

# Planck

Report on the status of the mission

Carlo Baccigalupi, SISSA

A decorative graphic consisting of several sets of concentric circles in a lighter shade of blue, resembling ripples on water, located in the bottom right quadrant of the slide.

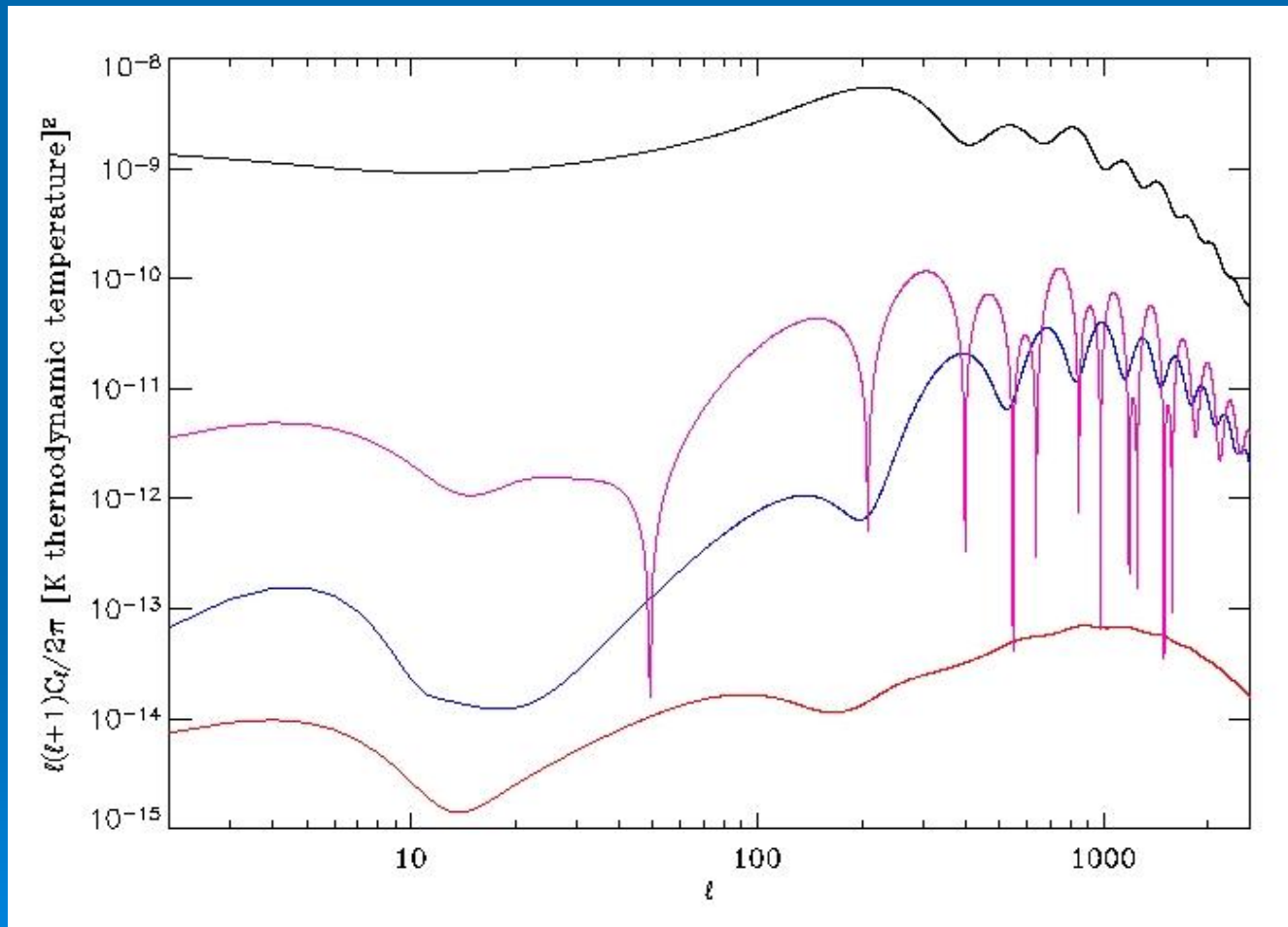
# Outline

- CMB
- The Planck satellite
- Data processing center
- Expectations from Planck
- Planck data

