# The X-ray view of Planck SZ clusters

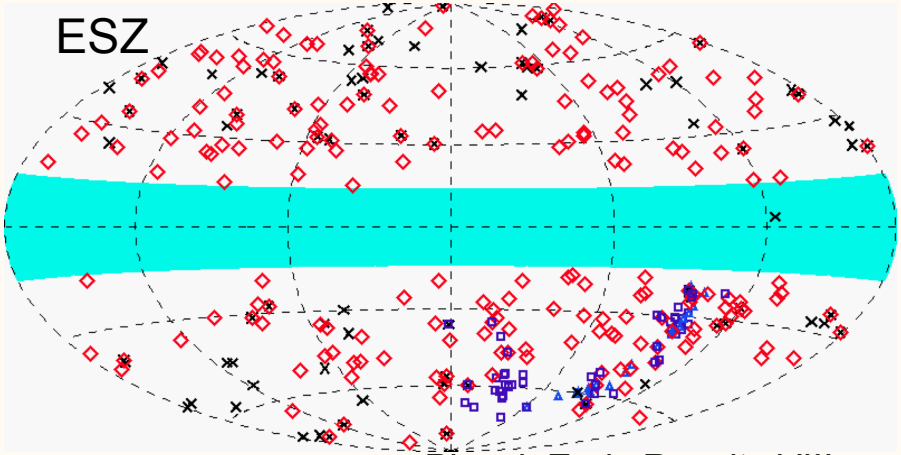
M. ARNAUD

CEA- Service d'Astrophysique

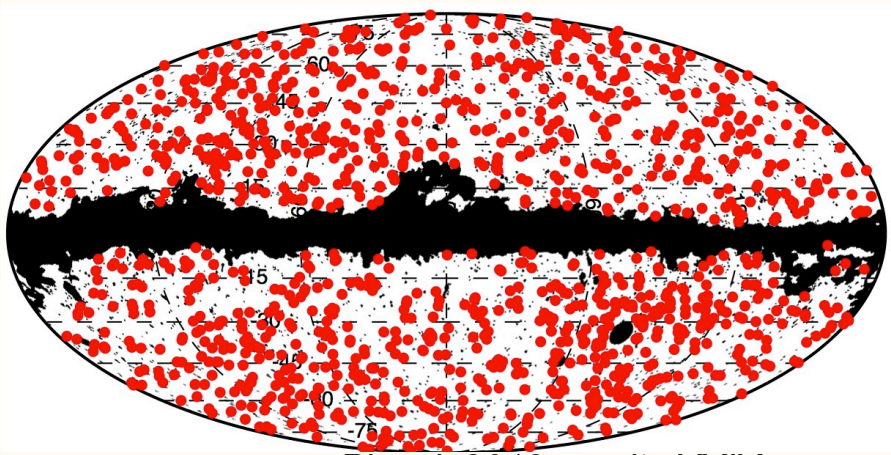
On behalf of the Planck collaboration

With inputs from non-Planck scientists

# The Planck catalogue of SZ sources




*Planck Early Results VIII*



*Planck 2013 results XXIX*

## 189 SZ sources with S/N > 6

- First SZ measure for ~80% of known clusters
- 20 new clusters; 19 confirmed

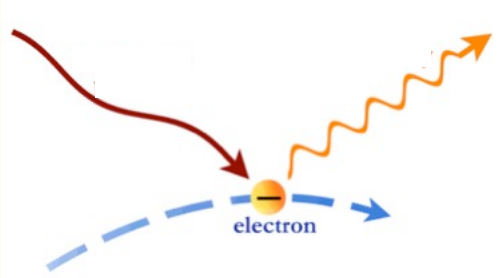
## 1227 SZ sources with S/N > 4.5

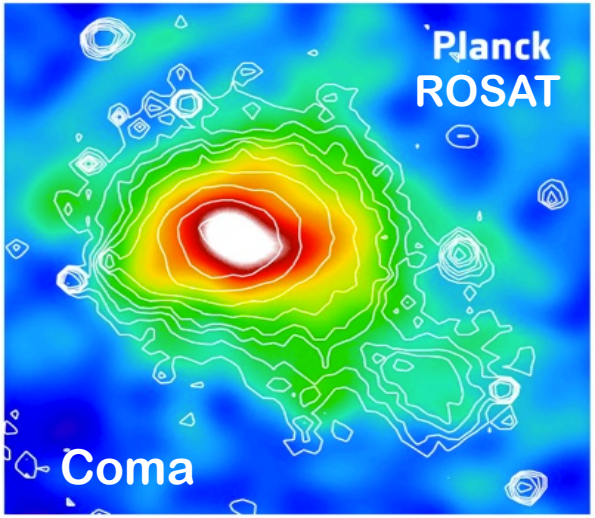
- 683 identified with known clusters
- 178 confirmed new clusters
- 366 cluster candidates Class 1,2,3

⇒ Position & S/N for all clusters and candidates
⇒ Y-Θ from blind detection
⇒ z when available
⇒ and more …

