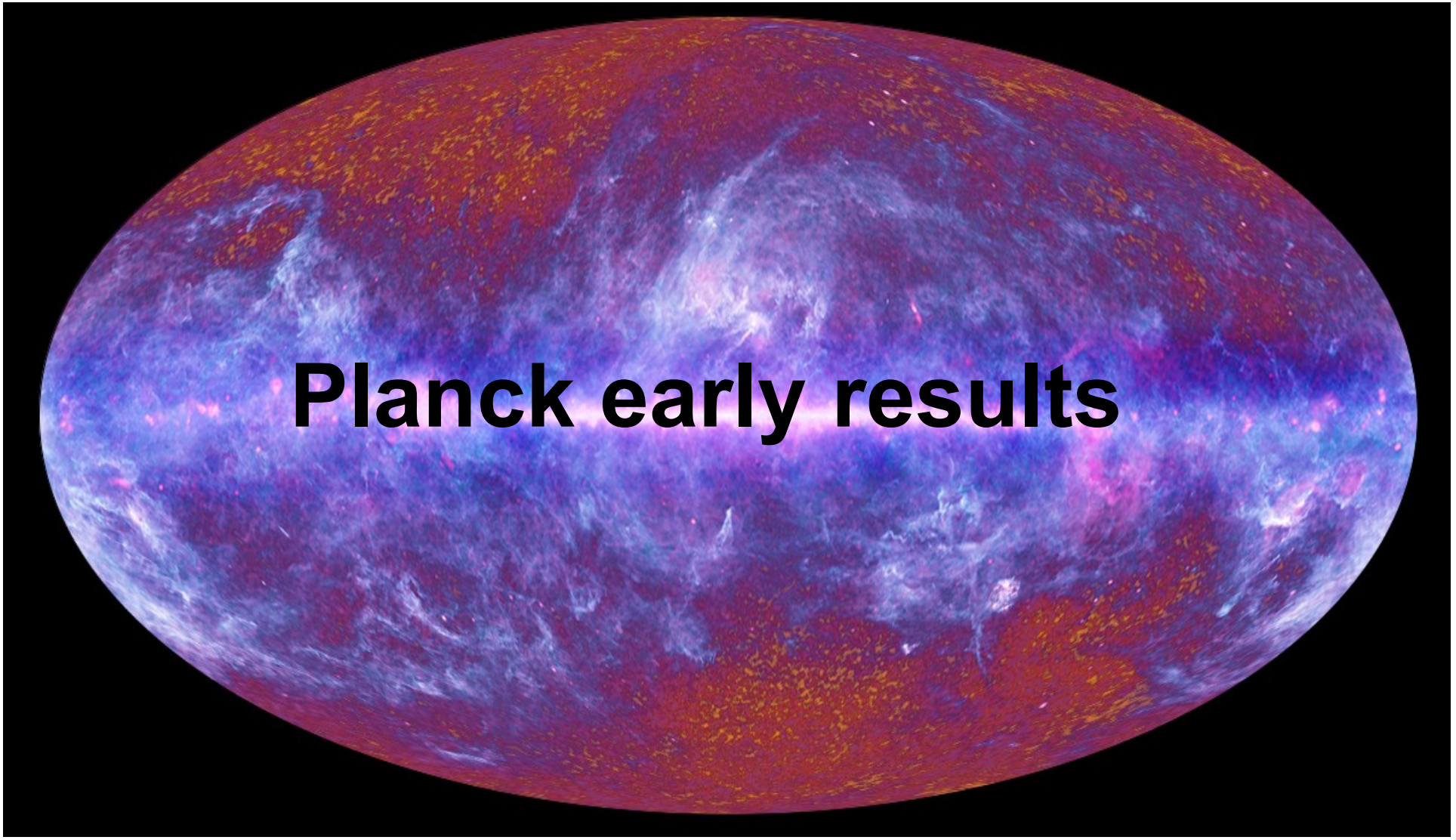

Planck early results

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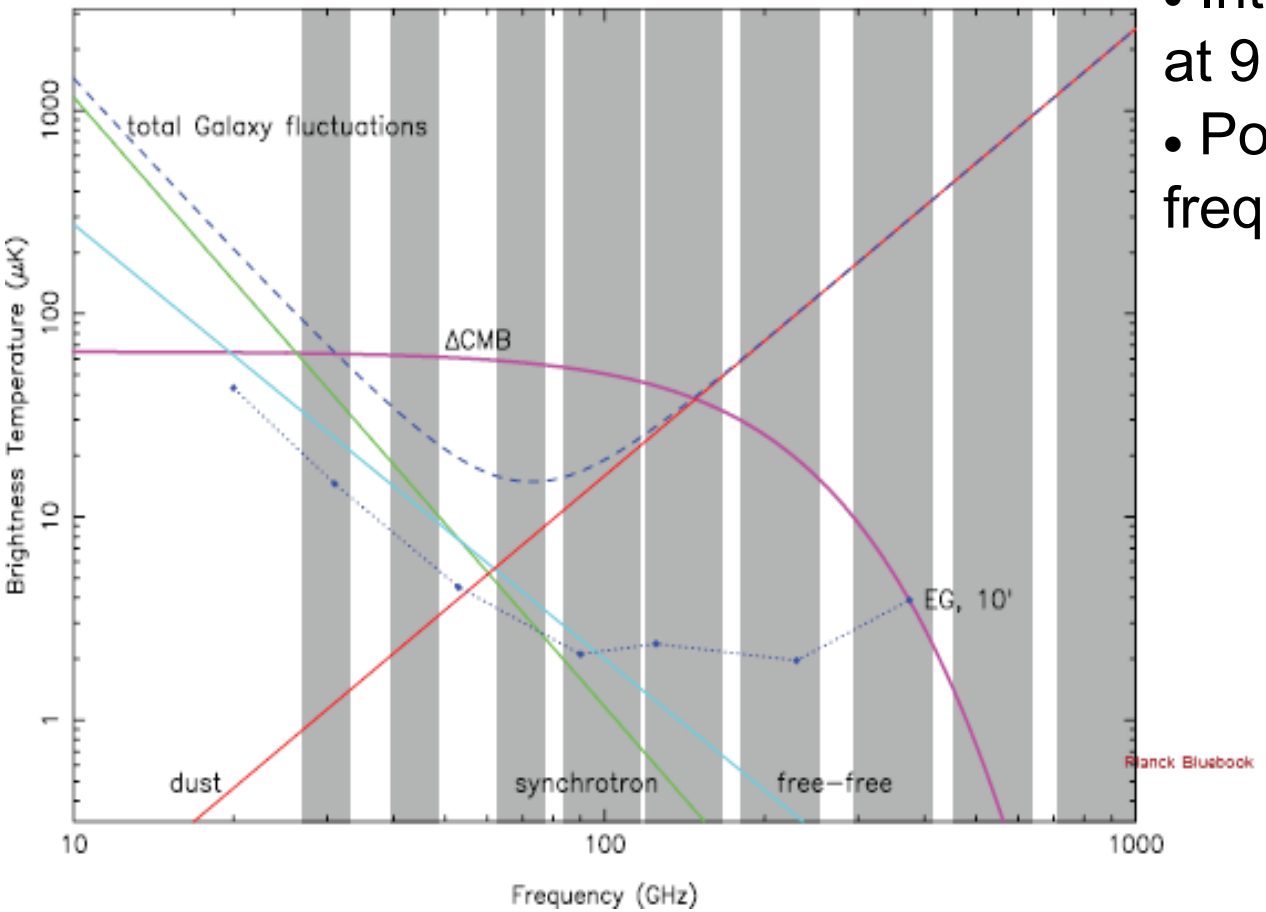
esa
planck
cnes
agenzia spaziale italiana
NASA
cnrs
DTU Space
National Space Institute
INAF
ISTITUTO NAZIONALE DI ASTROFISICA
Science & Technology Facilities Council
CSIC
Consejo Superior de Investigaciones Científicas
National Research Council of Italy
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
CSA ASC
DLR
Deutsches Zentrum für Luft- und Raumfahrt e.V.
UK SPACE AGENCY
MAX-PLANCK-GESELLSCHAFT
HFI
PLANCK
PLANCK
LFI
IAS
orsay
IAP
INAF - IASF BO
ISTITUTO NAZIONALE DI ASTROFISICA
ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI BOLOGNA
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
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
LAC
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
University of Oxford
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
asdc
ASI Science Data Center

Planck → Third generation of CMB space missions
Primary goals → Measure CMB temperature anisotropies to fundamental limits down to 4 arcmin & Measure CMB polarisation

- Need to separate CMB from foreground emissions
- Must measure the sky over many frequencies → A lot of astrophysics and ancillary science (subject of Planck early results)