CMB



# CMB angular power spectrum



Angle  $\approx 200/l$  degrees

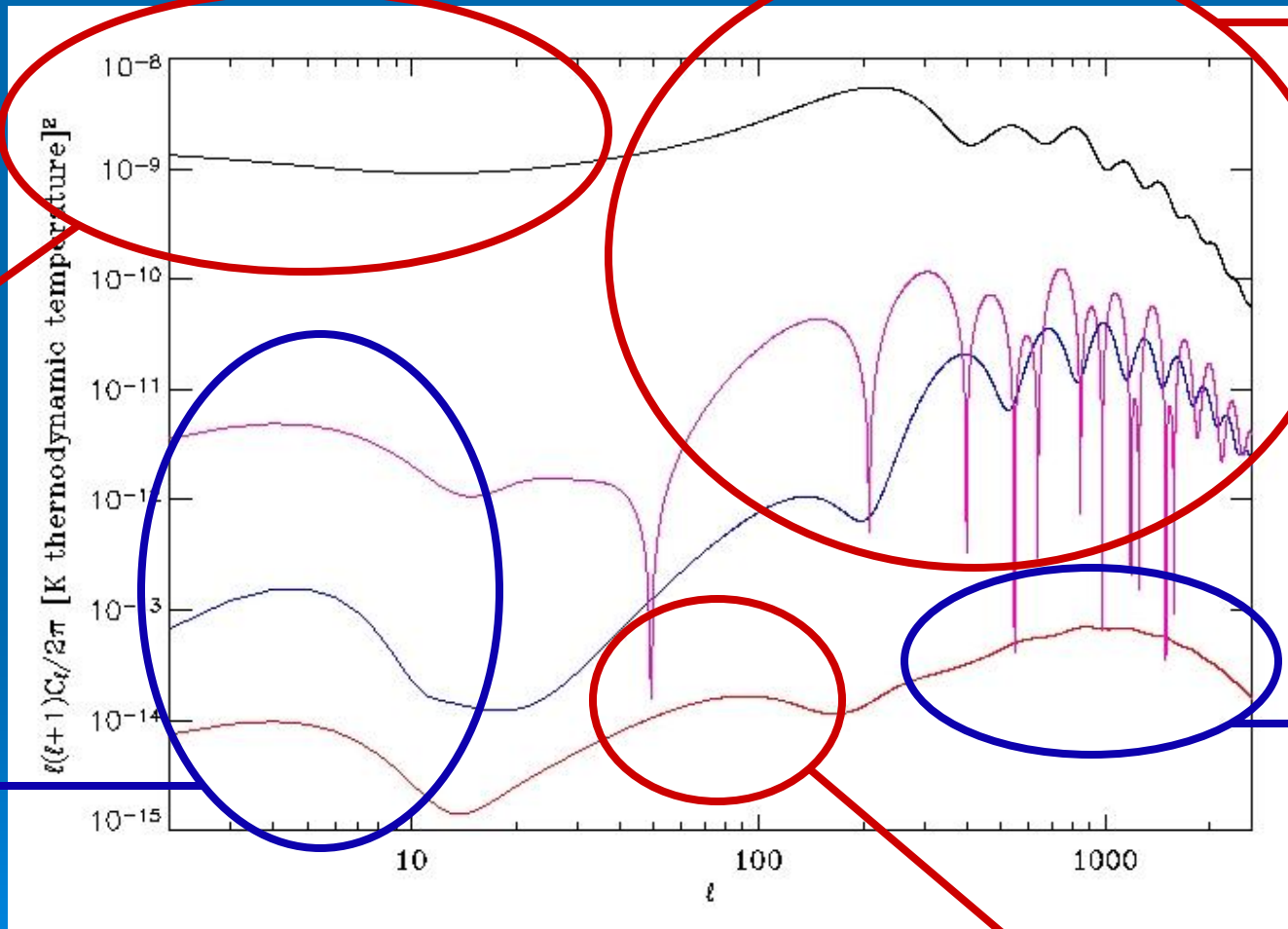
# CMB angular power spectrum

Acoustic oscillations

Primordial power

Reionization

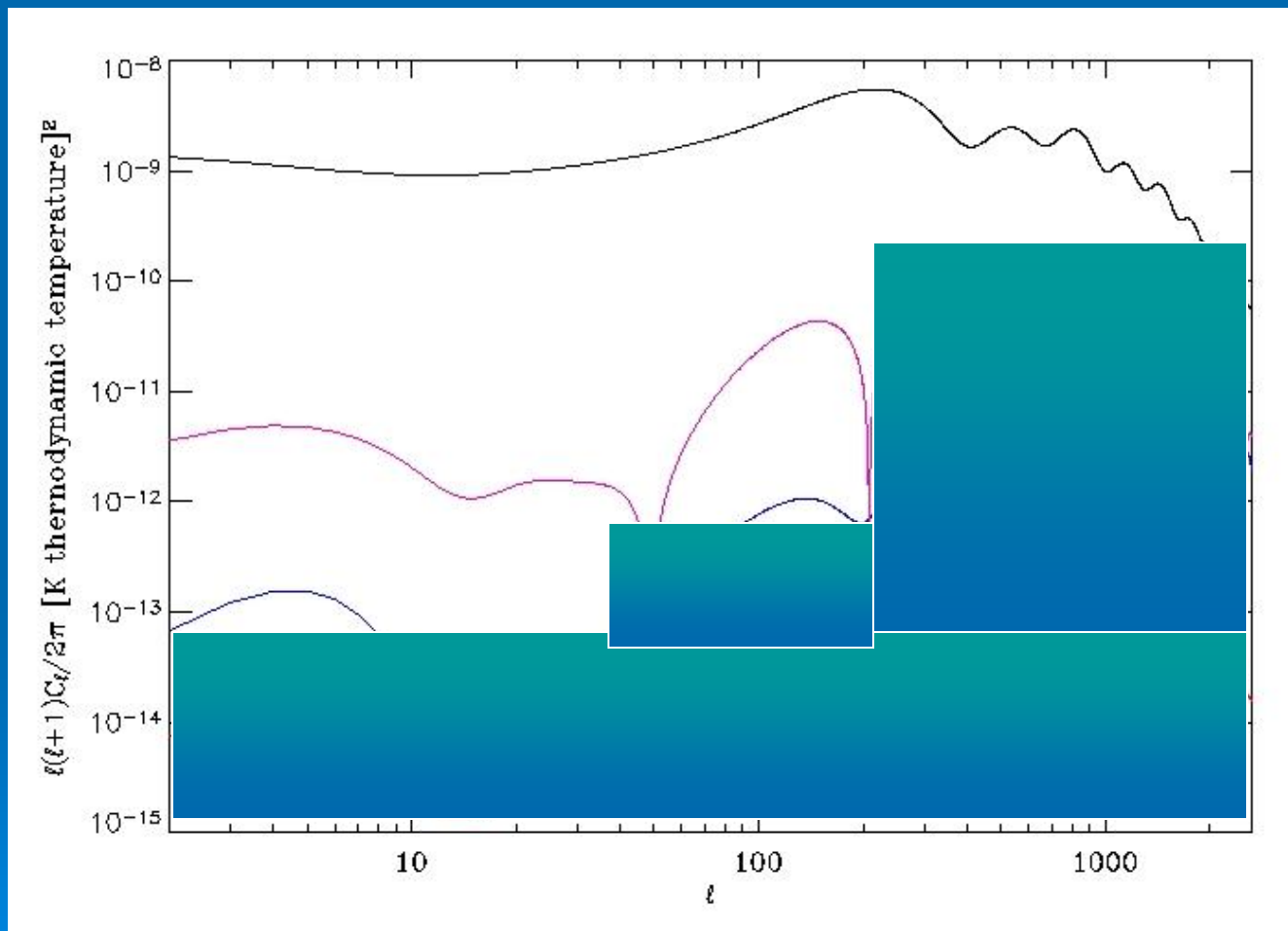
Lensing



Angle  $\approx 200/l$  degrees

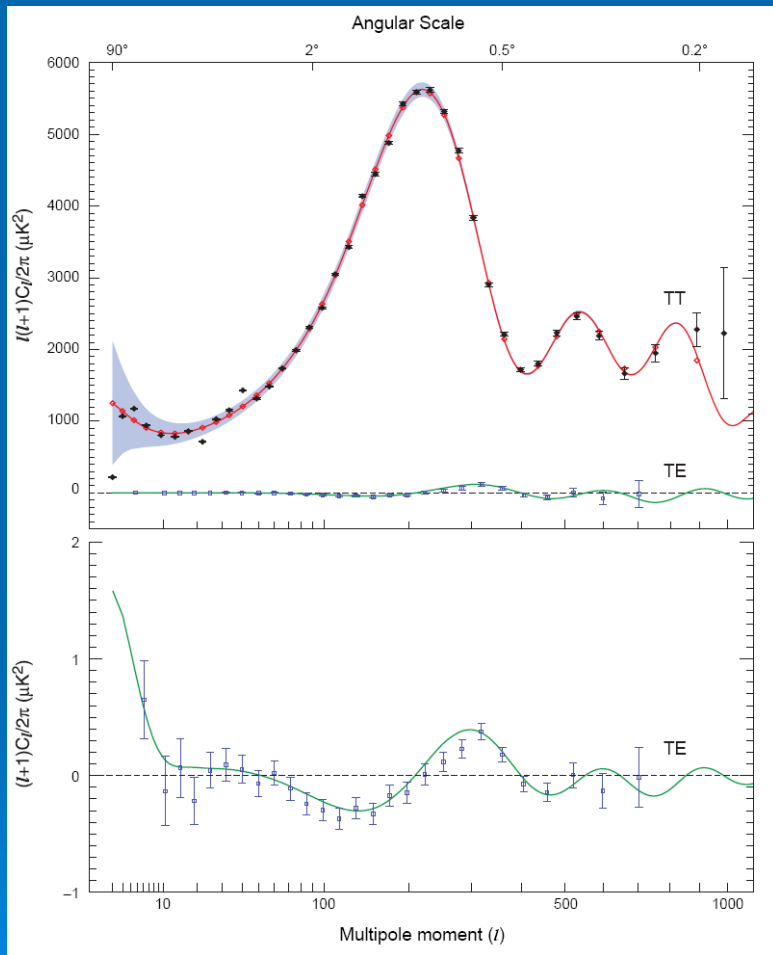
Gravity waves

# Known CMB anisotropies

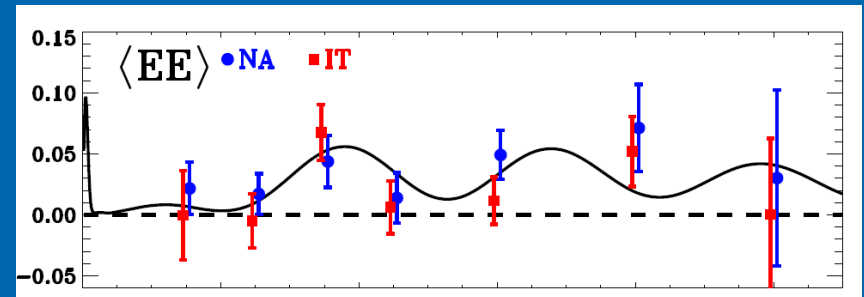


Angle  $\approx 200/\ell$  degrees

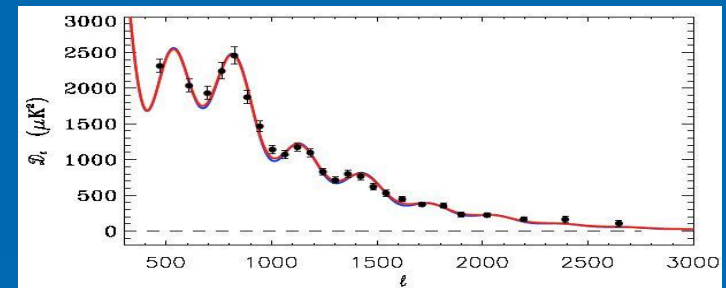
# CMB angular power spectrum



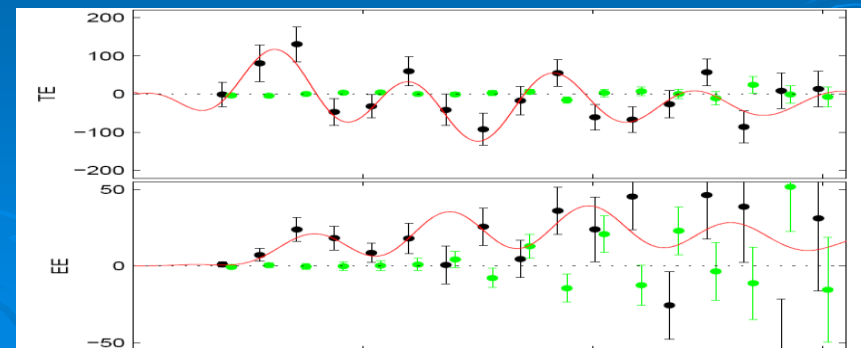
WMAP



boomerang



acbar



quad

# CMB anisotropies

$T(n), Q(n), U(n), V(n)$

$a_{lm}^T, a_{lm}^E, a_{lm}^B$

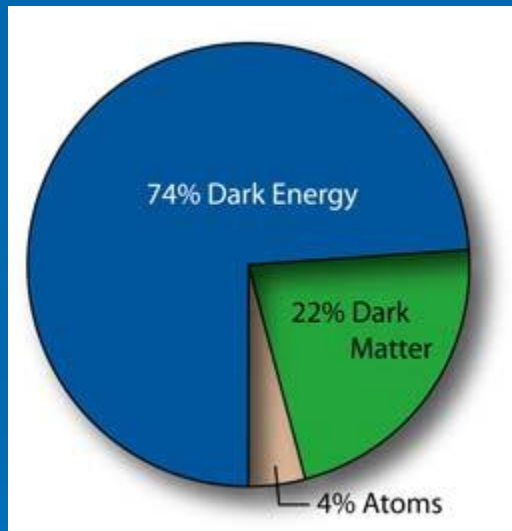
spherical  
harmonics

information  
compression

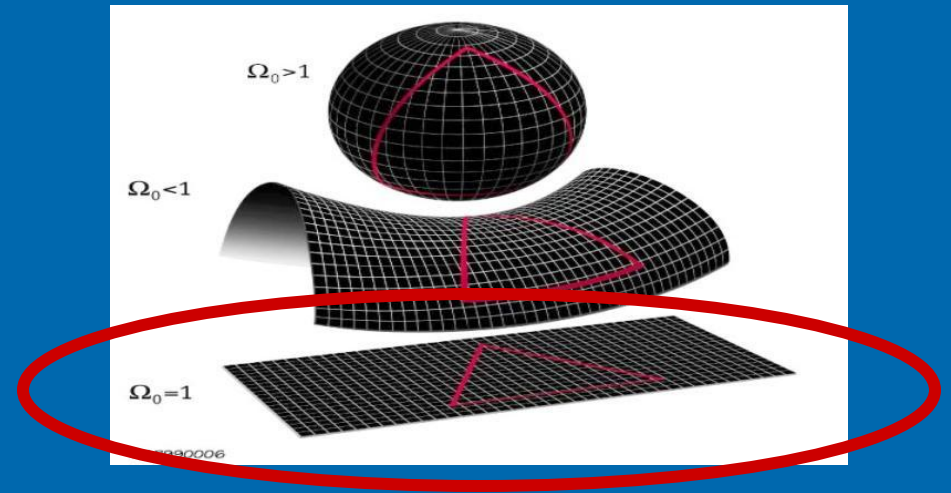
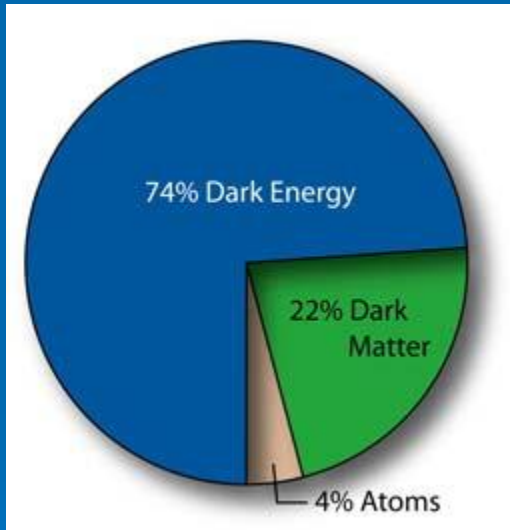
$$C_l = \sum_m (a_{lm}^{T,E,B})(a_{lm}^{T,E,B})^* / 2(l+1)$$