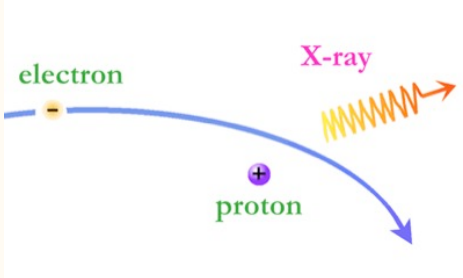
# X-ray and SZ observations

Inverse Compton scattering




Bremsstrahlung




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

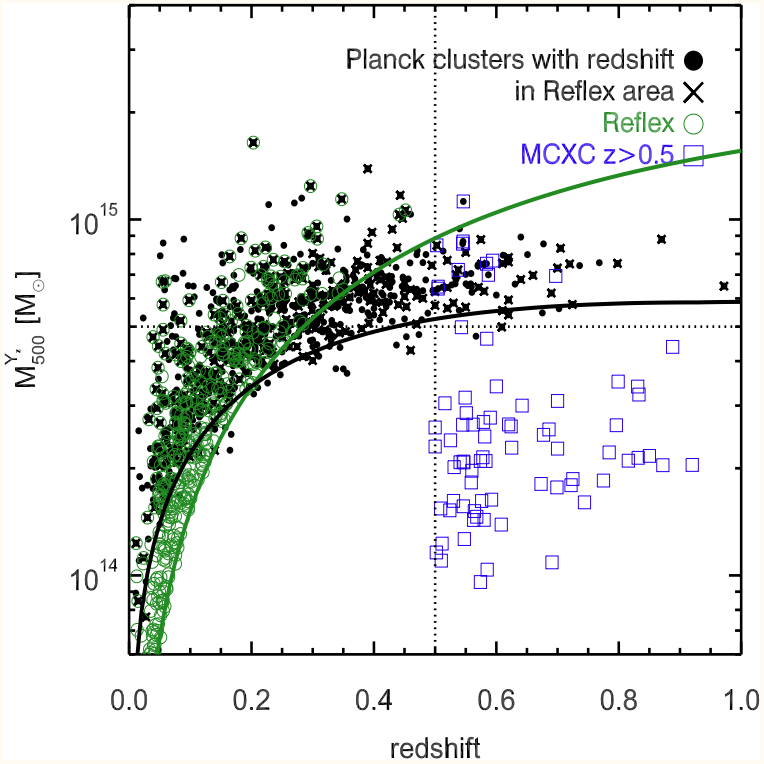
$$E_X \propto \int_V n_e^2 \Lambda(T) dV$$

Probing the same ICM component

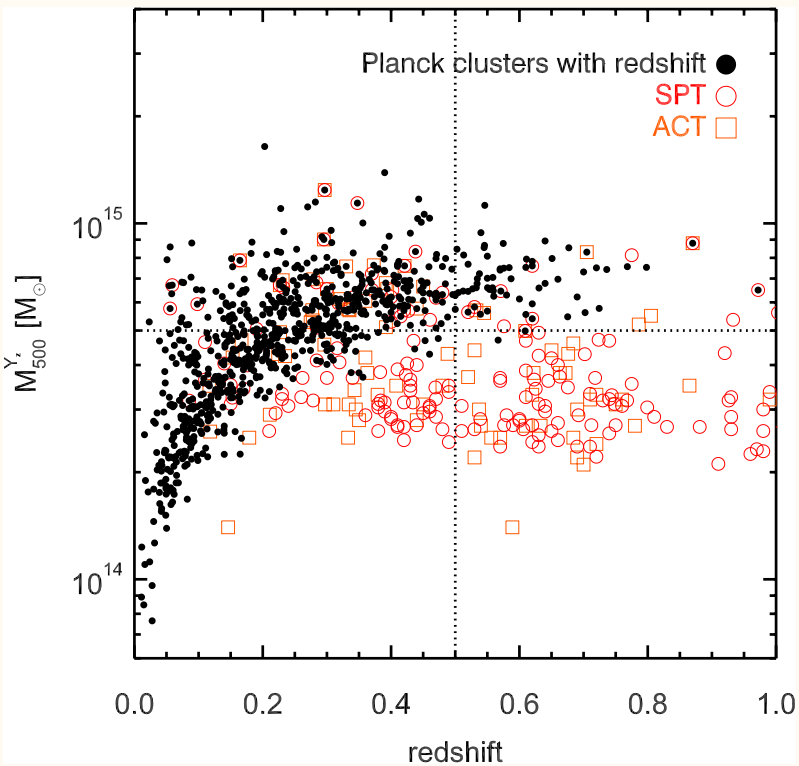
Lesson learned from combined X-ray/Planck information

