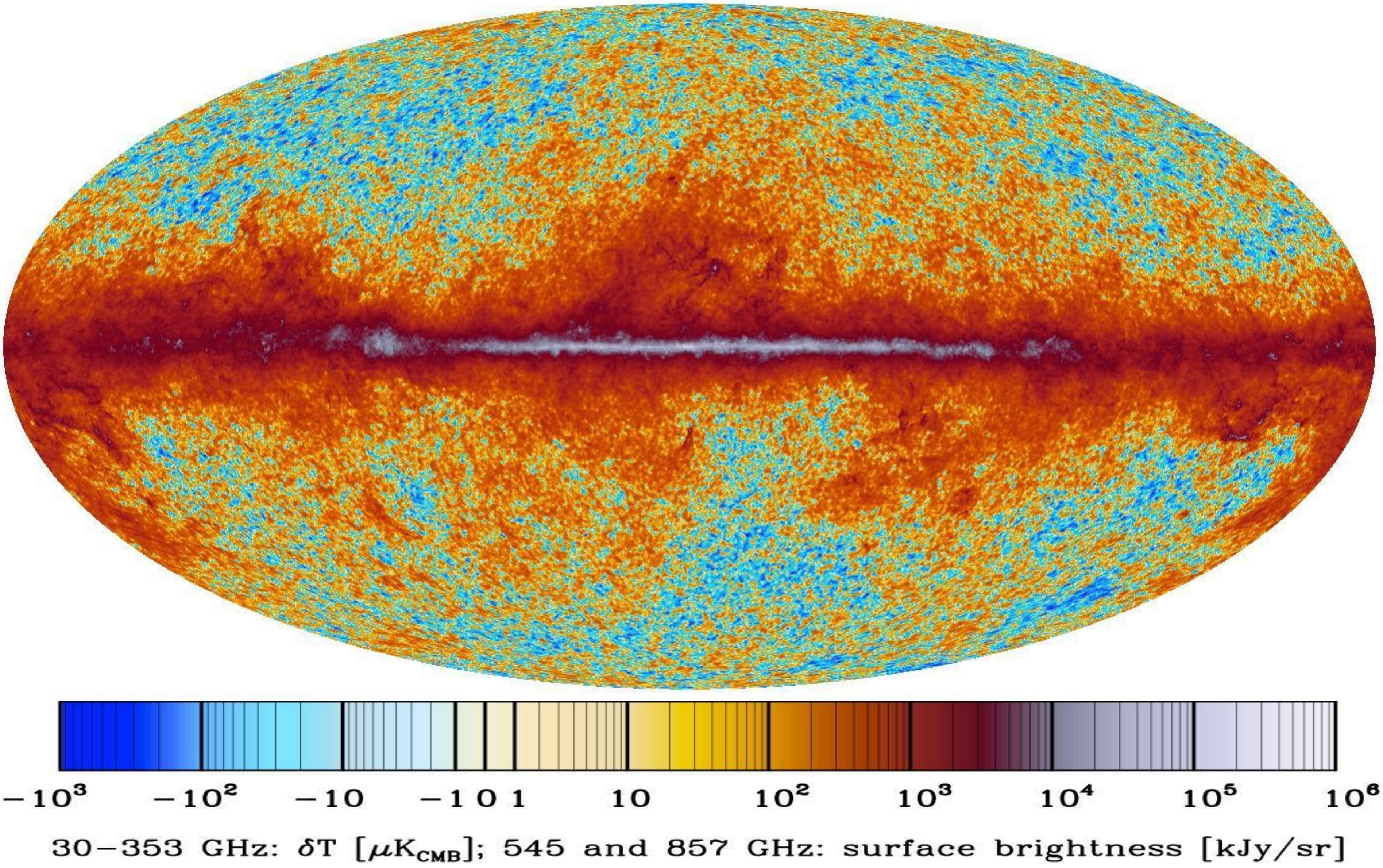
−10³ −10² −10 −1 0 1 10 10² 10³ 10⁴ 10⁵ 10⁶
30−353 GHz: δT [μK_CMB]; 545 and 857 GHz: surface brightness [kJy/sr]

143 GHz



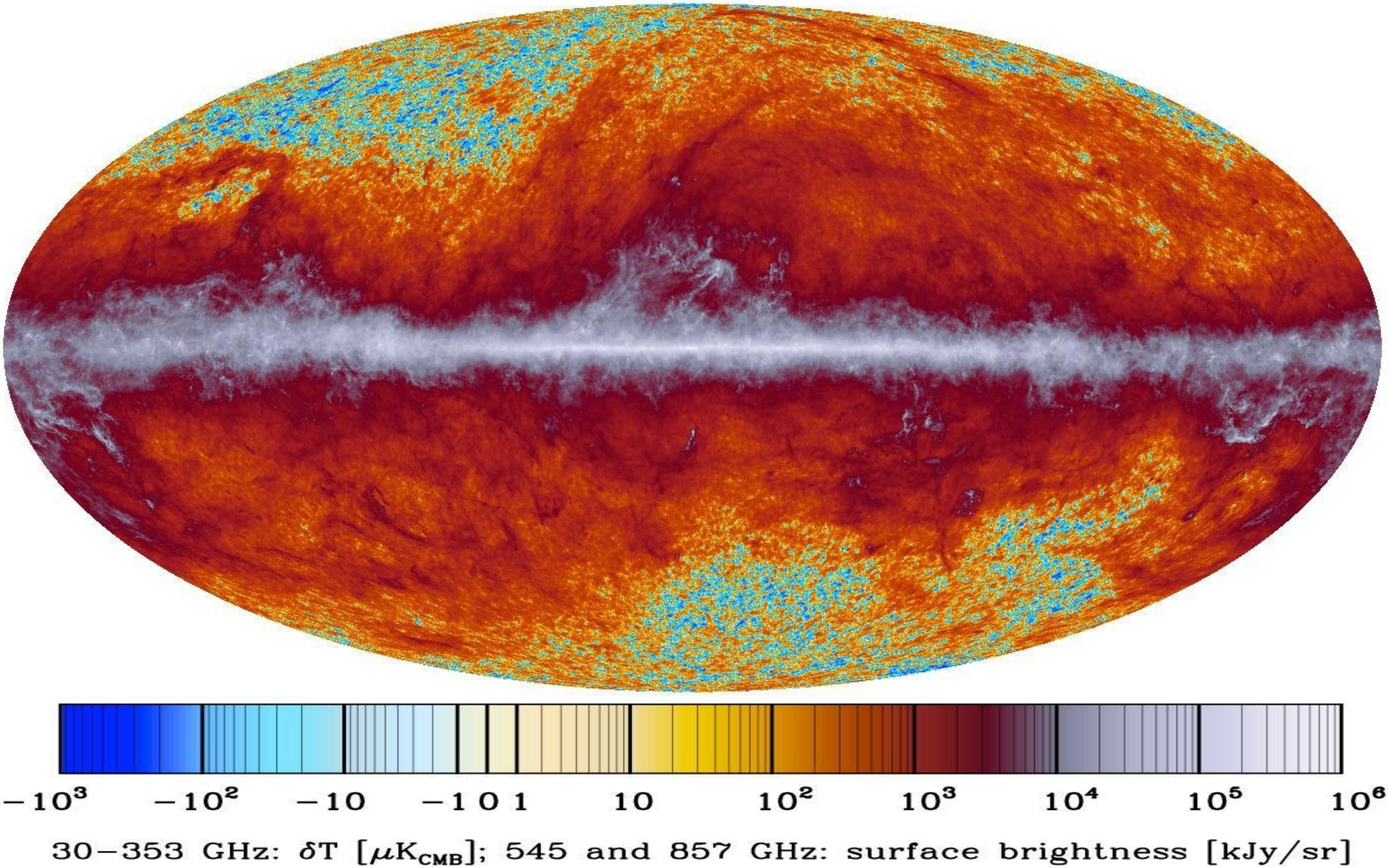
-10^3
-10^2
-10
-1 0 1
10
10^2
10^3
10^4
10^5
10^6
30–353 GHz: δT [μK_{CMB}]; 545 and 857 GHz: surface brightness [kJy/sr]

217 GHz

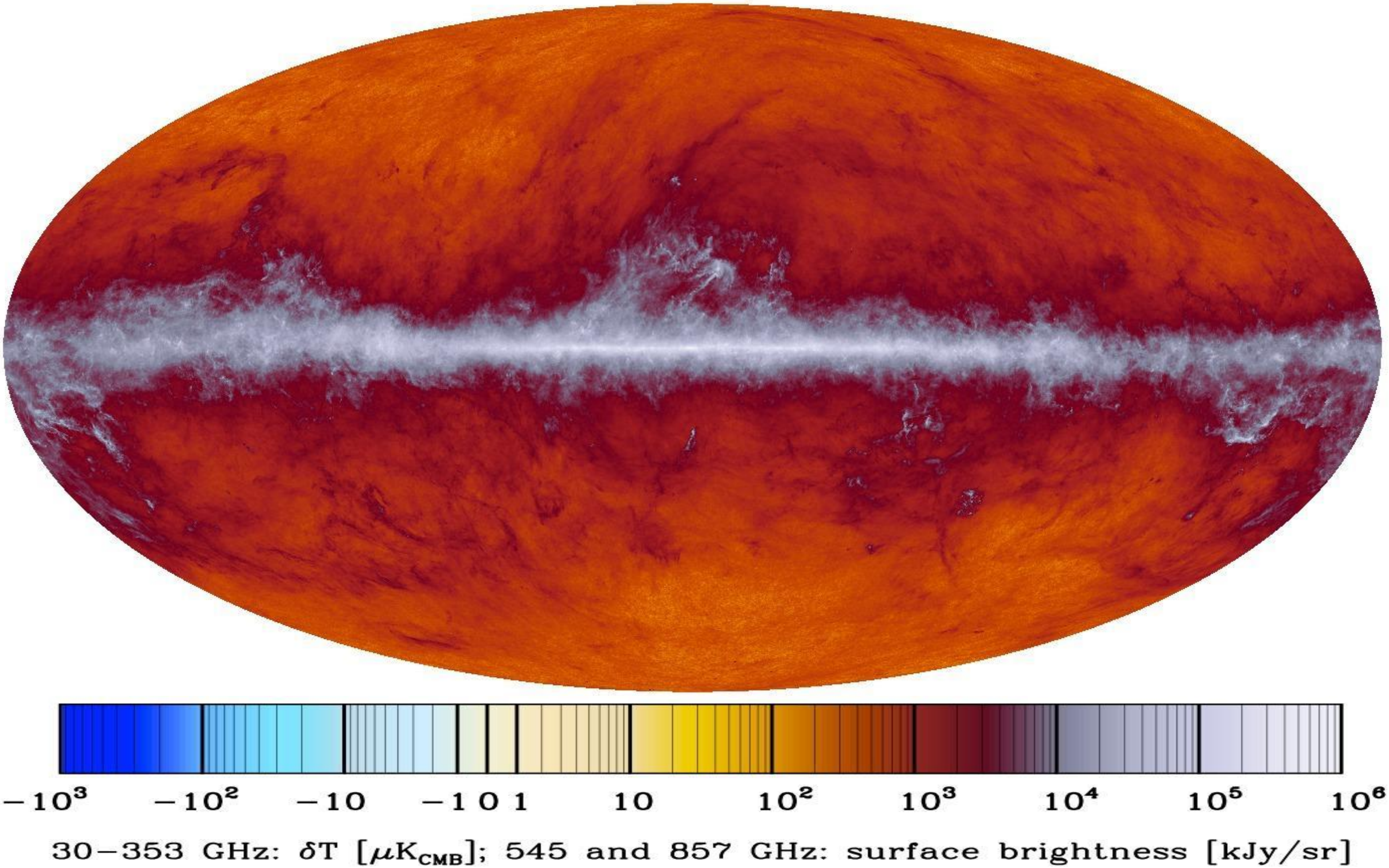


-10^3 -10^2 -10 -1 0 1 10 10^2 10^3 10^4 10^5 10^6
30−353 GHz: δT [μK_{CMB}]; 545 and 857 GHz: surface brightness [kJy/sr]

353 GHz

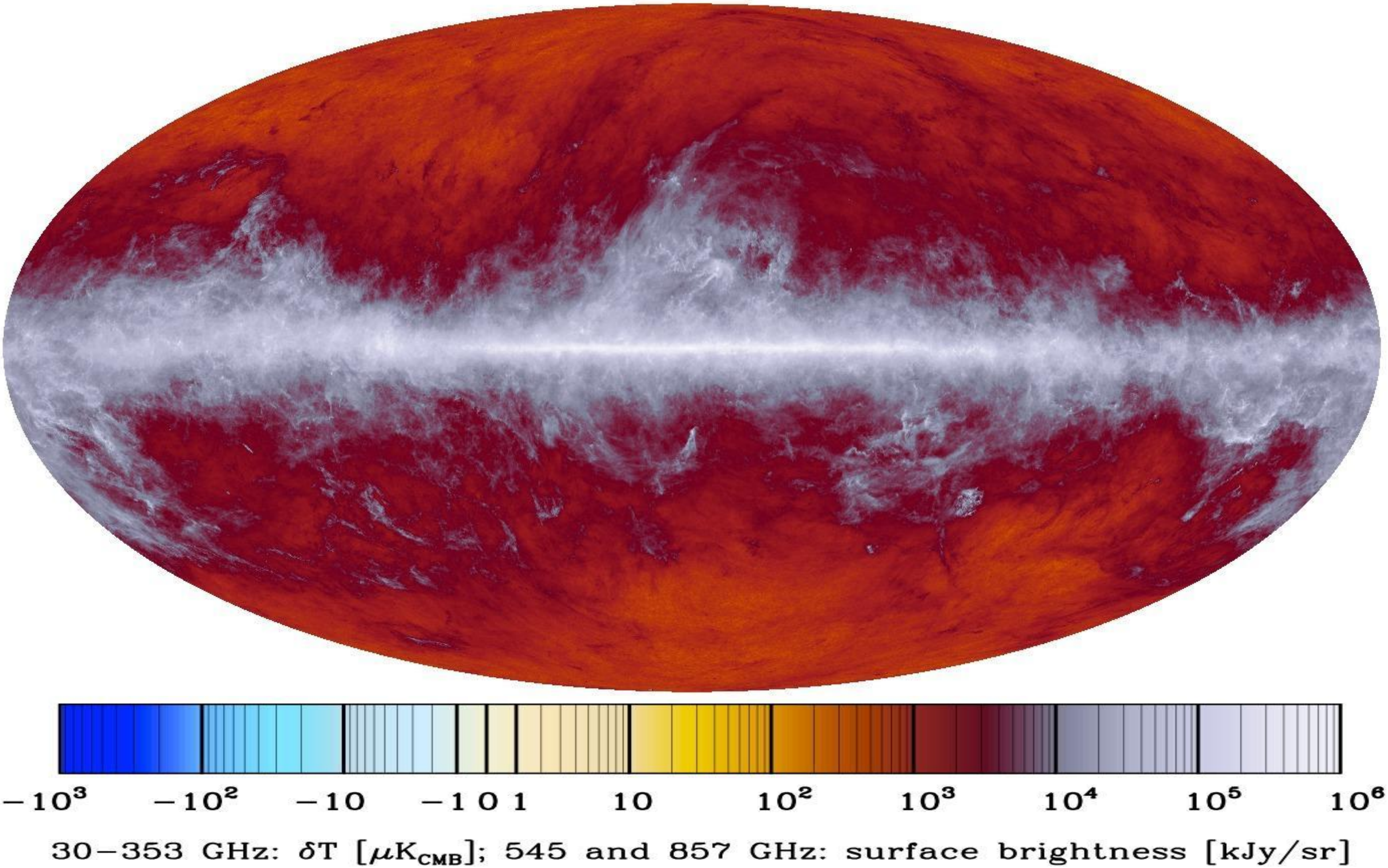

-10^3 -10^2 -10 -1 0 1 10 10^2 10^3 10^4 10^5 10^6
30−353 GHz: δT [μK_{CMB}]; 545 and 857 GHz: surface brightness [kJy/sr]

545 GHz



-10^3 -10^2 -10 -1 0 1 10 10^2 10^3 10^4 10^5 10^6
30−353 GHz: δT [μK_{CMB}]; 545 and 857 GHz: surface brightness [kJy/sr]

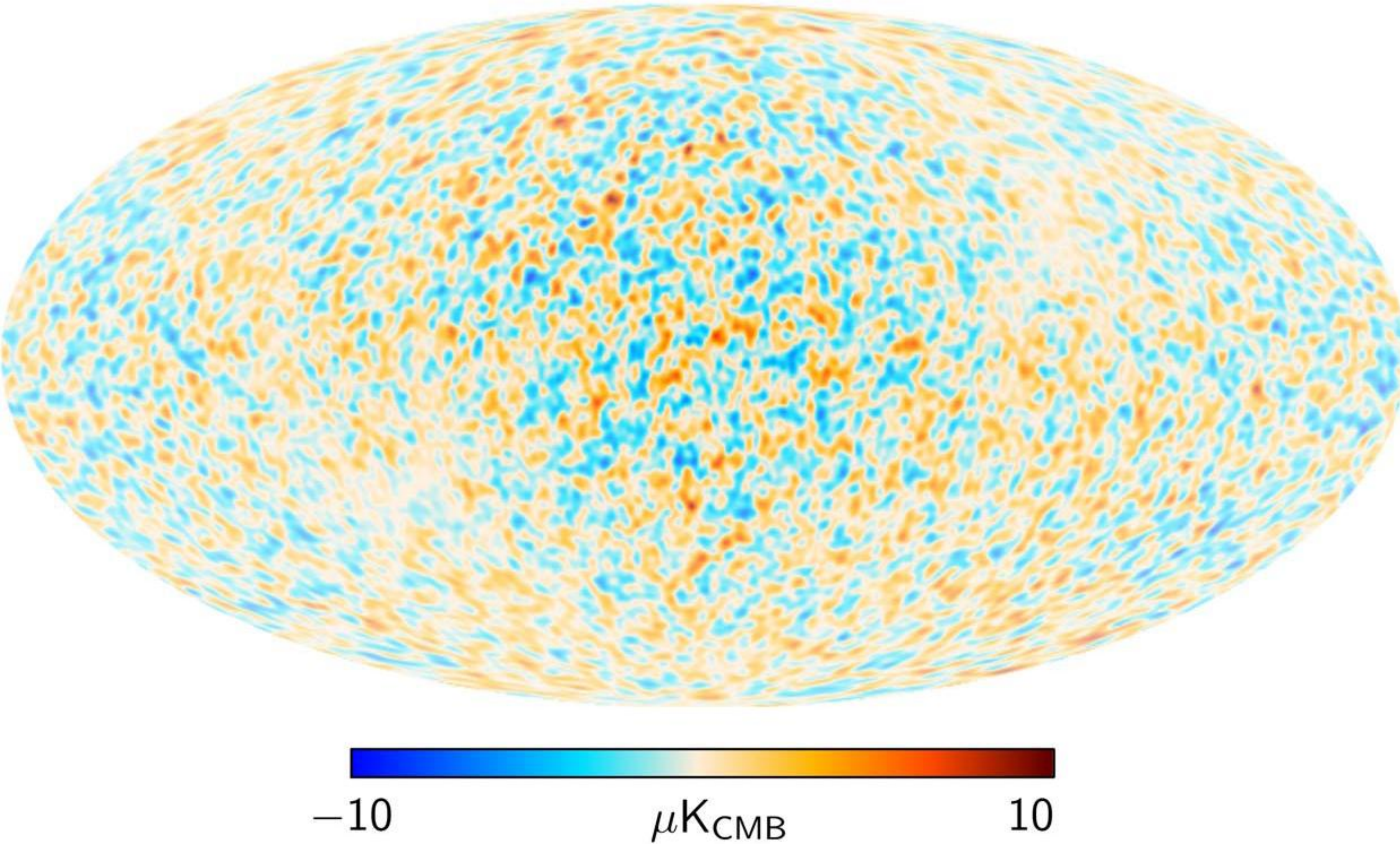
857 GHz



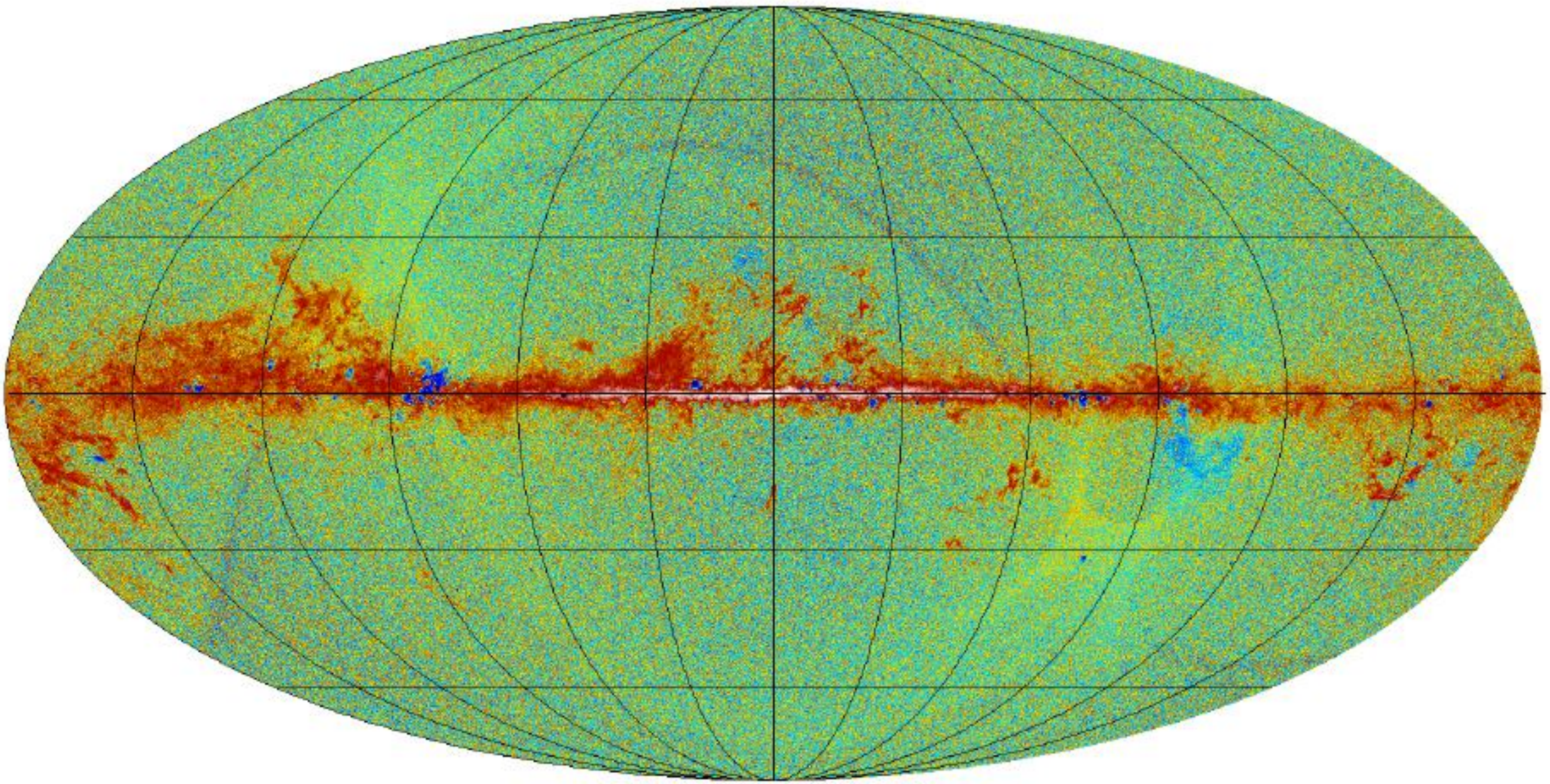
−10³ −10² −10 −1 0 1 10 10² 10³ 10⁴ 10⁵ 10⁶
30−353 GHz: δT [μK_CMB]; 545 and 857 GHz: surface brightness [kJy/sr]

