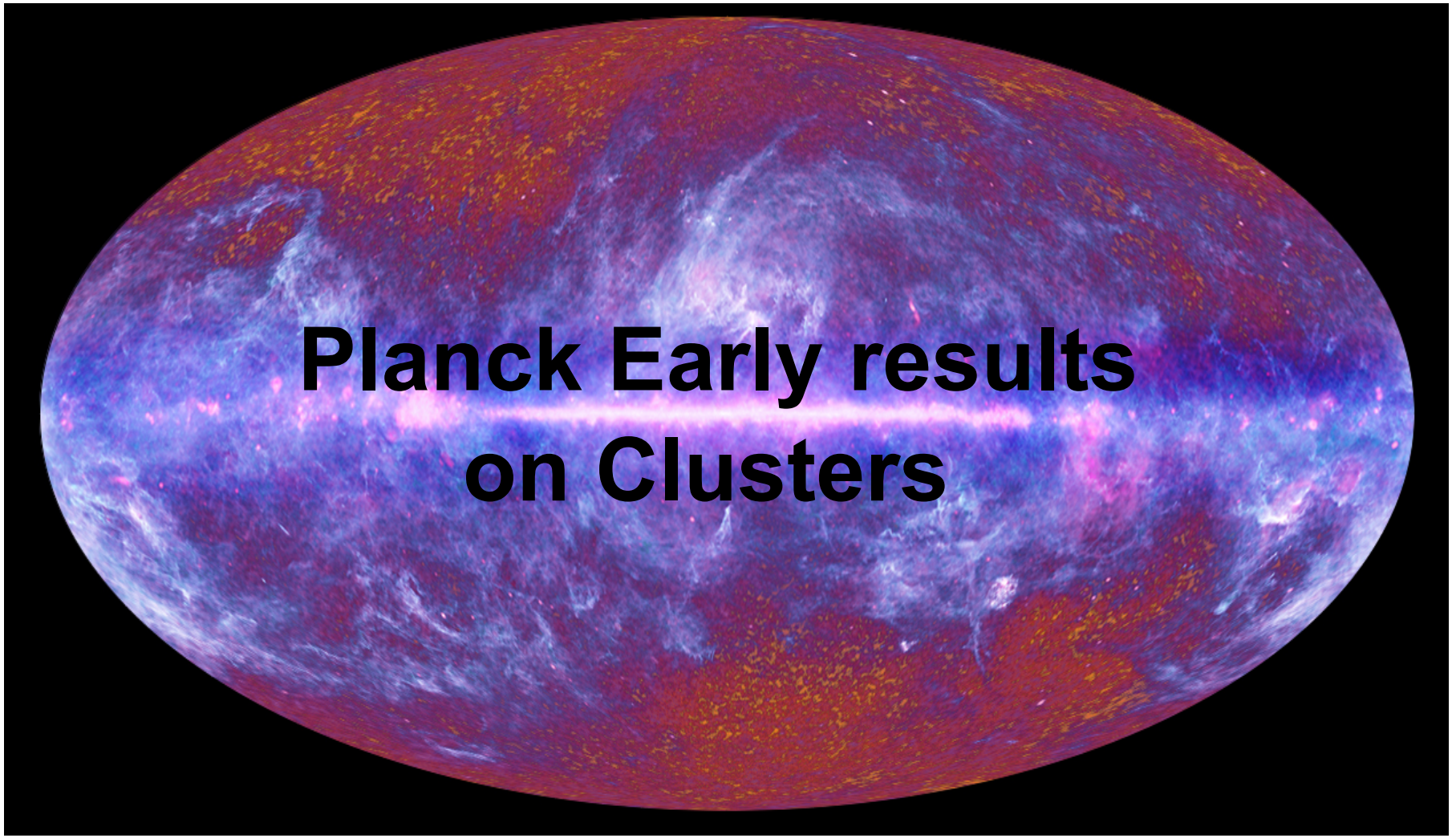


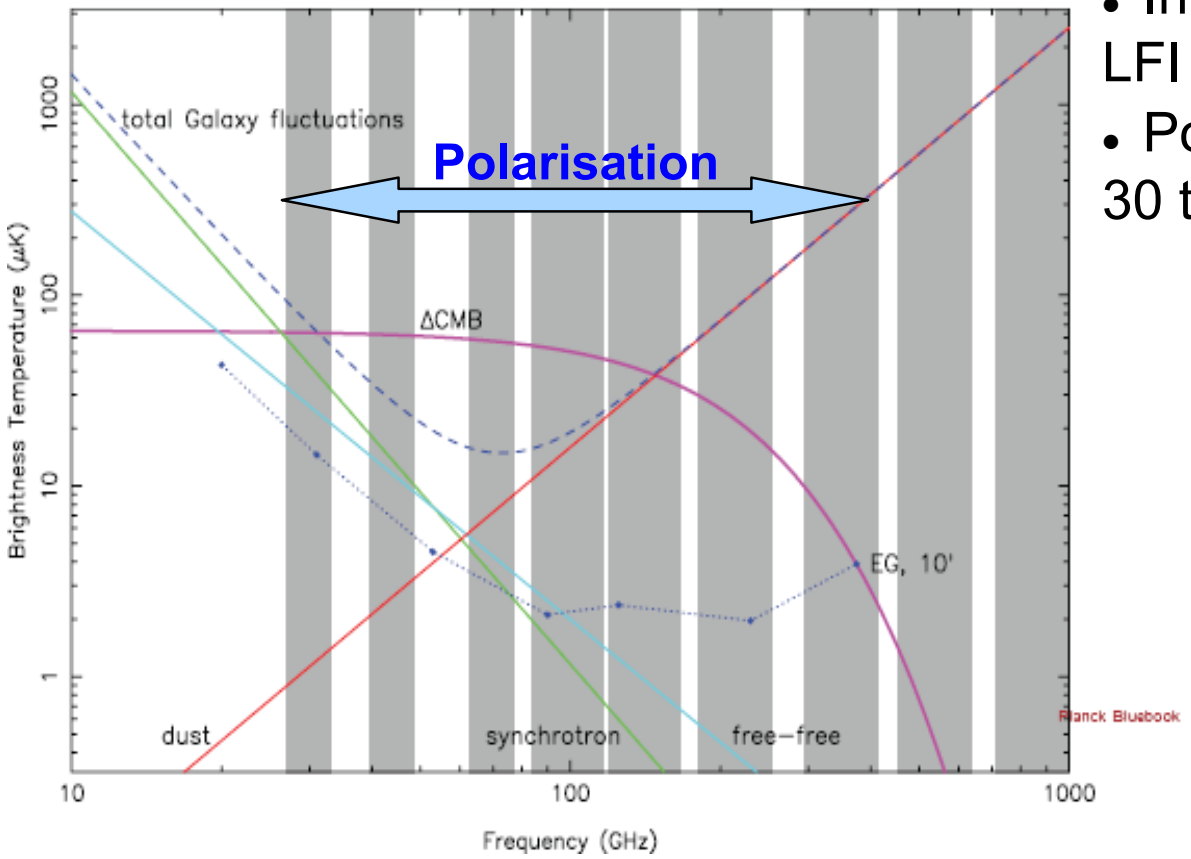
Planck Early results on Clusters

Nabila Aghanim
Institut d'Astrophysique Spatiale, CNRS-Univ. Paris Sud
on behalf of the Planck collaboration

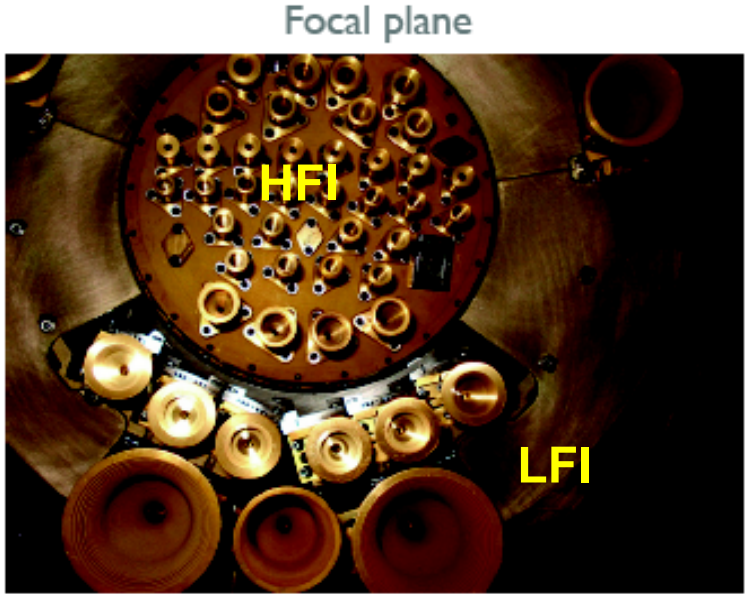

esa
planck
cnes
agenzia spaziale italiana
NASA
cnrs
DTU Space
National Space Institute
Science & Technology Facilities Council
INAF ISTITUTO NAZIONALE DI ASTROFISICA
CSIC
Consejo Superior de Investigaciones Científicas
HFI PLANCK
PLANCK LFI
IAS orsay
IAP
INAF - IASF BO
ISTITUTO NAZIONALE DI ASTROFISICA
ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI BOLOGNA
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
Aalto University
ioa
KICC
Kavli Institute for Cosmology Cambridge
Cavendish Astrophysics
University of Cambridge
Cardiff University
Prifysgol Caerdydd
irfu
saclay
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
ISDC Data Centre for Astrophysics
JPL
LAL Laboratoire de l'Accélérateur Linéaire
l'Observatoire de Paris LERMA
LPSC Grenoble
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
Università degli Studi di Roma 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 → 3rd generation of CMB space mission
Primary goals → CMB temperature anisotropies to fundamental limits down to 4 arcmin & CMB polarisation

