COSMIC MICROWAVE BACKGROUND

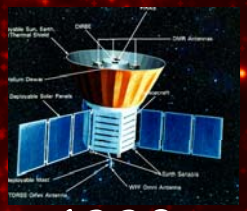
COVER SLIDE FROM A PREVIOUS TALK

1917

1943

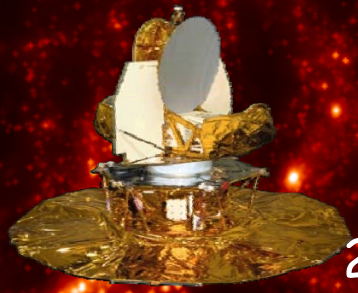
1965

1969

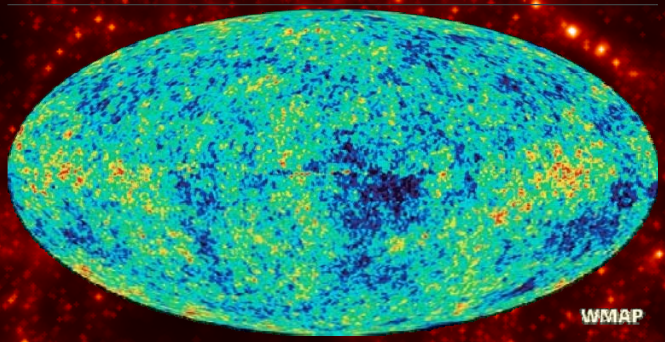


1990

1999



2002



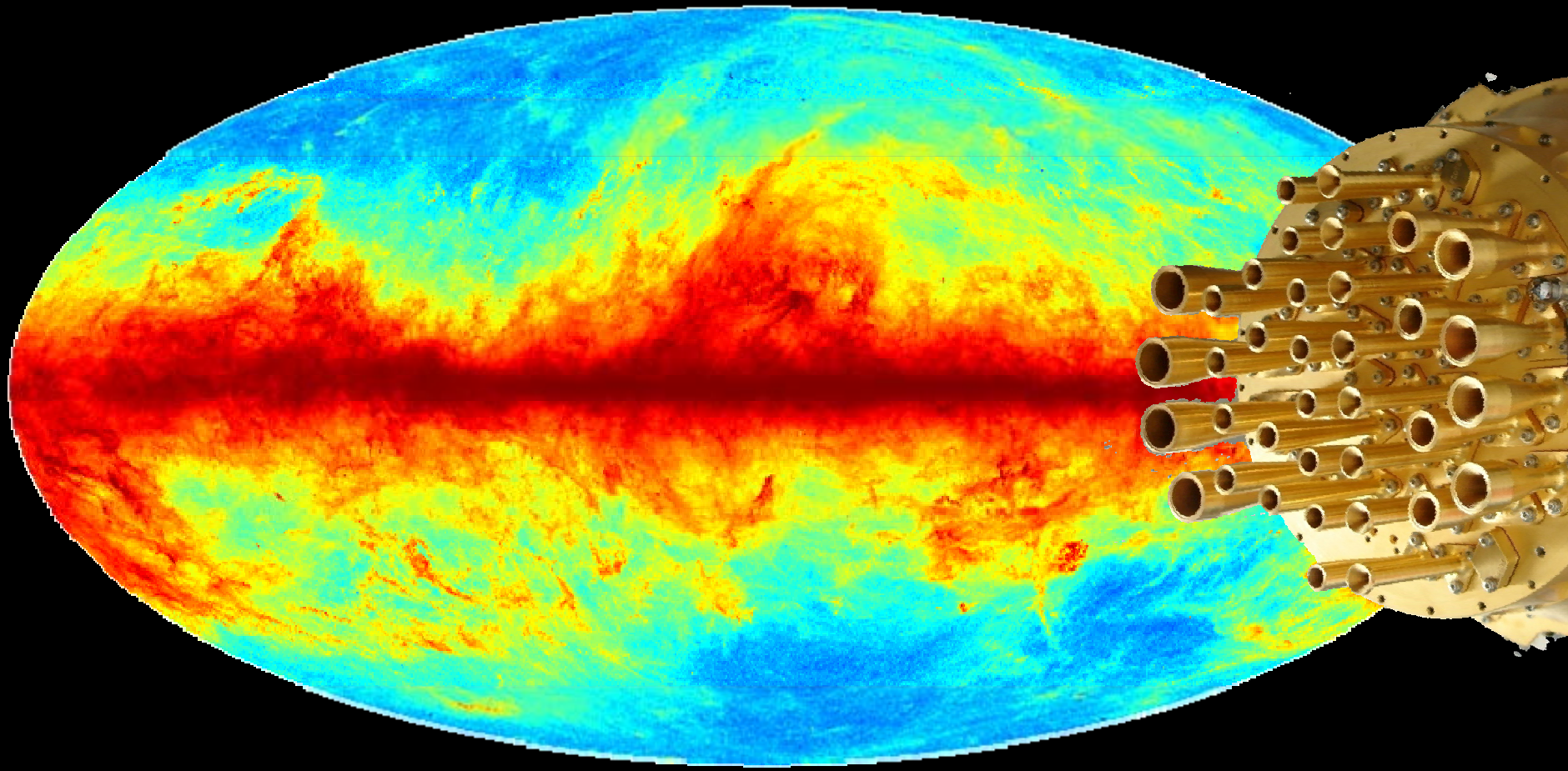
2009

2022?

F. R. BOUCHET

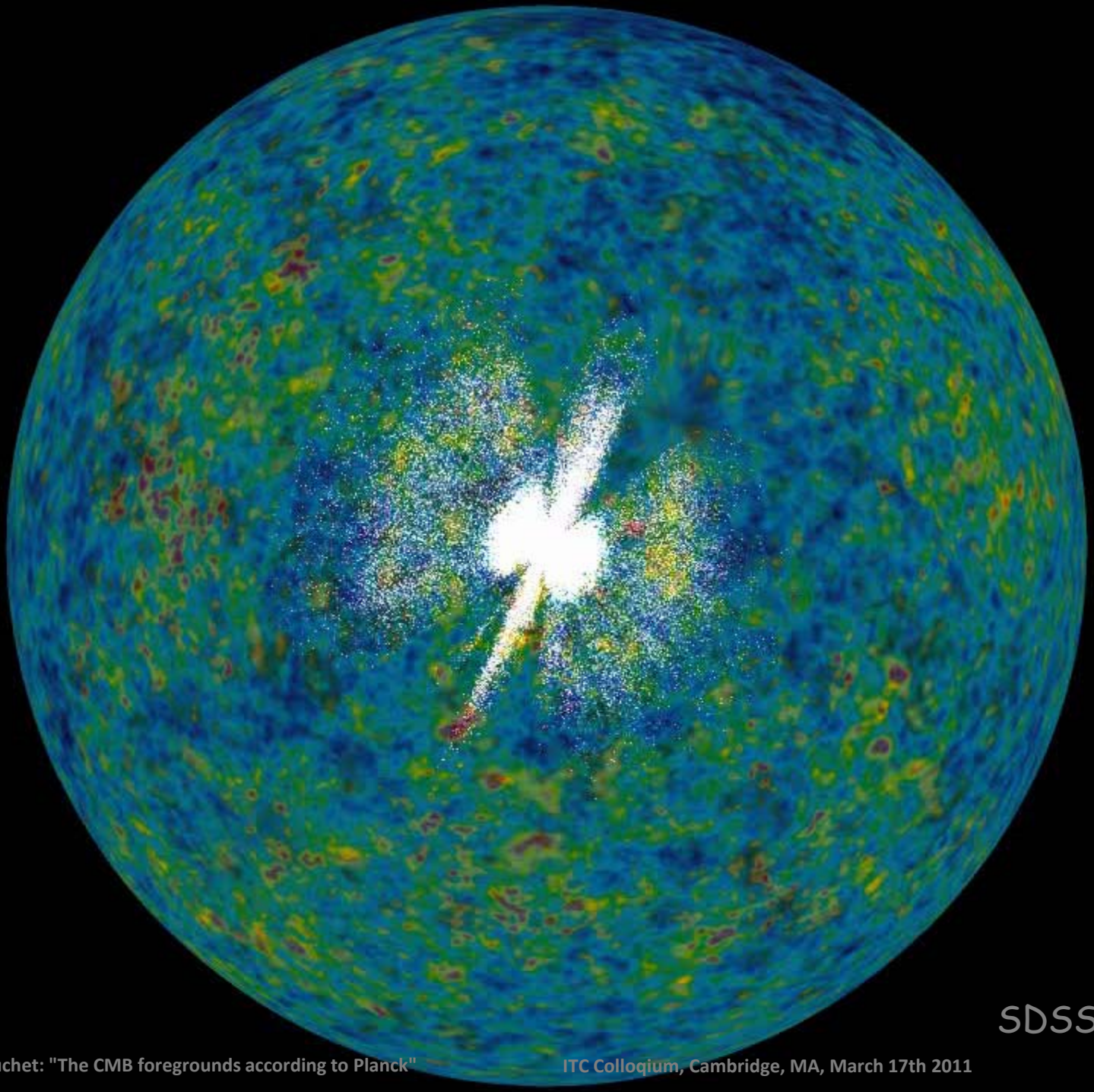
INSTITUT D'ASTROPHYSIQUE DE PARIS, CNRS

Planck Early Results: CMB Foregrounds Intensity



The first 295 days of survey

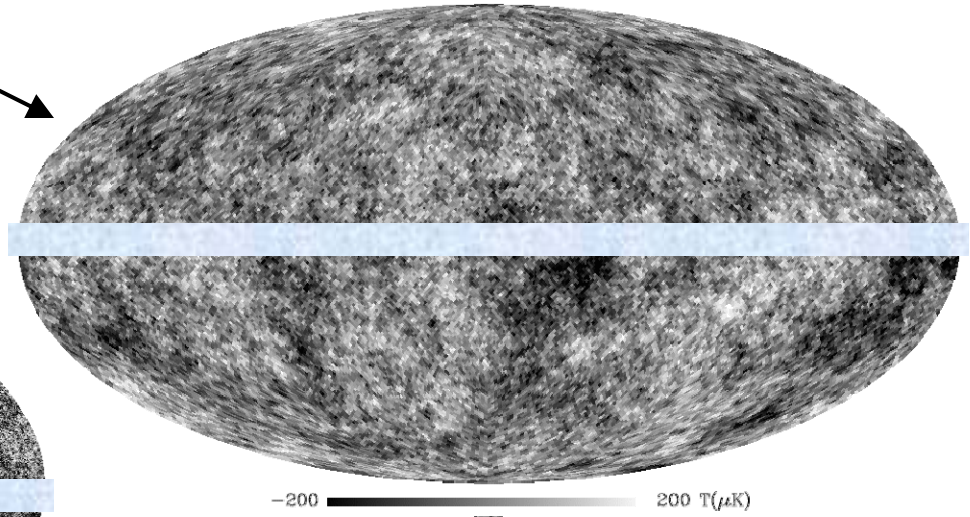
F. R. Bouchet, IAP

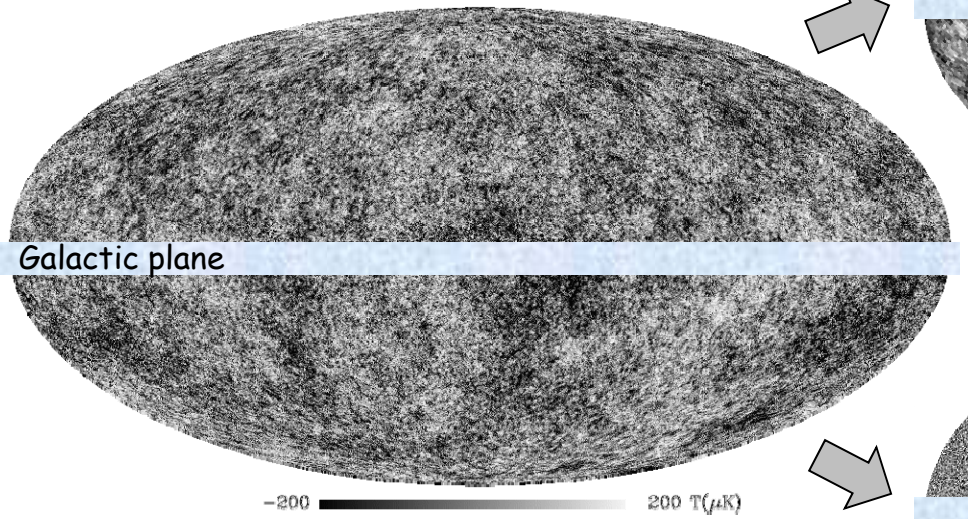


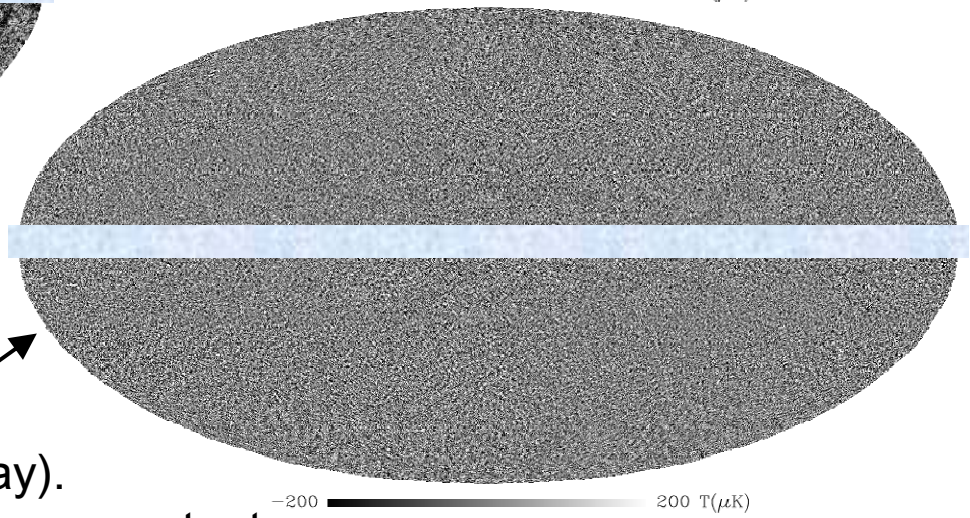
SDSS & WMAP

What is there to be seen?