70 GHz 'Half Ring difference'

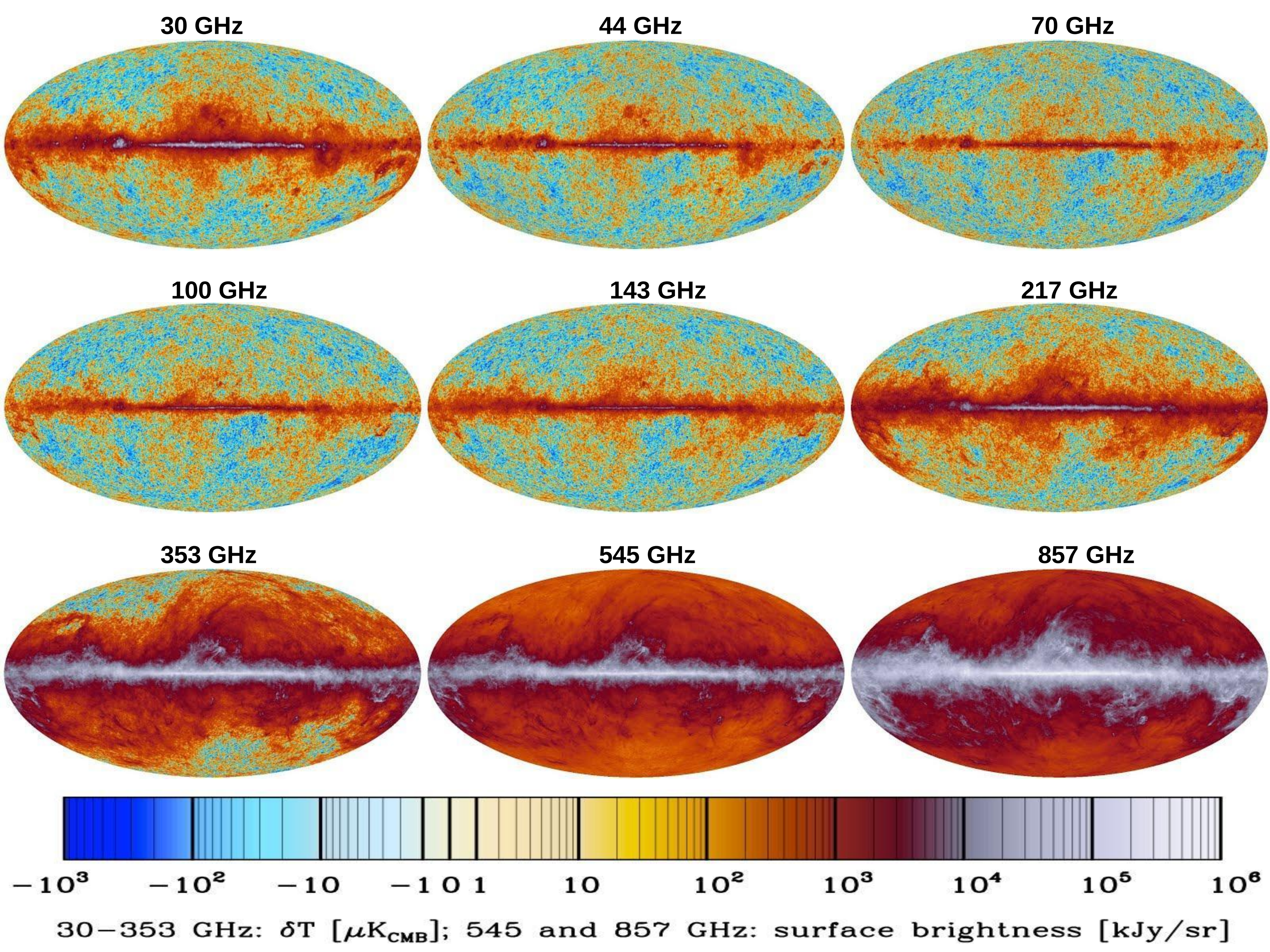
(1 degree smoothing)

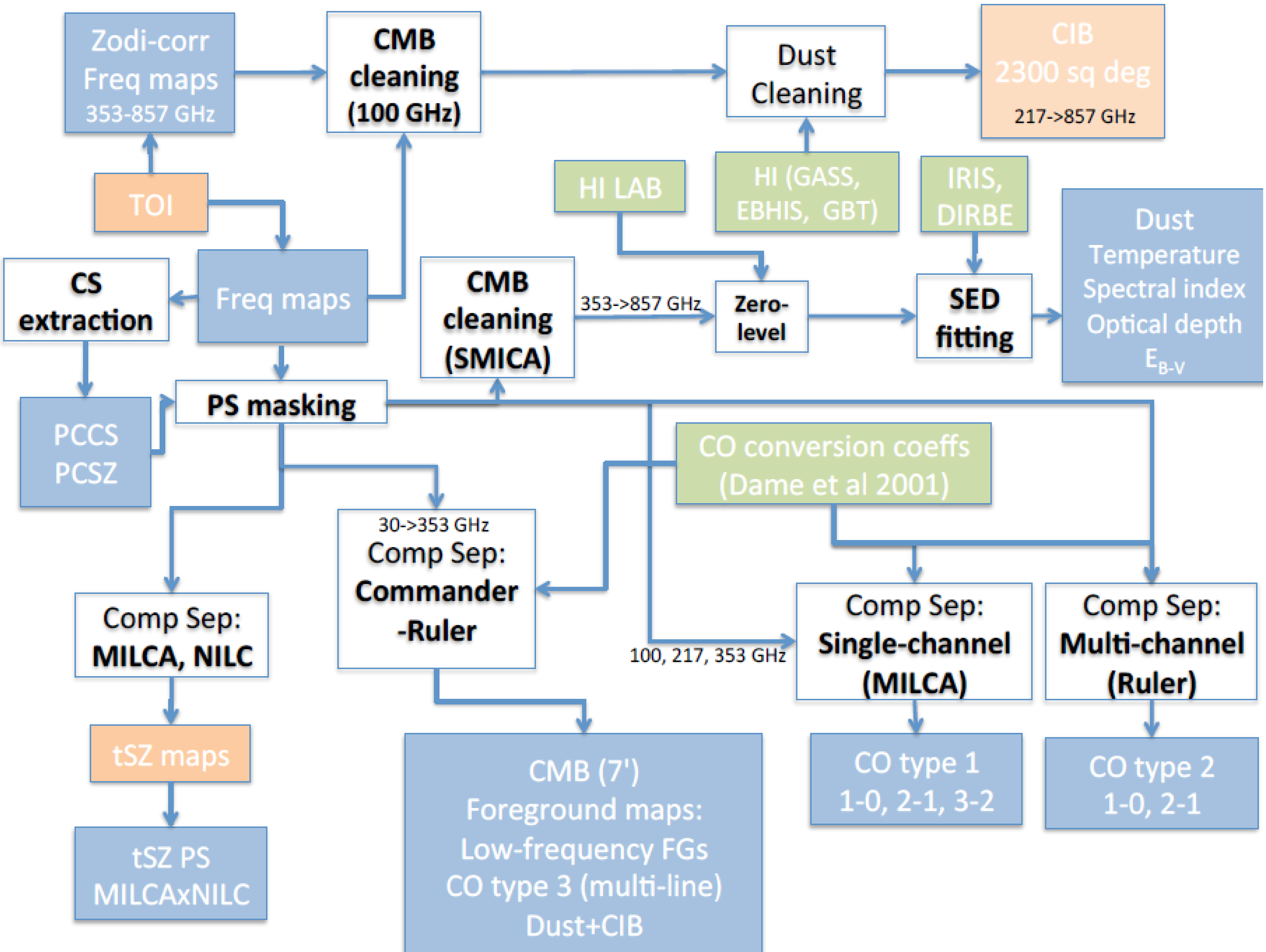


Channel to Channel reproducibility 100 – 70 GHz maps



Andrea Zonca


30 GHz
44 GHz
70 GHz
100 GHz
143 GHz
217 GHz
353 GHz
545 GHz
857 GHz
-10^3 -10^2 -10 -1 0 1 10 10^2 10^3 10^4 10^5 10^6
30–353 GHz: δT [μK_{CMB}]; 545 and 857 GHz: surface brightness [kJy/sr]



Zodi-corr
Freq maps
353-857 GHz
CMB cleaning (100 GHz)
Dust Cleaning
CIB
2300 sq deg
217->857 GHz
TOI
HI LAB
HI (GASS, EBHIS, GBT)
IRIS, DIRBE
CS extraction
Freq maps
CMB cleaning (SMICA)
353->857 GHz
Zero-level
SED fitting
Dust
Temperature
Spectral index
Optical depth
E_{B-V}
PCCS
PCSZ
PS masking
CO conversion coeffs
(Dame et al 2001)
30->353 GHz
Comp Sep:
Commander
-Ruler
Comp Sep:
MILCA, NILC
100, 217, 353 GHz
Comp Sep:
Single-channel
(MILCA)
Comp Sep:
Multi-channel
(Ruler)
tSZ maps
tSZ PS
MILCAxNILC
CMB (7')
Foreground maps:
Low-frequency FGs
CO type 3 (multi-line)
Dust+CIB
CO type 1
1-0, 2-1, 3-2
CO type 2
1-0, 2-1

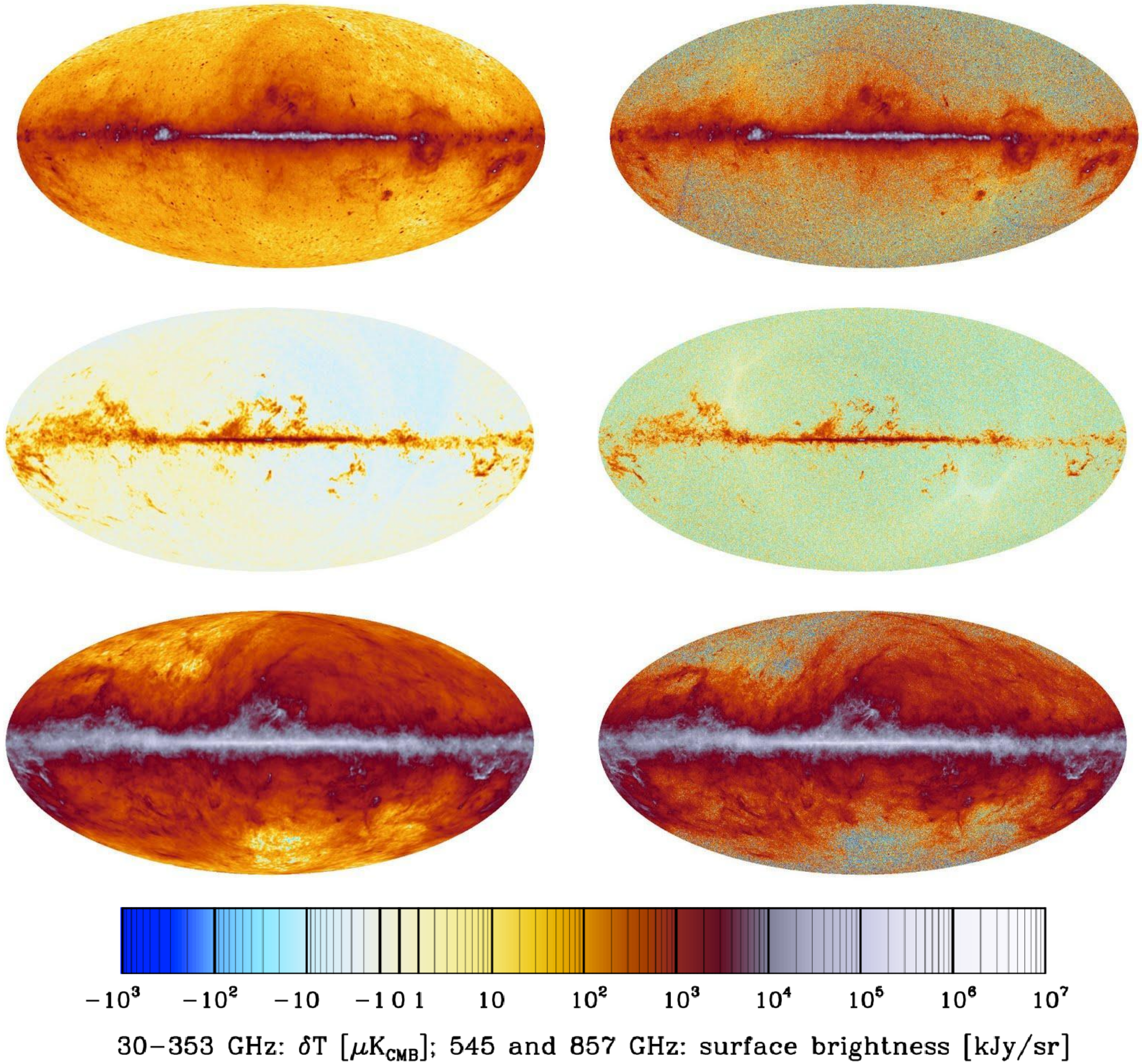
Component Separation

1 deg **7 arcmin**

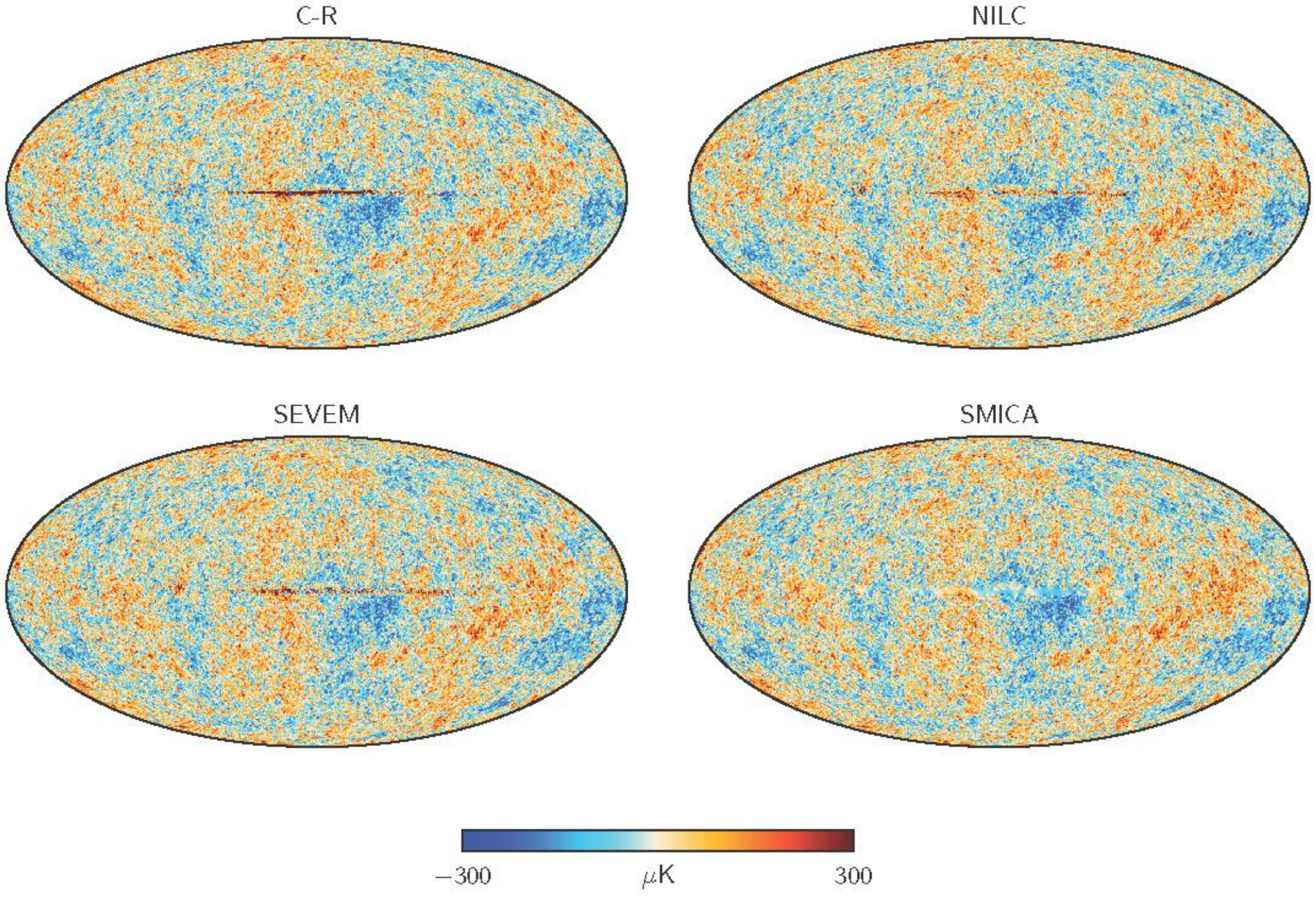
Low Frequency at 30 GHz

CO emission

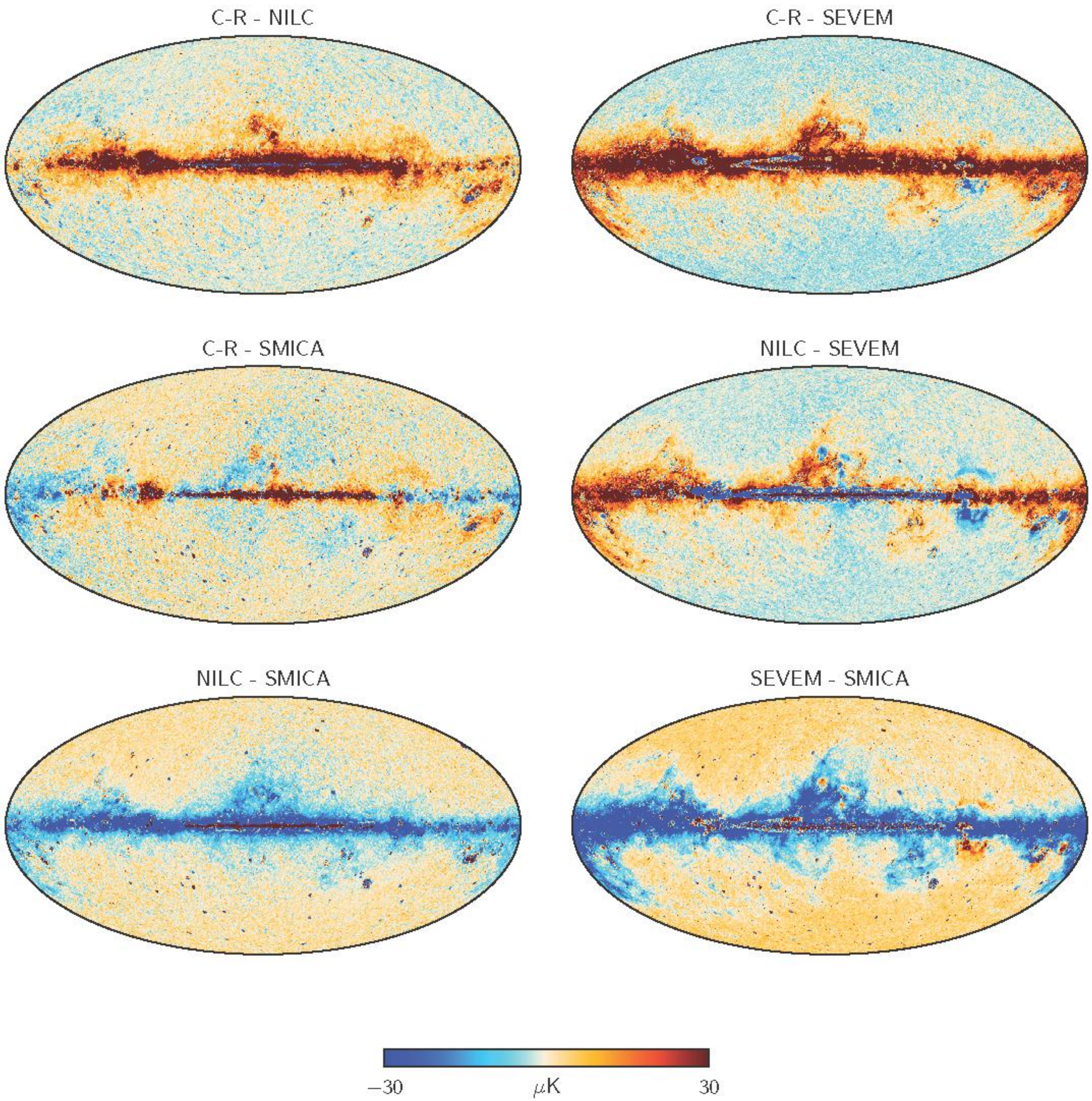
Dust at 353 GHz



Component Separation CMB extraction comparison



Component Separation: Simulation comparison



TT Power Spectra vs Extraction Method
"All PS assume random phase by design"