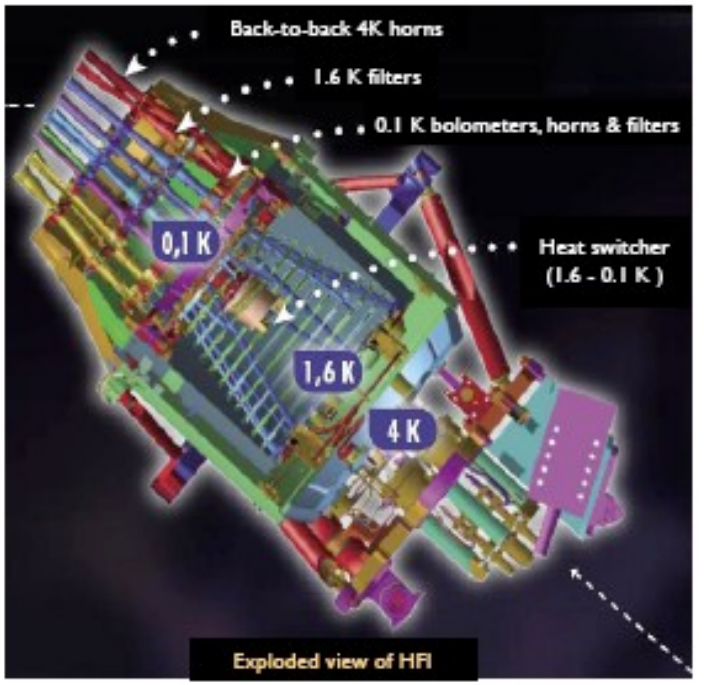


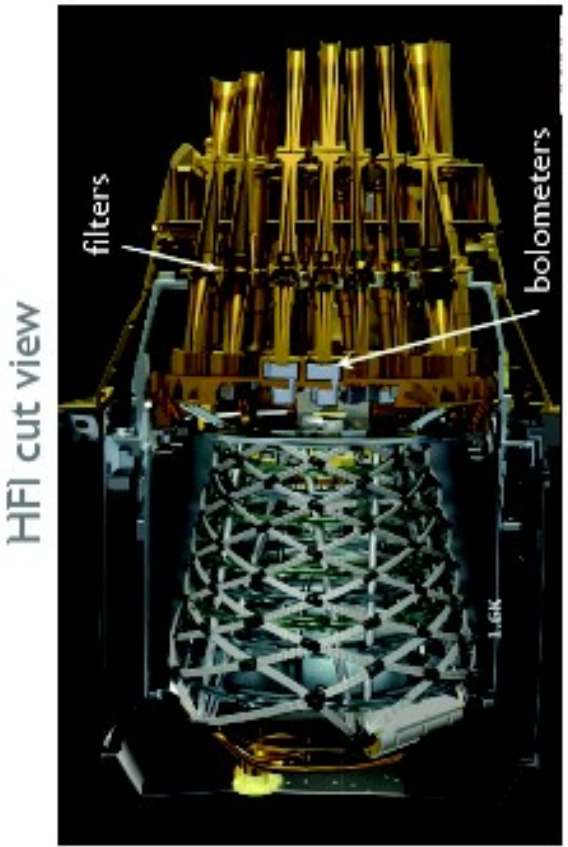
- Intensity measured with HFI & LFI at 9 frequencies, 30 to 857GHz
- Polarisation measurements at 7 frequencies, 30 to 353GHz

Planck required sensitivity → Technological performances never achieved in space before

In particular, flying:

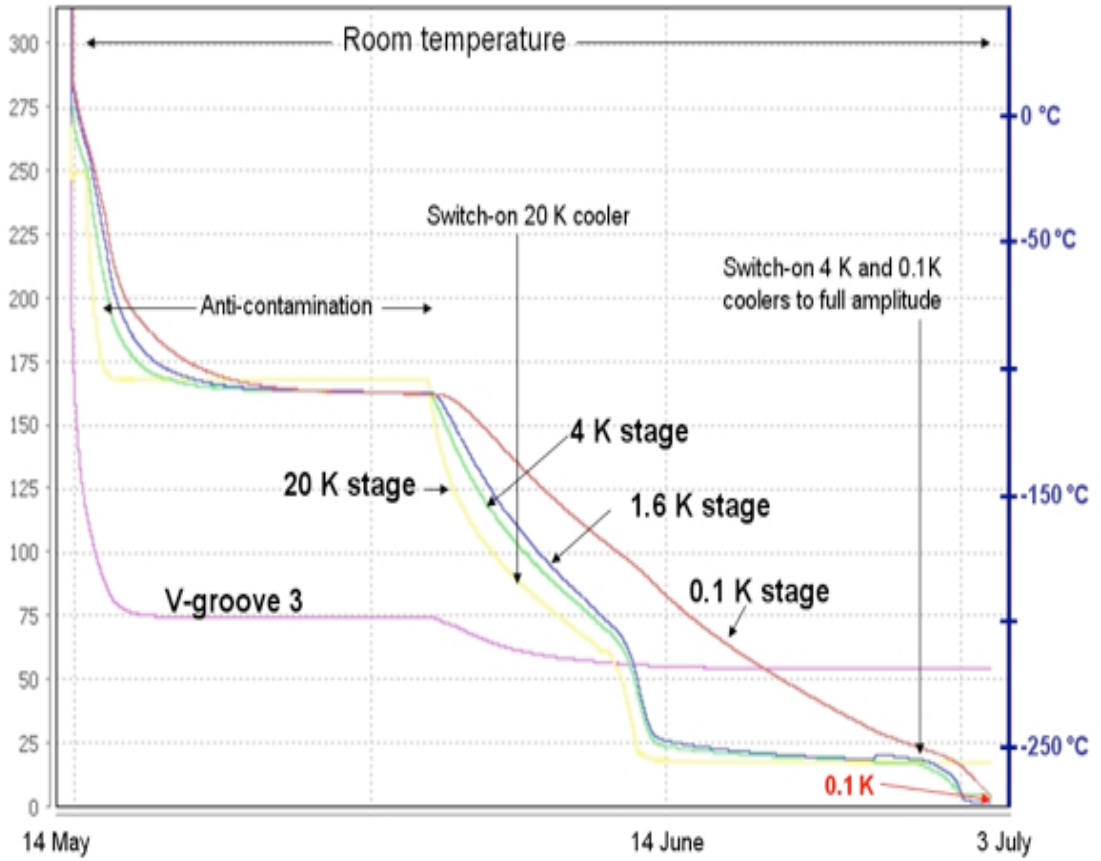
- Sensitive and fast bolometers → Need cooling at 100mK
- Complex cryogenic cooling chain: 50K (passive)+20K+4K+1.6K+0.1K (active)
- 100mK → Obtained from dilution cooler





Planck & Herschel launched on May 14th 2009 (Kourou, Fr. Guyana)

1.5 million km in 45 days → L2 July 2nd 2009



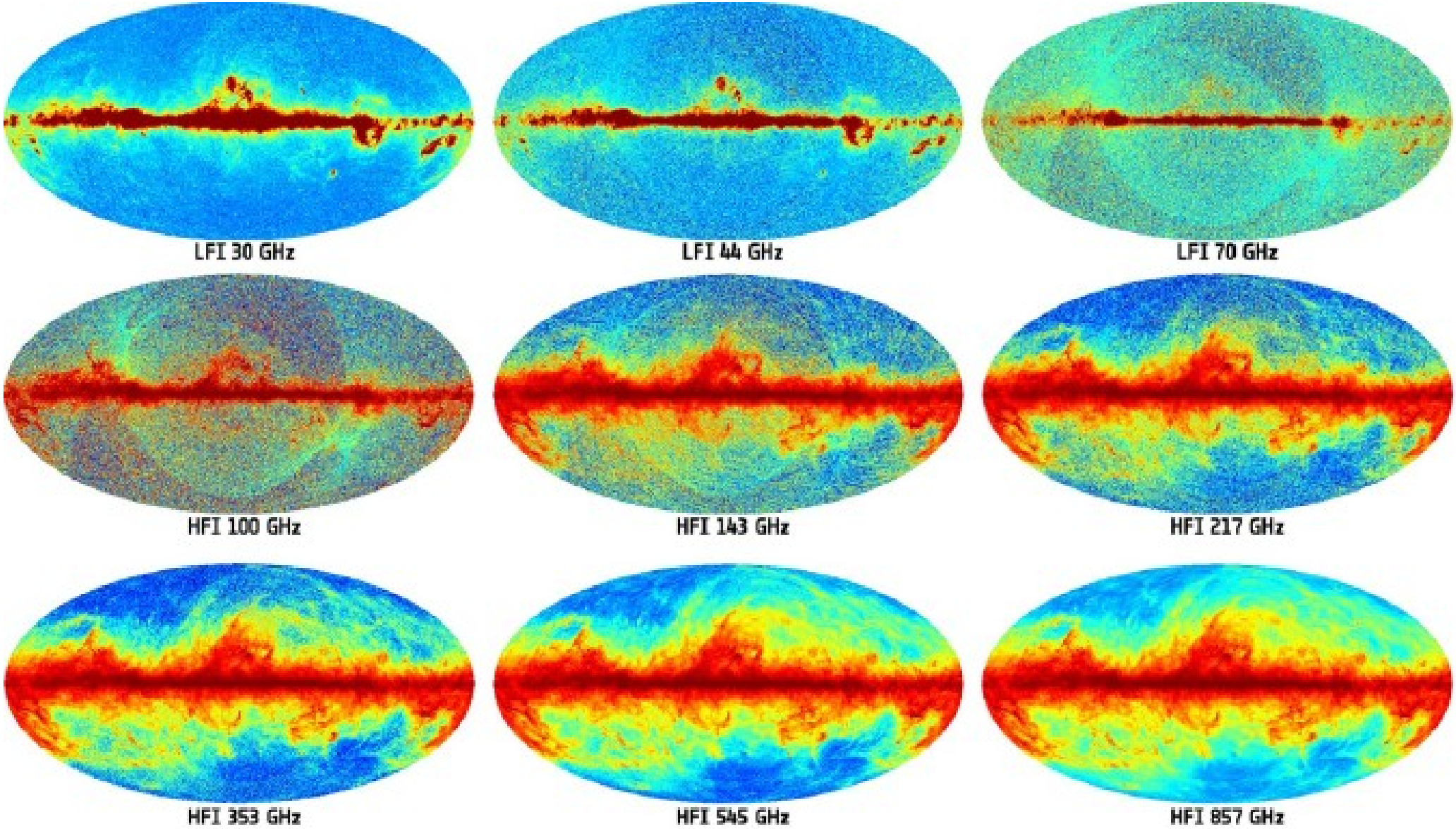
Planck is very stable scanning the sky since August 13th 2009 (~6 month to cover the whole sky)

Nominal mission achieved November 27th 2010

Extended "cryogenic mission" ~Dec. 2011 (5 vs 2 surveys → 30 vs 14 months)

