The Planck Satellite

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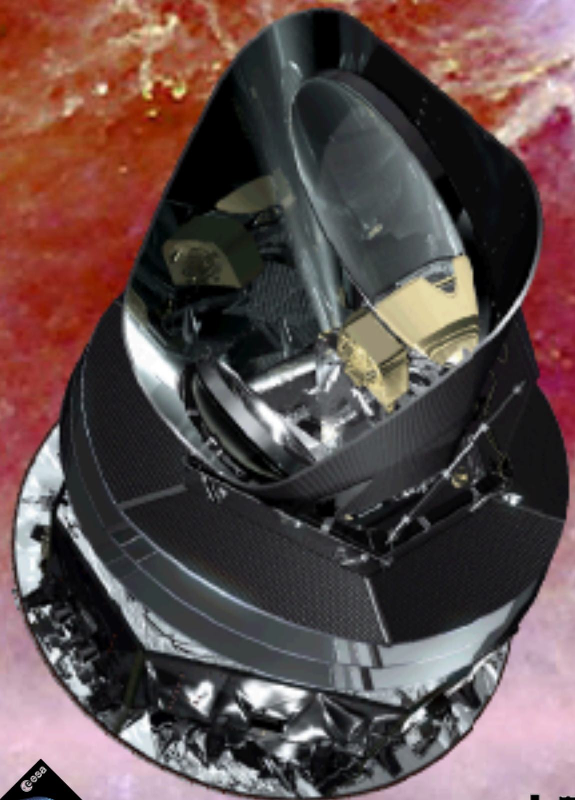
Ecole Internationale Daniel Chalonge
14^{th} Paris Cosmology Colloquium 2010

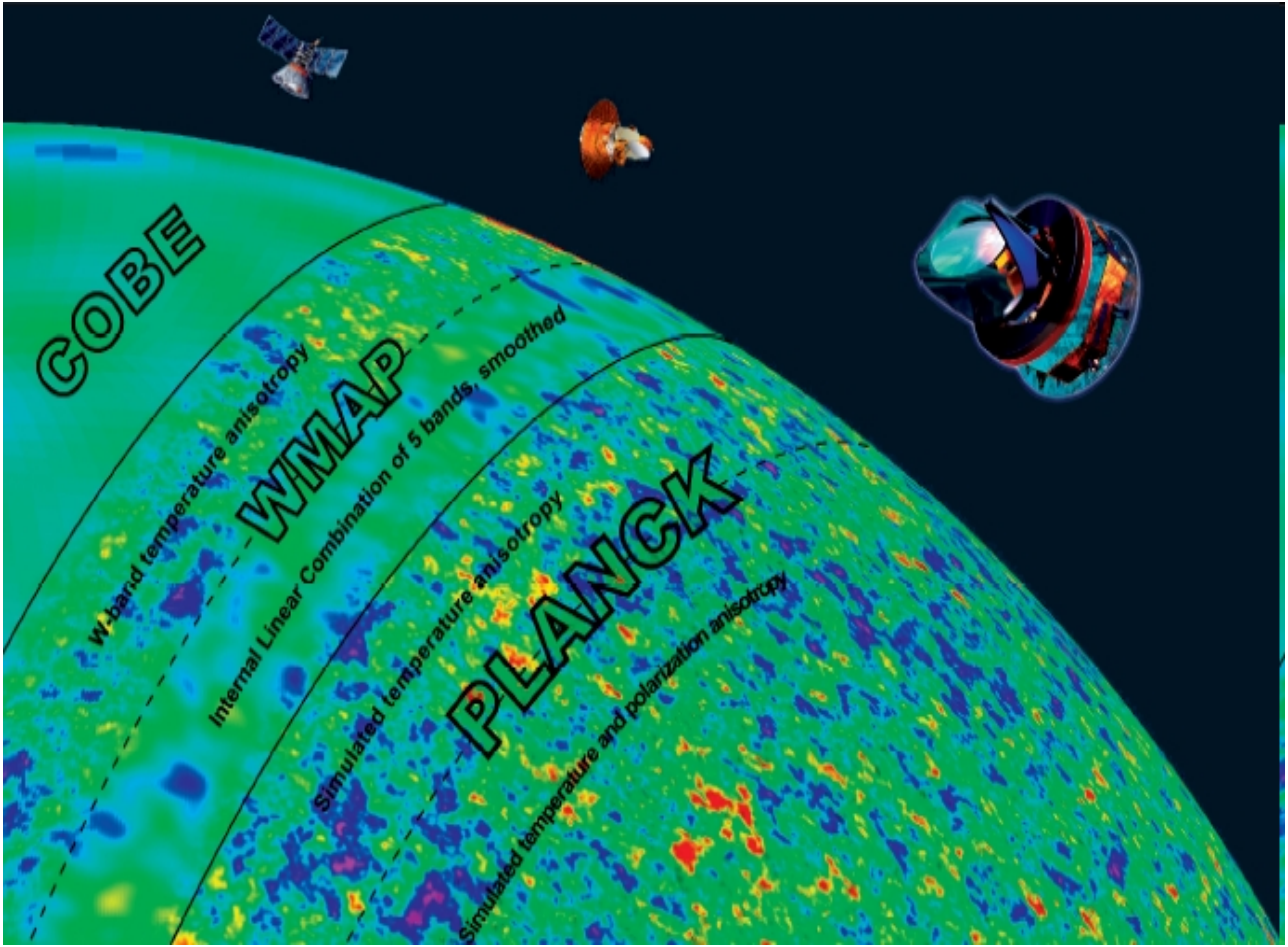
On behalf of the Planck collaboration

www.esa.int/Planck



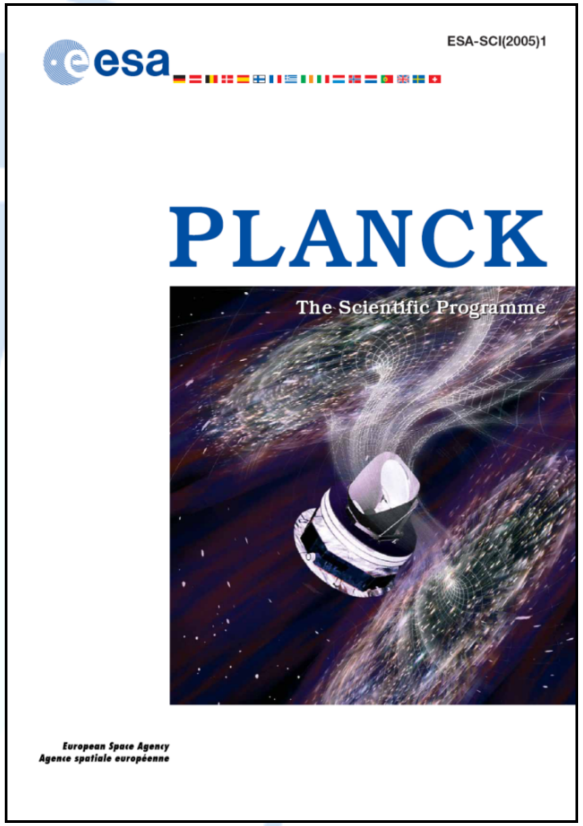
Planck

- *Planck* is a project of the European Space Agency - ESA – 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 collaboration between ESA and a scientific Consortium led and funded by Denmark
- *This talk is supported also by information provided by LFI, HFI and ESA*

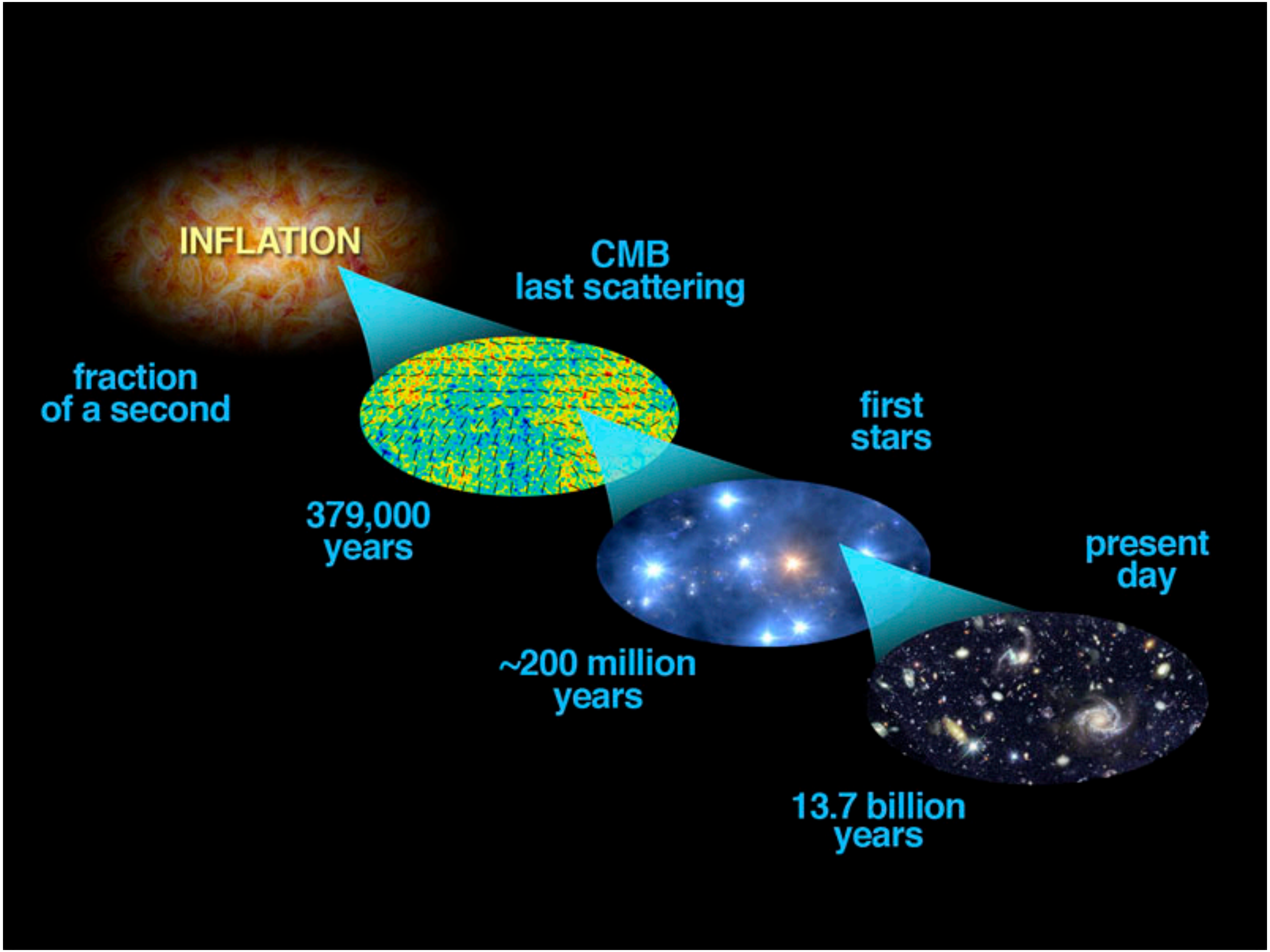

COBE
WMAP
W-band temperature anisotropy
Internal Linear Combination of 5 bands, smoothed
PLANCK
Simulated temperature anisotropy
Simulated temperature and polarization anisotropy

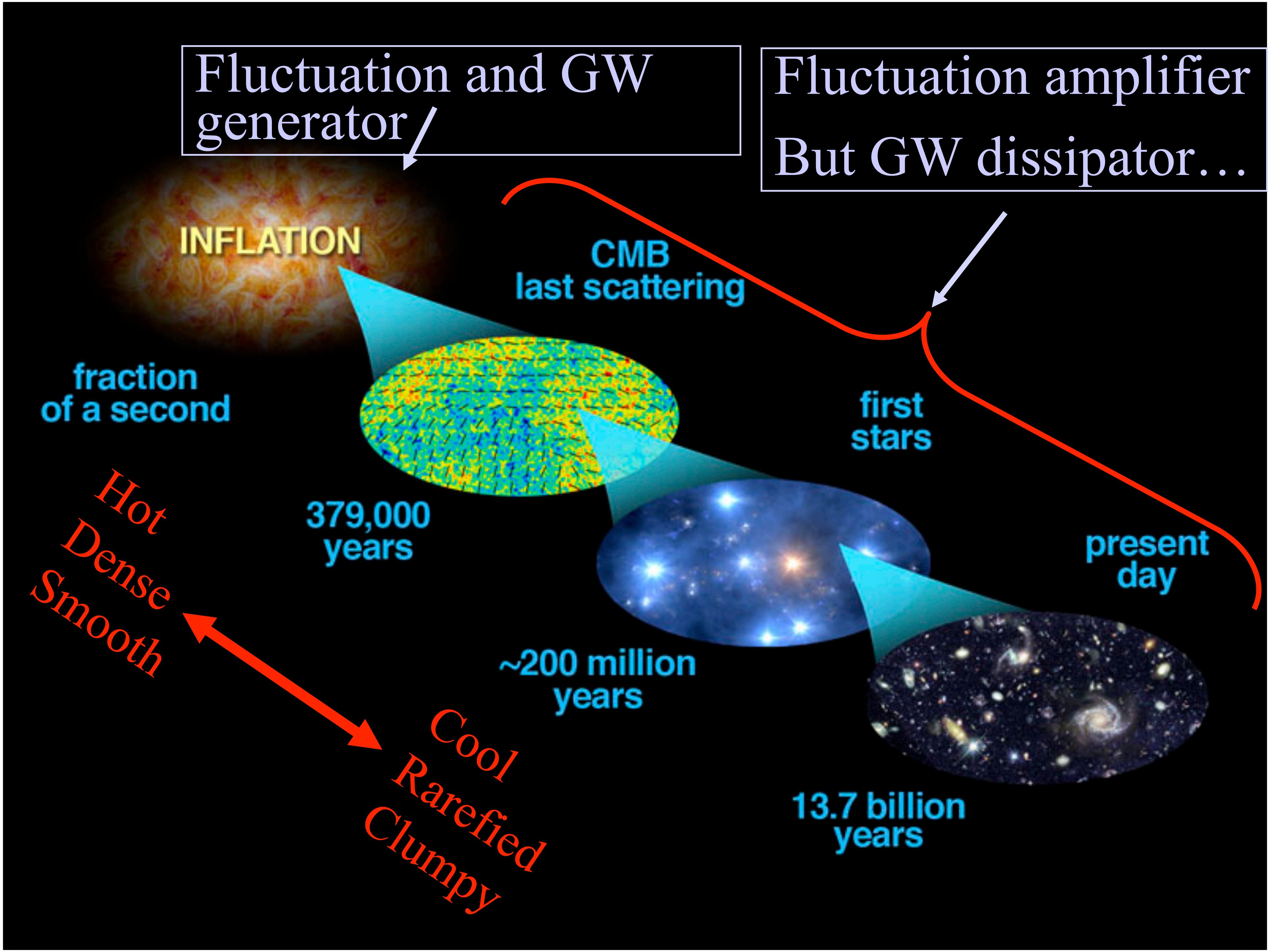
Science with the Cosmic Microwave Background

- Determining cosmological parameters to high accuracy
  - Geometry, Contents, Dynamics of Universe
  - epoch of reionisation: birth of the first stars
  - Constraining dark energy, neutrino mass, …
- Testing inflation:
  - constraining the inflaton potential
  - Finding signatures of primordial gravitational waves
- Finding primordial non-Gaussianity
  - Testing different inflationary scenario
- Evolution of structure and nature of dark matter
- …



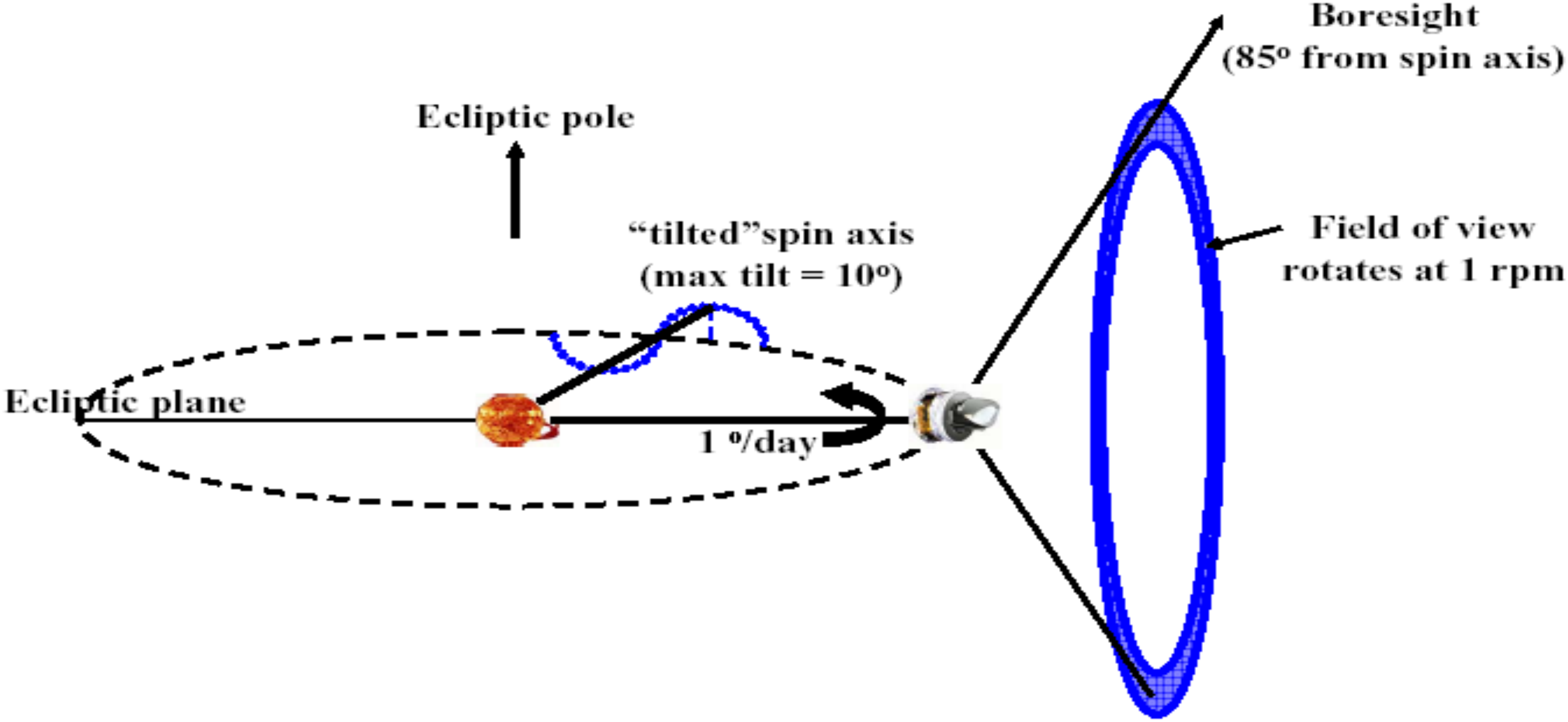
•*http://www.rssd.esa.int/Planck*

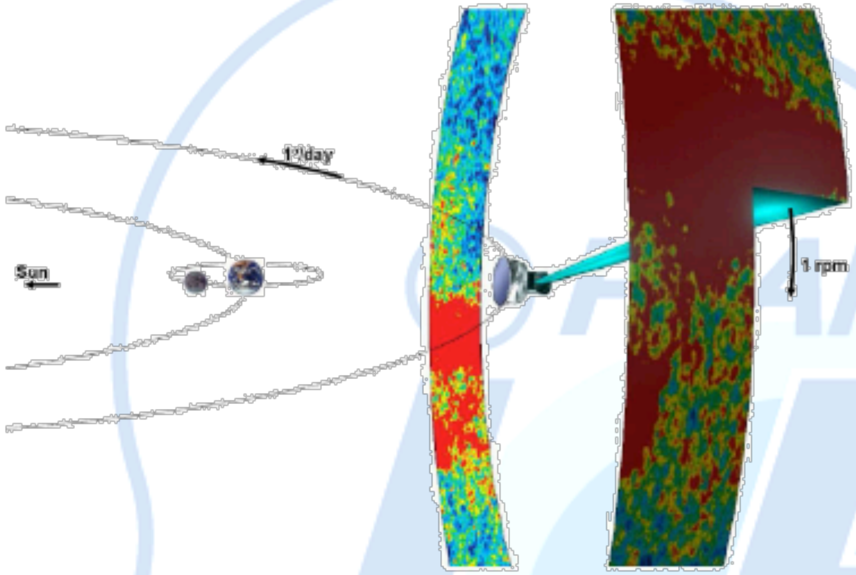

INFLATION
CMB
last scattering
fraction
of a second
first
stars
379,000
years
present
day
~200 million
years
13.7 billion
years



Fluctuation and GW generator
Fluctuation amplifier
But GW dissipator…
INFLATION
CMB
last scattering
fraction of a second
first stars
379,000 years
present day
Hot
Dense
Smooth
~200 million years
Cool
Rarefied
Clumpy
13.7 billion years

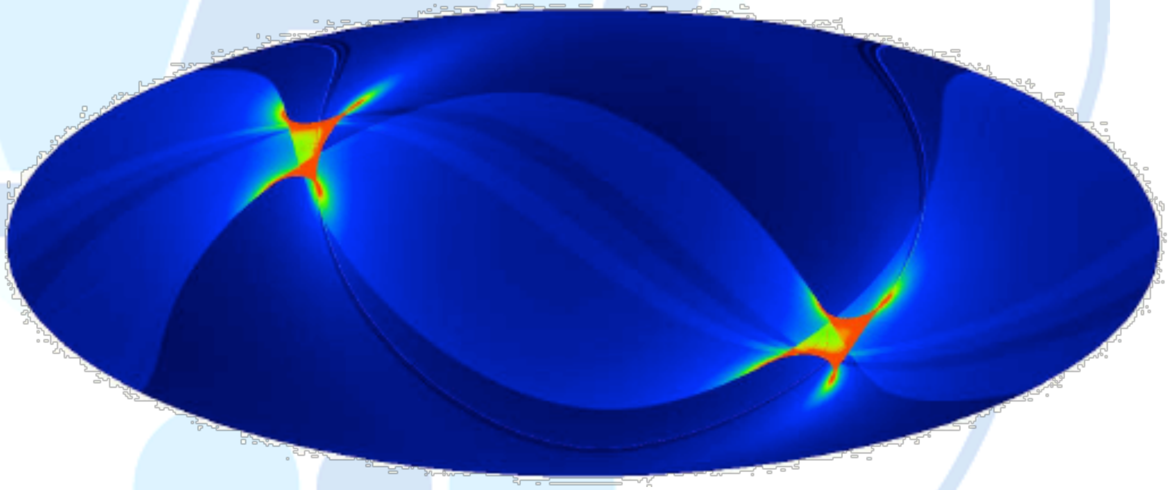
Observing strategy



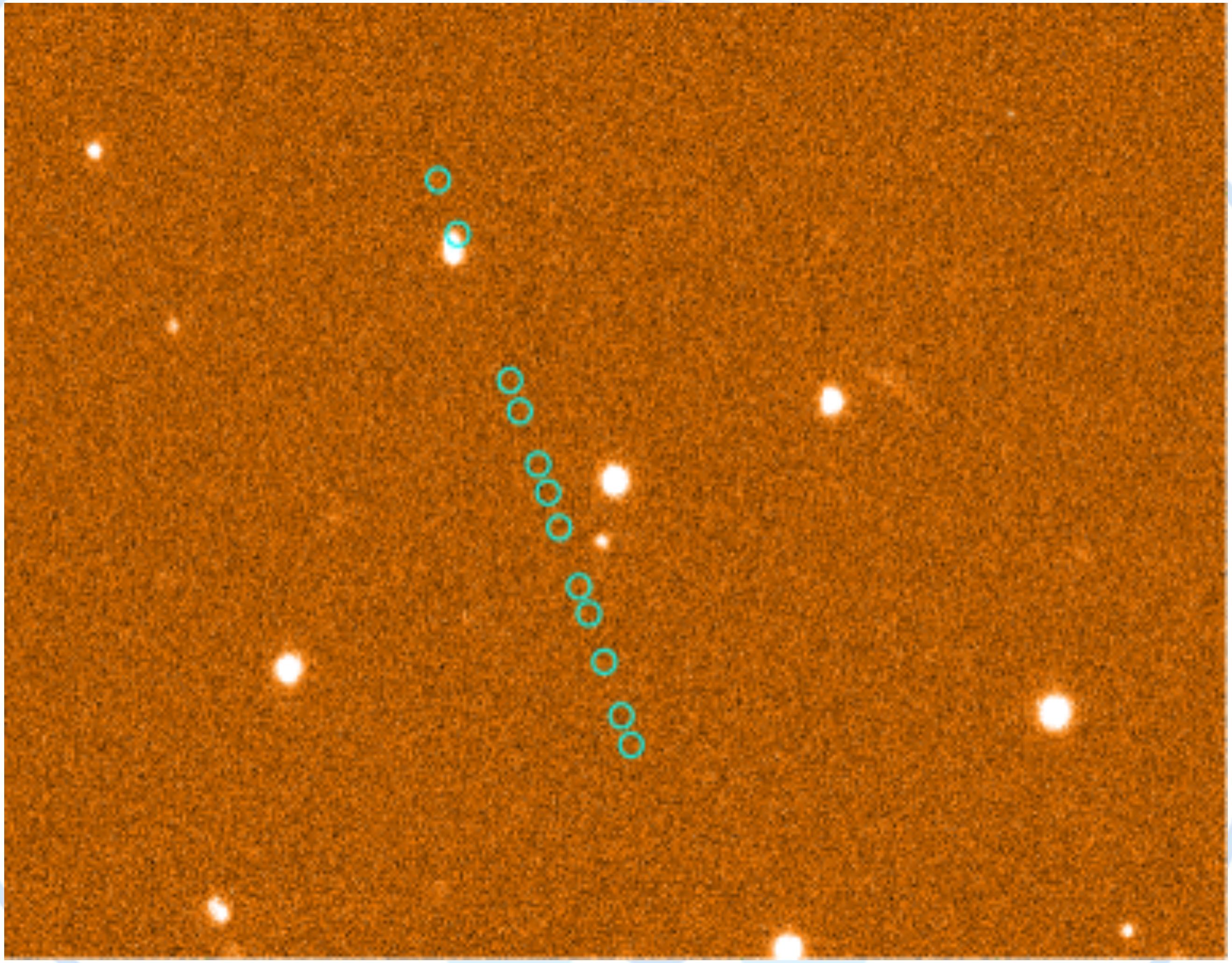


Planck is a survey mission

About 6 months are needed to cover ~95% of the sky.