The use of X-ray information in catalogue construction

# X-ray and SZ catalogues




No z dimming

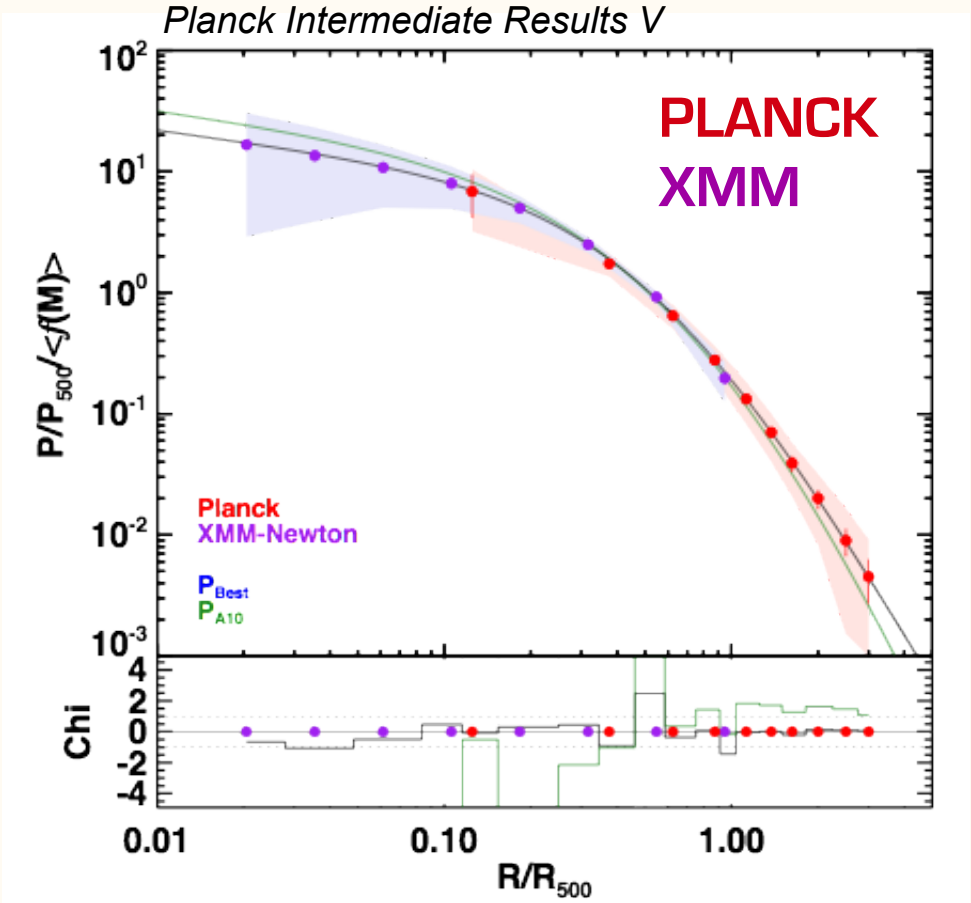



*Planck 2013 results XXIX*

Planck detect rarest and most massive clusters over the whole sky

Easily studied with XMM-Newton (and Chandra)