Planck all-sky frequency maps: Foreground maps

Planck early results obtained from data acquired until June 7th 2010
~10 months = complete coverage of sky by all detectors & 60% overlap between 2 surveys



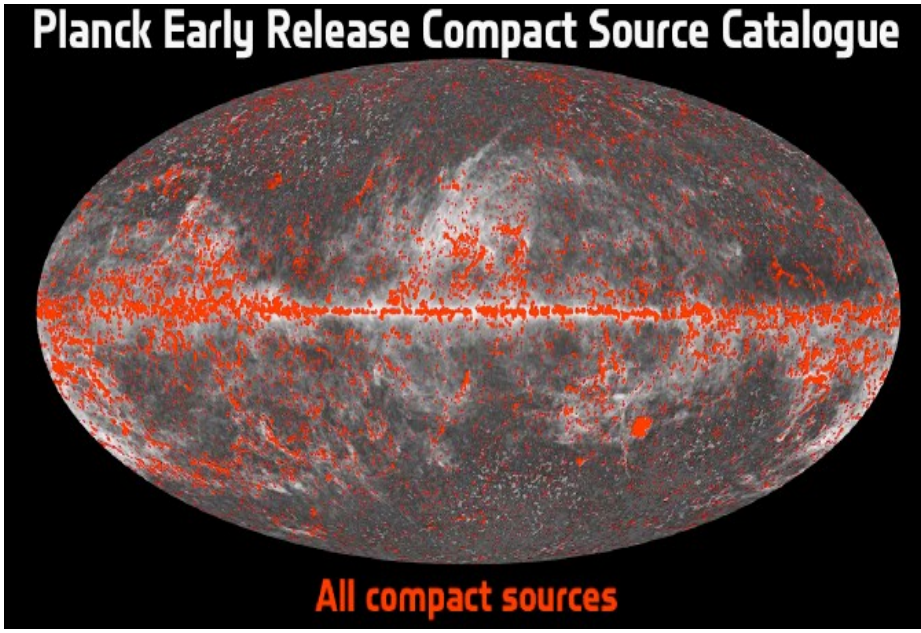
The Early Release Compact Source Catalogue

(Details in arXiv1101.2041)

- Planck first data product delivered
- First simultaneous radio through sub-mm all-sky survey
- **First all-sky catalogue 100 to 900GHz**

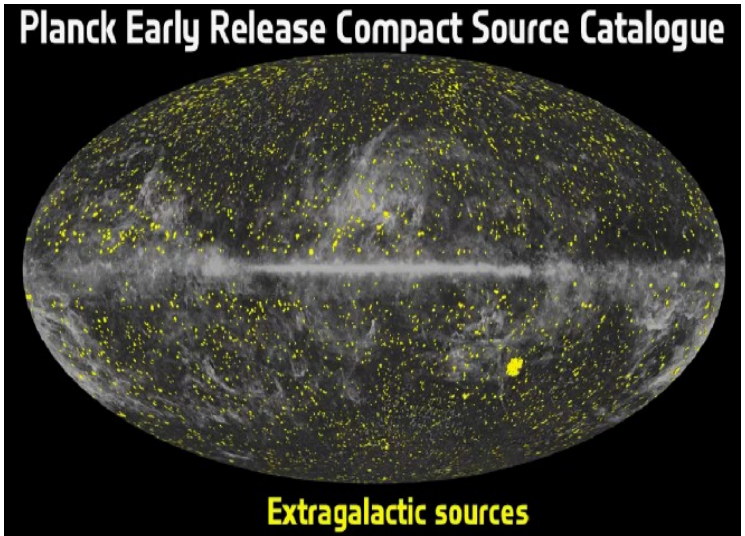
>15000 sources: 9 frequency lists + 2 multi-channel lists (Cold cores & SZ clusters)

Available from ESA Planck legacy archive:
www.rssd.esa.int/Planck

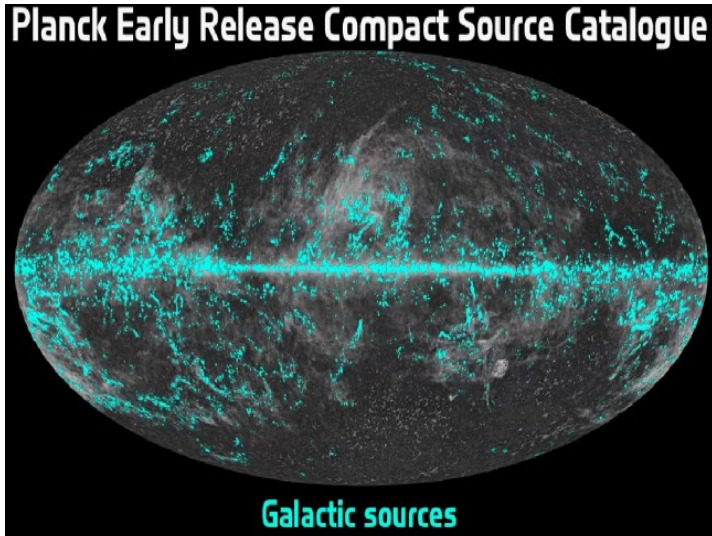


- Most radio sources have flat spectra (radio galaxies and NOT IR galaxies detected < 217GHz)
- Radio-source model over-predicts bright counts by factor 2
- Fluctuations (>217GHz) dominated by IR sources

- IR-luminous galaxies
- Radio galaxies, Blazars



- Features in the interstellar medium (flag extended)
- Cold cores/clumps



Cosmic Infra-red Background (CIB)

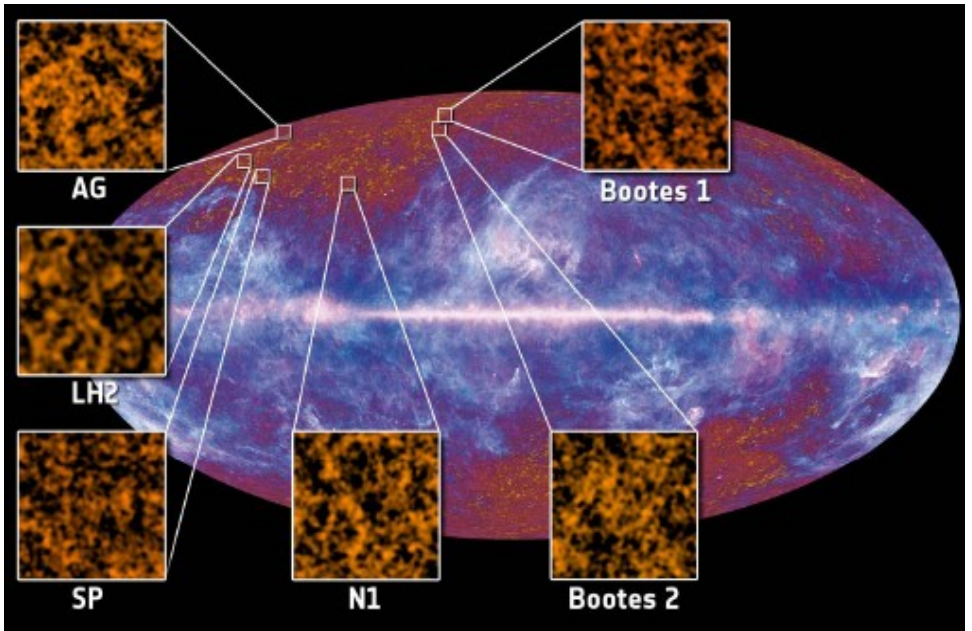
- C**umulative IR emission** of dusty star-forming galaxies (IR/Sub-mm emission from UV light reprocessed by dust)
- Probes much of the cosmic star formation
- Longer wavelengths probe higher z → CIB anisotropies in Planck → Forming galaxies @z~2-3

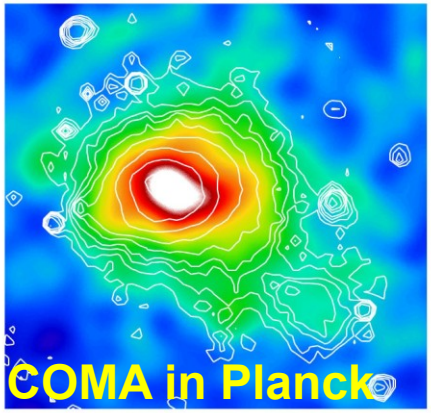
CIB measured by Planck in 6 high galactic latitude fields (total ~40 sq. deg.) with very low dust. Cleaning with template removal:

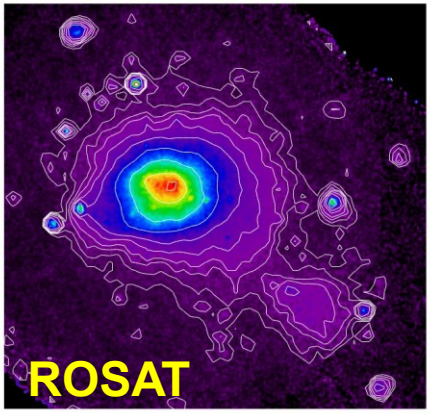
- CMB → Planck- HFI 143GHz Wiener filtered
- Dust → HI data from GBT *(Martin et al. 2011)*, tracer of diffuse dust emission

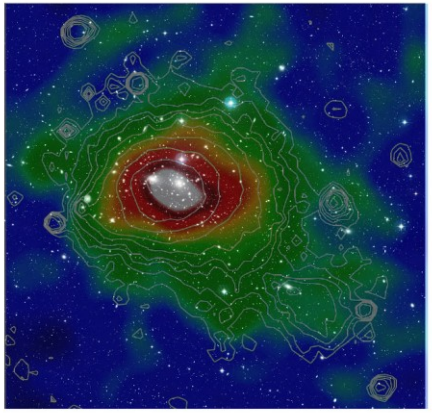
(details in arXiv1101.2028)