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



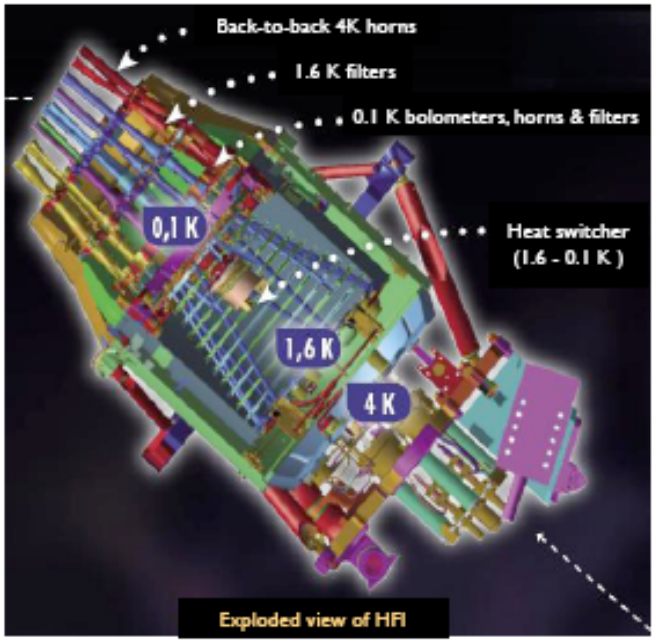
- Intensity measured with HFI & LFI at 9 frequencies, 30 to 857GHz
- Polarisation measurements from 30 to 353GHz

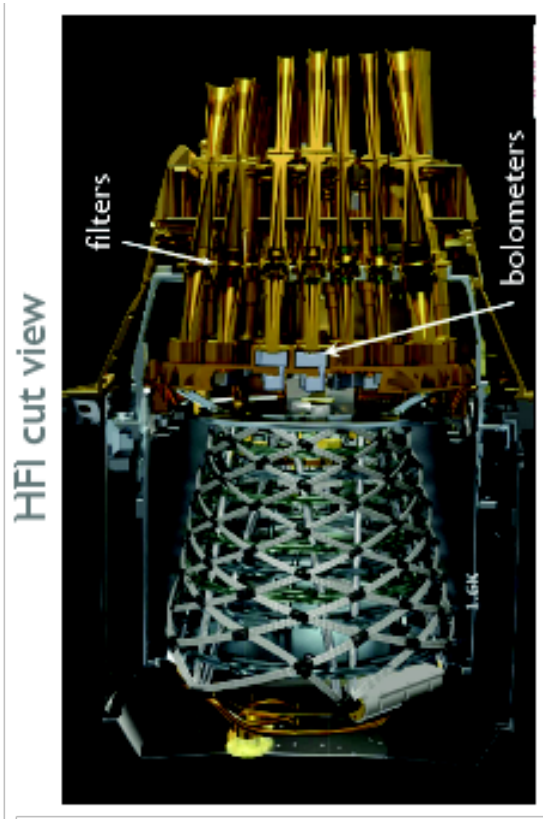


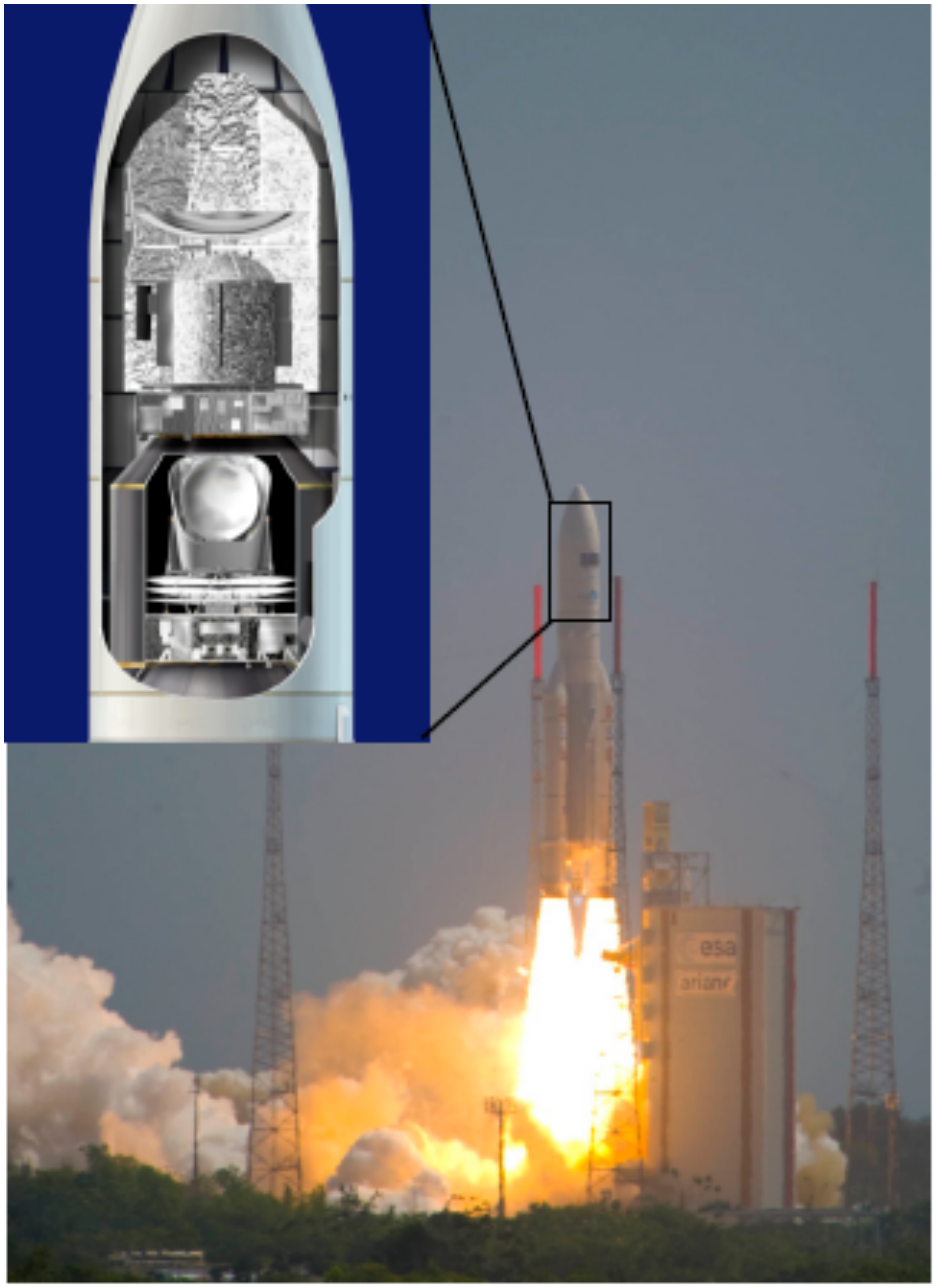
Planck required sensitivity → Technological performances never achieved in space before

In particular, flying:

- Sensitive and fast bolometers → Cooling at 100mK
- Complex cryogenic cooling chain: 50K (passive) +20K+4K+1.6K+0.1K (active)
- 100mK helium 3 & 4 dilution cooler