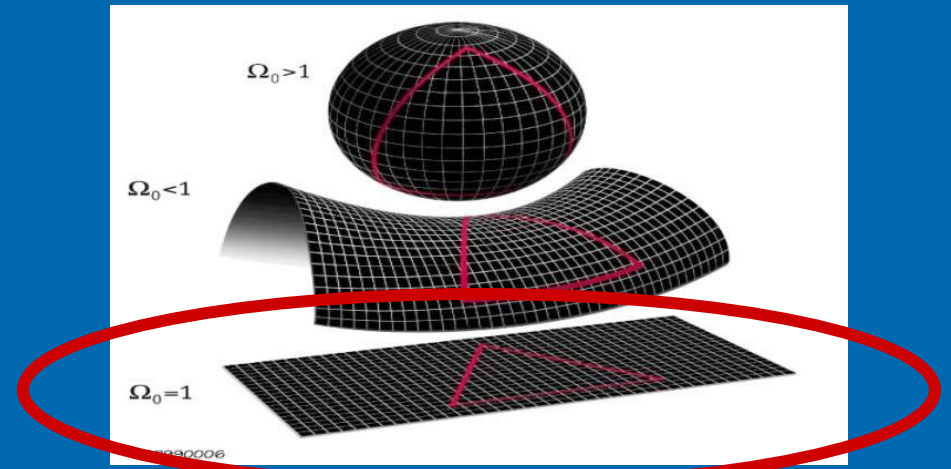
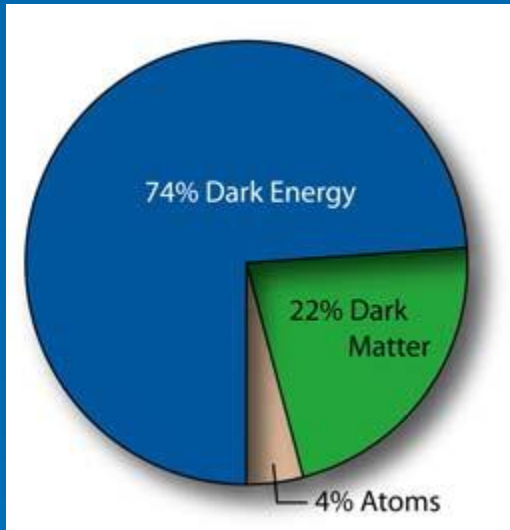
# Cosmological concordance model



# Cosmological concordance model



# Cosmological concordance model

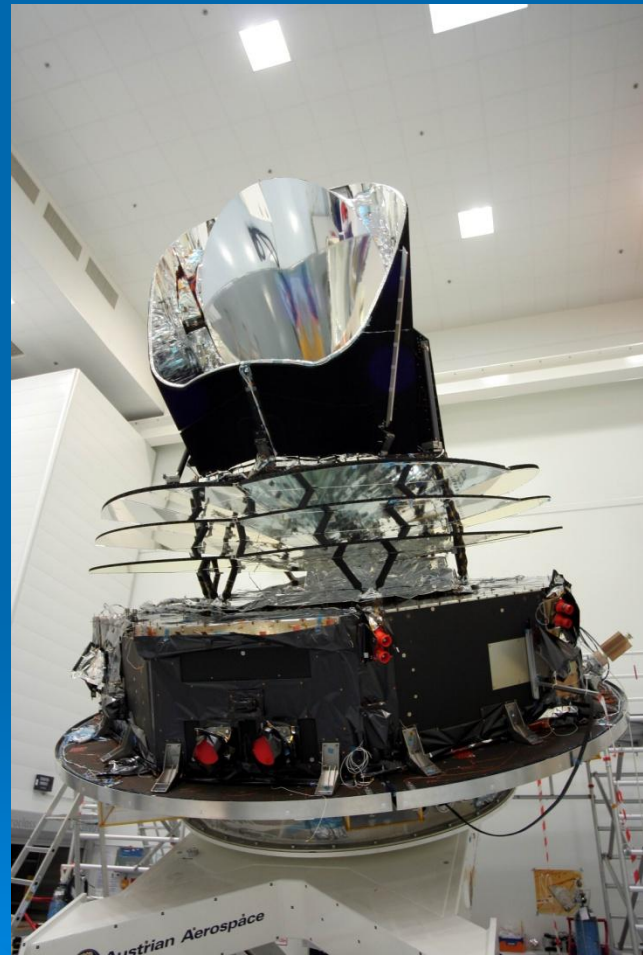


# The Planck satellite

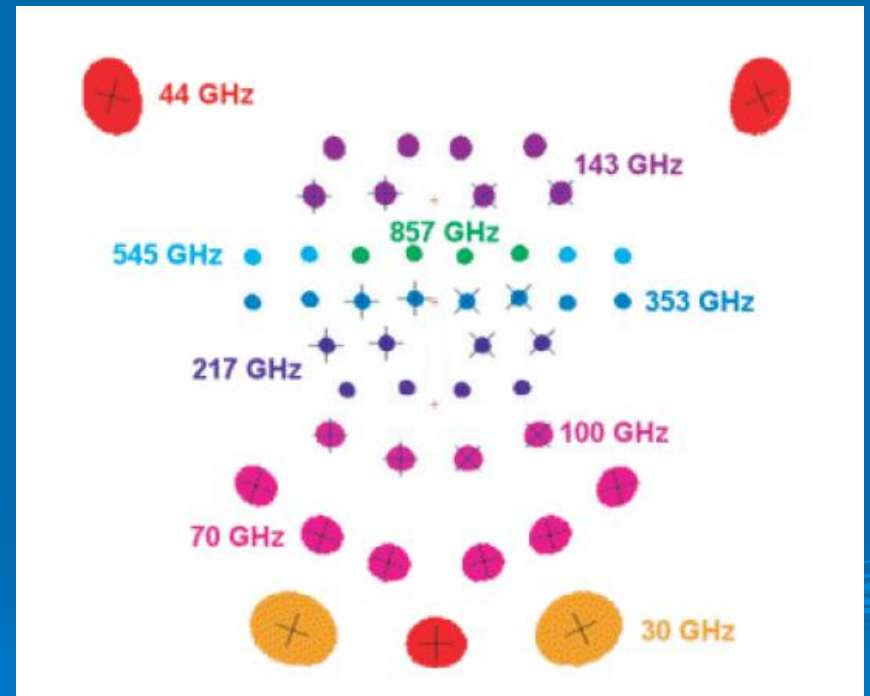
Source: Planck scientific program bluebook,  
available at [www.rssd.esa.int/Planck](http://www.rssd.esa.int/Planck)

# Planck

- Hardware: ~600 ME, third generation CMB probe, ESA medium size mission, NASA (JPL, Pasadena) contribution on cooling systems
- Low Frequency Instrument (LFI, Nazareno Mandolesi PI, instrument design and construction supervised by Marco Bersanelli) based on radiometer technology operating at three frequency channels, 30, 44, 70 GHz
- High Frequency Instrument (HFI, Jean-Loup Puget PI) based on bolometer technology, operating at 100, 143, 217, 353, 545 GHz
- About 16 years (1993-2009) of design and construction



# The Planck focal plane

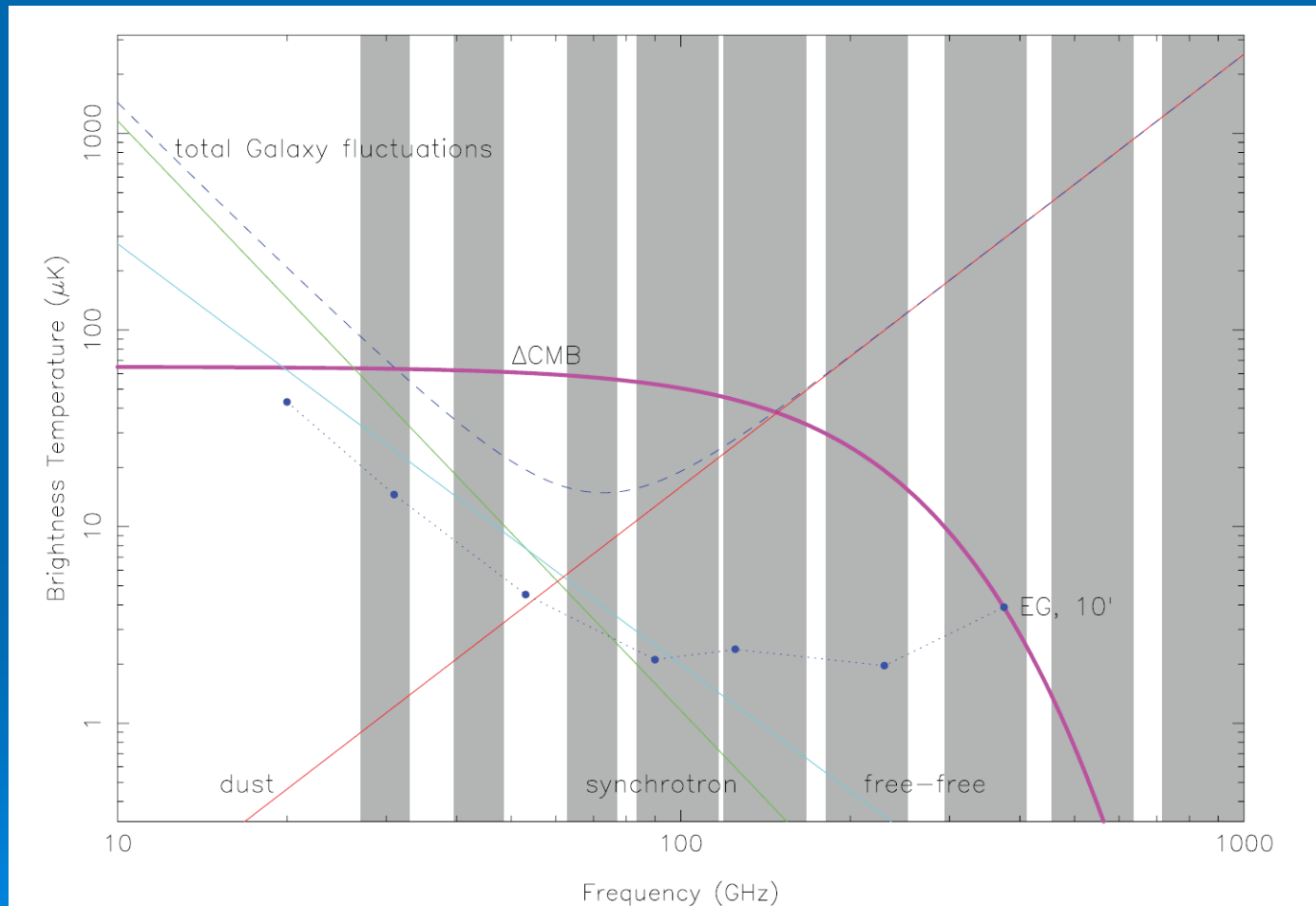


# Planck detectors

INSTRUMENT CHARACTERISTIC	CENTER FREQUENCY [GHz]		
	30	44	70
InP HEMT Detector technology	MIC		MMIC
Detector temperature	20 K		
Cooling system	H <sub>2</sub> Sorption Cooler		
Number of feeds	2	3	6
Angular resolution [arcminutes FWHM]	33	24	14
Effective bandwidth [GHz]	6	8.8	14
Sensitivity [mK Hz <sup>-1/2</sup> ]	0.17	0.20	0.27
System temperature [K]	7.5	12	21.5
Noise per 30' reference pixel [ $\mu$ K]	6	6	6
$\Delta T/T$ Intensity <sup>b</sup> [ $10^{-6}$ $\mu$ K/K]	2.0	2.7	4.7
$(\Delta T/T)$ Polarisation (Q and U) <sup>b</sup> [ $\mu$ K/K]	2.8	3.9	6.7
Maximum systematic error per pixel [ $\mu$ K]	< 3	< 3	< 3