Smoothed map (suppressing scales θ < 1 deg) :
Quantum Fluctuations imprinted
When the age of the Universe was in the interval [10^{-43}, 10^{-12}] seconds



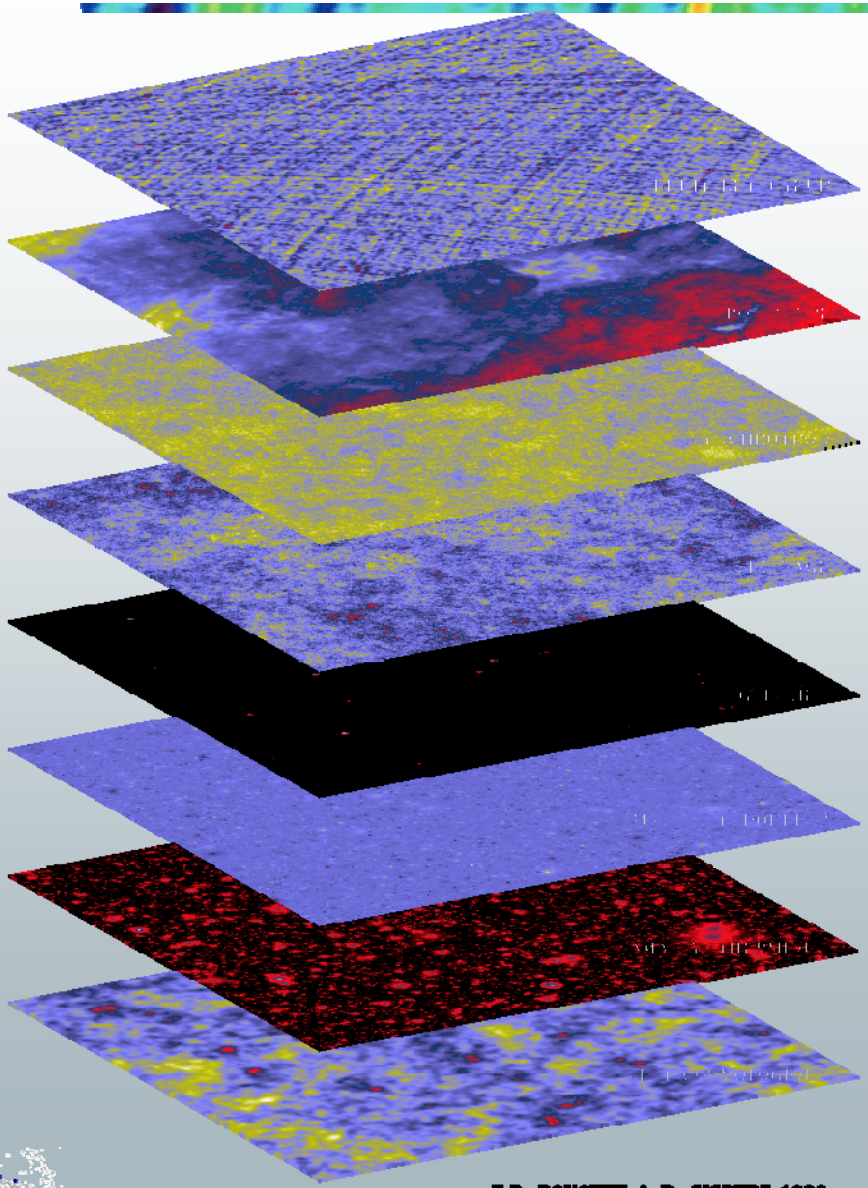


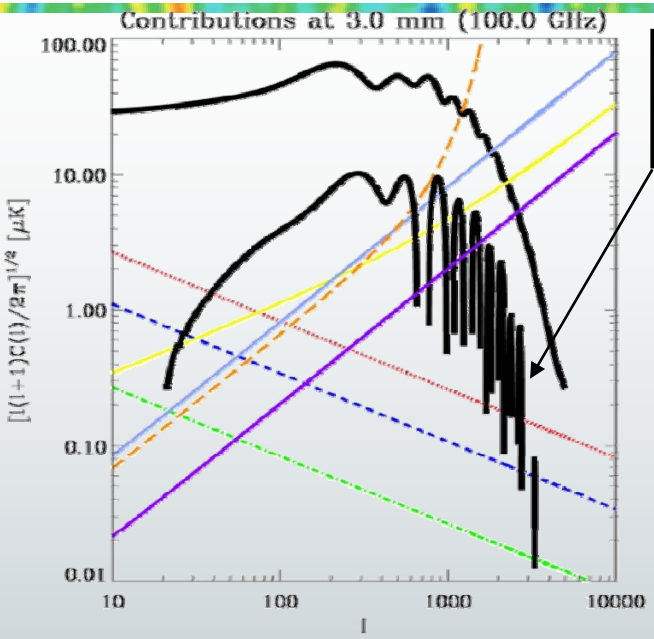


Difference map (scales θ < 1 deg) :
Acoustic oscillations at small scales
< ct when t=370 000 years (~150Mpc today).
Which allows to take a census of the Universe content

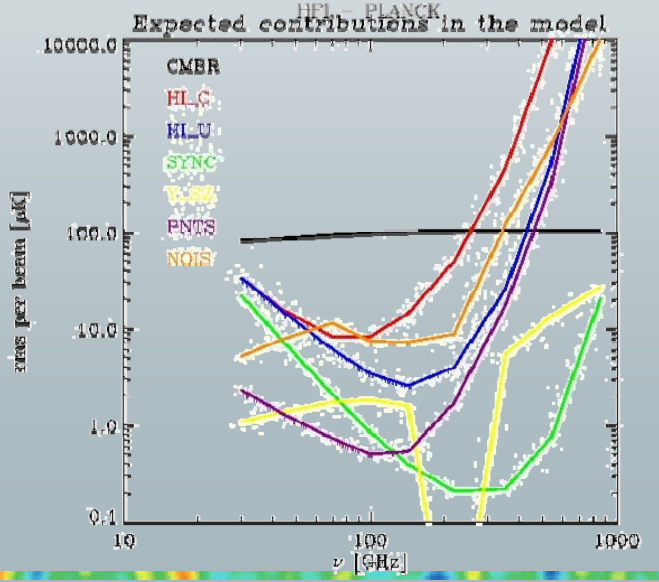
±200μK scale

Foregrounds !!





ΔH_0 =2%



The Planck concept

- to perform the “ultimate” measurement of the Cosmic Microwave Background (CMB) temperature anisotropies:
  - *full sky coverage & angular resolution / to survey all scales at which the CMB primary anisotropies contain information (~5’)*
  - *sensitivity / essentially limited by ability to remove the astrophysical foregrounds*

  ⇒ *enough sensitivity within large frequency range [30 GHz, 1 THz] (~CMB photon noise limited for ~1yr in CMB primary window)*

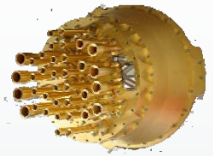
- get the best performances possible on the polarization with the technology available

⇒ ESA selection in 1996 (after ~ 3 year study)

NB: with the Ariane 501 failure delaying us by several years (03 → 07) and WMAP then flying well before us, polarization measurements became more and more a major goal

Planck performance goals

("Blue Book", twice better than requirements)



PLANCK	LFI			HFI					
Center Freq (GHz)	30	44	70	100	143	217	353	545	857
Angular resolution (FWHM arcmin)	33	24	14	10	7.1	5.0	5.0	5	5
Sensitivity in I [μK.deg] [$\sigma_{pix}\ \Omega_{pix}^{1/2}$]	3.0	3.0	3.0	1.1	0,7	1.1	3.3	33	3.0

The leap forward w.r.t. WMAP

WMAP Center Freq.	23	33	41	61	94
Angular resolution (FWHM arcmin)	49	37	29	20	12,6
Sensitivity in I [μK.deg], 1 yr (8 yr)	12.6 (4.5)	12.9 (4.6)	13.3 (4.7)	15.6 (5.5)	15.0 (5.3)

The aggregated sensitivity of Planck core CMB channels is ~0.5μK.deg in T (nominal mission – 14months)

NB: Anticipated survey duration is now ~30 months, so final sensitivity ~0.33 μK.deg in T (approx 1000 years of WMAP 60+90GHz aggregated sensitivity of 10.8 μK.deg in1yr)

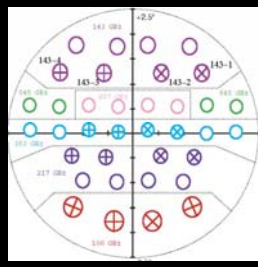
HFI cut-away

filters @ 1.6K

1.6K

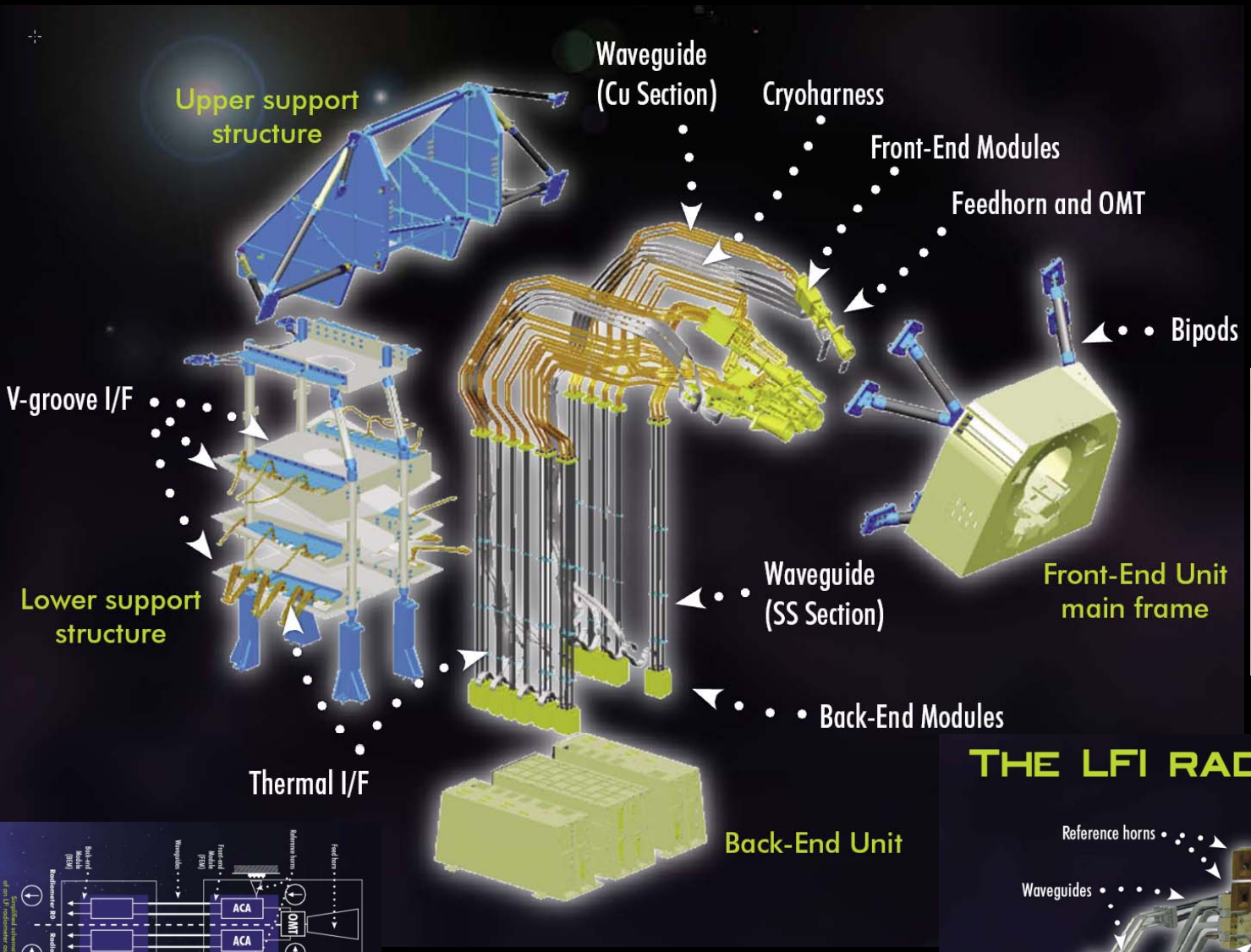
4 K

Bolometers @ 100mK

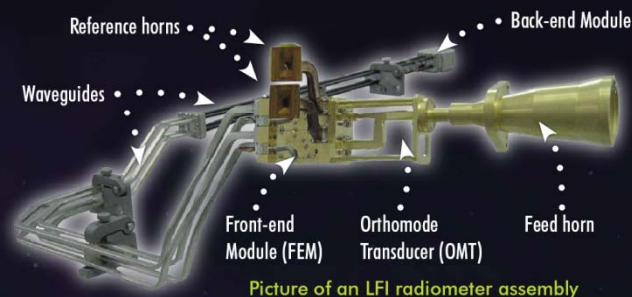


5° circle

The Low Frequency Instrument LFI



THE LFI RADIOMETER CHAIN



Picture of an LFI radiometer assembly

Birth of the Cool

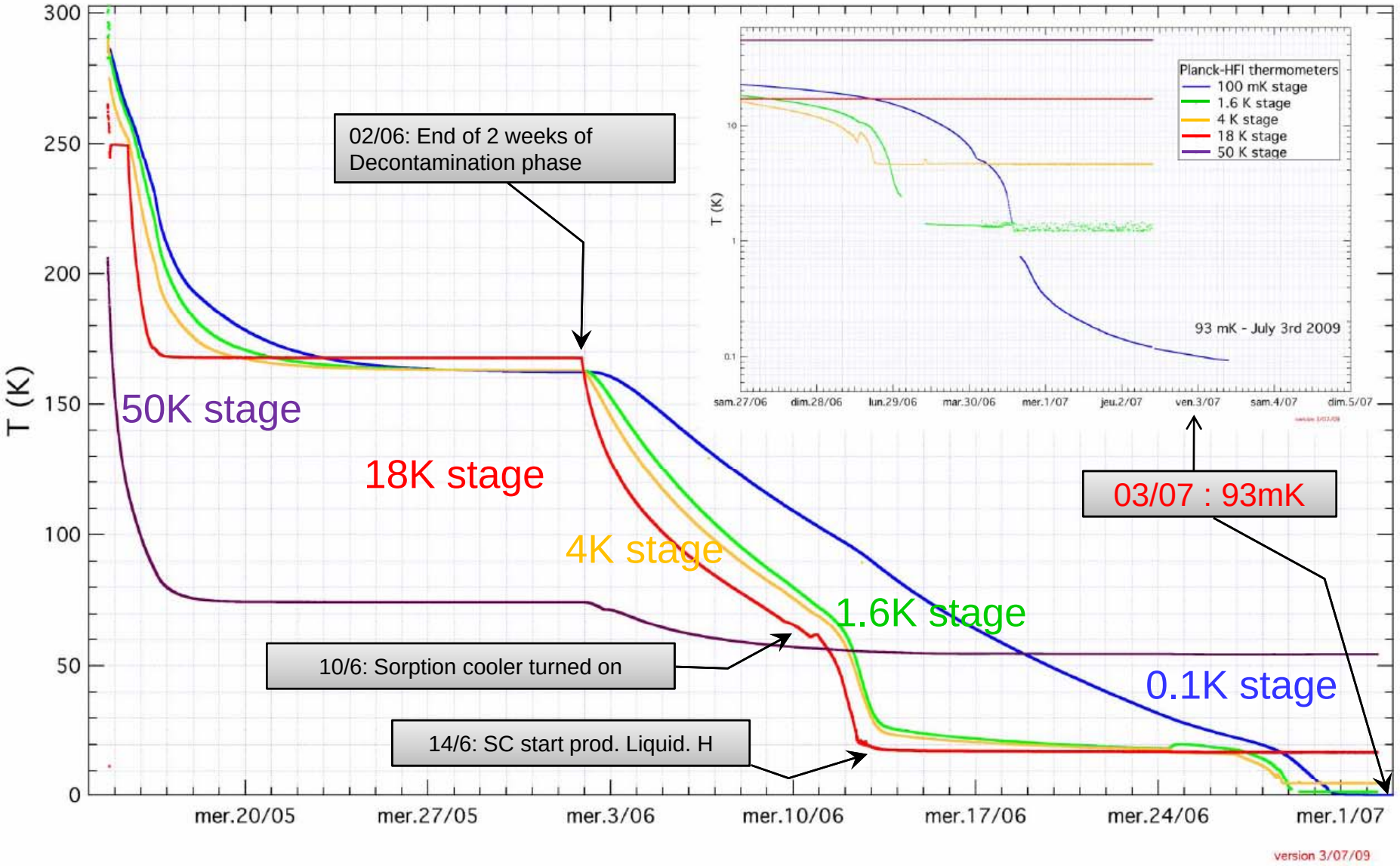

DUSTING IT OFF...
AFTER 16 YEARS
OF HOPES & WORK

Ariane 5 ECA Launch • HERSCHEL – PLANCK - *May 14, 2009*

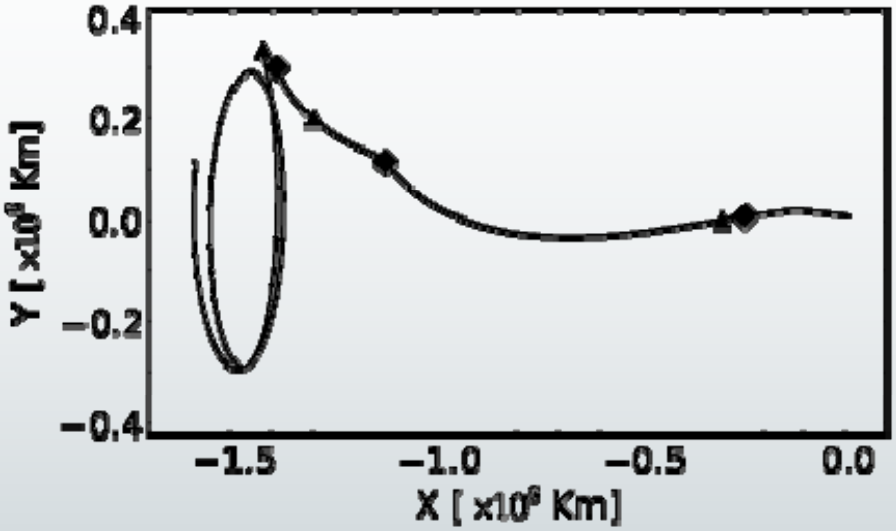
Tension subsides…

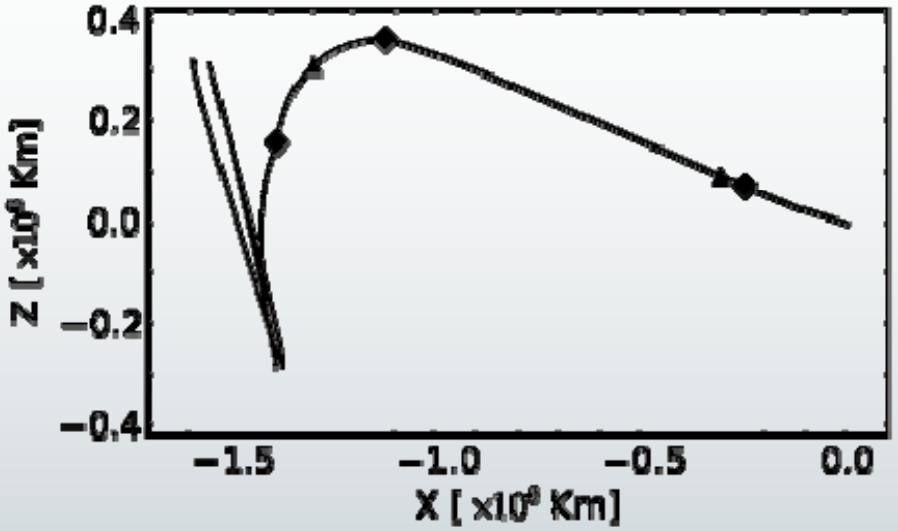
Picture by Ganga

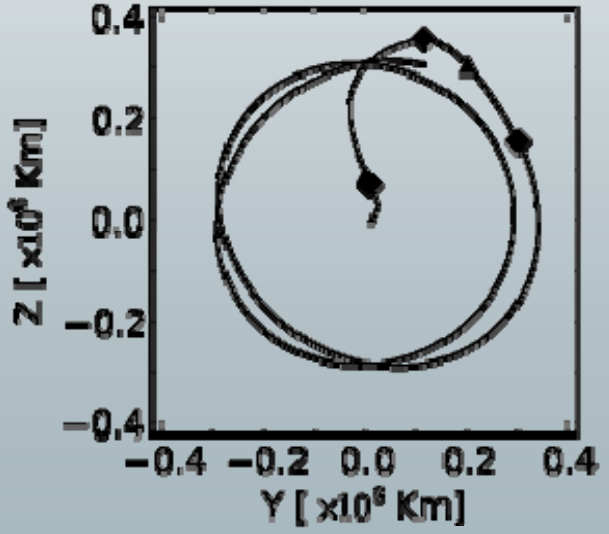
Planck is cool...