As seen from the 2.2 m telescope ESO - Chile

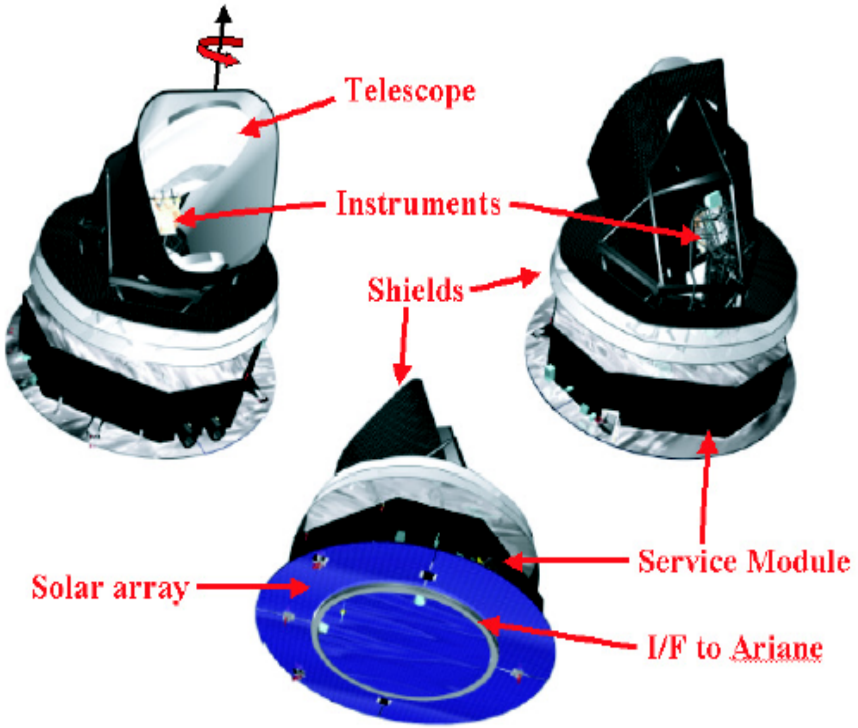


Current Status

- 436 days since launch.
- Satellite and instruments working nominally and continuously since start of sky surveys (mid August 2009)
- Sky coverage is 100%

A Planck view

FIG 1.2.—*Planck* focal plane unit. The HFI is inserted into the ring formed by the LFI horns, and includes thermal stages at 18 K, 4 K, 2 K and 0.1 K. The cold LFI unit (20 K) is attached by bipods to the telescope structure.



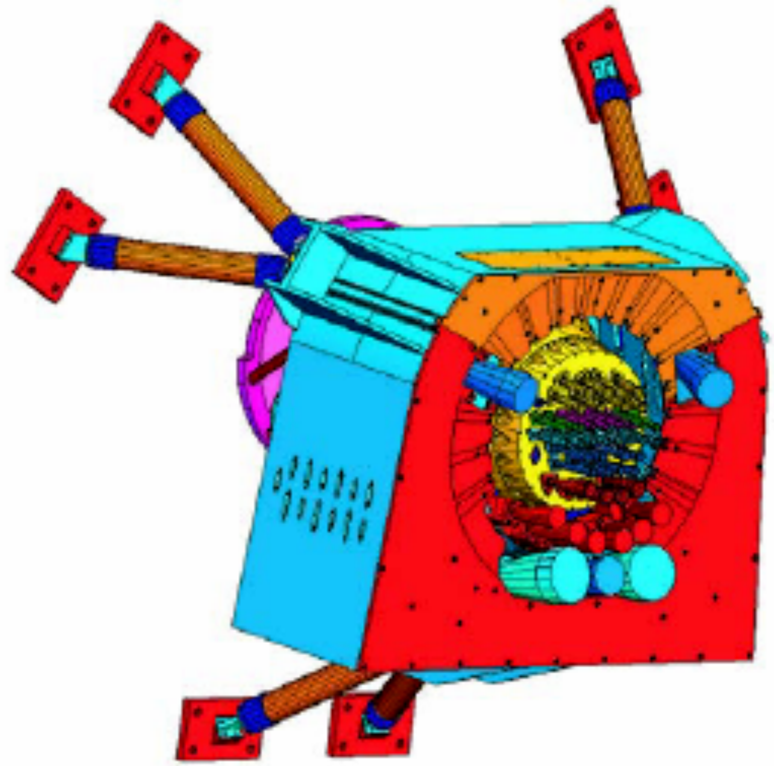


FIG 1.1.— Main elements of *Planck*. The instrument focal plane unit (barely visible) contains both LFI and HFI detectors. The function of the large baffle surrounding the telescope is to control the far sidelobe level of the radiation pattern as seen from the detectors. The specular conical shields (often called "V-grooves") thermally decouple the Service Module (which contains all warm elements of the satellite) from the Payload Module. The satellite spins around the indicated axis, such that the solar array is always exposed to the Sun, and shields the payload from solar radiation. Figures courtesy of Alcatel Space (Cannes).

Planck: the 3rd generation space CMB experiment

- Planck gains a factor 2.5 in angular resolution and up to10 in instantaneous sensitivity with respect to WMAP
- LFI uses coherent detection and HEMTS based amplifiers in 3 bands 30 to 70 GHz, photometric reference loads on the 4K box of the HFI FPU. LFI is cooled at 18 K, reads in total power (22 polarized channels, 44 total power signals). Small 1/f noise.
- HFI bolometers are cooled to 100 mK, 6 bands 100 to 857 GHz, read in total power mode with a white noise from 10 mHz to 100 Hz (no 1/f noise in the signal range), nearly photon noise limited in the CMB channels (100-200 GHz)
- Intensity power spectrum sensitivity is limited by the ability to remove foregrounds (supported by the broad frequency coverage: 30 GHz-1 THz)

•LFI view – I

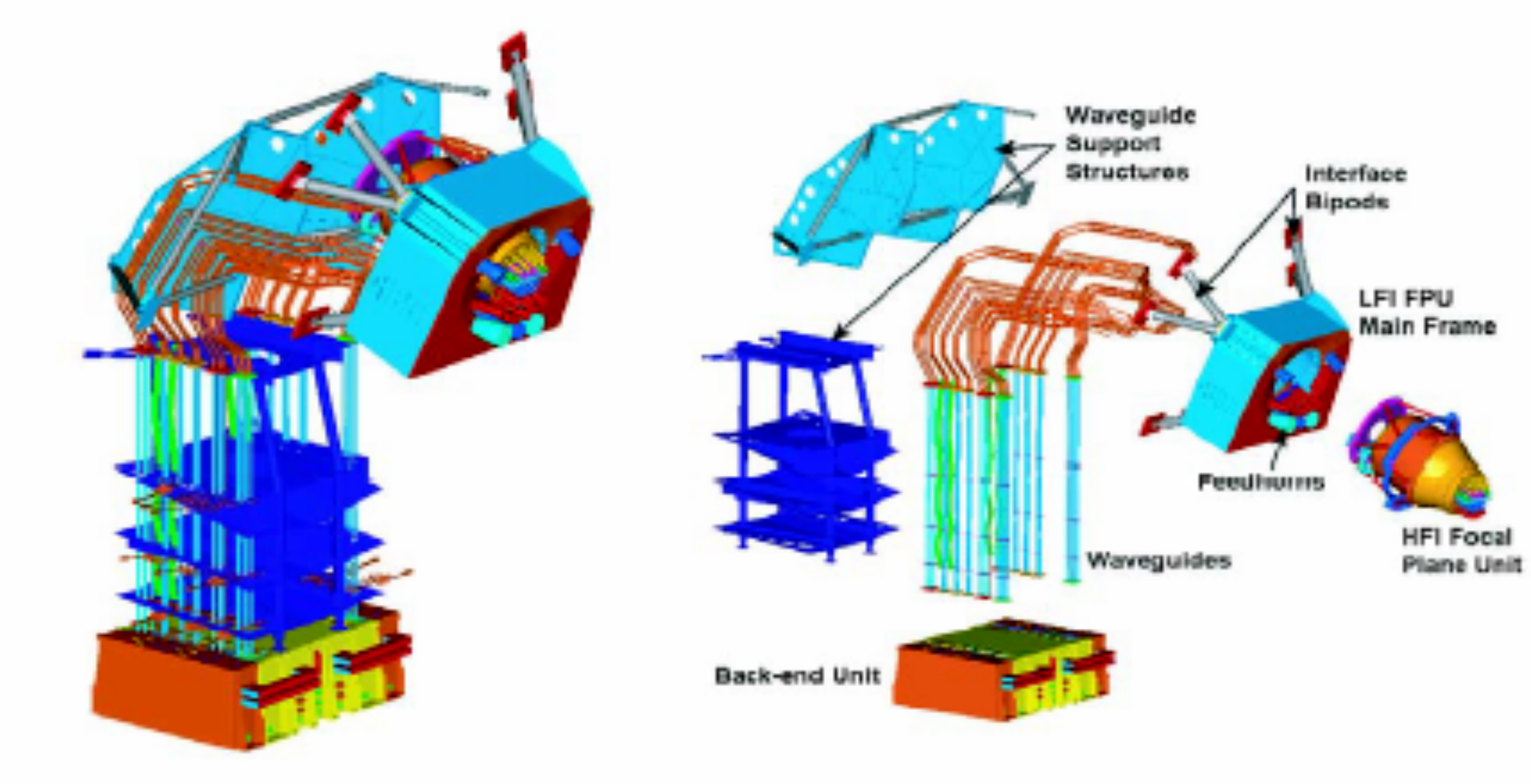
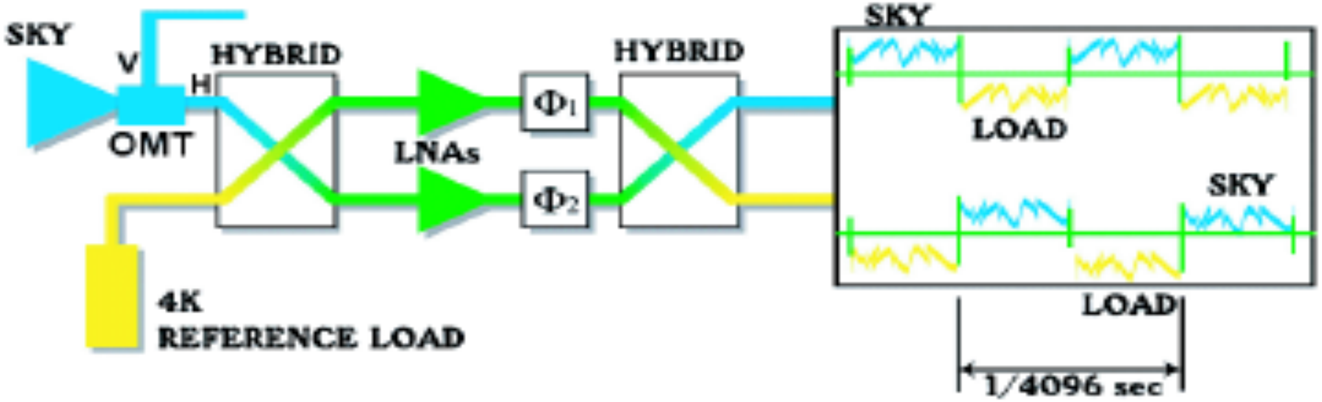


FIG 1.5.—The LFI radiometer array assembly (left), with details of the front-end and back-end units (right). The front-ends are based on wide-band low-noise amplifiers, fed by corrugated feedhorns which collect the radiation from the telescope. The waveguides transport the amplified signals from the front-end (at 20 K) to the back-end (at 300 K). They are designed to meet simultaneously radiometric, thermal, and mechanical requirements, and are thermally linked to the three V-groove thermal shields of the *Planck* payload module. The back-end unit, located on top of the *Planck* service module, contains additional amplification as well as the detectors, and is interfaced to the data acquisition electronics. The HFI is inserted into and attached to the frame of the LFI focal-plane unit.

•LFI view – II



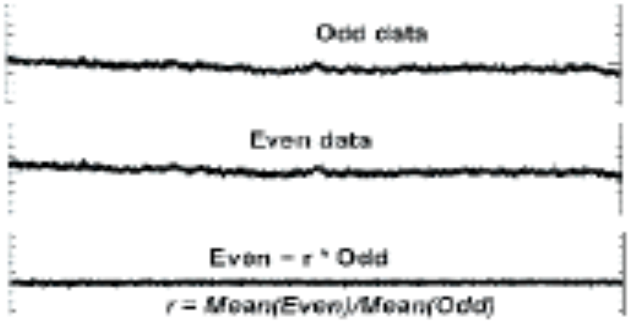
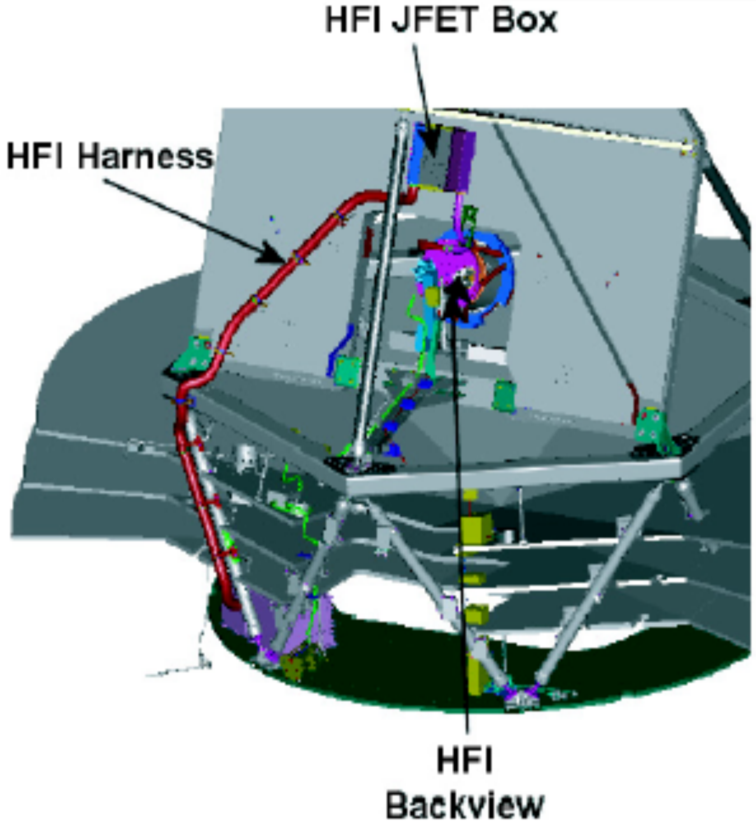


FIG 1.6.—(*Top*) Schematic of the LFI front-end radiometer. The front-end unit is located at the focus of the *Planck* telescope, and comprises: dual profiled corrugated feed horns (Villa et al. 2002); low-loss (~ 0.2 dB), wide-band ($> 20\%$) orthomode transducers; and radiometer front-end modules with hybrids, cryogenic low noise amplifiers, and phase switches. (*Bottom*) Measured radiometer output of the Elegant Breadboard model at 30 GHz. Shown are the signals from the two detector diodes ("odd" and "even" samples), which correspond to the sky and reference load, in which the noise is dominated by a non-white, $1/f$-type component. The radiometer design, however, is such that the $1/f$ component is highly correlated in the two diodes, so that the difference signal is extremely stable and insensitive to $1/f$ fluctuations.

•HFI view – I



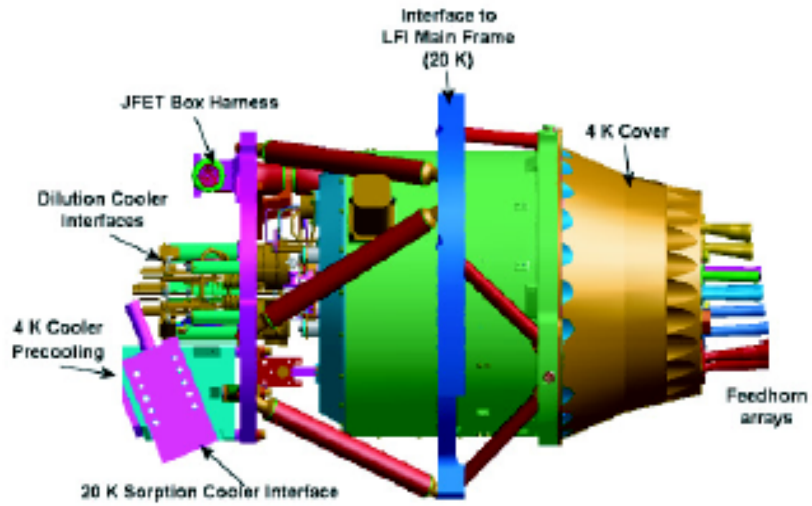


FIG 1.7.—The HFI focal plane unit. The telescope focuses radiation at the entrance of the corrugated horns. This flux is then filtered and detected by the low temperature (0.1 K) bolometers. The attachment points for the 20 K, 4 K, and 0.1 K coolers are shown, as well as the entrance point of the harness. The harness is shielded by a flexible bellows, and leads the bolometer signals to JFET-based circuits mounted in a box on the frame of the telescope. From this box, a second harness leads the signals to room-temperature electronics in the service module.

HFI view – II

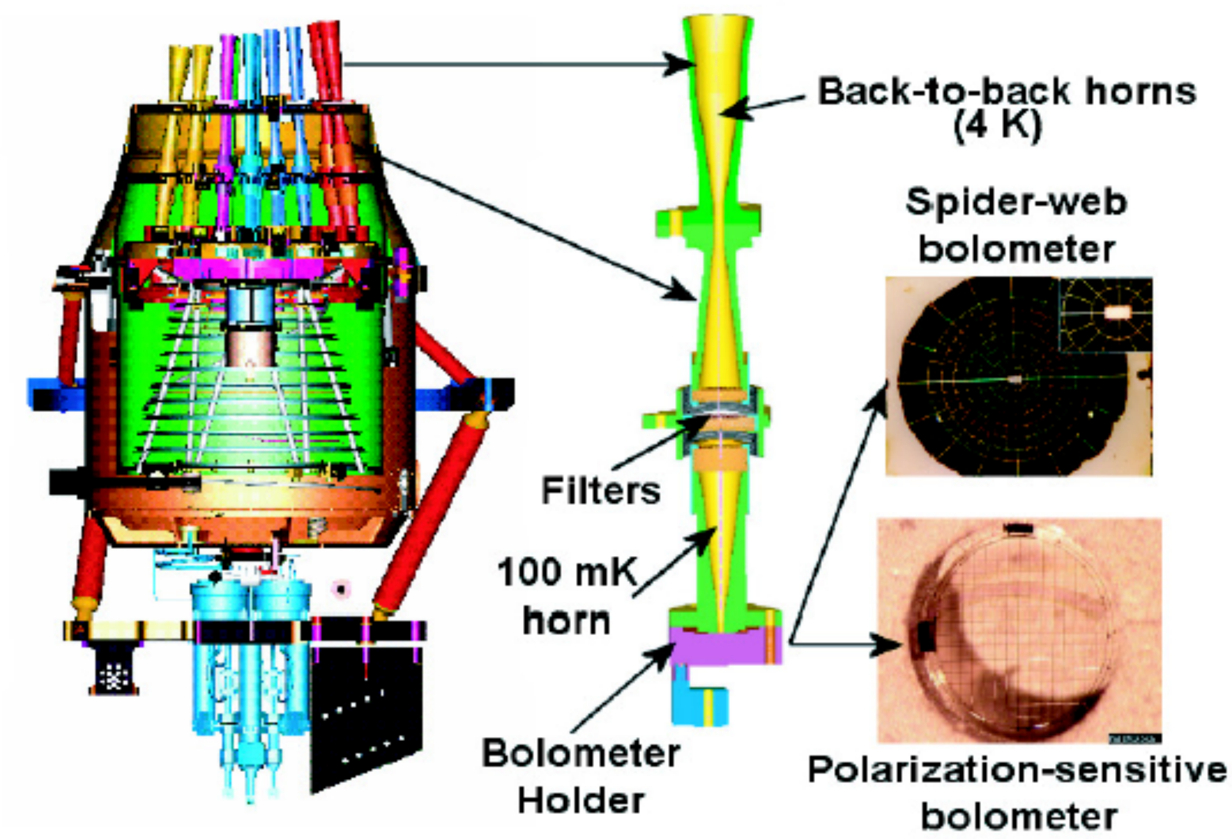
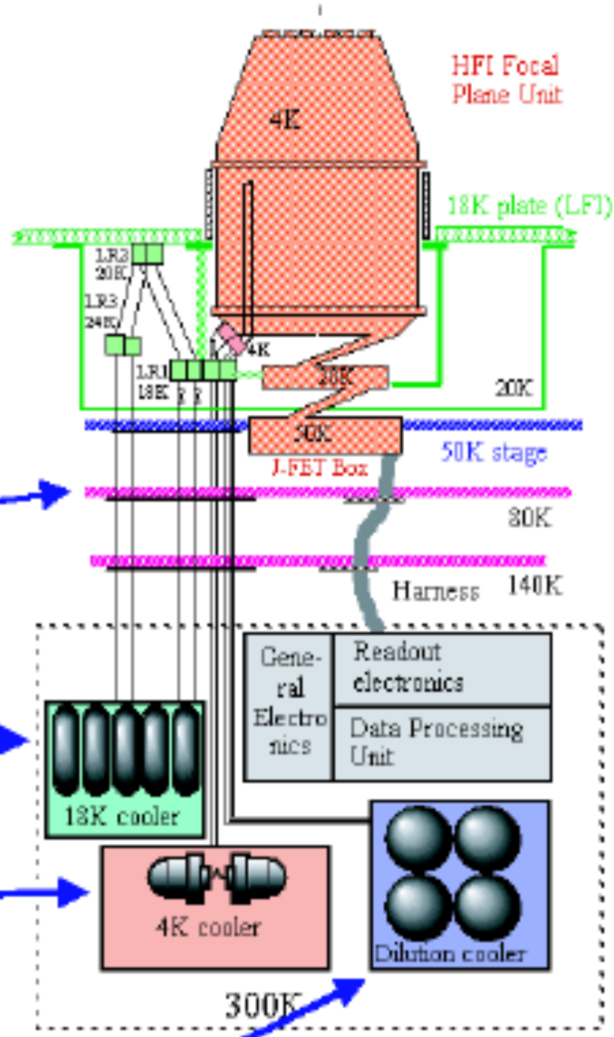


FIG 1.8.—Cutaway view of the HFI focal plane unit. Corrugated back-to-back feedhorns collect the radiation from the telescope and deliver it to the bolometer cavity through filters which determine the bandpass. The bolometers are of two kinds: (a) "spider-web" bolometers, which absorb radiation via a spider-web-like antenna; and (b) "polarisation-sensitive" bolometers, which absorb radiation in a pair of linear grids at right angles to each other. Each grid absorbs one linear polarization only. The absorbed radiant energy raises the temperature of a thermometer located either in the center of the spider-web, or at the edge of each linear grid.

Cooling system



V-groove radiators (to 60 K)

20 K H_2 sorption coolers (JPL)

4 K Stirling cooler (RAL/MMS)

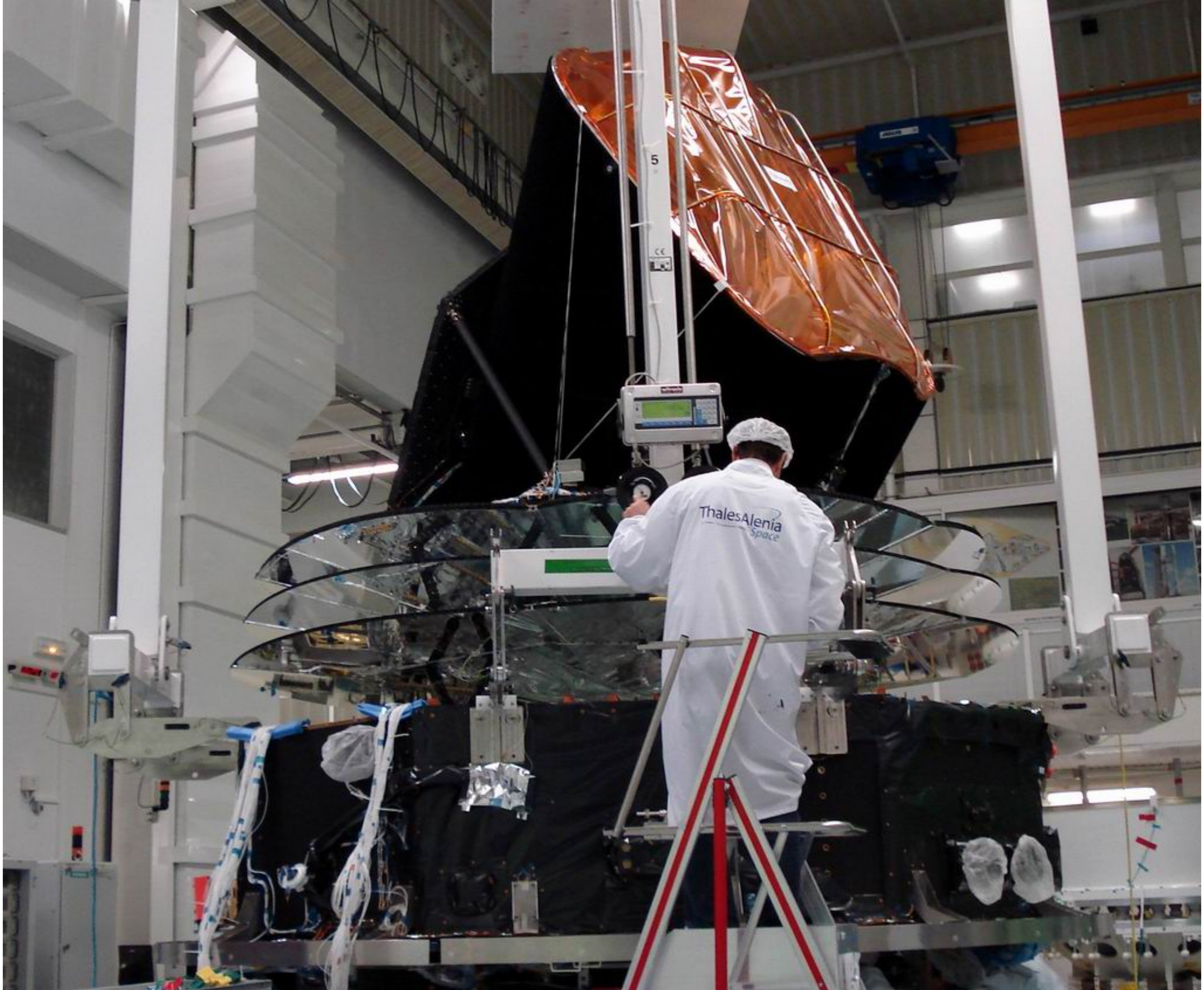
0.1 K $^3He/^4He$ dilution cooler (CRTBT)

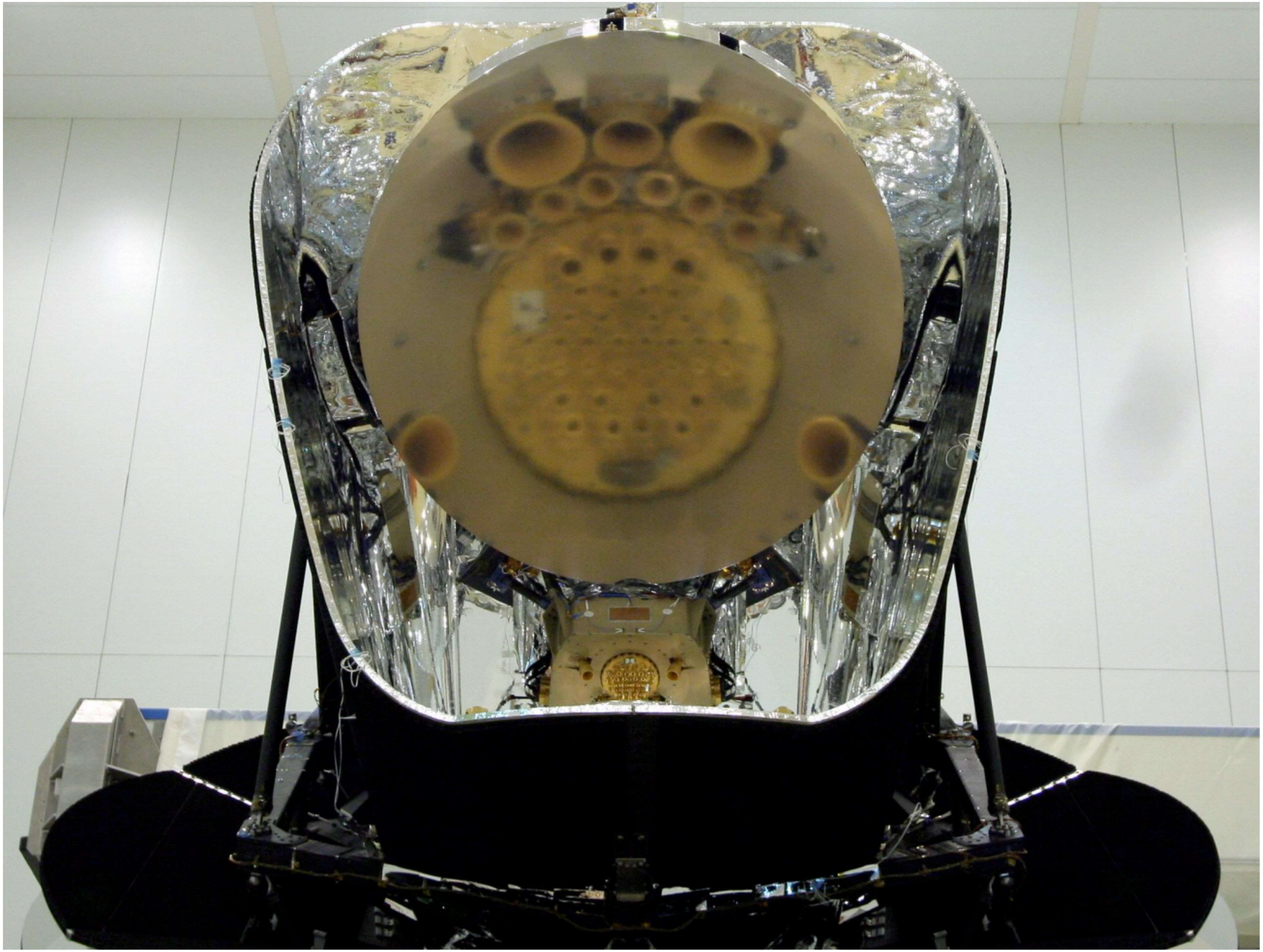
FIG 1.9.—The HFI cooling chain comprises the hydrogen sorption cooler providing 18 K, the closed-loop Joule-Thomson refrigerator providing 4 K, and a dilution refrigerator providing 0.1 K to the bolometers..