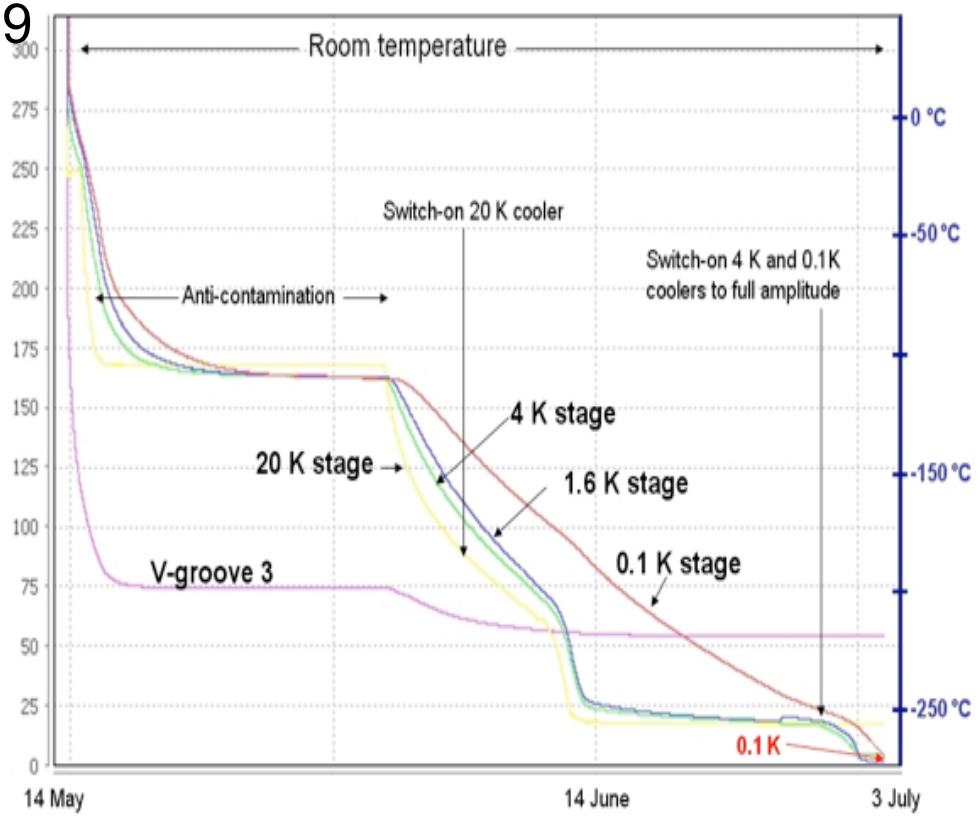






Planck and Herschel launched on May 14th 2009, Kourou Fr. Guyana

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



Very stable continuously scanning the sky since August 2009

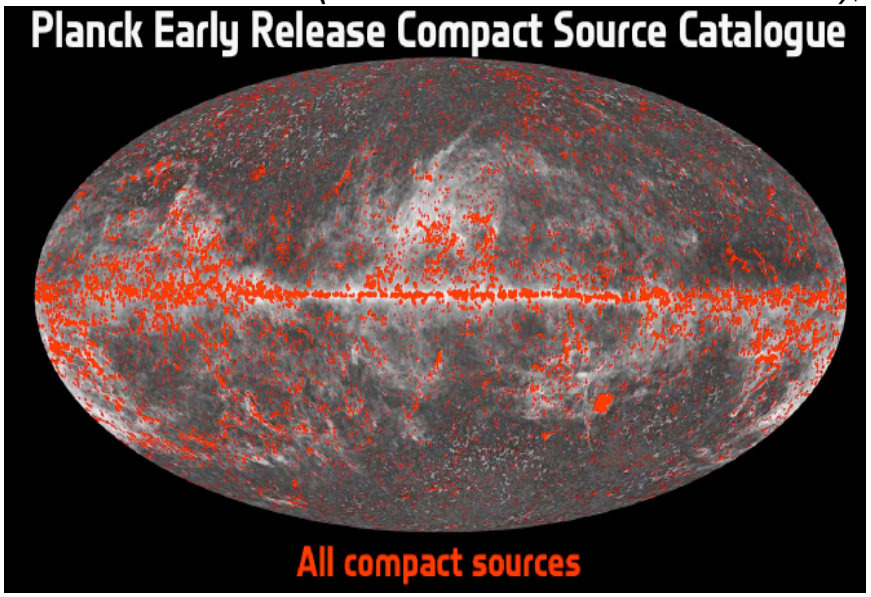
Nominal mission (14 months, 2 surveys) **achieved November 2010**

Extended cryogenic mission (30 months, 5 surveys) **achieved ~January 2012**

Early results from Planck

Early results & first product from 10 months of observation (~4 months analysis) → 20 science articles (sensitivity ~0.5 μK.deg **twice better** than requirements @100-217 GHz)

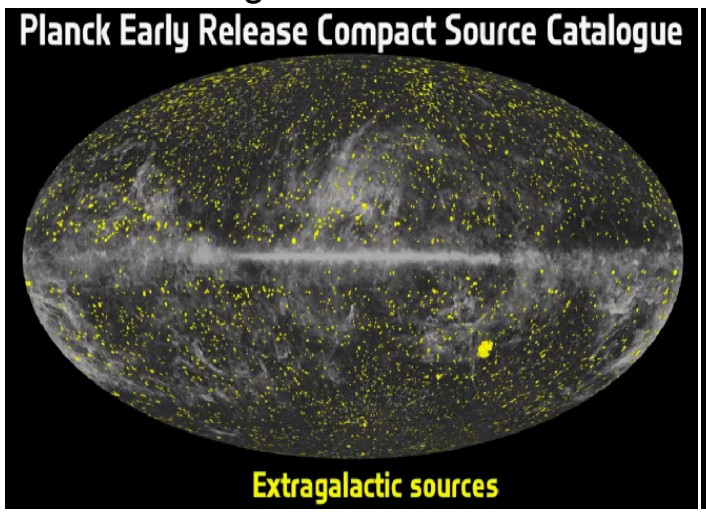
(Details in arXiv1101.2041)



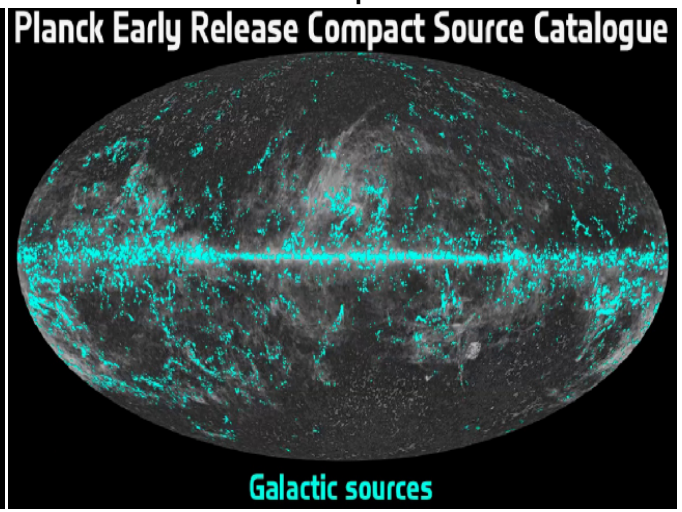
- Planck first product: **Early Release Compact Source Catalogue** available from www.rssd.esa.int/Planck
- **First all-sky catalogue 100 to 900GHz** (simultaneous radio through sub-mm all-sky survey)

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

- IR-luminous galaxies
- Radio galaxies



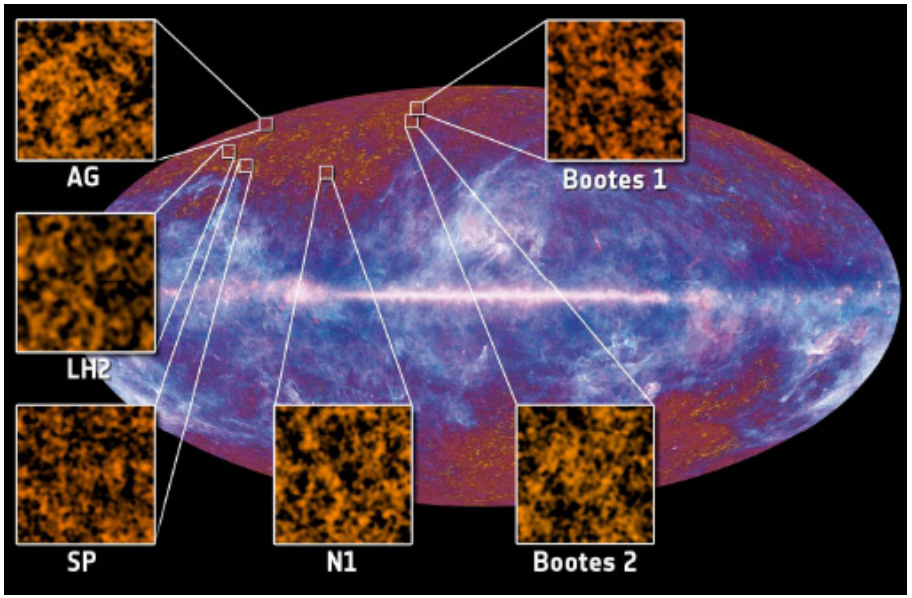
- Features in ISM (flag extended)
- Cold cores/clumps



Early results from Planck

- **CIB,** cumulative emission of dusty galaxies (cosmic star formation)

CIB measured in 6 high latitude fields (low dust contamination) → sub-degree structure correlated over freq., dominant over white noise agrees with BLAST, SPT