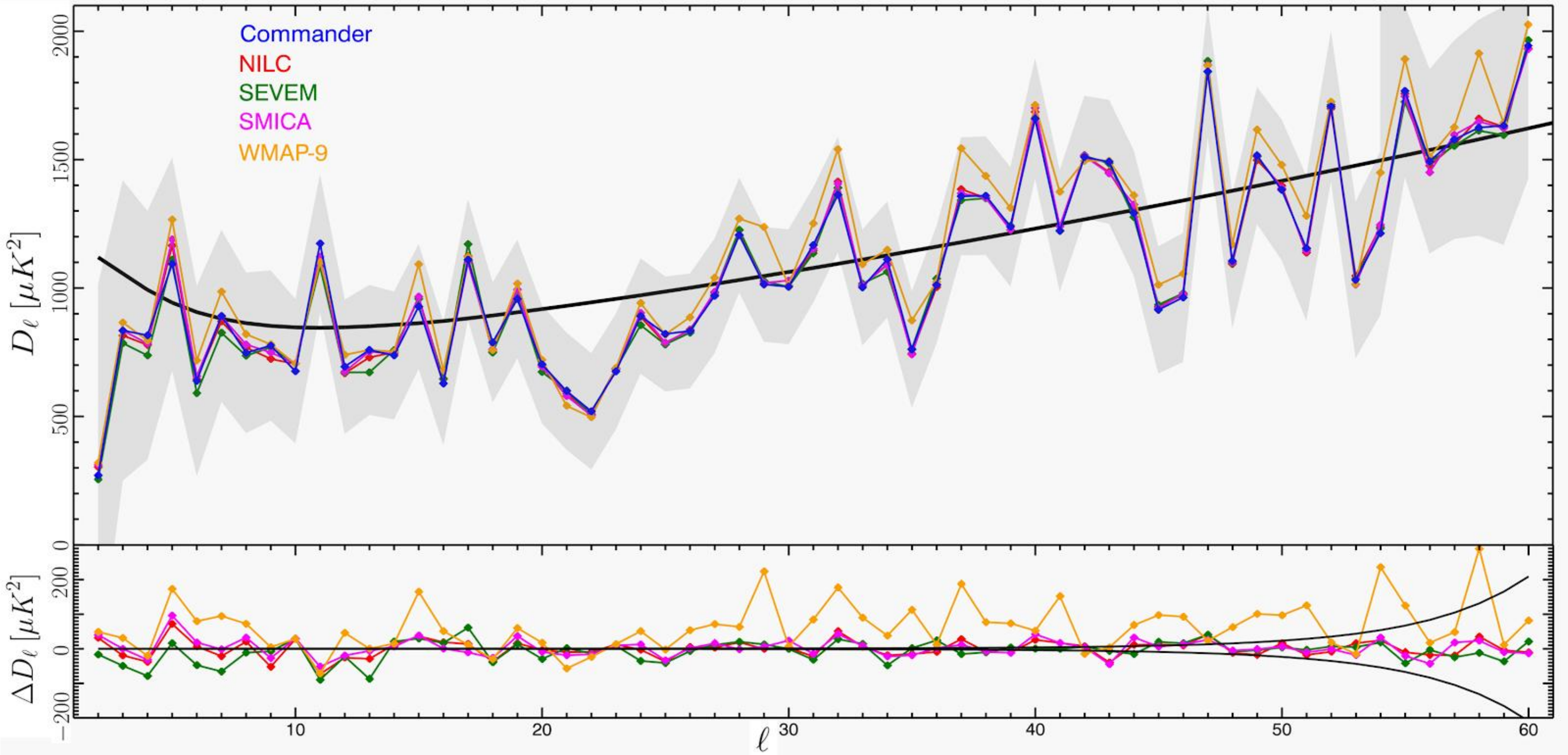
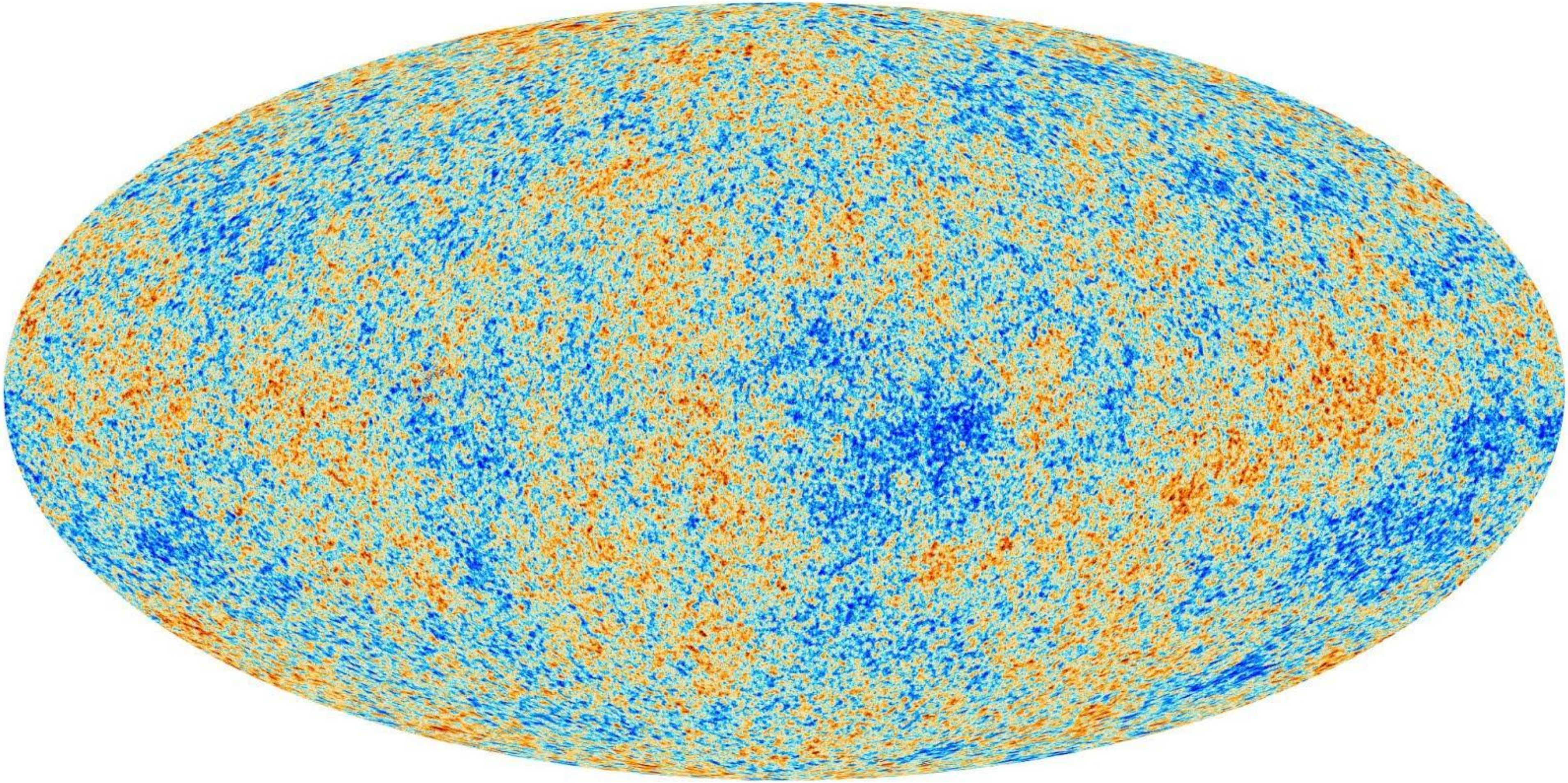


Fig. 14. Top panel: temperature power spectra evaluated from downgraded *Planck* maps, estimated with `Commander`, `NILC`, `SEVEM`, or `SMICA`, and the 9-year *WMAP* ILC map, using the `Bolpol` quadratic estimator. The grey shaded area indicates the 1 σ Fisher errors while the solid line shows the *Planck* ΛCDM best fit model. Bottom panel: Power spectrum differences for each algorithm/data set relative to the `Commander` spectrum, estimated from the spectra shown in the panel above. The black lines show the expected 1 σ uncertainty due to (regularization) noise.

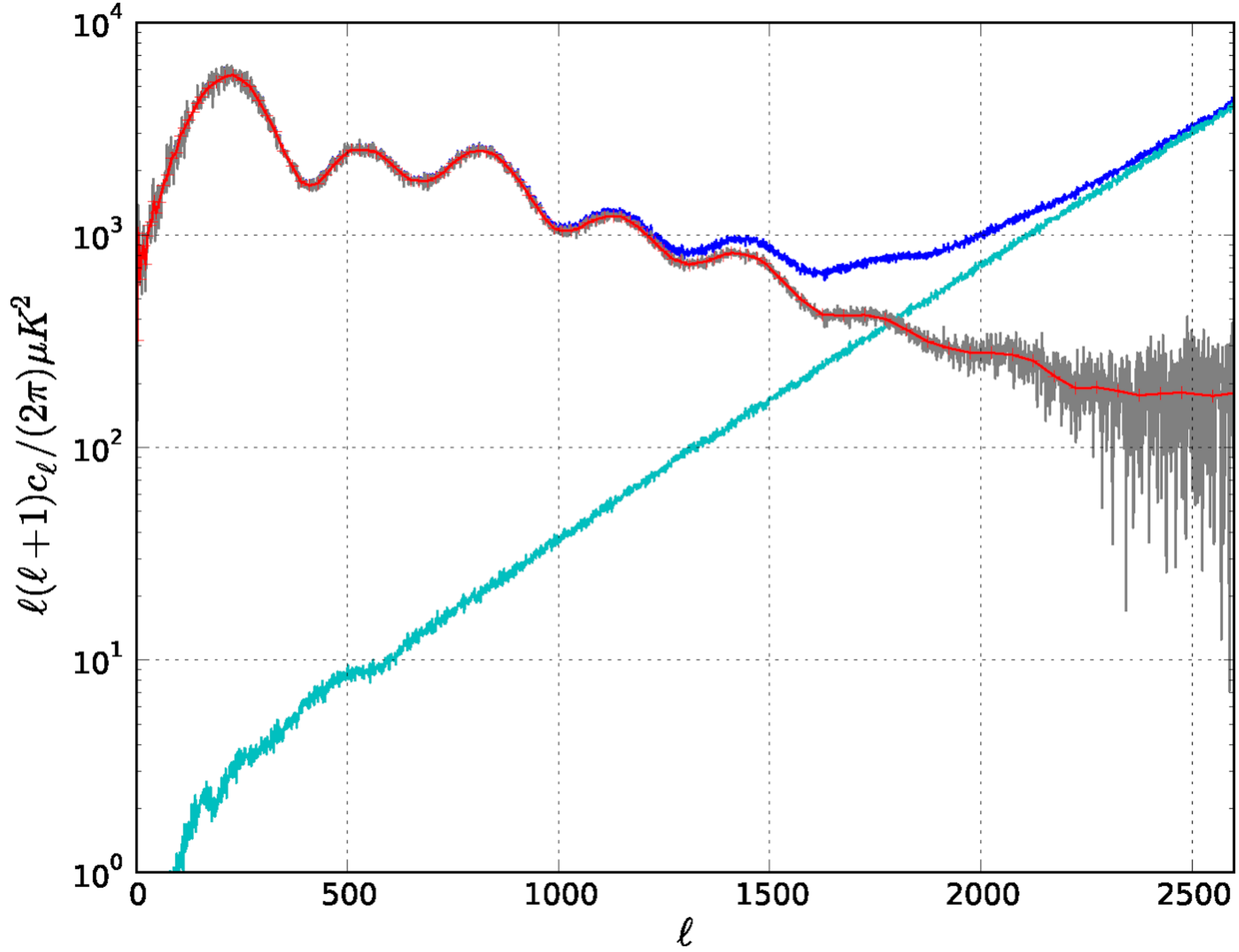
Foreground removed CMB



Sample Power Spectrum

Foreground removed CMB ("SMICA" code):

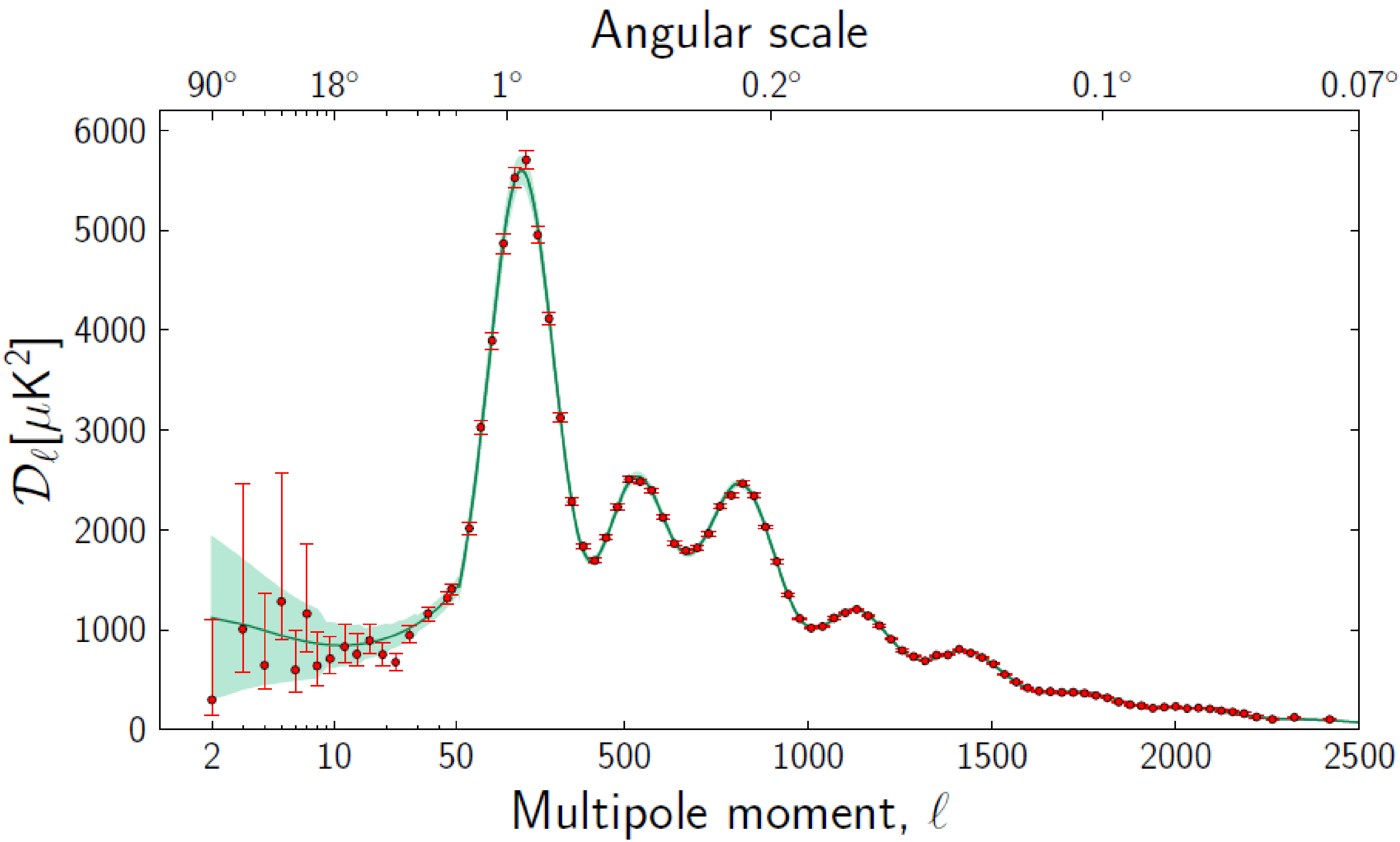
Dark Blue from map, Cyan from “half rings”, Grey – difference, Red is binned