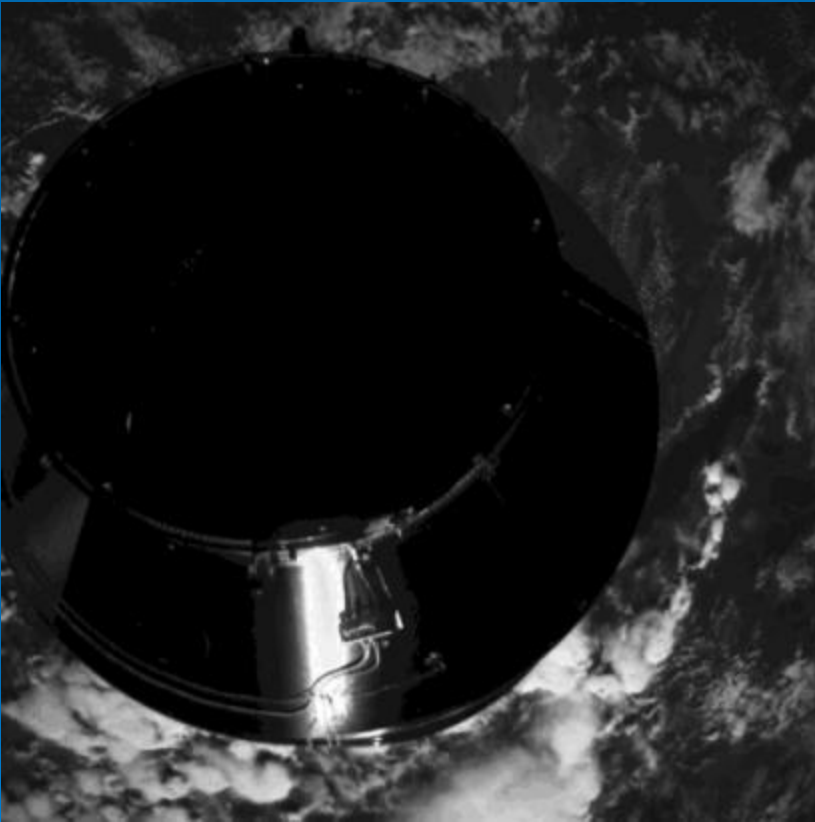
INSTRUMENT CHARACTERISTIC	CENTER FREQUENCY [GHz]					
	100	143	217	353	545	857
Spectral resolution $\nu/\Delta\nu$	3	3	3	3	3	3
Detector technology	Spider-web and polarisation-sensitive bolometers					
Detector temperature	0.1 K					
Cooling system	20 K Sorption Cooler + 4 K J-T + 0.1 K Dilution					
Number of spider-web bolometers	0	4	4	4	4	4
Number of polarisation-sensitive bolometers	8	8	8	8	0	0
Angular resolution [FWHM arcminutes]	9.5	7.1	5.0	5.0	5.0	5.0
Detector Noise-Equivalent Temperature [ $\mu$ Ks <sup>0.5</sup> ]	50	62	91	277	1998	91000
$\Delta T/T$ Intensity <sup>b</sup> [ $10^{-6}$ $\mu$ K/K]	2.5	2.2	4.8	14.7	147	6700
$\Delta T/T$ Polarisation (U and Q) <sup>b</sup> [ $10^{-6}$ $\mu$ K/K]	4.0	4.2	9.8	29.8	...	...
Sensitivity to unresolved sources [mJy]	12.0	10.2	14.3	27	43	49
ySZ per FOV [ $10^{-6}$ ]	1.6	2.1	615	6.5	26	605

# Planck frequency coverage

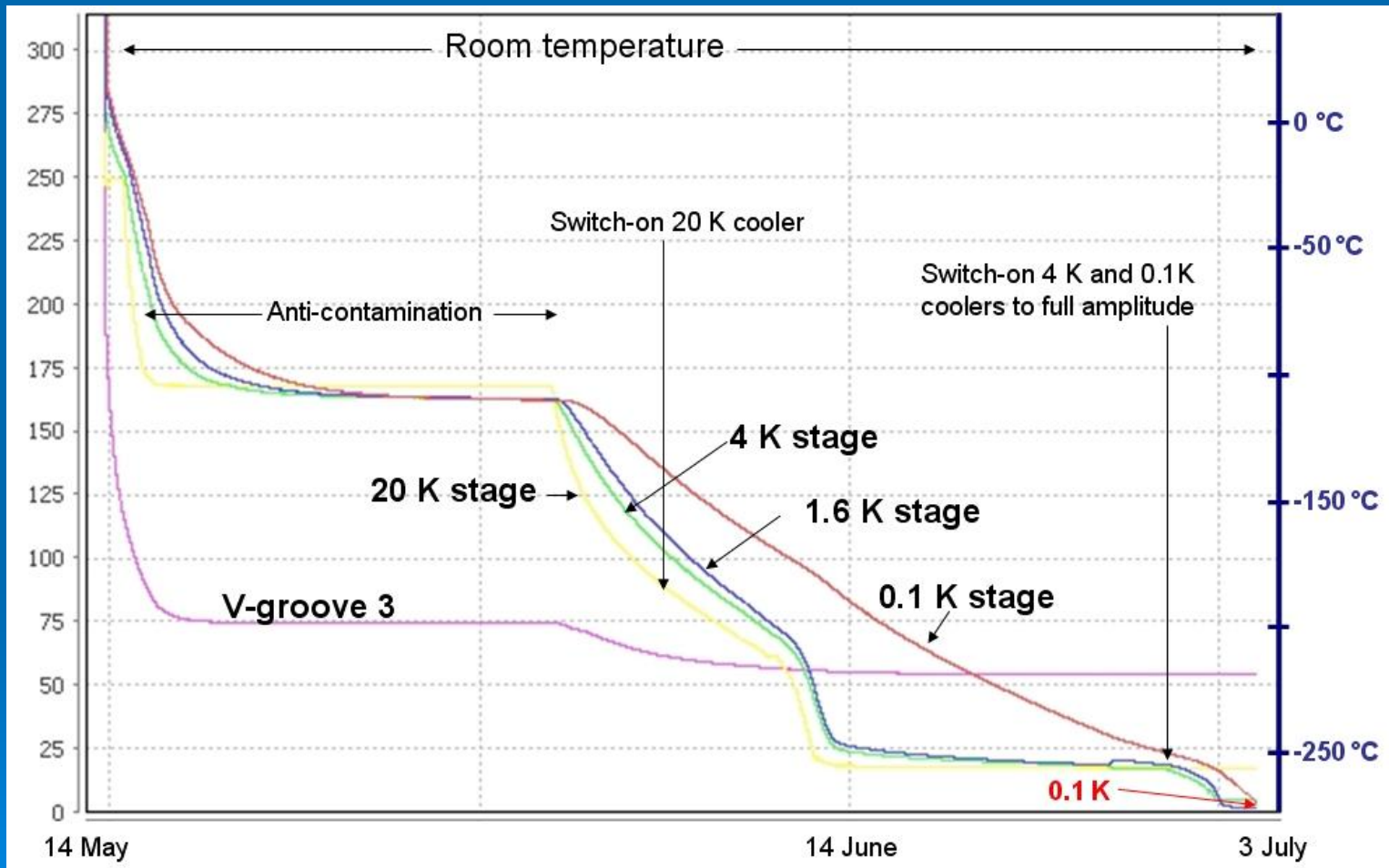




# The Planck launch, May 14<sup>th</sup>, 2009



# Planck cooling



# Data processing center





# Planck contributors

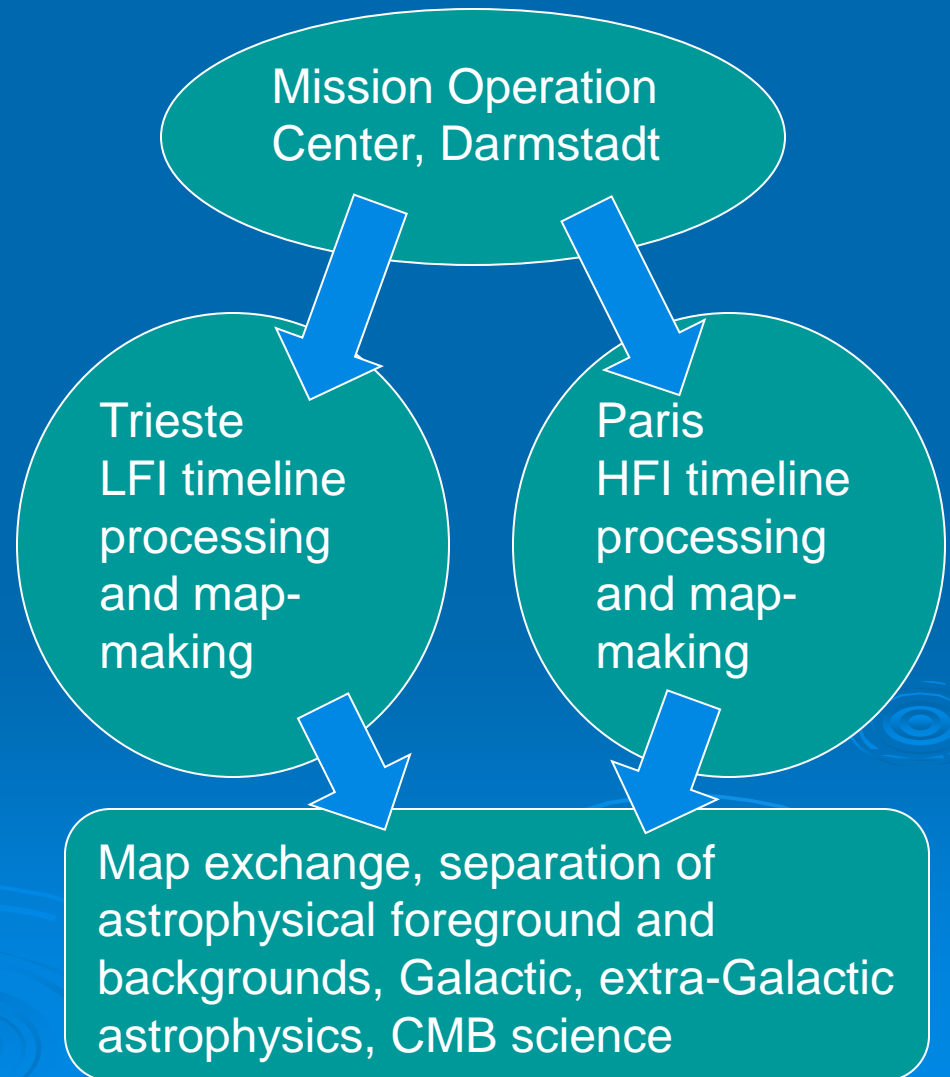
A world map at night, where the continents are outlined by a dense network of yellow and white lights representing city lights. The map is centered on Europe. Two specific locations are labeled in white text: 'Paris' and 'Trieste'.