CIB anisotropies in Planck → forming galaxies @z~2-3 *(details in arXiv1101.2028)*

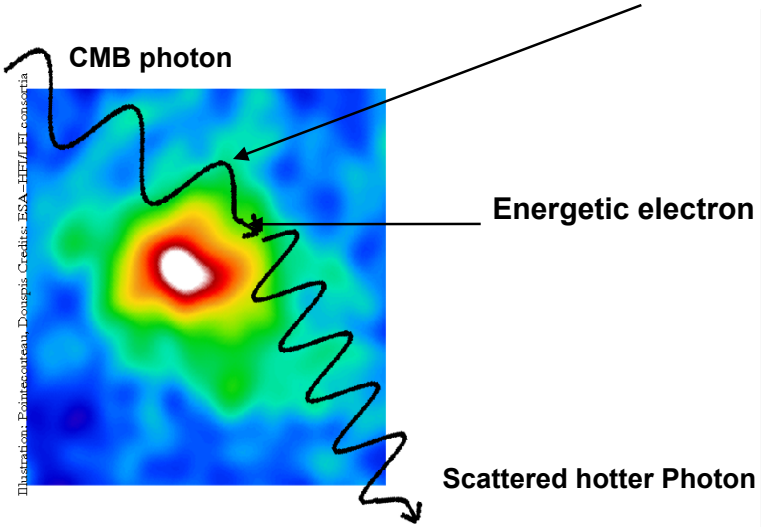
Galactic cold cores → Large numbers of cold compact objects: prospect for the study of the star formation

Confirmation of anomalous emission → Spinning dust most plausible, "New" regions of anomalous emission

All-sky temperature and dust optical depth from Planck and IRAS → Emission from diffuse molecular hydrogen, "dark gas"

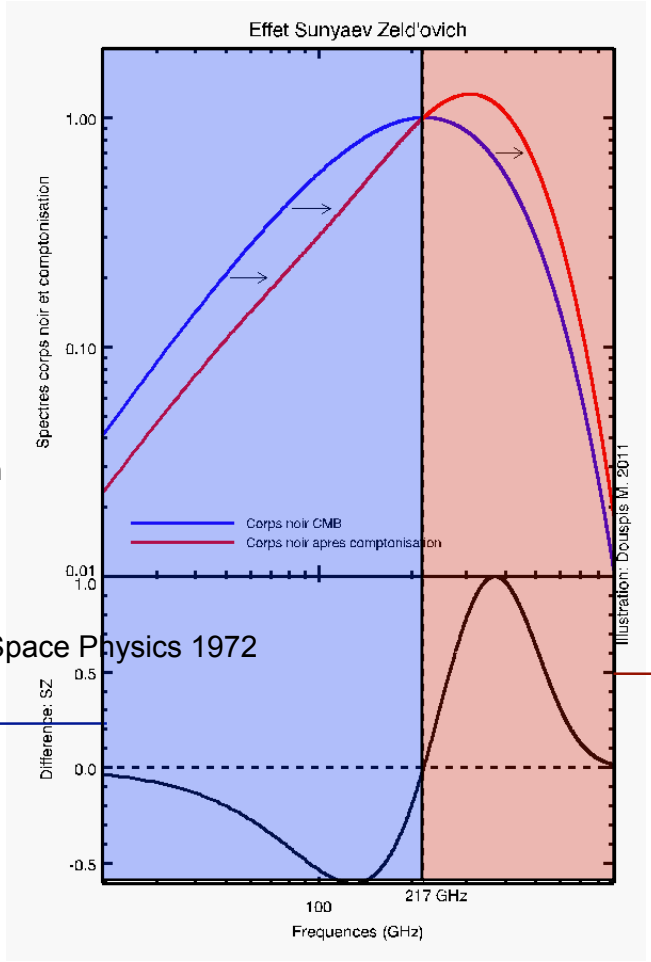
The Sunyaev-Zel'dovich (SZ) effect

Galaxy cluster = galaxies + hot gas



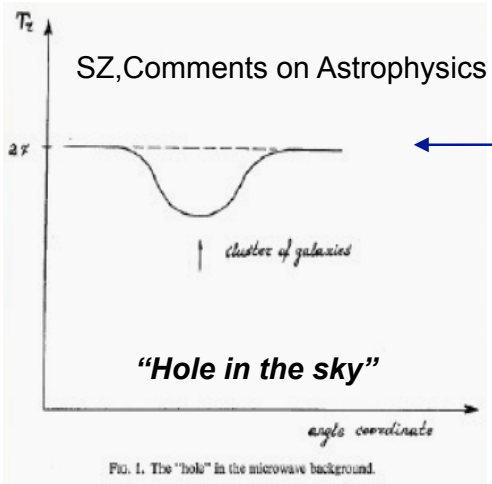
R. A. Sunyaev

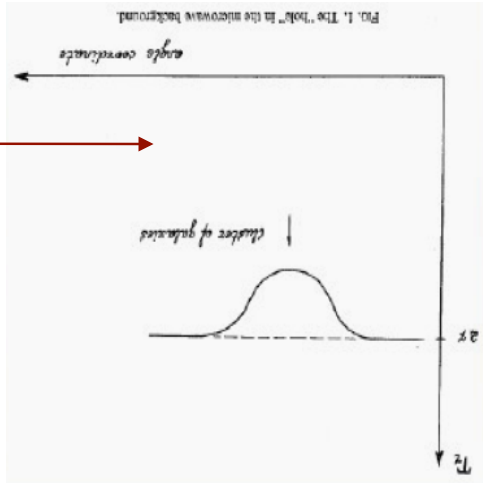
Ya. B. Zeldovich



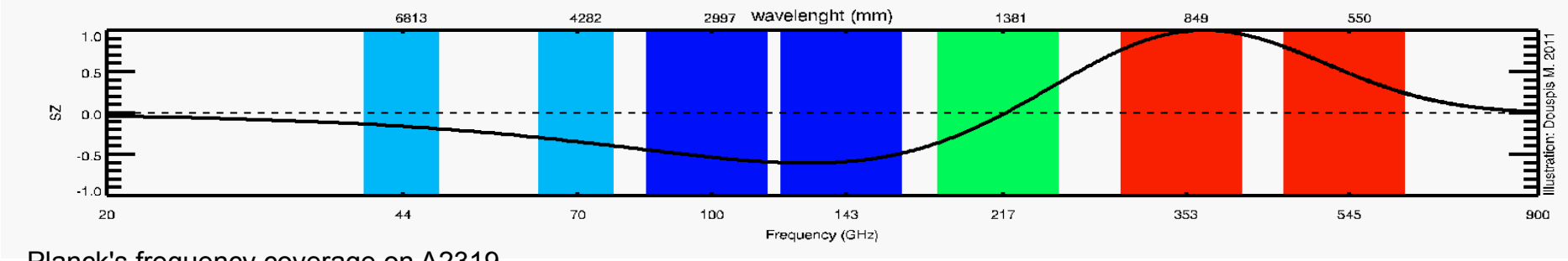
$$y = \int \frac{k_B T_e}{m_e c^2} n_e \sigma_T dl$$