TT Power Spectra – 7 peaks resolved

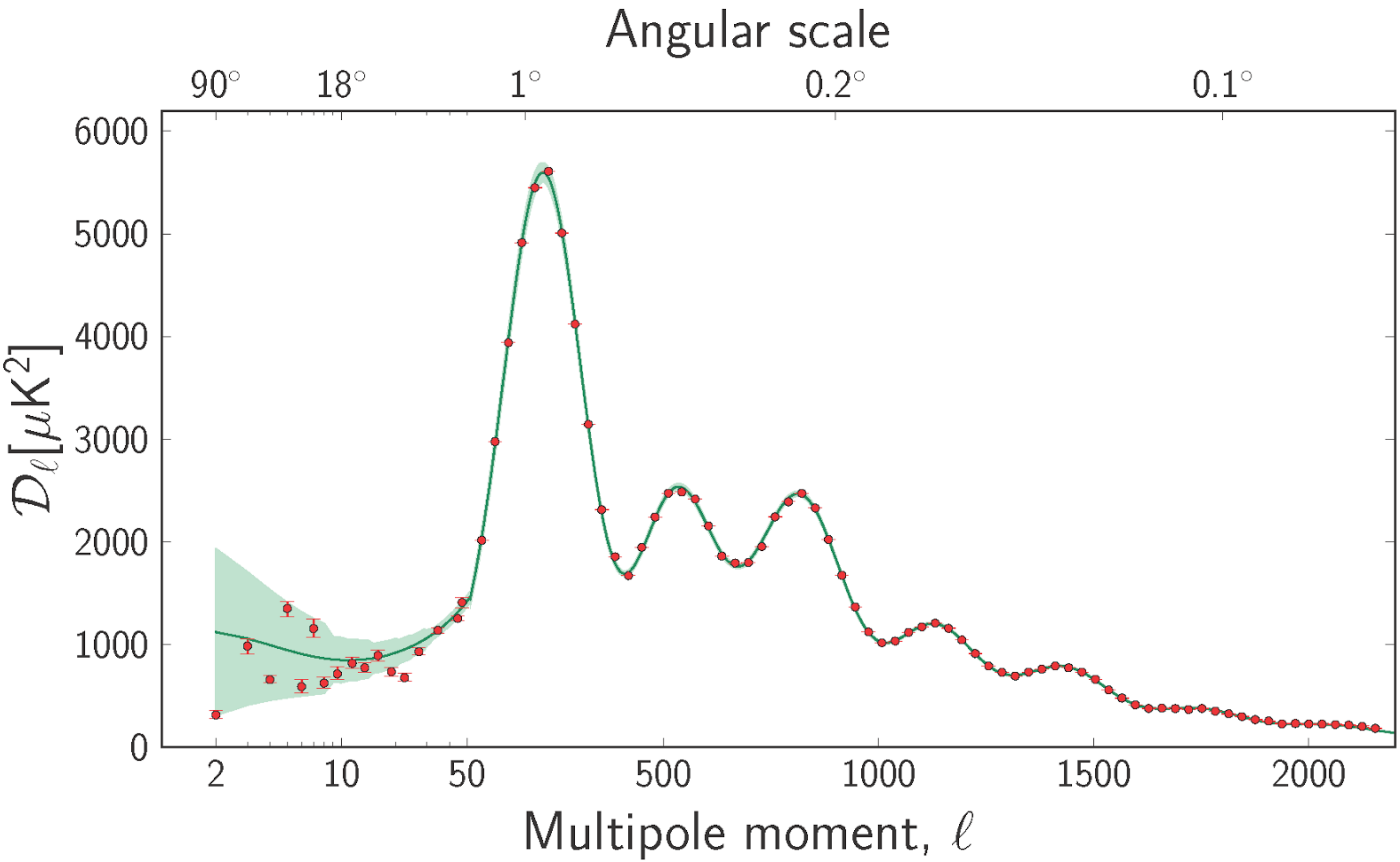
Error bars include SV and CV

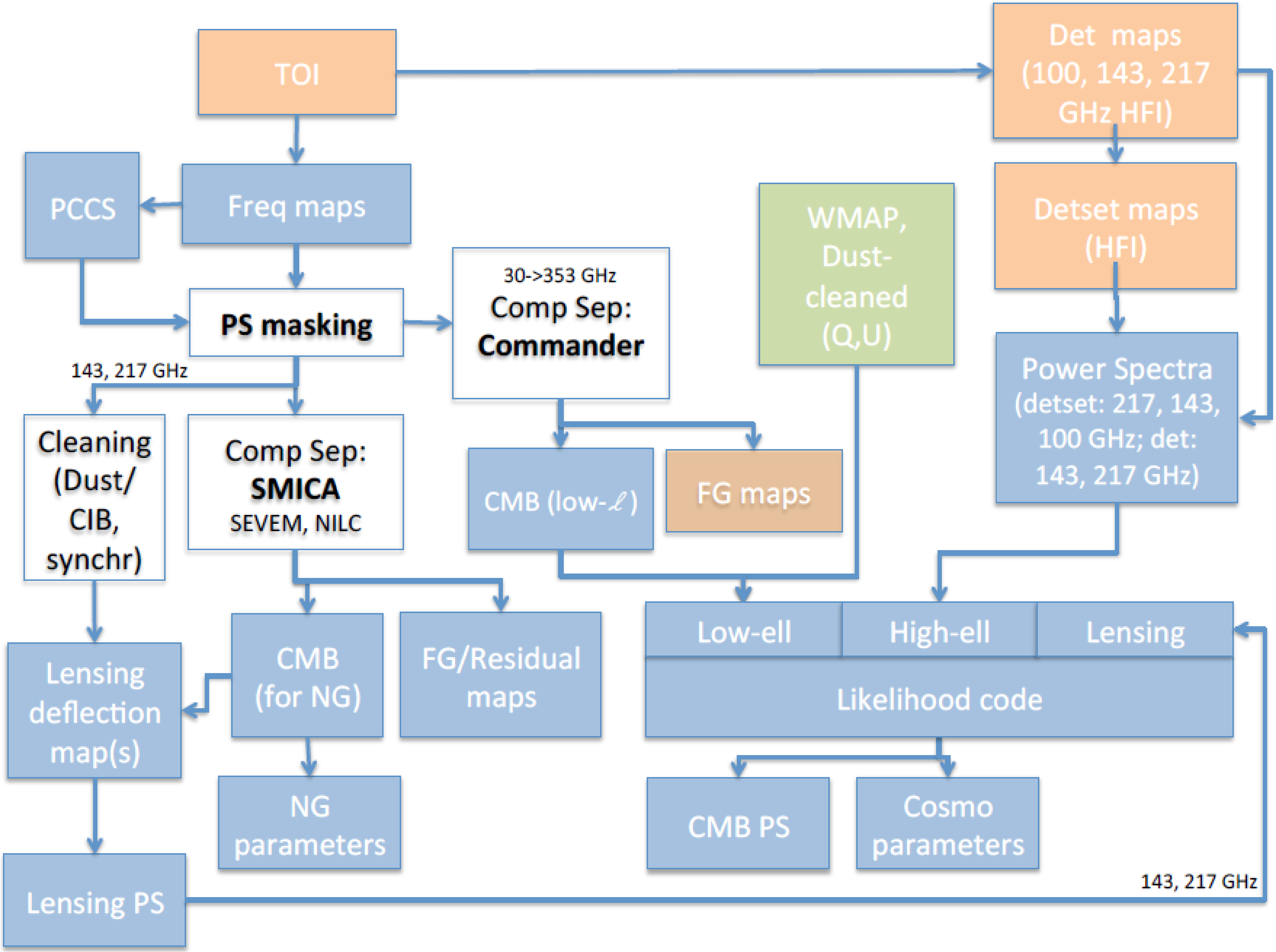
Note low quadrupole



TT Power Spectra

Error bars without SV and CV

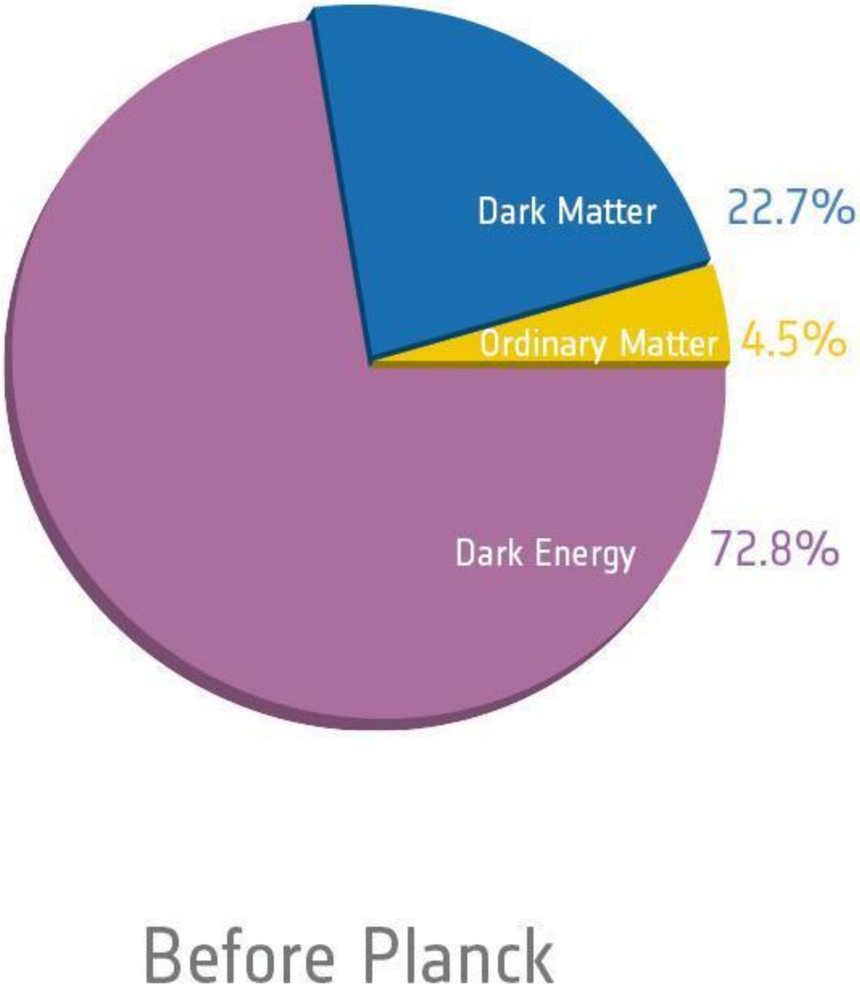


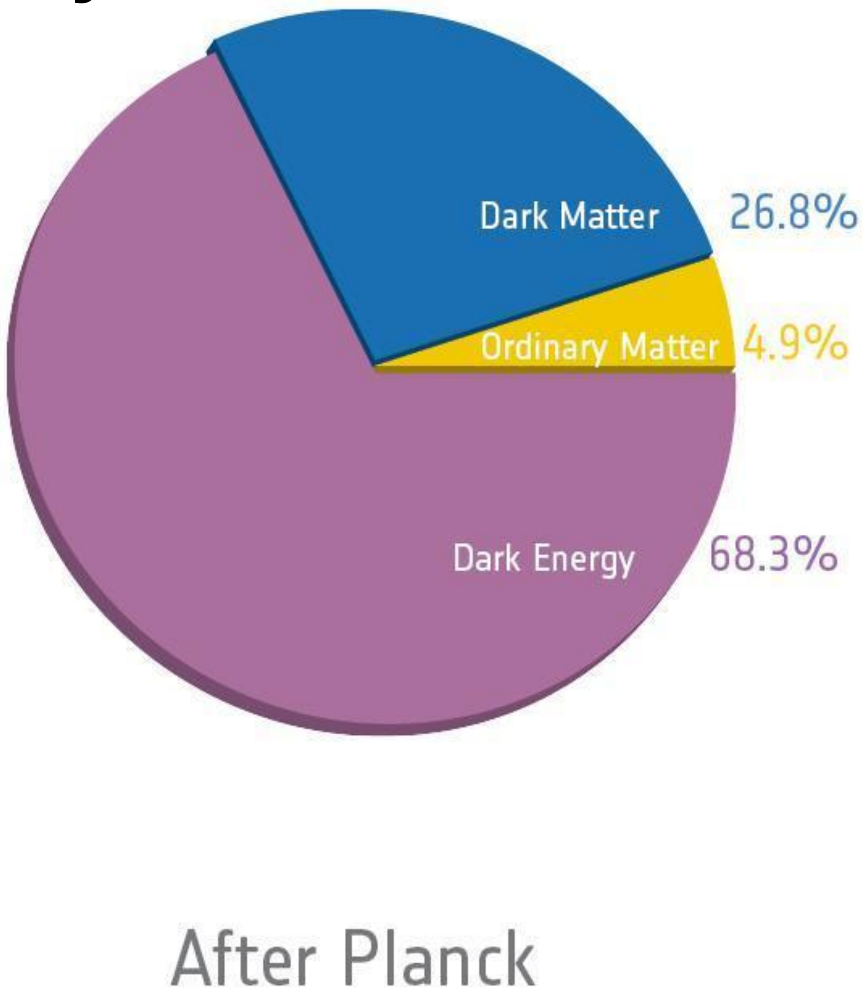


TOI
Det maps (100, 143, 217 GHz HFI)
PCCS
Freq maps
Detset maps (HFI)
WMAP, Dust-cleaned (Q,U)
PS masking
30->353 GHz
Comp Sep: Commander
143, 217 GHz
Power Spectra (detset: 217, 143, 100 GHz; det: 143, 217 GHz)
Cleaning (Dust/ CIB, synchr)
Comp Sep: SMICA
SEVEM, NILC
CMB (low-ℓ)
FG maps
Low-ell
High-ell
Lensing
Likelihood code
Lensing deflection map(s)
CMB (for NG)
FG/Residual maps
NG parameters
CMB PS
Cosmo parameters
143, 217 GHz
Lensing PS

Parameter	*Planck* (CMB+lensing)		*Planck*+WP+highL+BAO	
	Best fit	68 % limits	Best fit	68 % limits
$\Omega_b h^2$	0.022242	0.02217 ± 0.00033	0.022161	0.02214 ± 0.00024
$\Omega_c h^2$	0.11805	0.1186 ± 0.0031	0.11889	0.1187 ± 0.0017
$100\theta_{MC}$	1.04150	1.04141 ± 0.00067	1.04148	1.04147 ± 0.00056
τ	0.0949	0.089 ± 0.032	0.0952	0.092 ± 0.013
n_s	0.9675	0.9635 ± 0.0094	0.9611	0.9608 ± 0.0054
$\ln(10^{10} A_s)$	3.098	3.085 ± 0.057	3.0973	3.091 ± 0.025
Ω_Λ	0.6964	0.693 ± 0.019	0.6914	0.692 ± 0.010
Ω_m	0.3036	0.307 ± 0.019		
σ_8	0.8285	0.823 ± 0.018	0.8288	0.826 ± 0.012
z_{re}	11.45	$10.8^{+3.1}_{-2.5}$	11.52	11.3 ± 1.1
H_0	68.14	67.9 ± 1.5	67.77	67.80 ± 0.77
$10^9 A_s$	2.215	$2.19^{+0.12}_{-0.14}$		
$\Omega_m h^2$	0.14094	0.1414 ± 0.0029		
$\Omega_m h^3$	0.09603	0.09593 ± 0.00058		
Y_P	0.247785	0.24775 ± 0.00014		
Age/Gyr	13.784	13.796 ± 0.058	13.7965	13.798 ± 0.037
z_*	1090.01	1090.16 ± 0.65		
r_*	144.58	144.96 ± 0.66		
$100\theta_*$	1.04164	1.04156 ± 0.00066	1.04163	1.04162 ± 0.00056
z_{drag}	1059.59	1059.43 ± 0.64		
r_{drag}	147.74	147.70 ± 0.63	147.611	147.68 ± 0.45
k_D	0.13998	0.13996 ± 0.00062		
$100\theta_D$	0.161196	0.16129 ± 0.00036		
z_{eq}	3352	3362 ± 69		
$100\theta_{eq}$	0.8224	0.821 ± 0.013		
$r_{drag}/D_V(0.57)$	0.07207	0.0719 ± 0.0011		

CMB only estimates
Planck >> DM +18%, Baryons +9%, DE -6%





Philip Lubin

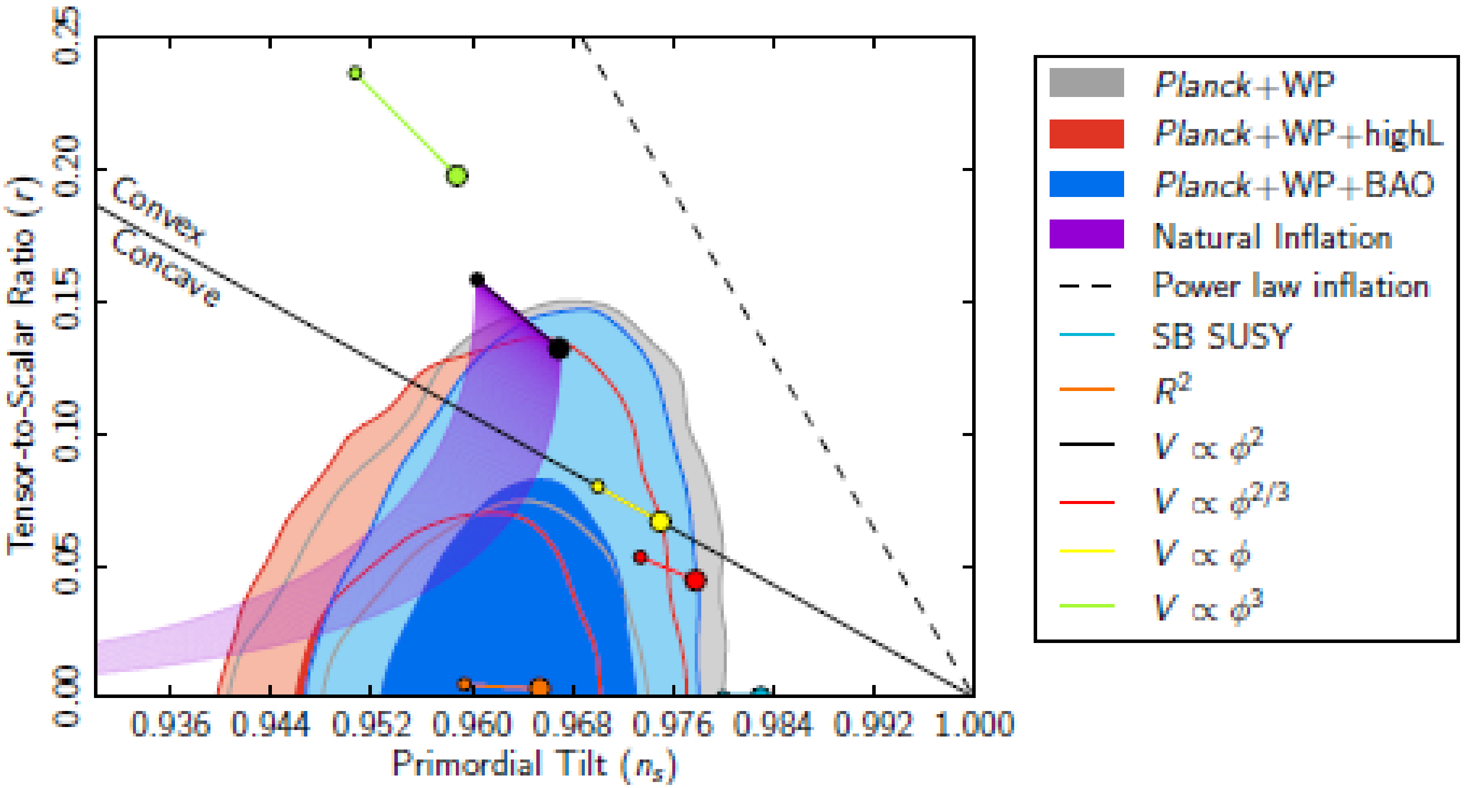
Marginalized n_s and r (1,2σ)

n_s does not equal 1

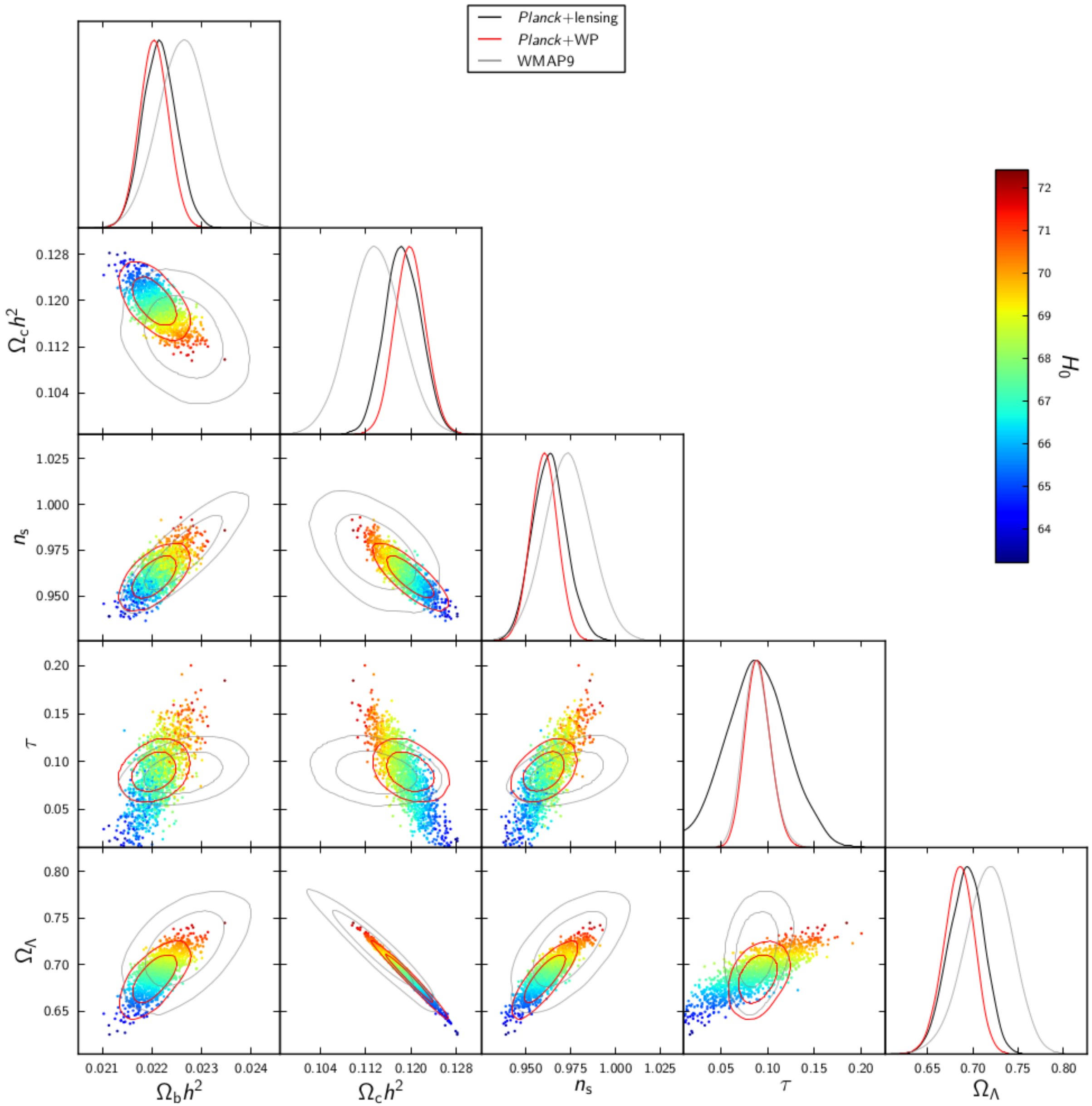
r<0.11 (2 σ) from T alone

Energy scale for “standard inflation” <1.9x10^{16} Gev (2 σ)

