The Planck Cluster Survey

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Members of the Planck WG5

XMM-Newton: The Next Decade  June 2007
The Planck Cluster Survey

- Clusters & the Sunyaev-Zel’dovich (SZ) effect
- The Planck catalog
- Science with Planck/XMM-Newton

Cosmology with massive clusters at high $z$
Thermal SZ Effect

Cluster
$T \sim 5\,keV$
$\tau \sim 0.001 - 0.01$

A2029 Chandra/optical

Planck

$\Delta i_v = i_v^O - i_v^C = y \cdot j_v$

$y = \int_{\text{los}} \frac{kT_e}{m_e c^2} n_e \sigma_T \, dl$

No redshift dependence!
Gains from SZ Surveying

**SZ ‘flux’ limited survey:**

\[
S_{sz} = \int d\Omega \Delta i_v \propto Y f_v
\]

\[
Y = \int d\Omega y \propto \frac{f_{gas} M_{tot} T_e}{D_{ang}^2 (z)}
\]

Gas thermal energy

- **Tight correlation to MASS**
  - Intrinsic scatter \( \sim 5\% \)
  - Insensitive to mergers, thermal structure, etc

The \( Y-M \) relation needs to be empirically calibrated (e.g., normalization)

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The Planck Mission

Ref: Planck Blue Book

Two instruments: HFI & LFI

9 bands: 30 → 5 arcmins

7 → 5 arcmins

Most clusters unresolved

• Launch: July 2008
• Transfer to orbit: 3-4 months
• 2 full-sky surveys: 14 months
• Data release: + 2 years
Gains from SZ Surveying

Close to a mass selected catalog, uniform in redshift at $z>0.5$

Important for evolutionary studies - *same kind of object observed at different epochs*

Under study by Planck WGs 2 & 5

An SZ Survey:
- Efficient at high $z$
- Mass selected
- Universal spectrum

Planck SZ Mass Limit

Fiducial model
Point-source approximation

$Y > 6 \times 10^{-4}$ arcmin$^2$

Planck: all-sky VOLUME

$Y > 10^{-4}$ arcmin$^2$

SPT: 4000 deg$^2$ DEPTH

Moss in $10^{15}$ solar masses

Redshift
The Planck SZ Catalog

Large modeling uncertainty: $\sigma_8, Y-M$ calibration & $Y_{\text{lim}}$

- WMAP-1: $\sigma_8 = 0.9 \pm 0.1$
- WMAP-3: $\sigma_8 = 0.76 \pm 0.05$

Solid red line consistent with:
- WMAP-3 (Spergel et al. 2007)
- M-T (Vikhlinin et al. 2006, Arnaud et al. 2005)
- Fit to local cluster abundance (Chamballu & Bartlett 2007)


|b| > 20 (30,000 deg$^2$)

WMAP-1: $\sigma_8 = 0.9 \pm 0.1$
WMAP-3: $\sigma_8 = 0.76 \pm 0.05$

$\sigma_8 = 0.85$
PSM

$\sigma_8 = 0.71$

$Y > 6 \times 10^{-4} \text{arcmin}^2$
|b| > 20 (30,000 deg²)

Planck SZ Catalog

Present X-ray Sample

Planck:
~ few 100 clusters at z > 0.6 & with T > 7 keV
~ 10 clusters at z > 1, T > 8 keV

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An XMM-Planck Sample

GOAL:
Target the massive clusters at high redshift to do this science with XMM-Newton

~300 clusters @ $z>0.6$ & $T>7\text{keV}$

Potential 100-fold increase in sample size!

NEW Planck clusters

$Y > 6 \times 10^{-4} \text{arcmin}^2$

$fx < 10^{-12} \text{cgs}$

Chamballu, JGB, Melin 2007
Massive Clusters at High $z$

Ideal for cosmology
- Most sensitive to cosmology
- Global properties less affected by galaxy formation

Key: cluster mass

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26 clusters, ONLY 4 above $z=0.5$
XMM-Newton follow-up - sensitivity to get:

- Gas properties: $L(r), T \text{ [some } T(r)\text{]}, M_{\text{gas}}$
- Total MASS from hydrostatic equilibrium (relaxed)

⇒ Calibration of $Y$-$M$ relation
  - Critical for cosmological application of cluster counts

⇒ Measure $f_{\text{gas}}(z)$
  - Cosmological constraints (e.g., Allen et al. 2004)

⇒ Scaling relations between $L, T, M_{\text{gas}}, M, Y$
  - Cluster properties and evolution

⇒ Mass profiles
  - Structure formation and dark matter properties
Observing with XMM

Model prediction for flux distribution of Planck clusters at $0.8 < z < 1$

$S_X[0.5-2] \sim 2.5 \times 10^{-13}$ cgs

Flux Distribution
$Y > 6 \times 10^{-4}$ arcmin$^2$

$10^{-13}$ cgs
$10^{-12}$ cgs

Example of XMM performance

25 ksec: $z = 0.83$,
$S_X[0.5-2] \sim 2.5 \times 10^{-13}$ cgs

$kT = 7.2 \pm 0.5$ keV

Gioia et al, 2004

Fe

Chamballu, JGB, Melin 2007
Conclusions

• Planck (2008): a unique cluster catalog for cosmology
  – Volume & mass selection (all-sky SZ survey)
  – ~100-fold increase in massive cluster sample
    \( (T>7\text{keV}) \) at \( z>0.6 \)

• Ideal for XMM-Newton studies
  – An array of exciting cosmology/structure formation studies
  – Phased program cutting in \( Y \) with 25-50 ks/cluster
  – Whole shebang:

  10 Ms program:
  ~300 clusters at \( z>0.6, T>7\text{keV} \)
  with \( T\pm10\% \), \( T \) profile
  MASSES
Planck vs ROSAT

ROSAT - RASS based

NORAS - north
REFLEX - south
(Böhringer et al. 00, 04)
\[ f_x [0.1 - 2.4\, keV] > 3 \times 10^{-12} \, \text{ergs} / \text{s} / \text{cm}^2 \]
(~1000 clusters)

Planck
\[ Y > 6 \times 10^{-4} \, \text{arcmin}^2 \]

- Moving out in \( z \)
- Volume

⇒ Massive clusters

Chamballu, JGB, Melin 2007

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