SZ,Comments on Astrophysics and Space Physics 1972

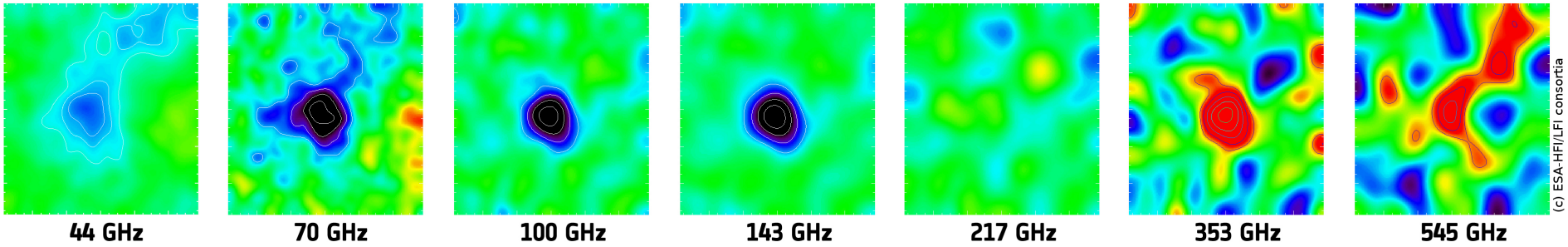




Planck's uniqueness for SZ detection

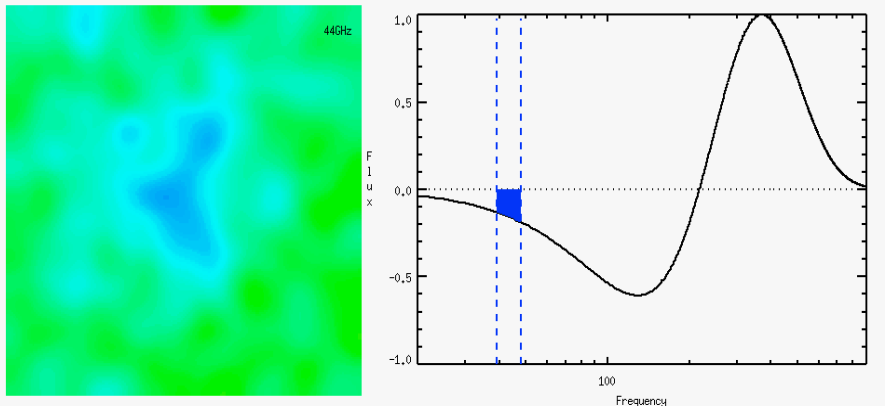


Planck's frequency coverage on A2319



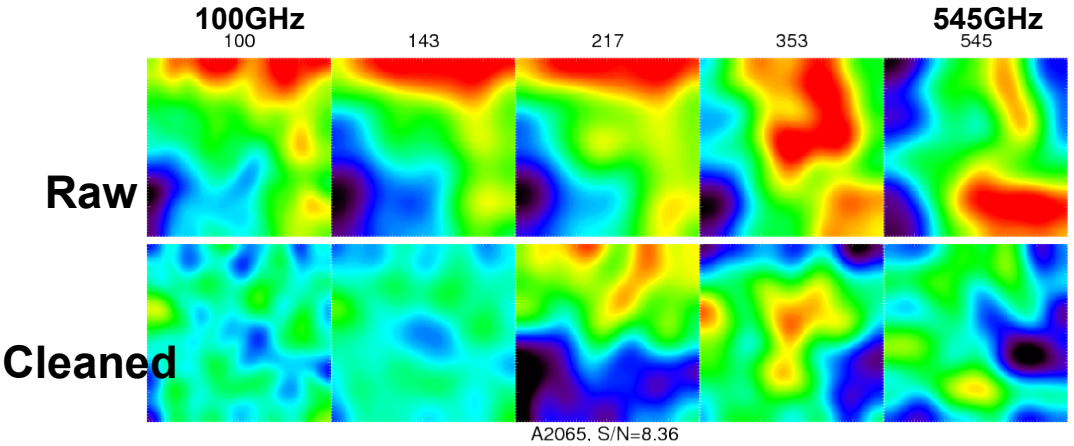
→ **Planck, designed from the start to measure SZ**

- **All-sky survey**
- **Frequency range from 30 to 857 GHz**
- **Blind and simultaneous measurement of "positive" and "negative" SZ effect**



SZ detection in Planck

Typical clusters → 1-2 sigma in individual cleaned frequency maps

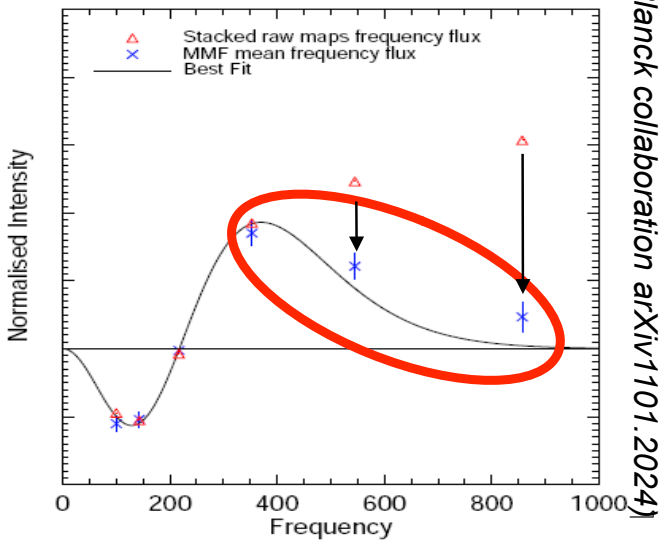


Adapted extraction technique → Matched Multi-Filter *(Melin et al. 2006)*:

- known spectrum → non-relativistic SZ
- known cluster shape → Generalised NFW pressure profile *(Arnaud et al. 2010)*

SZ signal enhanced over other components

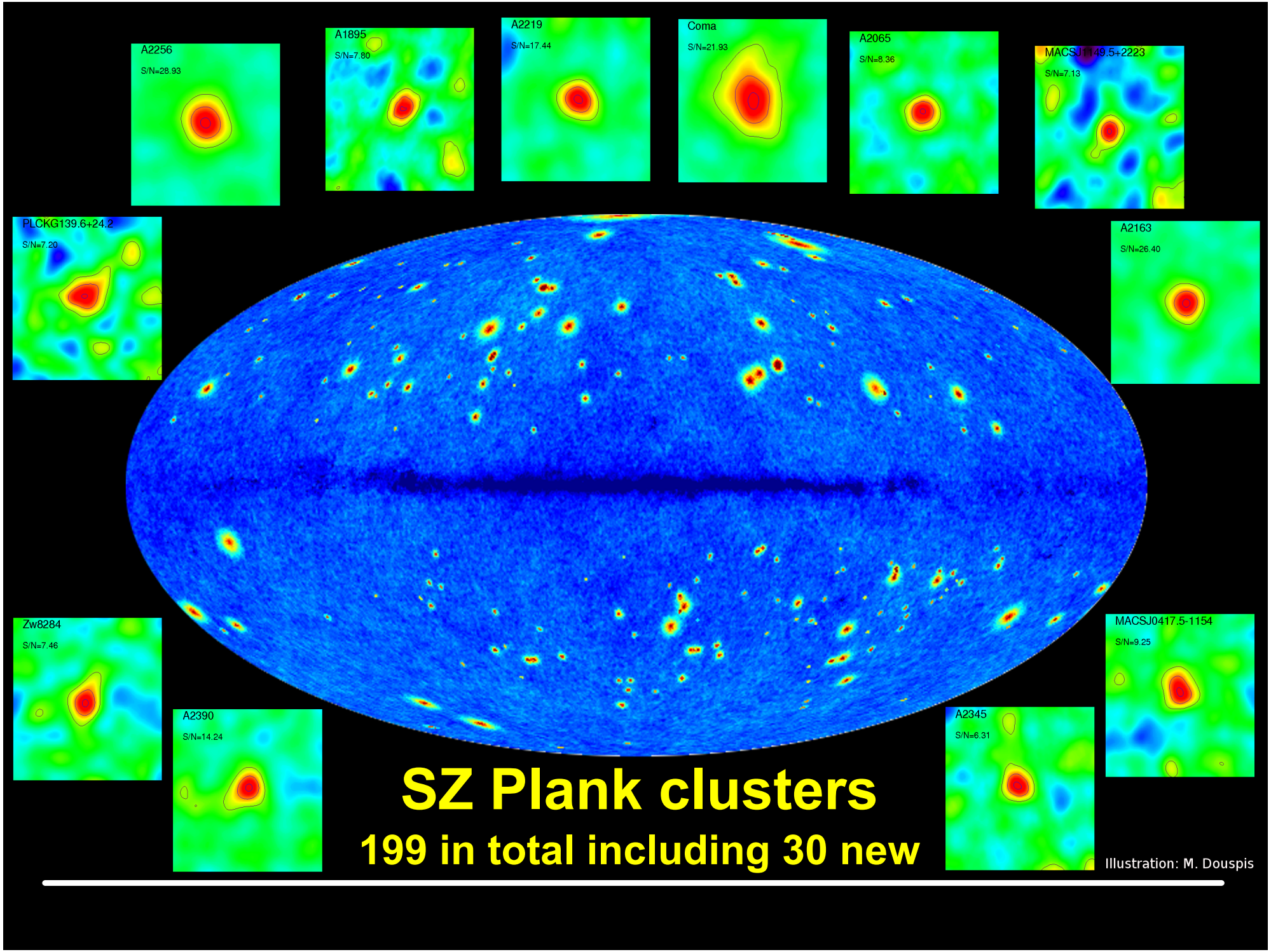
Validation → Planck internal criteria, use of ancillary data and follow-up observation for confirmation



Average Spectrum over the ESZ clusters

(Planck collaboration arXiv1101.2024)