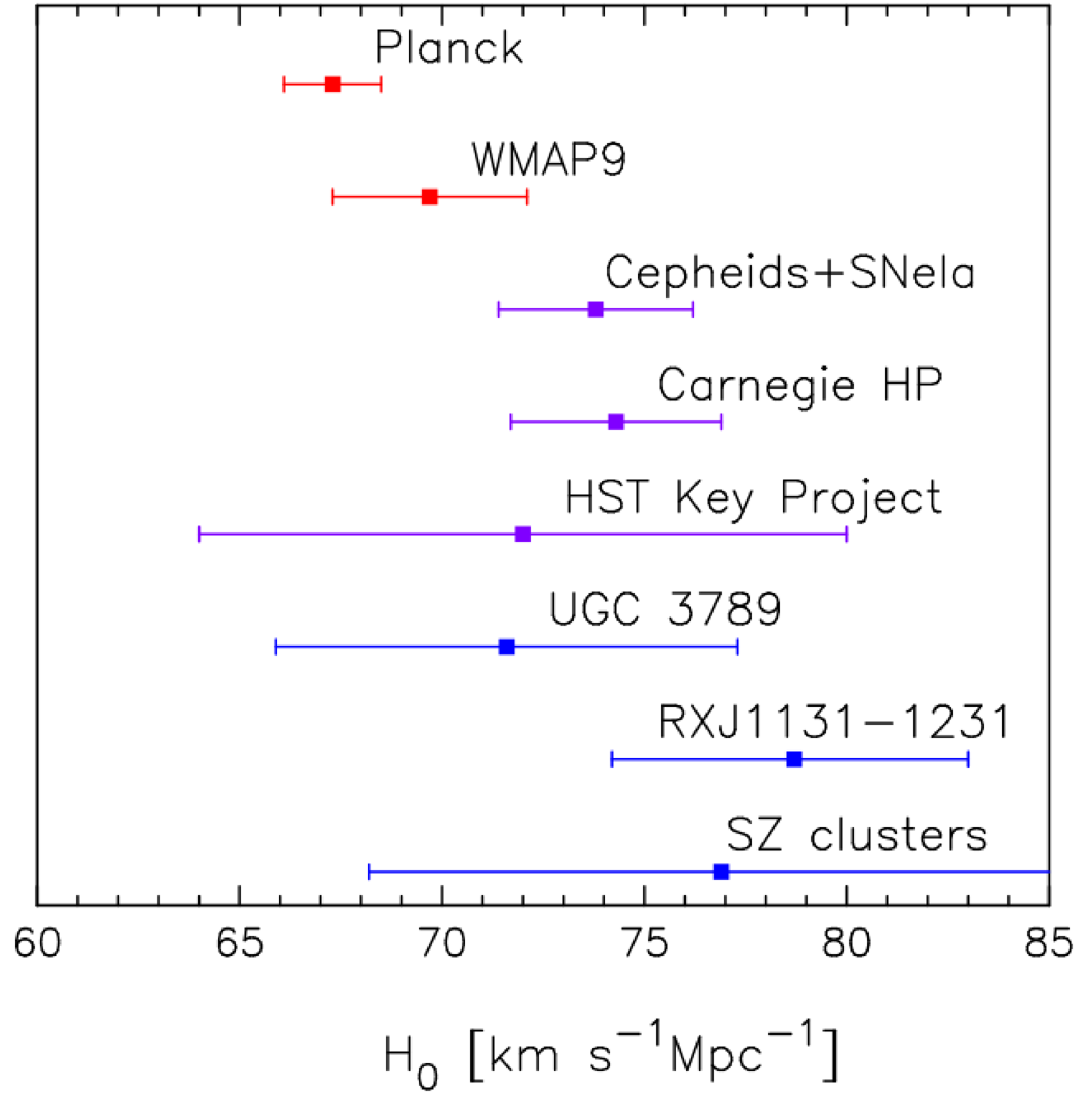
Wait for Planck polarization next year



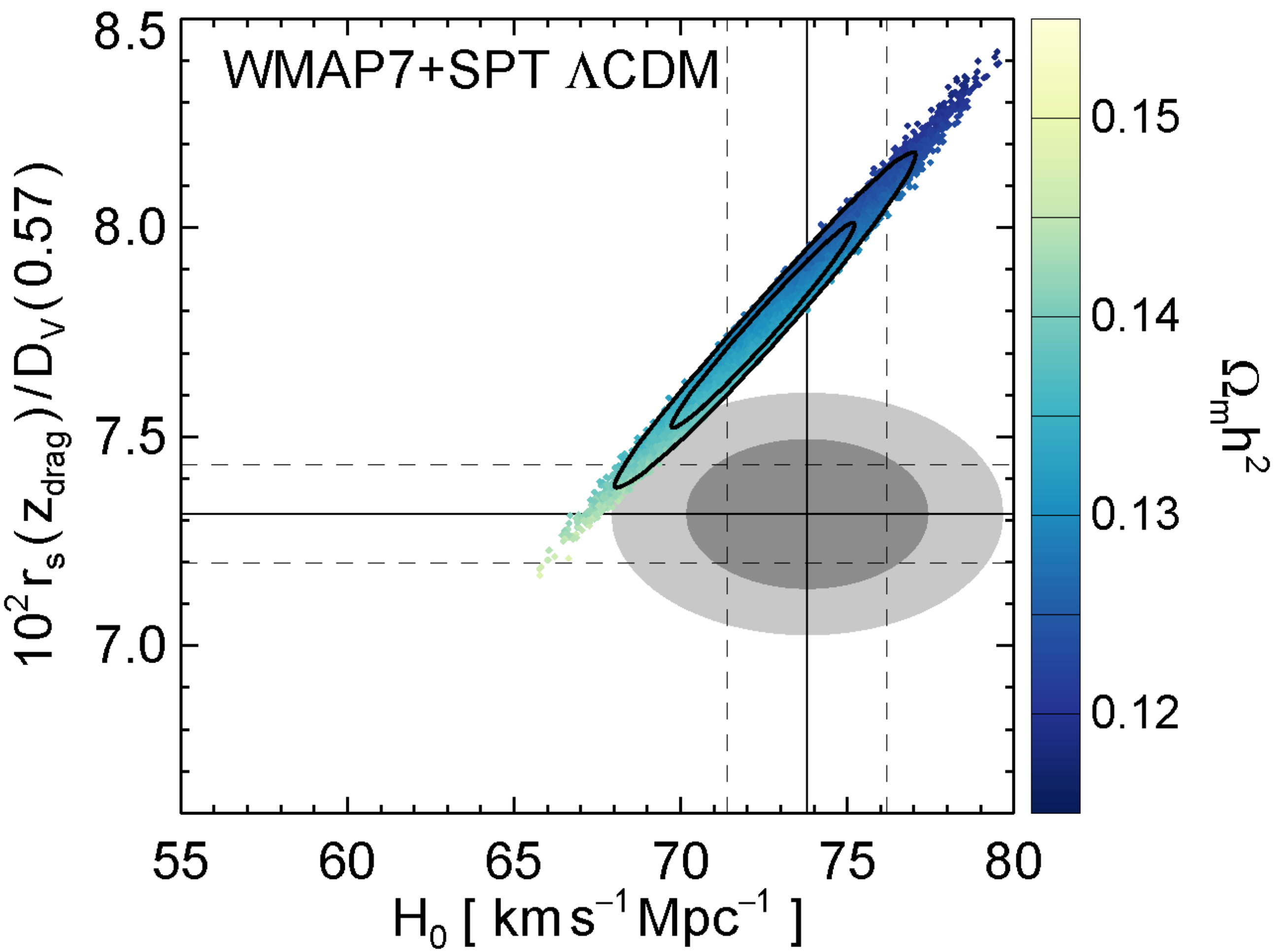
Selected parameters



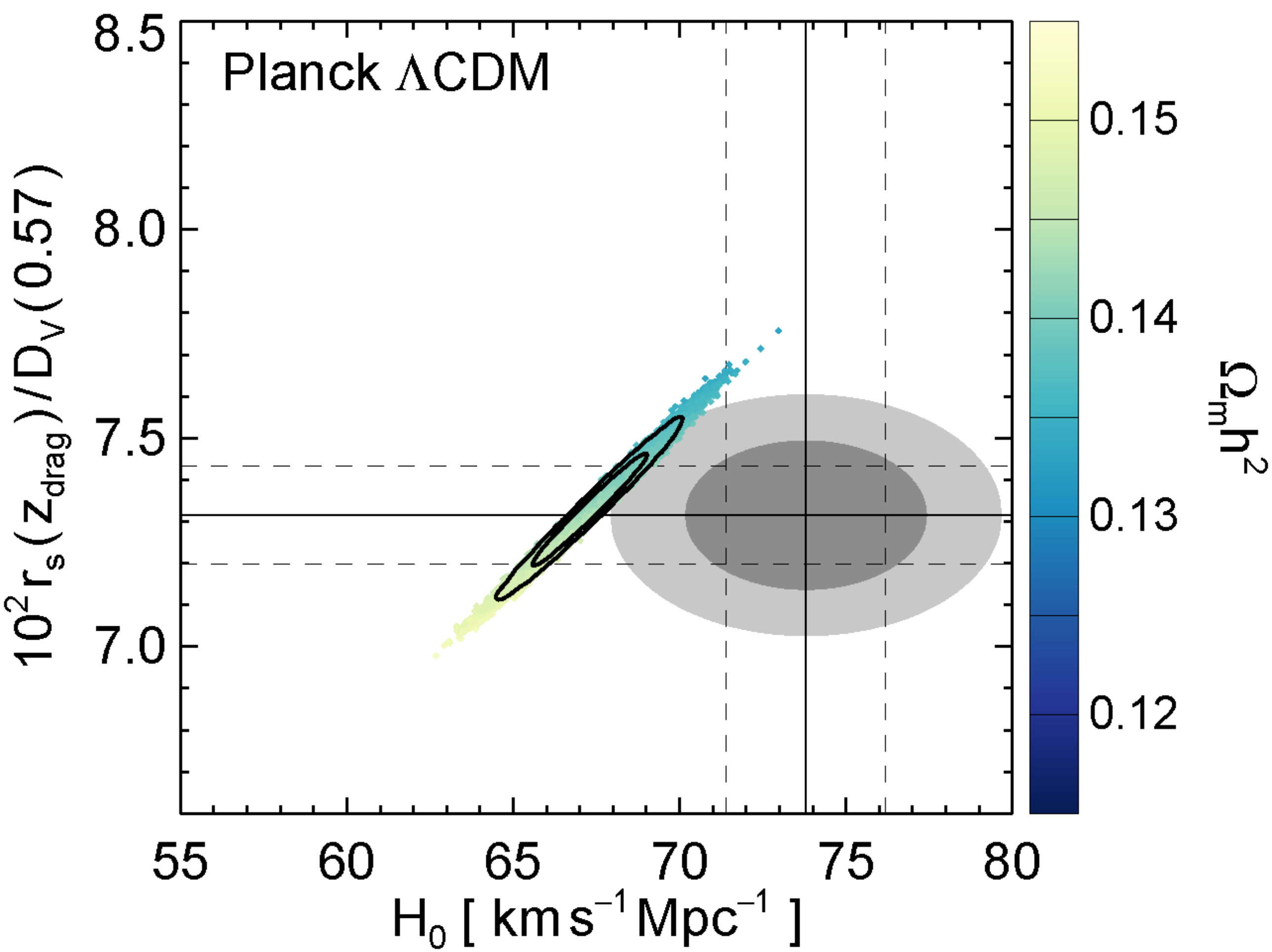
Measures of H_0



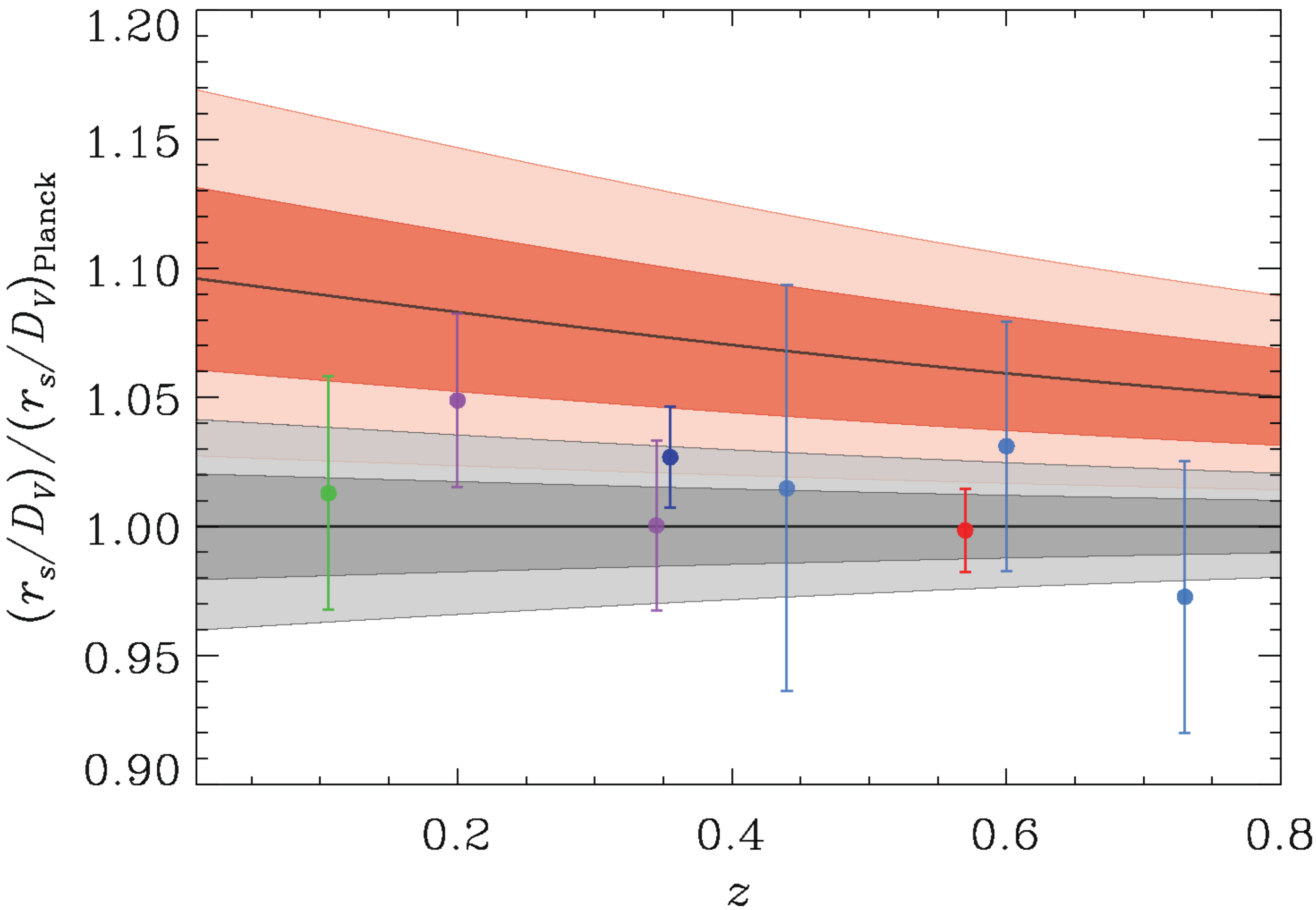
WMAP Inconsistency with Baryon Acoustic Oscillations (BAO)
Seljak last week colloq - new Physics?



Planck Consistency with Baryon Acoustic Oscillations (BAO) IF H is lower



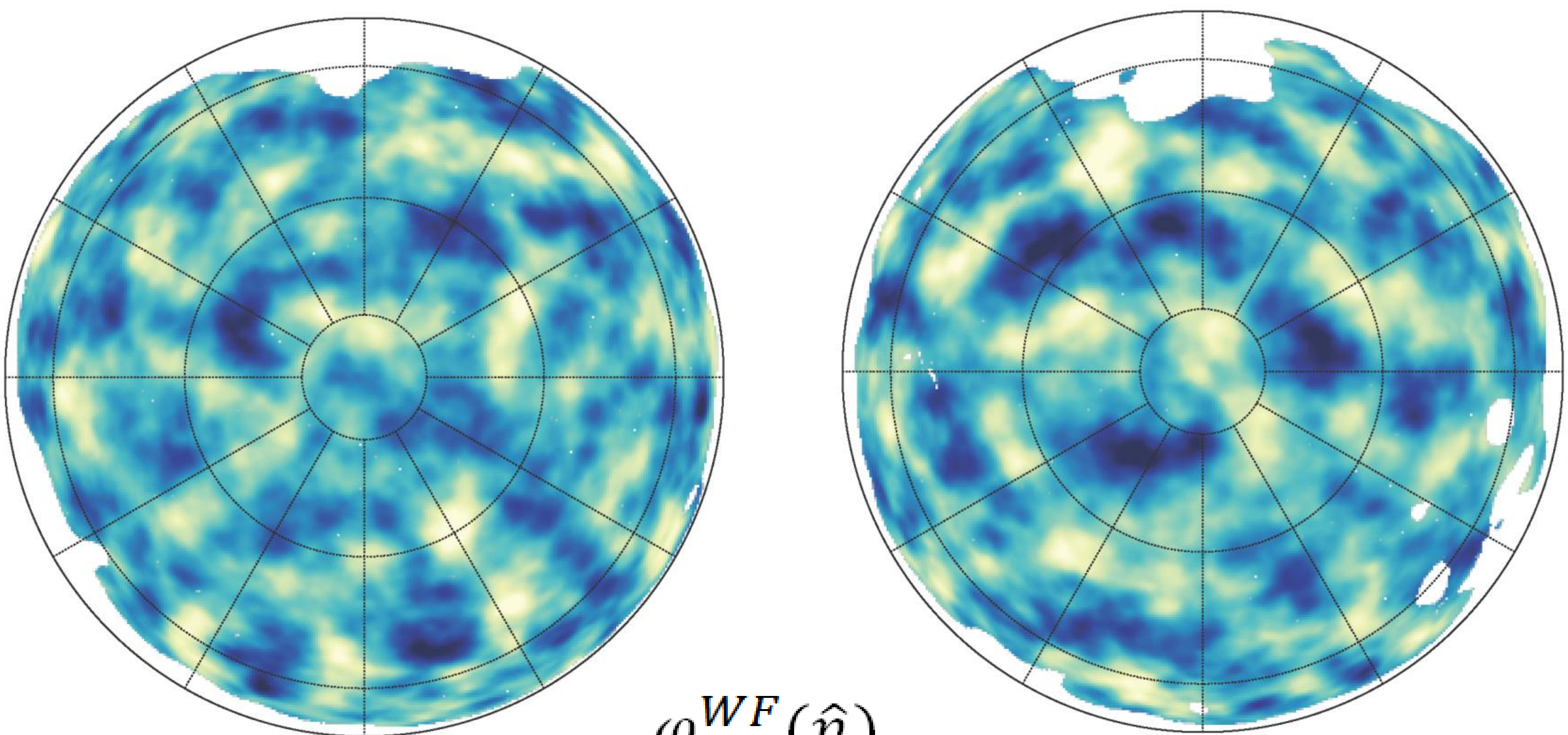
Consistency with Baryon Acoustic Oscillations (BAO) 3



Lensing Potential Measured

High Significance (25 sigma)

Mode by mode SNR ~ 0.7 at L=30

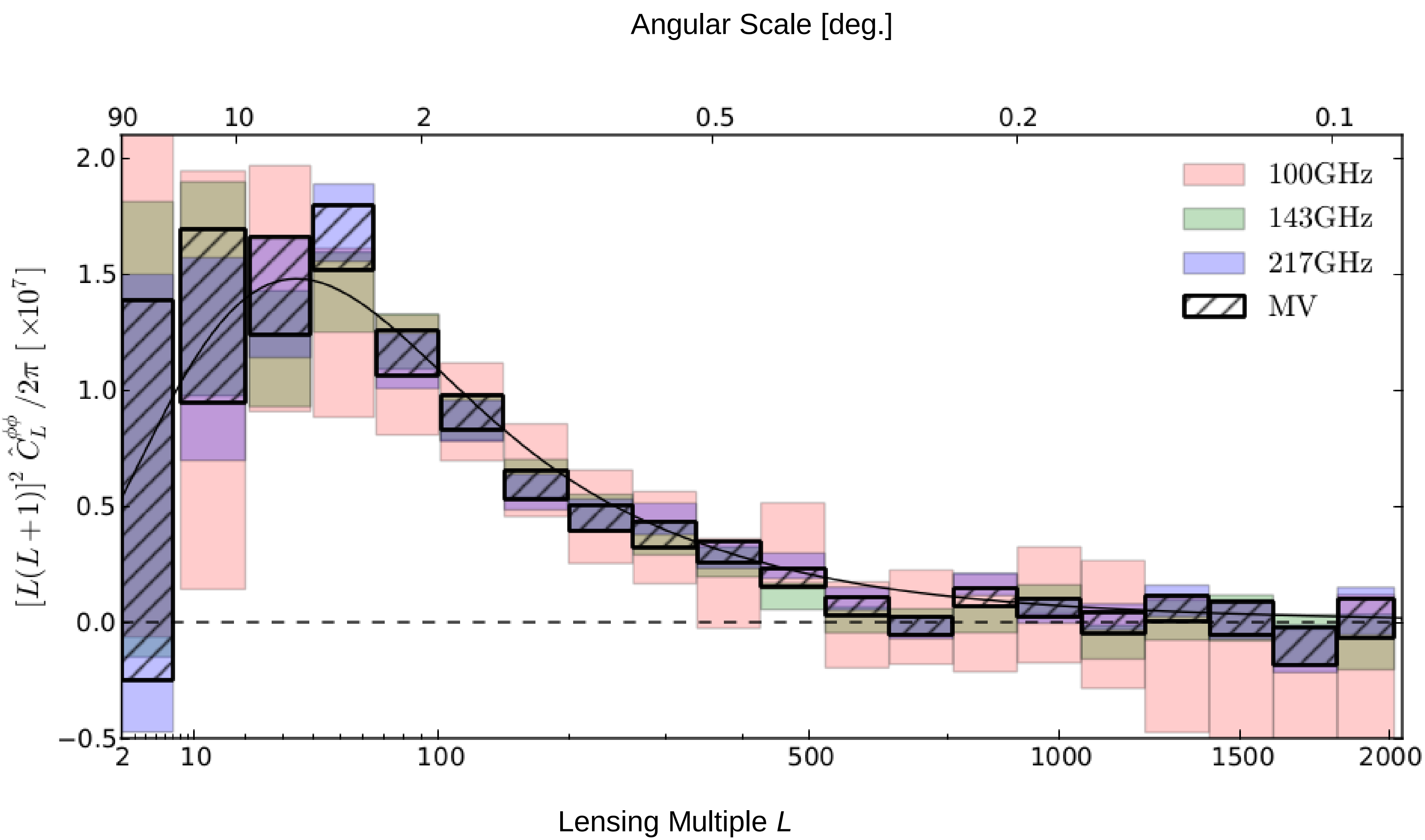


$\varphi^{WF}(\hat{n})$

Galactic North

Galactic South

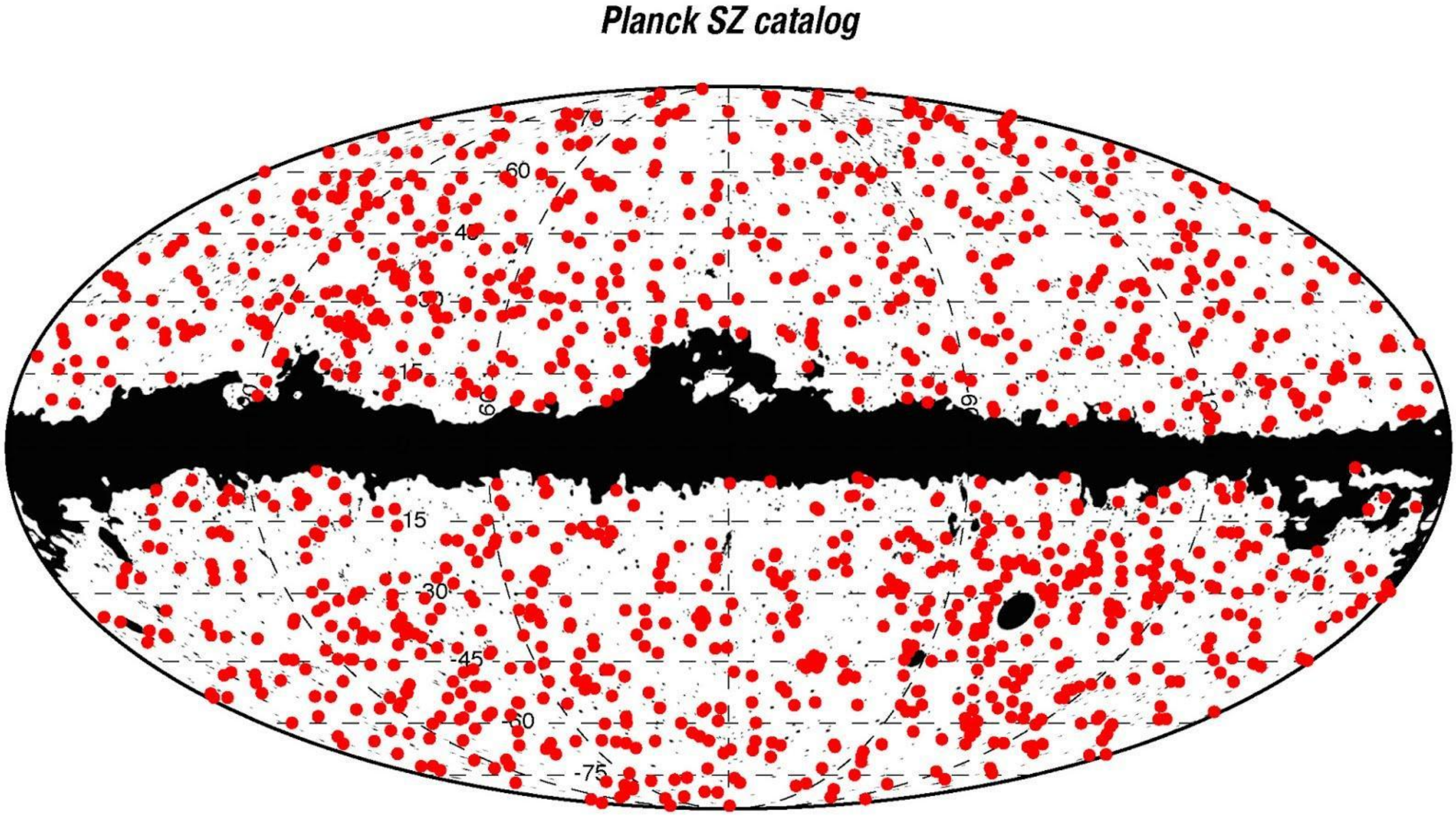
Lensing Power Spectra



Point Sources

Characteristic	30	44	70	100	143	217	353	545	857
	Channel [GHz]								
Frequency [GHz]	28.4	44.1	70.4	100.0	143.0	217.0	353.0	545.0	857.0
Wavelength [μm]	10561	6807	4260	3000	2098	1382	850	550	350
Beam FWHM [arcmin]	32.38	27.10	13.30	9.65	7.25	4.99	4.82	4.68	4.33
S/N threshold									
Full sky	4.0	4.0	4.0	4.6	4.7	4.8	...	...	...
Extragactic zone[b]	...	...	...	...	...	...	4.9	4.7	4.9
Galactic zone[b]	...	...	...	...	...	...	6.0	7.0	7.0
Number of sources									
Full sky	1256	731	939	3850	5675	16070	13613	16933	24381
$\vert b\vert > 30^\circ$	572	258	332	845	1051	1901	1862	3738	7536
Flux densities									
Minimum[c] [mJy]	461	825	566	266	169	149	289	457	658
90 % completeness [mJy]	575	1047	776	300	190	180	330	570	680
Uncertainty [mJy]	109	198	149	61	38	35	69	118	166
Position uncertainty[d] [arcmin]	1.8	2.1	1.4	1.0	0.7	0.7	0.8	0.5	0.4

1227 SZ Sources



Planck SZ Sources compared to external data sets

Category	N	n		Source
Previously known	**683**			
from:		472	X-ray:	MCXC meta-catalogue
		182	Optical:	Abell, Zwicky, SDSS
		16	SZ:	SPT, ACT
		13	Misc:	NED & SIMBAD
New confirmed	**178**			XMM, ENO, WFI, NTT, AMI, SDSS
New candidate	**366**			
reliability:		54	High	
		170	Medium	
		142	Low	
Total *Planck* SZ catalogue	**1227**			

Non Gaussianity
(K. Smith 2011)

"Local non-Gaussianity"

Primordial non-Gaussianity defined by:

$$\Phi(\mathbf{x}) = \Phi_G(\mathbf{x}) + f_{NL}(\Phi_G(\mathbf{x})^2 - \langle \Phi_G^2 \rangle)$$

Possible mechanisms:

- curvaton scenario (spectator field during inflation subsequently dominates energy density)
- models with variable inflaton decay rate
- models with modulated reheating
- multifield ekpyrotic models (e.g. "New Ekpyrosis")

WMAP constraint: $f_{NL} = 32 \pm 21 \ (1\sigma)$

(Smith, Senatore & Zaldarriaga 2009; Komatsu, Smith et al 2010)

Single-field slow-roll inflation predicts $f_{NL} = \frac{5}{12}(1 - n_s) \approx 0.017$ (Maldacena 2002)

Conversely, detection of $f_{NL} \gtrsim \mathcal{O}(10^{-2})$ would rule out all single-field models of inflation (Maldacena 2002; Creminelli et al 2004)