Paris Trieste

Planck data processing centers

# Data flow and analysis levels

- Level 1, telemetry, timeline processing, calibration
- Level 2, map-making
- Level 3, multi-frequency analysis, production of Galactic, extra-Galactic and CMB science products



Berkeley, simulations

Milano, calibration,  
component separation

Bologna, beam reconstruction,  
power spectra,  
cosmological parameters

Helsinki, destriper map-making

Trieste, time ordered data processing,  
Component separation, cosmological parameters

Padova, component separation

Rome, GLS map-making, power spectra,  
cosmological parameters

# The LFI DPC



# Planck DPC facilities

- DPC people physically in Trieste are about 20 at OATs and SISSA
- The data are hosted on two computers, ENT (OATs, front-end database and computing resource, 256 CPUs, hundreds of GB RAM, tens of TB disk space), HG1 (SISSA, computing resources, 160 CPUs, hundreds of GB RAM, tens of TB disk space)





# Planck milestones

- May 14<sup>th</sup>, 2009, launch, the High Frequency Instrument (HFI, bolometers) is on
- June 1<sup>st</sup>, 2009, active cryogenic systems are turned on
- June 8<sup>th</sup>, 2009, the Low Frequency Instrument (LFI, radiometers), is turned on
- Summer 2009, Planck gets to L2, survey begins, 14 months
- 2 years of proprietary period and data analysis
- Early papers on extra-Galactic astrophysics, early 2011
- Complete results including cosmology, end of 2012
- Mission extended! Survey doubled, beginning October 2010, ending end of 2011



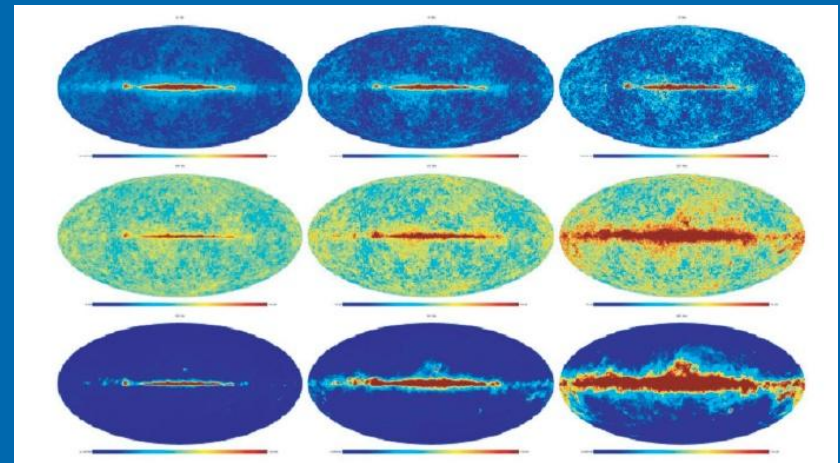
# Expectations from Planck

Source: Planck scientific program bluebook,  
available at [www.rssd.esa.int/Planck](http://www.rssd.esa.int/Planck)



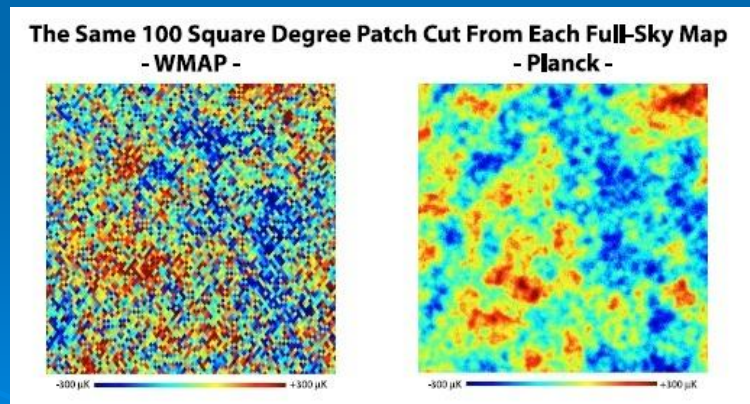
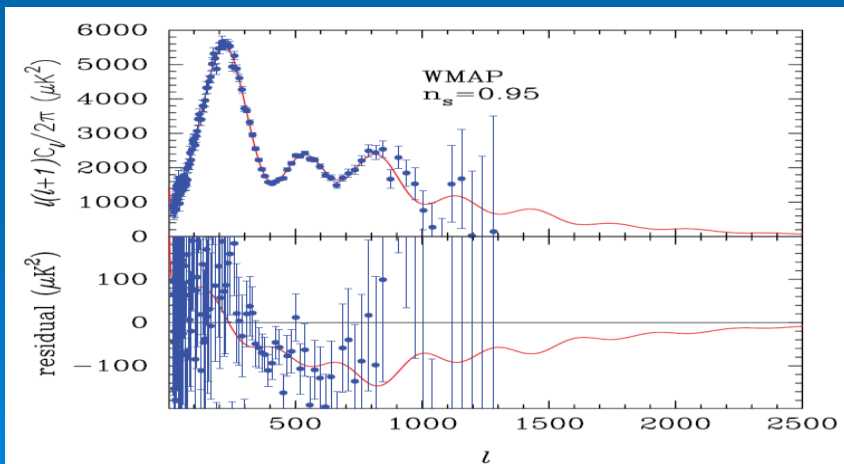
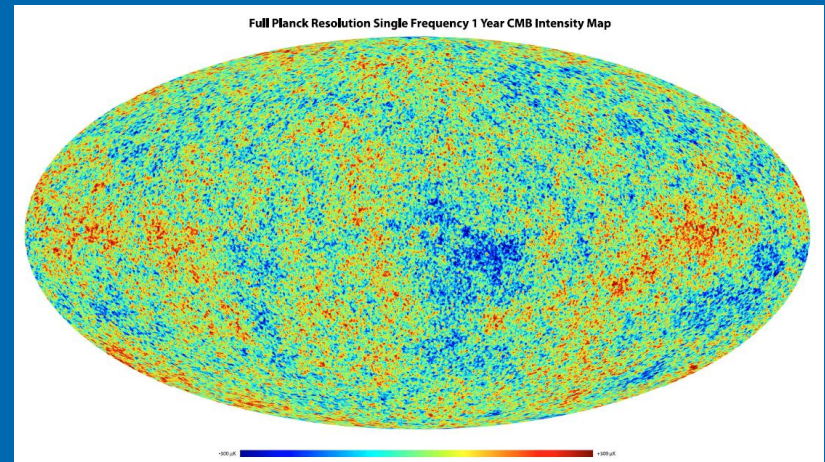
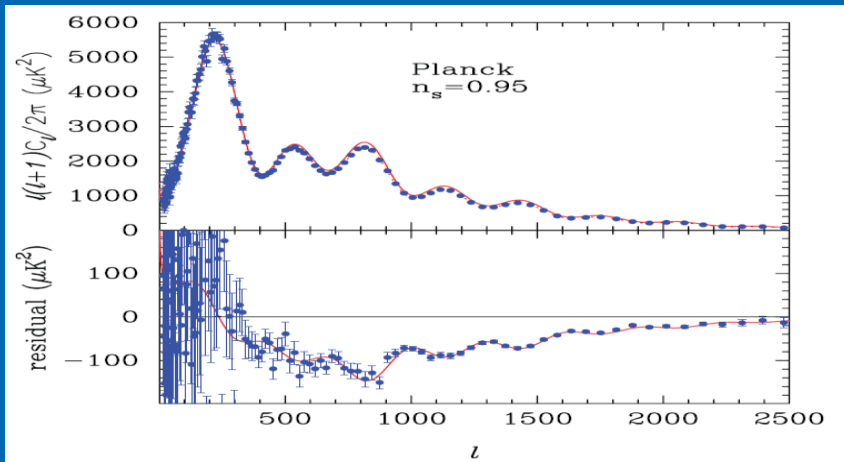
# Planck deliverables

- All sky maps in total intensity and polarization, at 9 frequencies between 30 and 857 GHz
- Angular resolution from 33' to 7' between 30 and 143 GHz, 5' at higher frequencies
- S/N  $\approx 10$  for CMB in total intensity, per resolution element
- Catalogues with tens of thousands of extra-Galactic sources