Early SZ sample → High reliability = **S/N>6** & purity >98%

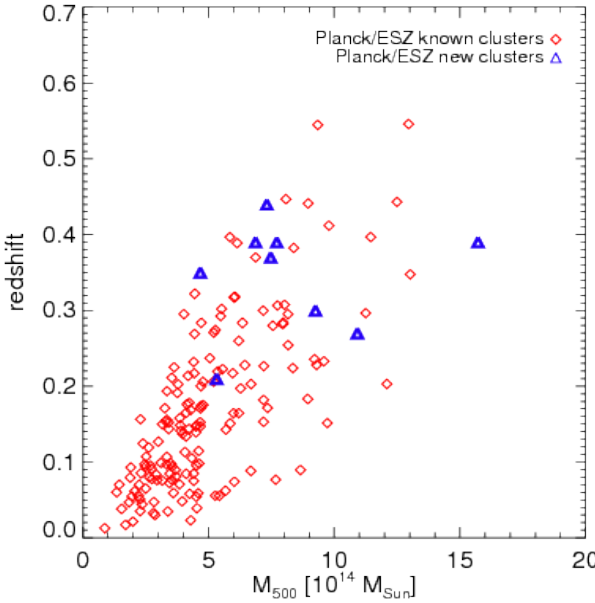

A2256
S/N=28.93
A1895
S/N=7.80
A2219
S/N=17.44
Coma
S/N=21.93
A2065
S/N=8.36
MACSJ1149.5+2223
S/N=7.13
PLCKG139.6+24.2
S/N=7.20
A2163
S/N=26.40
Zw8284
S/N=7.46
A2390
S/N=14.24
A2345
S/N=6.31
MACSJ0417.5-1154
S/N=9.25
SZ Plank clusters
199 in total including 30 new
Illustration: M. Douspis

The all-sky Early SZ (ESZ) cluster sample

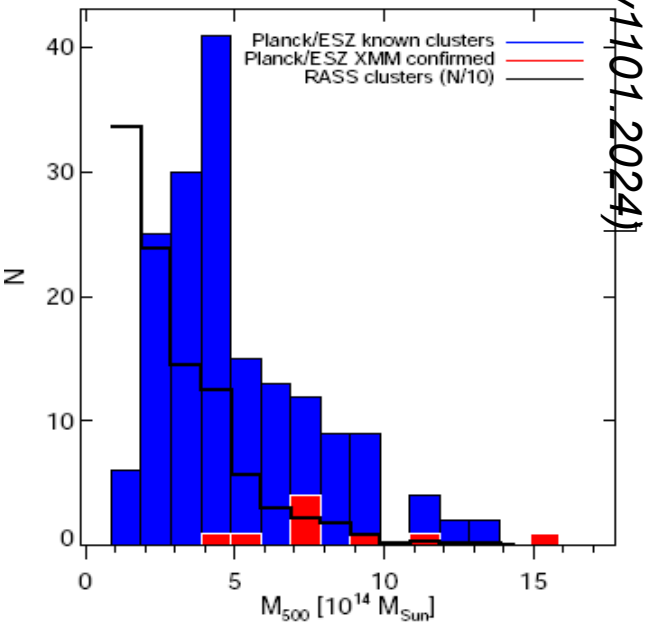
ESZ sample = 189 candidates (S/N> 6 & |b| >14deg)

- 169 identified with known clusters
- 20 candidate new clusters (18 confirmed to date, including 6 by SPT & AMI independently from Planck collaboration)

Further 10 new clusters (S/N <6)



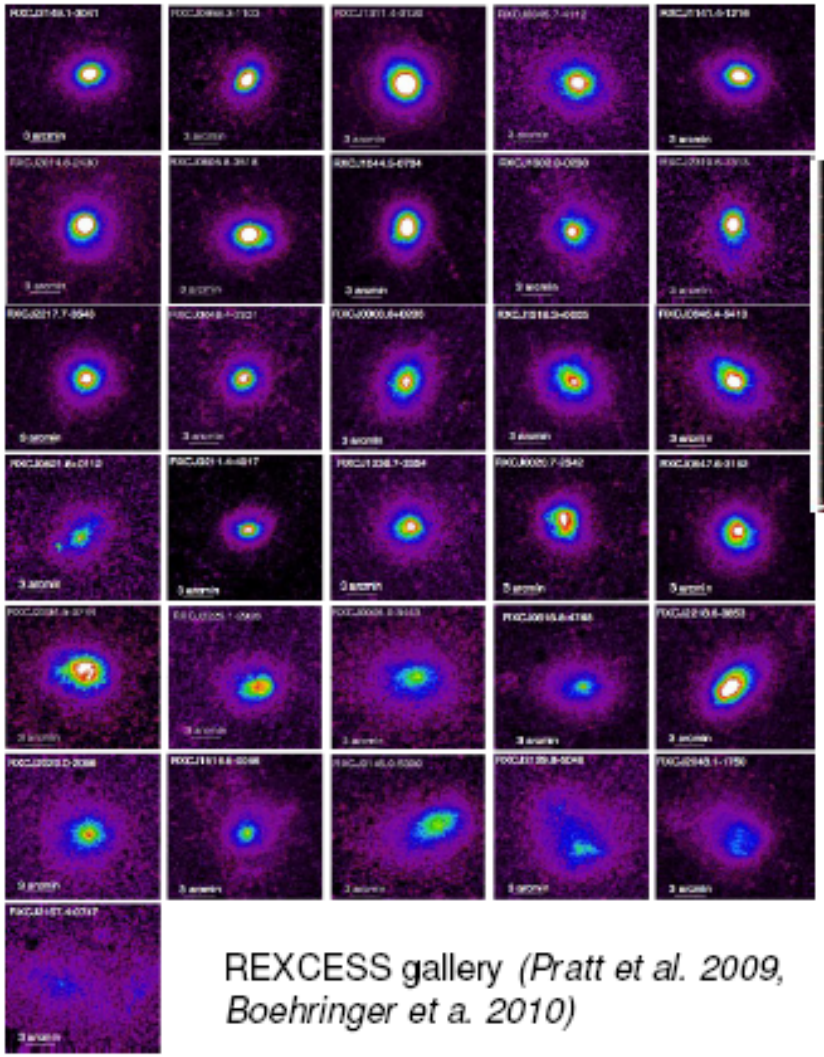
- First **all-sky SZ sample** of clusters
- Largest **homogeneous** sample of SZ clusters with moderate redshifts (86% with z<0.3) & First SZ measure for ~80% of the known clusters
- Largest SZ sample of **massive clusters** detected blindly (up to 1.5×10^{15} M_{sol}). Includes 90% of RASS massive clusters (20% new clusters are massive)



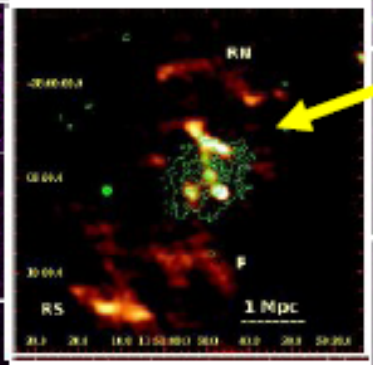
(Details in arXiv1101.2024)

Preview of Planck cluster properties from XMM-*Newton*

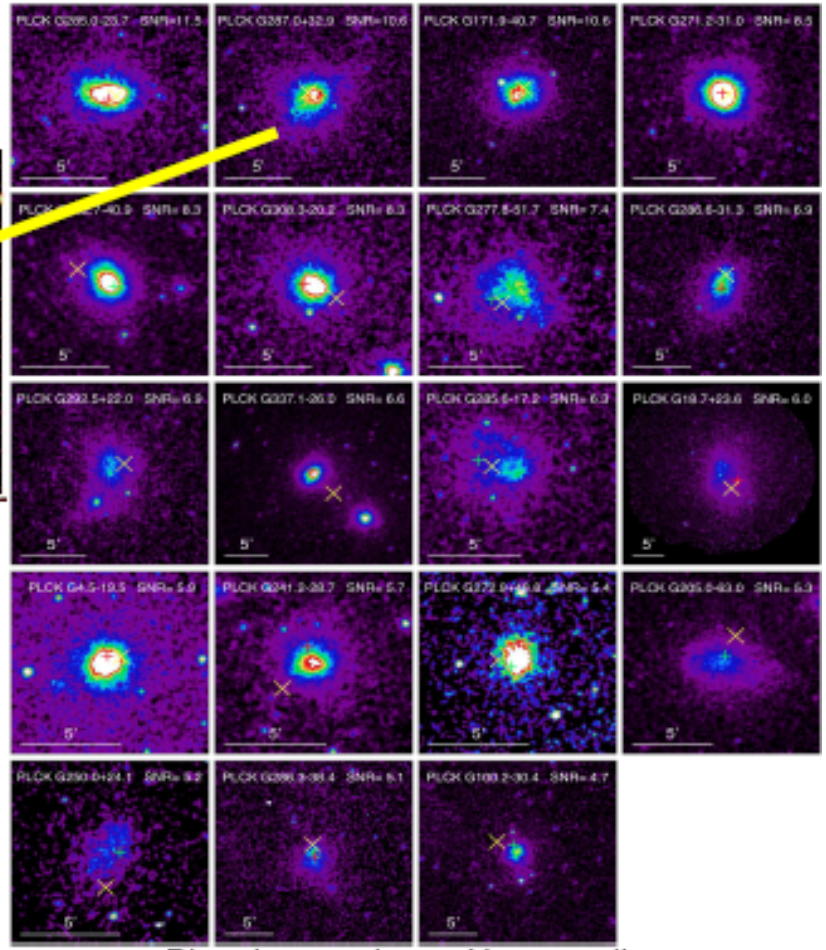
- 21 of 30 cluster candidates confirmed with XMM-Newton DDT snapshots
- Most Planck new clusters have **disturbed morphologies**