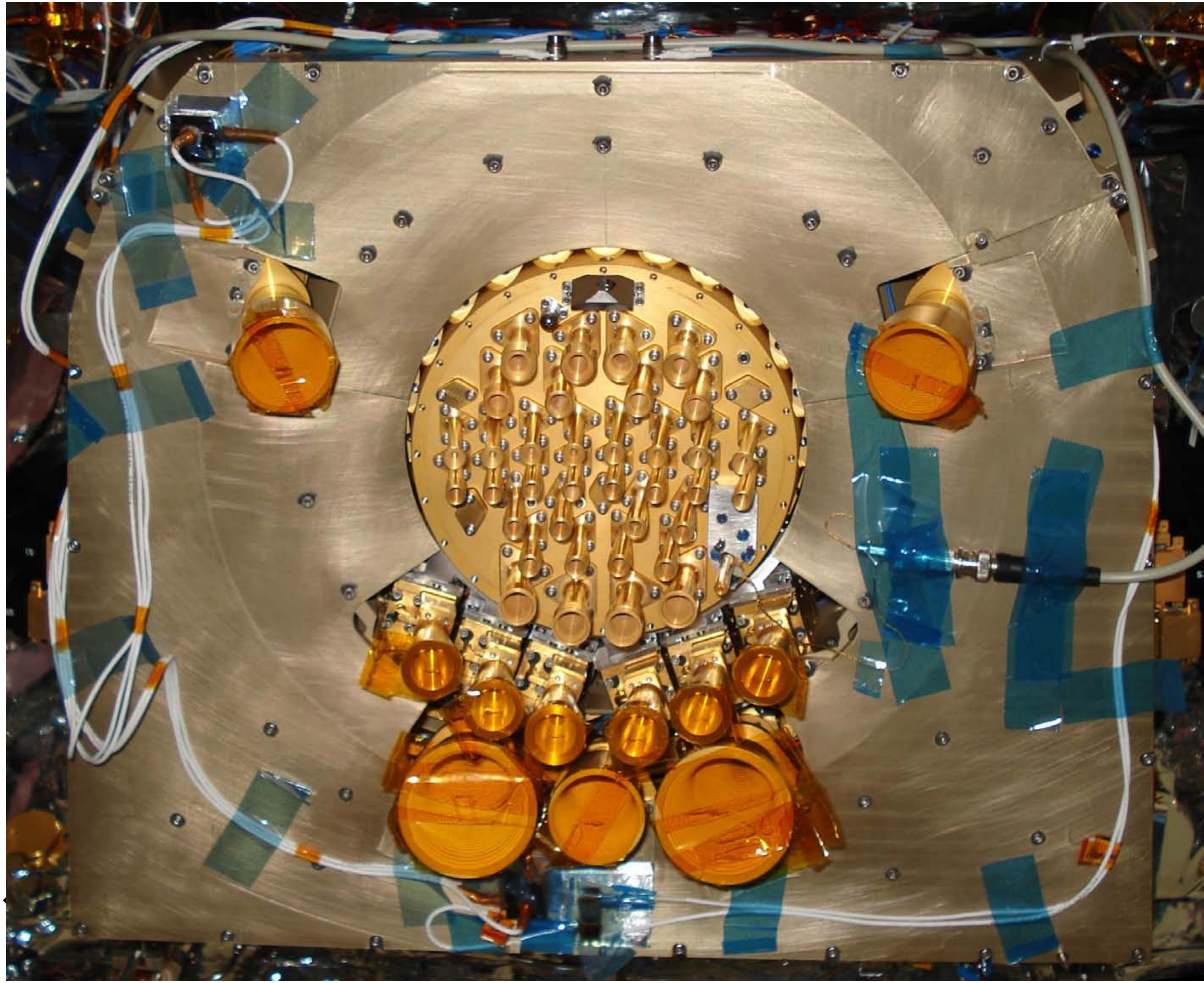
Summary of Planck Instrument Characteristics

Instrument Characteristic	LFI			HFI					
Detector Technology	HEMT arrays			Bolometer arrays					
Center Frequency [GHz]	30	44	70	100	143	217	353	545	857
Bandwidth ($\Delta\nu/\nu$)	0.2	0.2	0.2	0.33	0.33	0.33	0.33	0.33	0.33
Angular Resolution (arcmin)	33	24	14	10	7.1	5.0	5.0	5.0	5.0
$\Delta T/T$ per pixel (Stokes I)[a].........	2.0	2.7	4.7	2.5	2.2	4.8	14.7	147	6700
$\Delta T/T$ per pixel (Stokes Q &U)[a].....	2.8	3.9	6.7	4.0	4.2	9.8	29.8	...	...

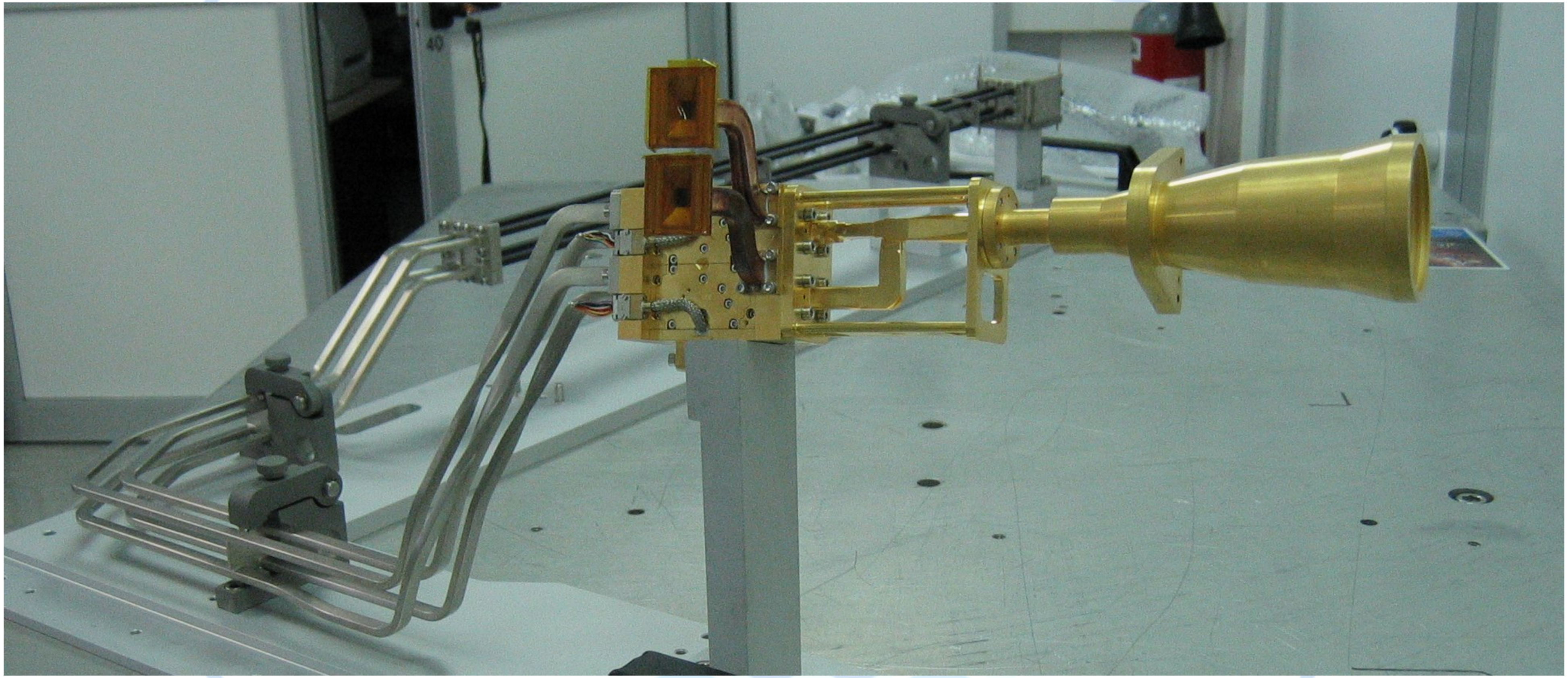
[a] Goal (in μK/K) for 14 months integration, 1σ, for square pixels whose sides are given in the row "Angular Resolution".


5
ThalesAlenia
Space

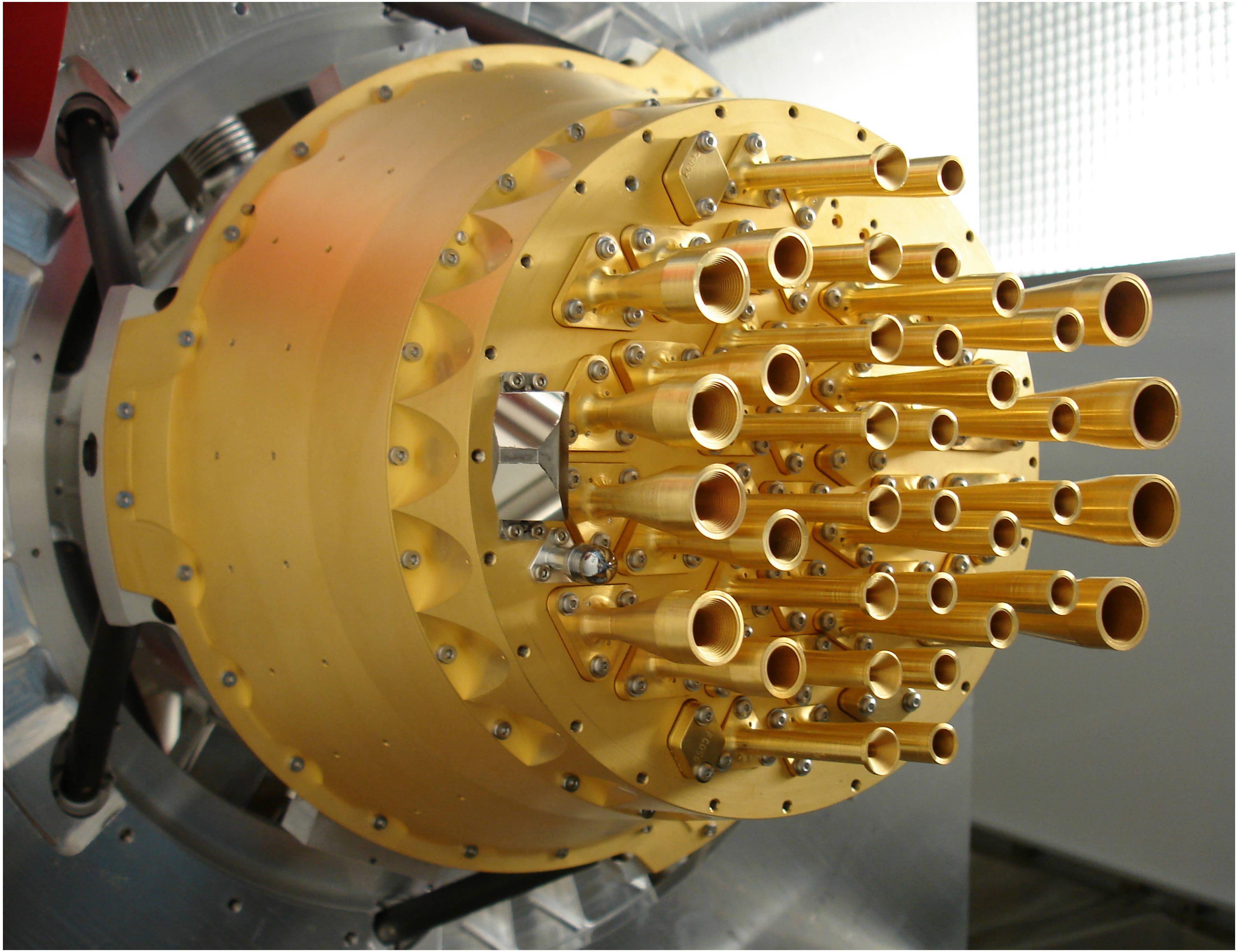




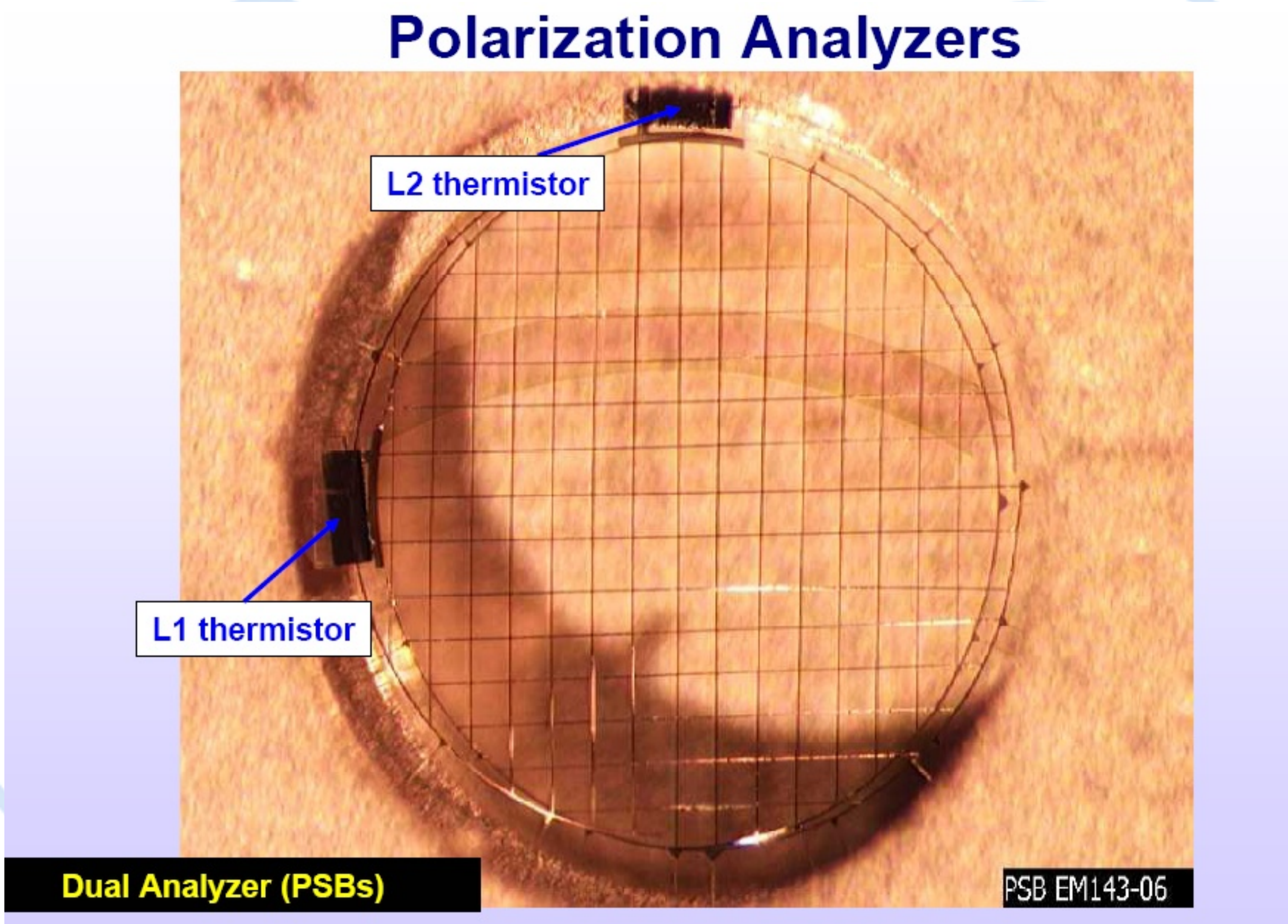
LFI 30 GHz Radiometer

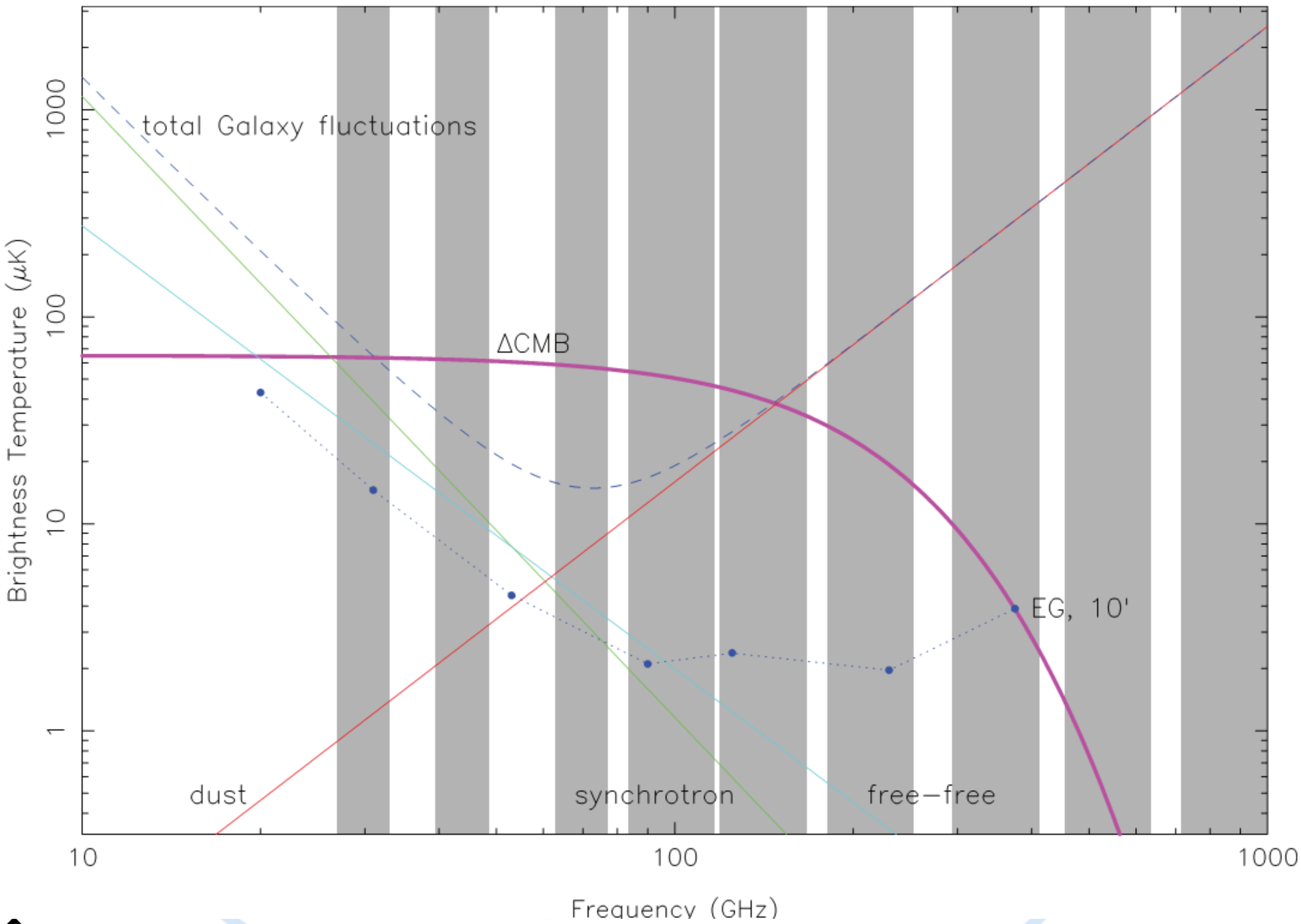


Thales Alenia Space Milano

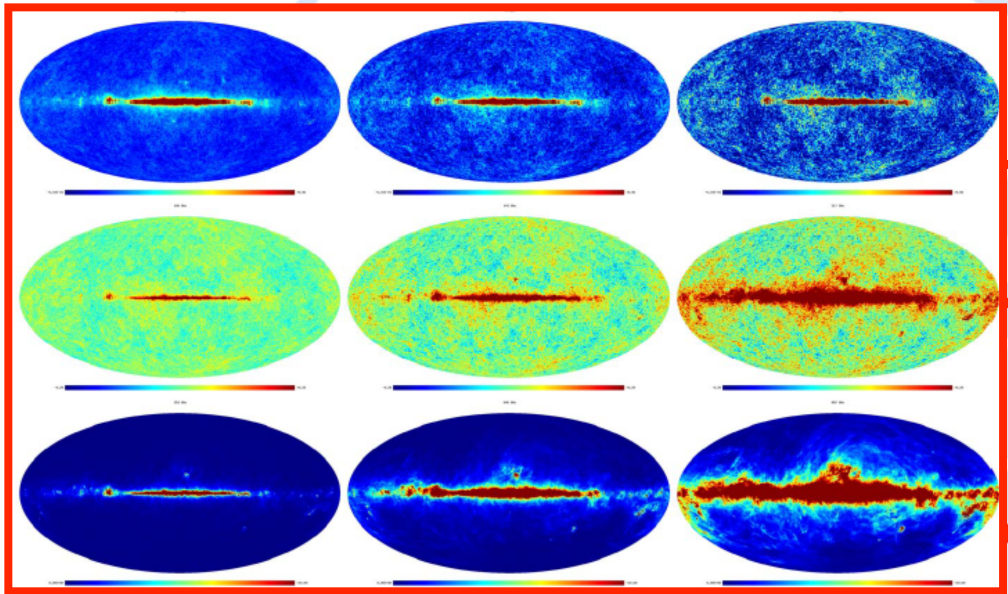


Spider web and polarization sensitive bolometers (Caltech-JPL)

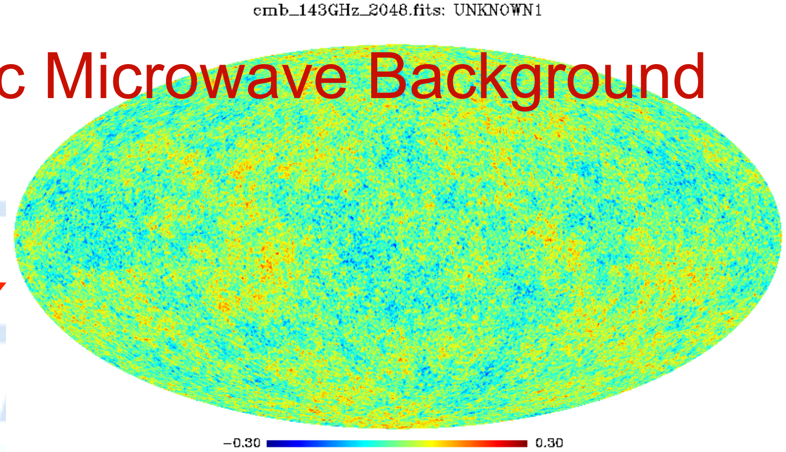



total Galaxy fluctuations
ΔCMB
EG, 10'
dust
synchrotron
free−free
Brightness Temperature (μK)
Frequency (GHz)
1
10
100
1000
10
100
1000

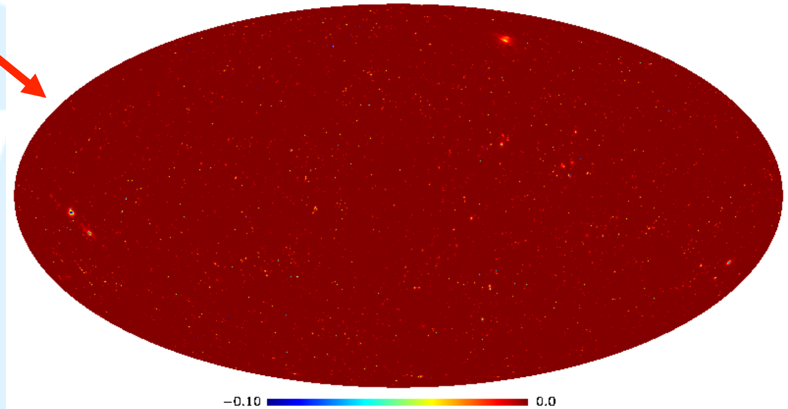
30, 44, 70, 100, 143, 217, 353, 545, 857 GHz – I, Q, U at all channels
Except 545 & 857 GHz