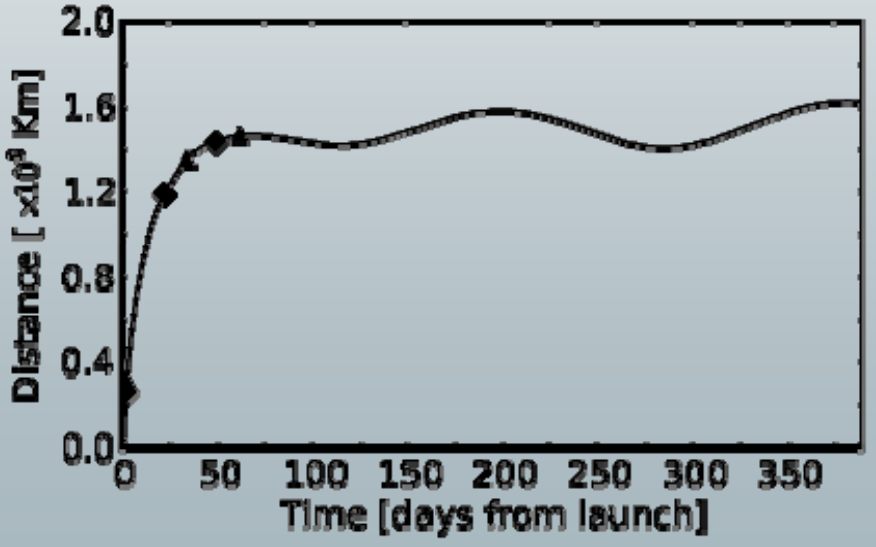


Trajectory of Planck from launch until 6 June 2010

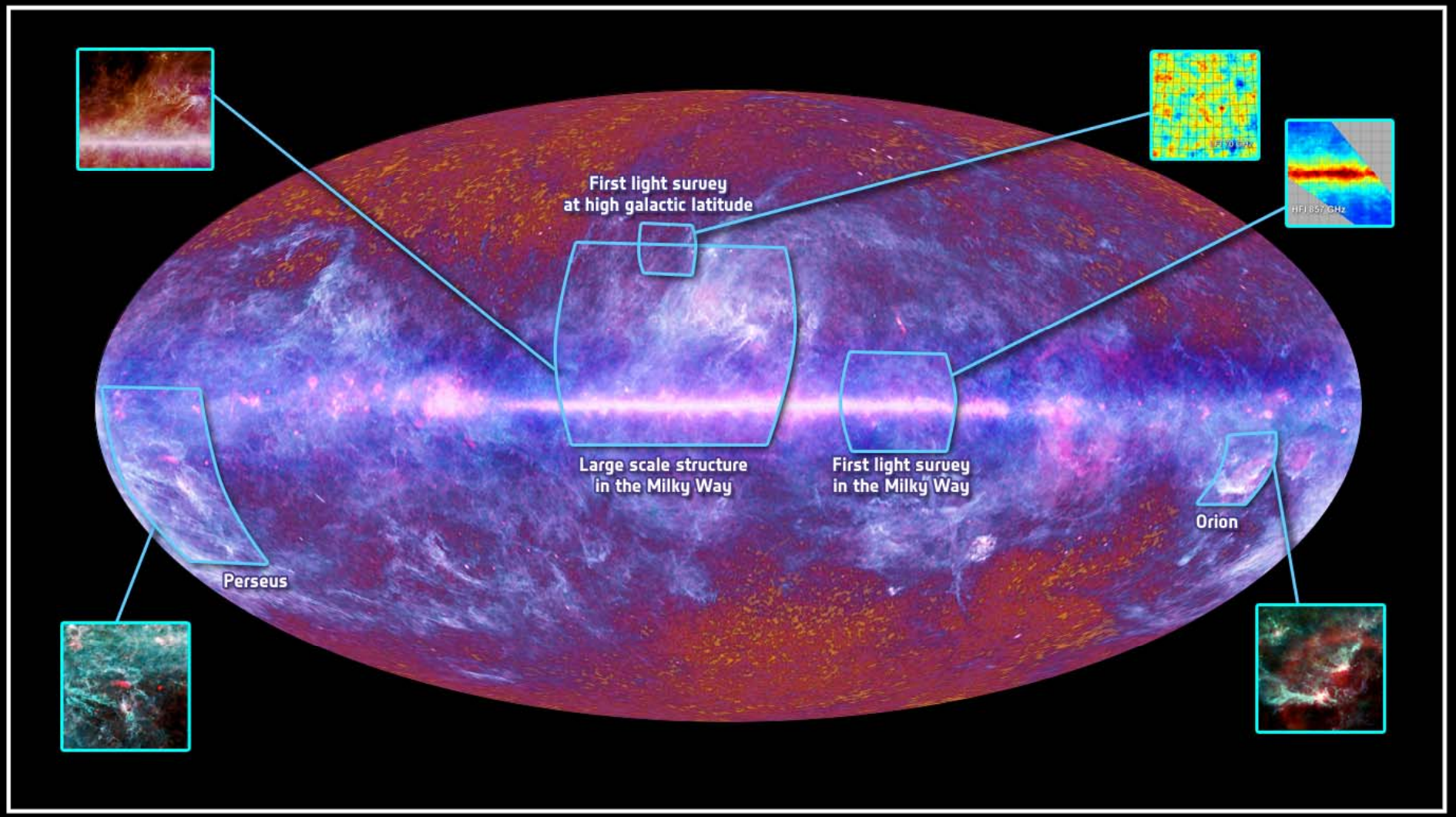








4th Press Release (05/07/2010)



The Planck``one-year"all-sky survey

esa

Overall

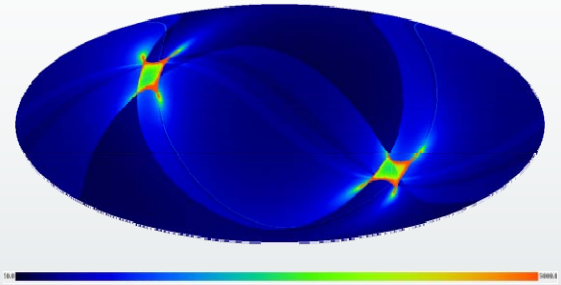
- Instrument is very stable, continuously mapping the sky, with essentially no hiccups from the beginning of the first light survey on the 13th August 2009, till today.
- Ground (high)expectations on sensitivities confirmed in flight, i.e.
  - *HFI reaches or exceeds its goals*
  - *LFI is close to its requirements*
- HFI: Surprise of Glitch rate!

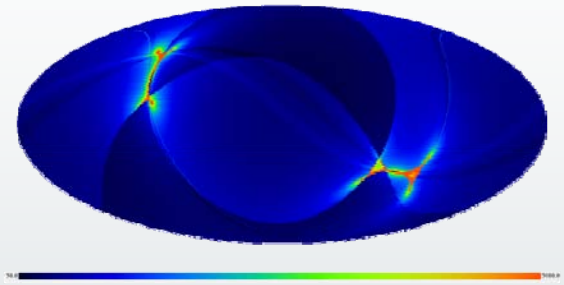
- The data acquired up to June 7th 2010, i.e. the nearly 10 months of survey data provide complete coverage of the sky by all detectors (by roughly 3 days more than the minimum duration needed),
  - *but only limited redundancy. Indeed the overlap between the two consecutive six-month surveys is only about 60%.*
  - *Our fourth data exchange, DX4, was released on July 17th 2010 to LFI DPC & ERCSC team, with a Data Release, DR2 (CMB-removed), to all Planck collaboration on August 2nd, while characterisation continued till shortly before early papers submission in Jan 2011, just before the ERCSC release & Planck Paris Conference.*

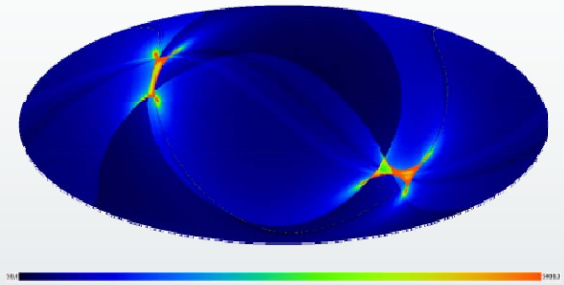
- The data acquired up to November 27th 2010, i.e. about 15.5 months of survey data (the nominal mission) insure that all the sky at been seen at least twice by each detector
  - *Our sixth data exchange, DX6, was released on march 1st 2011 to LFI DPC (T only), to help prepare DR3, and DX7 has just been released, on June 16th 2011, with DR3 due just after the MCR.*
  - *Indeed the MCR is conveniently happening right in the middle of DR3 production.*
  - *DR3 will contain the first production of the regular catalogues (ie not ERCSC, CPAC&Trieste rather than IPAC)*
  - *DX7 /DR3 data is the basis for all intermediate papers to come (mostly in early 2012), with a detailed data characterization ongoing in parallel till then (as previously for DX4).*

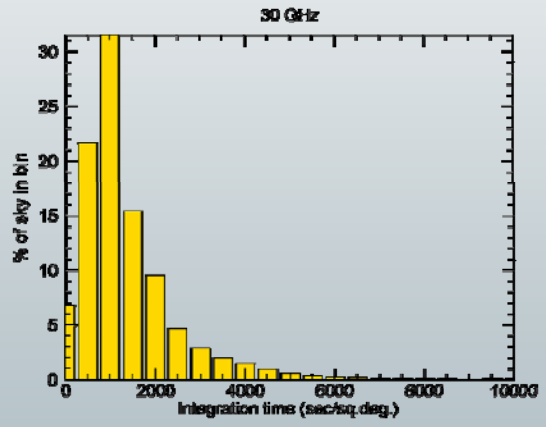
- There will be two more takes (DX8 and DX9) on the nominal mission duration before public delivery
  - *NB: Foreground polarization analyses are being considered for intermediate papers, but may have to be based on DX9 (no DPC paper planned for characterizing DX8)*

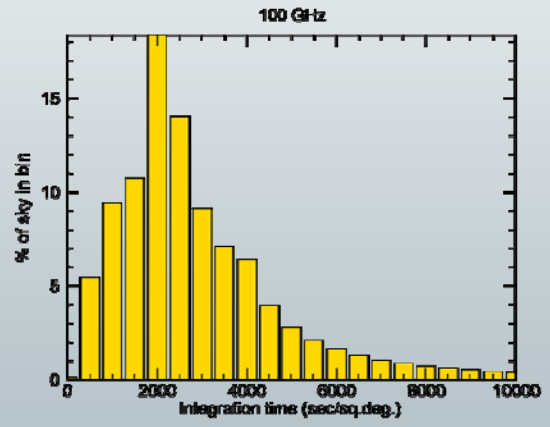
Cumulated integration time

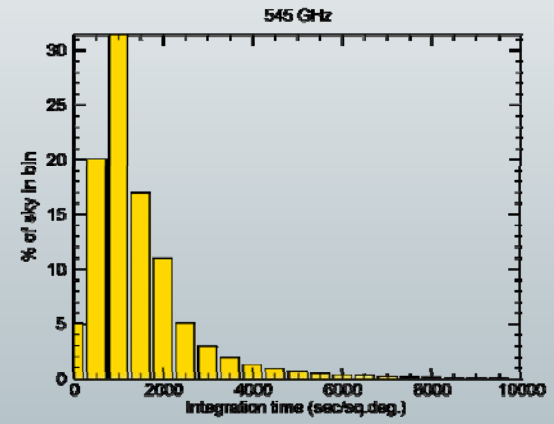












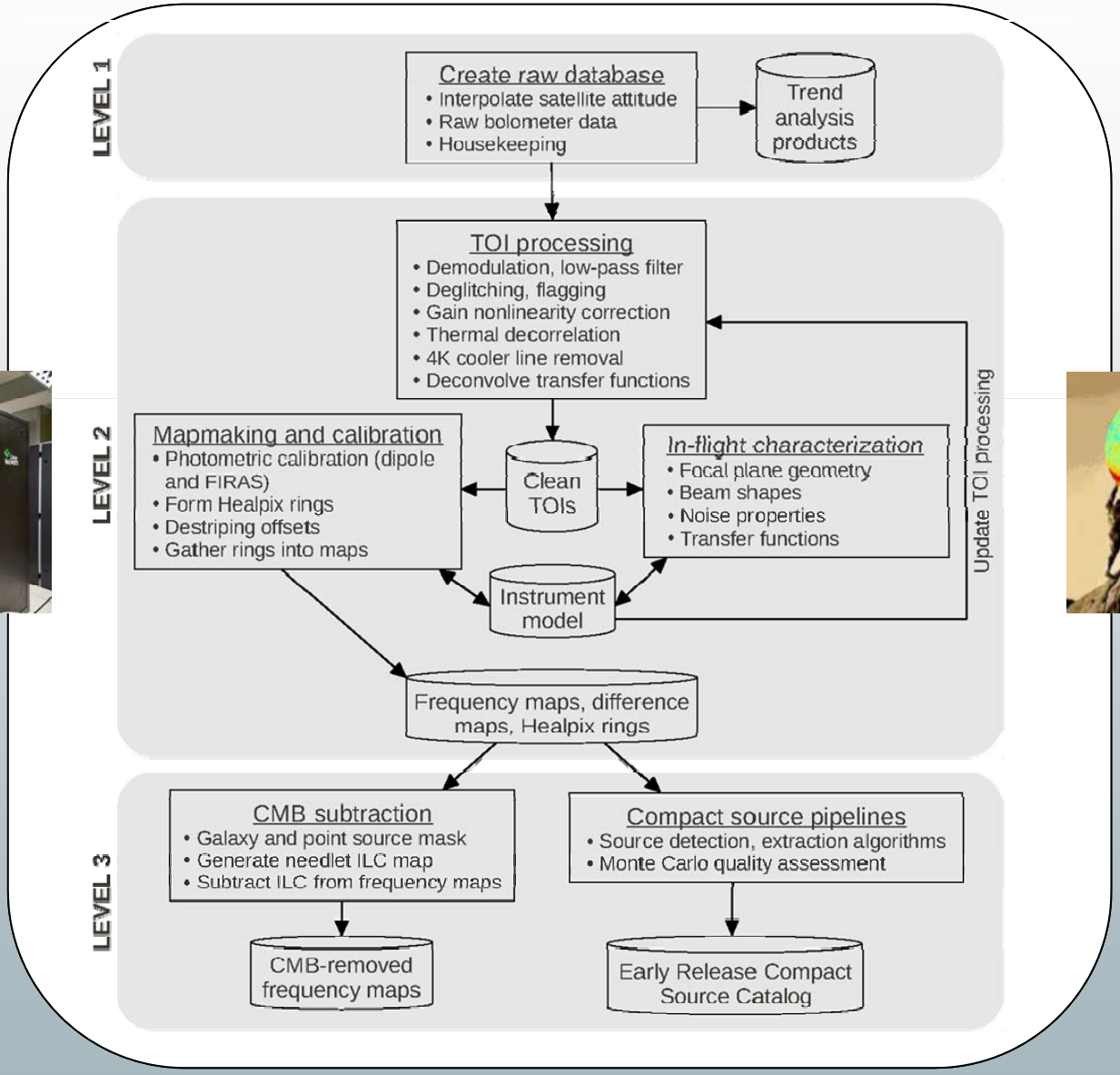
	30 GHz	100 GHz	545 GHz	
Mean[a]	2293	4575	2278	sec deg^2
Minimum	440	801	375	sec deg^2
< half Mean[b]	14.4	14.6	15.2	%
> 4× Mean[c]	1.6	1.5	1.2	%
> 9× Mean[d]	0.41	0.42	0.41	%