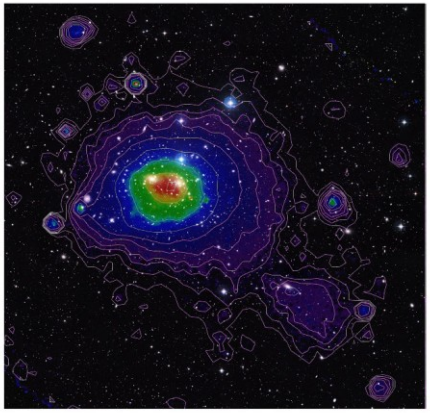
- Sub-degree (l~200 to 1000) structure at all freq. partially correlated across freq. dominates white noise term
- Agrees with other measurements (e.g. BLAST, SPT)
- Constant linear bias model ruled out









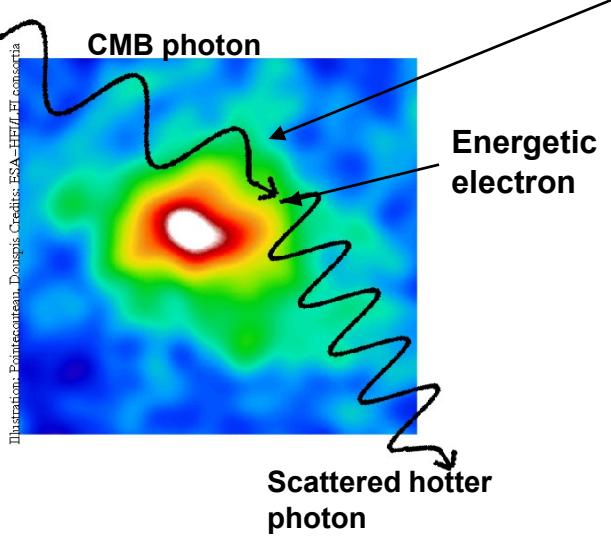


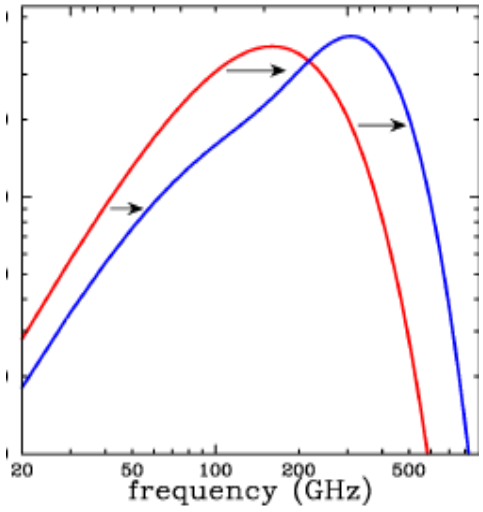
The Sunyaev-Zel'dovich (SZ) effect

Inverse Compton interaction in clusters = **Thermal SZ** another view of the hot intra-cluster gas through the thermal pressure

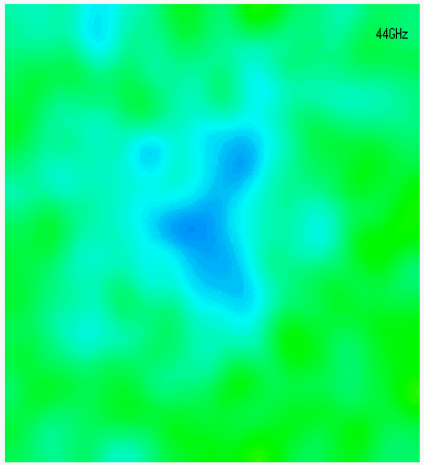
Doppler effect in clusters = **Kinetic SZ** very small but may be detected in a statistical way

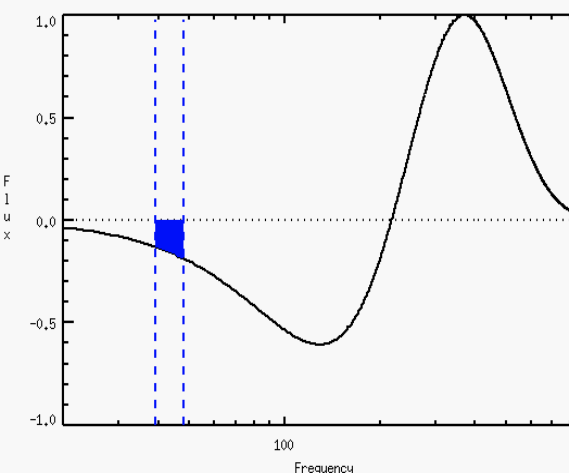
Galaxy cluster = galaxies + hot gas





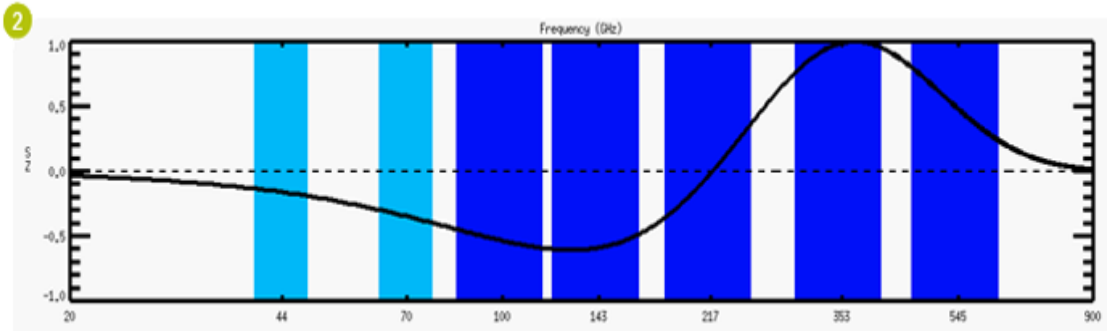
Planck observations of A2319 from 44 to 554 GHz





Planck's uniqueness for SZ detection

- **Frequency range from 30 to 857 GHz**
- **All-sky survey**

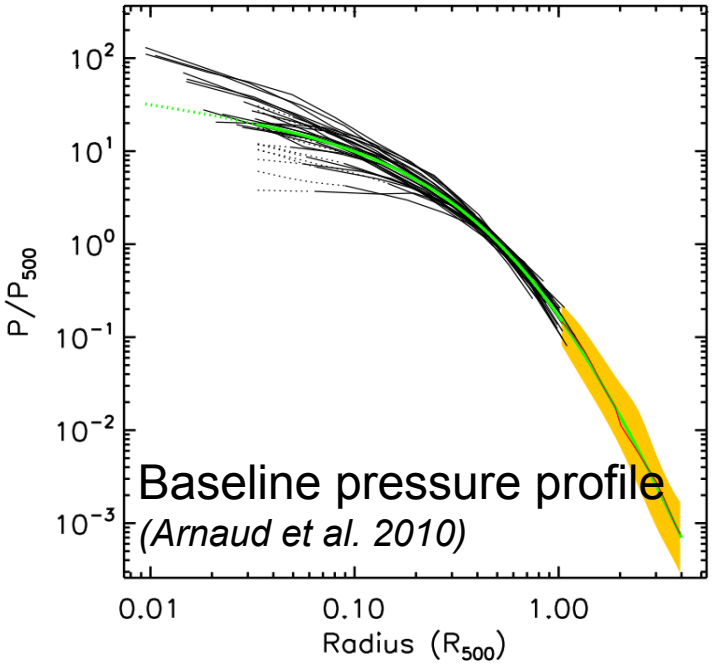


Adapted extraction technique → MMF

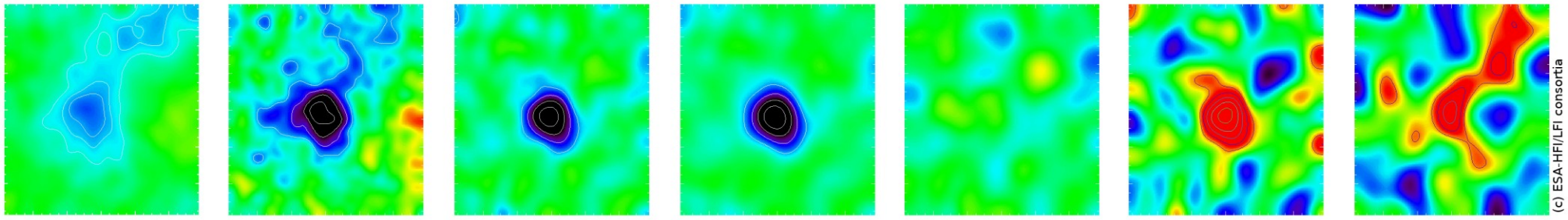
Matched Multi-Filter *(Melin et al. 2006)*