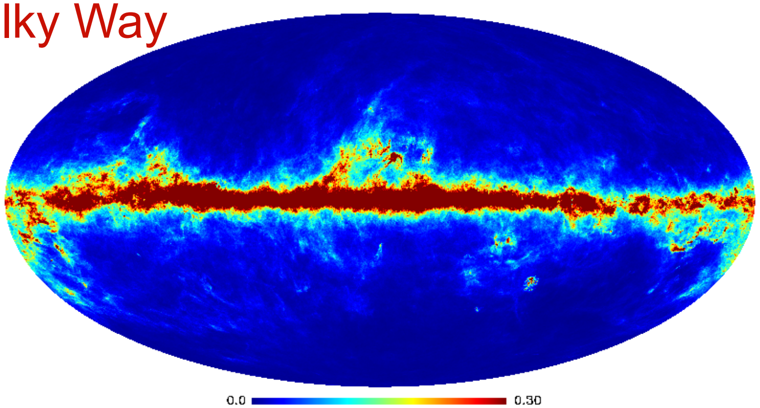
•Cosmic Microwave Background



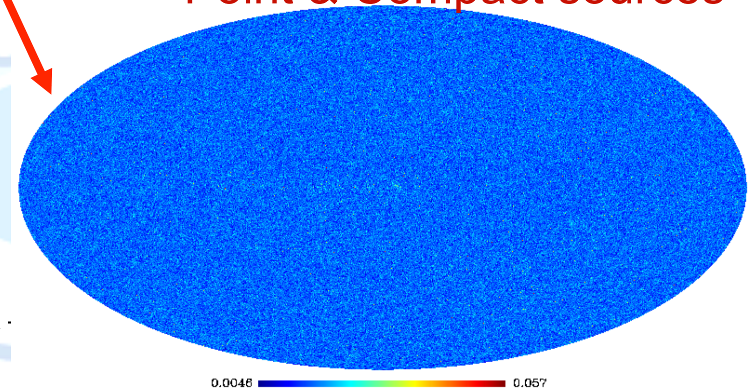
•Sunyaev-Zeldovich



•The Milky Way

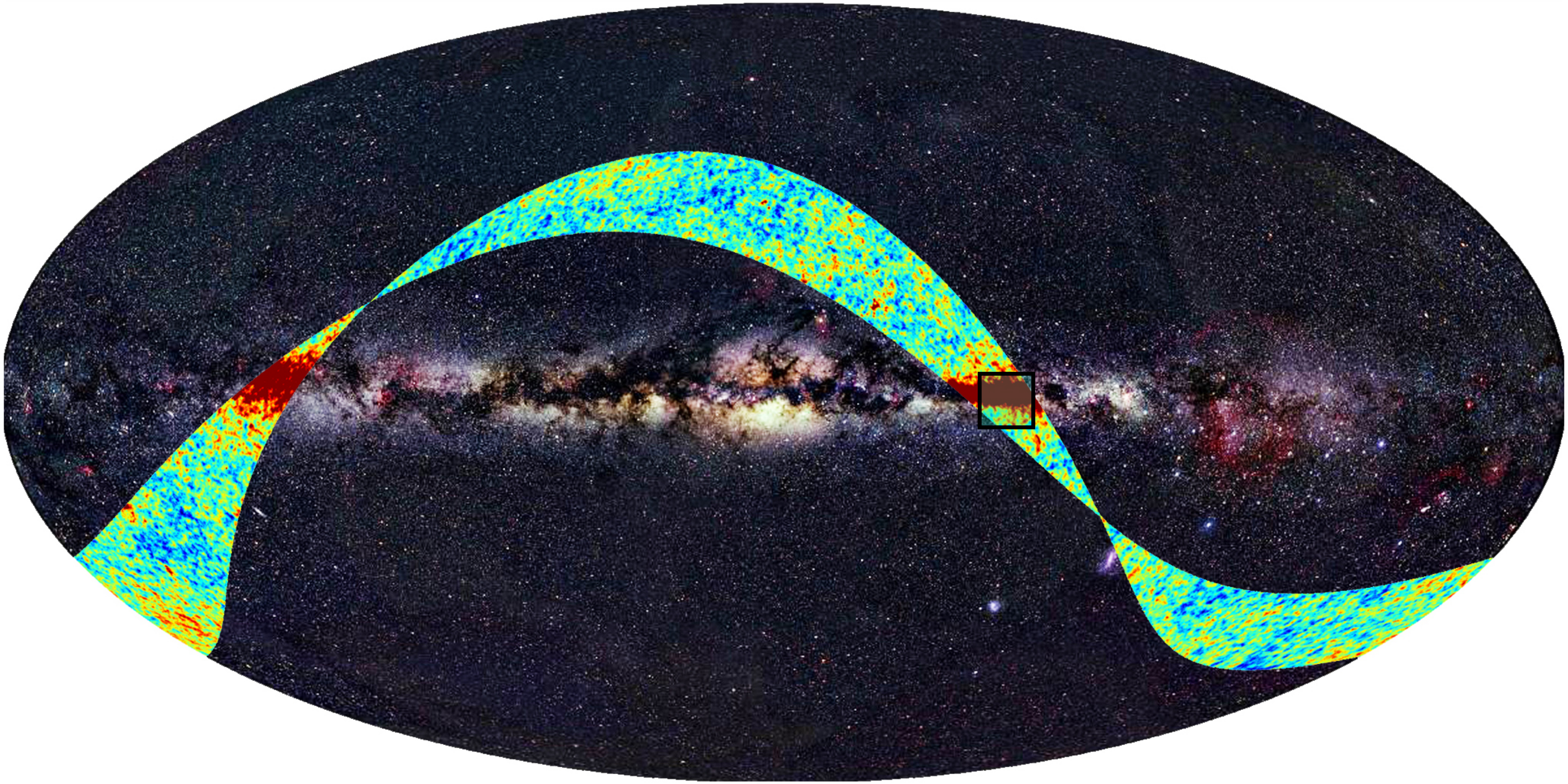


•Point & Compact sources

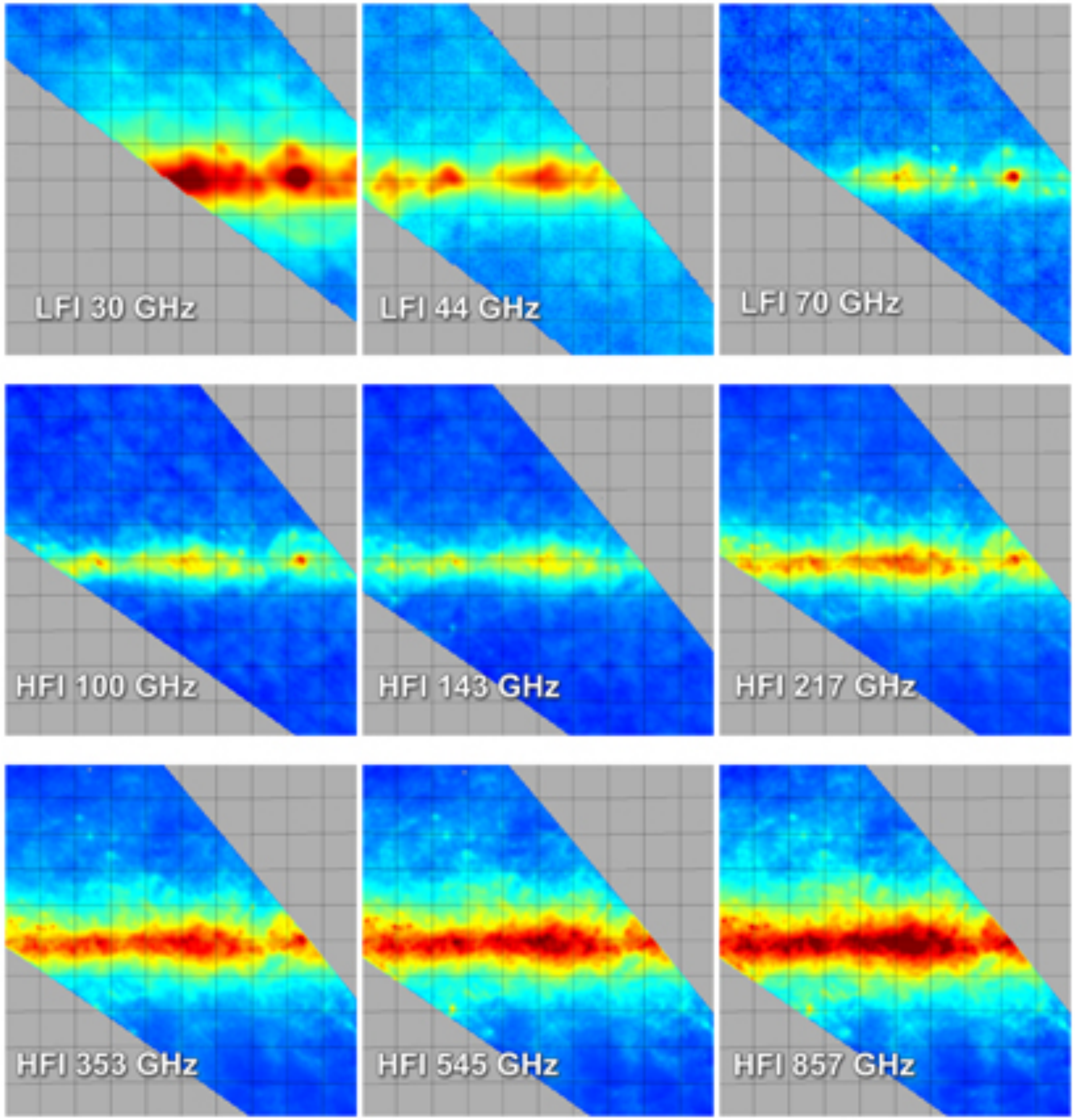


Colloquium

~ 7.5 % of the sky observed during the First Light Survey!

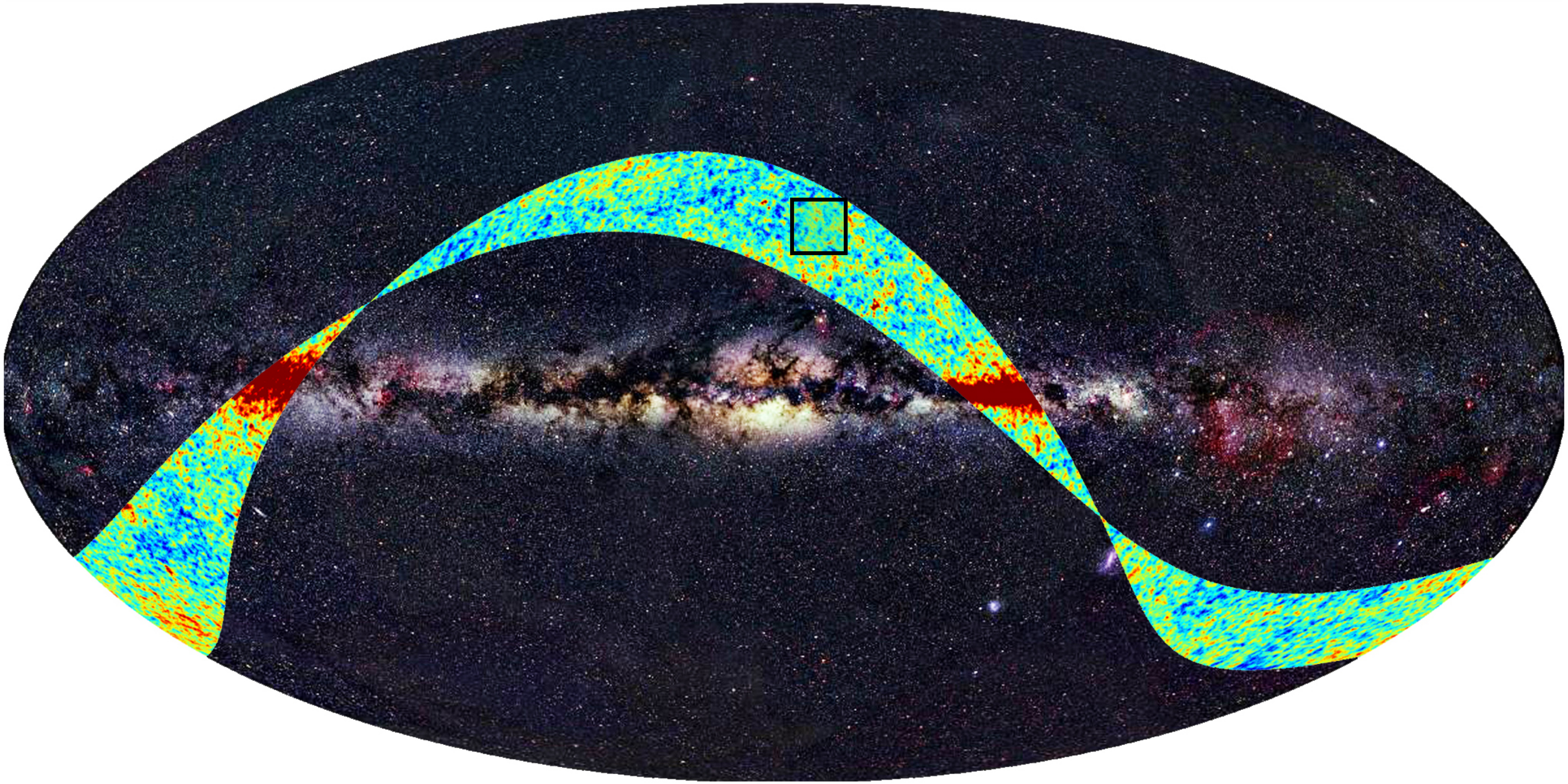


Credit: ESA

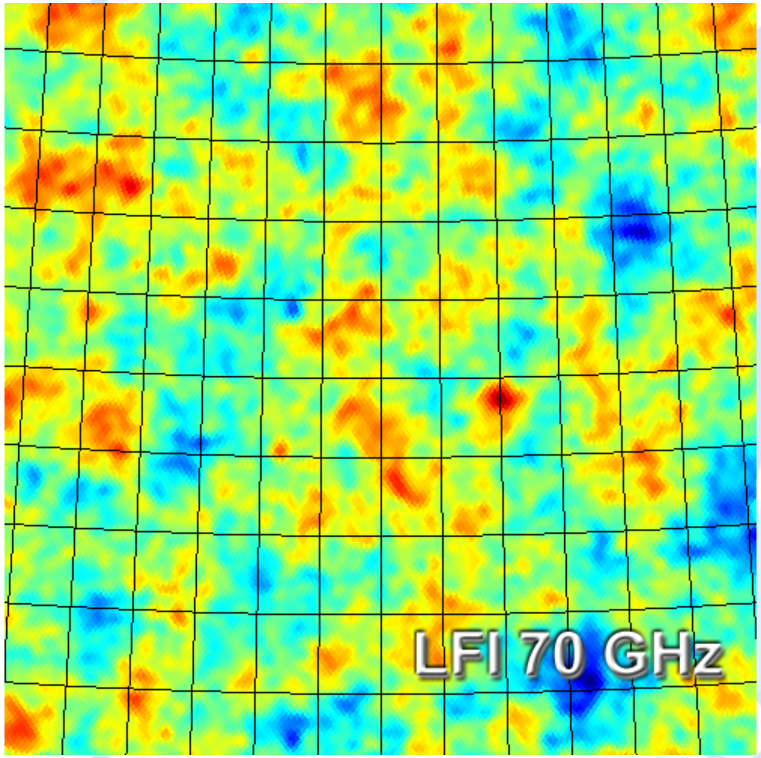

LFI 30 GHz
LFI 44 GHz
LFI 70 GHz
HFI 100 GHz
HFI 143 GHz
HFI 217 GHz
HFI 353 GHz
HFI 545 GHz
HFI 857 GHz

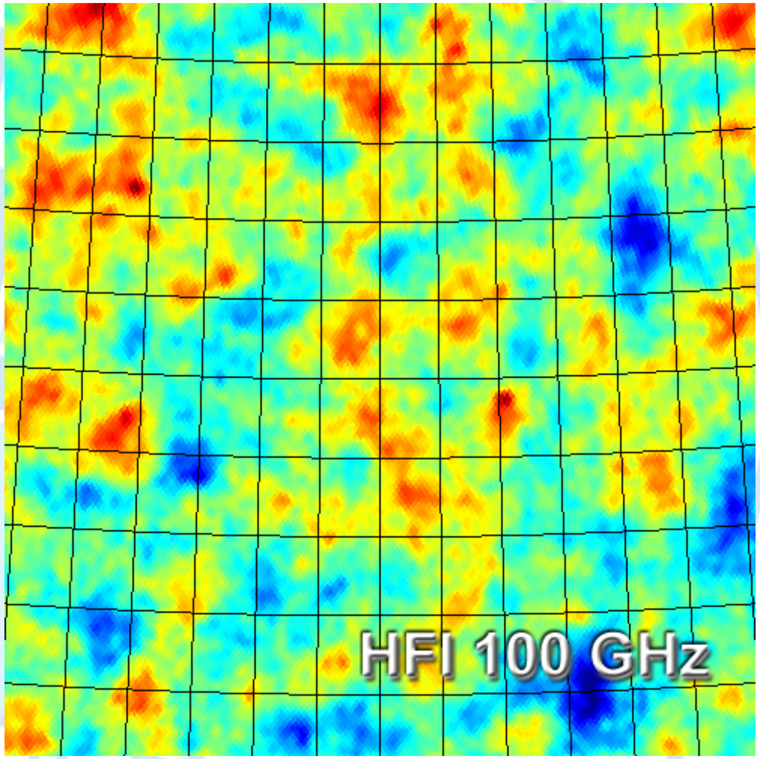
Credit: ESA

~ 7.5 % of the sky observed during the First Light Survey!