# Planck + XMM pressure profile




- 62 ESZ clusters with XMM archive data

$$F_\nu \propto \int_\Omega (P = n_e T)\, d\Omega$$

- Deprojection/deconvolution of profile from Planck SZ map

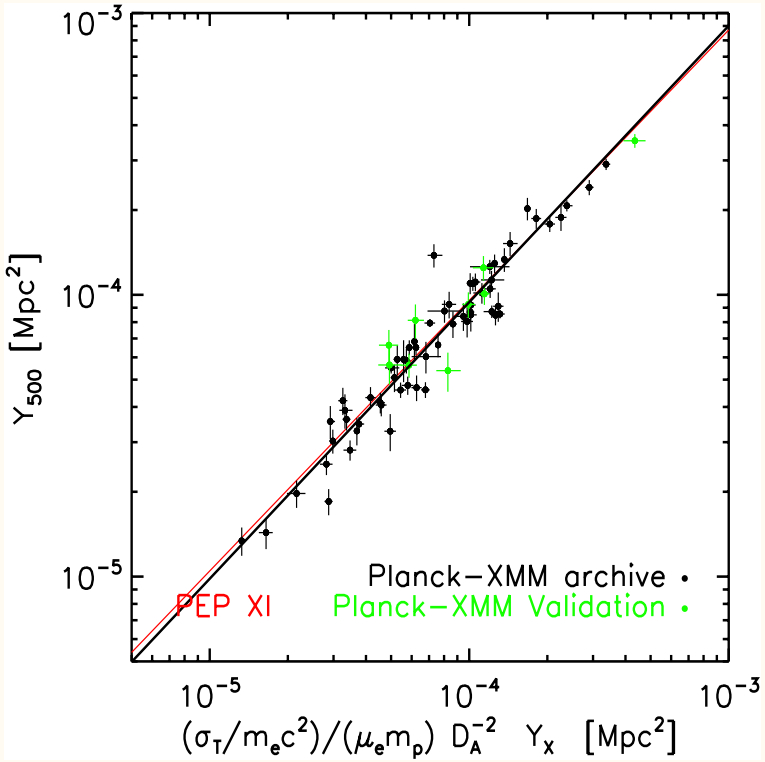
  ⇒ 0.02-5 $R_{500}$ from X-ray+SZ

⇒ X-ray and SZ view consistent , No 'missing' hot baryons

⇒ Low dispersion

⇒ Shallower than expected by simulations at high radius

# SZ-X scaling relation




$$Y_X = M_{gas} T_X$$

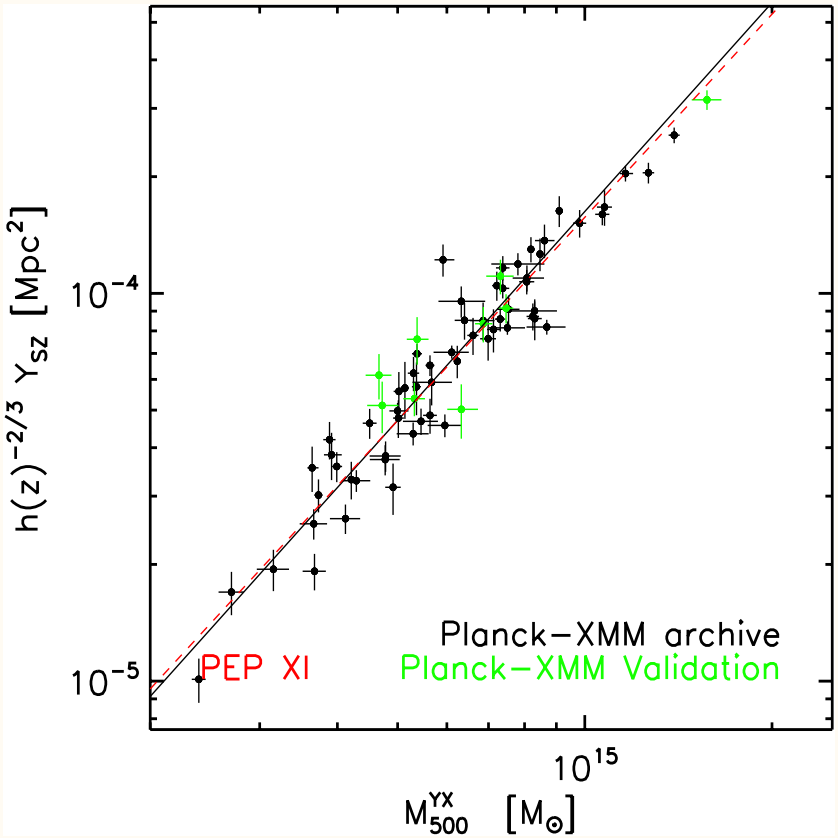
$$\frac{D_A^2\, Y_{500}}{C_{XSZ}\, Y_X} = \frac{1}{Q}\frac{\langle n_e T\rangle_{R_{500}}}{\langle n_e\rangle_{R_{500}} T_X}$$

$$Q = \frac{\sqrt{\langle n_e^2\rangle_{dr}}}{\langle n_e\rangle_{dr}},$$

- Ratio consistent with X-ray P shape
- Error now dominated by systematics
  ⇒ limit clumpiness constrain
- Low scatter relation
  ⇔ $Y_{SZ}/Y_X$ good mass prox

*Planck 2013 results XXIX*
*Update of Planck Early Results XI,IX +Planck Intermediate Results I,IV*
*See also, Rozo, Vikhlinin & More, 2012 (Planck + Chandra)*

# Calibration of the $Y_{SZ}$ - mass relation




*Planck 2013 results XX*

Using XMM calibration of $Y_X$- M relation using HE mass

$Y_{SZ}$- Mass error dominated by systematics (calibration, HE bias, correction of selection effect..)