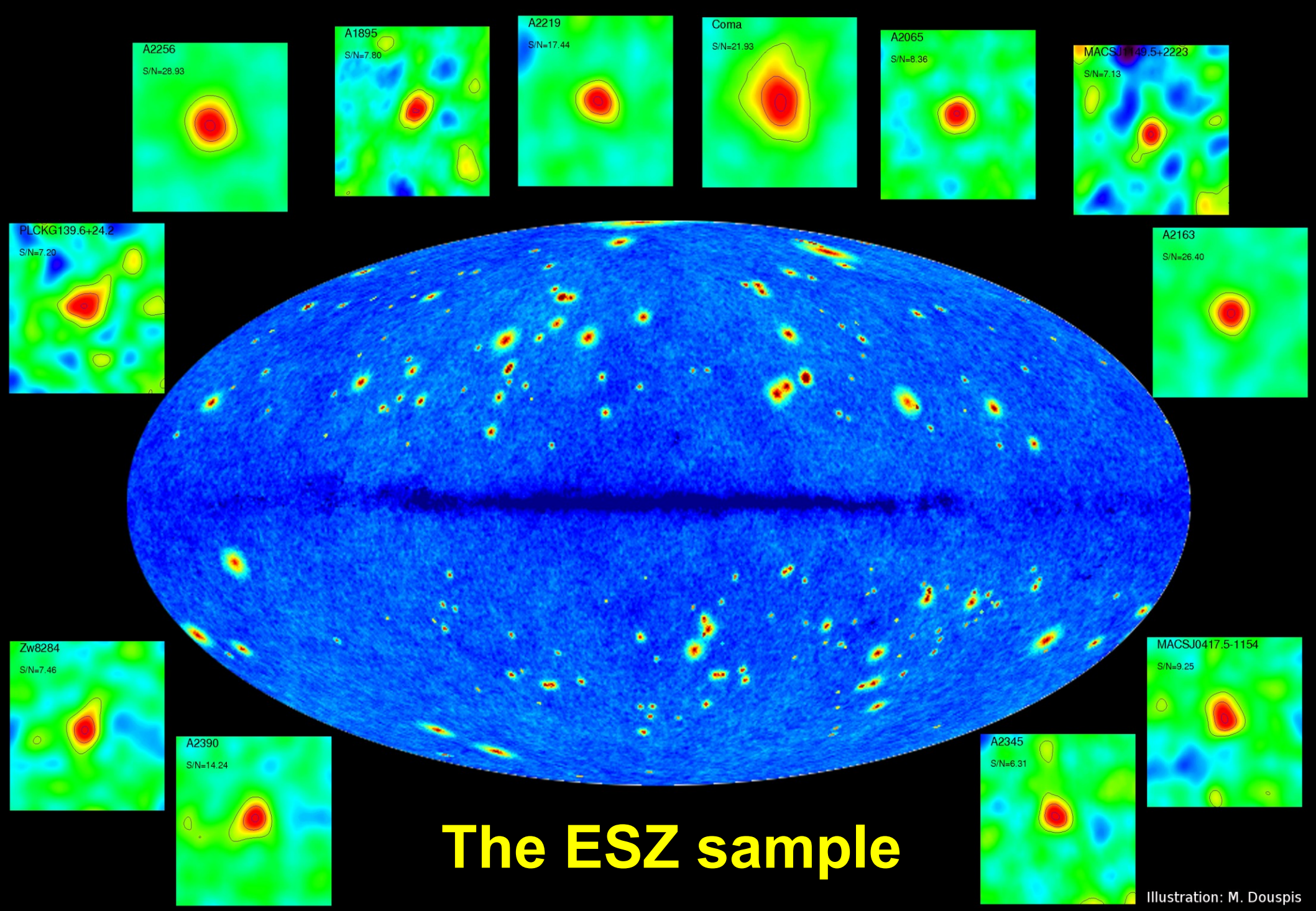
enhances SZ signal over other components (from red to blue points):

- known spectral dependence → non-relativistic
- known cluster shape → GNFW pressure profile



Planck's frequency coverage on A2319




A2256
S/N=28.93
A1895
S/N=7.80
A2219
S/N=17.44
Coma
S/N=21.93
A2065
S/N=8.36
MACSJ1149.5+2223
S/N=7.13
PLCKG139.6+24.2
S/N=7.20
A2163
S/N=26.40
Zw8284
S/N=7.46
A2390
S/N=14.24
A2345
S/N=6.31
MACSJ0417.5-1154
S/N=9.25
The ESZ sample
Illustration: M. Douspis

The all-sky Early SZ (ESZ) cluster sample

(Details in arXiv1101.2024)

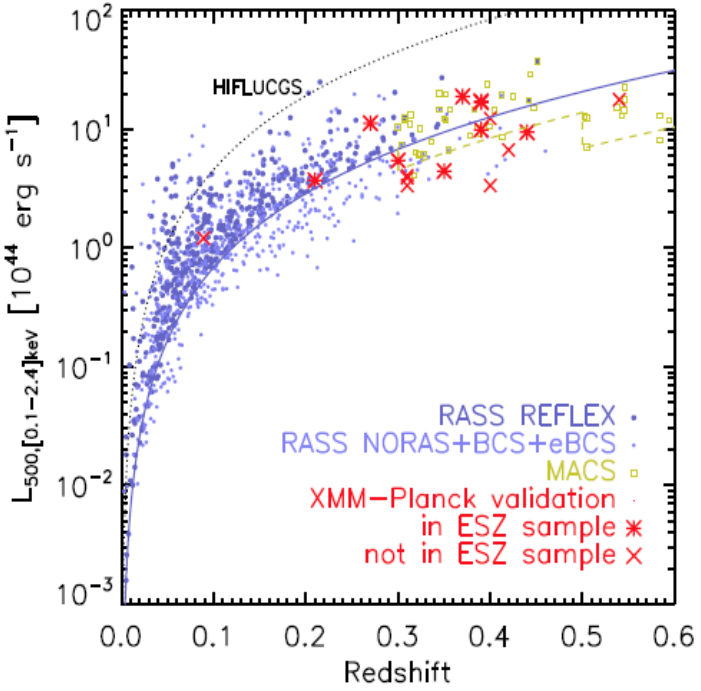
199 clusters in total including 30 new clusters

ESZ sample = 189 candidates (S/N> 6 & |b| >14deg)

- 169 identified with known clusters
- 20 candidates 19 confirmed as new clusters

Further 10 new clusters (S/N <6)

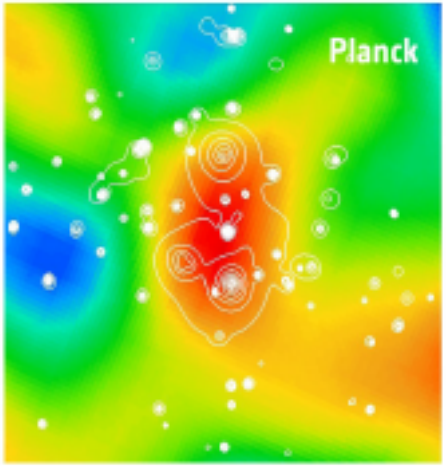
All new Planck clusters (red/orange(



- First & largest **all-sky SZ sample** of clusters
- Only all-sky cluster survey since ROSAT 1992
- First SZ measure for ~80% of the known clusters
- Moderate redshifts (86% with z<0.3)
- Rarest & most massive clusters over the whole sky (up to 1.5×10^{15} M_{sol}) detected blindly by Planck
- Completes RASS clusters in high M-z region

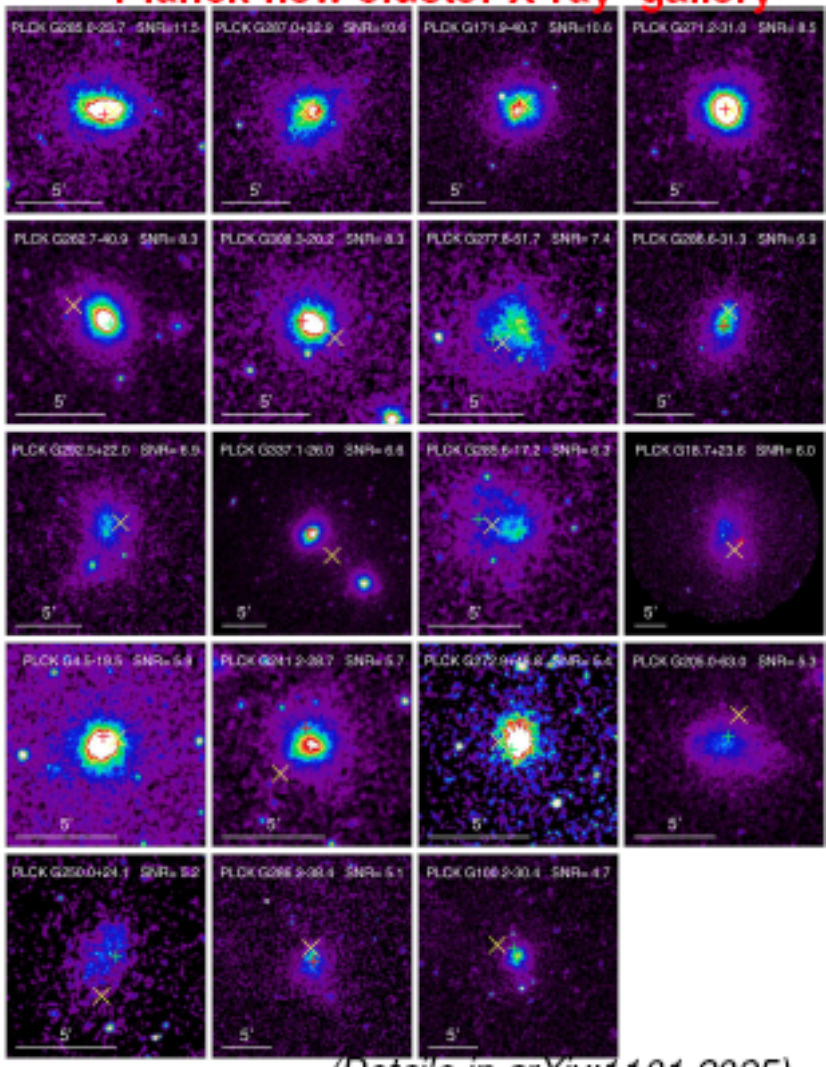
Planck clusters properties from XMM-*Newton*

- 21 candidates confirmed with XMM-Newton DDT snapshots
- Most Planck new clusters have **disturbed morphologies**
- **Multiple systems** (double, triple systems) → first super-clusters in SZ