Nside=1024

HFI Data Processing Centre flow

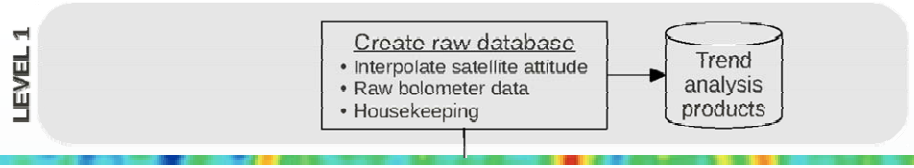
IAP cellar

Sisyphus



Internal communication

- Within HFI, apart from face to face meetings, the central tool is the HFI wiki, which we started in 2007-10-16.
- Since then the number of entries has been about
  - *19 in 2007,*
  - *92 in 2008,*
  - *431 in 2009,*
  - *467 in 2010*
  - *187 en 2011…*
- We also started an HFI/LFI wiki for common analyses (Component separation, etc) in December 2009, at the time of the DX0 data exchange



- **L1** received 4 x10^8 telemetry packets during the first 295 days of survey (till june 2010, i.e. basis for early papers):
  - *29%, 6% and 4% for the housekeeping of respectively the satellite, the Sorption Cooler System and HFI (25 425 HK pars followed out of 63 100) and*
  - *61% for HFI science data. Only 20 packets lost from L2.*
  - *NB: LFI data volume is about 1/10^{th} of HFI data volume*
- 4.7 x 10^9 / 7.4 x 10^9 / 10.6 x 10^9 time samples for 72 detectors, i.e. 334 x 10^9 / 531 x 10^9 / 761 x 10^9 detector samples from, respectively, the first 295 days of survey/ the nominal mission /as of today (ie a TOI = 45GB, all raw=3.3TB, processed=21TB)
- Decompress, QLA and update/append Time Ordered Information objects (TOIs) in reference database.
- Attitude History File of the Satellite quaternion pointings at 8Hz linearly interpolated daily at Time-of-Sample of the bolometers and stored for later On-the-fly generation of any pointing using the Focal Plane Geometry.

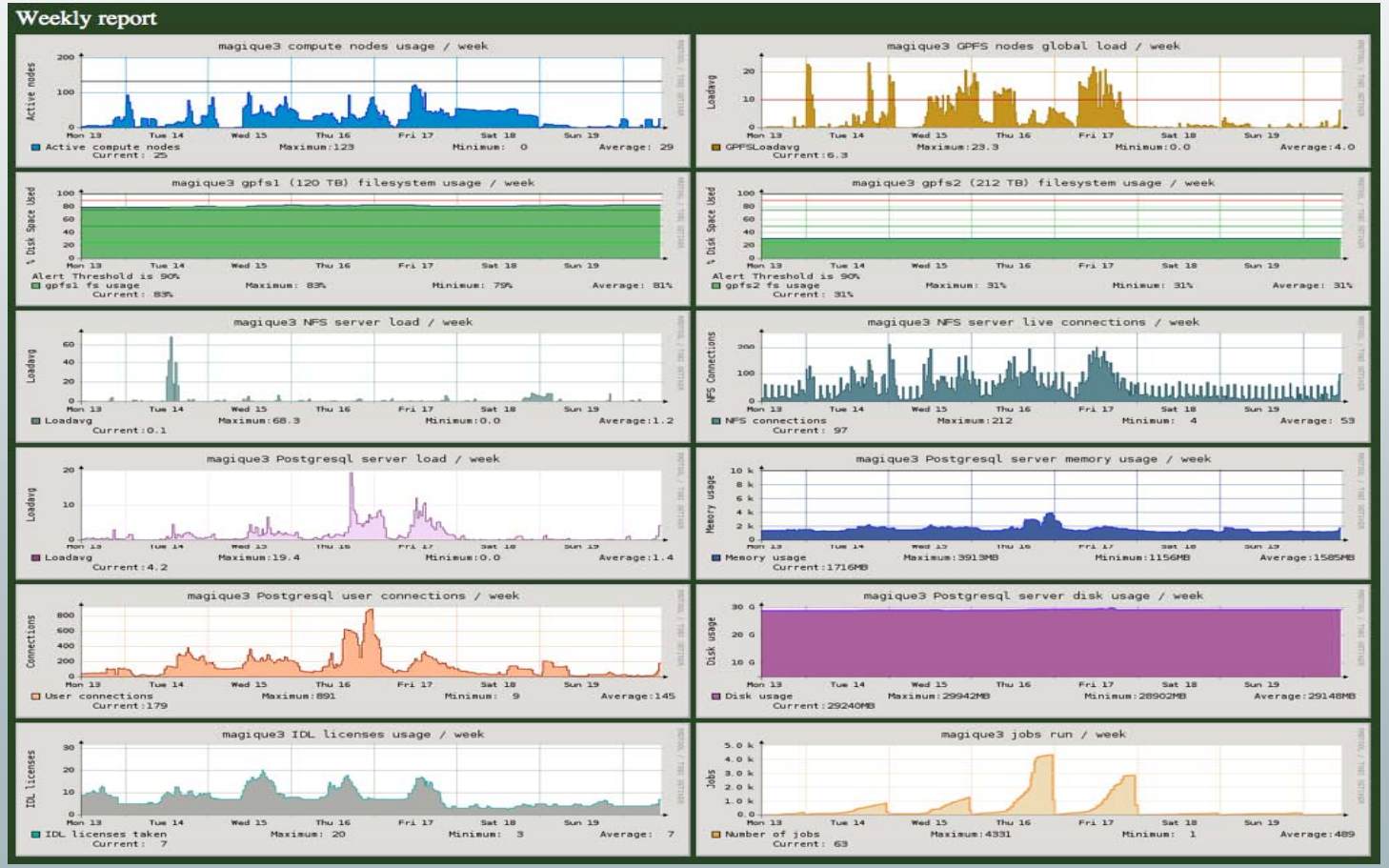
Processing times (1 pass, mission to date)

- TOI processing: ~ 5 days
  - *Demodulation, deglitching, gain correction, 4K cooler line removal, time-constant deconvolution, flagging, etc.*
- FPG reconstruction: ~ 1 day
  - *Based on Mars 1st passage; quaternions written to IMO*
- Detector noise estimation: ~ 2 days
  - *NEPs written to IMO*
- Mapmaking and flux calibration: ~ 3 days
  - *Calib factors (fixed ones) written to IMO*
- Component separation … human intensive
- Power spectrum estimation ... human intensive
- Information transfer & coordination… human intensive

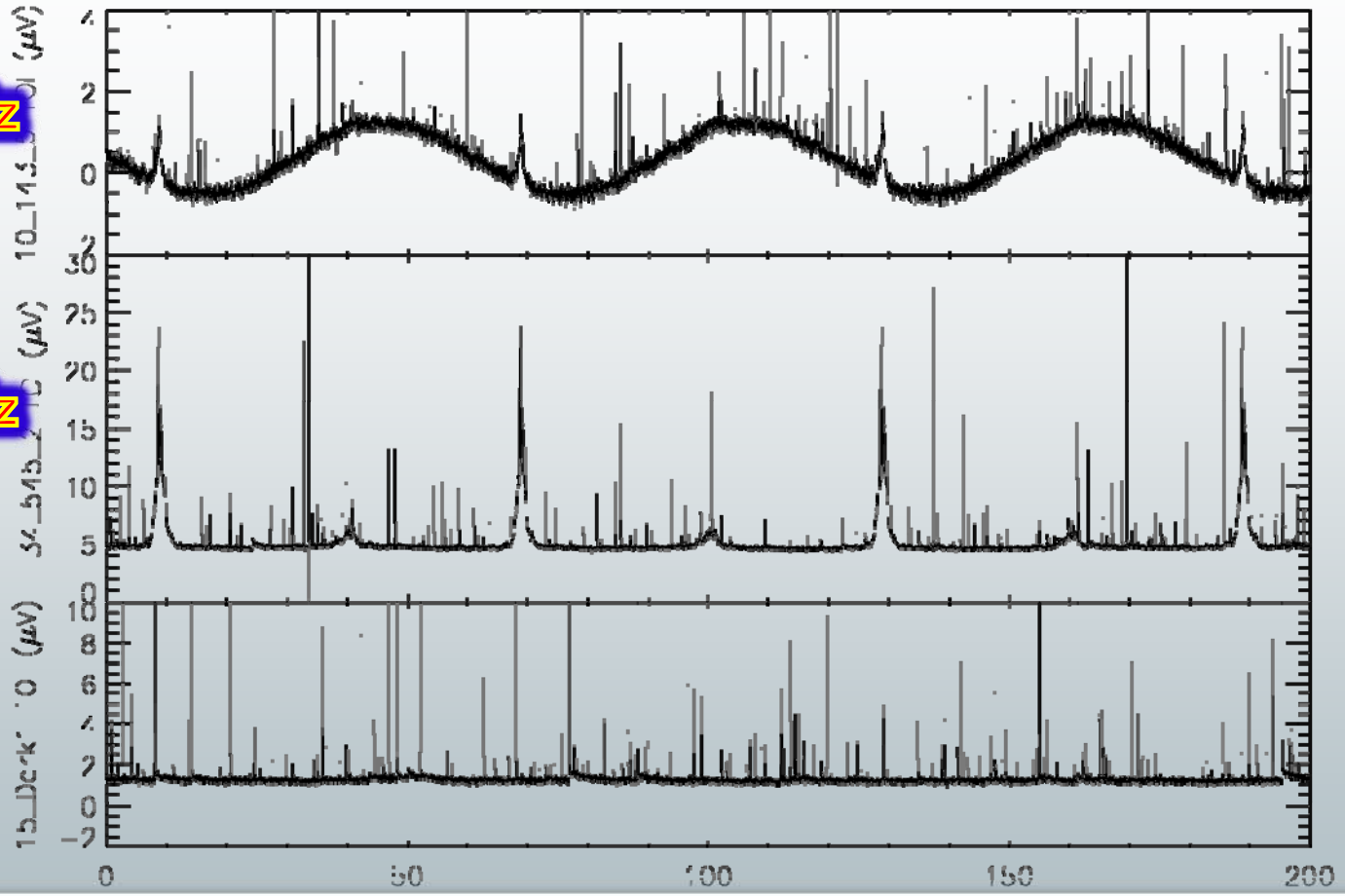
- NB. Non-human limiting factors (TOIproc, detnoise, HPR): are data I/Os

Hardware; Current main is Magique-3

- 8 login nodes, 132 compute nodes, 8 service nodes
  - *Nodes have 2 quad-core processors, 32 GB RAM, 0.8 TB local disk*
- Fast filesystem (/data): size 117 TB, ~80 TB used
- Slow filesystem(/space): size 204 TB, ~32 TB used
- Main bottleneck are I/Os and storage



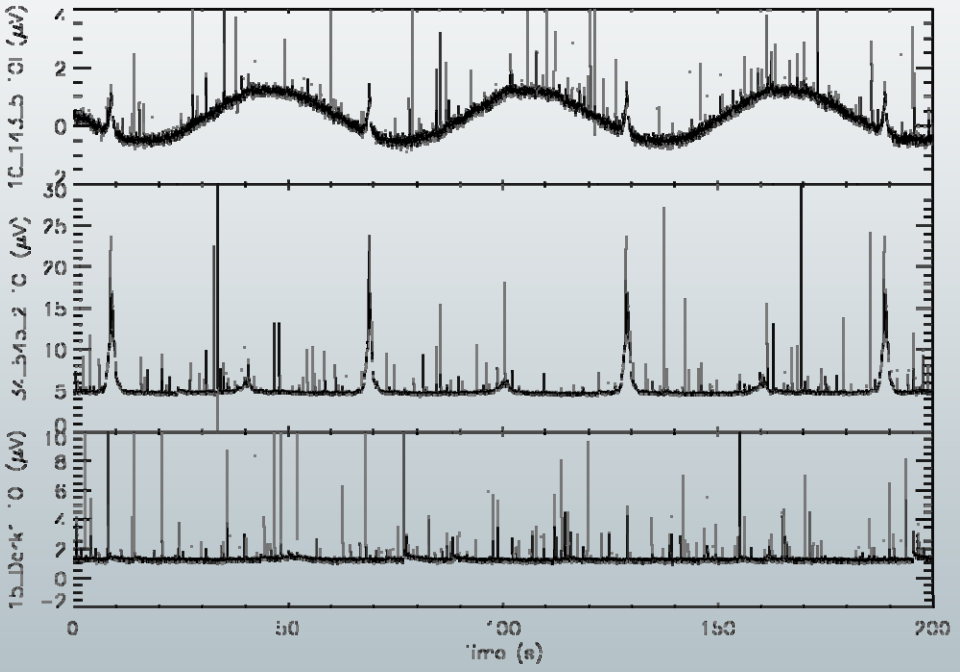
HFI Raw Detector TOI (Time Ordered Information)

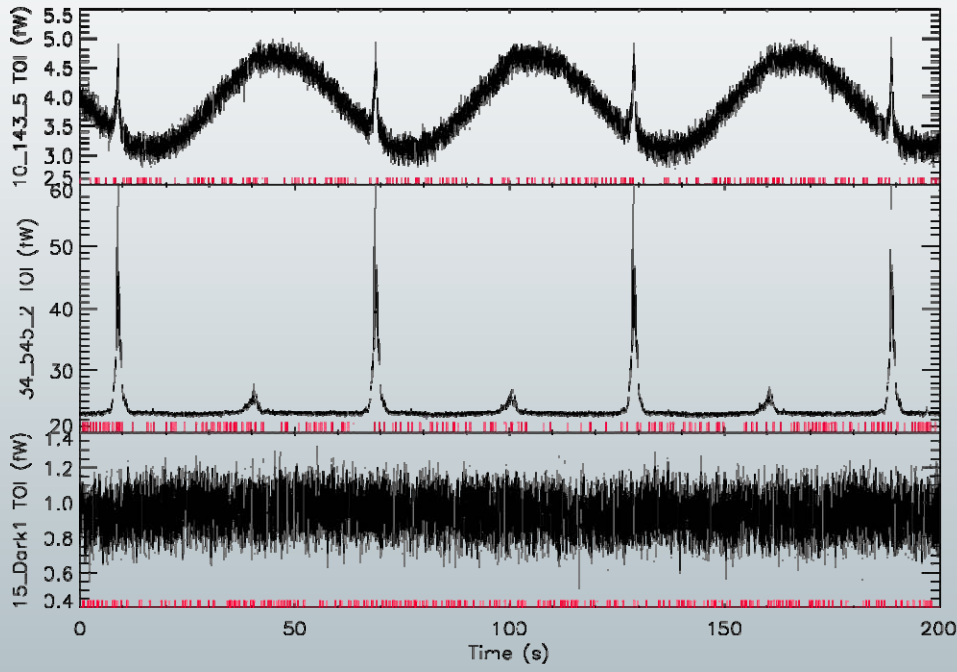


3 minutes of quasi ‘raw” data (i.e. only demodulated).The Solar (cosmological) dipole is clearly visible at 145GHz with a 60 seconds period (the satellite rotates at 1 rpm), while the Galactic plane crossings (2 per rotation) are more visible at 545 GHz than at 143 GHz. The Dark bolometer sees no sky signal, but displays a similar population of glitches from cosmic rays.

“Turning the crank”, et voila!