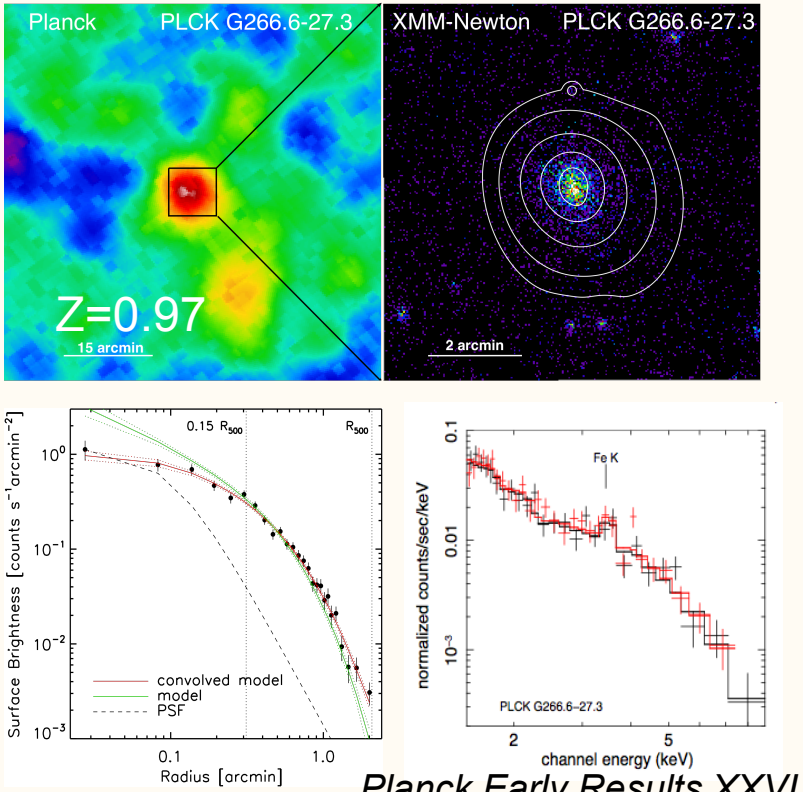
⇒ Input for cosmo from clusters counts

⇒ Y-Θ degeneracy breaking and M estimate for clusters with z

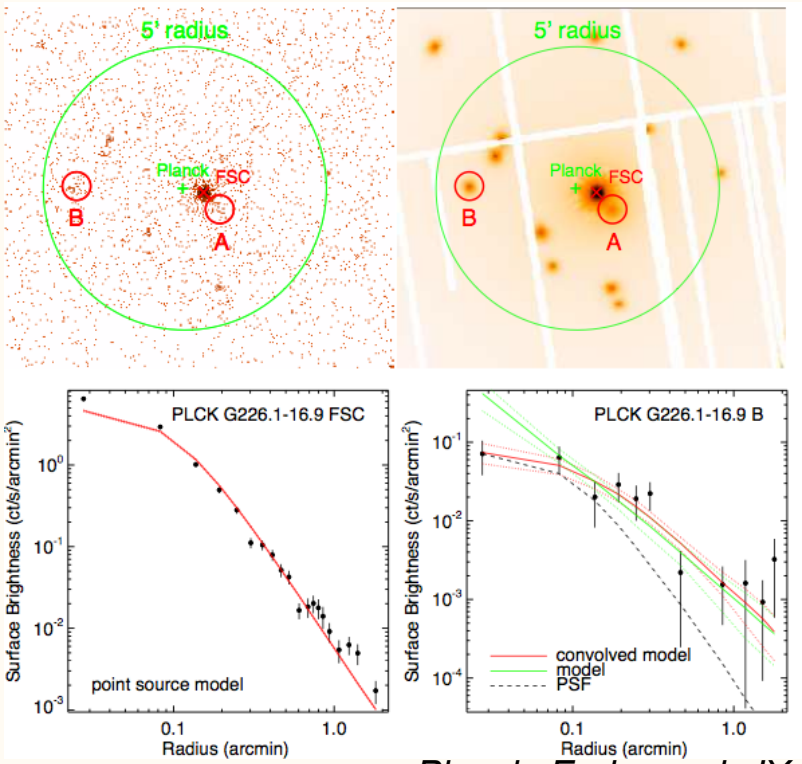
# X-ray validation method

based on source extent and consistency X/SZ

Unique XMM capability to distinguish



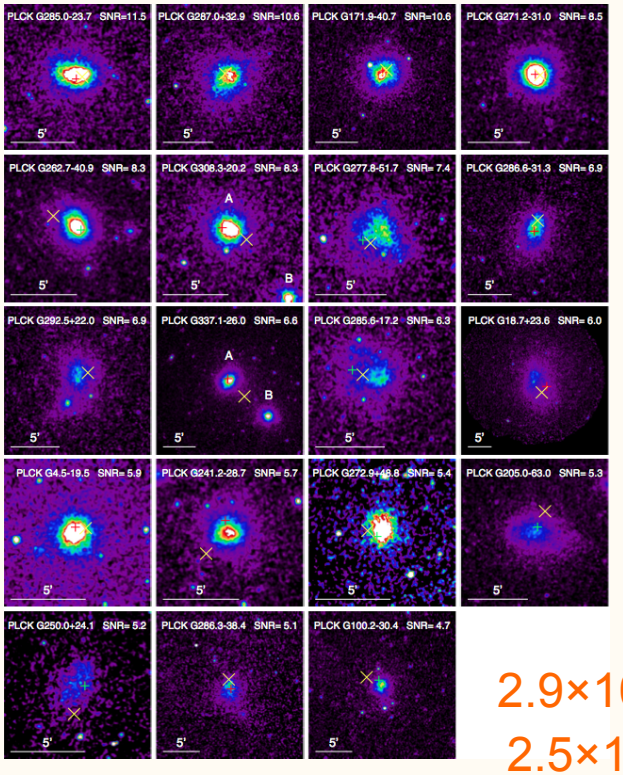

*Planck Early Results XXVI*



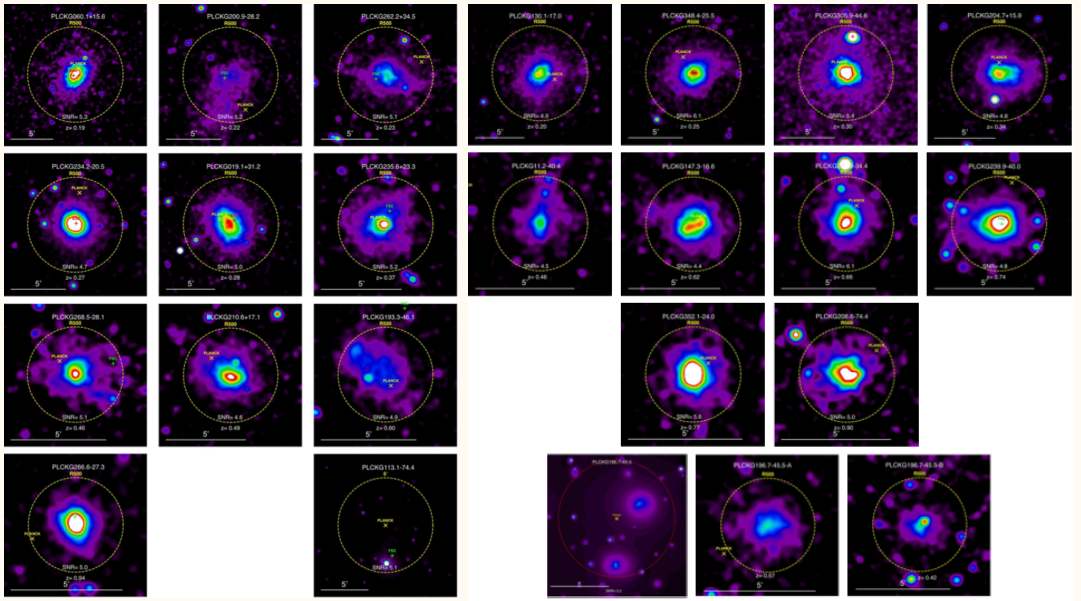

*Planck, Early resuls IX*

true cluster versus false candidates

# The XMM-Newton Validation (DDT)




*Planck Early Results IX, XXVI*