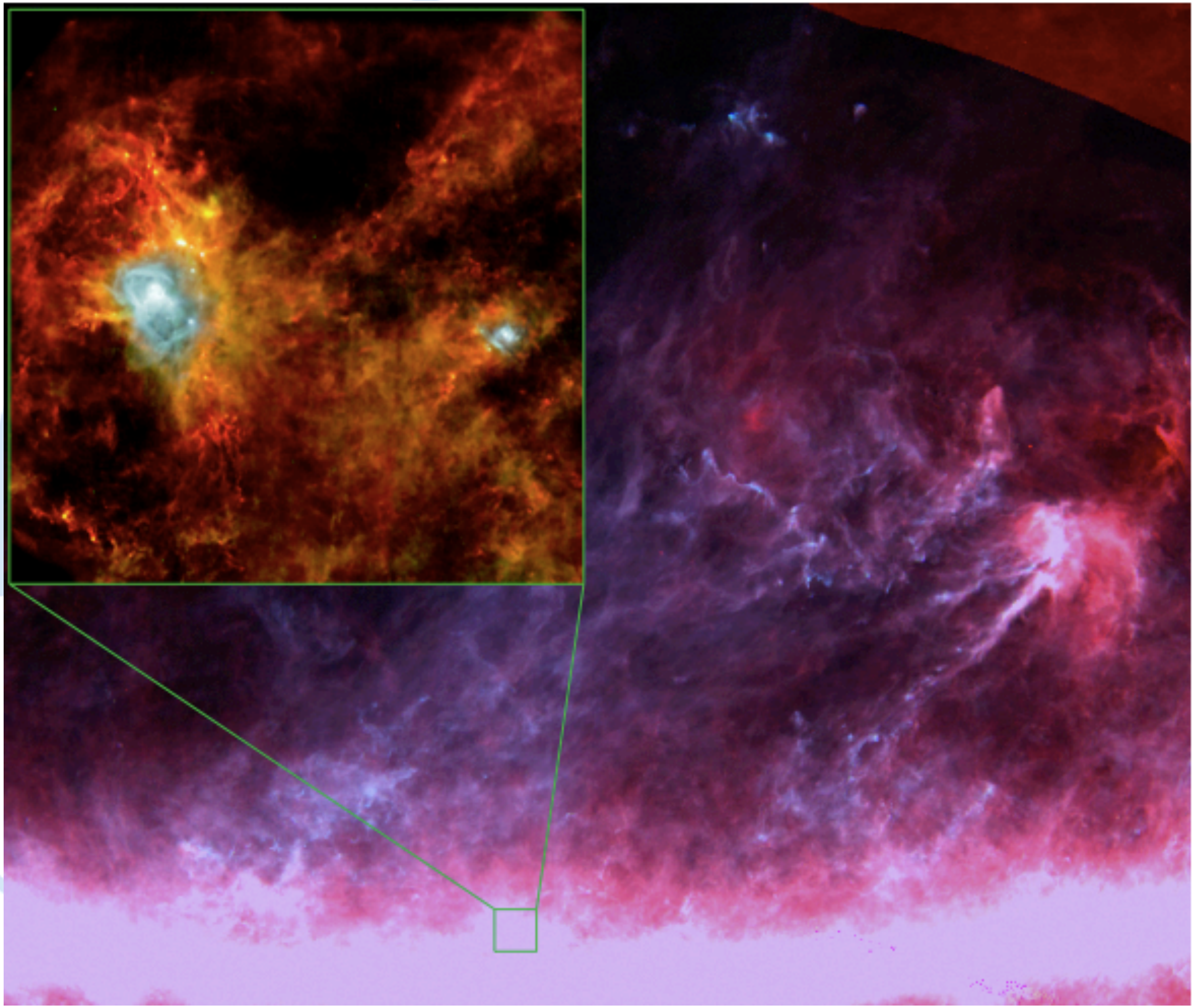


Credit: ESA

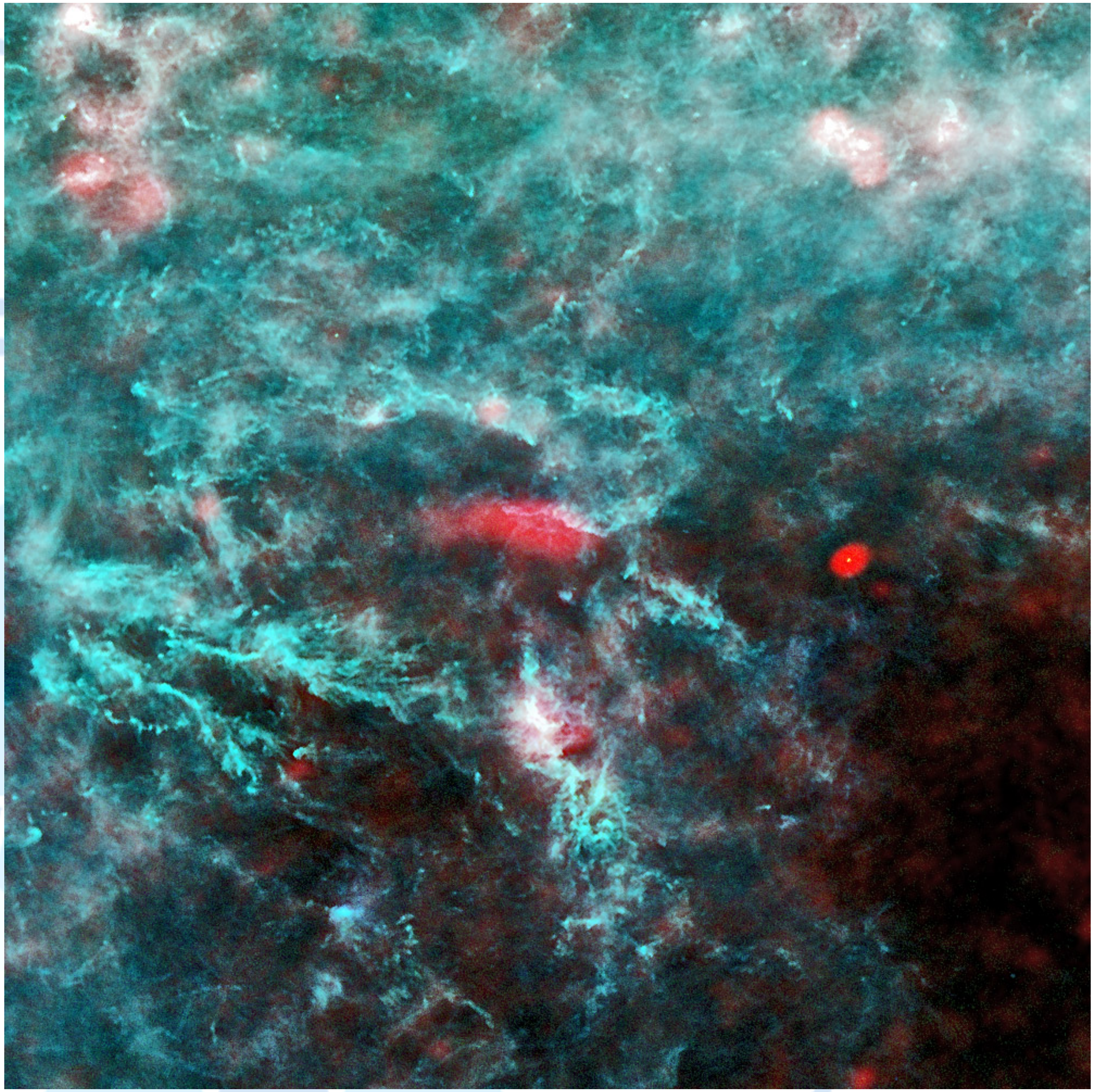

LFI 70 GHz

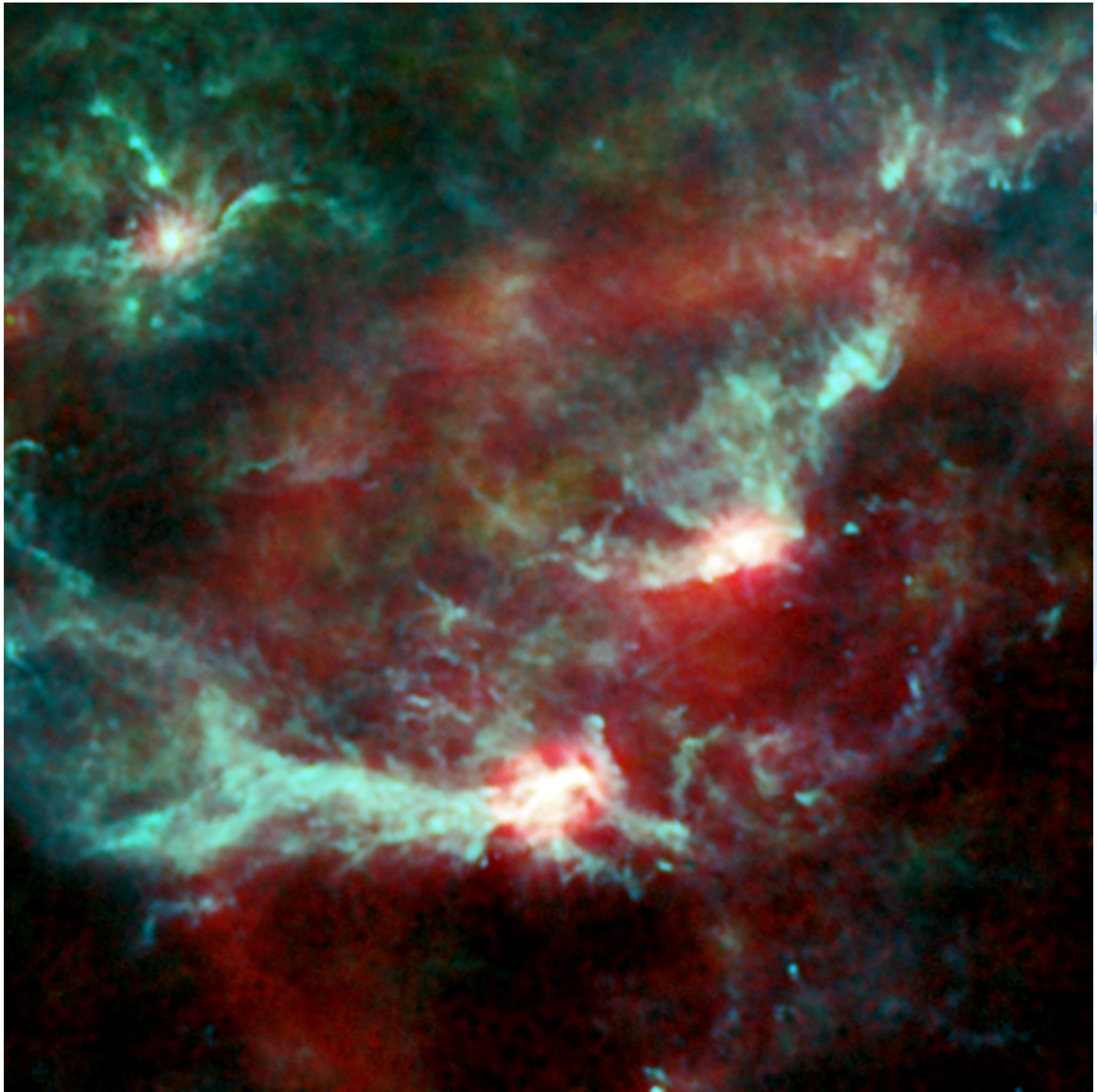

HFI 100 GHz

Cold dust in our Galaxy observed by Planck and Herschel



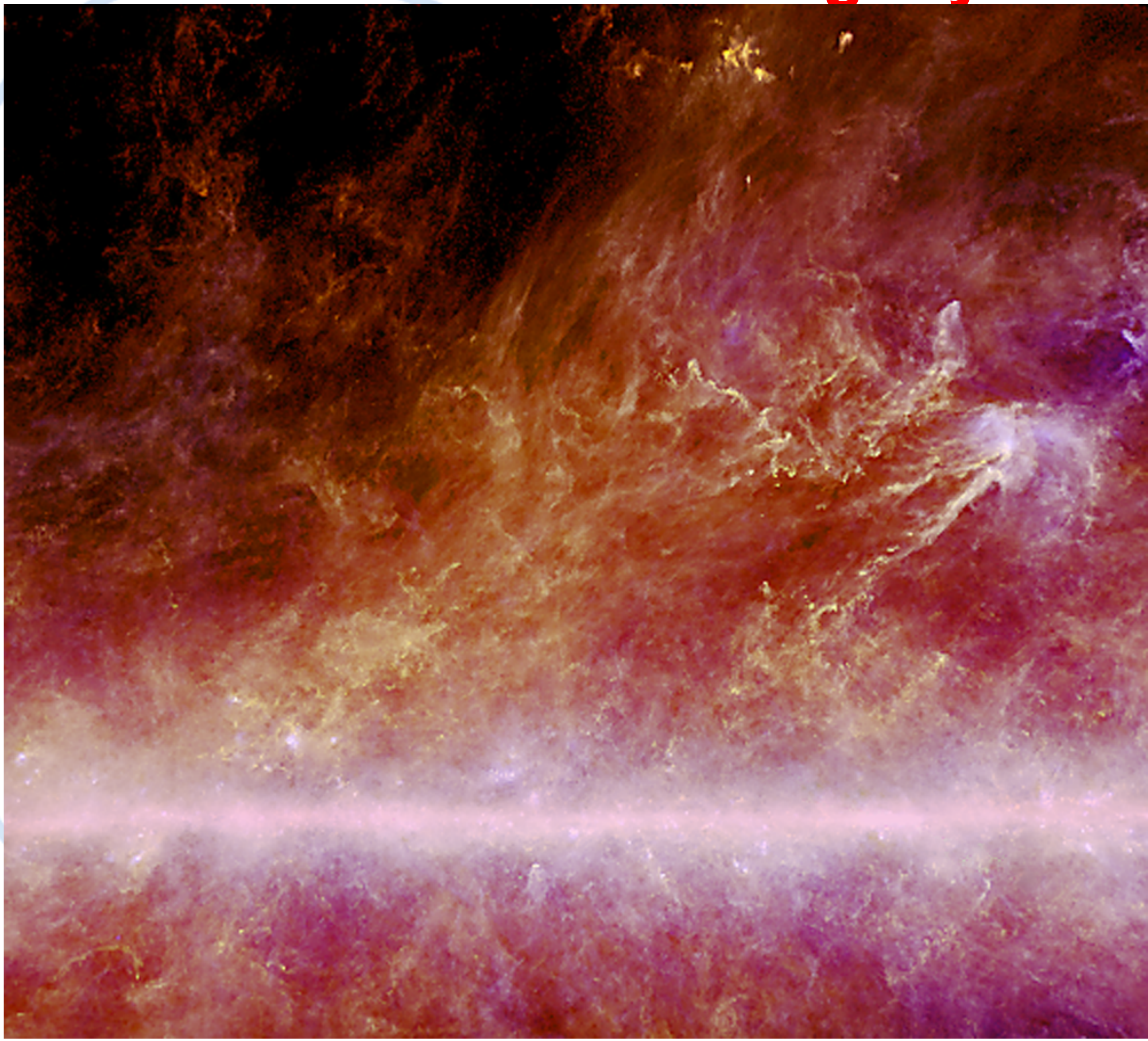
Perseus at 30, 353 & 857 GHz

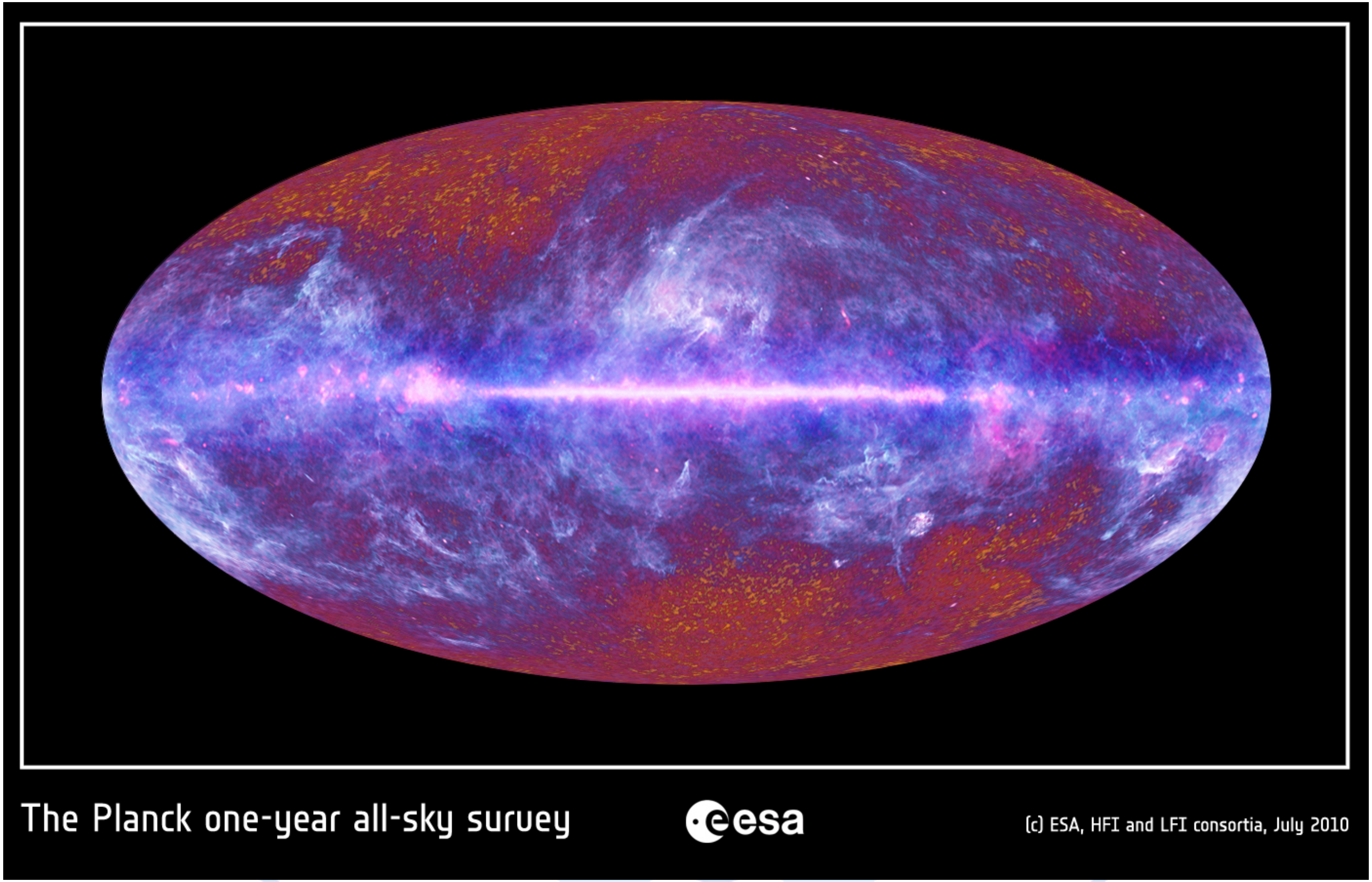


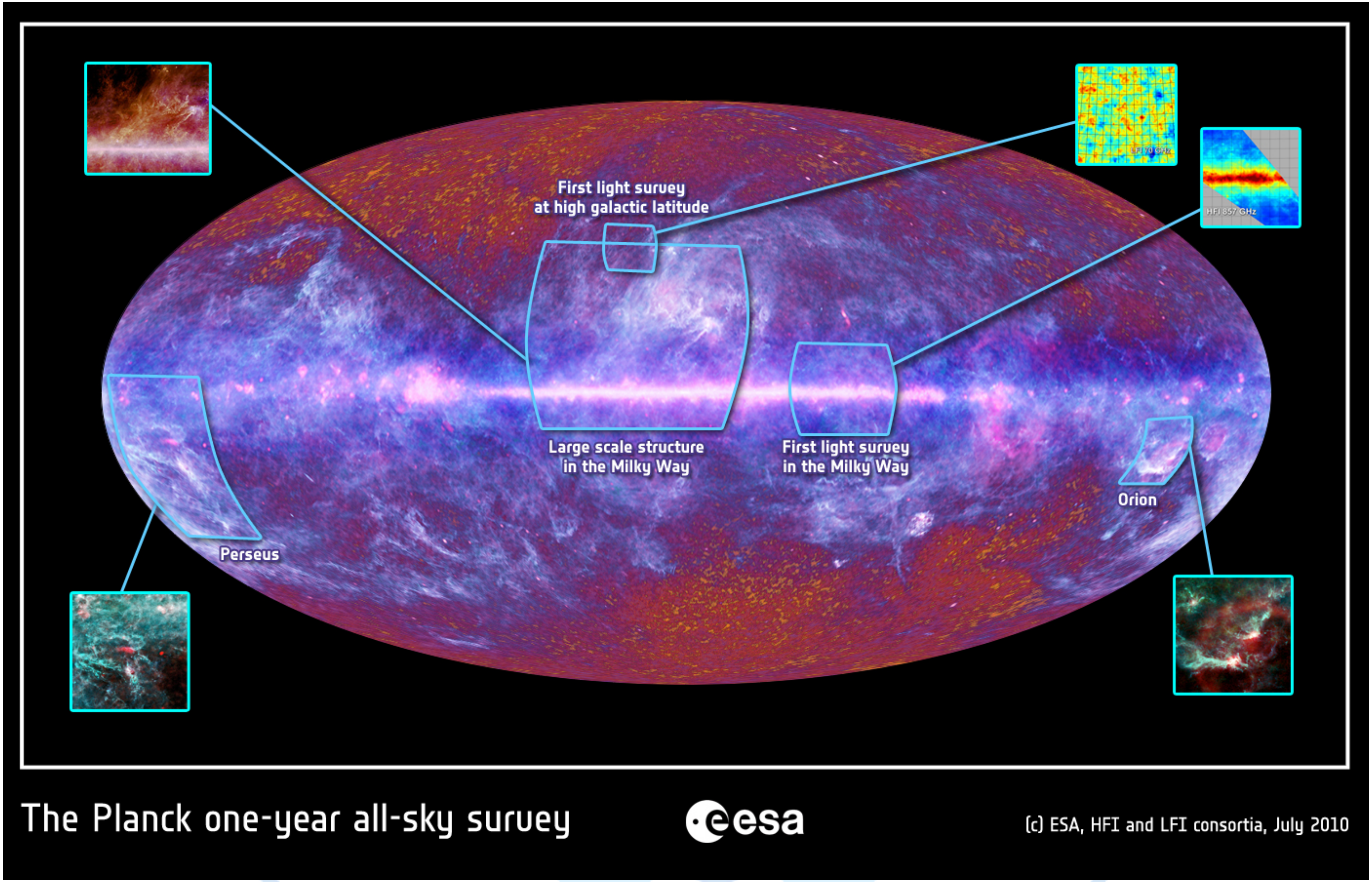


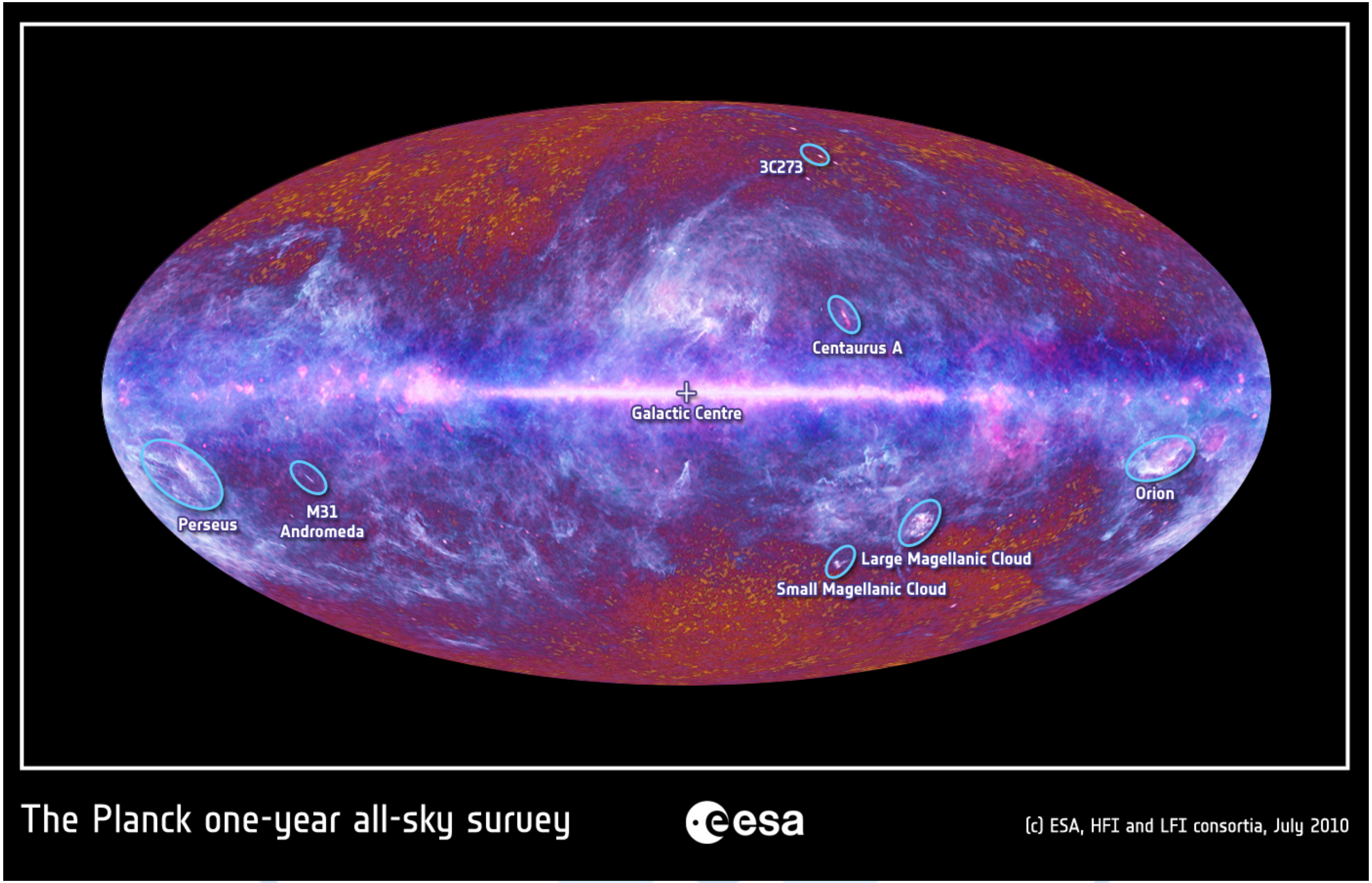
Orion at 30, 353 e 857 GHz

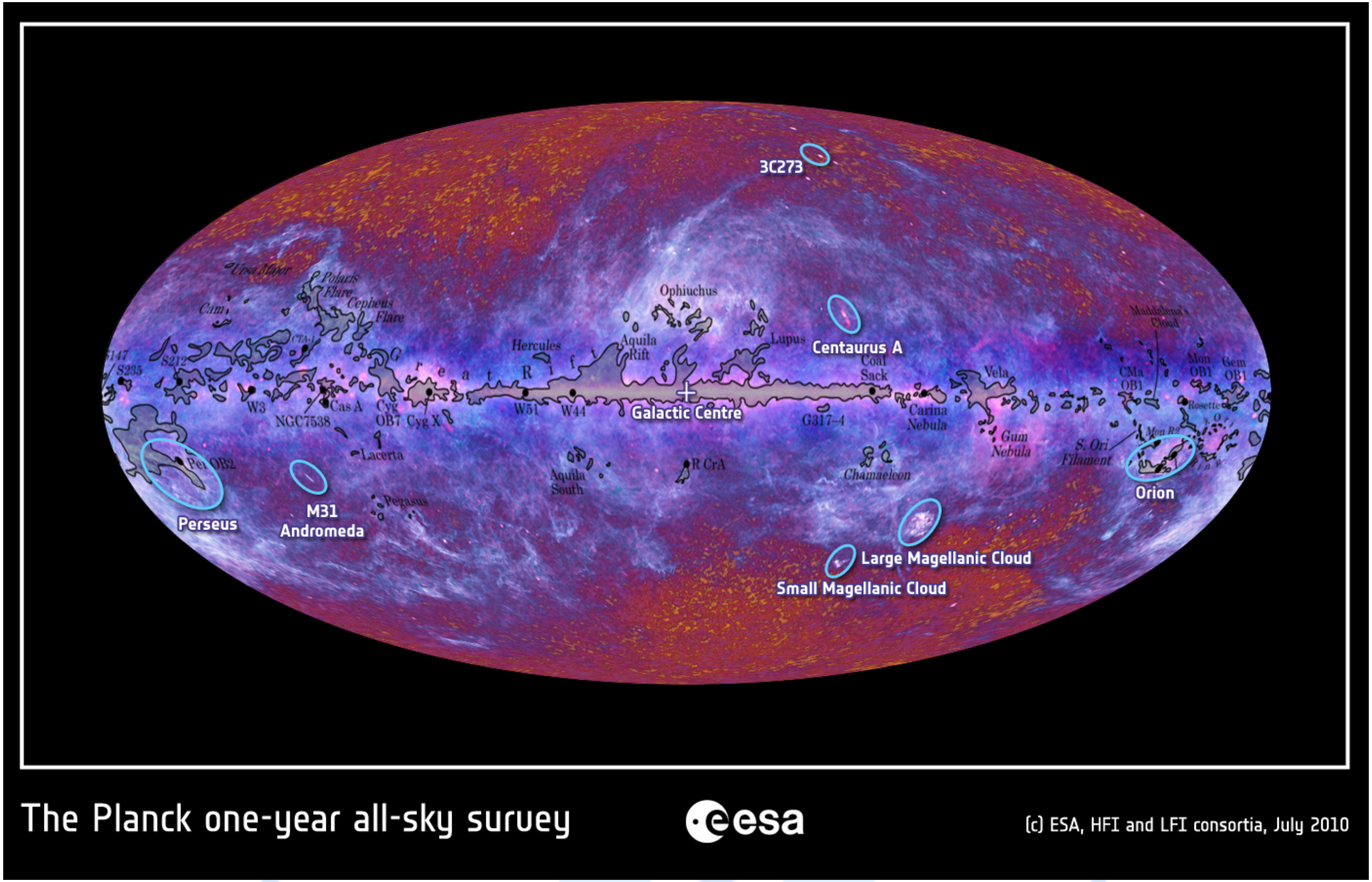
Dust structures at 500 light years



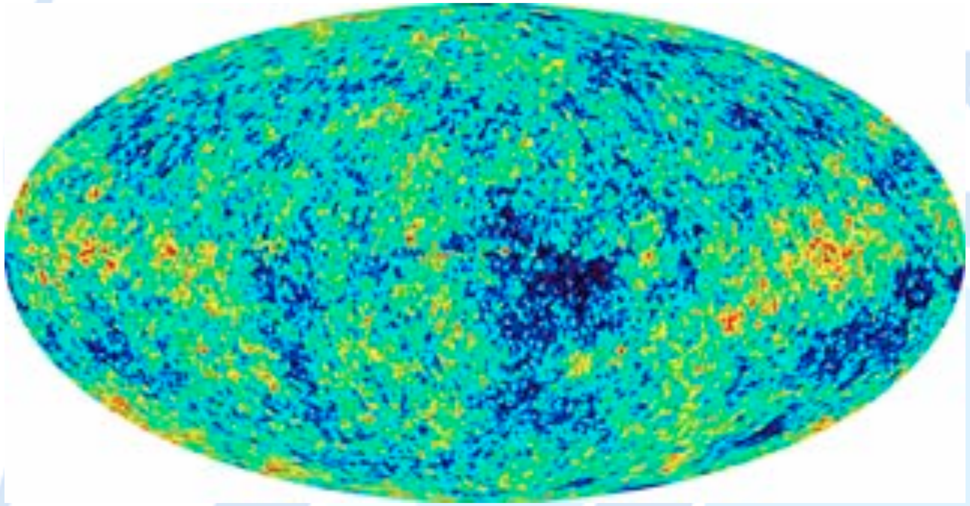

The Planck one-year all-sky survey
(c) ESA, HFI and LFI consortia, July 2010


First light survey
at high galactic latitude
Large scale structure
in the Milky Way
First light survey
in the Milky Way
Perseus
Orion
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010


3C273
Centaurus A
Galactic Centre
Perseus
M31
Andromeda
Orion
Large Magellanic Cloud
Small Magellanic Cloud
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010


3C273
Ophiuchus
Centaurus A
Lupus
Aquila
Rift
Hercules
Great Rift
Coal
Sack
Galactic Centre
W51
W44
G317-4
Carina
Nebula
Vela
Gum
Nebula
Ursa Major
Polaris
Flare
Cepheus
Flare
Cam
S212
S235
S147
W3
NGC7538
Cas A
Cyg
OB7
Cyg X
Lacerta
Per OB2
Perseus
M31
Andromeda
Pegasus
Aquila
South
R CrA
Chamaeleon
Large Magellanic Cloud
Small Magellanic Cloud
Maddalena's
Cloud
CMa
OB1
Mon
OB1
Gem
OB1
Rosette
Mon R2
S. Ori
Filament
Orion
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010

Statistics of CMB anisotropy



Analysis on the celestial sphere can be performed in terms of angular correlation functions

$$\left\langle \frac{\Delta T}{T}(\vec{\gamma})\frac{\Delta T}{T}(\vec{\gamma}\,')\right\rangle$$ Two-point

$$\left\langle \frac{\Delta T}{T}(\vec{\gamma})\frac{\Delta T}{T}(\vec{\gamma}\,')\frac{\Delta T}{T}(\vec{\gamma}\,'')\right\rangle$$ Three-point

$$\left\langle \frac{\Delta T}{T}(\vec{\gamma})\frac{\Delta T}{T}(\vec{\gamma}\,')\frac{\Delta T}{T}(\vec{\gamma}\,'')\frac{\Delta T}{T}(\vec{\gamma}\,''')\right\rangle$$ Four-point …

For a Gaussian field, all CF of order > 2 can be deduced from the two-point CF

$$C(\alpha) \equiv \left\langle \frac{\Delta T}{T}(\hat{\gamma})\frac{\Delta T}{T}(\hat{\gamma}')\right\rangle$$

2-point correlation function depends only on a single angle: *statistical isotropy*

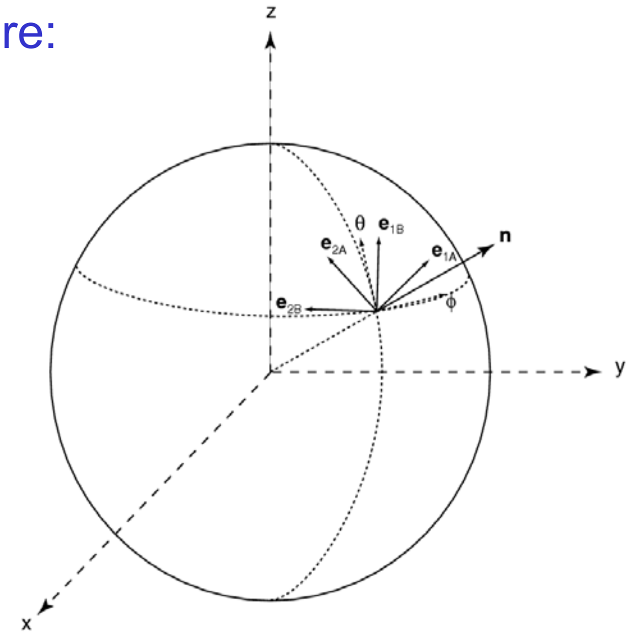
Spherical harmonic expansion

$$\frac{\Delta T}{T}(\vec{x},\hat{\gamma}) = \sum_{\ell=0}^{\infty}\sum_{m=-\ell}^{\ell} a_{\ell m}(\vec{x}) Y_{\ell m}(\hat{\gamma}) \quad \Longleftrightarrow \quad a_{\ell m}(\vec{x}) = \int_{4\pi} Y_{\ell m}^{\ *}(\vec{\gamma}) \frac{\Delta T}{T}(\vec{x},\vec{\gamma})$$