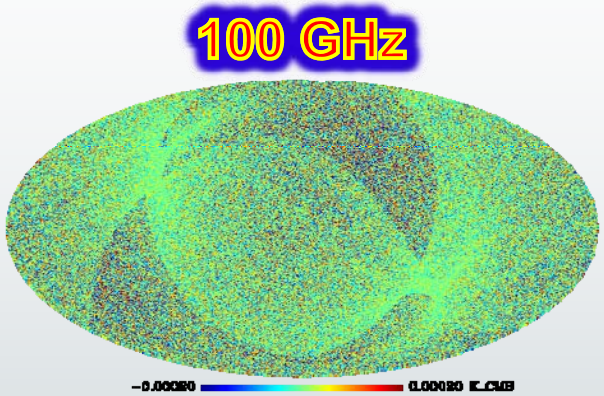
(skipping 12 slides summarising HFI TOI processing...)
(Deglitching, T decorrelation, nonlinearity corrections, 4Klines, TF deconvolution, RTS)

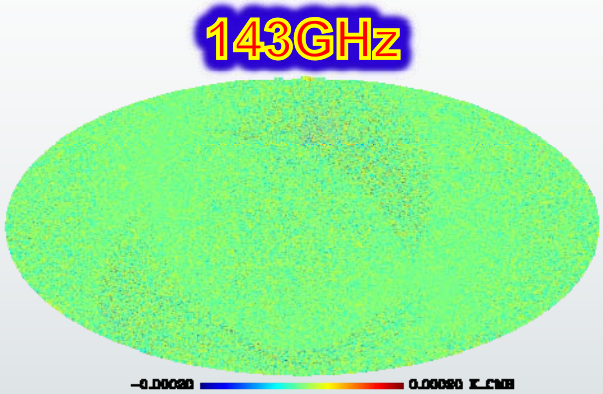


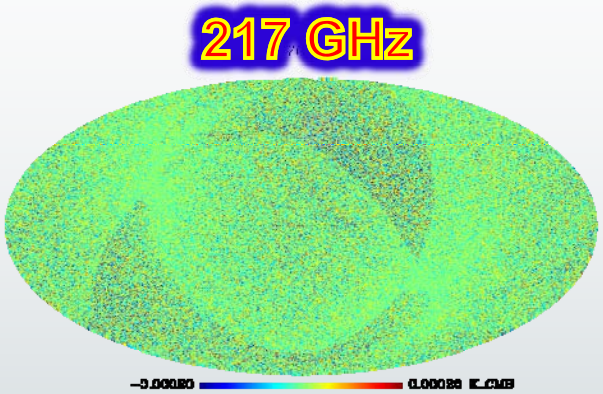


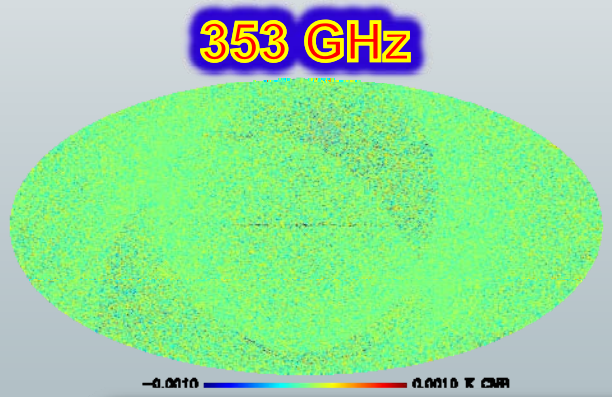
From μV to femto-Watts

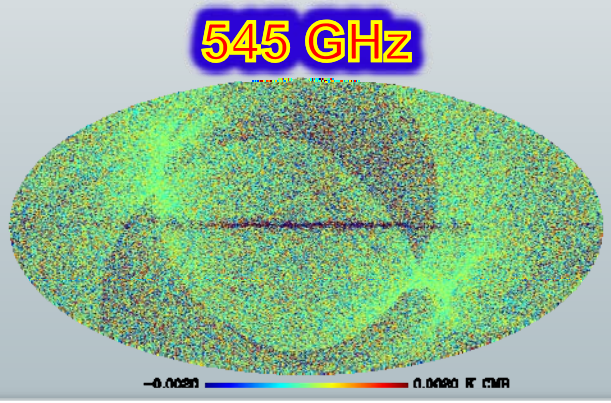
½ difference maps

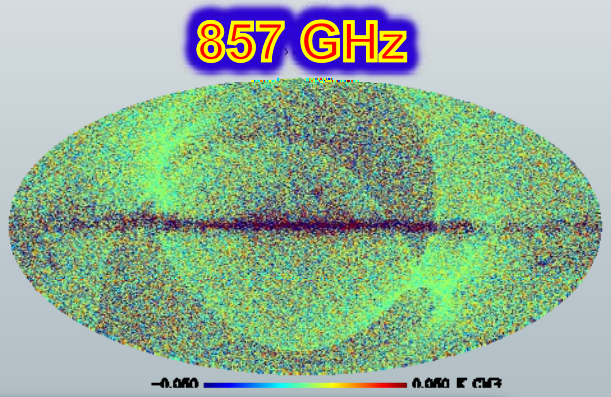






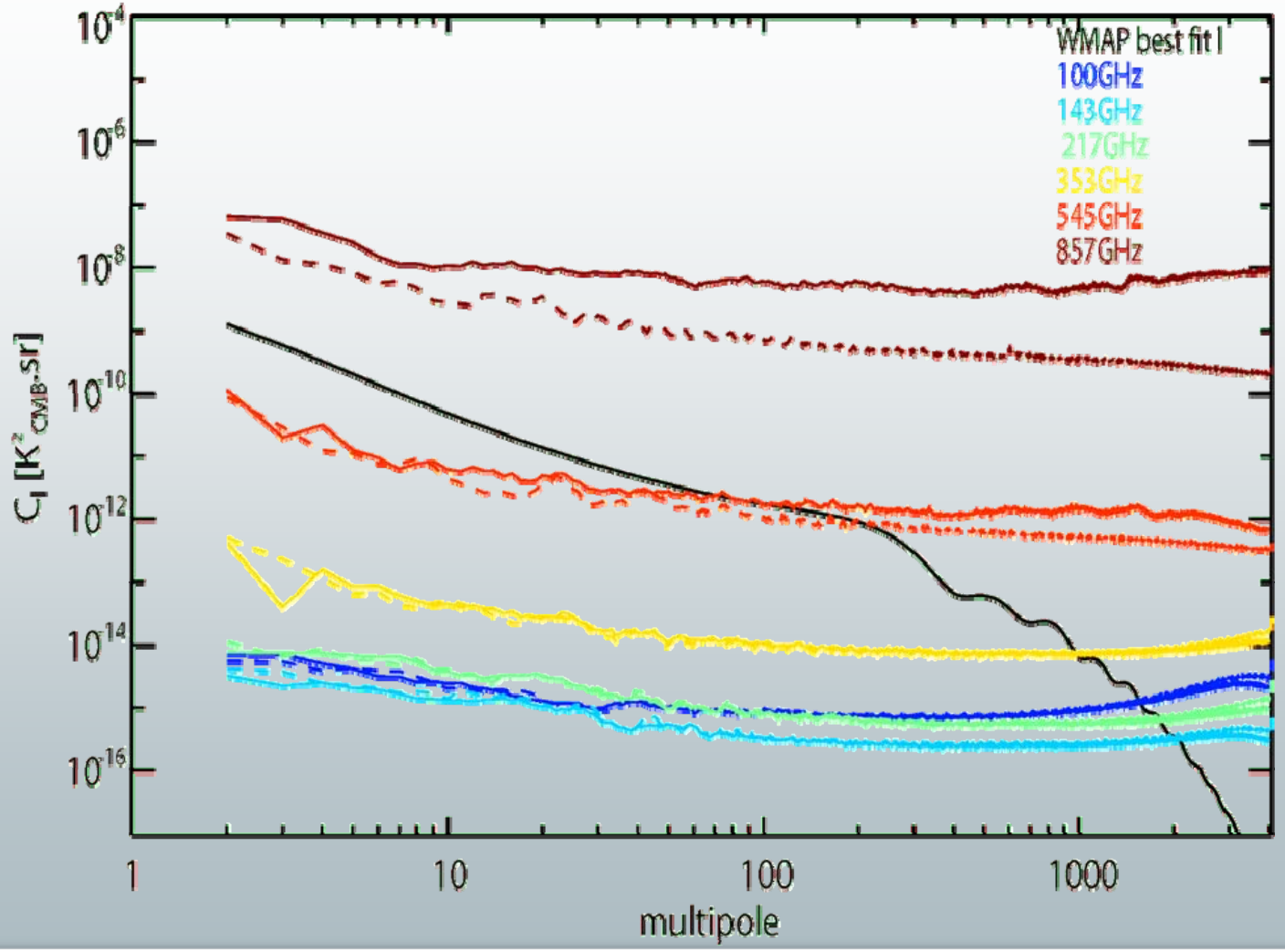






One can build 2 maps at each frequency out of the first or the second half of the data acquired during each stable pointing period of ~40mn.
In forming half difference maps, slowly varying effect on 20mn timescale are subtracted. But it does provide a good view of the high frequency residuals.

½ difference maps spectra



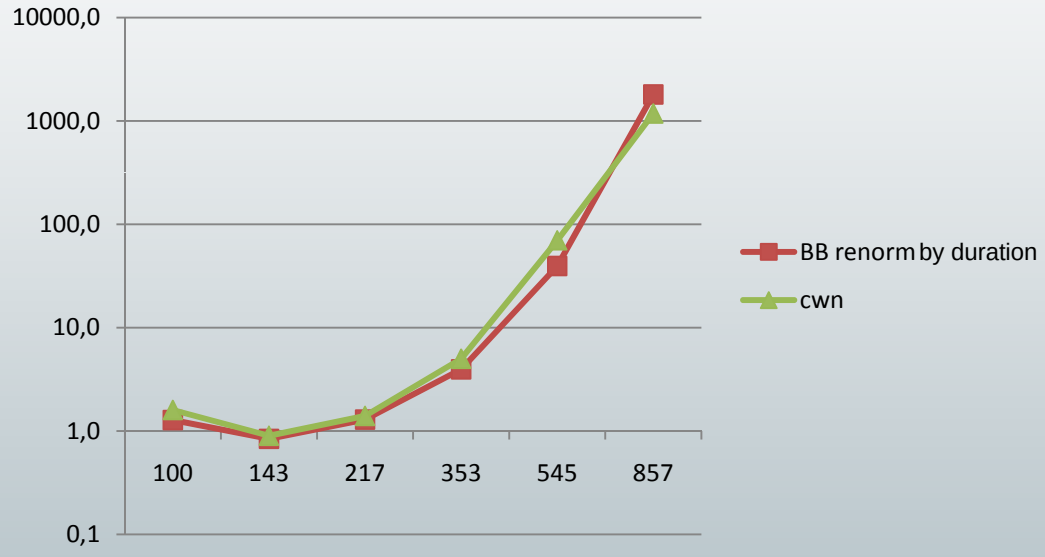
300

143GHz

The C(l) of the ½ difference maps offer a synthetic view on the map residuals, at least at small scales. Dashes are for a 40% masked sky. c_{WN} is computed from the mean level between l=100 and l=1000

C_{wn} versus BB values

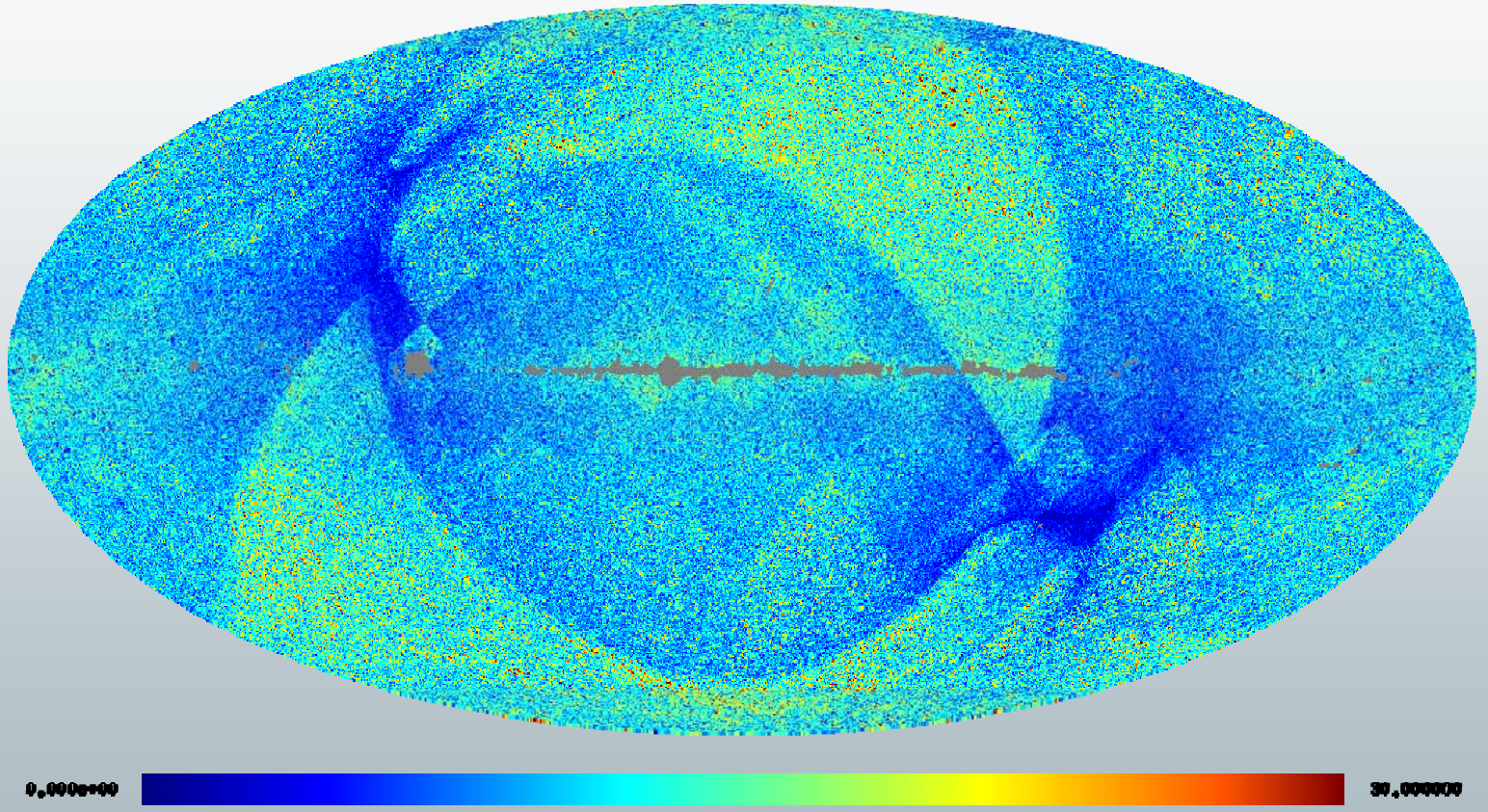
[μK degree]



The combination of residual excess low frequency noise and better than the goals NETs leads to current maps whose high frequency noise is rather close to goal values ☺

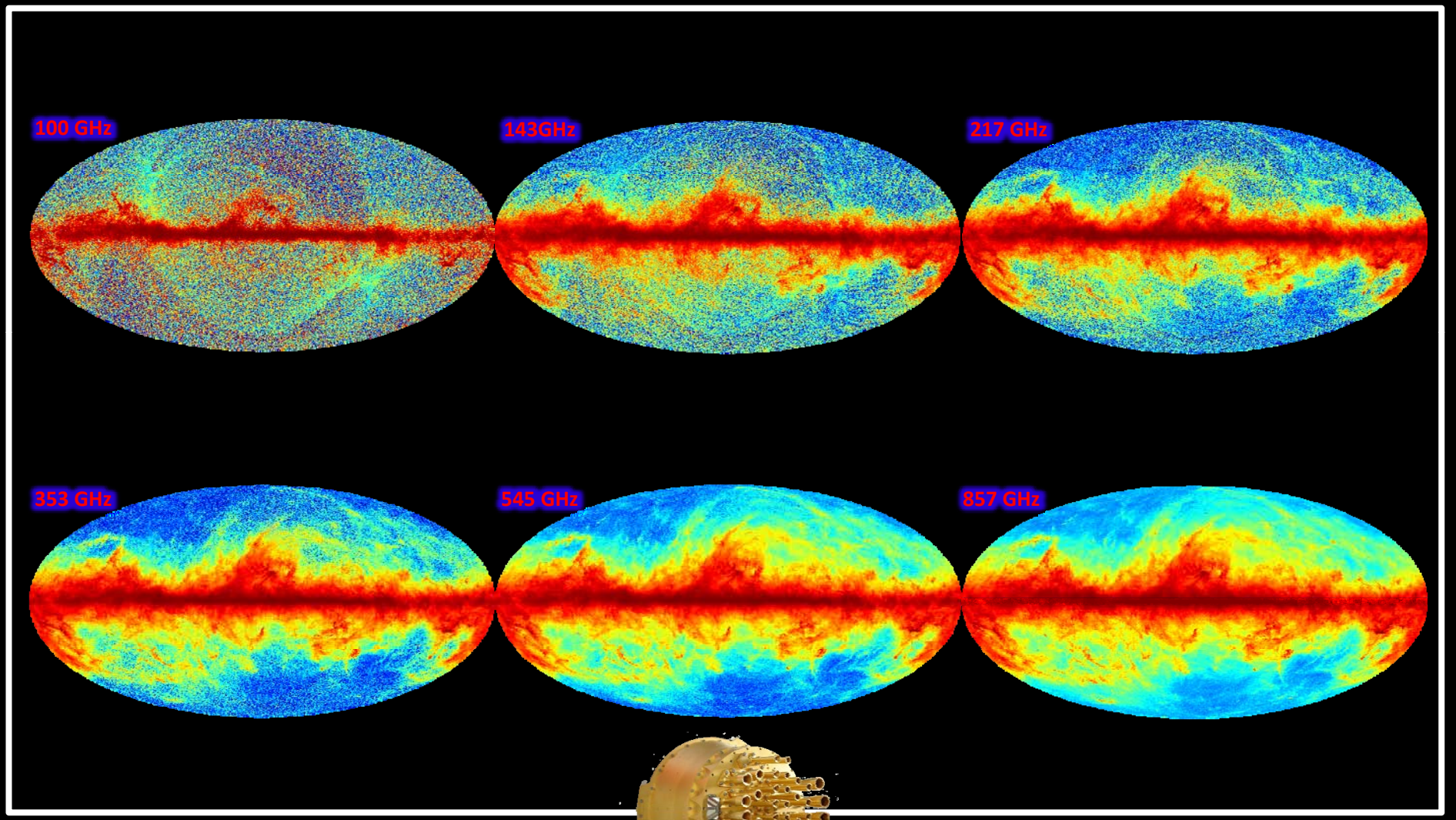
CMB removal (DX4→ DR2)

In common with LFI, we compared 6 methods and picked a Needlet based ILC, masking very little of the data.