$0.09 < z < 0.97$

$2.9\times10^{-4} < Y_{SZ} < 3\times10^{-3}$ arcmin$^2$

$2.5\times10^{14} < M_{500} < 1.6\times10^{15}\ M_{\odot}$

*Planck Intermediate Results I, IV*

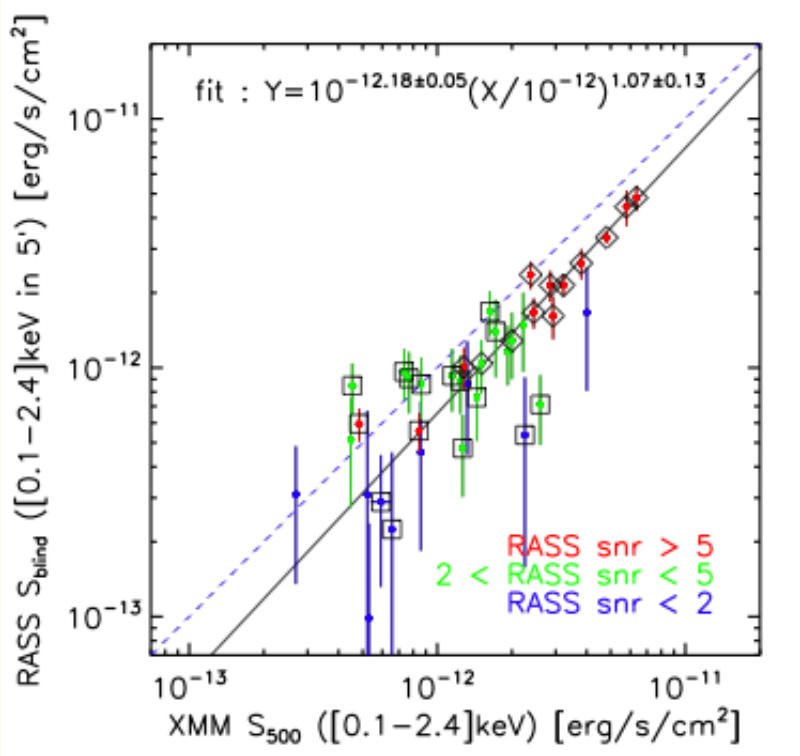
51 observed candidates; 4< S/N< 10.6

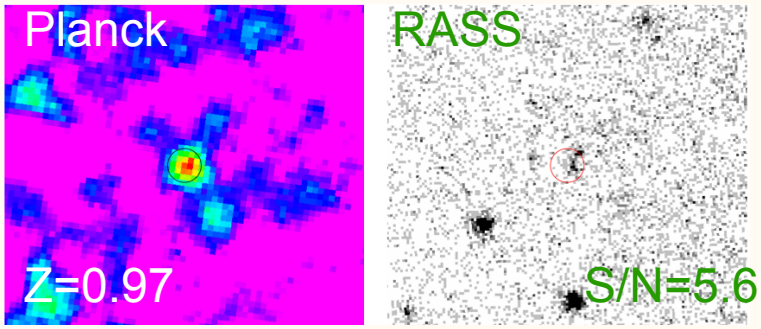
43 confirmed incl. 4 doubles & 2 triples (SC)

51 new clusters ; 32 with good $z_X$ from FeK line

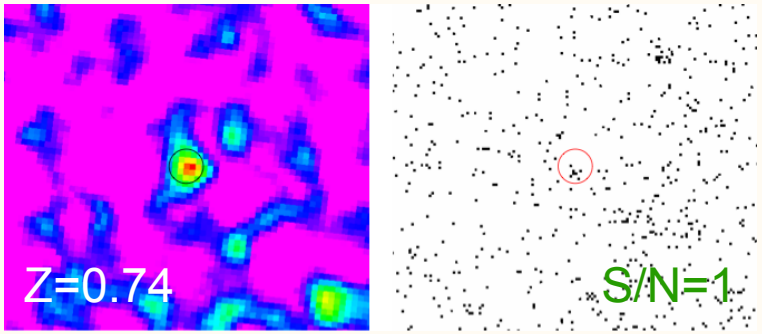
⇒Planck performance Verification (eg flux threshold; position accuracy; z range)