REXCESS gallery *(Pratt et al. 2009, Boehringer et a. 2010)*

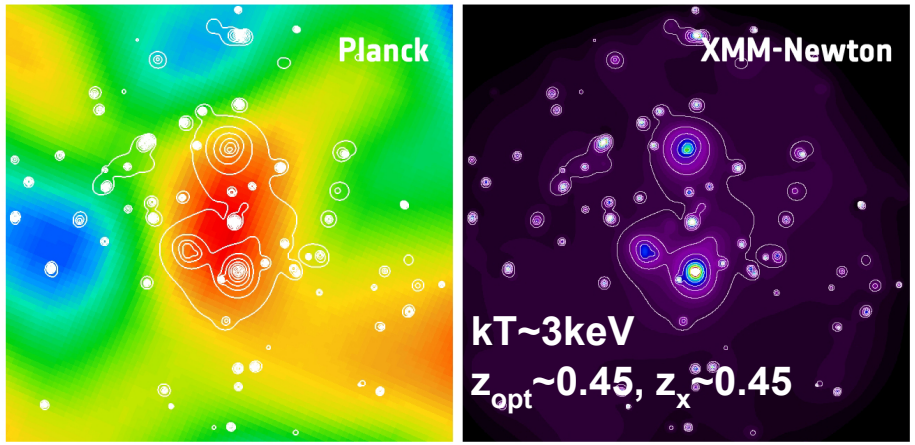


GMRT 150Mhz.
Bagchi et al. '11

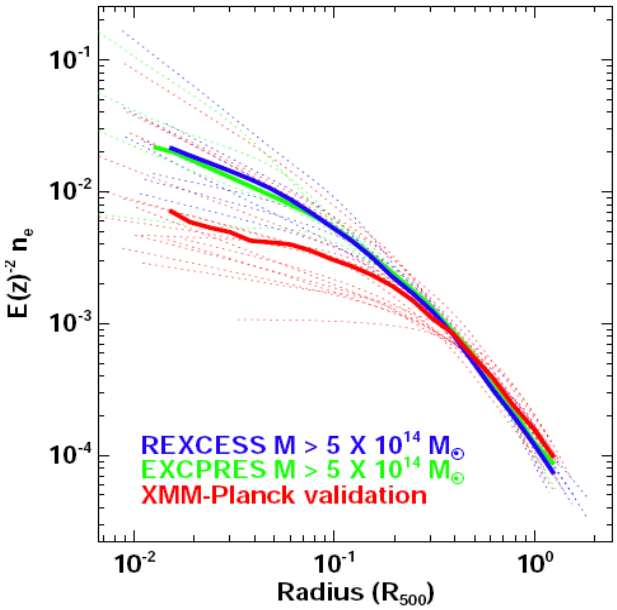


Planck new cluster X-ray gallery
(Planck collaboration arXiv:1101.2025

Preview of properties of new Planck clusters from XMM-*Newton*



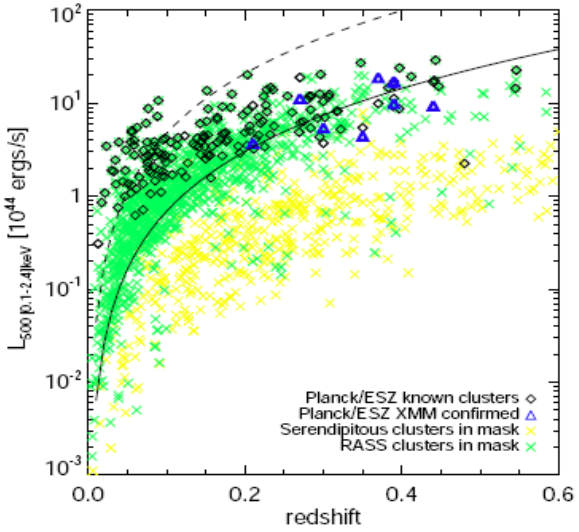
Multiple systems: double, triple systems
→ First super-clusters in SZ



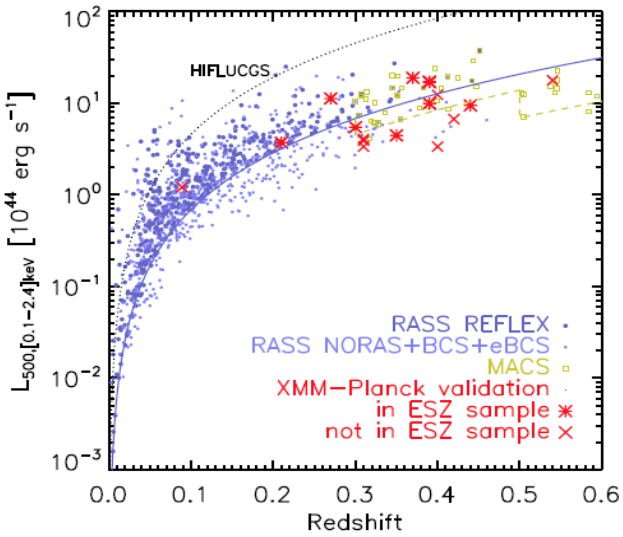
- Density profiles of Planck new clusters **shallower than X-ray clusters** of similar masses REXCESS or EXCPRES)
- X-ray under-luminous for their masses

ESZ sample vs other surveys

Planck ESZ clusters (black & blue)



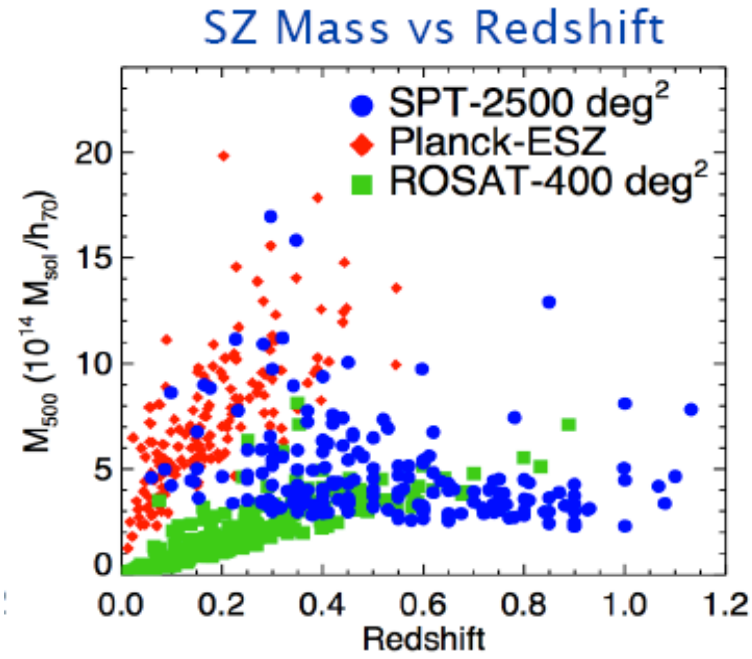
All new Planck clusters red/orange



- ESZ completes the high M-z region sparsely-populated by RASS clusters (massive dynamically perturbed systems)

Planck has the unique capability to detect the most massive clusters over the whole sky

- ESZ reference sample for z<0.5 massive clusters complementary to high-z SPT sample



Courtesy, B. Benson & G. Holder

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

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

Optical: Statistical analysisof **~13000 MaxBCG clusters** from SDSS *(Koester et al. 2007)*

SZ signal measured in Planck at cluster positions (& binned)
SZ signal Y_{sz} predicted from X-ray and optical relations
(Details in arXv1101.2027, 1101.2043)

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** (e.g. *Rozo et al. 2009*) + gas pressure profile & scaling relations