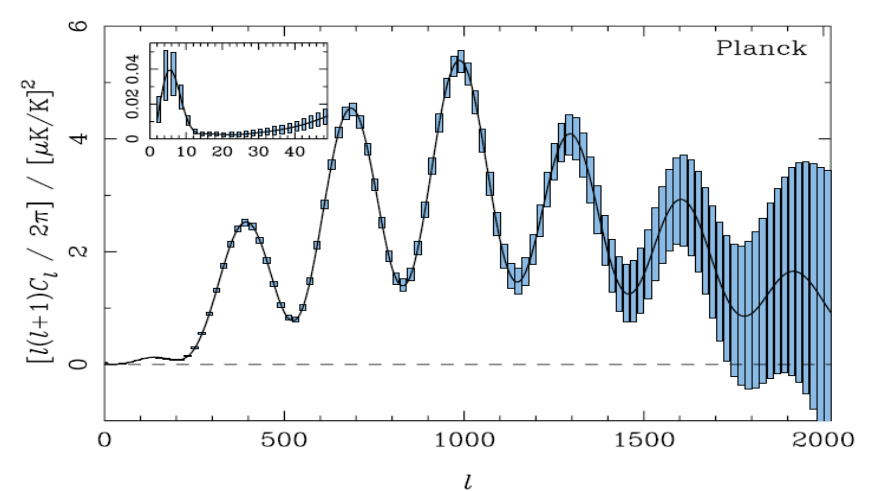
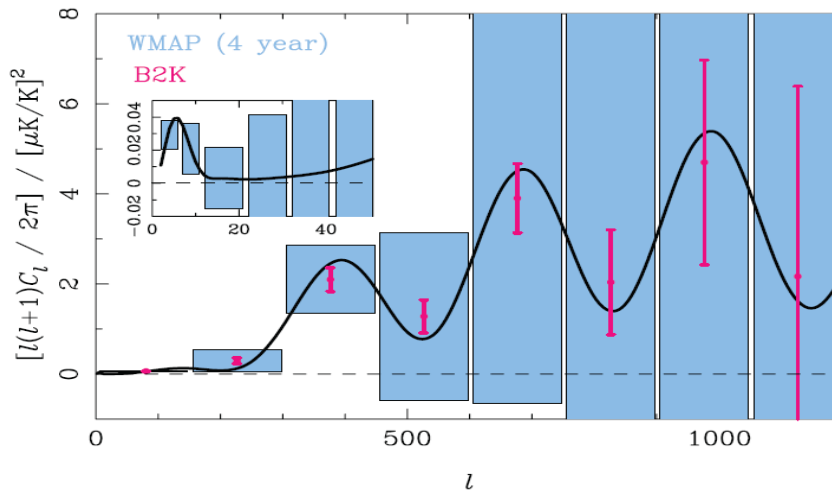
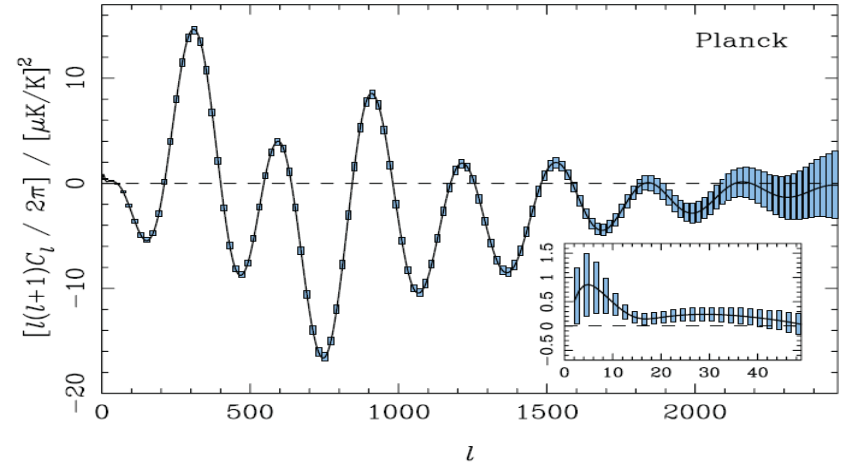
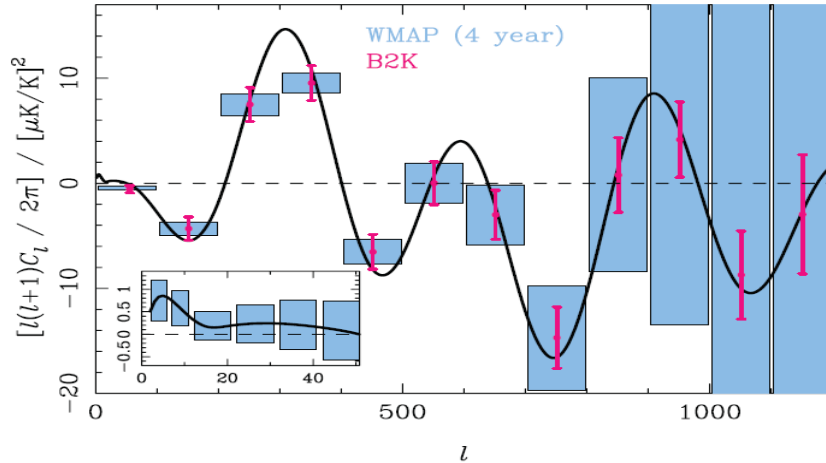


PLANCK GALAXY SURVEYS					
	FREQUENCY [GHz]				
	143	217	353	550	850
Confusion limit [mJy, $3\sigma$ ] .....	6.3	14.1	44.7	112	251
Planck All Sky Survey sensitivity [mJy, $3\sigma$ ] .....	26	37	75	180	300
Planck Deep Survey sensitivity [mJy, $3\sigma$ ] .....	10	18.4	49	170	280
Number of galaxies [all sky] .....	570	860	1700	4400	35000