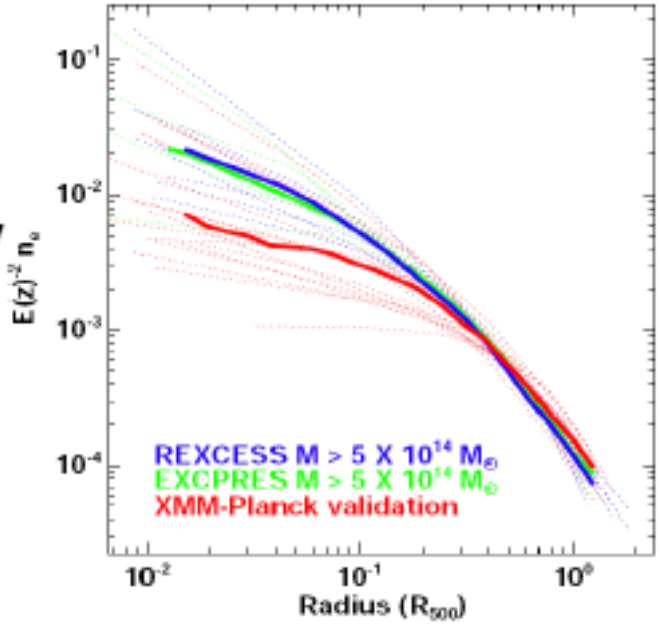


z_{opt}~0.45,
z_x~0.45
kT~3keV

Planck new cluster X-ray gallery



Density profiles of Planck new clusters **shallower than X-ray clusters** of similar masses → X-ray under-luminous for their masses



(Details in arXiv:1101.2025)

Planck's preview of the cluster properties: SZ, optical, X-rays

SZ signal measured in Planck at cluster positions & binned

(Details in arXv1101.2027, 1101.2043)

X-rays: Statistical analysis of ~1600 **X-ray clusters**,mostly from RASS with homogeneised data *(Piffaretti et a. 2010)*

Optical: Statistical of ~13000 **MaxBCG clusters** from SDSS with optical richness *(Koester et al. 2007)*

SZ signal Y_{sz} predicted from X-ray and optical relations

Y_{sz} from X-rays → **gas pressure profile** *(Arnaud et al. 2010)* + **scaling relations**

Y_{sz} from weak-lensing → calibrated **N_{200}-M_{500} relation** (*Jonhston et al. 2007, Rozo et al. 2009*) + gas pressure profile & scaling relations

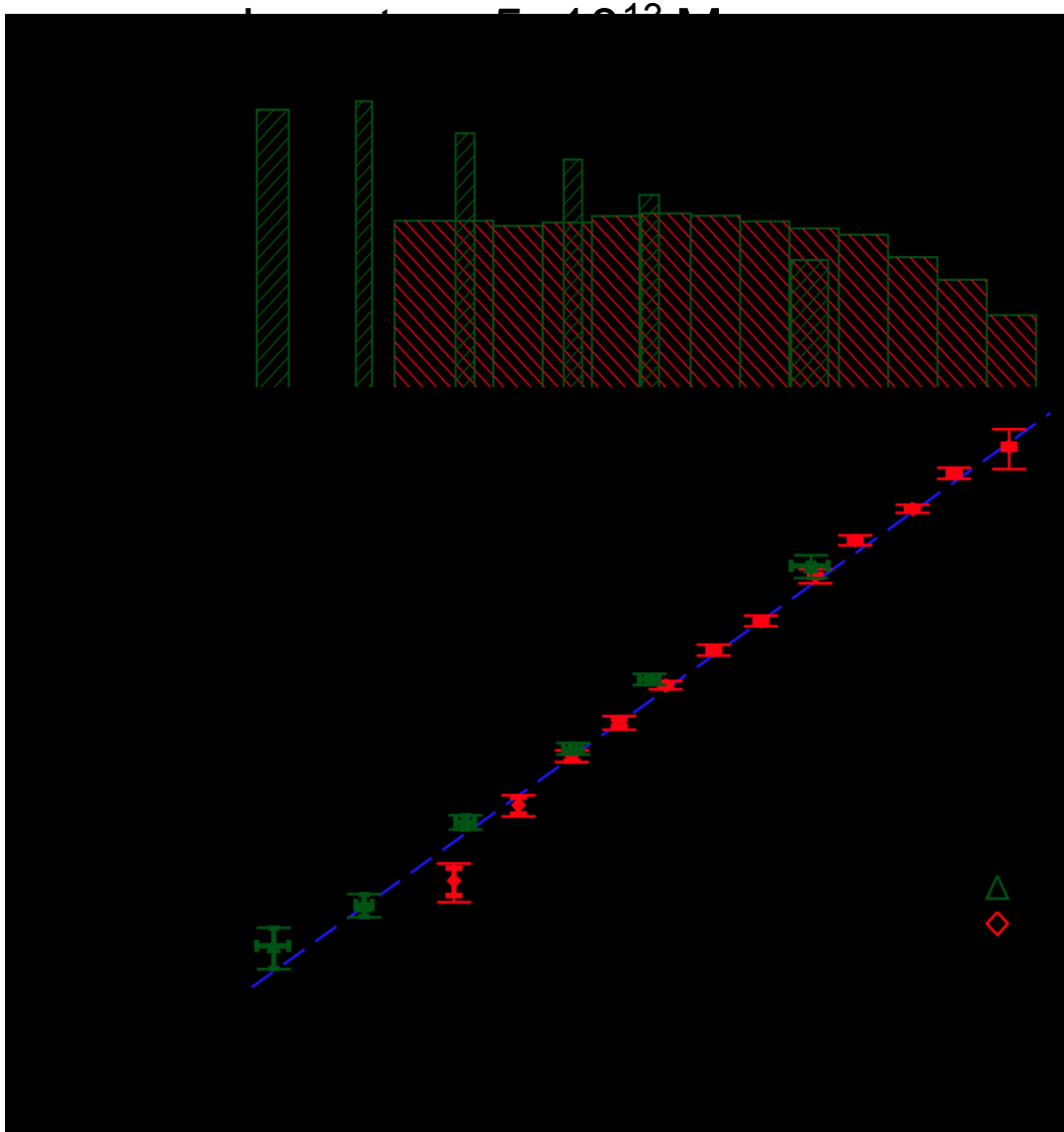
Minimise systematics → consistent approach for (i) SZ extraction & X-ray predictions and (ii) for homogeneisation

Planck's preview of the cluster properties: SZ, X-rays

- SZ measure from Planck & X-ray luminosities (MCXC) agree from highest to lowest luminosity bins
- Excellent agreement with X-ray predictions (normalisation and slope of Y-L and Y-M relations)
- No SZ deficit (*Details in arXiv1101.2043)*

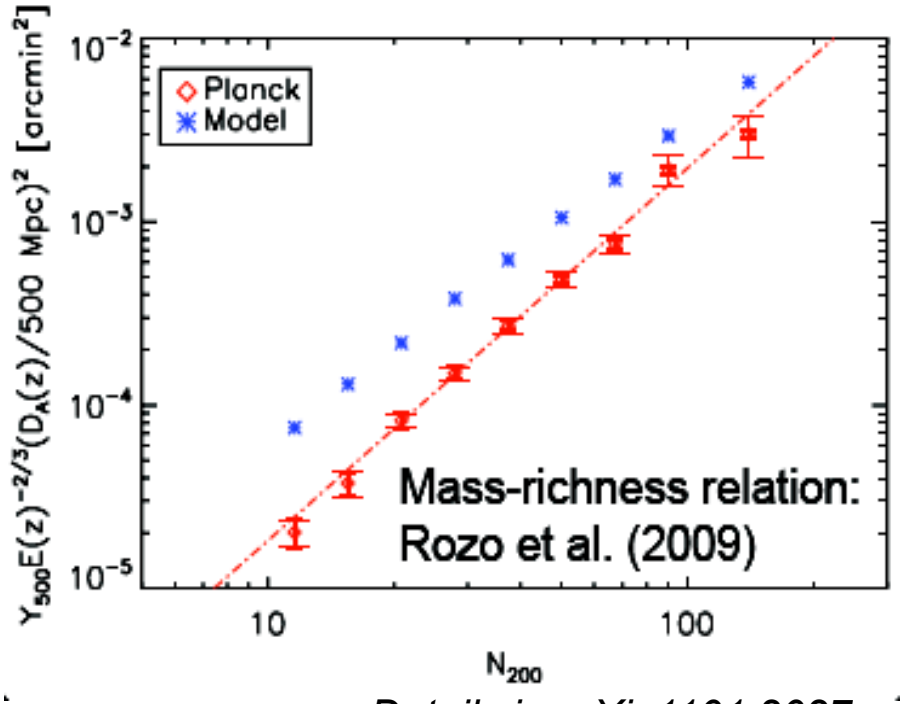
⇒ Robust and consist overall view of Intra-Cluster Medium properties from X-ray and SZ

SZ signal measured in Planck



Planck's preview of the SZ-optical cluster properties

- SZ detection down to ~ 5. 10^{13} M_{sol}
- Predictions from combines WL calibration and X-ray model not in agreement with measured SZ signal
- Better agreement for X-ray subsample from SDSS



Details in arXiv1101.2027

Unexplained SZ-optical discrepancy between data and prediction:

Sub-population of clusters and Selection effects?

Difference in hydrostatic X-ray and lensing masses?

Dispersion in scaling relations?

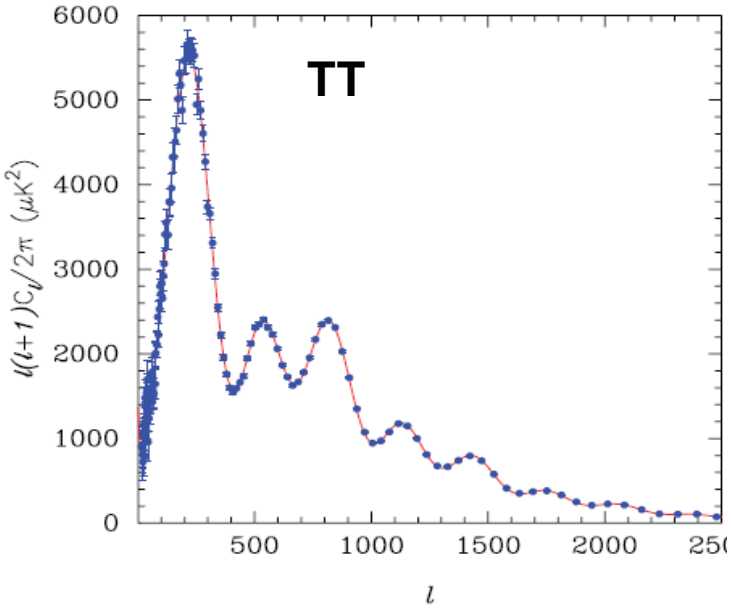
A combination of all?