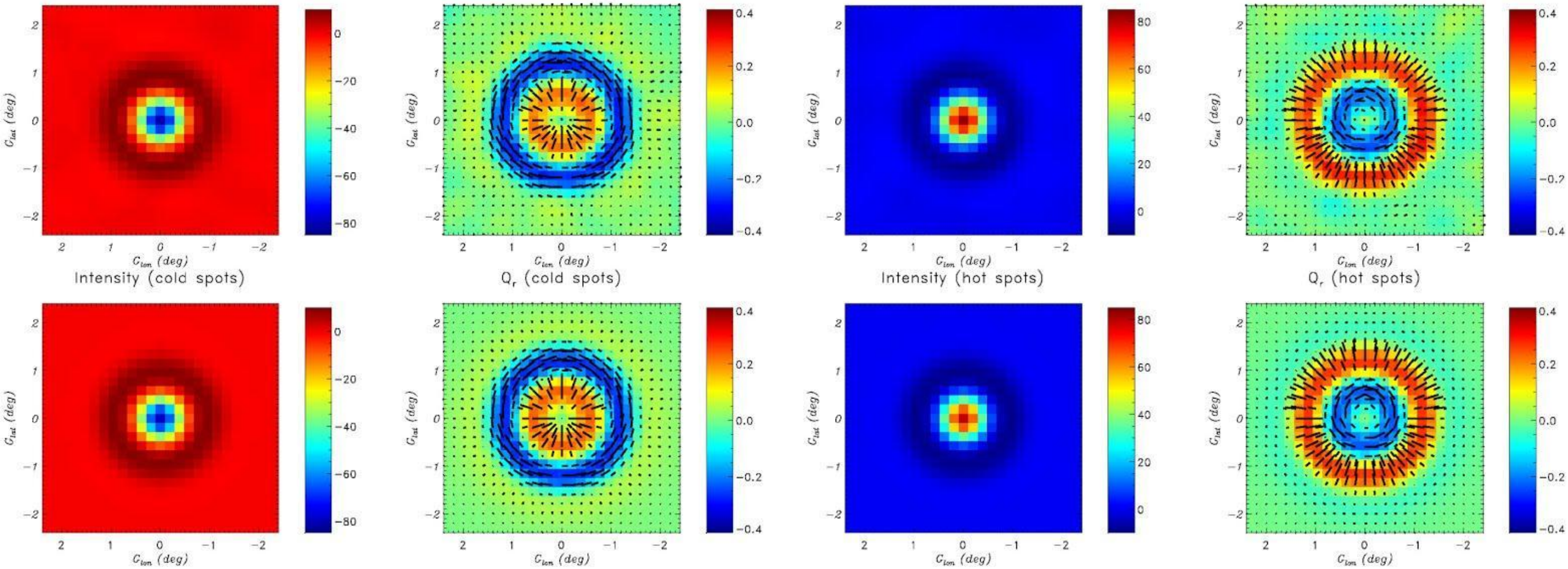
f_{NL} (Limits so far)

f_{NL}		
Local	Equilateral	Orthogonal
2.7 ± 5.8	-42 ± 75	-25 ± 39

Planck polarization at Extrema T and Q

Left – cold spots , Right – hot spots

Top -data, bottom - Best fit model prediction



Lensing deflection and CIB

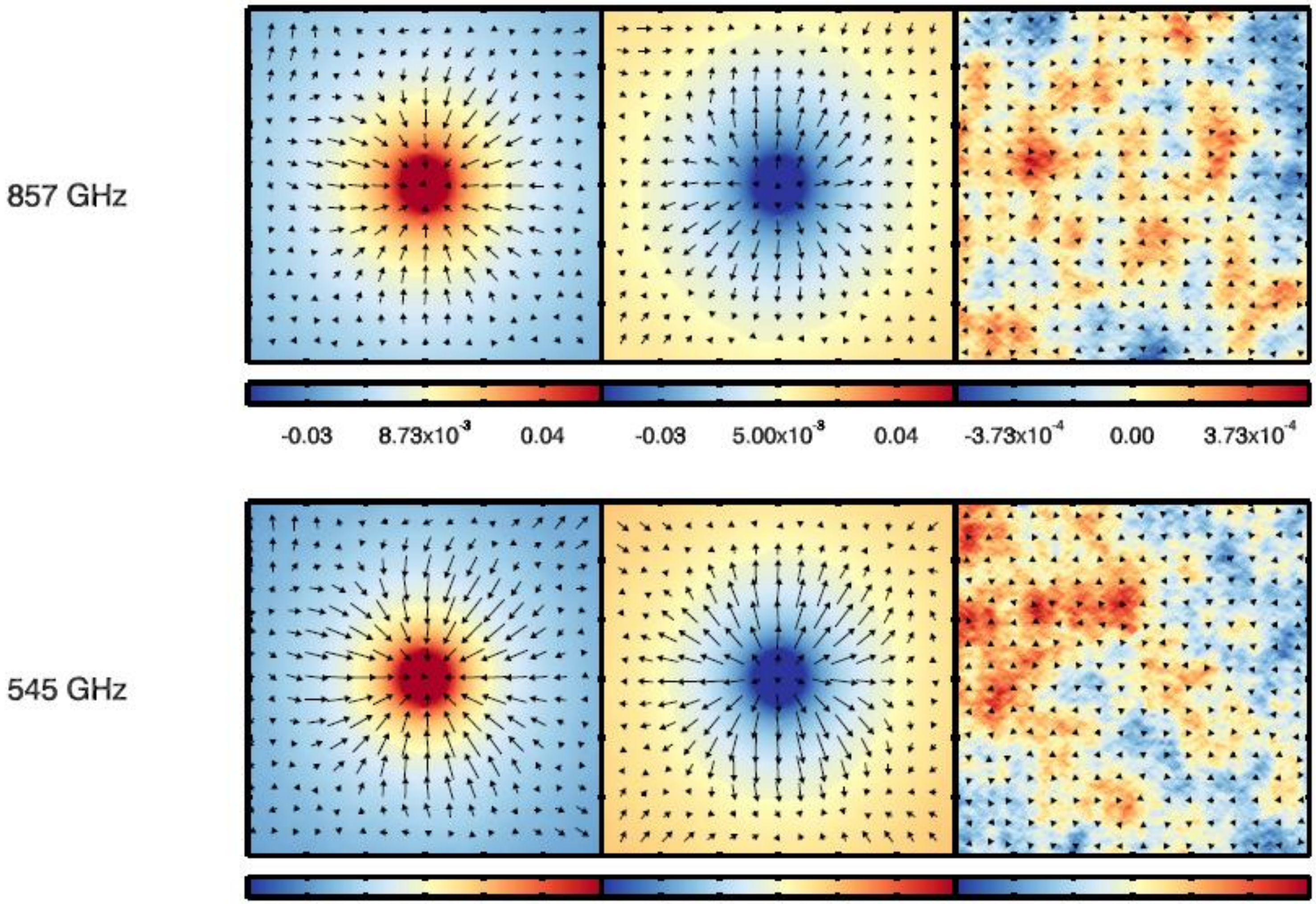
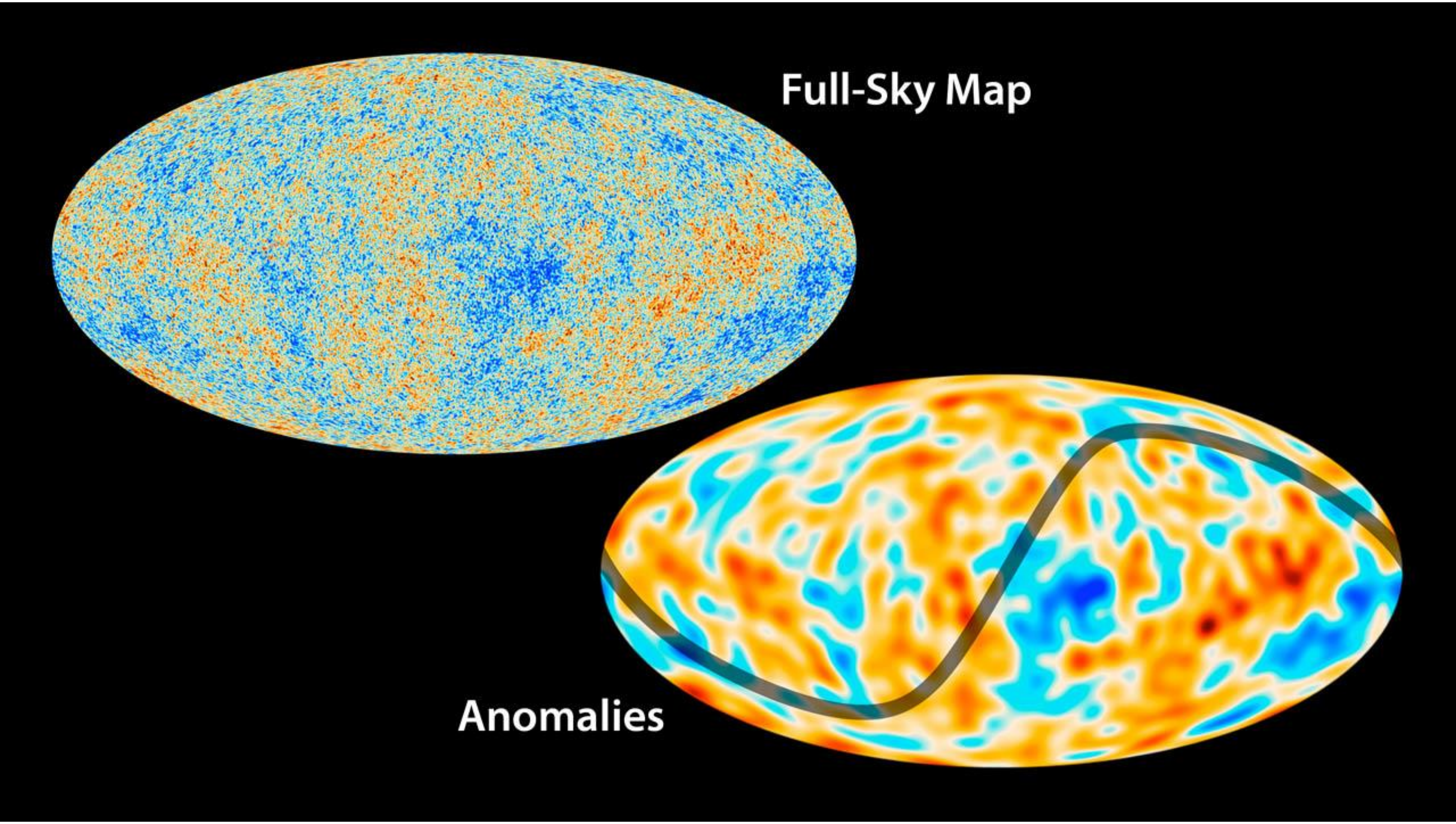


Fig. 30. Temperature maps of size 1 deg^2 at 545 and 857 GHz stacked on the 20,000 brightest peaks (left column), troughs (centre column) and random map locations (right column). The stacked (averaged) temperature maps is in K. The arrows indicate the lensing deflection angle deduced from the gradient of the band-pass filtered lensing potential map stacked on the same peaks. The longest arrow corresponds to a deflection of 6.3″, which is only a fraction of the total deflection angle because of our filtering. This stacking allows us to visualize in real space the lensing of the CMB by the galaxies that generate the CIB. The small offset between the peak of the lensing potential and the CIB is due to noise in the stacked lensing potential map. We choose the same random locations for both frequencies, hence the similar pattern seen in the top and bottom right panels.

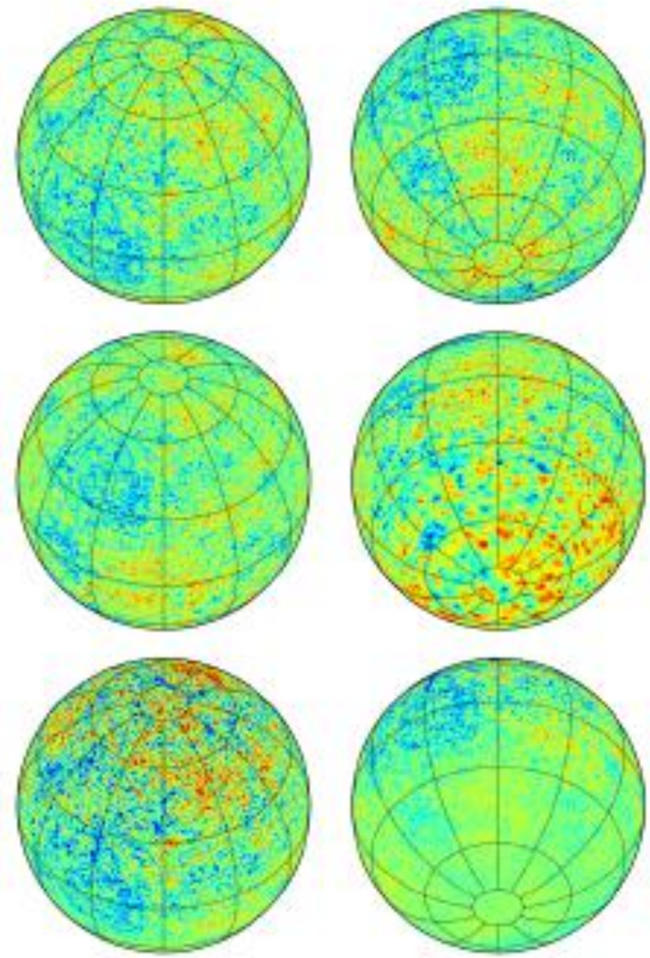

Full-Sky Map
Anomalies

Aberration of the CMB

Our motion shifts amplitude and angles

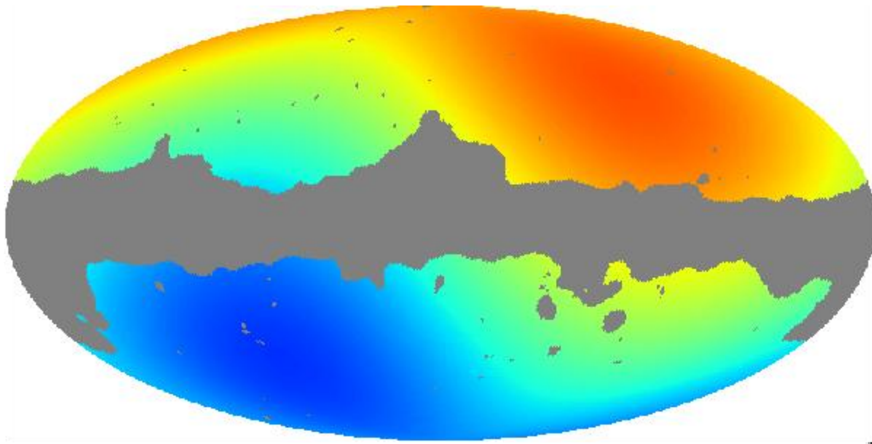
Expected effect is 10^{-3} of 10^{-5} = 10ppb!

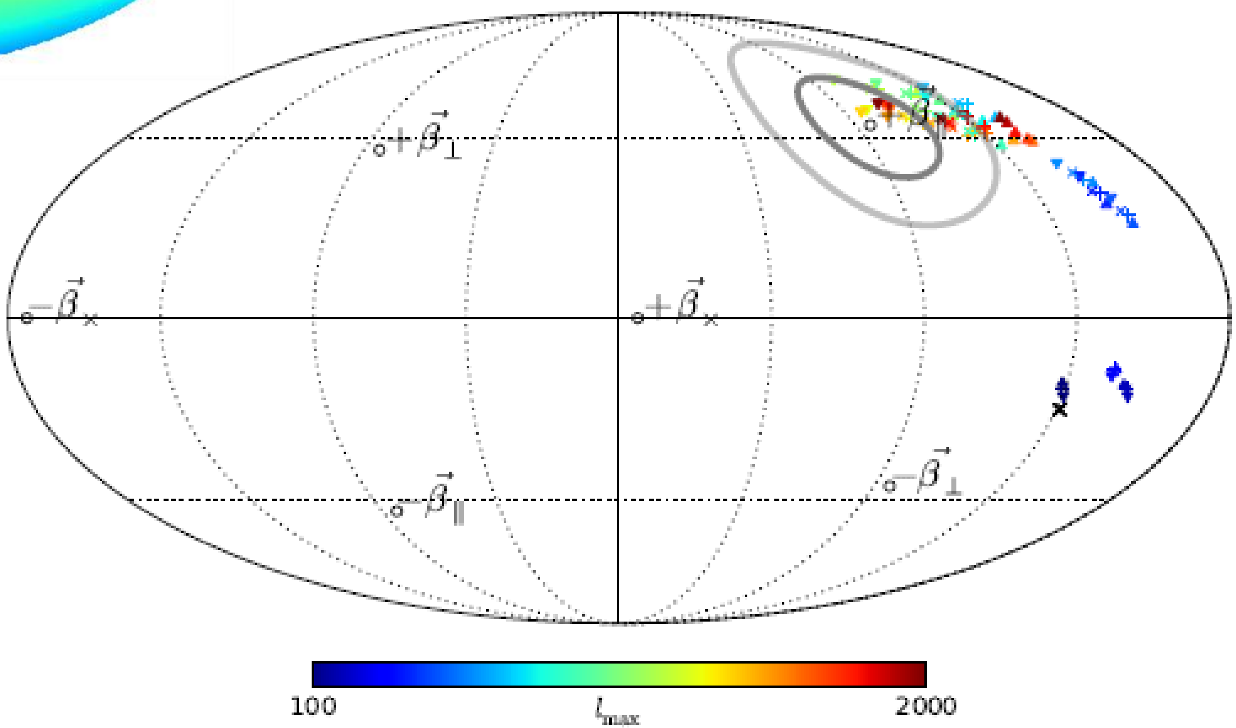
- Left show exaggerated effect - 700x increase in our speed to 85% c.
- Our real speed relative to CMB is ~ 0.12% c
- We use this to look for the effect
- We know the direction and speed from CMB dipole
- Effects both amplitude and angles (~ 4’)
- Angular effect is not trivial compared to lensing
- $\delta T(\hat{n}) = T0\, \hat{n} \cdot \beta + \delta T\, 1(\hat{n} - \nabla(\hat{n} \cdot \beta))(1 + \hat{n} \cdot \beta)$



We observe this at >4σ

This also implies we are stable to <10 ppb





Summary (1)

- No significant improvements beyond 6 parameters **no new physics**
- Lower H_0
- Excellent agreement with current BAO data with lower H_0 = **67.4+-1.4** km/s-Mpc
- No neutrino's beyond 3 implied Neff = 3.36+-0.34
- CMB **alone** : DE (- 6%), Baryons (+ 9%), Dark Matter (+18%)
- CMB **+ external data priors** : DE (- 2%), Baryons (+ 3%), Dark Matter (+5%)
- Spacetime flat to 0.1%
- Improved constraints on total mass of neutrinos, primordial He and running of spectral index $dn_s/dln(k)$ = -0.015+-0.09
- Spectral index not unity - ~5.5 sigma (0.960 +-0.0072) from Planck alone - density PS -> $P(k) \sim k^{(n_s - 1)}$
- No evidence for tensor modes yet $r < 0.11$ (2σ)
- Sum neutrino masses <0.66 eV (2σ)
- No evidence for dynamical DE, or time variation of fundamental constants

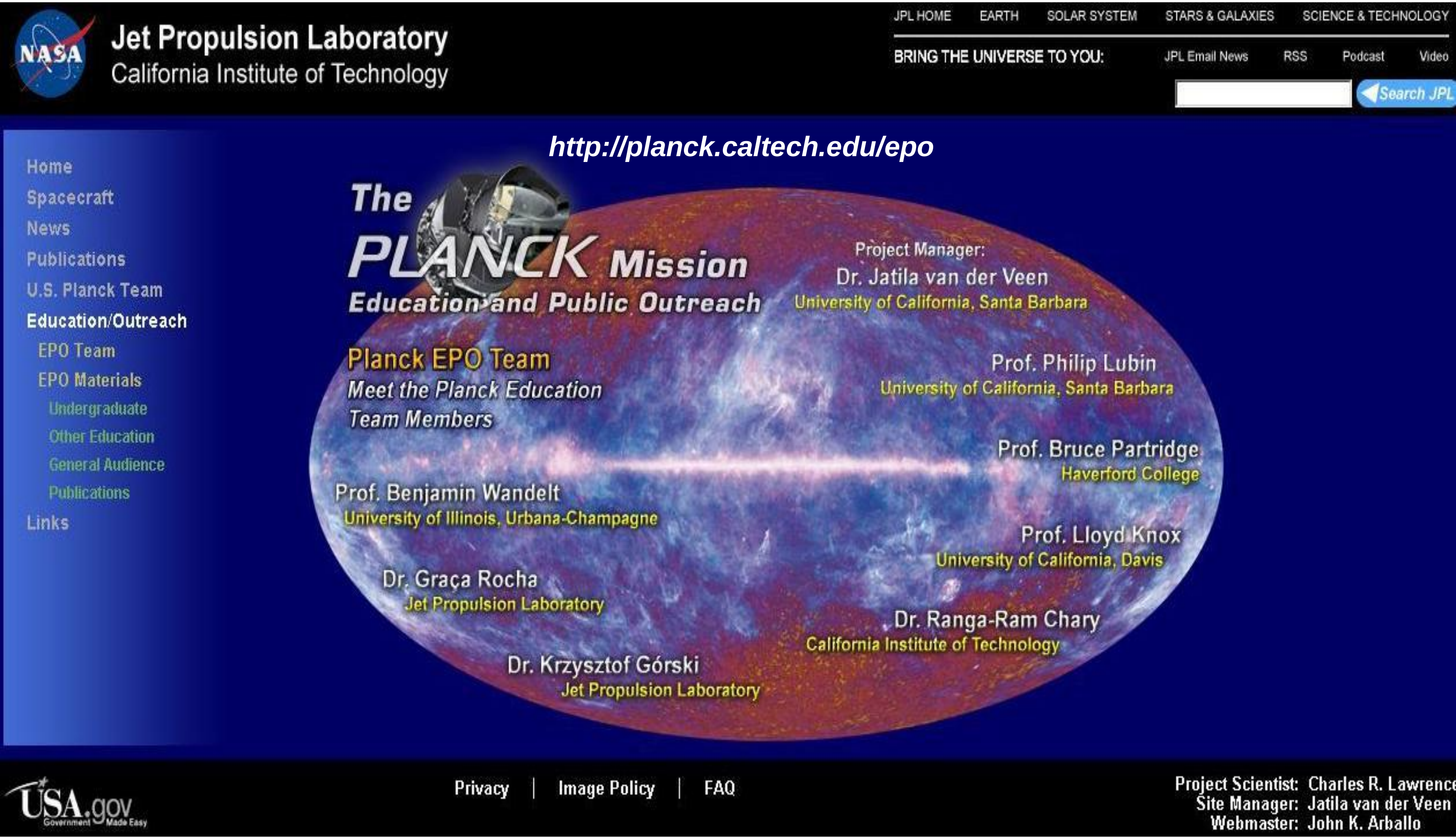
Summary (2)

- Some "tension" between matter fluctuations from CMB and from SZ -> SZ modeling issue?
- Evidence for low "l" (l~ 20-30) intrinsic deviations from "isotropy" (anomolies)
- No evidence of higher "l" intrinsic deviations from isotropy
- Consistent with slow roll inflation
- 25 σ detection of CMB lensing - > help break degeneracies, τ without polarization (though still preferred)
- 42 σ detection of cross correlation of CMB lensing and CIB
- Measurement of CIB power spectra as low as 217 GHz - > constrain DM halos at high z
- First all sky SZ map and power spectrum - σ_8 =0.828+_0.012
- First robust detection of ISW effect (2.5σ) via cross correlation with Planck lensing -> Ω_Λ ~0.7 from CMB alone

PLANCK Education and Public Outreach

Jatila van der Veen, Ph.D.