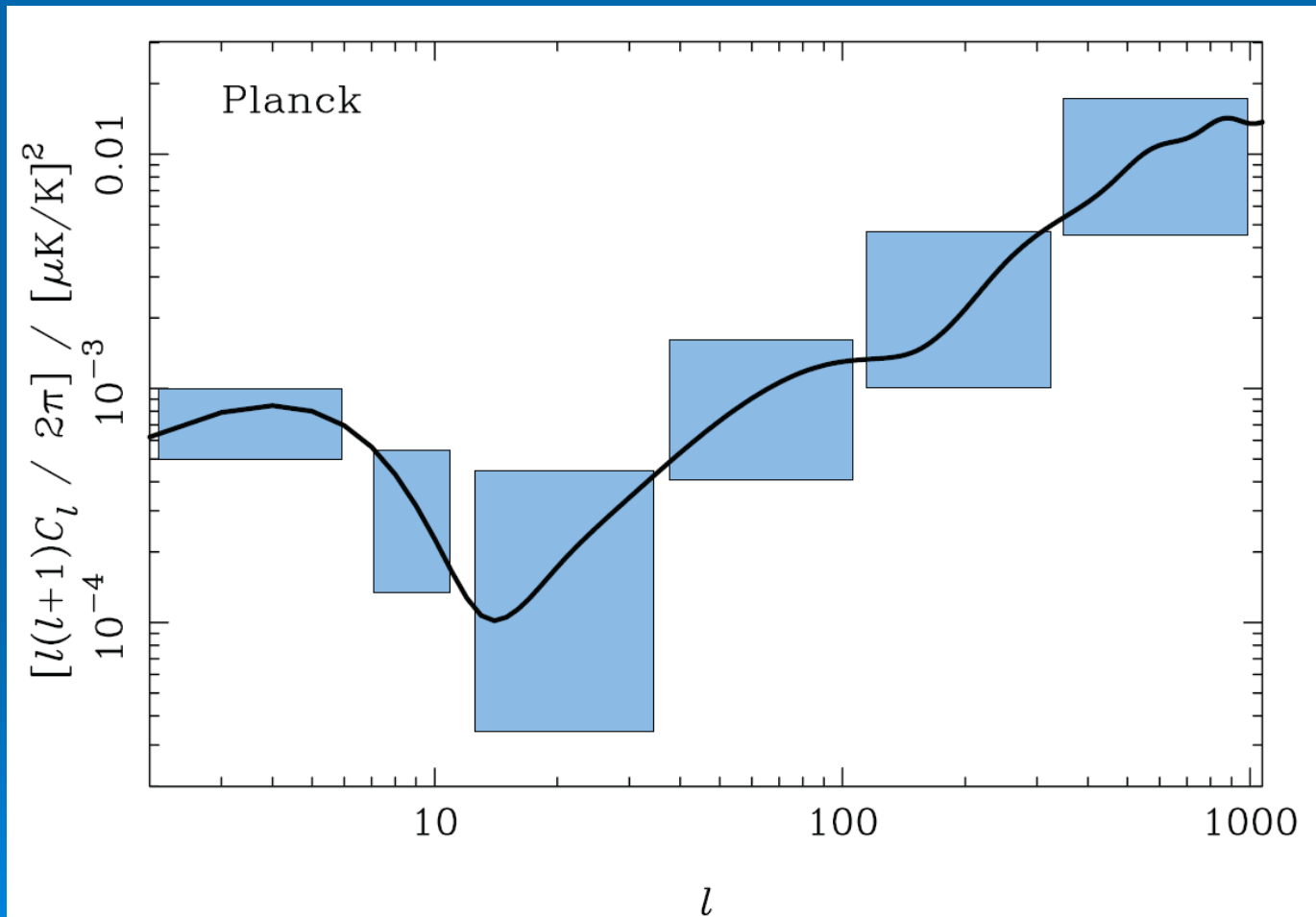
# CMB imaging



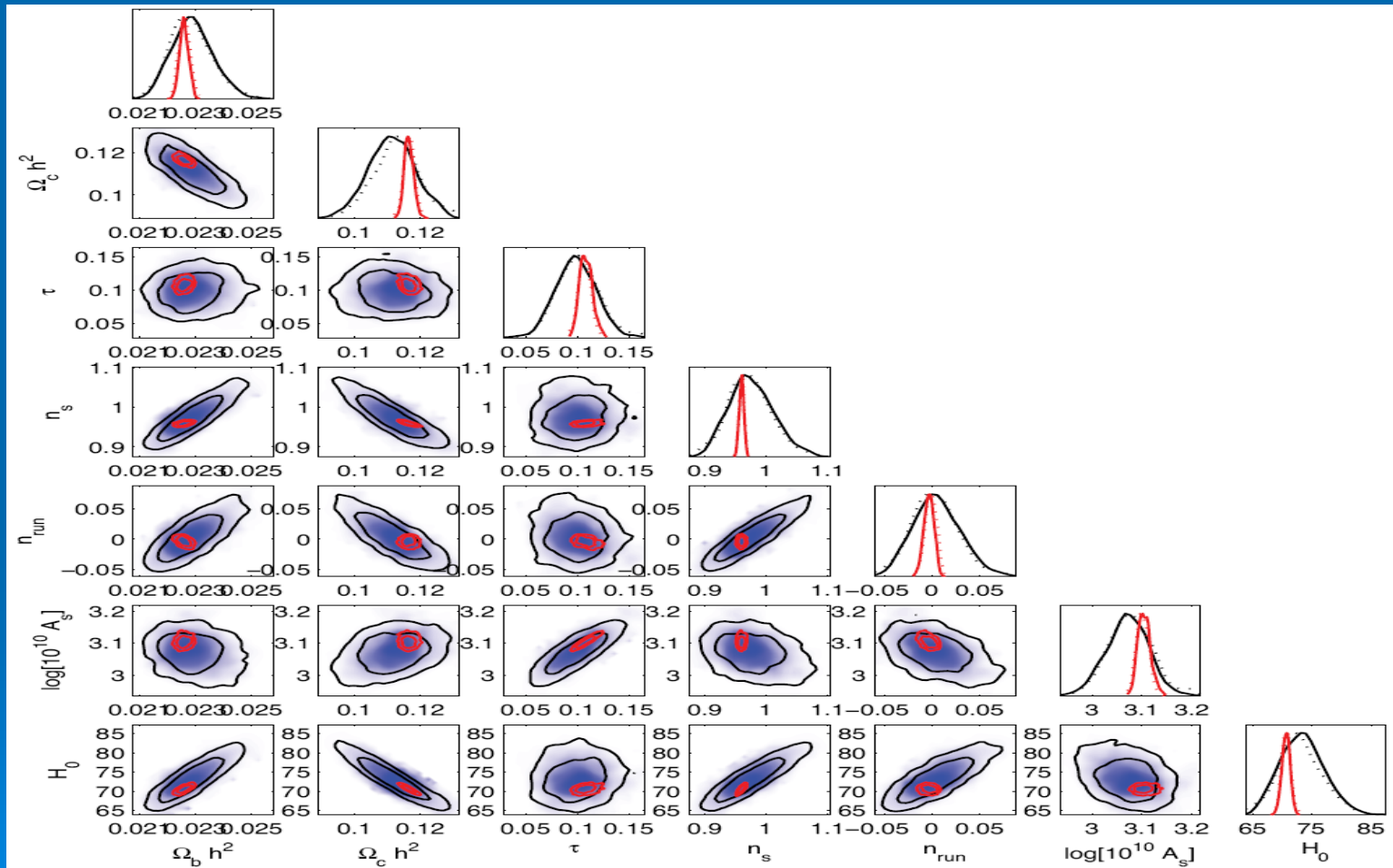
# CMB polarization



# Probing next generation CMB goals



# Cosmological parameters



# Non-CMB Planck scientific deliverables

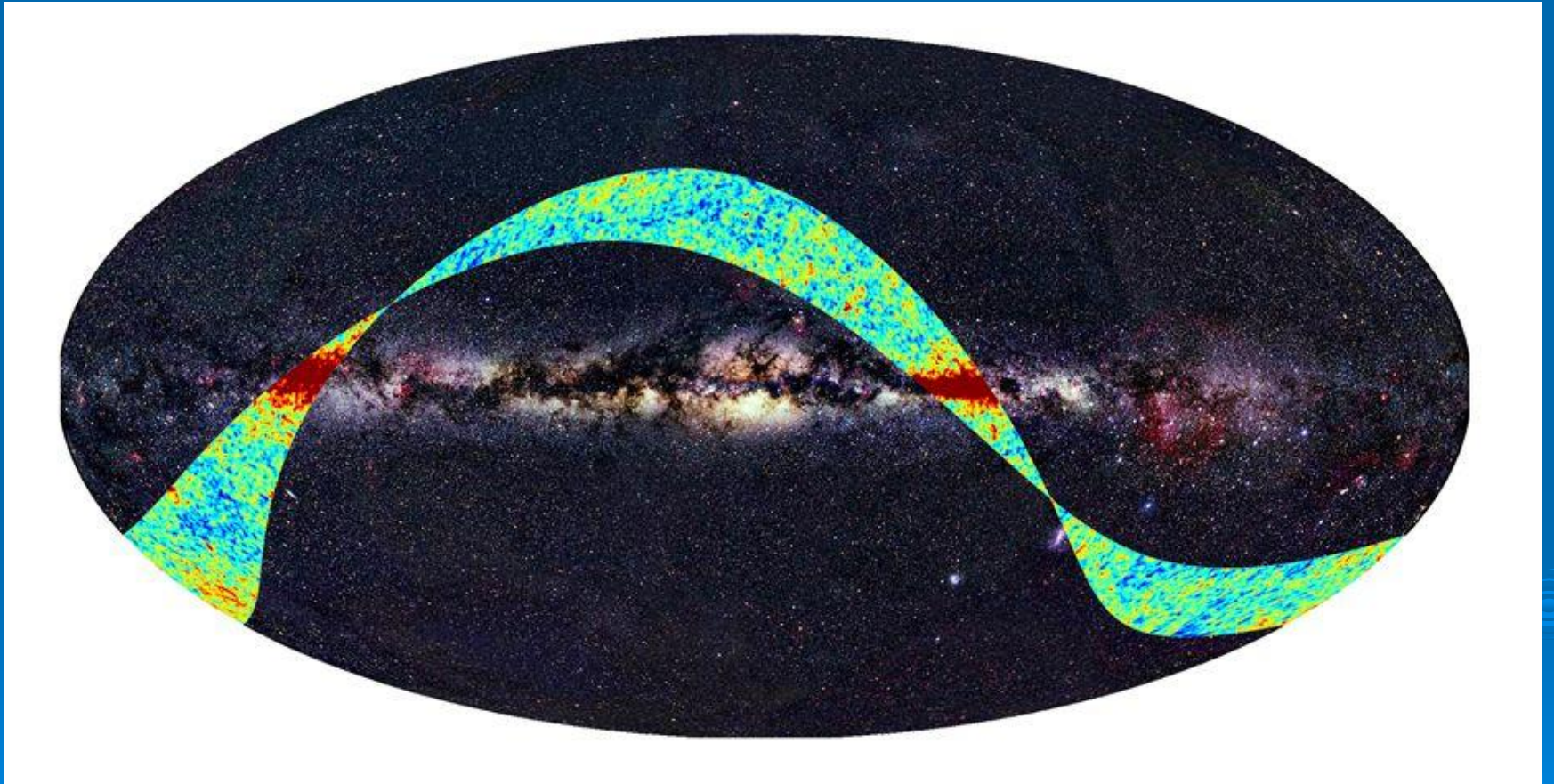
- $\sim 10^3$  galaxy clusters
- $\sim 10^4$  radio and infrared extra-Galactic sources
- Unprecedented insight into the physics of diffuse gas in the Galaxy, Galactic magnetic field, ...
- ...