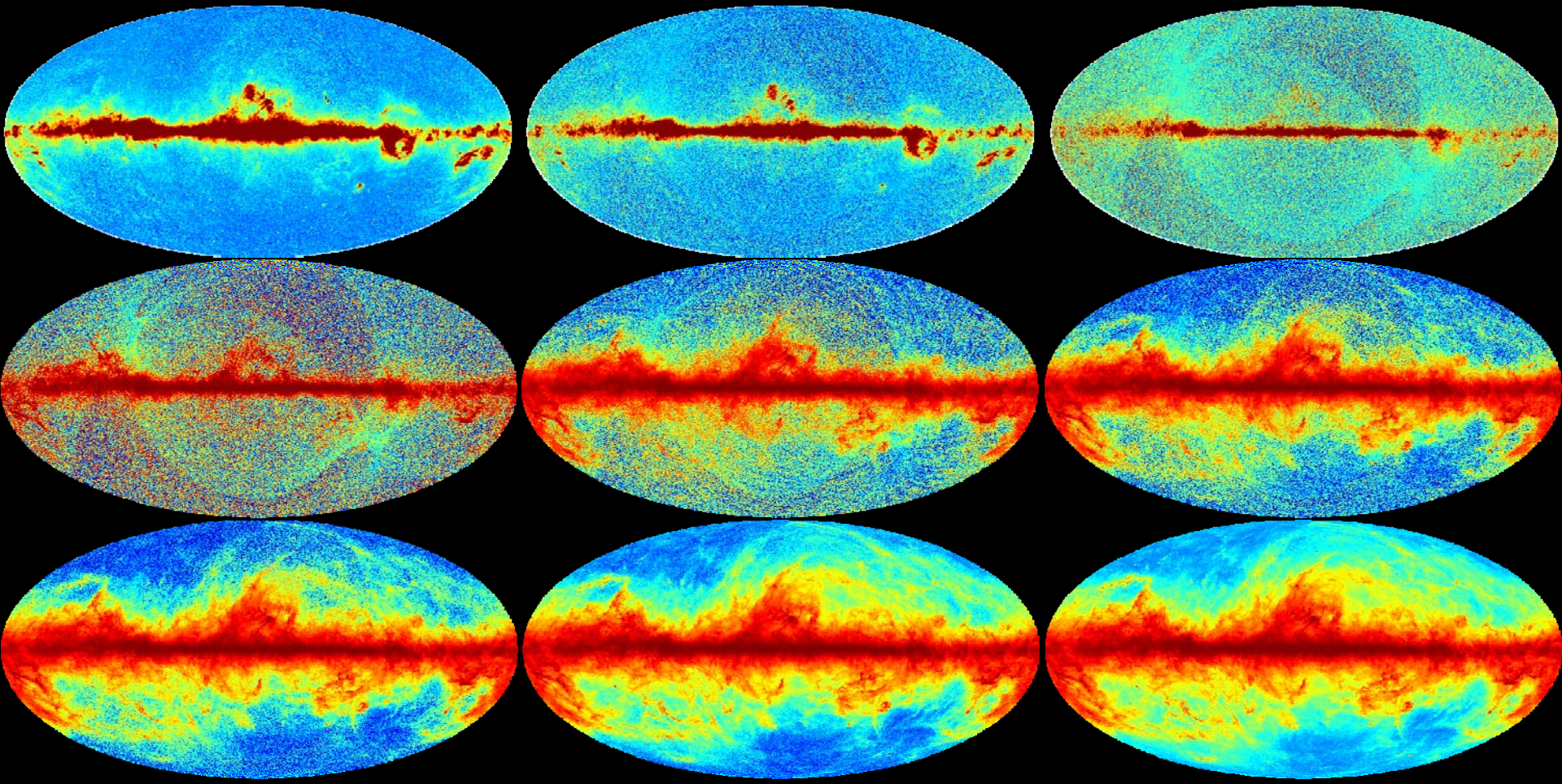


The same operations performed on the channel maps were performed on the ½ difference maps, offering a view on the residual in the CMB template removed from the maps (σ=11μK).

The HFI foregrounds sky



The Planck Foregrounds sky

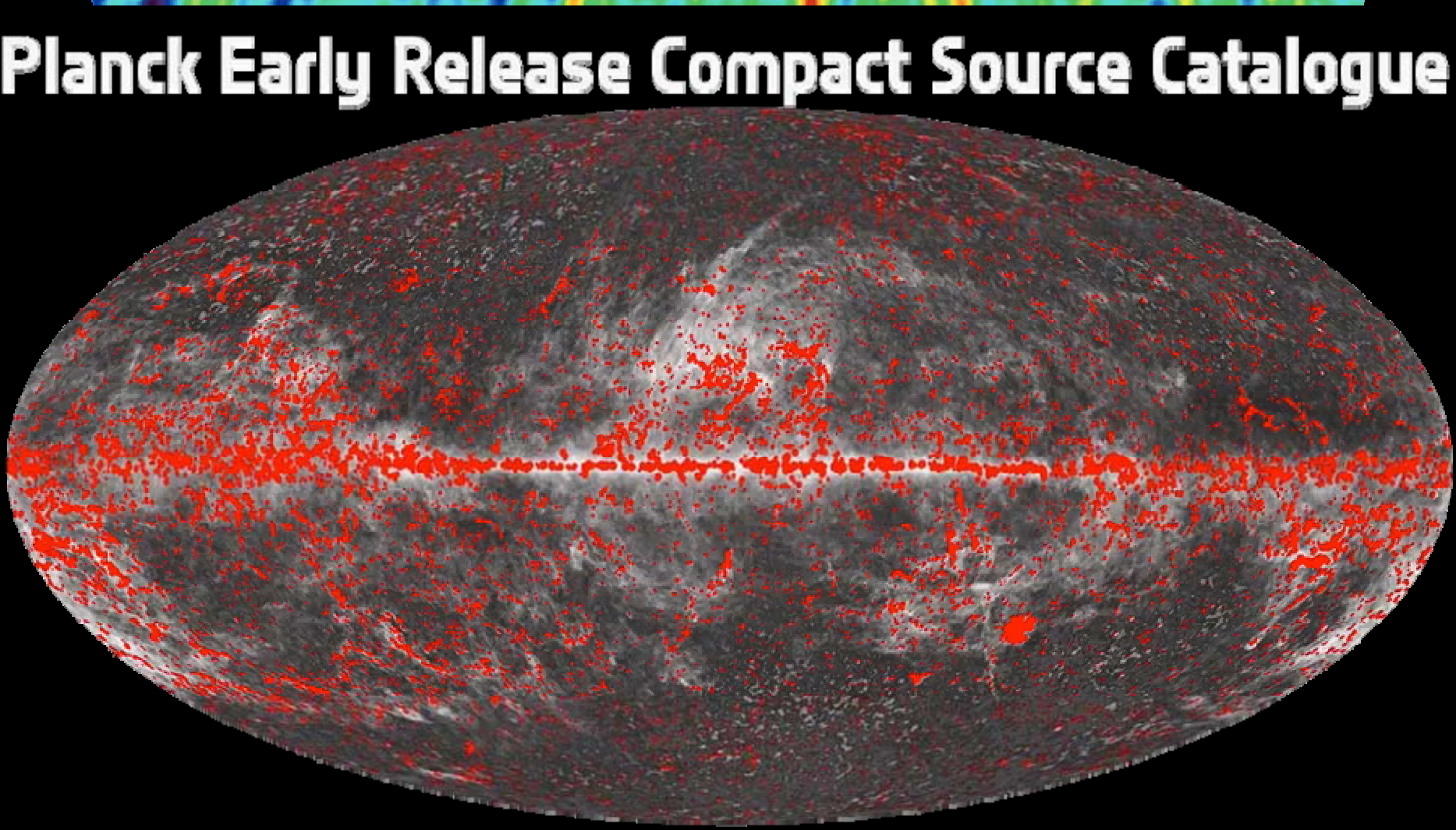


THE ERCSC/ECC/ESZ delivery

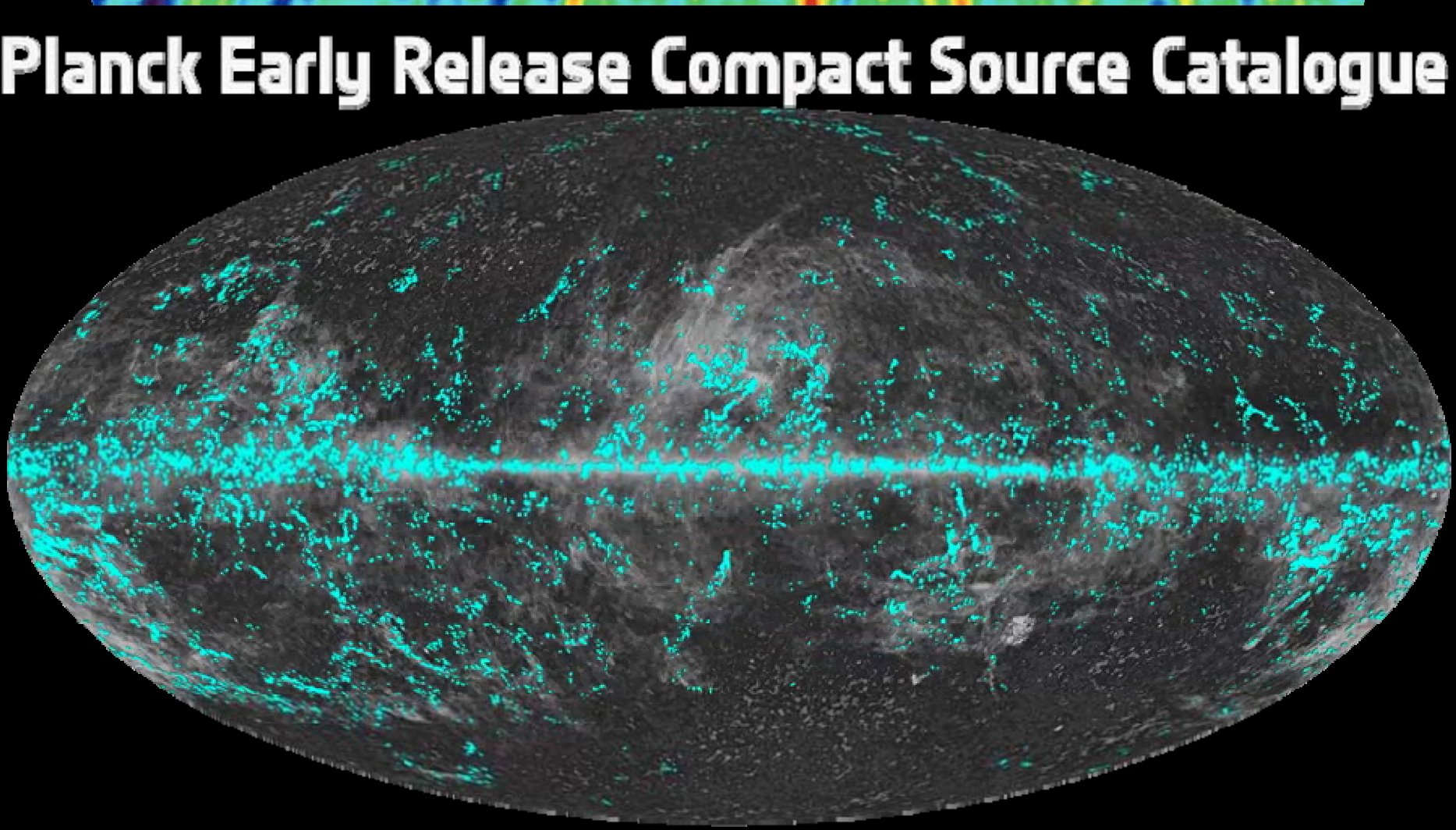
- The Early Release Compact Source Catalog (ERCSC) is an early, >90% reliability catalog based on 1.6 sky coverages
- Produced and released with a rapid turnaround (<9 months)
- Consists of 9 single frequency catalogs as well as band-filled 217-857 GHz entries for each 857 GHz source
- Includes the Early Cold Cores (ECC) and Early SZ-cluster (ESZ) catalogs
- More than 15 000 unique sources including stars with dust shells, cold molecular cloud cores, radio galaxies, blazars, infrared luminous galaxies, Galactic ISM features, SZ clusters
  - *Beware of CO contamination for Galactic sources at 100 GHz*
- Available from ESA Planck Legacy Archive and NASA's Infrared Science Archive (IRSA) starting Jan 11, 2011
- Interesting astrophysics is evident in the ERCSC
- Suitable for follow-up with Herschel, SOFIA, ALMA, VLA etc.