Project Manager, Planck Education and Outreach
Experimental Cosmology Group,
Department of Physics,
Lecturer, College of Creative Studies

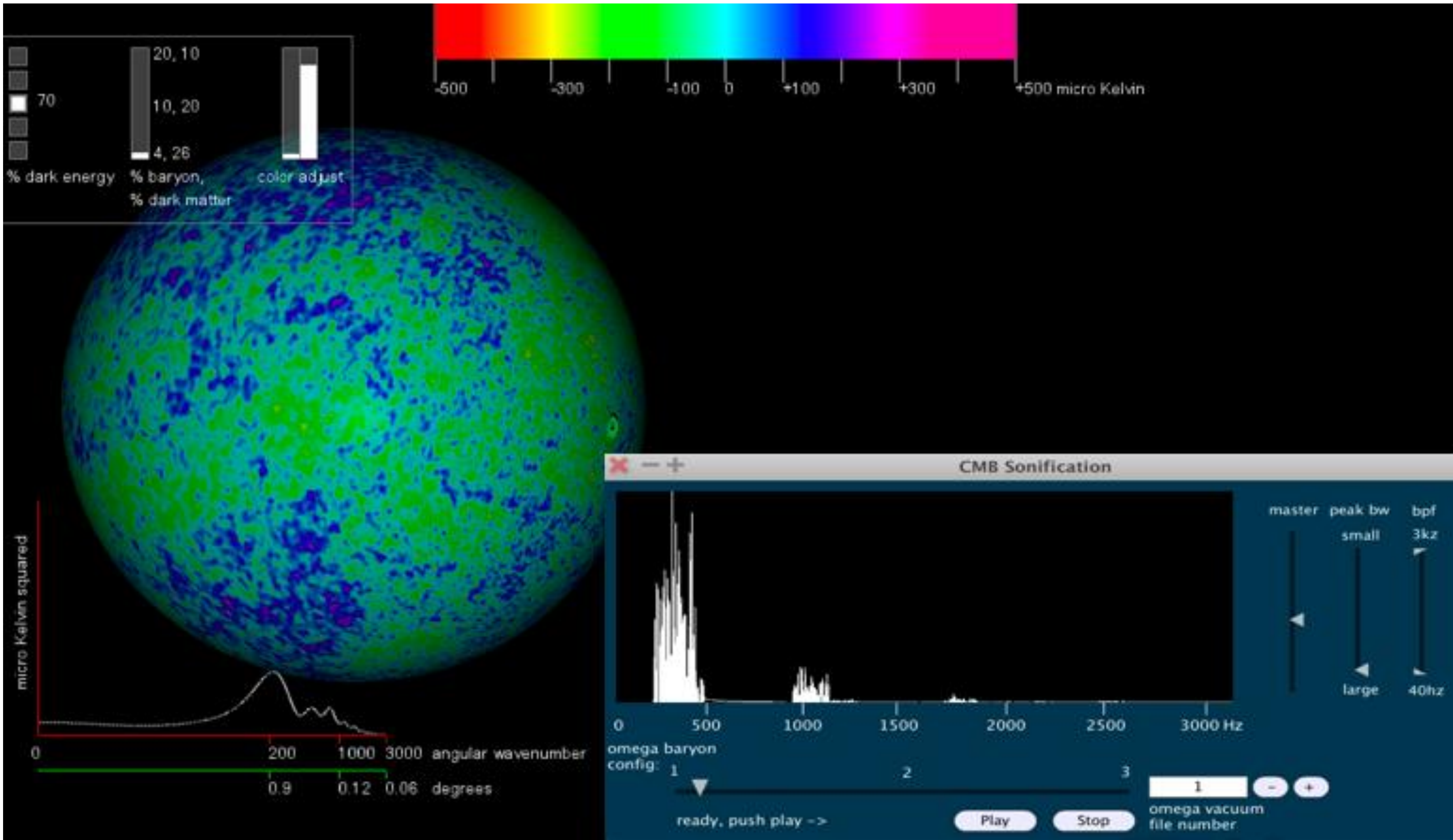


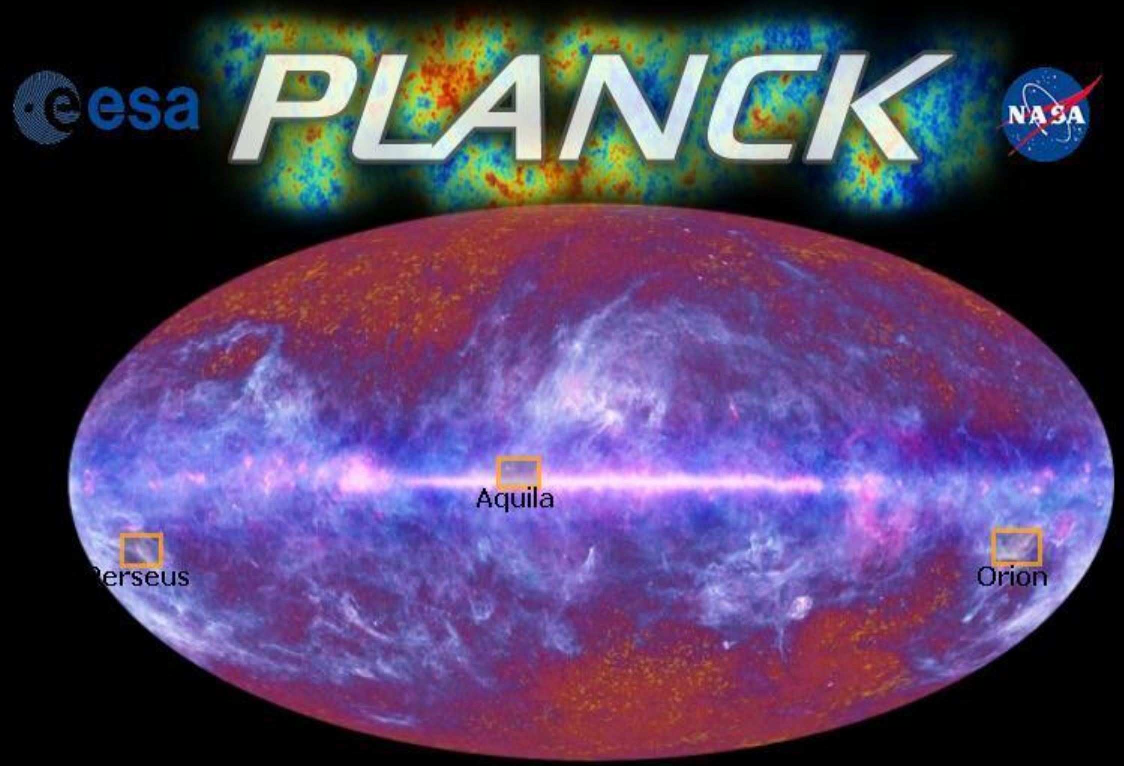
Planck Mission in Virtual Reality
Navigate around the Solar System while Planck maps the sky

collaborators: Jatila van der Veen, UCSB Physics Department; Gerald Dekker & John Moreland, Purdue University Calumet Center for Visualization and Simulation

Visualization and Sonification of the CMB
Model the CMB power spectrum, see the map, and hear the sounds

collaborators: Jatila van der Veen, Philip Lubin, UCSB Phyiscs Department;
Ryan McGee, R.J. Duran, JoAnn Kuchera-Morin, Matthew Wright, UCSB AlloSphere Group





Planck Presents!

Interactive Display for Museums and Science Centers

Currently installed in the Santa Barbara Planetarium

Oprima para Español

collaborators: Jatila van der Veen, UCSB Physics Department & Blake Regalia, UCSB Geography Department

Wrap up

Even more to come

Planck is releasing much less than **half** the data already in hand:

Data for 2014 and 2015 releases

- Polarization!
- **2x** as much data for HFI (5 surveys, 2.5 years of data)
- More than **3x** data for LFI (8+ surveys, more than 4 years of data)

Planck 2014 and 2015

- Polarization
- Additional 15 months LFI + HFI
- Yet more LFI (still operational)
- Better estimators using polarization
- Better measure or limits on r (to 0.05 2σ)
- Better measure or limits on inflation models
- More SZ and lensing
- …

PLANCK Data released today 15.5 months of data :

- Full sky maps for 9 freq,surveys 1-2,halfrings
- Component separation maps:
  - CMB-only, full sky
  - thermal dust + residual CIB
  - CO
  - synchrotron + free-free + spinning dust
  - dust temperature / opacity
- low-resolution CMB map used in low ell likelihood (+ likelihood code, with lensing)
- Catalog of Compact Sources (PCCS)
- Catalog of Sunyaev-Zeldovich Sources (PSZ)

I. Overview of products and results (*this paper*)
II. Low Frequency Instrument data processing
III. LFI systematic uncertainties
IV. LFI beams
V. LFI calibration
VI. High Frequency Instrument data processing
VII. HFI time response and beams
VIII. HFI calibration and mapmaking
IX. HFI spectral response
X. HFI energetic particle effects
XI. Consistency of the data
XII. Component separation
XIII. Galactic CO emission
XIV. Zodiacal emission
XV. CMB power spectra and likelihood
XVI. Cosmological parameters
XVII. Gravitational lensing by large-scale structure
XVIII. Gravitational lensing by star-forming galaxies
XIX. The integrated Sachs-Wolfe effect
XX. Cosmology from Sunyaev-Zeldovich cluster counts
XXI. All-sky Compton-parameter map and characterization
XXII. Constraints on inflation
XXIII. Isotropy and statistics of the CMB
XXIV. Constraints on primordial non-Gaussianity
XXV. Searches for cosmic strings and other topological defects
XXVI. Background geometry and topology of the Universe
XXVII. Special relativistic effects on the CMB dipole
XXVIII. The Planck Catalogue of Compact Sources
XXIX. The Planck catalogue of Sunyaev-Zeldovich sources

29 Planck Cosmology and Product Papers 2013

will be on Astro-ph tomorrow!

On ESA site right now: http://sci.esa.int/planck

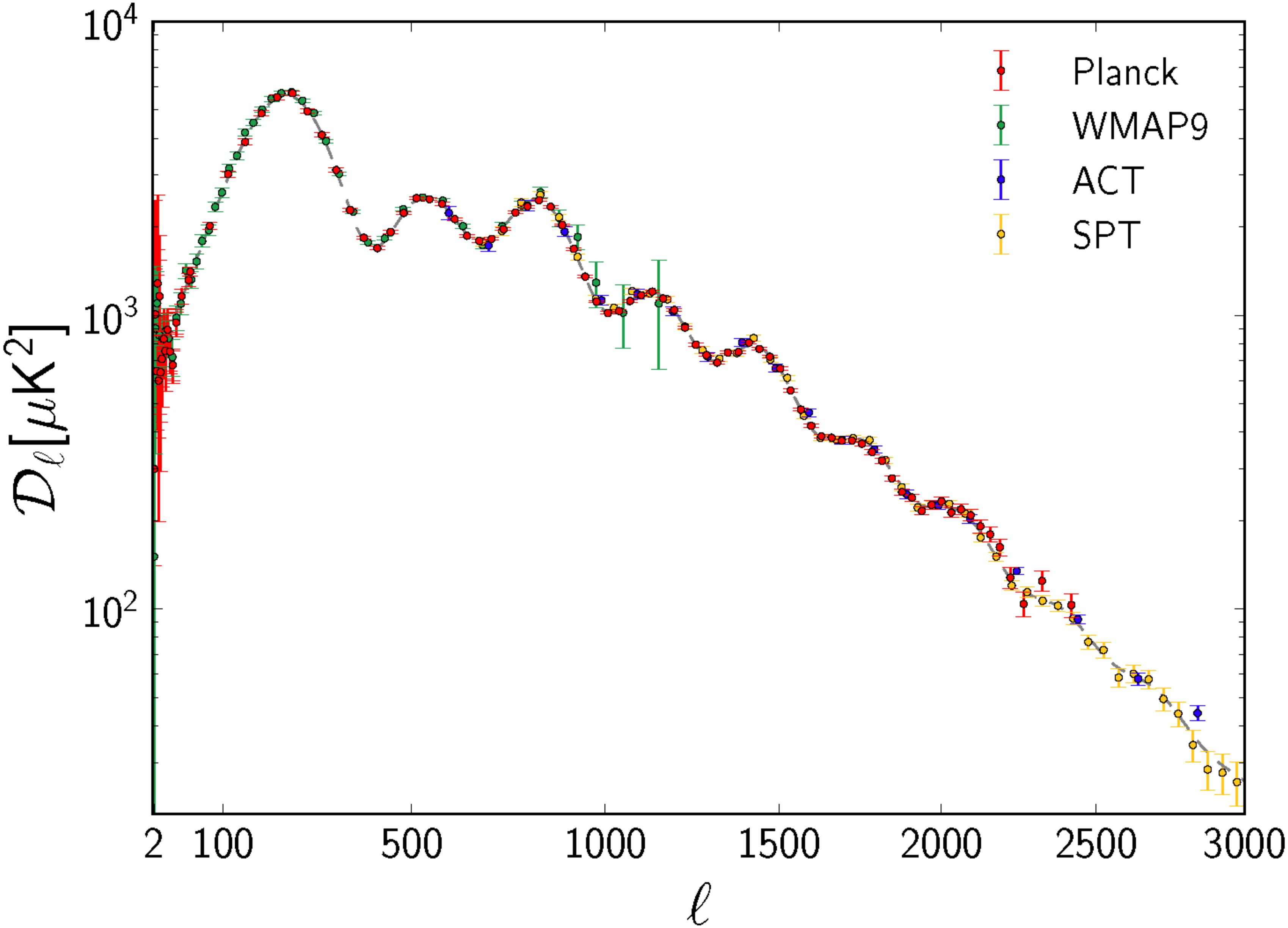
Upcoming KITP Cosmology Programs:
Primordial Cosmology
April 1-28, 2013

Observational and Theoretical Challenges in
Primordial Cosmology
April 22-26

Thank you

Backup slides

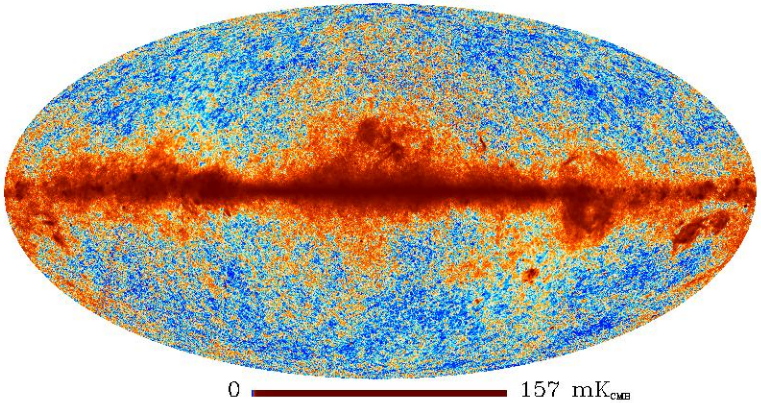
TT Power Spectra Model fits includes Planck, WMAP pol,

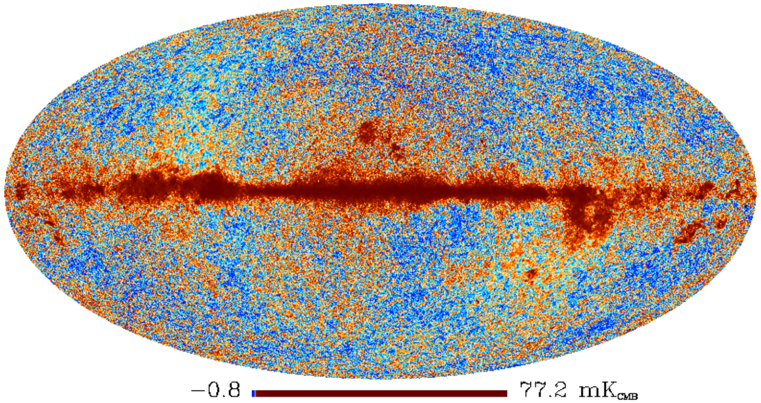


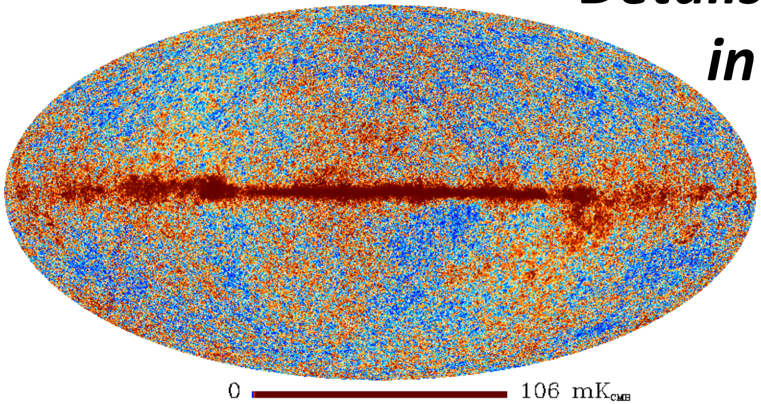
Map Properties
*** pixel size list

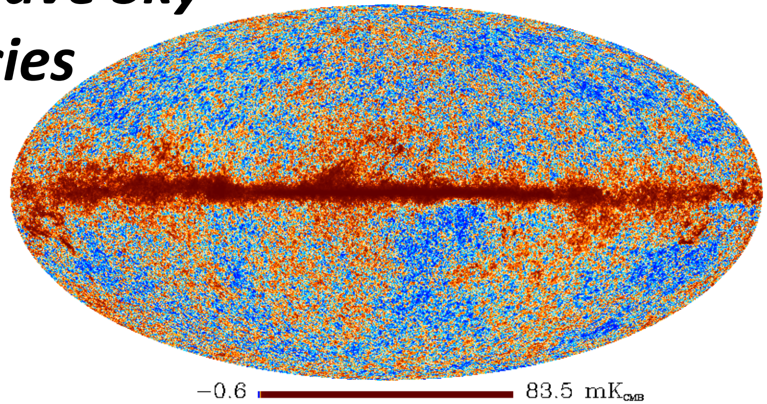
Property	Applies to	Frequency [GHz]								
		30	44	70	100	143	217	353	545	857
Effective frequency [GHz]	Mean	28.4	44.1	70.4	100	143	217	353	545	857
Noise rms per pixel [μK_{CMB}]	Median	9.2	12.5	23.2	11	6	12	43	. . .	. . .
[MJy sr^{-1}]	Median	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.0149	0.0155
Gain calibration uncertainty[b]	All sky	0.82 %	0.55 %	0.62 %	0.5 %	0.5 %	0.5 %	1.2 %	10 %	10 %
Zero level[c] [MJy sr^{-1}]	All sky	0	0	0	0.0047	0.0136	0.0384	0.0885	0.1065	0.1470
Zero level uncertainty [μK_{CMB}]	All sky	±2.23	±0.78	±0.64	. . .	. . .	. . .	. . .	. . .	. . .
[MJy sr^{-1}] . . .	All sky	. . .	. . .	. . .	±0.0008	±0.001	±0.0024	±0.0067	±0.0165	±0.0147
Color correction unc.[d]	non-CMB emission	0.1β %	0.3β %	0.2β %	$0.11\Delta\alpha$ %	$0.031\Delta\alpha$ %	$0.007\Delta\alpha$ %	$0.006\Delta\alpha$ %	$0.020\Delta\alpha$ %	$0.048\Delta\alpha$ %
Beam Color correction unc.[e]	non-CMB emission	0.5 %	0.1 %	0.3 %	<0.3 %	<0.3 %	<0.3 %	<0.5 %	<2.0 %	<1.0 %

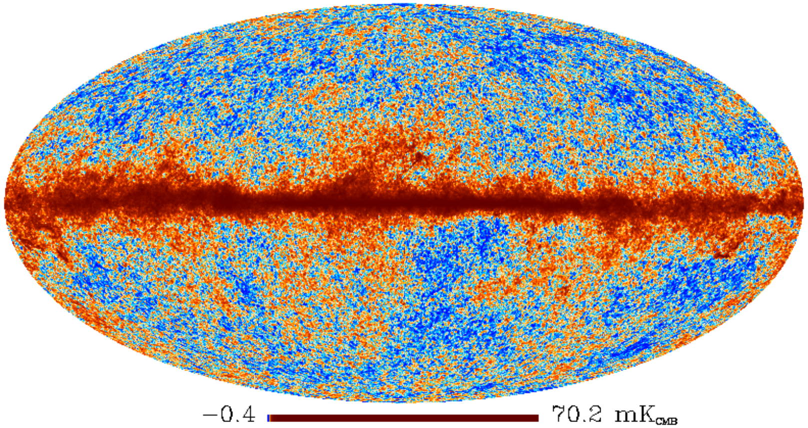
PLANCK:
Details of the Microwave Sky in Nine Frequencies

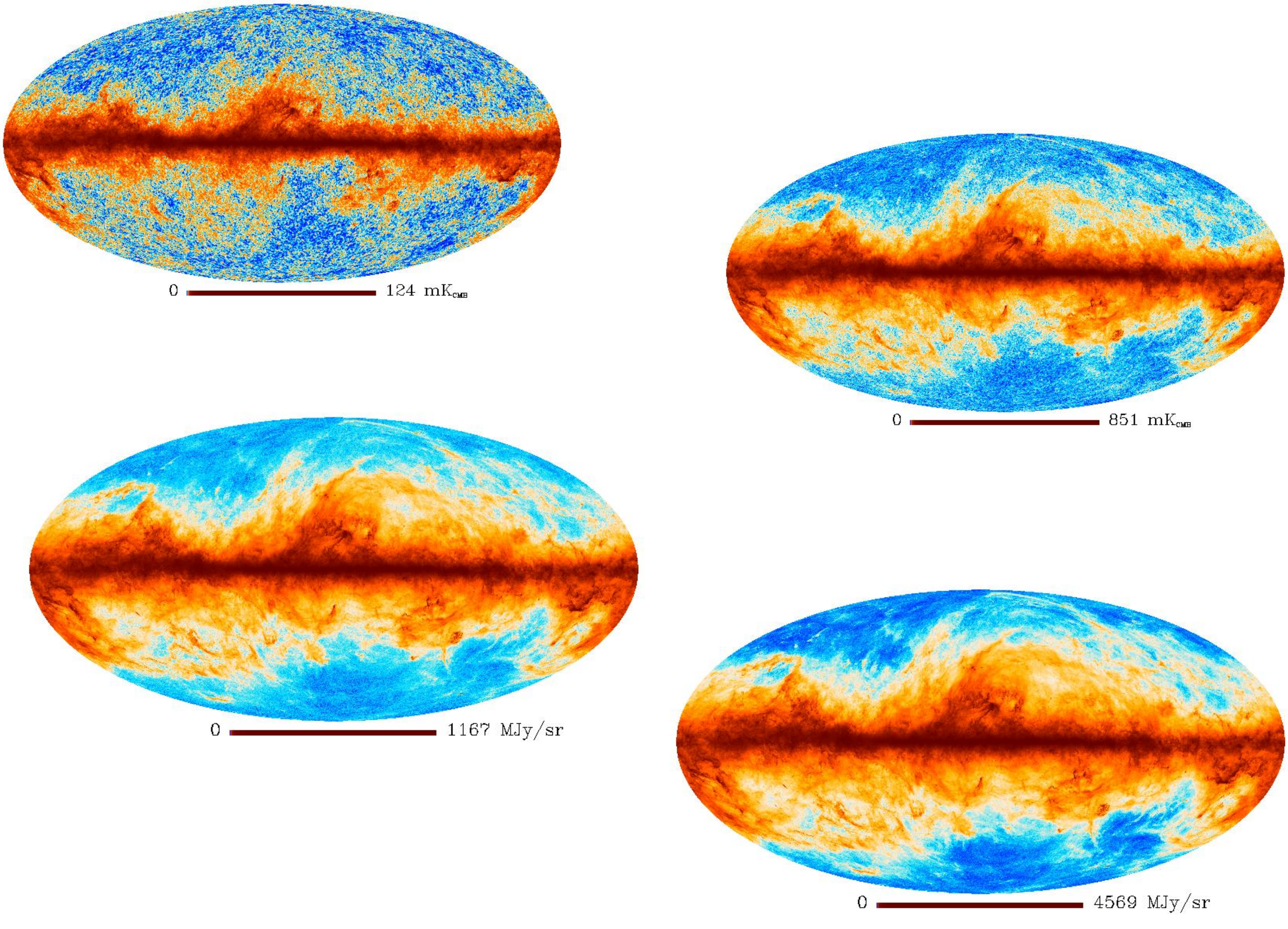






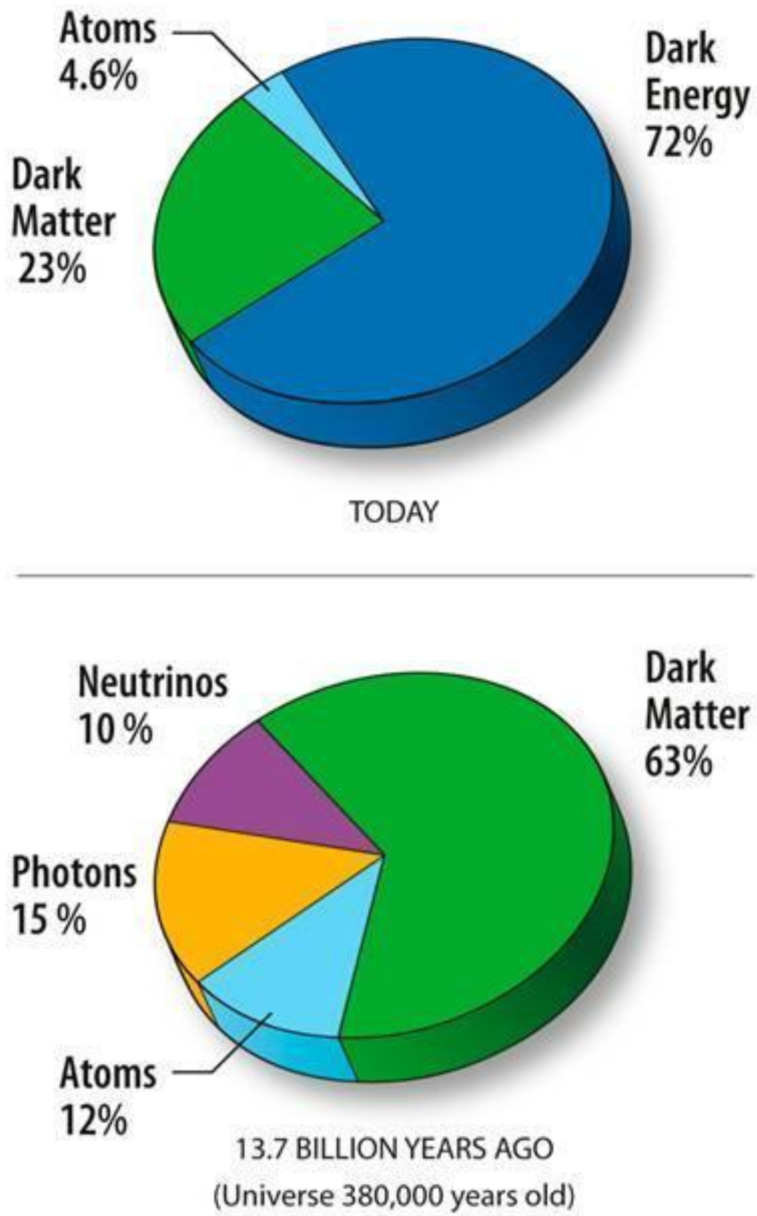




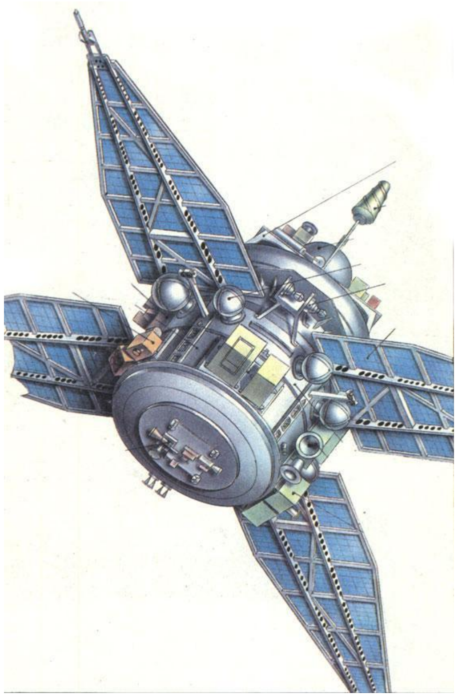


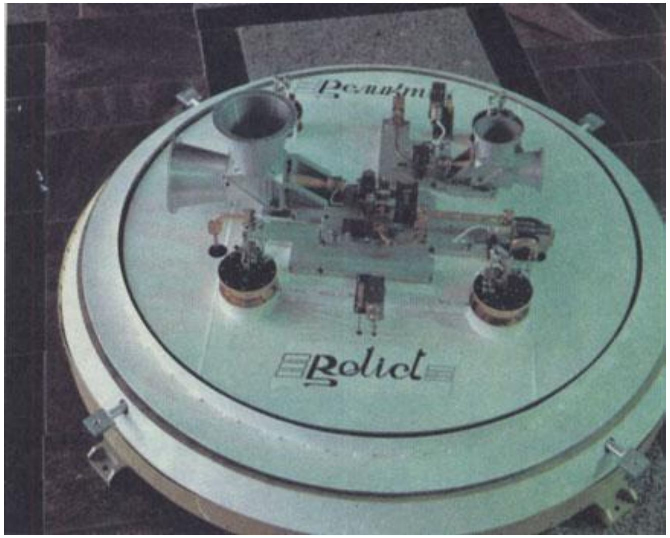
0 124 mK_CMB
0 851 mK_CMB
0 1167 MJy/sr
0 4569 MJy/sr