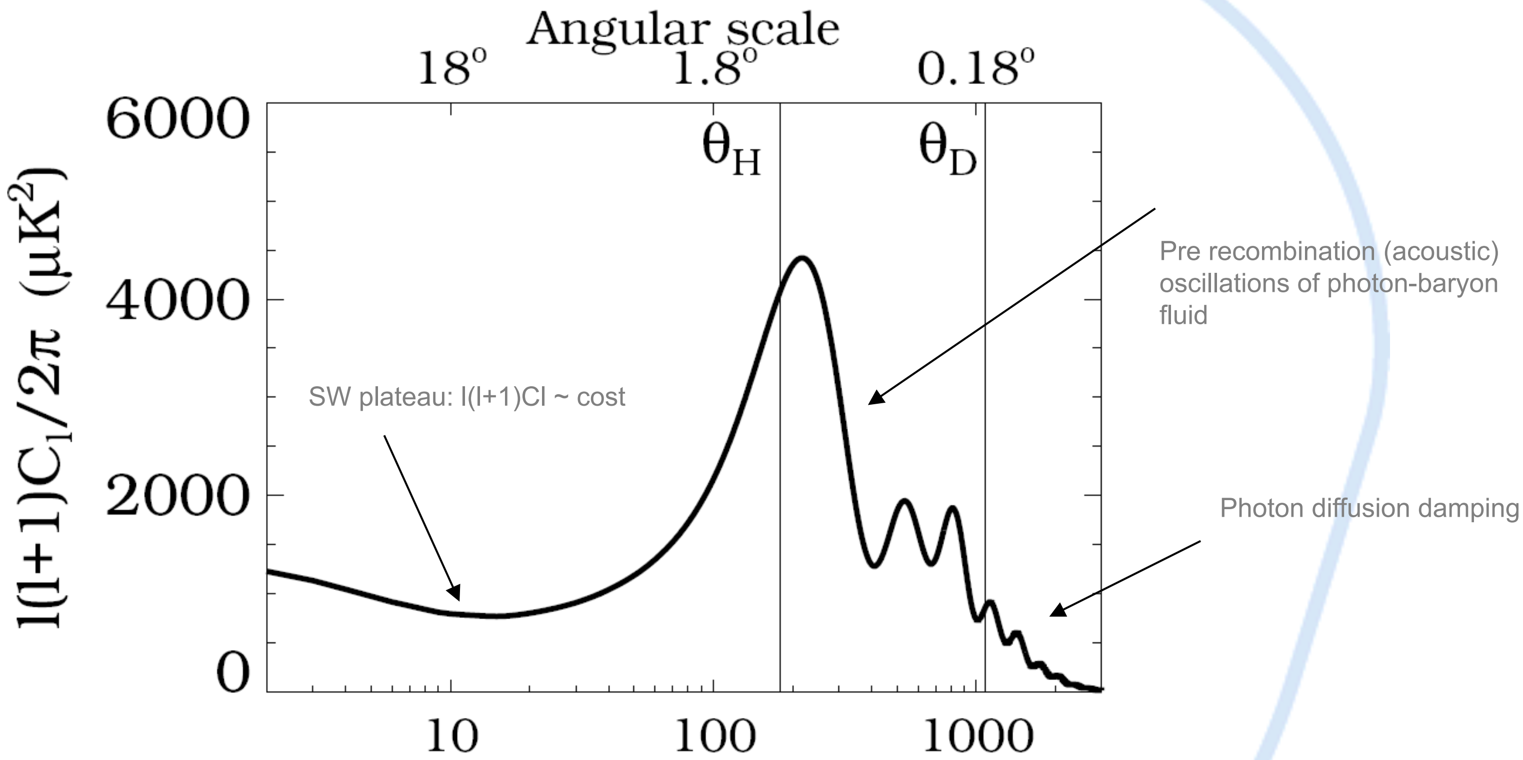
Orthogonal, complete basis on the 4π sphere:

$$\langle a_{\ell m} a^{\star}_{\ell' m'} \rangle = C_\ell \delta_{\ell \ell'} \delta_{m m'} .$$

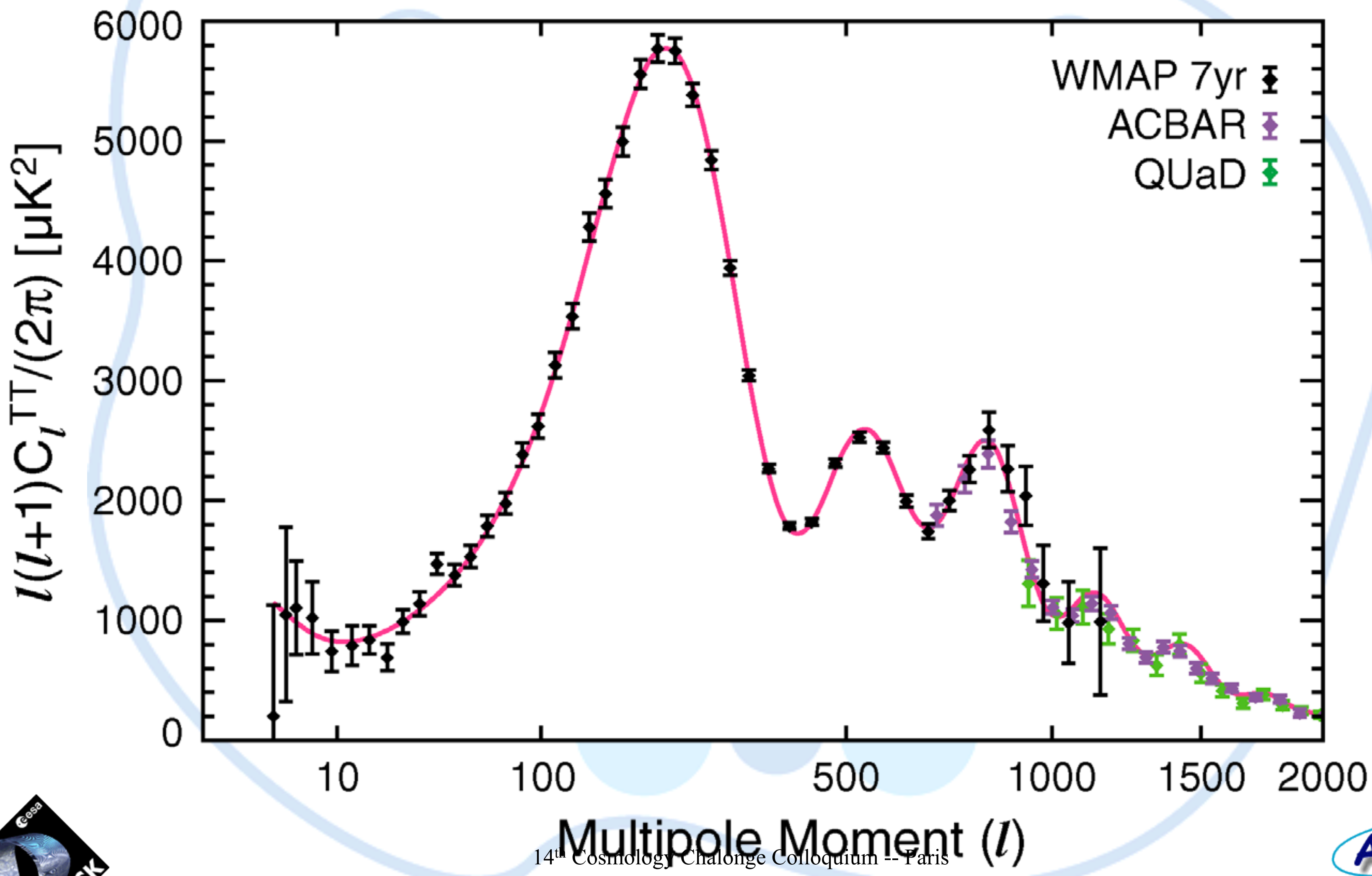
$$C(\alpha) = \sum_{\ell=0}^{\infty} \frac{2\ell+1}{4\pi} C_\ell P_\ell(\cos\alpha)$$



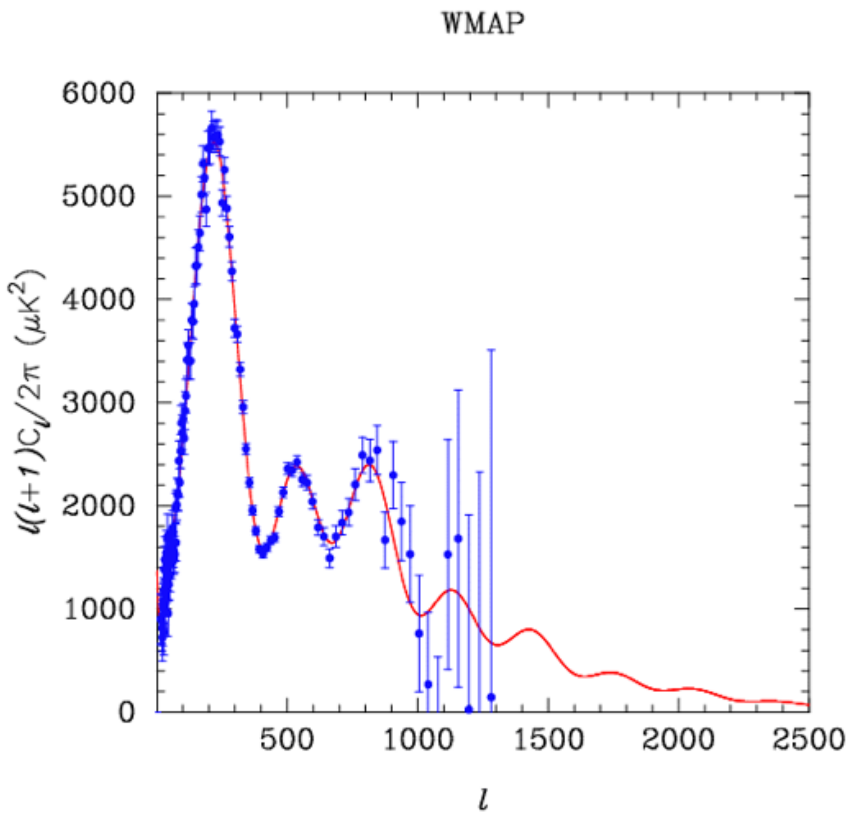
Typical model prediction for CMB anisotropy APS

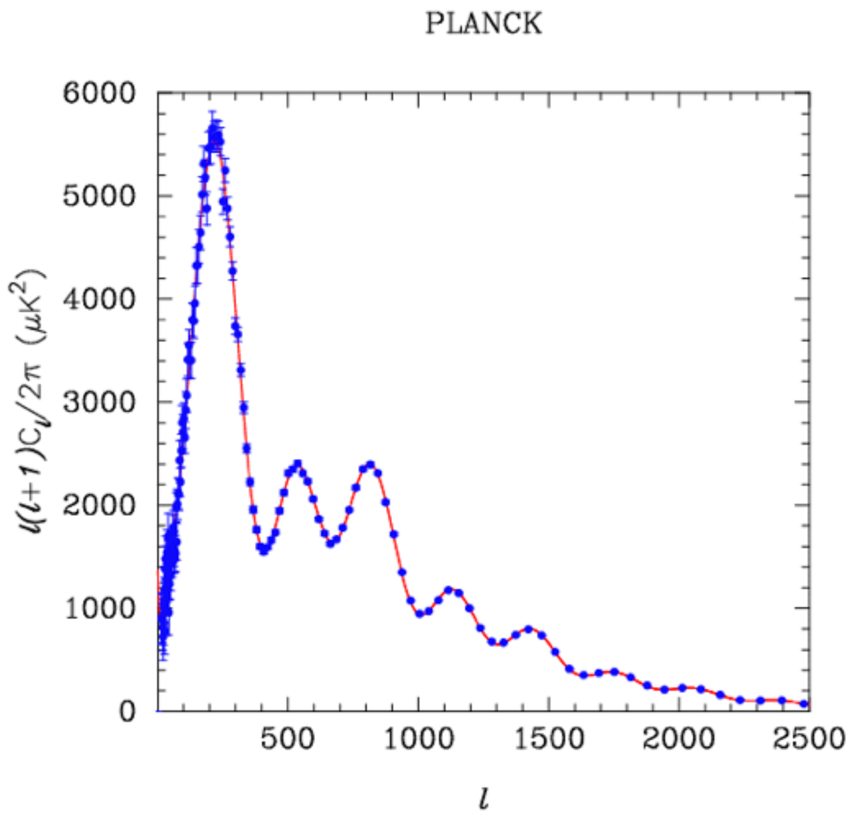


Current status of CMB anisotropy observations



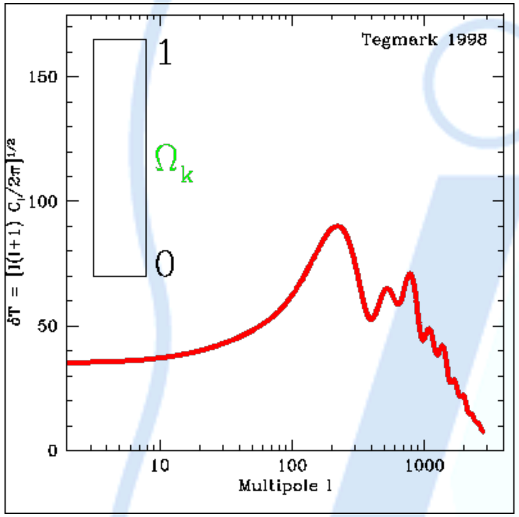
Komatsu et al 2010

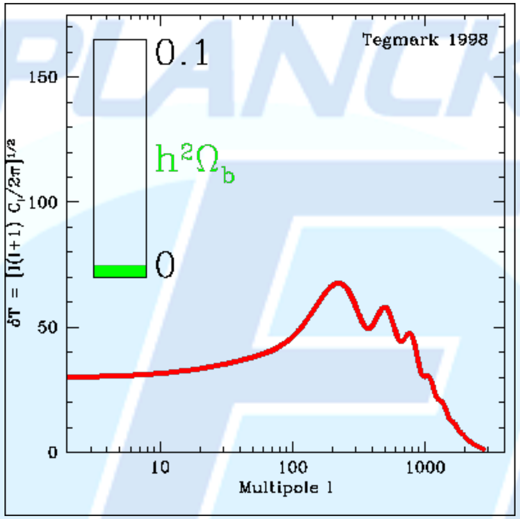

WMAP
6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000
2500
l
l(l+1)C_l/2π (μK²)

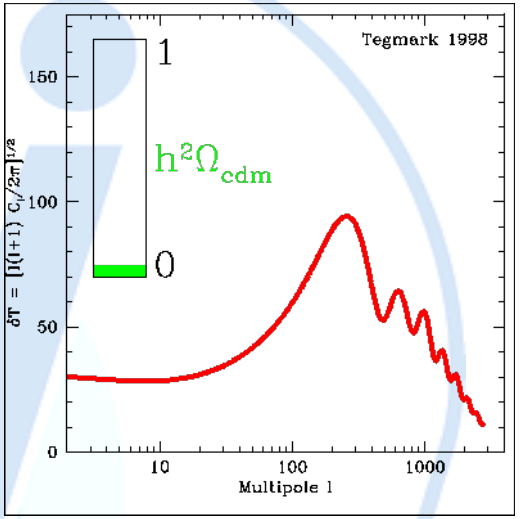

PLANCK
6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000
2500
l
l(l+1)C_l/2π (μK²)

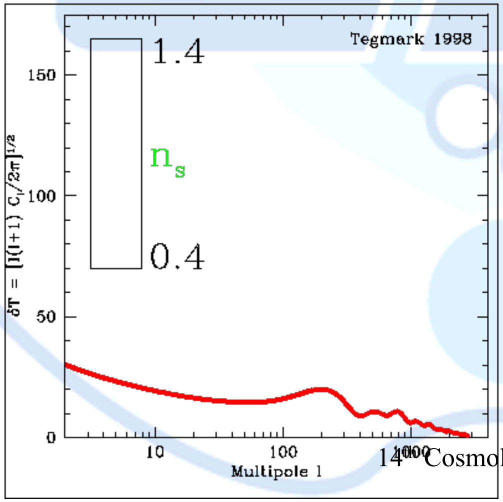
We can measure cosmological parameters with CMB !

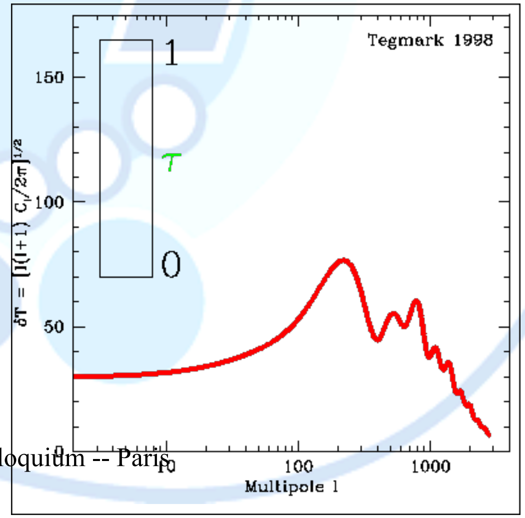
Temperature Angular spectrum varies with Ω_{tot} , Ω_b , Ω_c, Λ, τ, h, n_s, ...





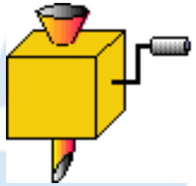


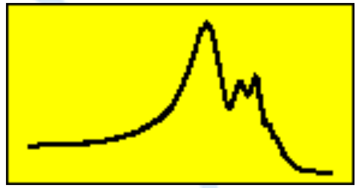


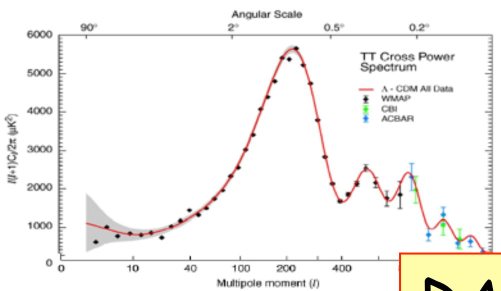


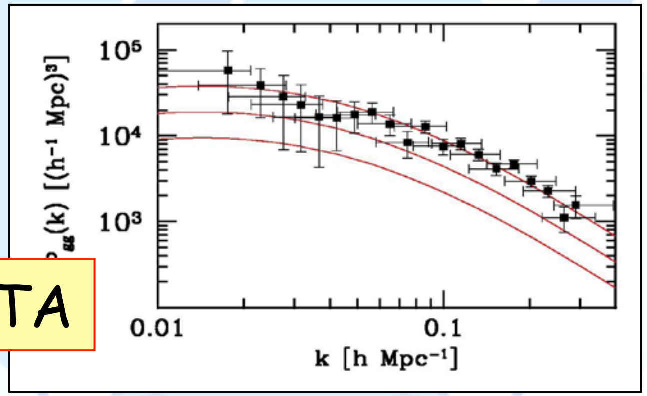
How to get a bound on a cosmological parameter

Fiducial cosmological model:
$(\Omega_b h^2 , \Omega_m h^2 , h , n_s , \tau, \Sigma m_\nu)$

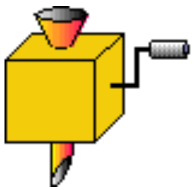






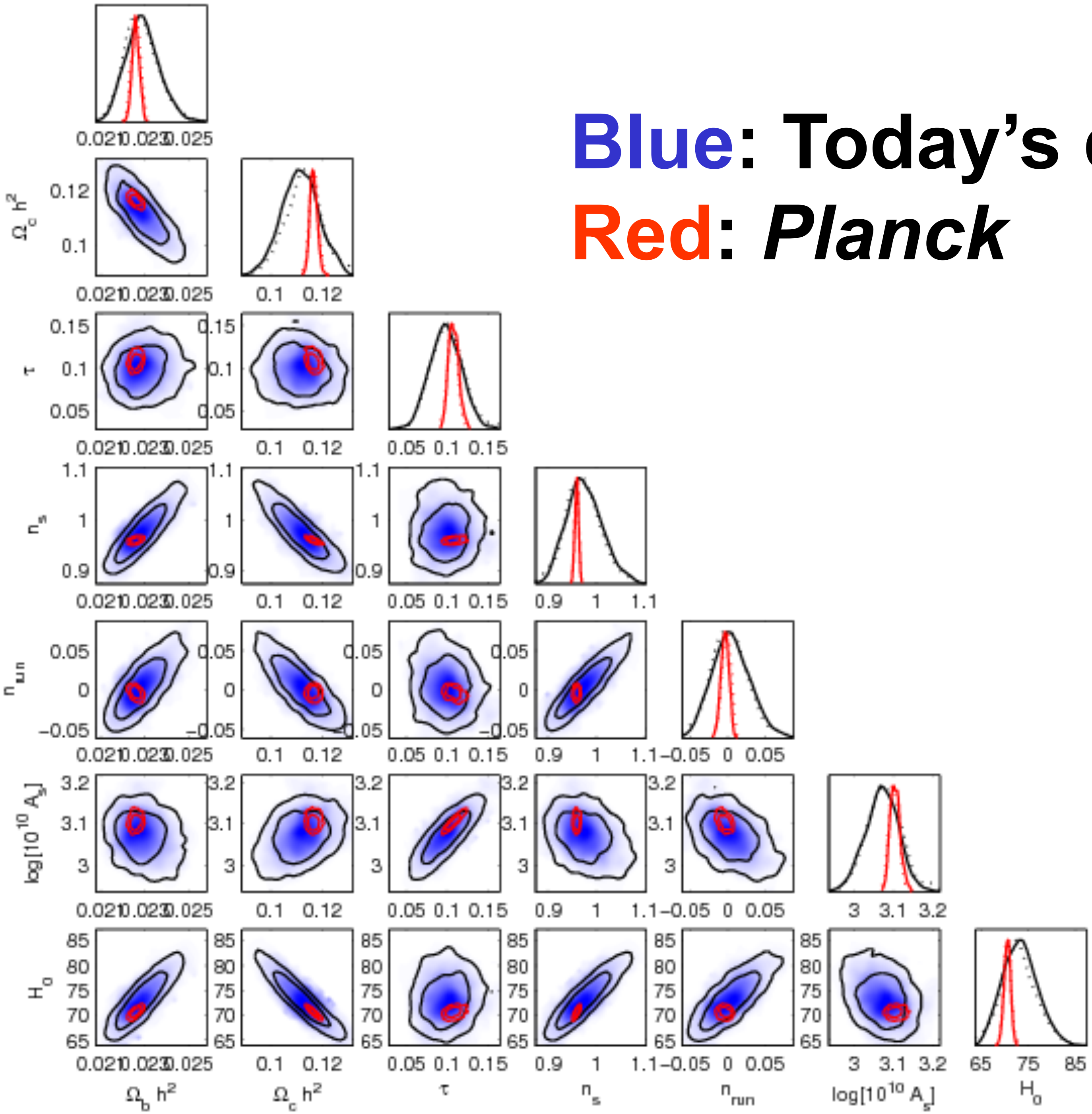


DATA



PARAMETER ESTIMATES

ASDC
ASI Science Data Center

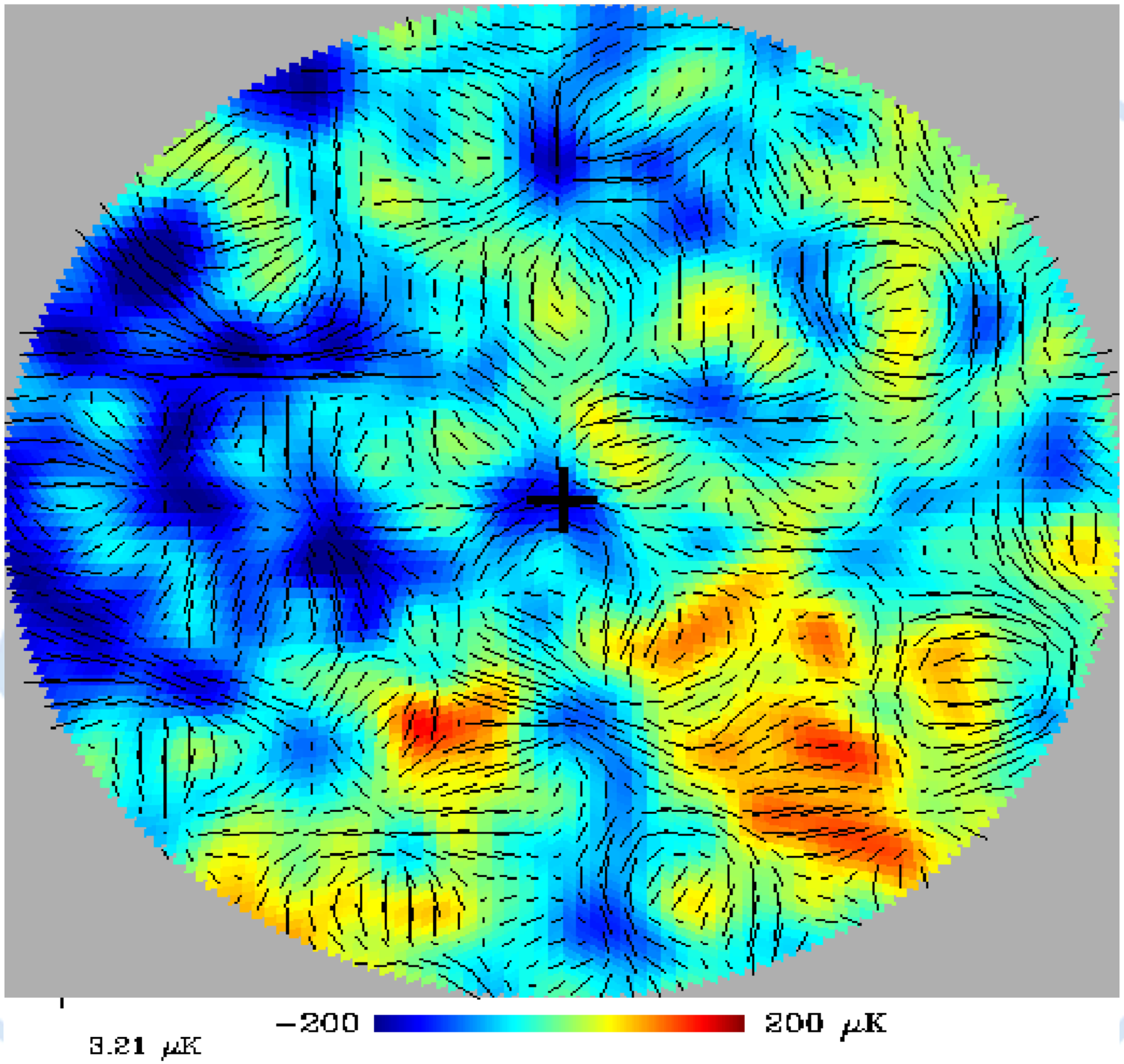


Blue: Today's data

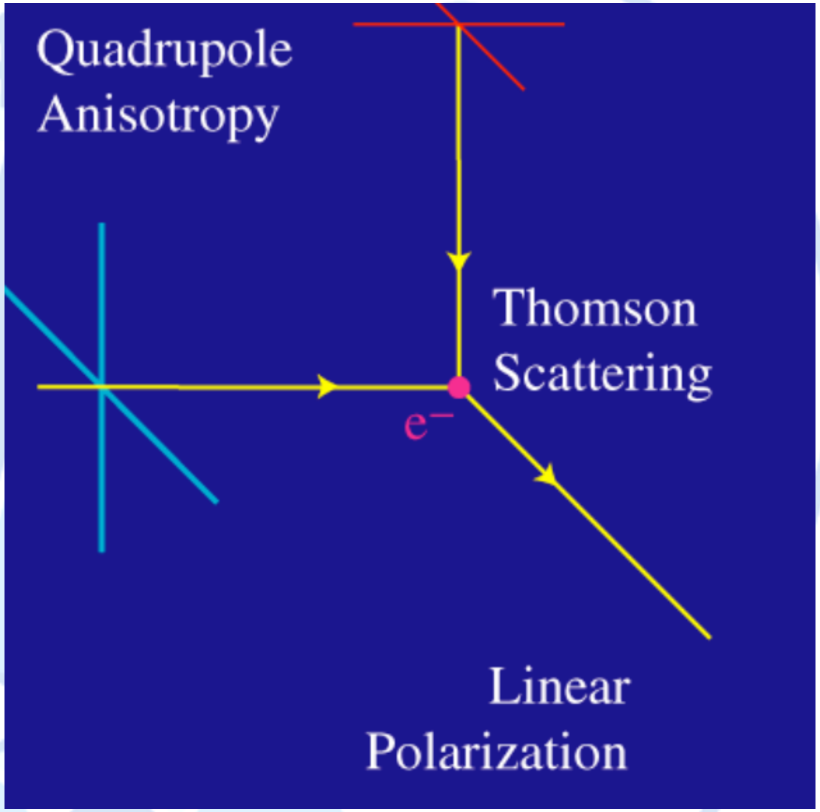
Red: *Planck*

CMB POLARIZATION

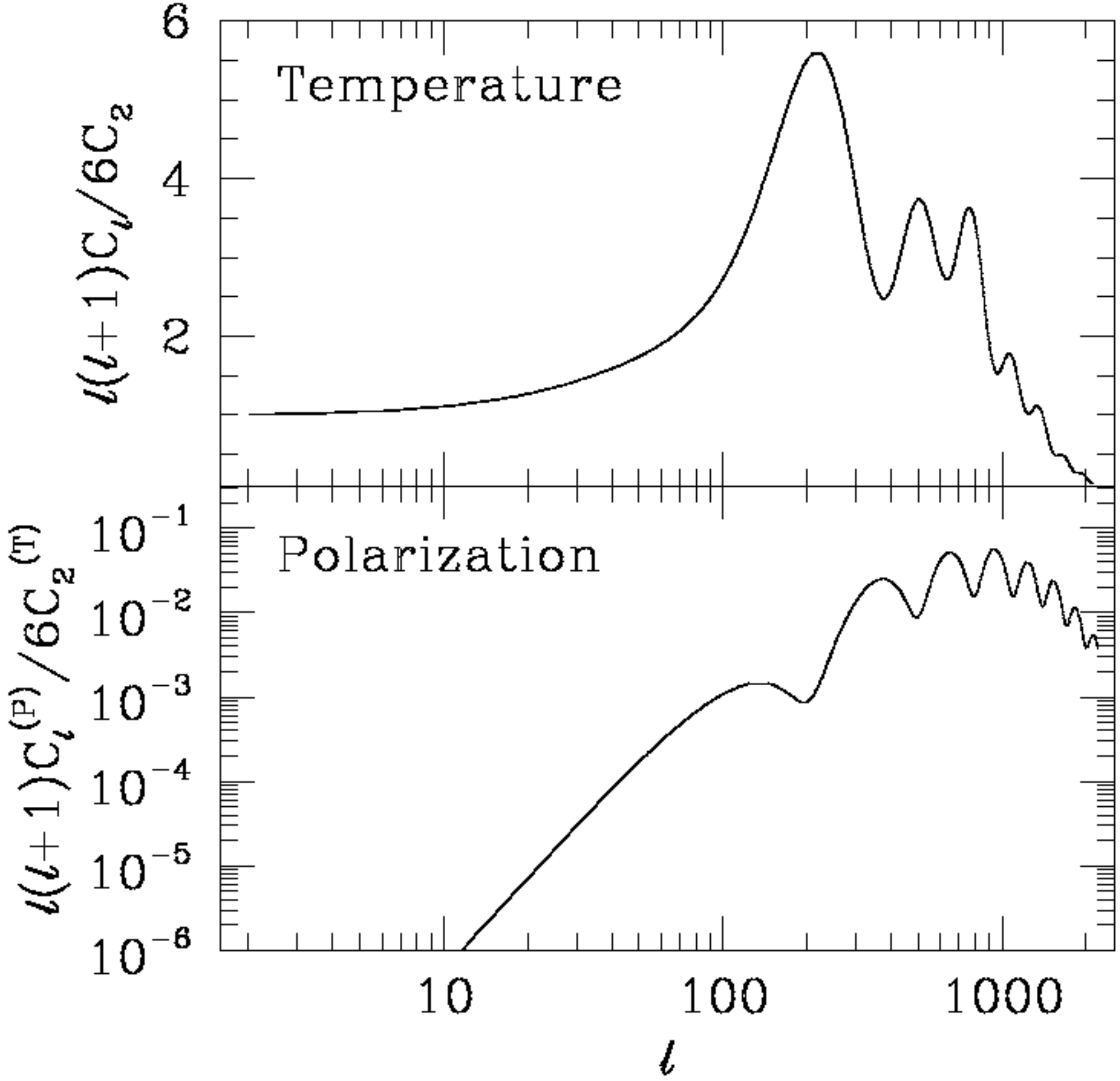
1 deg. beam, 400 sq.deg. polar cap



$$\frac{d\sigma_T}{d\Omega} \propto |\hat{\varepsilon} \cdot \hat{\varepsilon}'|^2$$