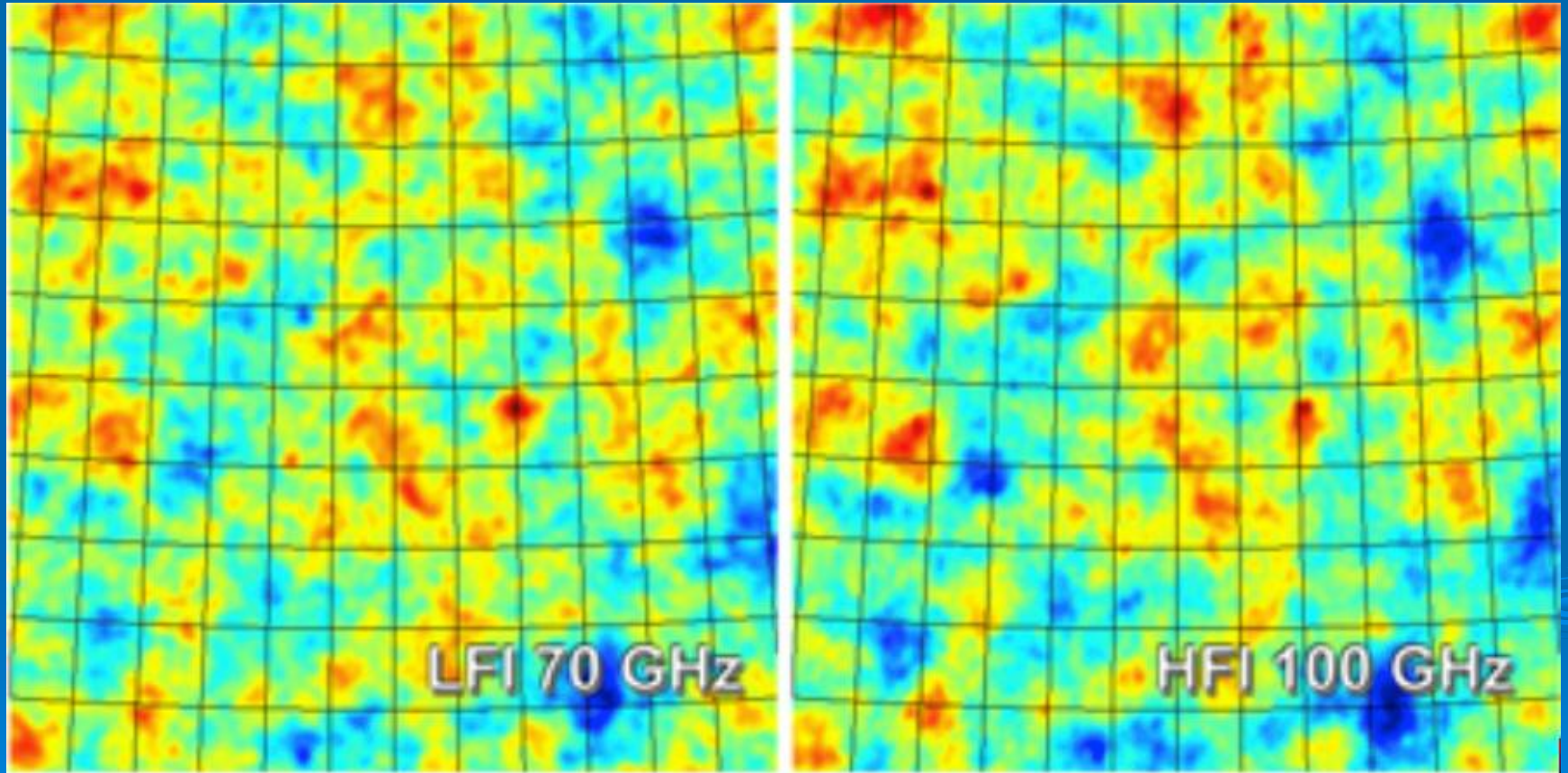
# Planck data



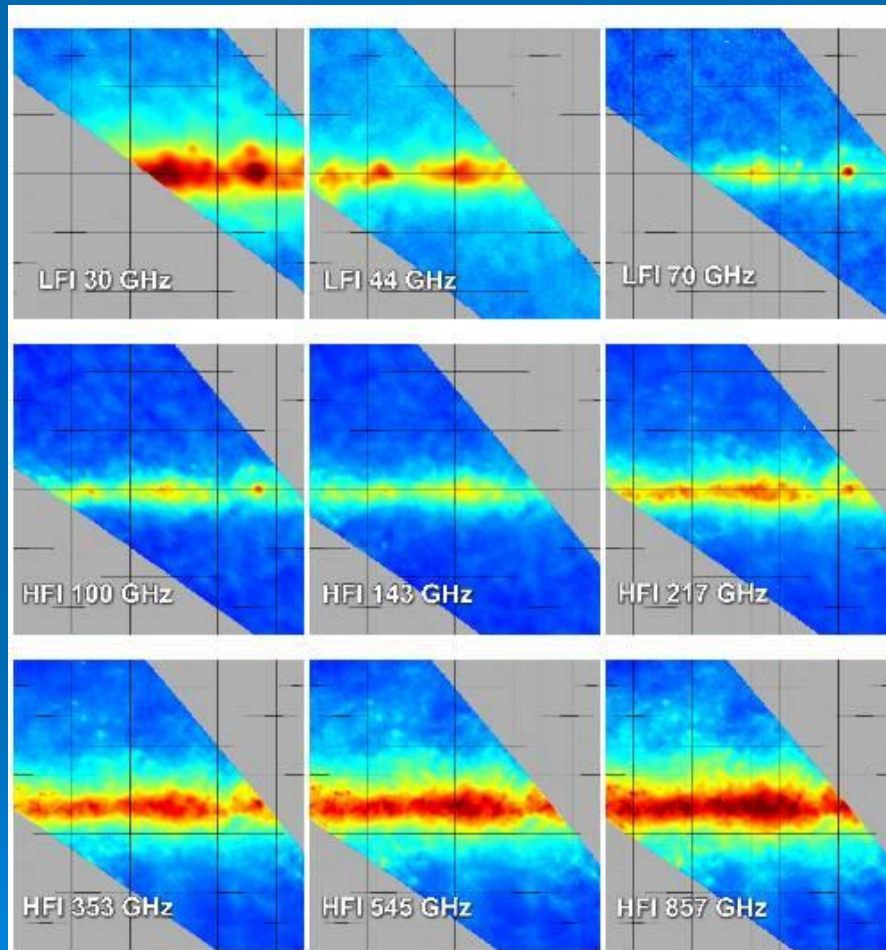
# First light survey



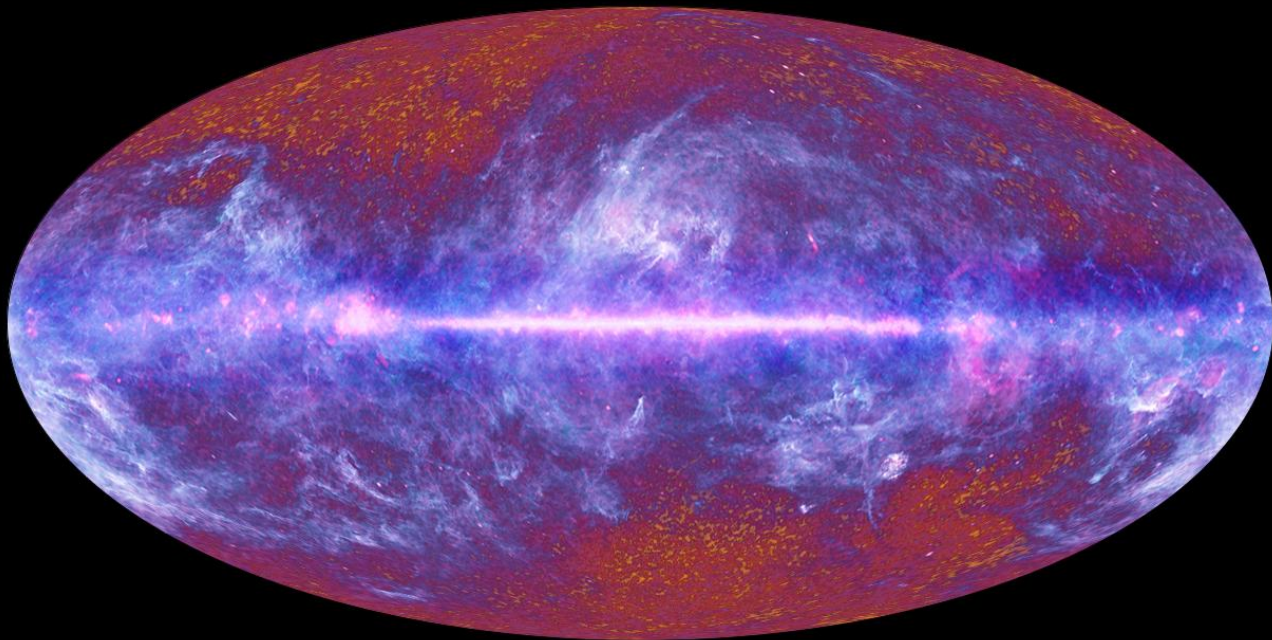
# First light survey



# First light survey



# First year survey

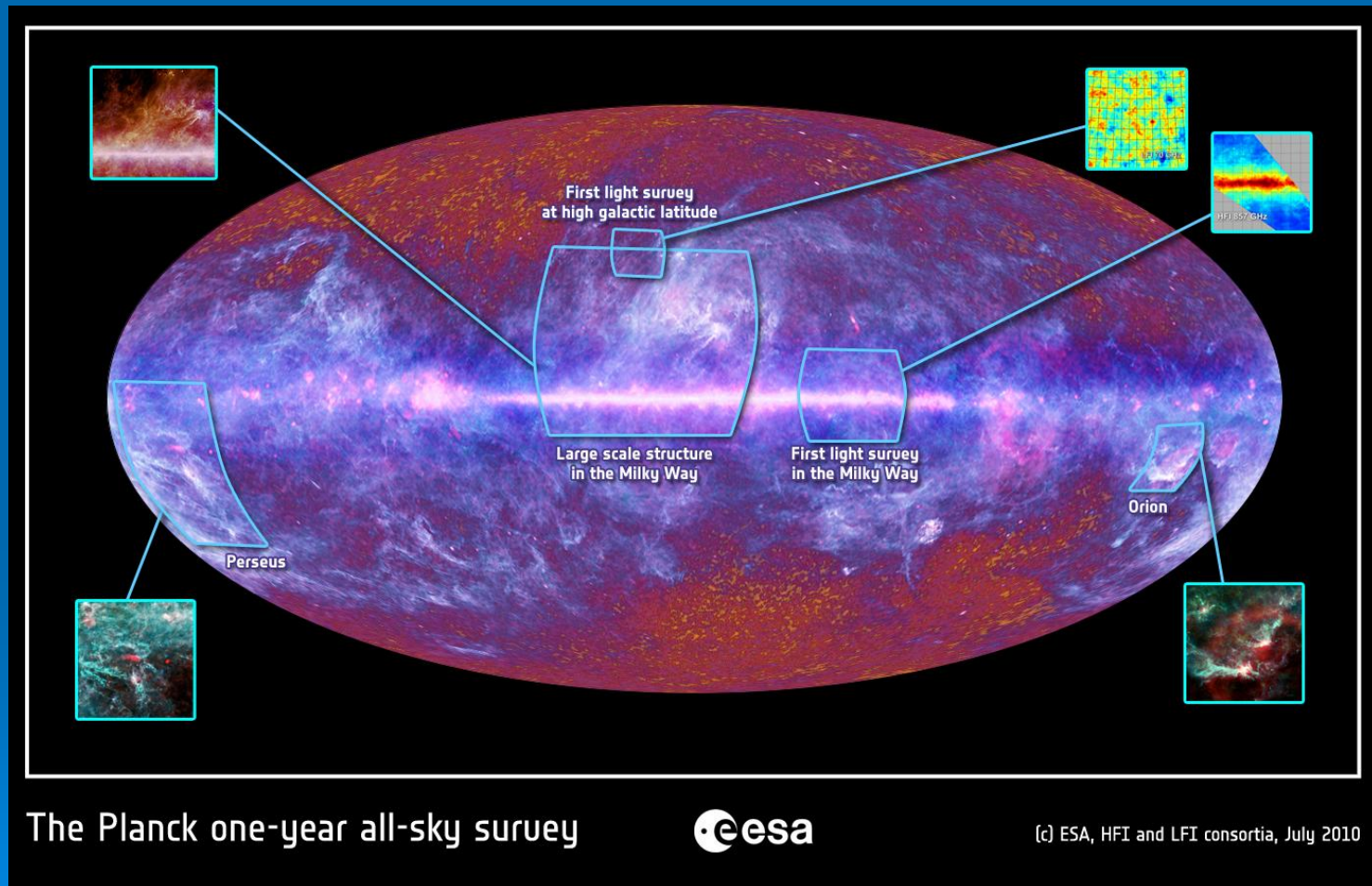


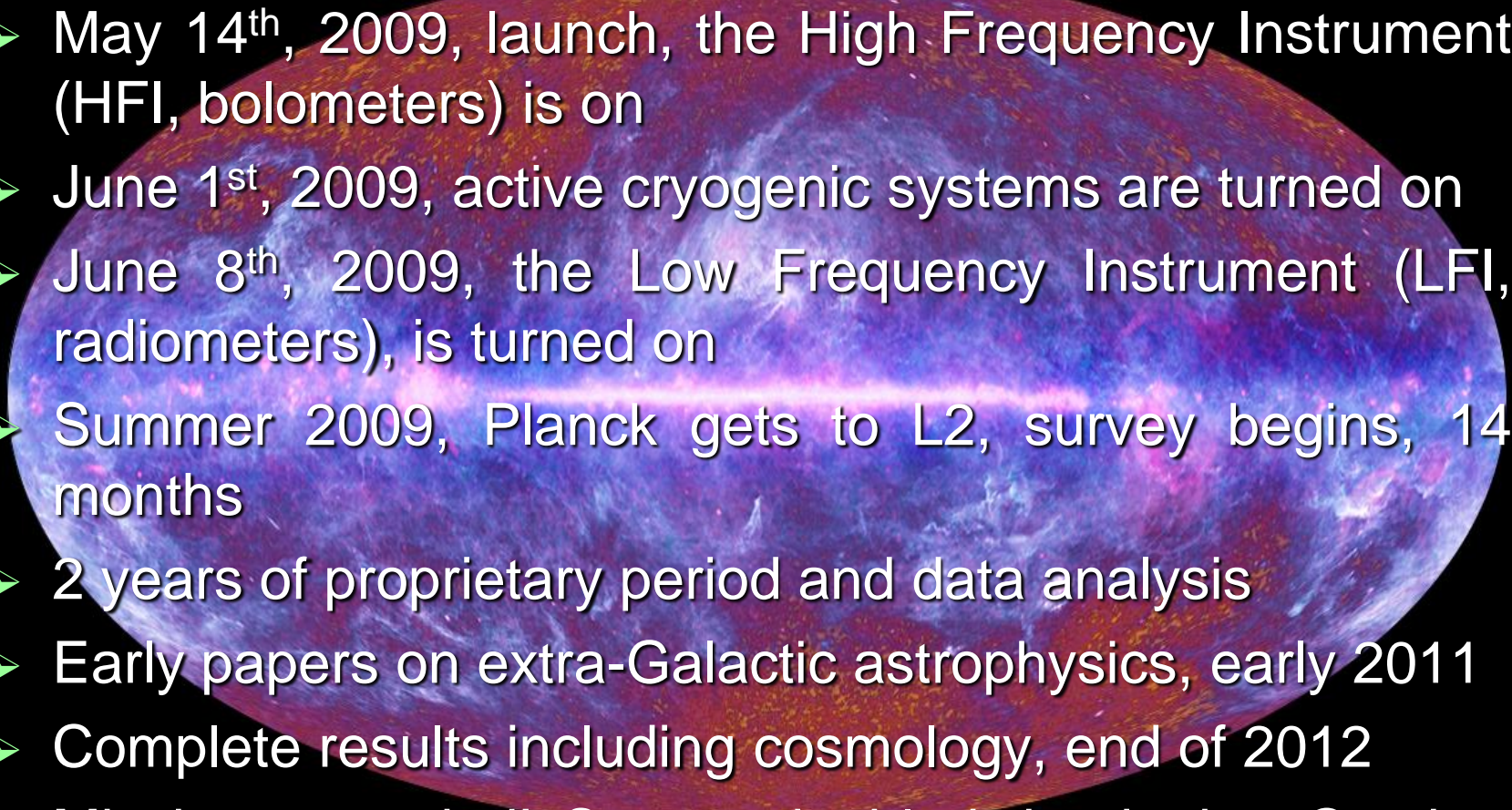
The Planck one-year all-sky survey



(c) ESA, HFI and LFI consortia, July 2010

# First year survey



- 
- May 14<sup>th</sup>, 2009, launch, the High Frequency Instrument (HFI, bolometers) is on
  - June 1<sup>st</sup>, 2009, active cryogenic systems are turned on
  - June 8<sup>th</sup>, 2009, the Low Frequency Instrument (LFI, radiometers), is turned on
  - Summer 2009, Planck gets to L2, survey begins, 14 months
  - 2 years of proprietary period and data analysis
  - Early papers on extra-Galactic astrophysics, early 2011
  - Complete results including cosmology, end of 2012
  - Mission extended! Survey doubled, beginning October 2010, ending end of 2011