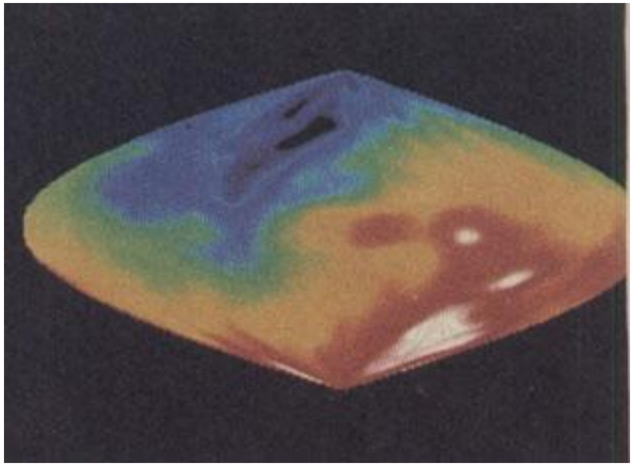
Matter and Energy Distribution Changes with Time
(source: http://wmap.gsfc.nasa.gov/media/080998/index.html)



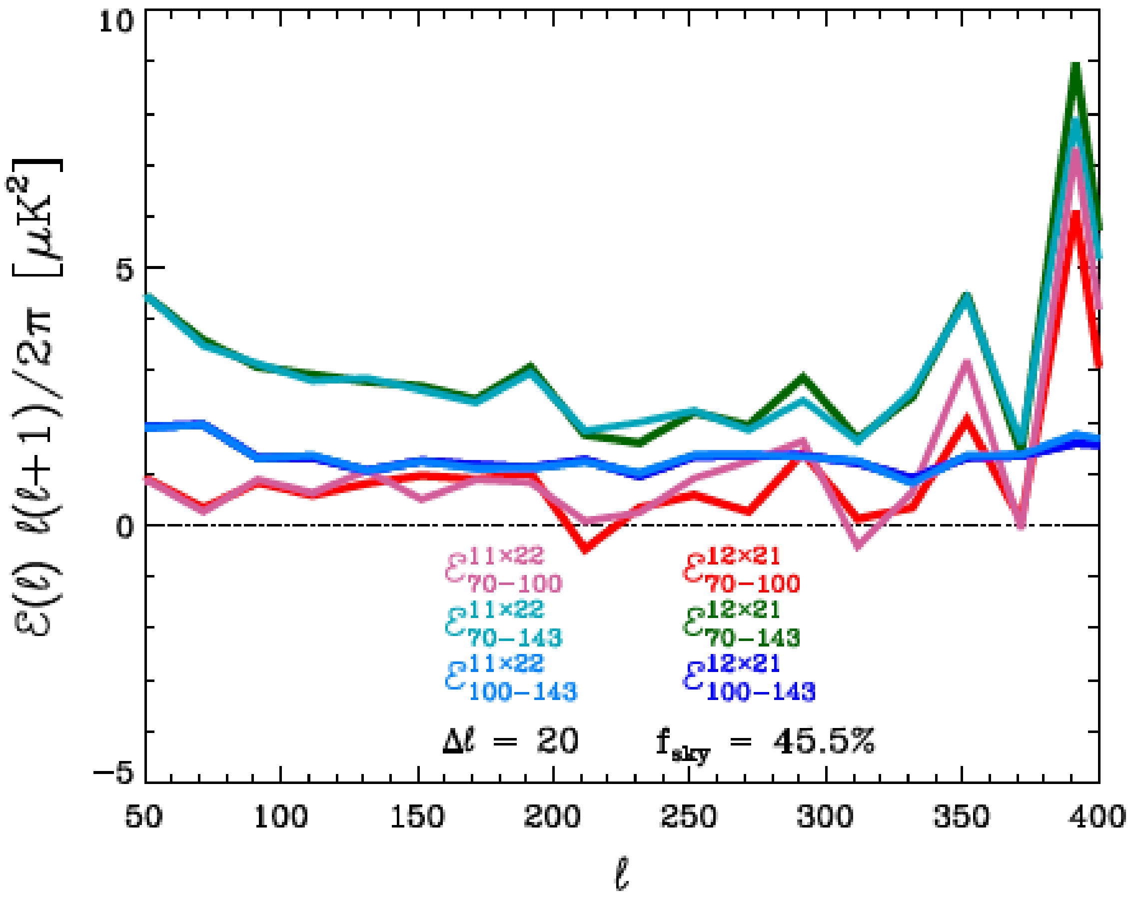
RELIKT Mission – launched July 1, 1983



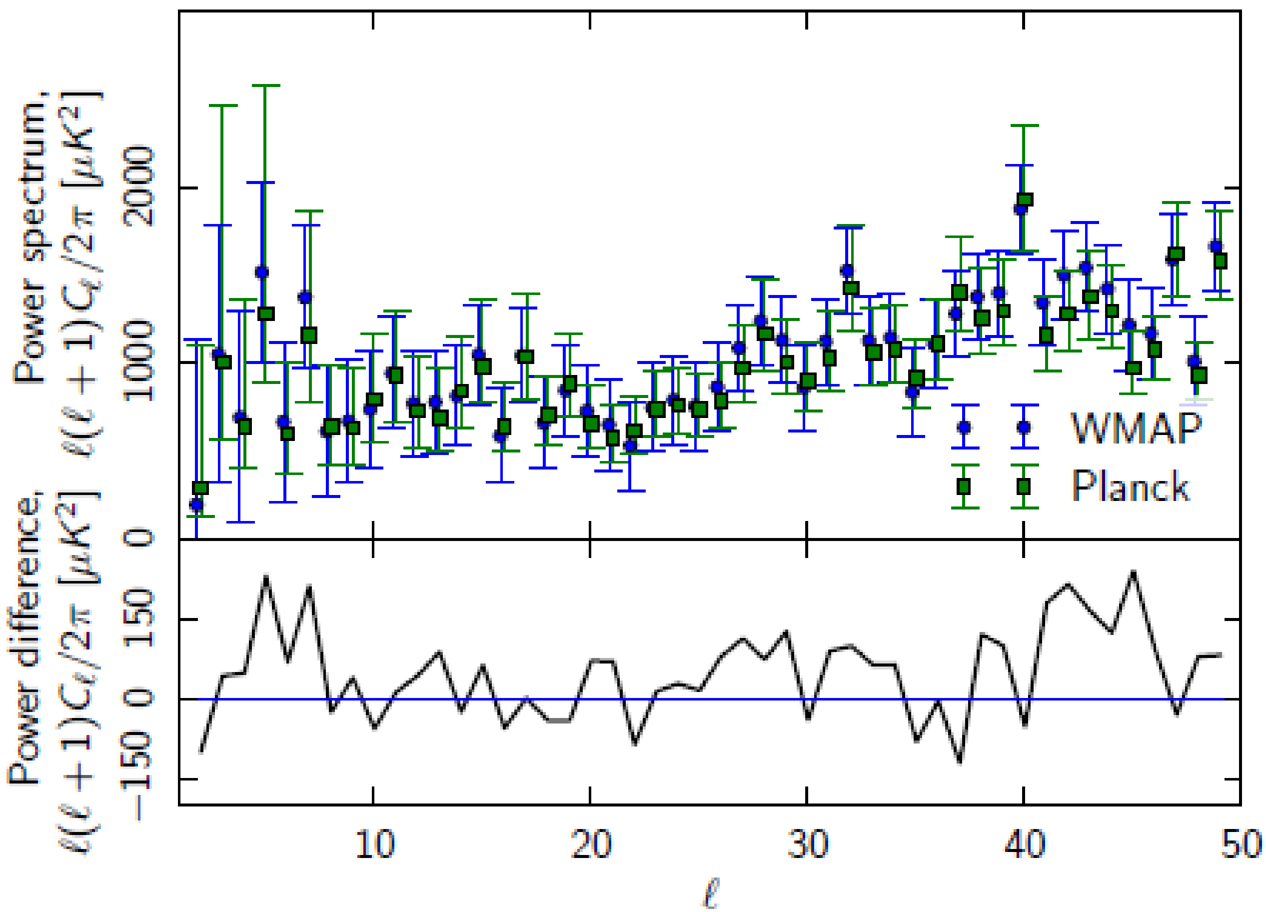


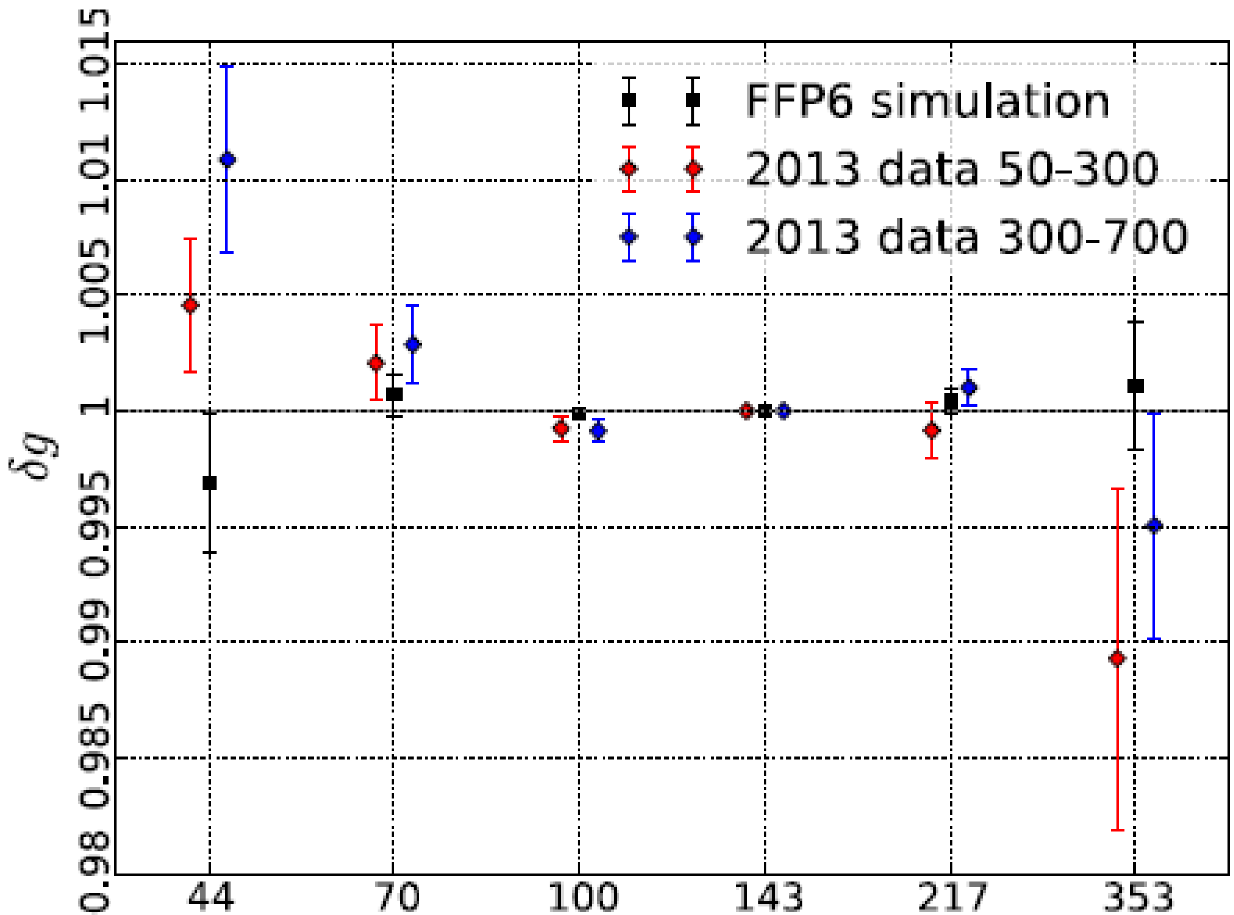


Power Spectra differences

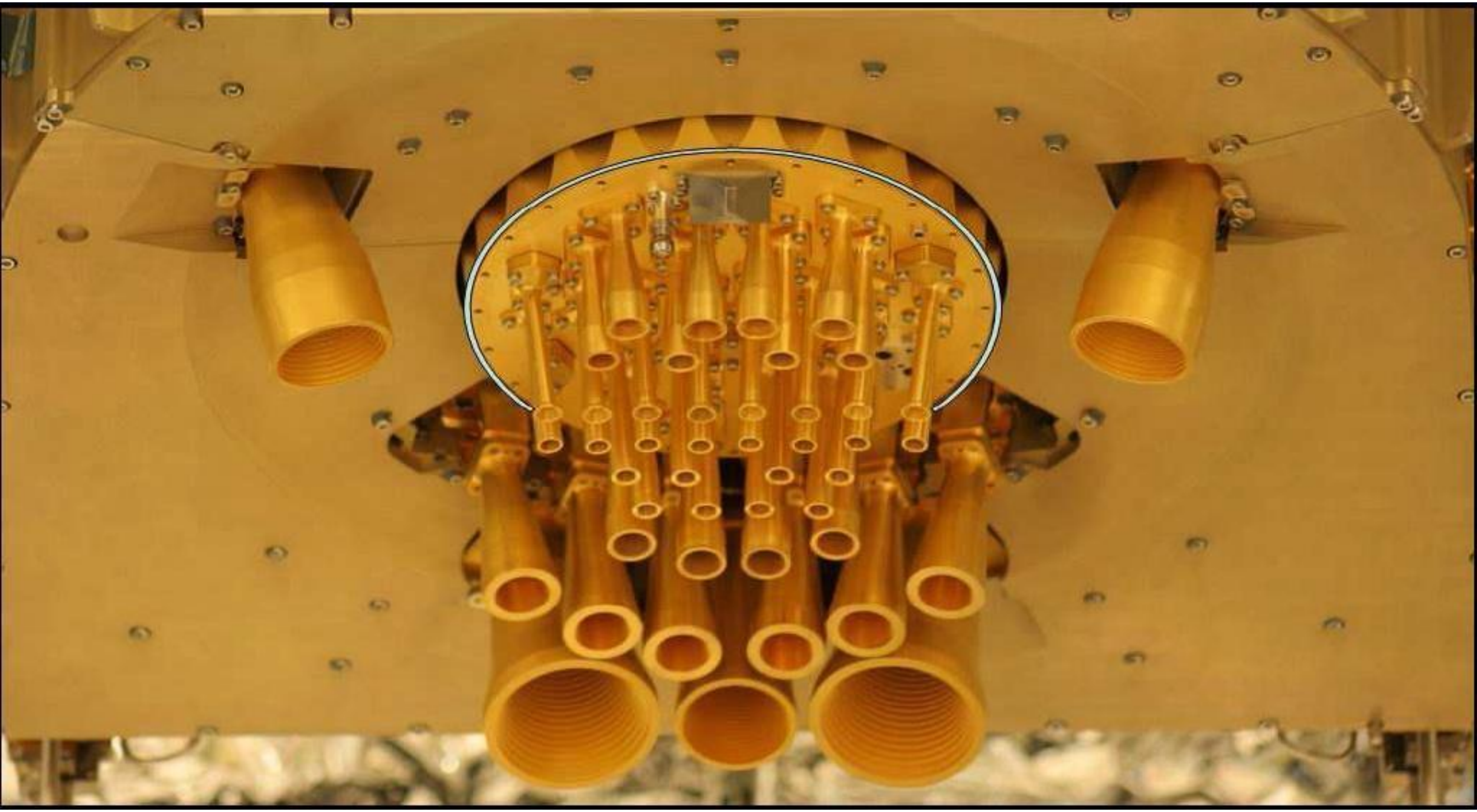


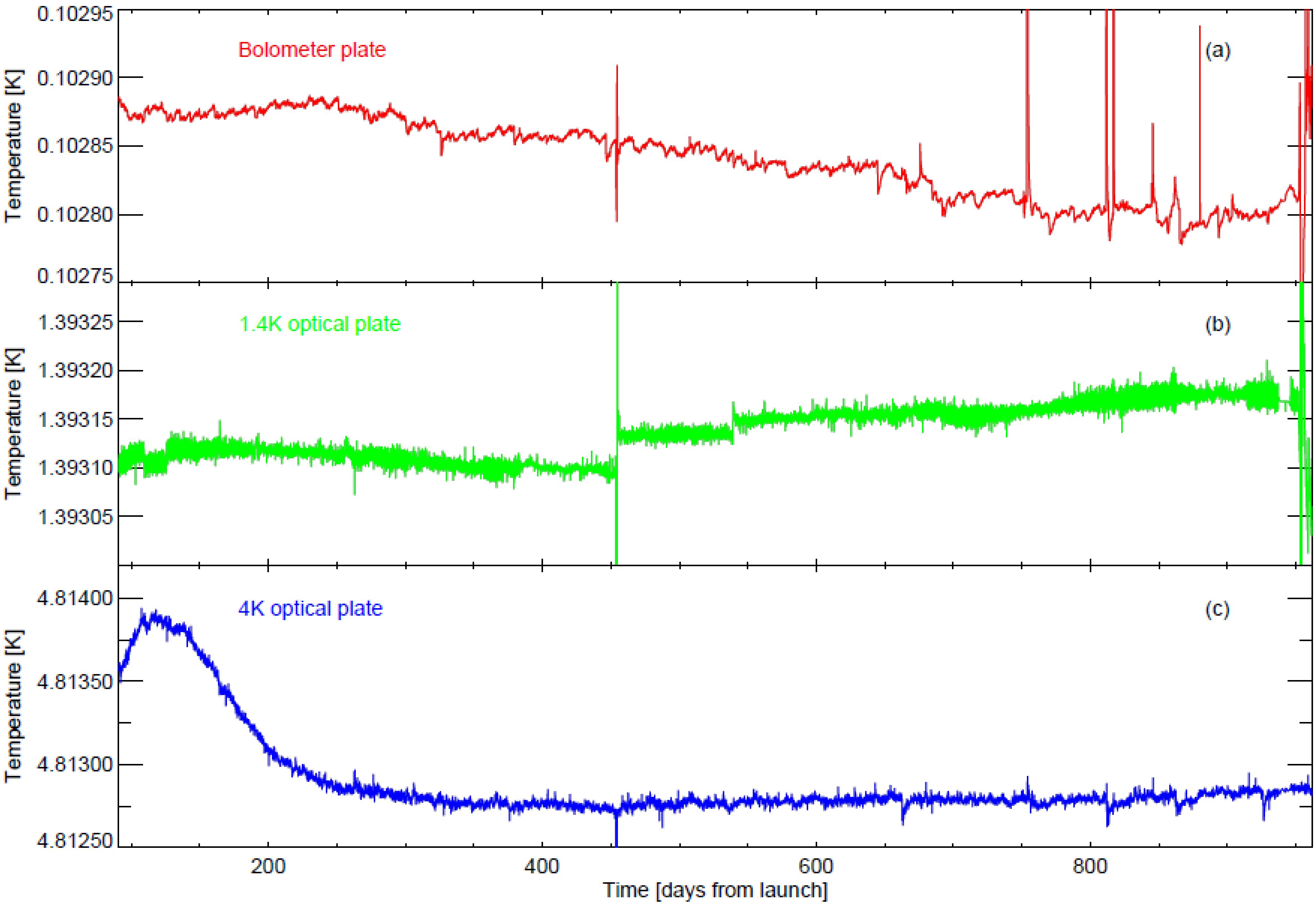
Low "l" Power Spectra Error bars dominated by sample and cosmic variance and




FFP6 simulation
2013 data 50-300
2013 data 300-700
δg
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
44
70
100
143
217
353

Focal Plane – 100 mK bolometers + 20 K HEMTS





0.10295
0.10290
0.10285
0.10280
0.10275
Temperature [K]
Bolometer plate
(a)
1.39325
1.39320
1.39315
1.39310
1.39305
Temperature [K]
1.4K optical plate
(b)
4.81400
4.81350
4.81300
4.81250
Temperature [K]
4K optical plate
(c)
200
400
600
800
Time [days from launch]

What comes after Planck?

- We are now at the photon noise limit
- Only way to improve sensitivity is more detectors
- 10-100K feasible
- Larger optics -> better resolution
- Limits from foregrounds – they are already a serious issue
- CMB Weak Lensing machines…
- Space vs Balloon vs Ground