Galaxy clusters at the Planck time

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The Planck expected SZ sky

Waizmann & Bartelmann, 2009
The SZ effect in a nutshell

\[ \frac{\Delta I_\nu}{I_\nu} \bigg|_{th} = y \mathcal{G}(x, T_e) \]

\[ Y = \int_{\Omega} y(\Omega') d\Omega' = \frac{kT}{m_e c^2} \frac{\sigma_T}{d_A^2} N_e = f_{gas} kT \frac{\eta}{m_p} \frac{M_{tot}}{d_A^2} \]

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Etienne Pointecouteau - Rencontres de Moriond, Sunday March 14th: “Galaxy clusters at the Planck time”

Sunday, March 14, 2010
Predicted counts

- ~1000 clusters
  - → gLON, gLAT, Y\textsubscript{SZ}
  - → massive clusters M > a few 10\textsuperscript{14} M\odot
  - → toward a mass limited survey... [modulo f(Y\textsubscript{SZ},\theta)]
  - → efficient at high z (i.e 0.3 < z < 1.0)

[see also

Chamballu et al. 2010
Catalogue extraction

- **Match filter approach**
  - multi-frequency (all 6 HFI bands)
  - high detection efficiency
  - photometric precision = $f(Y_{SZ}, \theta)$
  - implement SZ cluster profile model

Melin et al. 2006
Generalised pressure profile of clusters
→ follows a GNFW
\[ P_{500} \equiv h(z)^{8/3} M_{500}^{2/3} ; \]
\[ \frac{P(r)}{P_{500}} = \frac{P_0}{x^\gamma (1 + x^\alpha)^{\beta - \gamma / \alpha}} ; \quad x = c_{500} r / R_{500} \]

→ REXCESS XMM P(r)
➤ strong constraints up to R_{500}
→ 3 sets of simulated P(r)
➤ breaking the \( \beta_{\text{GNFW}} \) degeneracy
extrapolation at high R

Universal pressure profile defined up to high r
→ consistent with SZ profiles derived by SPT (Plagge et al. 2010)

see also:
Croston et al. 2008,
Pratt et al. 2009,
Pratt et al. 2010
Predictions of SZ quantities

- **SZ scaling relations**
  \[ Y_{SZ} \rightarrow \text{consistent with recent SZA measurements (Mroczkowski et al. 2009)} \]
Validation on WMAP

- Statistical approach
  → WMAP 5 year
  → NORAS + REFLEX ~ 900 clusters

Melin et al. 2010
Known X-ray clusters

- Homogenised compilation of X-ray clusters catalogues
  → RASS, ROSAT-serendipitous, EMSS,...
  → ~2000 clusters: $L_X$, R, P, Y,... within $\delta = 500$

Piffaretti et al. 2010
Expectations for high z clusters

- **Known ROSAT distant clusters**
  - $\sim 30$ with $z > 0.6$
  - $\sim 5$ with $z > 0.6$ & $kT > 7\text{keV}$

- **Expected new distant clusters**
  - 100-200 with $z > 0.6$, $kT > 7\text{keV}$
  - $\sim 20$-$40$ fold increase

(Courtesy M. Arnaud)
Follow-up of Planck clusters

- Massive clusters are rare thus most constraining for cosmology and formation of structures (gravitation driven evolution)

- **Optical follow-up**
  - identification + redshift
  - cluster galaxies overall properties

- **X-ray follow-up**
  - ICM properties of new SZ clusters: $L_X$, $kT$ (or $kT(r)$), $M_{\text{gas}}$
  - $M_{\text{tot}}$ (from HE+spherical symmetry), entropy
  - $f_{\text{gas}}$ measurements
  - evolution of clusters properties scaling laws: $L_X$, $kT,Y,M$
  - calibration of $Y_{\text{SZ}}-M$ and its evolution

- **Target massive high z candidates**
  - SZ selected sample ($Y_{\text{SZ}}$)
  - All sky survey!

\[ \sim \text{Volume & mass selection } - f(Y_{\text{SZ}}, \theta) - \]
X-ray follow-up of Planck clusters

- **XMM/Chandra follow-up**
  - easy to detect \( (kT > 6-7\text{keV} \text{ at } z>0.6) \)
  - cross check with XCS (PI: K. Romer)
  - snapshot exposures
    - global properties
  - deeper exposures
    - \( kT(r), M_{\text{gas}}(r), M_{\text{tot}}(r) \)

- X-ray vs Planck resolution
  - high resolution SZ follow-up

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**Added value of SZ “high resolution”**

- **DIABOLO/IRAM & NOBA/NRO**
  
  → resolution = 15-22” & maps ~ 2-5’

  RXJ1347-1145
  z=0.45
  150GHz (2mm)

- **MUSTANG/GBT**

  → resolution = 8-10” & maps ~ 2’

  Pointecouteau et al. 1999, 2001
  Komatsu et al. 1999, 2001, Kitayama et al. 2004

  ➤ ICM structure, evolution of clusters dynamical state from SZ
Combined SZ + X-ray imaging

- **X-ray + SZ imaging**
  - resolved SZ + resolved X-ray images
  - two independent $P(r)$ measurements
  - RXJ2228+2037: $P_X(r) \equiv P_{SZ}(r)$

- $kT_{mw}(r)$

**Graphs and Figures:**

- RXJ1347-1145, $z=0.45$
  - NOBA/NRO
  - Kitayama et al. 2004

- RXJ2228+2037, $z=0.42$
  - NRO/22GHz
  - Jia et al. 2008,
    Pointecouteau et al. 2002

- A2163, $z=0.2$
  - APEX-SZ

- Nord et al. 2009
Summary

- Expected ~1000 clusters from the Planck survey
  → detection of new SZ distant clusters
  → ~20-40-fold increase at $z > 0.6$ & $kT > \sim 7\text{keV}$

- ~2000 known X-ray clusters in the local Universe (mainly)
- ~100-200 new Planck detected distant and massive clusters

➤ optical/NIR identification + redshift
➤ X-ray follow-up
➤ SZ ground based follow-up

→ selection function = $f(Y_{SZ},\theta), N(M,z)$
→ $P(r), kT(r), M(r), S(r),...$
→ better calibration $Y_{SZ}-M$ + evolution
→ cosmology/formation and evolution of structures
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