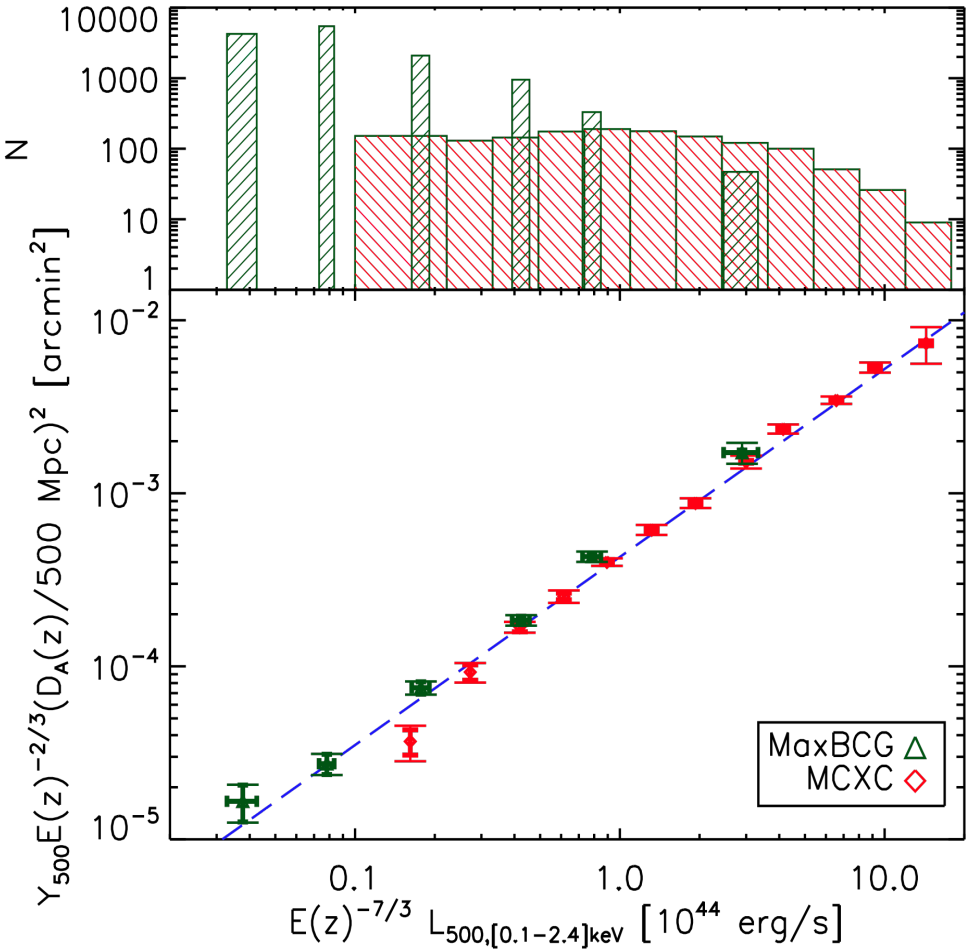
Minimise systematics → consistent approach for (i) SZ extraction & X-ray predictions and (ii) for homogeneisation

Planck's preview of the cluster properties

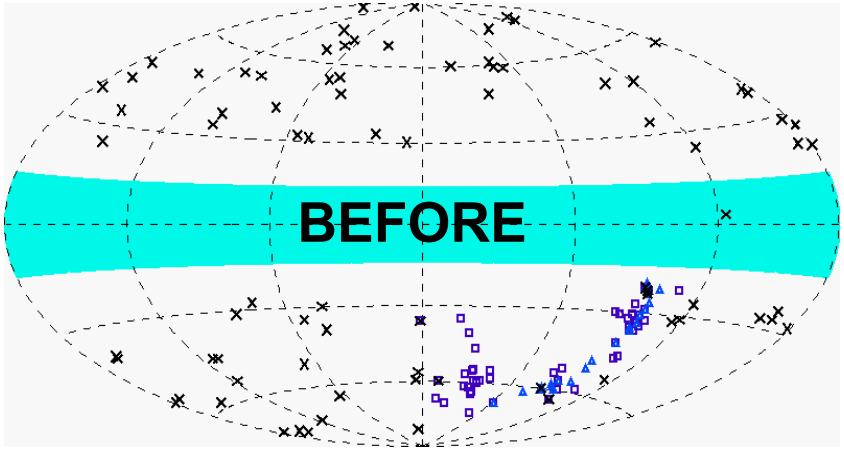
Optical and X-ray statistical studies → SZ signal measured in Planck down to ~ 5. 10^{13} M_{sol}

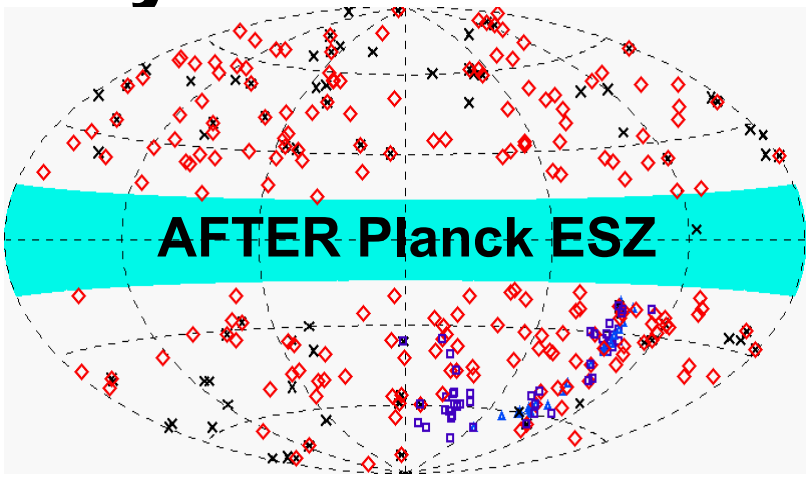
- SZ measure from Planck & X-ray luminosities agree down to lowest luminosity bins
- No SZ deficit (*Details in arXiv1101.2043*)
- Discrepancy between data and predictions of SZ-richness (SZ signal lower than predicted) (*Details in arXiv1101.2027*)

⇒ Robust and consistant overall view of ICM properties from X-ray and SZ **BUT** unexplained SZ-optical discrepancy

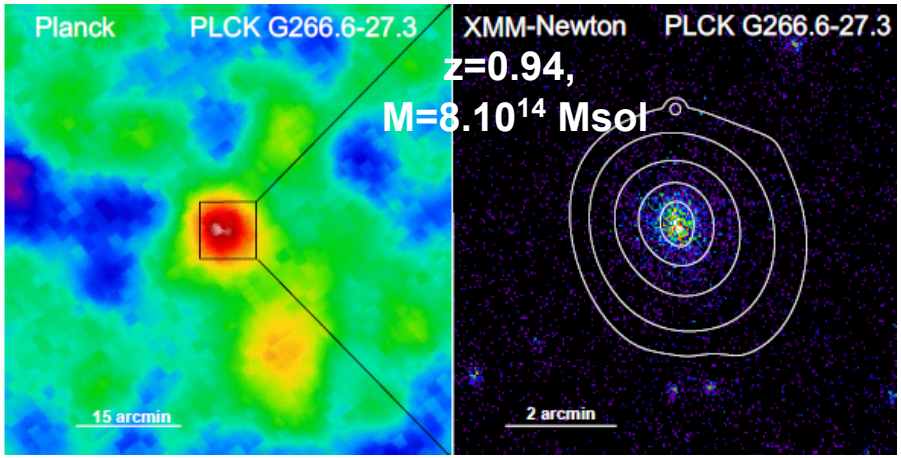


Summary



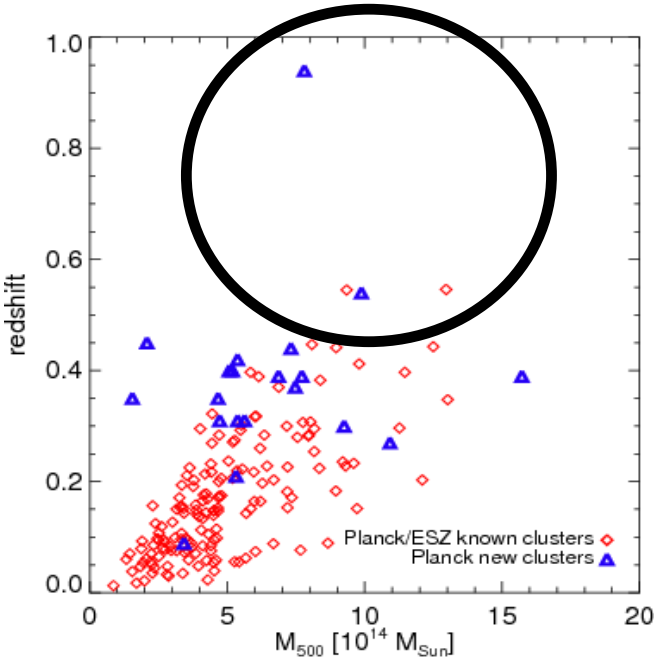


- Unique all-sky SZ sample of 199 SZ clusters (~4 times present SZ samples) →
  Largest set of SZ massive clusters at z<0.5
- Most of the new Planck clusters are dynamically perturbed
- Converging X-ray and SZ views of the ICM
- Tension between SZ signal and predictions from optical richness



Early results =
high reliability
→ **High S/N**

At lower S/N
→ Beyond ESZ detection limit



Conclusion

- ✓ Planck in routine mode since August 2009, with HFI exceeding requirements
- ✓ Nominal mission 14 months achieved November 2010
- ✓ End of extended cryogenic mission ~January 2012 (sensitivity ~0.33 μK.deg)
- ✓ **First cosmological results and nominal mission data (catalogues & maps) to be released beginning 2013**