⇒Catalogue validation optimisation (e.g. definition SZ quality Flag; RASS use)



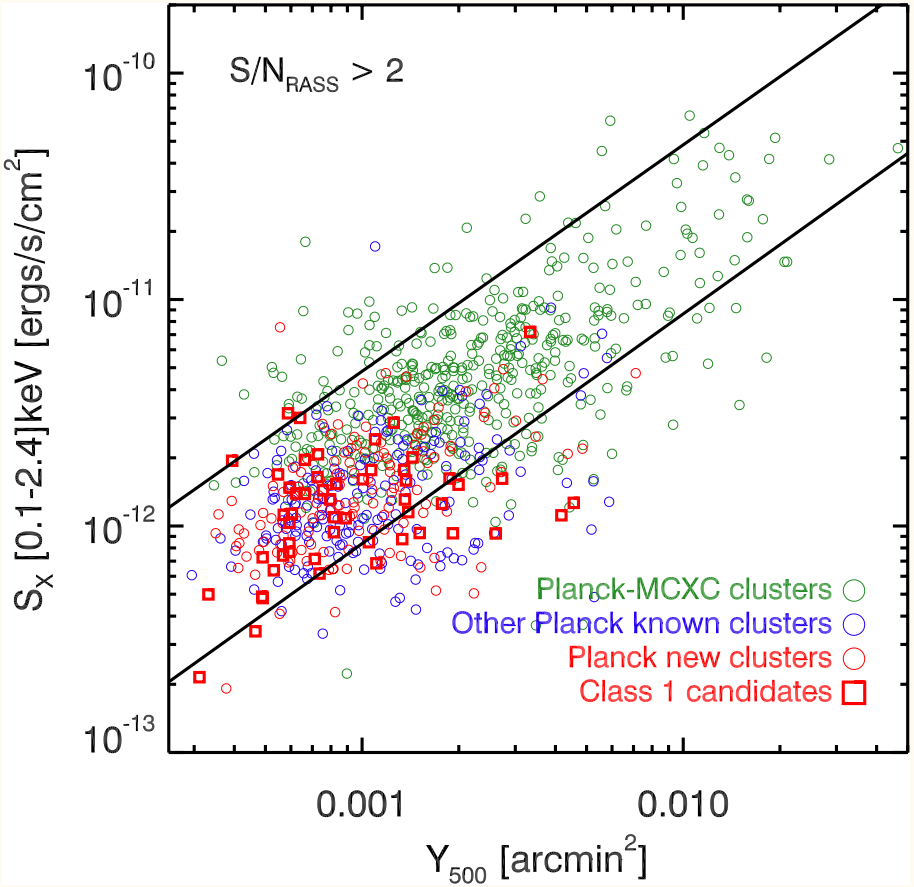

2 of 105,924 sources of the RASS-FSC




*Planck Intermediate Results IV*

RASS properties of XMM confirmed & false Planck candidate

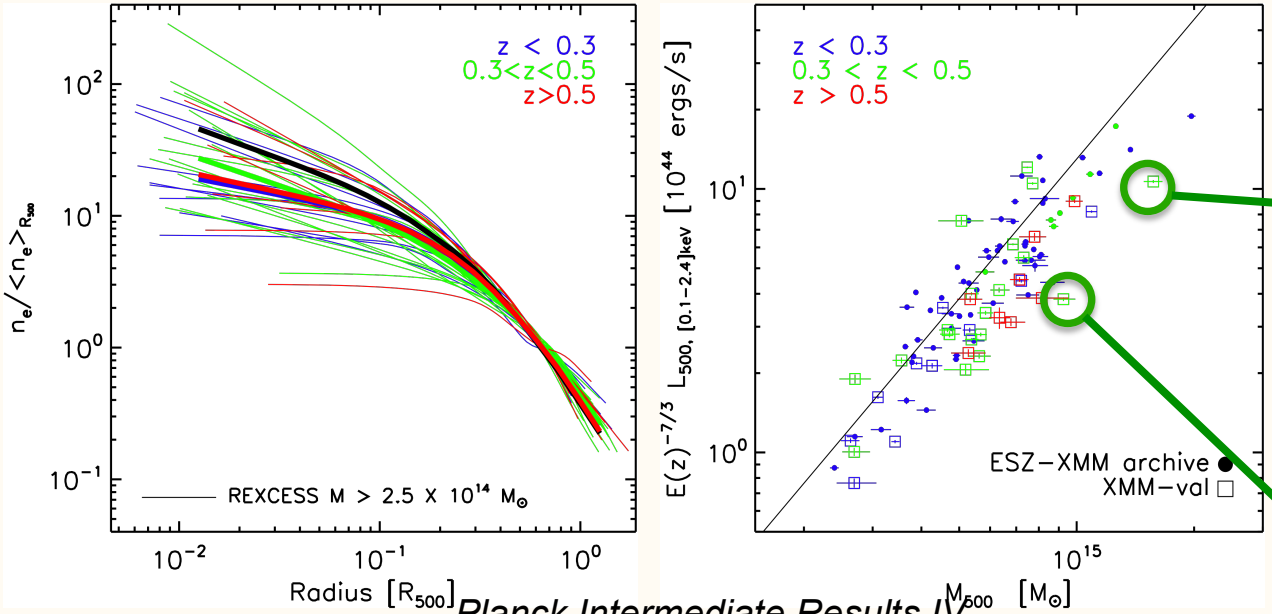
# RASS and Planck catalog construction



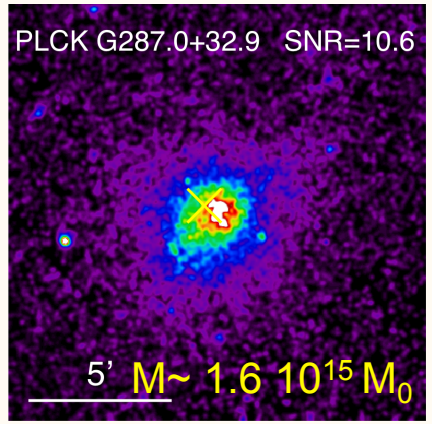

*Planck 2013 results XXIX*