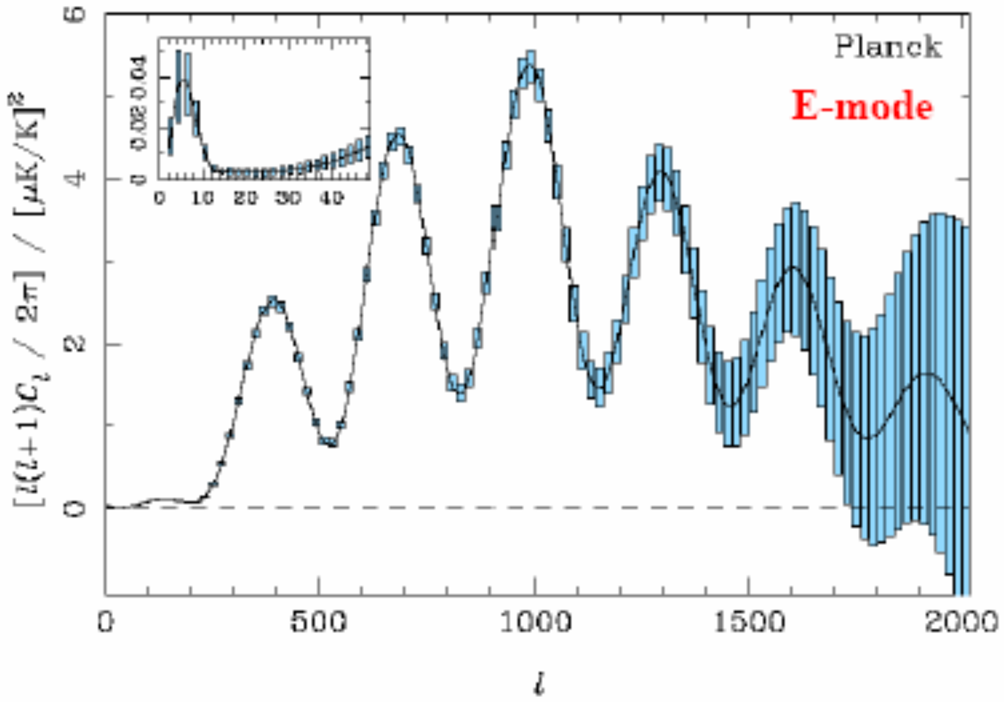
$$\left\langle \frac{\Delta T}{T}(\vec{\gamma}_1)\frac{\Delta T}{T}(\vec{\gamma}_2)\right\rangle = \frac{1}{2\pi}\sum_{\ell}(2\ell+1)C_\ell P_\ell(\vec{\gamma}_1\cdot\vec{\gamma}_2)$$

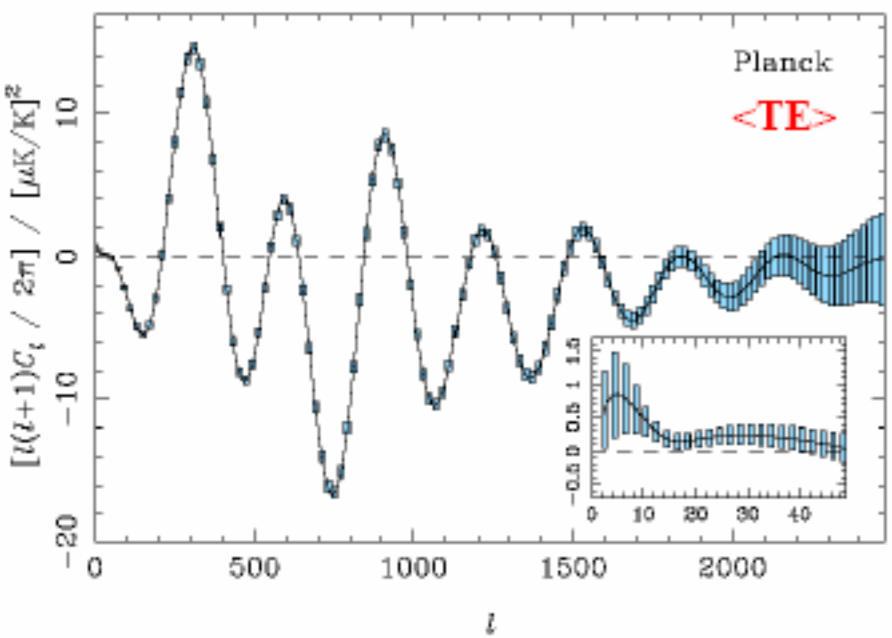


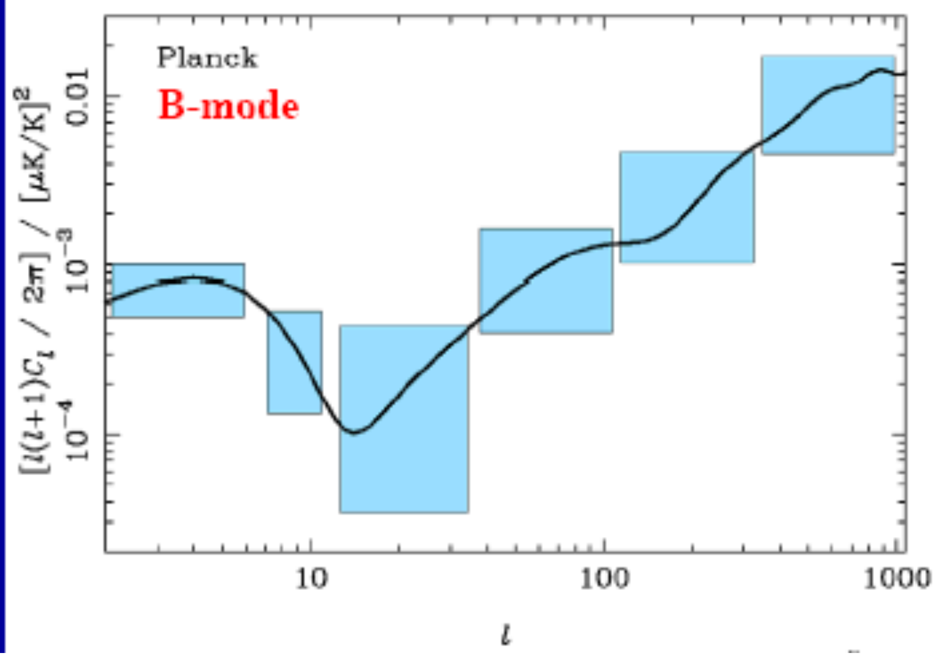
The Planck results

(in a few years' time)

Predicted power spectrum recovery for Planck

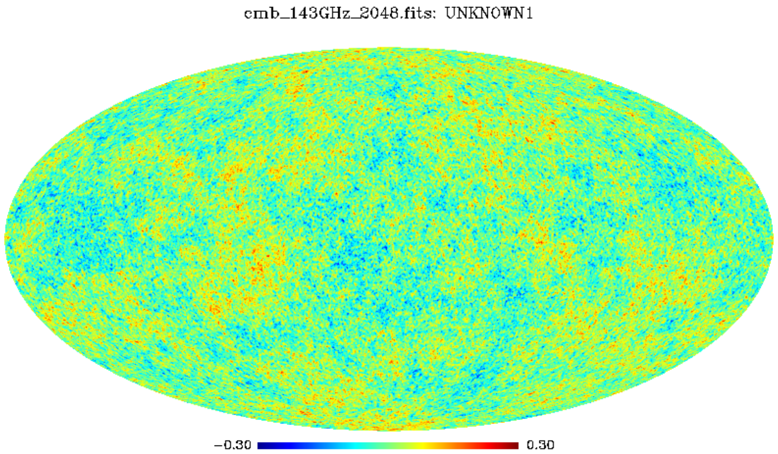


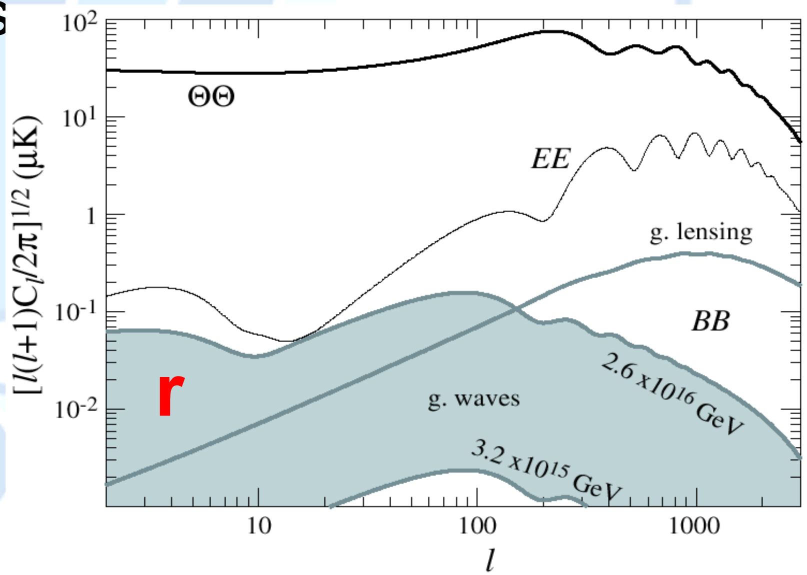




•Main Observational Objective of PLANCK

- To image the temperature and polarisation anisotropies of the Cosmic Microwave Background (CMB), over the whole sky, with an uncertainty on the temperature limited by "natural effects" (foreground fluctuations, cosmic variance) rather than intrinsic or systematic detector noises, and an angular resolution ~5 arcminutes





CMB Polarization

- **Polarization is described by Stokes-Q and -U**
- **These are coordinate dependent**
- **The two dimensional field is described by "gradient" (E) plus "curl" modes (B).**

Temperature map : $T(\hat{n})$

Polarization map : $P(\hat{n}) = \nabla E + \nabla \times B$

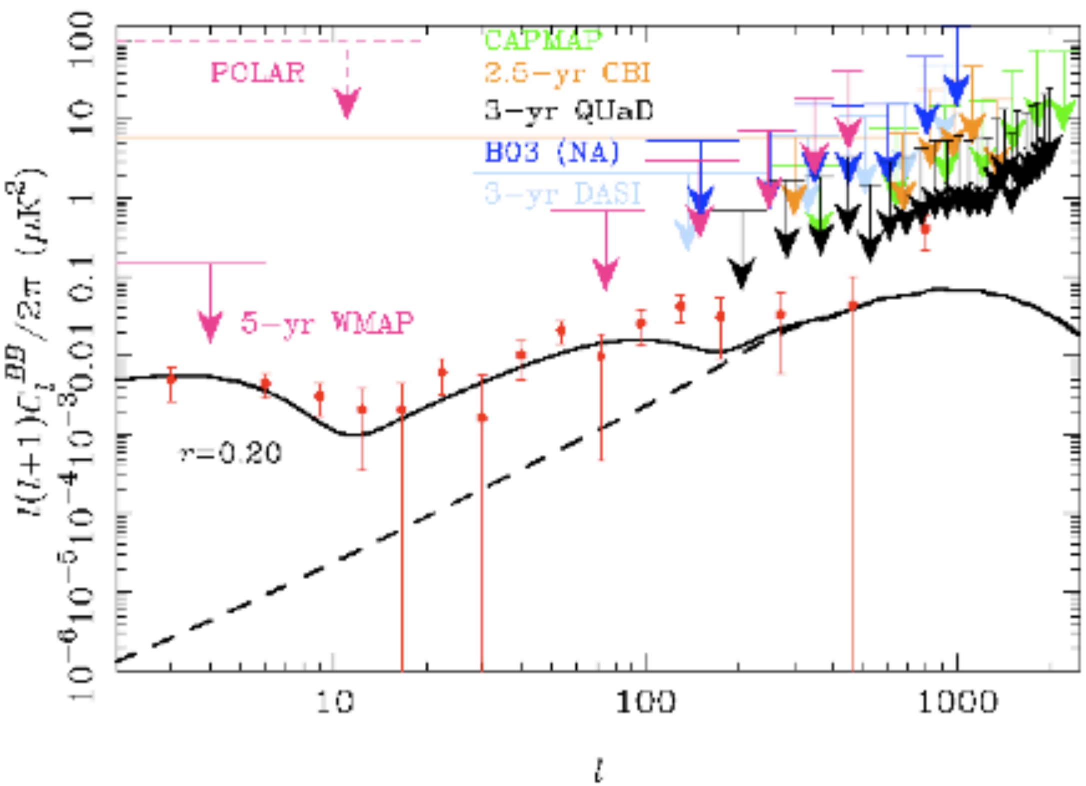
Grad (or E) modes

Curl (or B) modes

(density fluctuations have no handness,
so no contribution
to B-modes). B-Modes=Gravity Waves !!

B-modes: present limits

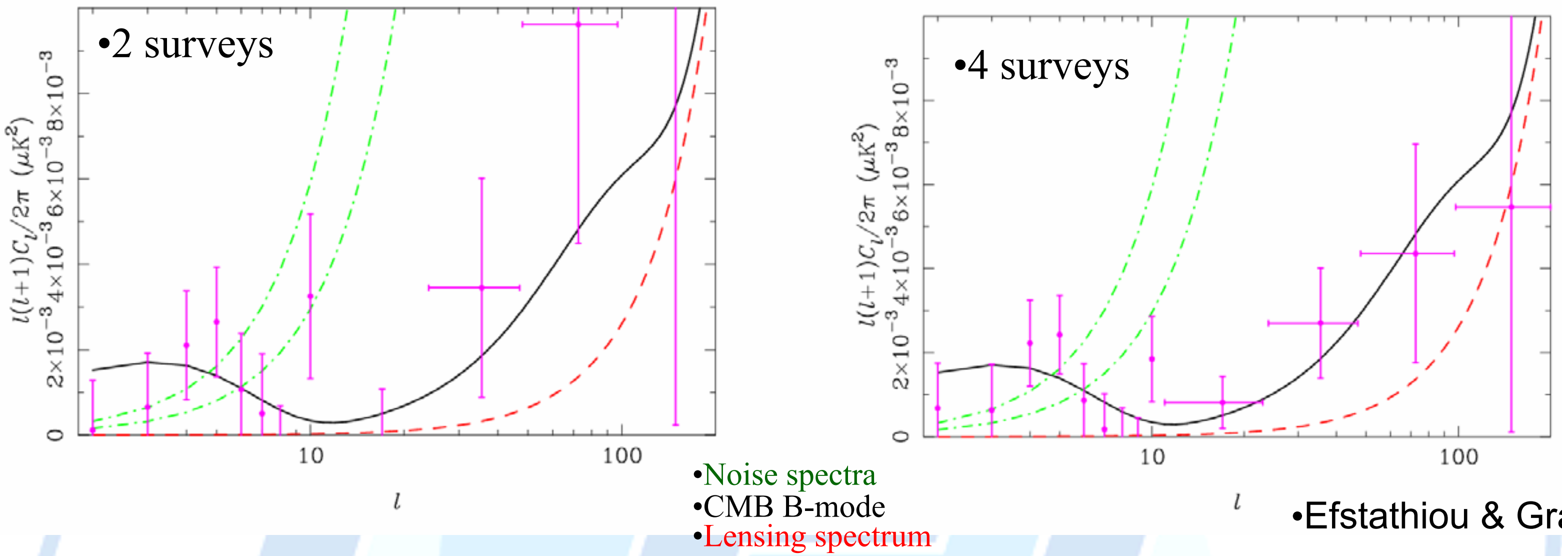
Present best direct upper limit is 0.3 one sigma (Bicep: Chiang et al 2009)



George Efstathiou 19

European Space Agency

•B-mode detectability

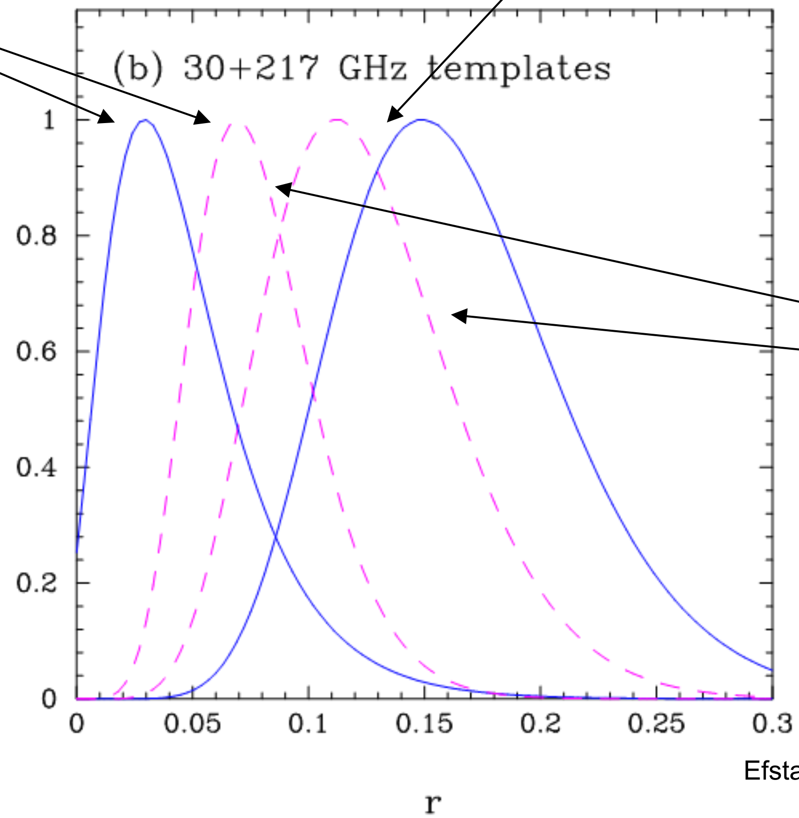


•Efstathiou & Gratton 2009

- B-modes are a signature of primordial gravitational waves
- They point directly to inflation
- With the sensitivity and control of systematics provided by 4 surveys, Planck will approach the limit of r~0.05

r = 0.1

r = 0.05



Planck 4 surveys (2 years)

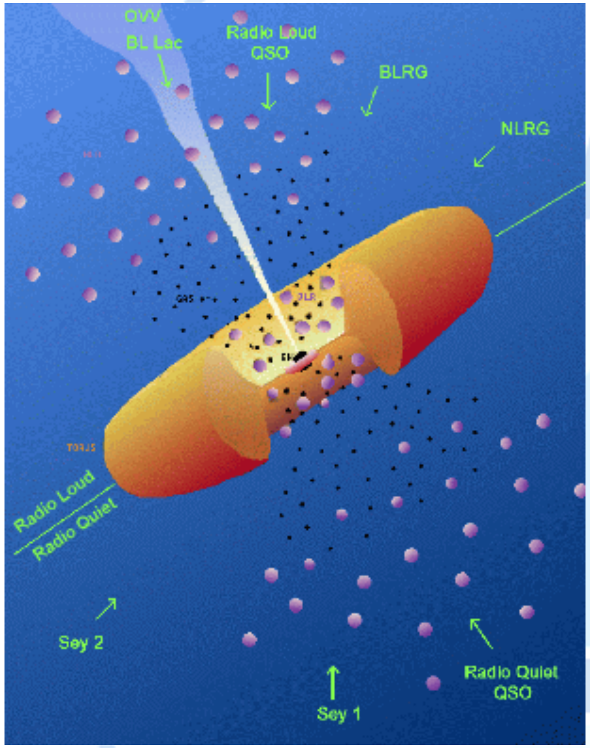
Efstathiou & Gratton, 2009

•Planck, Fermi, Swift Simultaneous observations of Blazars

•Paolo Giommi
•Italian Space Agency, ASI

•on behalf of the Planck, Fermi, Swift collaboration on blazars

ASI Science Data Center



- **AGN** : **Two main categories**
  1. *Dominated by (mostly) thermal emission from accretion disk -*

     TD-AGN (>~90 %)

  1. *Dominated by Non-Thermal radiation -*

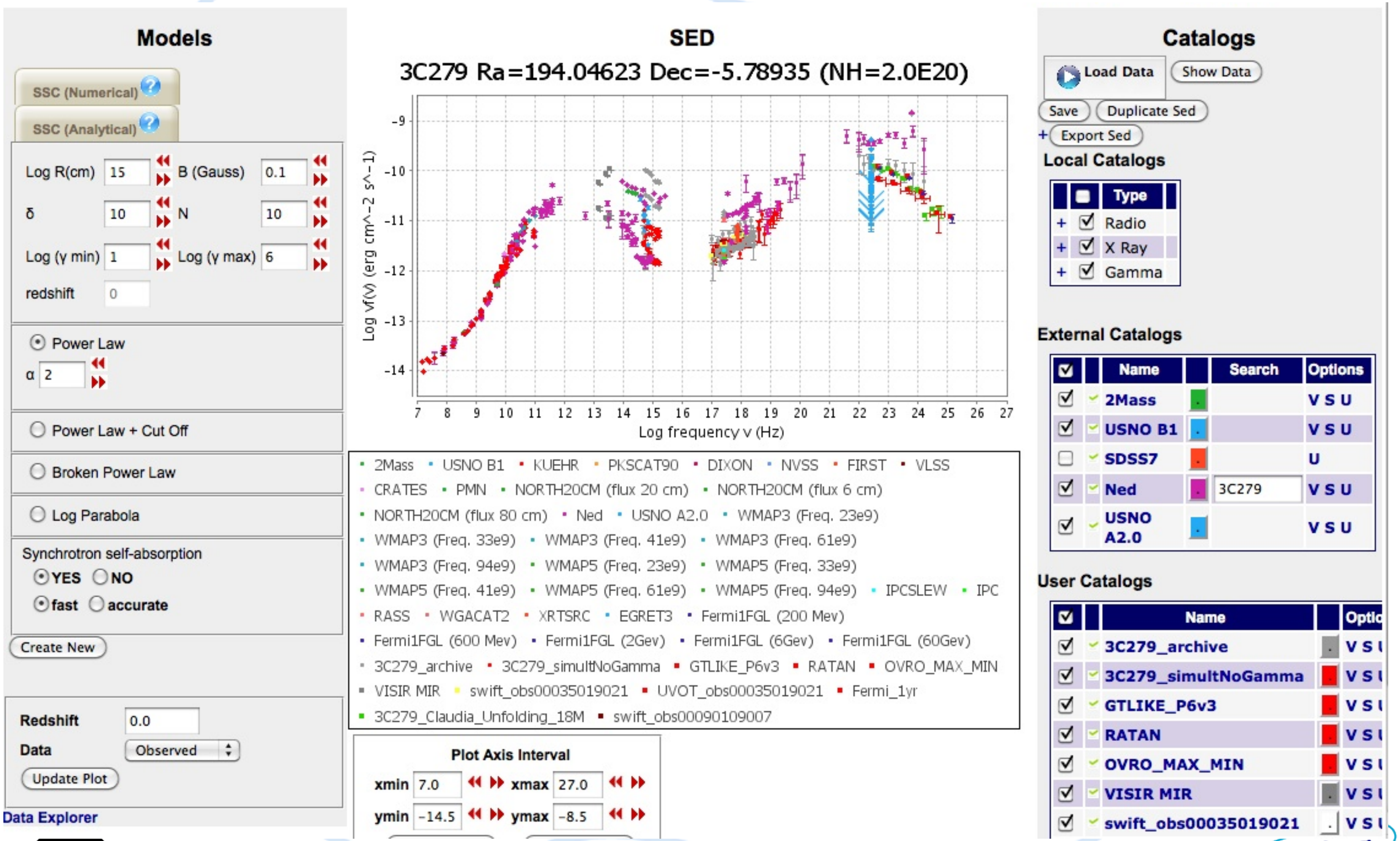
     jet emission - NT-AGN (< 10%)

•As of today, about 3,100 blazars are known.
•Only small good statistical samples exist so far, each including a few hundred objects at best! …but Fermi, Planck, Swift and other facilities (e.g. SDSS) are quickly changing this.