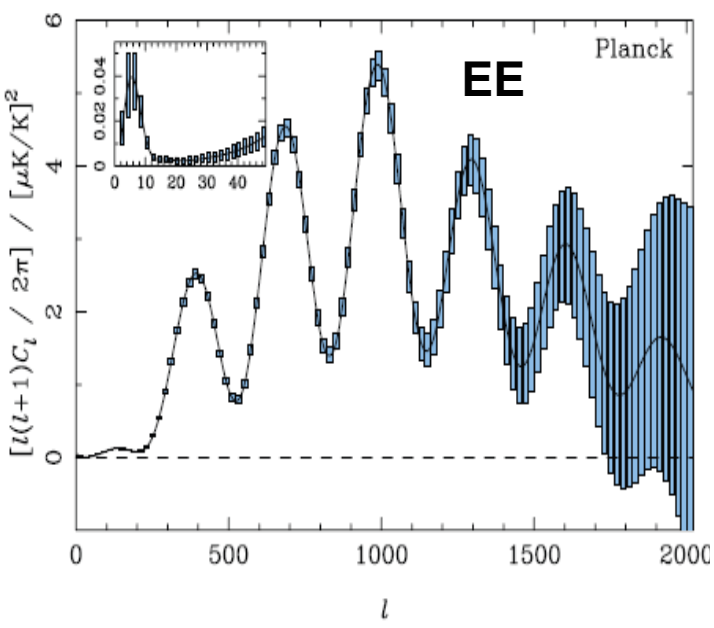
→ Ongoing work...

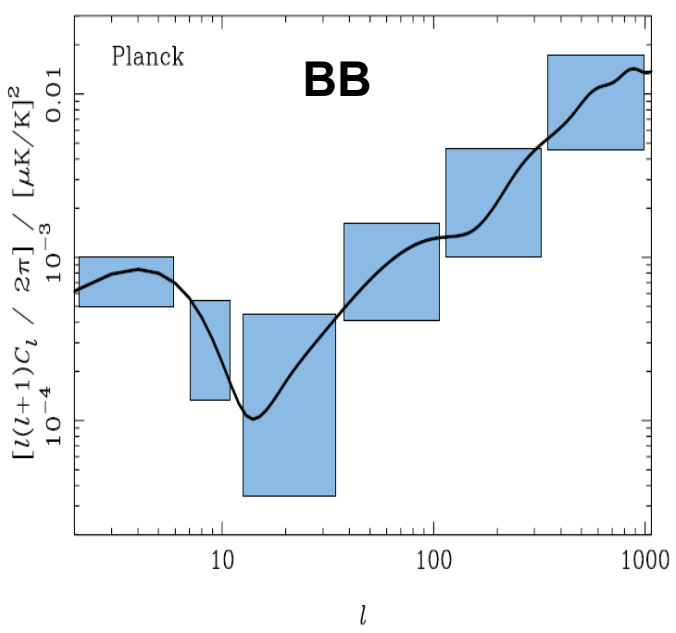
Planck prospects for cosmology

- ✓ Planck observes on a routine mode since August 13th 2009. Extended "cryogenic-mission" ~December 2011 → 30 months (vs 14) = 5 surveys (vs 2)
- ✓ Planck-HFI twice better than requirements (2/3 better @end extension ~0.33 μK.deg)
- ✓ **Release of Planck data and cosmological results ~end 2012**

Predictions of power spectra measurements from the Blue book (nominal 14month mission)







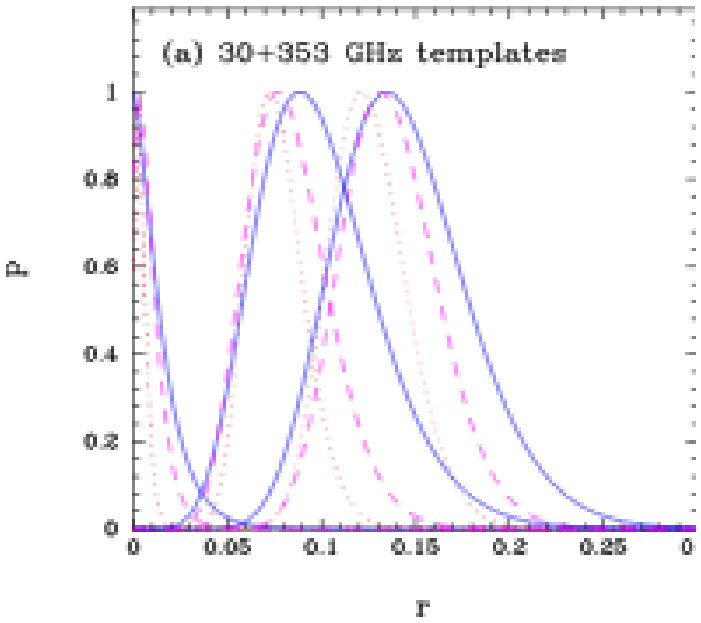
Goal → **Test simplest inflation**: n_s to 4.5 10^{-3}, $dn_s d\ln k$ to 5. 10^{-3} (and τ to 6. 10^{-3}) & non-Gaussianity

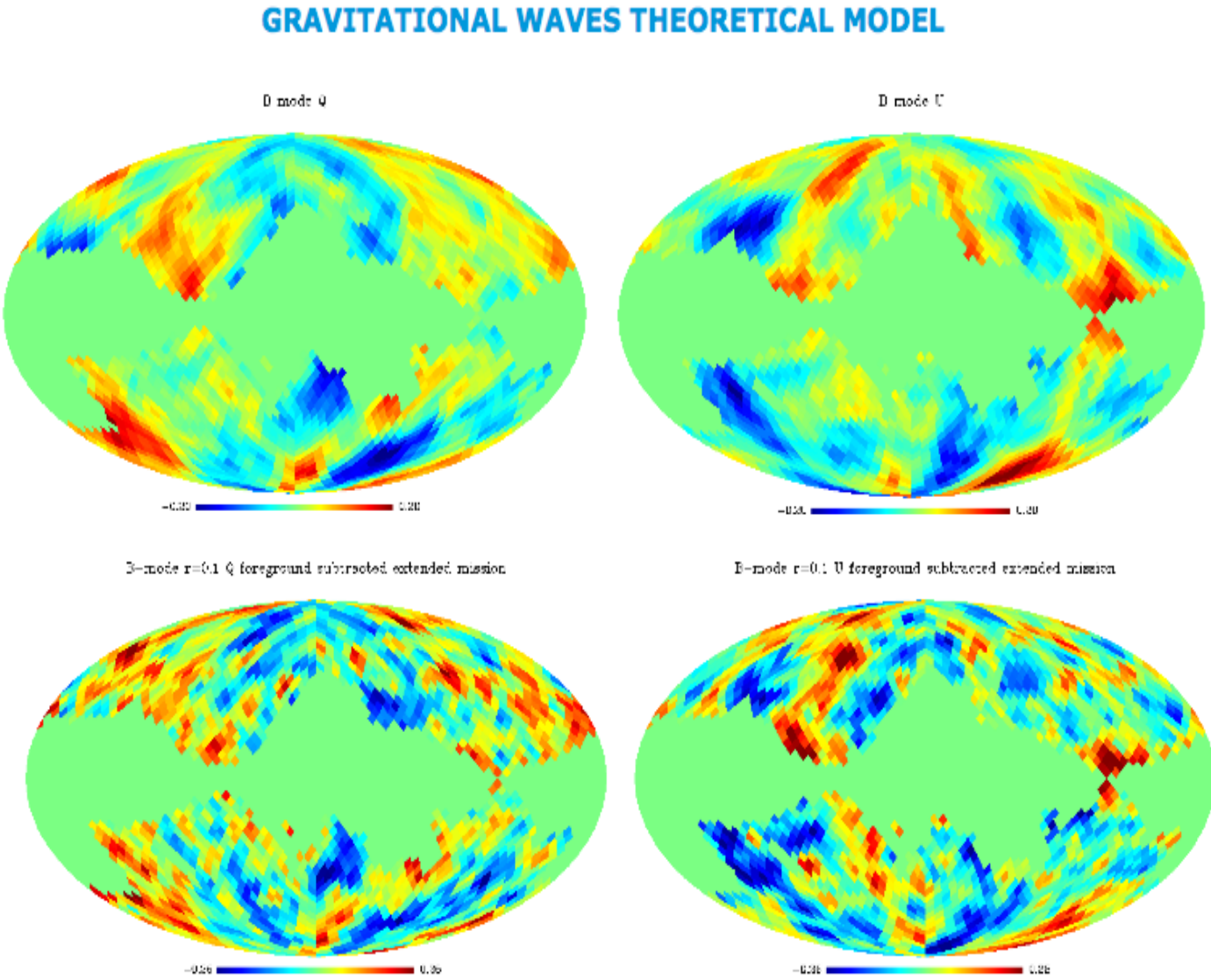
Planck prospects for cosmology

Goal → **Constrain the tensor to scalar ratio from B-modes**
Test case from simulation template fitting using Planck channels 30 and 217 (353) GHz

→ Planck should detect tensor-to-scalar ratio down to 0.05
Blue: nominal mission
Magenta: extended mission