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

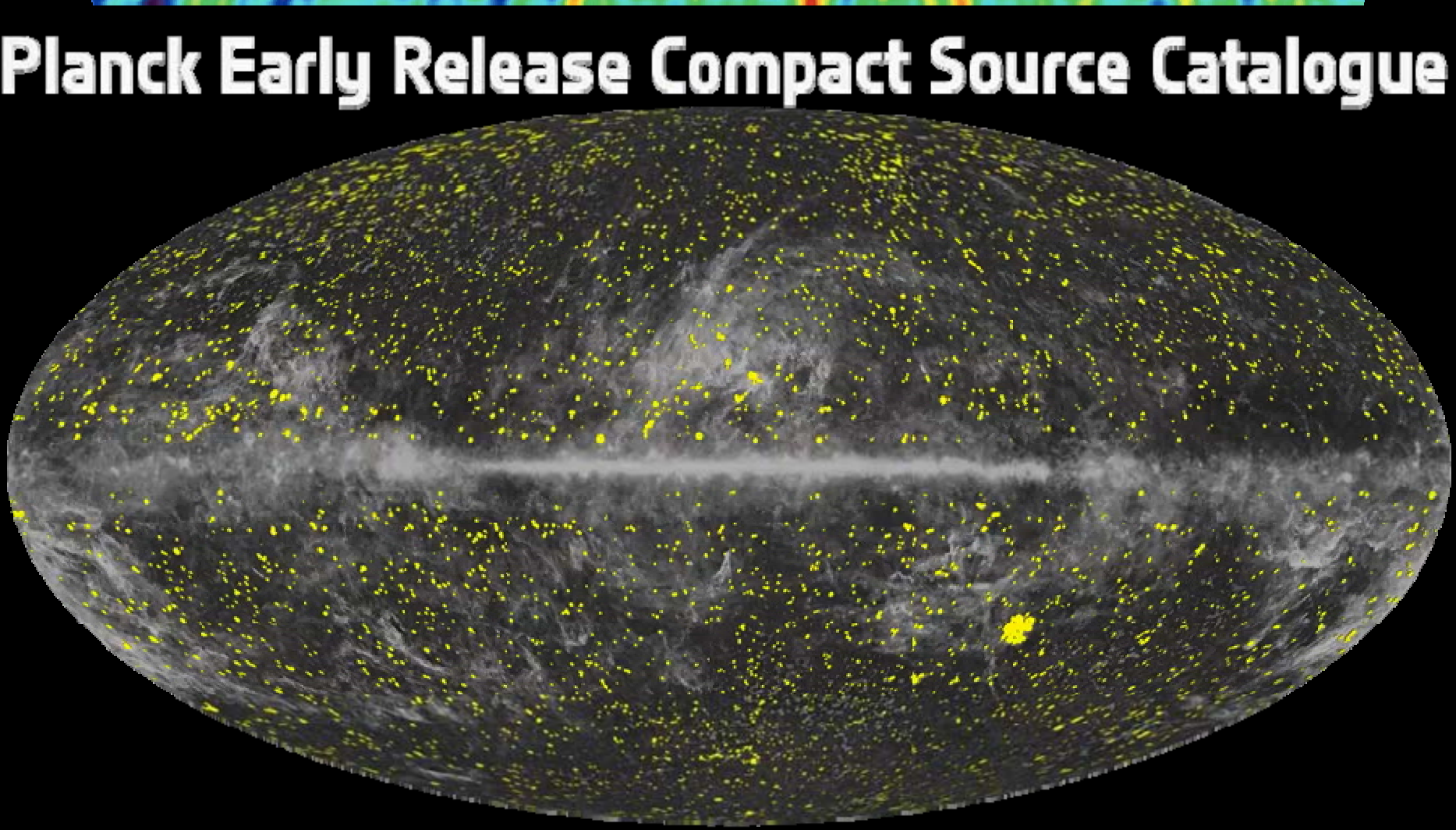
The Planck Foregrounds sky



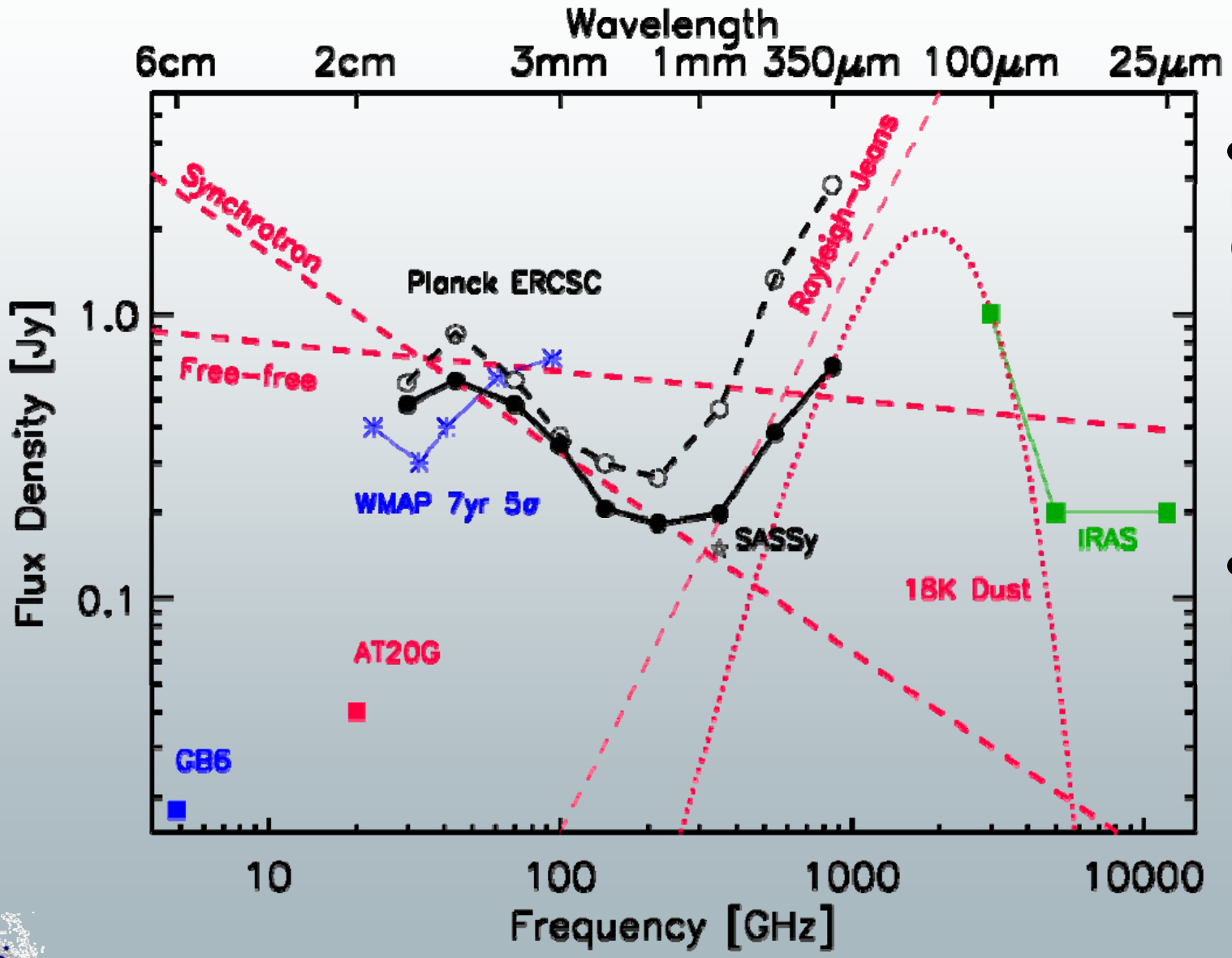
The Planck Foregrounds sky



The Planck Foregrounds sky



ERCSC sensitivity

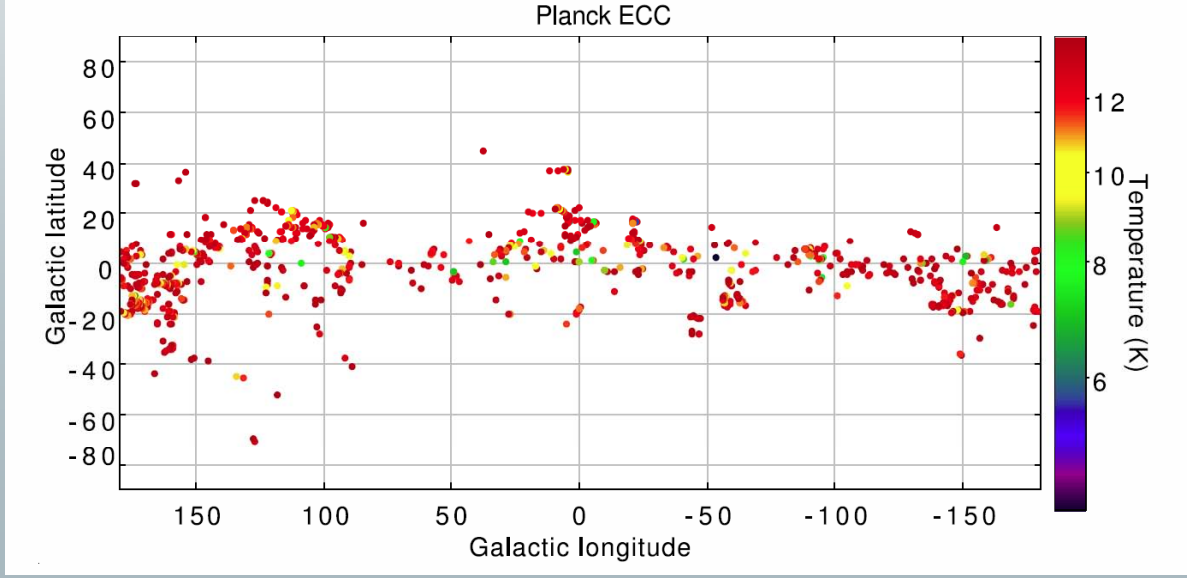


Planck Galactic Plane, i.e. |b|<10 deg

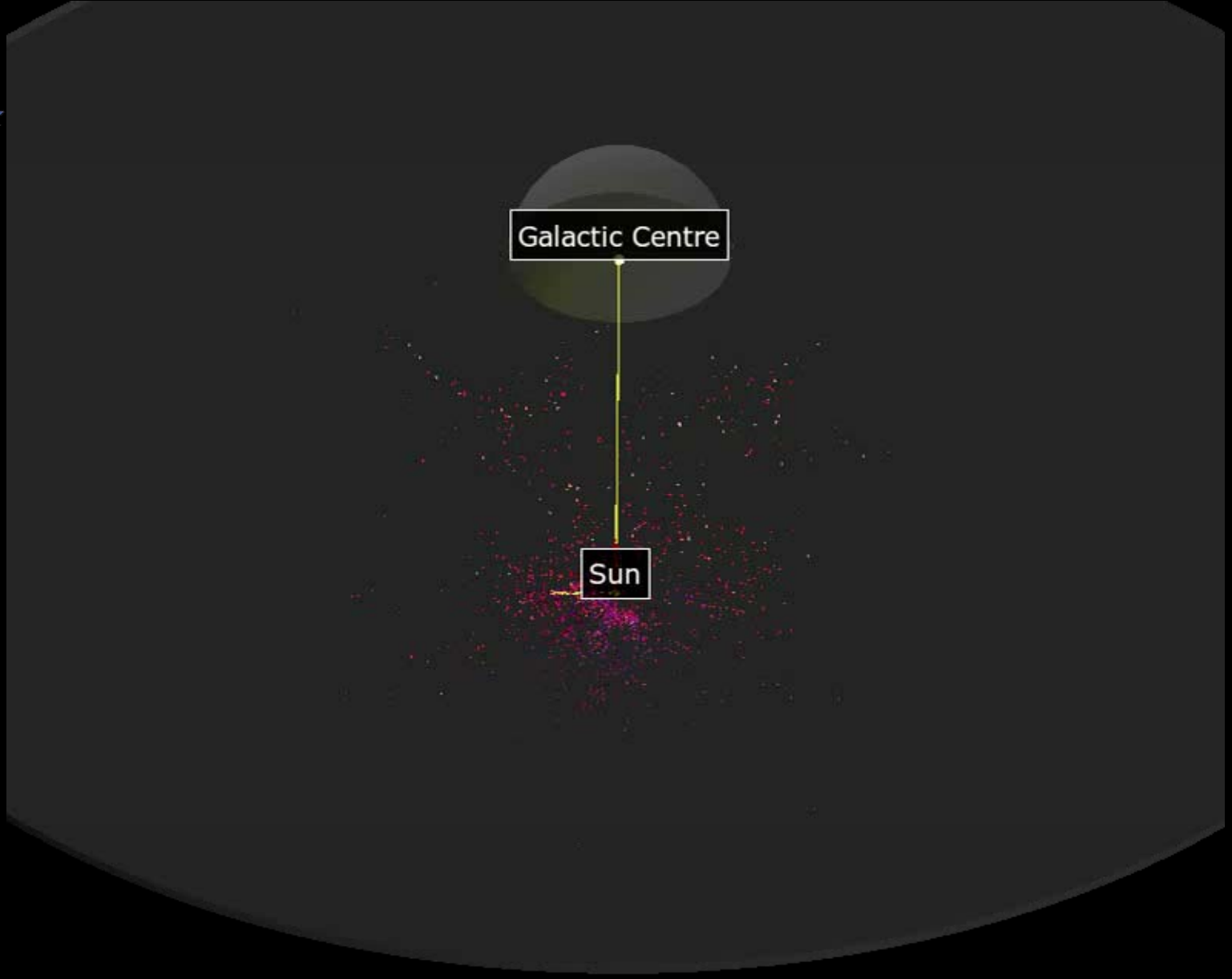
Planck Extragalactic |b|>30 deg

The Early Cold "Core" (ECC) Catalogue

- Subtract a warm template, the IRAS 100 μm map, from each of the 353, 545, 857 GHz maps, before running a source detection at each ν
- Merge all single frequency detections when matching within 5'
- Impose S/N > 4 in each and all bands
- Fit a modified blackbody to all
- ➔ the Cold Core Catalogue of Planck Objects (C3PO) containing 10 783 sources over the whole sky.
- Impose for high reliability (from Monte-Carlo) S/N > 15 and T < 14K
  ➔ ECC with 915 Sources



See Planck Collaboration 2011 r,s & [q-u] for science


Galactic Centre
Sun

The first 25 (a to y)

Title	Authors
Planck early results 01: The Planck mission	Planck Collaboration
Planck early results 02: The thermal performance of Planck	Planck Collaboration
Planck early results 03: First assessment of the Low Frequency Instrument in-flight performance	Mennella et al.
Planck early results 04: First assessment of the High Frequency Instrument in-flight performance	Planck HFI Core Team
Planck early results 05: The Low Frequency Instrument data processing	Zacchei et al.
Planck early results 06: The High Frequency Instrument data processing	Planck HFI Core Team
Planck early results 07: The Early Release Compact Source Catalogue	Planck Collaboration
The Explanatory Supplement to the Planck Early Release Compact Source Catalogue	Planck Collaboration
Planck early results 08: The all-sky early Sunyaev-Zeldovich cluster sample	Planck Collaboration
Planck early results 09: XMM-Newton follow-up for validation of Planck cluster candidates	Planck Collaboration
Planck early results 10: Statistical analysis of Sunyaev-Zeldovich scaling relations for X-ray galaxy clusters	Planck Collaboration
Planck early results 11: Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations	Planck Collaboration
Planck early results 12: Cluster Sunyaev-Zeldovich optical scaling relations	Planck Collaboration
Planck early results 13: Statistical properties of extragalactic radio sources in the Planck Early Release Compact Source Catalogue	Planck Collaboration
Planck early results 14: Early Release Compact Source Catalogue validation and extreme radio sources	Planck Collaboration
Planck early results 15: Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources	Planck Collaboration
Planck early results 16: The Planck view of nearby galaxies	Planck Collaboration
Planck early results 17: Origin of the submillimetre excess dust emission in the Magellanic Clouds	Planck Collaboration
Planck early results 18: The power spectrum of cosmic infrared background anisotropies	Planck Collaboration
Planck early results 19: All-sky temperature and dust optical depth from Planck and IRAS – constraints on the "dark gas" in our Galaxy	Planck Collaboration
Planck early results 20: New light on anomalous microwave emission from spinning dust grains	Planck Collaboration
Planck early results 21: Properties of the interstellar medium in the Galactic plane	Planck Collaboration
Planck early results 22: The submillimetre properties of a sample of Galactic cold clumps	Planck Collaboration
Planck early results 23: The Galactic cold core population revealed by the first all-sky survey	Planck Collaboration
Planck early results 24: Dust in the diffuse interstellar medium and the Galactic halo	Planck Collaboration
Planck early results 25: Thermal dust in nearby molecular clouds	Planck Collaboration

What's next?

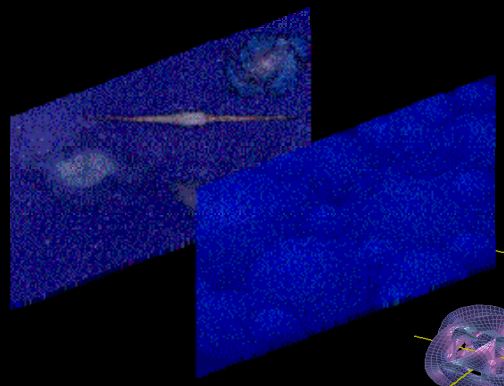
- 10 billion samples recently acquired. HFI should remain cold & acquiring data till January 2012. LFI should continue for 6 to 12 more months.
- We just launched a "Planck Intermediate Results" effort
  - *foregrounds, but on all 15.5 months of nominal mission. Should include polarisation.*
  - *Deadline for internal call was March 15th*
  - *Internal Workshop at IAP concluded on April 15th*
  - *Relevant Data set being produced by DPC right now*
  - *Next batch of papers on astroph targeted for early next year*
- Deliverable based on the 15.5 months of the nominal mission (at least intensity) will be released early 2013 (DPC to ESA in Dec 2012)
  - *Includes clean, calibrated TOI, frequency & component maps & legacy catalogue*
  - *CMB cosmology analyses of that data will be released at about the same time ($\mathcal{L}$, Θ, NG...)*
- Same products, but based on all data acquired, and updated analysis will be released one year later, in early 2014.