•Blazar research is much less developed than that of TD-AGN.
•Still, blazars dominate the extrag. sky in a number of emerging
•observational windows (μ-wave, γ-ray, TeV)


ASDC – ASI Science Data Center Home Page
http://www.asdc.asi.it/
ASDC – ASI Science Data Cente...
SED
NuSTAR
agenzia spaziale italiana
ASI SCIENCE DATA CENTER
ASDC ASI Science Data Center
Home About ASDC News Events Quick Look Data Missions Multimission Archive ASDC Catalogs Current pointings Tools ASDC for all
Helpdesk/Feedback ASI Related Sites Bibliographic services
AGILE SWIFT FERMI HERSCHEL PLANCK BeppoSAX NUSTAR OLIMPO
Astrophysics and Cosmology
Exploration of the Solar System
Astroparticle Physics
The ASI Science Data Center for
space astrophysics and cosmology,
astroparticle physics
and
solar system exploration
The ASDC is located at the European Space Agency's establishment of ESRIN, Frascati, Italy
TOP RESULTS/PRESS RELEASES
500 GRBs
April 19, 2010: Swift catches its 500th Gamma-ray Burst!
March 25, 2010: FERMI 1-year Catalogs now on line!
February 15, 2010: The AGILE satellite detects "super-energetic TGFs" that could affect air travel
December 3, 2009: AGILE detects an extraordinary gamma-ray activity from the FSRQ 3C 454.3
November 12, 2009: AGILE science operations resumed on November 4th, 2009
ASDC Sky Explorer
Enter source name or coordinates:
RA, DEC
J2000
Local SIMBAD NED
Radius: 1 arcmin FIND
NEWS
May 28, 2010: AGILE detection of gamma-ray emission from Cygnus X-3
May 28, 2010: GRB 100528A: SuperAGILE Localization of a Long GRB
May 26, 2010: AGILE detection of gamma-ray emission from 4C+21.35 (PKS 1222+21)
EVENTS
AGILE
AO3 closed
March 30 - April 30, 2010
8th AGILE Workshop
28/04/2010 - Bologna
Trova:
Successivo
Precedente
Evidenzia
Maiuscole/minuscole

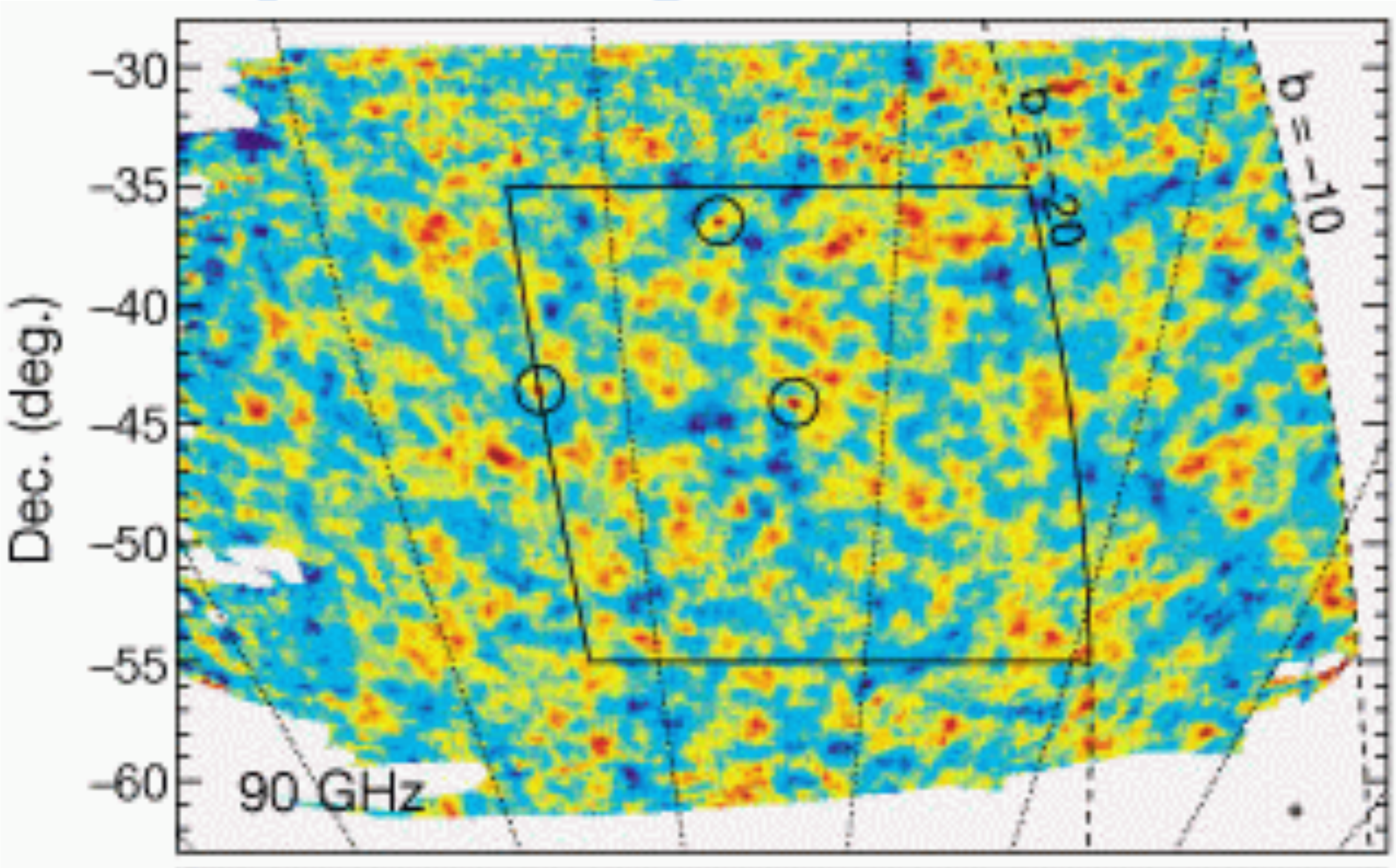
•ASDC SED Builder

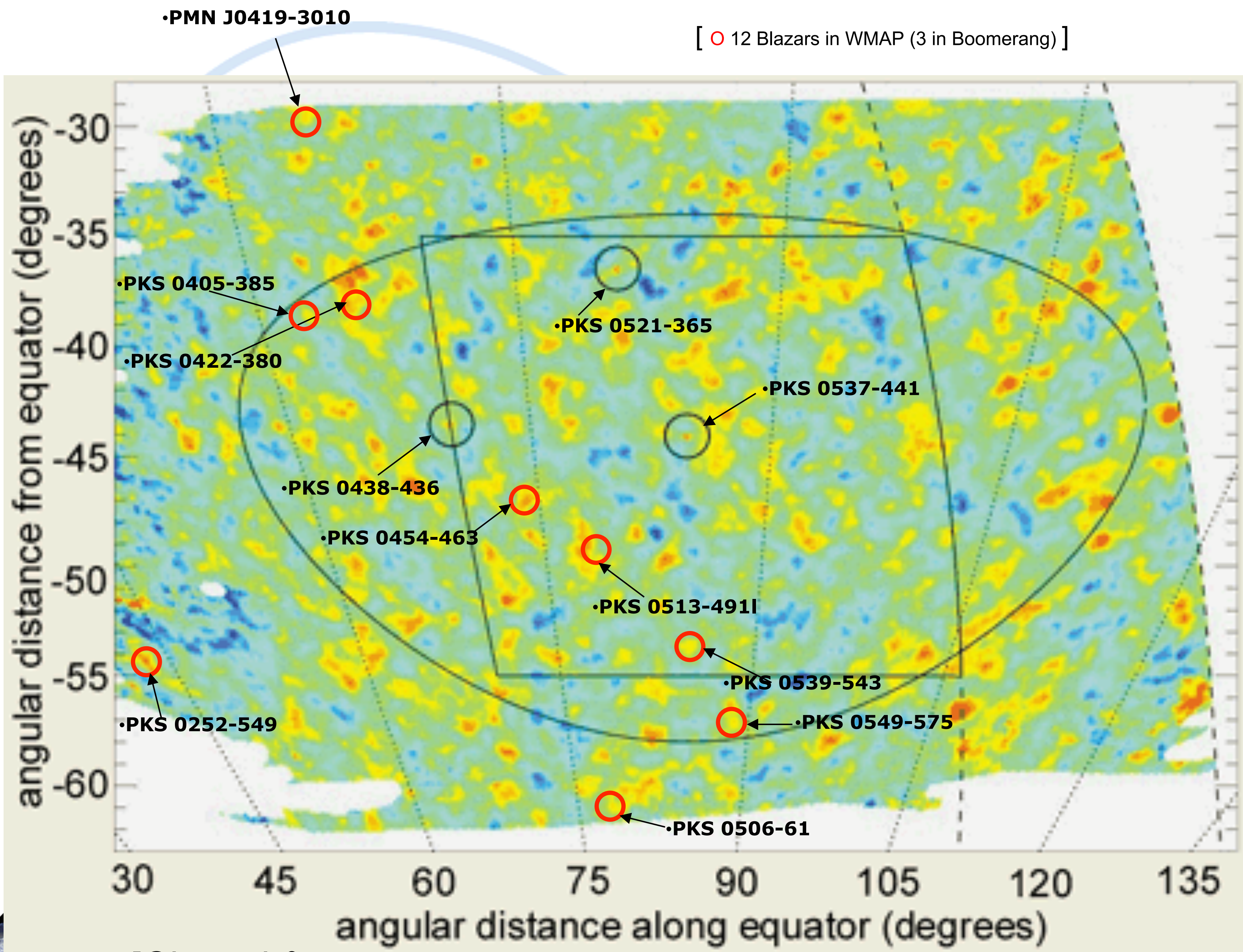


•The ASDC SED Builder

•Radiotelescopes and Planck •Herschel •Swift •AGILE and Fermi •TeV/CTA

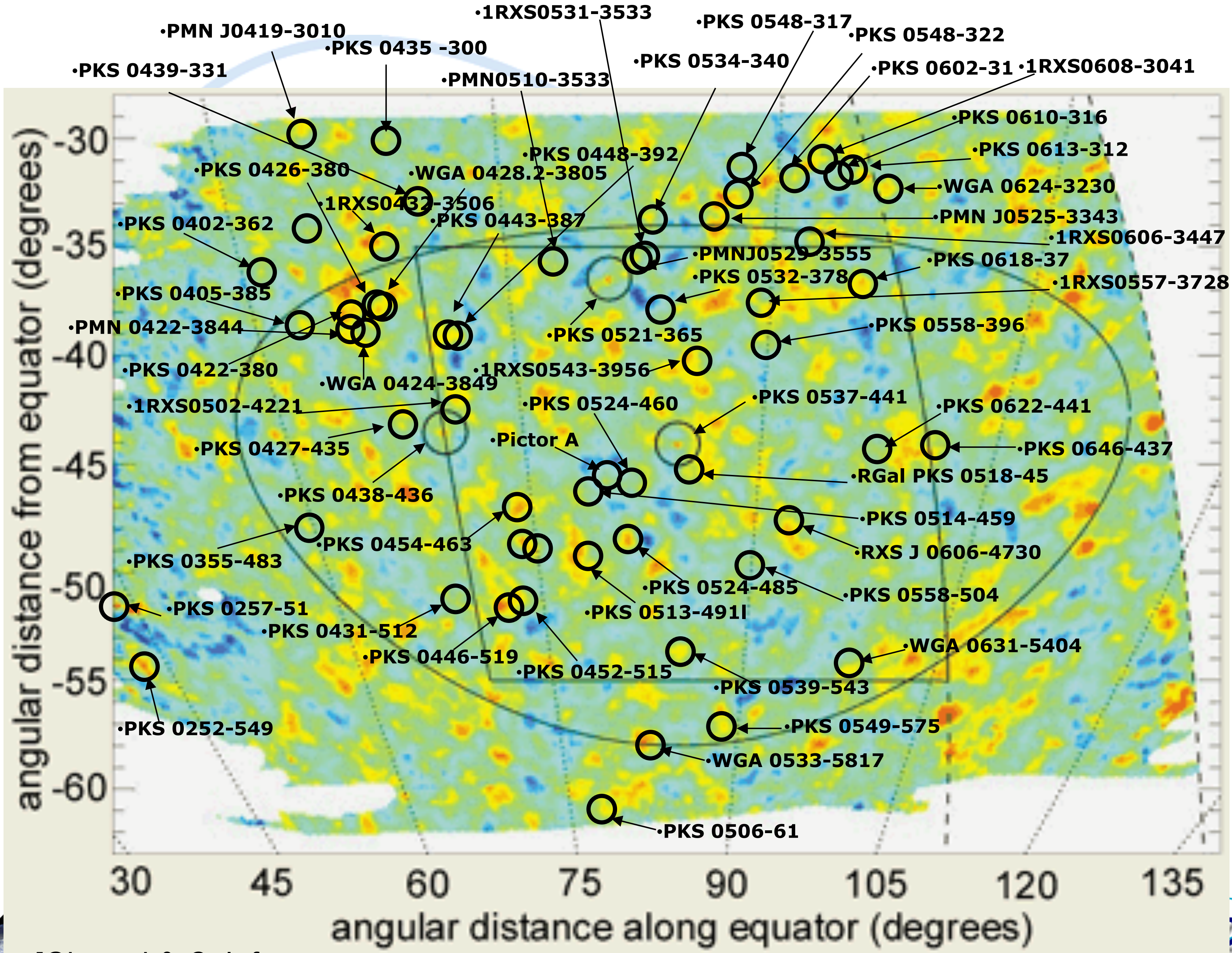
•Boomerang 90 GHz CMB MAP
•De Bernardis et al. 2000





•[Giommi & Colafrancesco 2004]

ASI Science Data Center

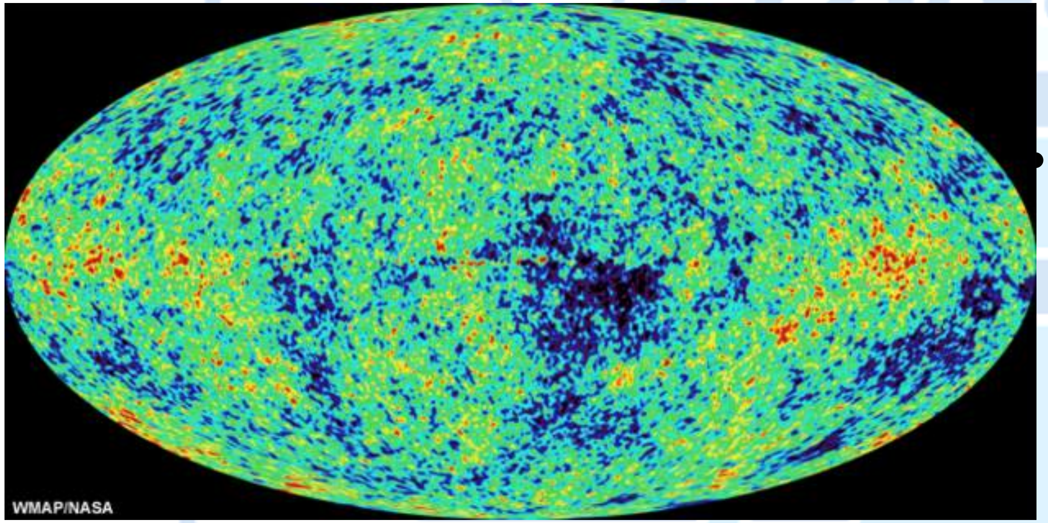


[Giommi & Colafrancesco 2004]

•[O 54 Blazars with ΔT > 50 μK]

Blazars & WMAP

- WMAP CMB fluctuation map



- WMAP bright foreground source catalog

- 208 bright sources
  - 141 FSRQs
  - 23 BL Lacs
  - 13 Radio galaxies
  - 5 Steep Spectrum QSOs
  - 2 starburst galaxies
  - 2 planetary nebule
  - 17 unidentified
  - 5 without radio counterpart
  - (probably spurious)

- The vast majority (85%-90%) of bright WMAP foreground sources are Blazars

- http://www.asdc.asi.it/wmap/

The ASDC catalog of known Blazars

http://www.asdc.asi.it/bzcat/

Multi-frequency Catalogue of Blazars

Second Edition, June 2010

E. Massaro, P. Giommi, C. Leto, P. Marchegiani, A. Maselli,
M. Perri, S. Piranomonte and S. Sclavi

arXiv:1006.0922

On-line table. Last update: 09-July-2010

Available parameters

- Name, Ra, Dec
- Z
- Rmag
- Class, Radio Flux
- X-ray flux
- Comm redshift
- Comm rmag
- Comm radio flux

GO

BL Lacs | FSRQs | Uncertain

00h -- 04h 04h -- 08h 08h -- 12h 12h -- 16h 16h -- 20h 20h -- 24h 00h -- 24h

Reset TXT

Cone Search

Source Name Search

RA,Dec Search

(e.g. 00 02 34.6,-53 01 10.2 or 0.64417,-53.0195)

radius 5 arcmin Clean

Entry number		Source name (BZCAT Name)	RA (J2000.0) (hh mm ss.d)	Dec (J2000.0) (dd mm ss.d)	Redshift (Z)	Rmag	Source classification (Classification)
Selection mode: inclusive		Stat	Stat	Stat	Stat	Stat	Stat
1 Select	Data Explorer	BZBJ0002-0024	00 02 57.1	-00 24 47.0	0.523	19.7	BL Lac
2 Select	Data Explorer	BZQJ0003+2129	00 03 19.3	+21 29 44.0	0.45	19.7	QSO RLoud flat radio sp.
3 Select	Data Explorer	BZQJ0004+4615	00 04 16.0	+46 15 18.0	1.81	20.4	QSO RLoud flat radio sp.
4 Select	Data Explorer	BZQJ0004+2019	00 04 35.6	+20 19 41.9	0.677	20.2	QSO RLoud flat radio sp.
5 Select	Data Explorer	BZQJ0004-4736	00 04 35.5	-47 36 17.9	0.88	15.9	QSO RLoud flat radio sp.
6 Select	Data Explorer	BZQJ0005+0524	00 05 20.2	+05 24 10.0	1.9	16.3	QSO RLoud flat radio sp.
7 Select	Data Explorer	BZQJ0005+3820	00 05 57.1	+38 20 14.9	0.229	17.6	QSO RLoud flat radio sp.
8 Select	Data Explorer	BZQJ0006-0623	00 06 13.8	-06 23 35.0	0.347	17.8	QSO RLoud flat radio sp.

Completato

Planck, Swift, Fermi simultaneous observations of blazars

Large sample of blazars selected from

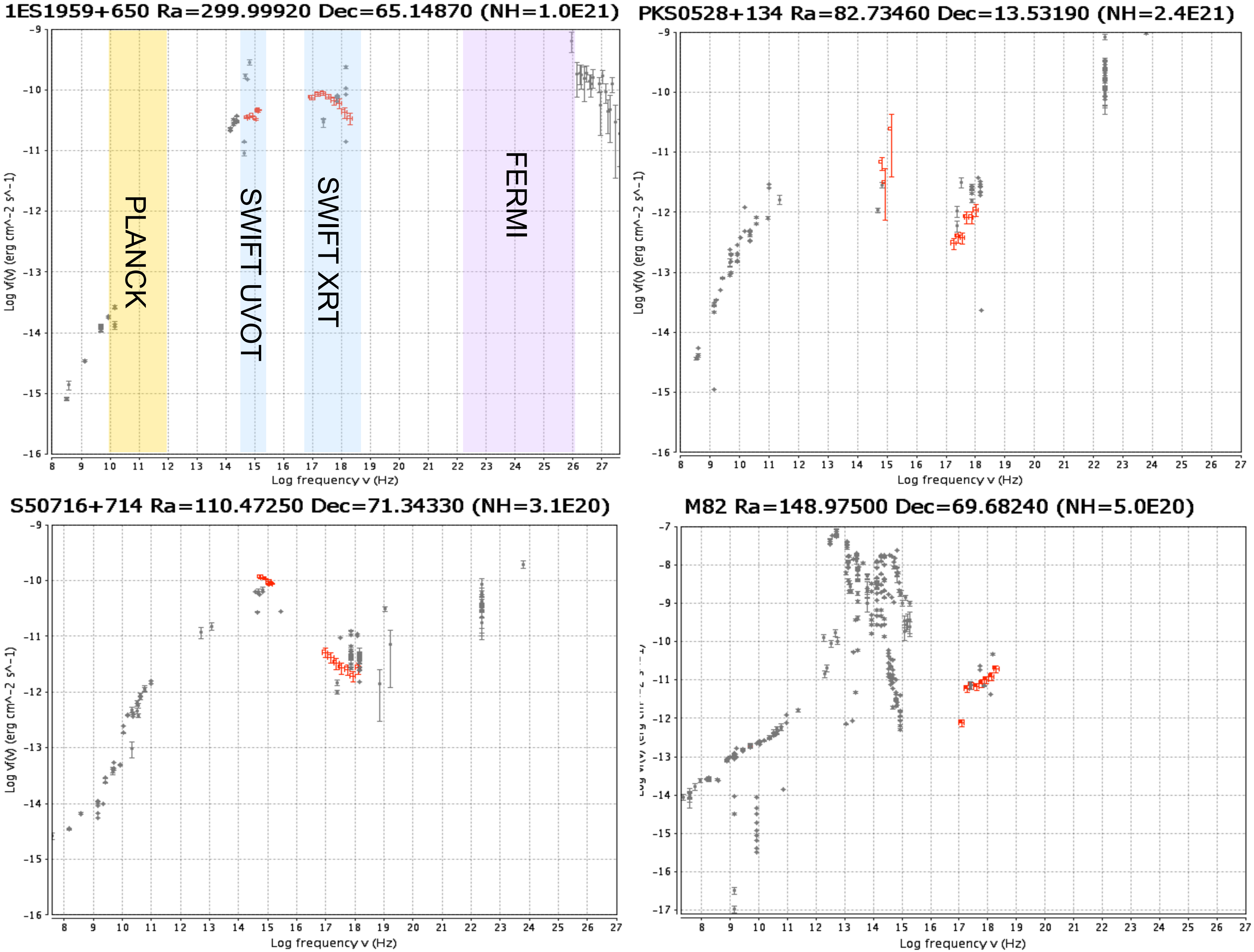
- List of sources selected by the Planck-WG6 catalog
- WMAP 5yr catalog
- Fermi 3-months bright source catalog
- Bright HBL/HSP list
- BAT and Plotkin (SDSS BL Lacs) catalogs

Observed as Swift ToOs when they happen to be in the field of view of Planck

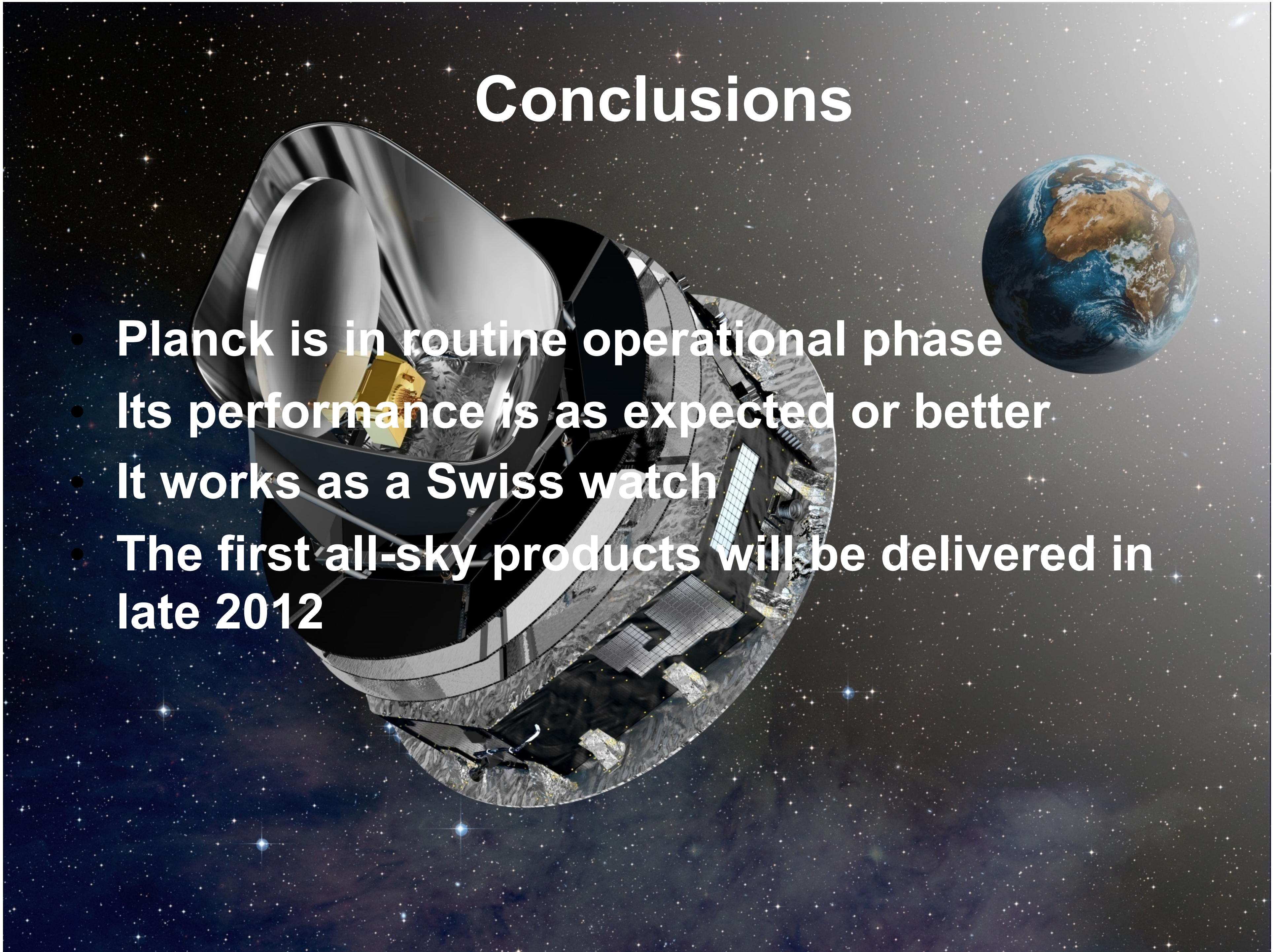
Program started in September 2009. Since then Swift has been observing an average of 3 Planck blazars/week

- ~ 80 sources per survey
- ~ 150 sources per year

As of 22 July 2010 we have simultaneous data for over 100 blazars including 69 FSRQ and 38 BL Lacs


1ES1959+650 Ra=299.99920 Dec=65.14870 (NH=1.0E21)
PLANCK
SWIFT UVOT
SWIFT XRT
FERMI
Log νf(ν) (erg cm^-2 s^-1)
Log frequency ν (Hz)
PKS0528+134 Ra=82.73460 Dec=13.53190 (NH=2.4E21)
Log νf(ν) (erg cm^-2 s^-1)
Log frequency ν (Hz)
S50716+714 Ra=110.47250 Dec=71.34330 (NH=3.1E20)
Log νf(ν) (erg cm^-2 s^-1)
Log frequency ν (Hz)
M82 Ra=148.97500 Dec=69.68240 (NH=5.0E20)
Log frequency ν (Hz)

Conclusions



- Planck is in routine operational phase
- Its performance is as expected or better
- It works as a Swiss watch
- The first all-sky products will be delivered in late 2012