CLUSTERS OF GALAXIES IN THE PLANCK SURVEY

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on behalf of the Planck Collaboration
THE PLANCK MISSION
AND
THE SUNYAEV-ZEL’DOVICH EFFECT IN THE PLANCK SURVEY
The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada.

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 a collaboration between ESA and a scientific Consortium led and funded by Denmark.
THE PLANCK MISSION

- Launch in May 2009; L2 orbit
- 1.5m gregorian telescope
- 9 frequency bands 30-857GHz
- ~5-30 arcmin resolution

- LFI 22 radiometers, 3 frequencies
- HFI 72 bolometers+thermometers cooled down to 0.1 K, 6 frequencies

<table>
<thead>
<tr>
<th>Frequency</th>
<th>NET [μK_CMB s^{1/2}]</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>100P</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>143P</td>
<td>53</td>
<td>82</td>
</tr>
<tr>
<td>143S</td>
<td>41</td>
<td>62</td>
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<td>217P</td>
<td>79</td>
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<td>353P</td>
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<td>353S</td>
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<td>1410</td>
<td>1998</td>
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<tr>
<td>857S</td>
<td>41220</td>
<td>91000</td>
</tr>
</tbody>
</table>

nominal mission = 2 full sky surveys
extended mission = 4 surveys+
early results based on 1st sky survey (~7 months)
Inverse Compton scattering of CMB photons by ICM $e^-$:

$$F_\nu \propto Y \propto \int_\Omega P_{th} d\Omega \int_\Omega n_e T d\Omega$$
DETECTION OF CLUSTERS

Based on Matched Multi-Filter algorithm
[Melin et al. 2006]

- known spectral shape
  → non-relativistic SZ
  [Sunyaev & Zel’dovich 69, 72]

- known cluster spatial distribution
  → GNFW pressure profile
  [Arnaud+10]

→ Unique catalogue; only all sky cluster catalogue since RASS
THE EARLY RELEASE SZ SKY

(c) M. Douspis & N. Aghanim
THE ESZ SAMPLE

189 SZ sources with S/N > 6
- First SZ measure for ~80% of the known clusters
- 20 new clusters
  - 10 XMM confirmed
  - 1 AMI confirmed
  - 8 unconfirmed (01/2011) → now: 6 confirmed with SPT & AMI
SZ (PLANCK) / X-RAY (XMM)
VIEW OF HOT BARYONS IN THE UNIVERSE
**X-RAYS and SZ PROBING THE ICM**

Bremsstrahlung

\[ E_X \propto \int_V n_e^2 \Lambda(T) dV \]

Inverse Compton scattering

\[ F_\nu \propto \int_\Omega (P = n_e T) d\Omega \]

Hot intracluster gas probed by two different physical processes and signals

Expected relations between SZ and X-ray properties
Pressure is the fundamental quantity

\[ F_\nu \propto Y \propto \int \left( P_{th} = n_e T \right) d\Omega \]

\[ Y_X = M_{gas} T_X \]

from the REXCESS sample
[see also: Böhringer+07, Croston+08, Pratt+09]

Tight \( Y_{SZ} - Y_x \) relation depends on \( T_{mw}/T_X \) [+clumpiness]
FROM CLUSTERS TO GROUPS

Scaling law and universal profile down to group regime

[Sun+11]
MISSING HOT BARYONS?

THE SUNYAEV-ZEL'DOVICH EFFECT IN A SAMPLE OF 31 CLUSTERS: A COMPARISON BETWEEN THE X-RAY PREDICTED AND \textit{WMAP} OBSERVED COSMIC MICROWAVE BACKGROUND TEMPERATURE DECREMENT

Richard Leu, Jonathan P. D. Maitz, and Shiou-Nan Zelang

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ABSTRACT

The \textit{WMAP} Q, V, and W-band radial profiles of temperature deviation of the cosmic microwave background (CMB) were constructed for a sample of 31 randomly selected nearby clusters of galaxies in directions of Galactic latitude $|b| > 30^\circ$. The profiles were compared in detail with the expected CMB Sunyaev-Zel'dovich effect (SZE) caused by these clusters, with the hot gas properties of each cluster inferred observationally by applying gas temperatures as measured by \textit{ASCA} to isothermal $\beta$-models of the \textit{ROSAT} X-ray surface brightness profiles, with the \textit{WMAP} point-spread function fully taken into consideration. After co-adding the 31 cluster fields to significantly reduce the systematic and random uncertainties, it appears that \textit{WMAP} detected the SZE in all three bands. Quantitatively, however, the observed SZE only accounts for about 1/4 of the expected decrement. The discrepancy represents too much unexplained extra flux: in the W band, the detected SZE corresponds on average to 5.6 times less X-ray gas mass within a $10'$ radius than the mass value given by the \textit{ROSAT} $\beta$-model. We critically examined how the X-ray prediction of the SZE may depend on our uncertainties in the density and temperature of the hot intracluster plasma.