Efstathiou & Gratton 2009





“Legacy” from Planck early results

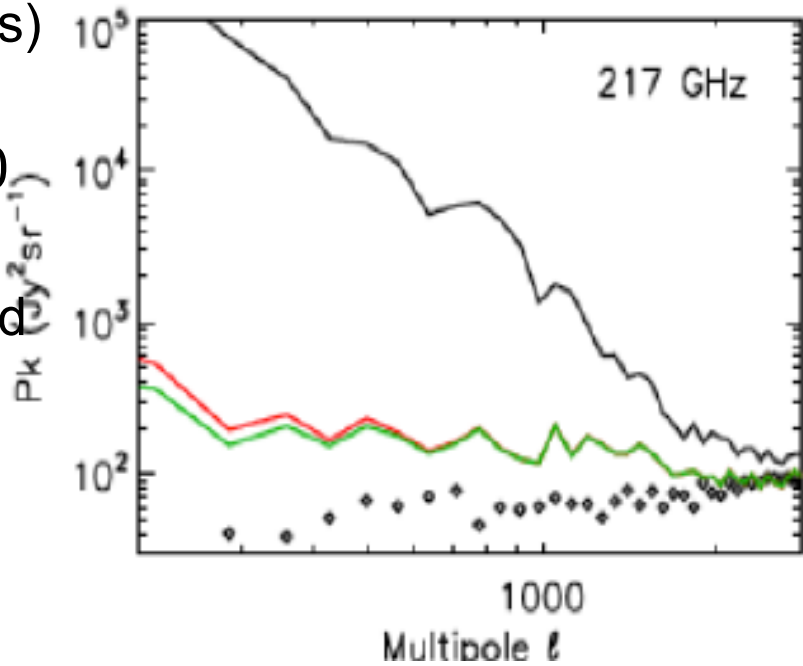
Noise Level OK → Sensitivity (~0.5 µK.deg) twice better than requirements (WMAP ~5.3 µK.deg in 8yrs) extended mission ~0.33 µK.deg

→ 10 sigma detection of CIB (0.1% CMB) @l=200

Challenges for cosmology

→ Control of instrumental systematics (intensity and polarisation)

→ Control of astrophysical contamination for intensity (high l) & polarisation (E and B modes)



I. For Polarisation: Two main polarised foregrounds

- Synchrotron emission (40%) → measured @30GHz
- Interstellar dust (5%) → measured @353GHz

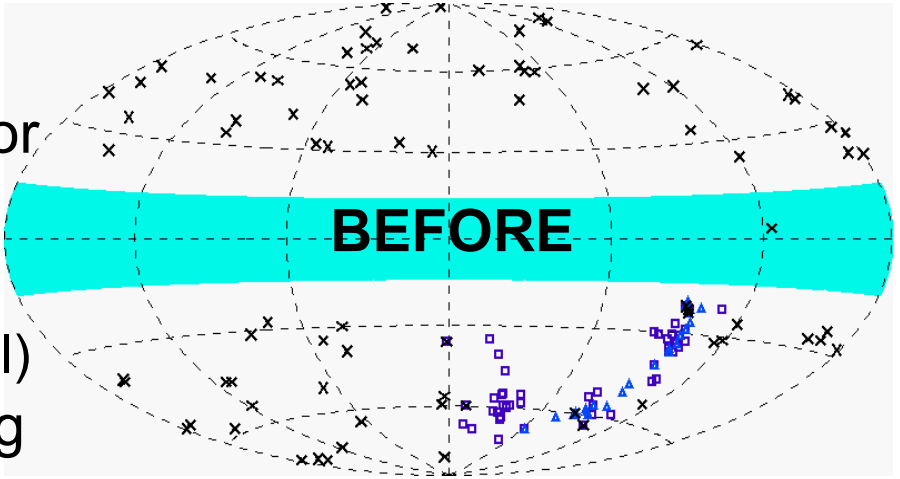
II. For Intensity: Main domains of progress for component separation

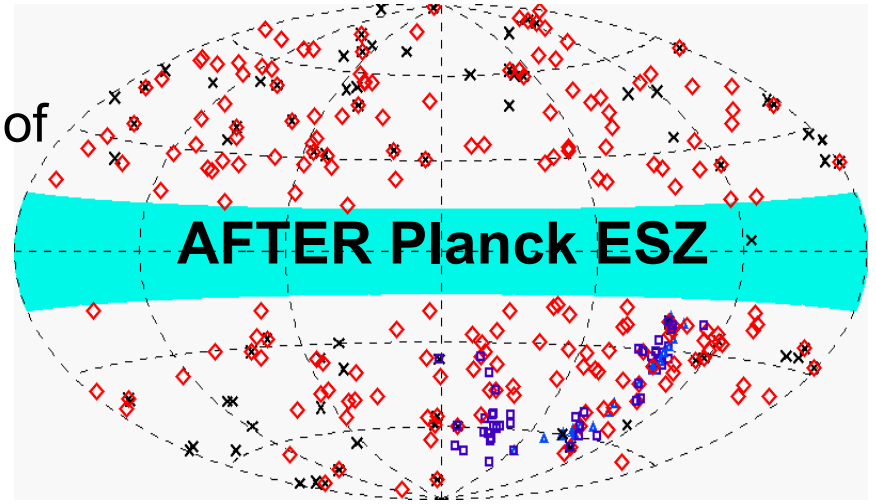
- Anomalous emission measured by Planck & fitted all over the sky
- Dust model improved (evolution from diffuse ISM to molecular clouds, emission from diffuse molecular hydrogen, CO emission)

“Legacy” from Planck early results

II. For Intensity : Main domains of progress for cosmological parameter estimates

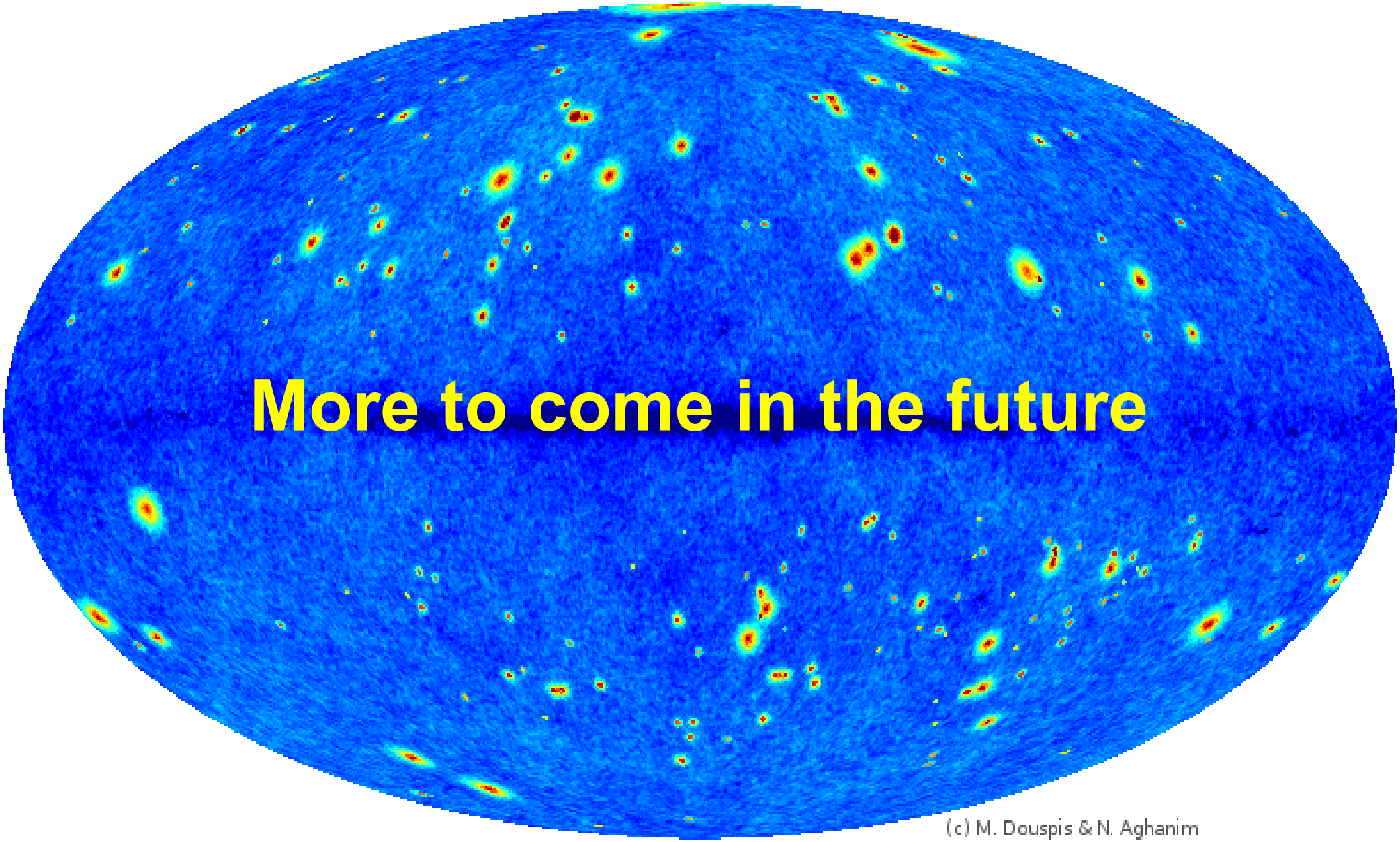
- CIB anisotropies measured (high l control)
- Radio counts & model improved (high l control)
- Model of SZ signal improved from converging view of the ICM (high l control)
- Future constraints from clusters (ESZ ~4 times larger than present SZ samples, Most complete set of the most massive clusters at z<0.5(
- Lensing measurements
- And more





Planck is a CMB mission with very wide astrophysical capabilities (19 Planck early result articles, 10months of data ~6 months of analysis)

- Limited resolution (>4') but excellent sensitivity
- All-sky survey, First ever above 100GHz


More to come in the future
(c) M. Douspis & N. Aghanim