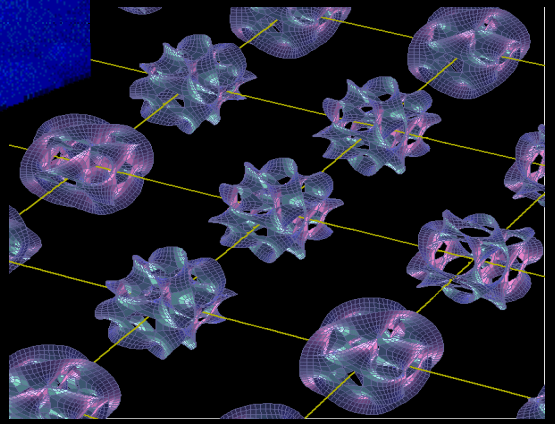
Inflations...

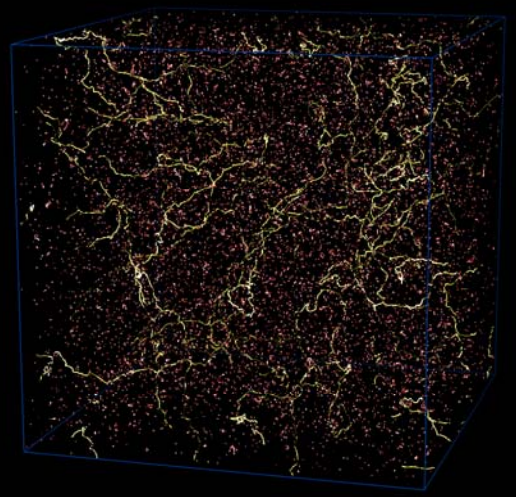
- S-dimensional assisted inflation
- assisted brane inflation
- anomaly-induced inflation
- assisted inflation
- assisted chaotic inflation
- boundary inflation
- brane inflation
- brane-assisted inflation
- brane gas inflation
- brane-antibrane inflation
- braneworld inflation
- Brans-Dicke chaotic inflation
- Brans-Dicke inflation
- bulky brane inflation
- chaotic inflation
- chaotic hybrid inflation
- chaotic new inflation
- D-brane inflation
- D-term inflation
- dilaton-driven inflation
- dilaton-driven brane inflation
- double inflation
- double D-term inflation
- dual inflation
- dynamical inflation
- dynamical SUSY inflation
- eternal inflation
- extended inflation
- extended open inflation
- extended warm inflation
- extra dimensional inflation
- F-term inflation
- F-term hybrid inflation
- false-vacuum inflation
- false-vacuum chaotic inflation
- fast-roll inflation
- first-order inflation
- gauged inflation
- Hagedorn inflation
- higher-curvature inflation
- hybrid inflation
- hyperextended inflation
- induced gravity inflation
- intermediate inflation
- inverted hybrid inflation
- isocurvature inflation.....

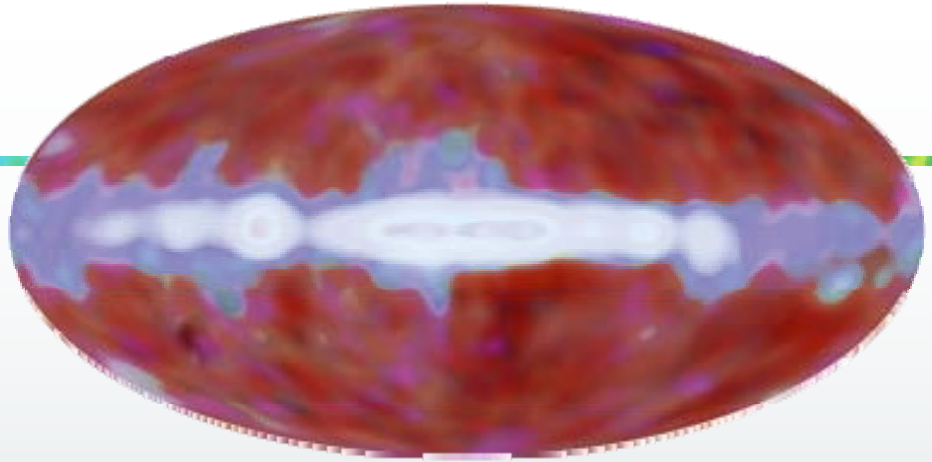
Beyond the standard BB model

- 1. Branes – signatures of extra dimensions
- 2. Signatures of Pre-big bang
- 3. Cosmic defects (strings), superstrings
- 4. Non-Gaussianity (ies)
- 5. Indication of a curved / non trivial geometry
- 6. Isocurvature perturbations
- 7. Deviations from Einstein Relativity
- 8. Neutrinos masses
- 9. Interacting dark matter
- 10.....



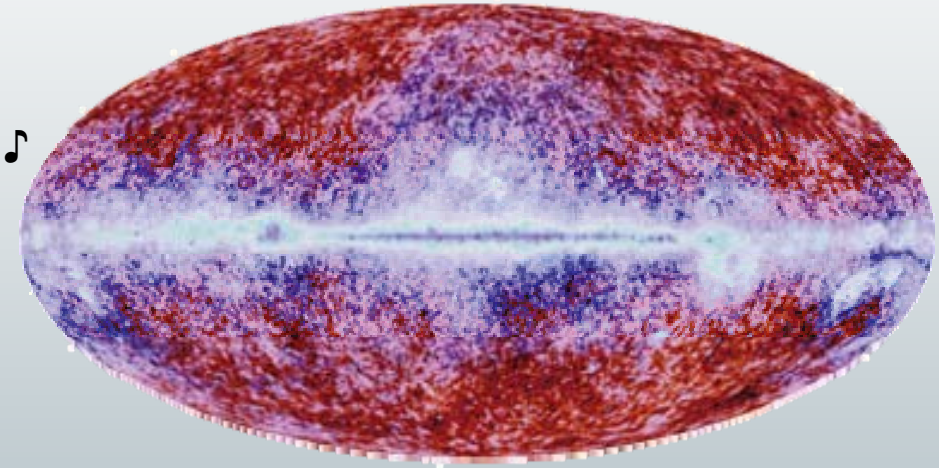




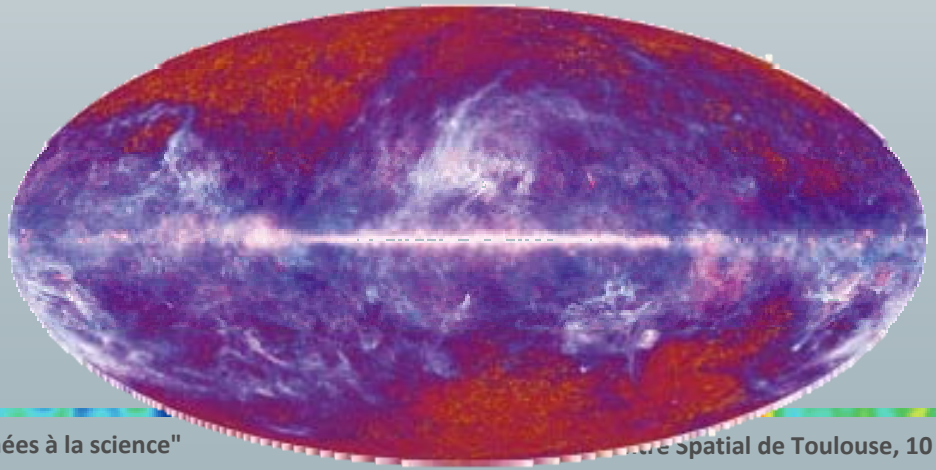


COBE ~1993

♫ It's a long way to... ♪
CMB cosmology ♪
But ..
On our way!



WMAP ~2003



Planck ~2010

esa

planck

cnes

agenzia spaziale italiana

PLANCK LFI

NASA

cnrs

DTU Space
National Space Institute

INAF ISTITUTO NAZIONALE DI ASTROFISICA

HFI PLANCK

Science & Technology Facilities Council

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

IAS orsay

National Research Council of Italy

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

IAP

INAF - IASF BO
ISTITUTO NAZIONALE DI ASTROFISICA
ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI BOLOGNA

CSA ASC

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.

UK SPACE AGENCY

MAX-PLANCK-GESELLSCHAFT

Aalto University

ioa

KICC Kavli Institute for Cosmology Cambridge

CAVENDISH ASTROPHYSICS

UNIVERSITY OF CAMBRIDGE

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

irfu
saclay
energie atomique • energies alternatives

CESR

CITA–ICAT

cnrs IN2P3 Les deux infinis

ipac Infrared Processing and Analysis Center

HELSINKI INSTITUTE OF PHYSICS

INSTITUTO DE ASTROFISICA DE CANARIAS

IFCA Instituto de Física de Cantabria

Imperial College London

UNIVERSITÀ DEGLI STUDI DI MILANO

NÉEL institut

IPAG Institut de Planétologie et d'Astrophysique de Grenoble

ISDC DATA CENTRE FOR ASTROPHYSICS

JPL

LAL LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

l'Observatoire de Paris LERMA

LPSC Grenoble Laboratoire de Physique Subatomique et de Cosmologie

The University of Manchester

MilliLab

Max-Planck-Institut für Astrophysik

NUI MAYNOOTH

INAF OSSERVATORIO ASTRONOMICO DI PADOVA

DIPARTIMENTO DI FISICA SAPIENZA UNIVERSITÀ DI ROMA

Science & Technology Facilities Council Rutherford Appleton Laboratory

TOR VERGATA

OSSERVATORIO ASTRONOMICO DI TRIESTE

UBC

UC UNIVERSIDAD DE CANTABRIA

UCSB

SISSA

ALMA

ESO

US University of Sussex

esa

UNIVERSITY OF HELSINKI

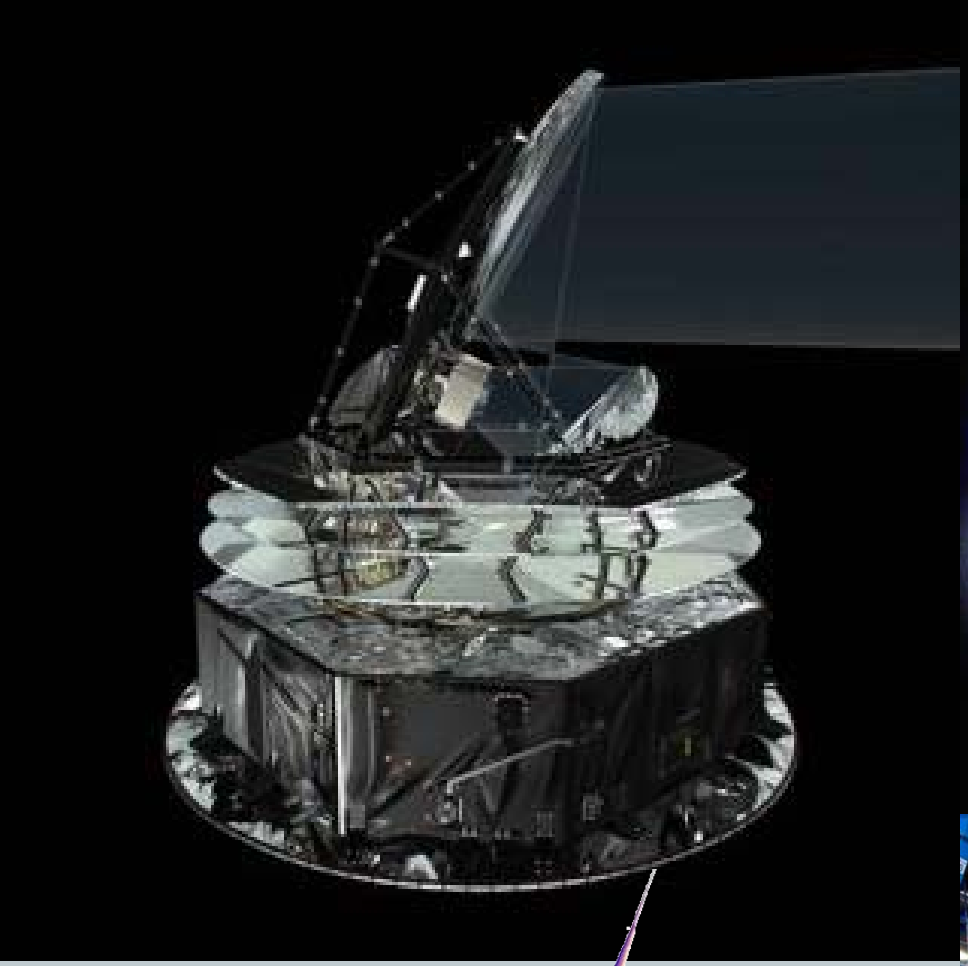
UNIVERSITÉ DE GENÈVE

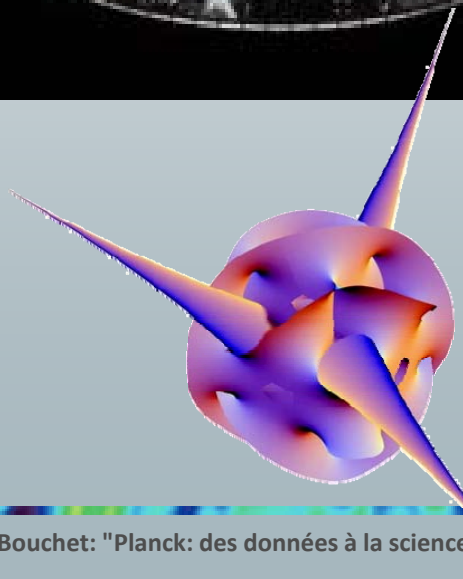
UNIVERSITY OF TORONTO

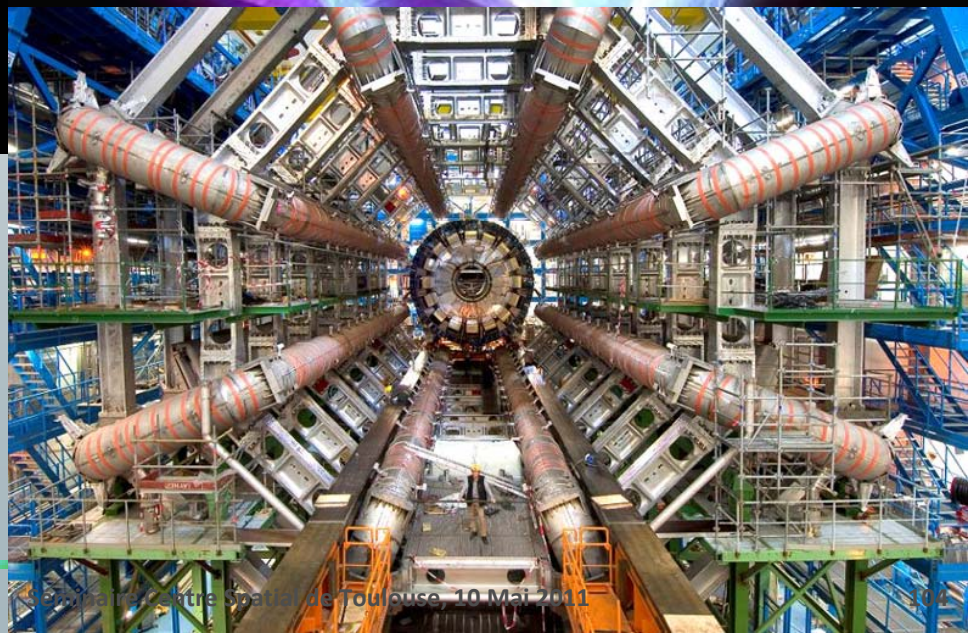
UNIVERSITÉ DE PARIS-SUD XI

ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

asdc ASI Science Data Center







HFI PLANCK
un regard vers l'origine de l'Univers

Présentation de Planck | Les défis du projet | Sociologie de Planck | Les Planckiens | Cosmo/astro | Supports pédagogiques | Espace presse

Le projet Planck a pour objectif de mesurer avec grande précision un certain rayonnement présent dans l'Univers, le rayonnement fossile.

Comme son nom le suggère, il s'agit du rayonnement le plus ancien qui ait été émis dans l'Univers. Son observation joue un rôle crucial en astrophysique car elle permet de reconstituer avec précision le contenu ainsi qu'une grande partie de l'histoire de l'Univers.

Planck à la ville européenne des sciences

Ce projet doit permettre de mieux répondre à de nombreuses questions :

- Quel est l'âge et la géométrie de l'Univers ?
- Quel sera le futur de l'Univers, expansion ou implosion ?
- Quand l'Univers est-il devenu transparent ?
- Quels sont les mécanismes à l'origine des fluctuations primordiales qui ont initié la formation des grandes structures de l'Univers comme les galaxies ?
- Quelle est la nature de la fameuse énergie noire de l'Univers?

ESPACE PRO

MULTIMÉDIA

JEUX

PARTENAIRES

Contact | Liens | Foire aux questions | Mentions légales | Plan du site | Site optimisé pour IE 7 et FireFox