SEVEN-YEAR WILKINSON MICROWAVE ANISOTROPY PROBE (\textit{WMAP}) OBSERVATIONS: COSMOLOGICAL INTERPRETATION


Accepted for Publication in the Astrophysical Journal Supplement Series

Zel'dovich (SZ) effect at the locations of known clusters of galaxies. The measured SZ signal agrees well with the expected signal from the X-ray data on a cluster-by-cluster basis. However, it is a factor of 0.5 to 0.7 times the predictions from “universal profile” of Arnaud et al., analytical models, and hydrodynamical simulations. We find, for the first time in the SZ effect, a significant difference between the cooling-flow and non-cooling-flow clusters (or relaxed and non-relaxed clusters), which can explain some of the discrepancy. This lower amplitude is consistent with the lower-than-theoretically-expected SZ power spectrum recently measured by the South Pole Telescope collaboration.
OR NO MISSING HOT BARYONS?

\[ Y_{500}E(z)^{2/3}(D_{\text{e}}(z)/500 \text{ Mpc})^2 \text{ [arcmin]} \]

\[ E(z)^{-7/3} \quad L_{500} (0.1 - 2.4 \text{ keV}) [10^{44} \text{ erg/s}] \]

\[ WMAP \]

\[ \text{WMAP (intrinsic) } L_{500} - M_{500} \quad + \quad \text{WMAP (REXCESS) } L_{500} - M_{500} \quad \text{model} \]

\[ Y_{\text{SZ, sph}} D_A^2 [M_{\odot} \text{ keV}] \]

\[ 10^{14} \quad 10^{15} \]

\[ Y_X [M_{\odot} \text{ keV}] \]

\[ 10^{14} \quad 10^{15} \]

\[ \text{REXCESS} \]

[Melin+10]

[Andersson+09]
THREE COMPLEMENTARY STUDIES

1. Statistical approach
   - 1882 X-ray selected clusters (MCXC, Piffaretti +11), with homogenised $L_{500}$, $z$

2. Planck ESZ clusters
   - high quality SZ signal
   - clusters with good XMM archive data

3. New Planck clusters, XMM confirmed

![Graphs and diagrams illustrating the three studies.](image)
SZ - X SCALING RELATIONS

1. **Y_{SZ} - L_{X} relation**
   - Real SZ data and X-ray based prediction consistent
   - NO MISSING HOT BARYONS

2. **ESZ+XMM**
   - Planck-XMM validation
   - in ESZ sample
   - not in ESZ sample

3. **ESZ-XMM archive**
   - REXCESS prediction
NEW CLUSTERS DETECTED BY PLANCK AND CONFIRMED WITH XMM
DDT program
maximize the synergy between the two ESA missions

Short snapshot exposures
10ksec

25 Planck candidates
- 17 single clusters
- 2 double systems
- 2 triple clusters
- 4 false detection (SNR<4.1)

0.1<z<0.6
- redshift from FeK line
~30% (REXCESS) vs ~70% (PLANCK) morphologically disturbed
A non-negligible population of massive dynamically perturbed systems, under-represented in X-ray surveys @ z>0.3 ?
Blind SZ detection of super-cluster[s]

Physics: boosted by merger shocks? Contribution of filaments?
Cosmology: how many? must we take SC in the ‘selection’ function?

→ AO10 XMM-newton/VLT GO follow-up accepted
**DISTANT CLUSTERS**

**PLCK G266.6-27.3**

- $\text{SNR}_{\text{PLCK}} = 5$
- $z_{\text{FeK}} = 0.94$
- $L_{\text{X}[0.5-2\text{keV}]} = (1.4 \pm 0.5) \times 10^{45} \text{ erg/s}$
- $M_{500} = (7.8 \pm 0.8) \times 10^{14} M_{\odot}$
- Highly relaxed
CONCLUSIONS

PLANCK ESZ: A UNIQUE ALL SKY SZ SAMPLE OF 189 CLUSTERS

⇒ most complete set of the rarest and massive clusters in the z < 0.5 Universe
⇒ first SZ measure for ~80% of the known clusters in the ESZ.

UNVEILING A POPULATION OF DYNAMICALLY PERTURBED CLUSTERS @ z>0.3, POSSIBLY UNDER-REPRESENTED IN X-RAY SURVEYS
from XMM validation follow-up of Planck SZ sources

IMPROVED ROBUSTNESS OF OUR OVERALL VIEW OF ICM PROPERTIES
from complementary high precision X-ray/SZ studies
⇒ Close long standing issue of the « missing hot baryons » from excellent agreement between observed $Y_{SZ}$ and X-ray-based predictions
⇒ High precision calibration of the $Y_{SZ}$ – $Y_X$ and $Y_{SZ}$ – $L_X$

DETECTION OF NEW DISTANT VERY MASSIVE CLUSTERS
1. Planck Early Results VIII: The all-sky Early Sunyaev-Zeldovich cluster sample [arXiv:1101.2024]


4. Planck Early Results XI: Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations [arXiv:1101.2026]

5. Planck Early Results XII: Cluster SZ-Optical Scaling Relations [arXiv:1101.2027]

6. Planck Early Results XXVI: Detection with Planck and confirmation by XMM-Newton of PLCK G266.6−27.3, an exceptionally X-ray luminous and massive galaxy cluster at z~1 [arXiv:1106.1376]

→ MORE TO COME FROM 02/2012 ; STAY TUNED !
→ PLANCK NOMINAL MISSION DATA RELEASE : 01/2013