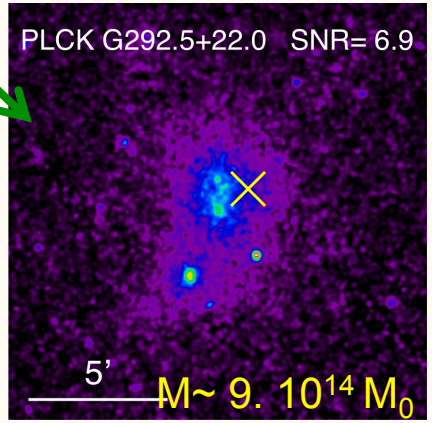
- Use RASS S/N for
  - optical ID consolidation
  - candidate classification
- RASS $S_X$ provided

# X-ray versus SZ selection




*Planck Intermediate Results IV*



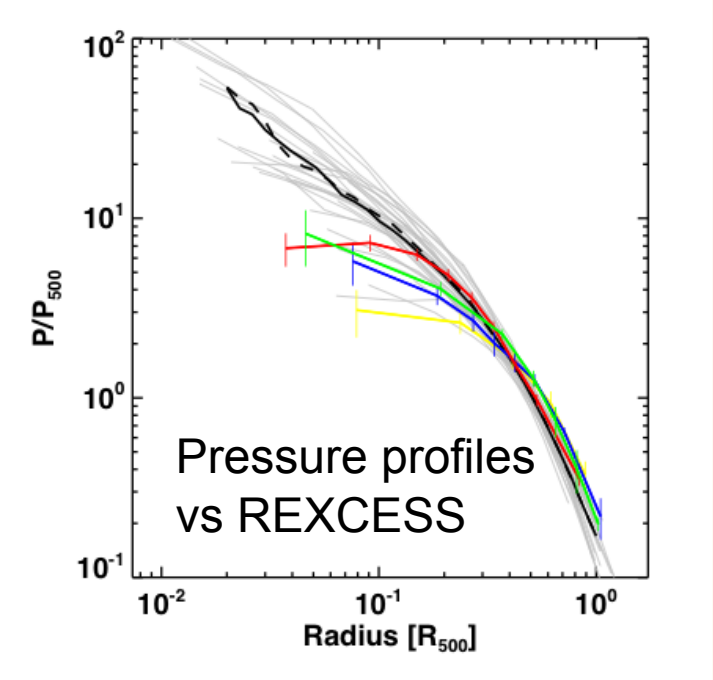

New SZ selected clusters versus X-ray selected

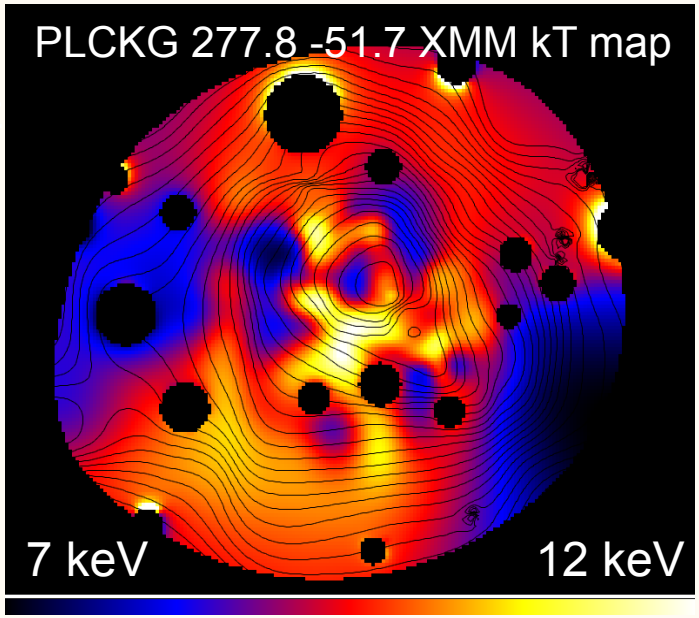
- more morphologically disturbed ; flatter core
- lower X-ray luminosity at given mass on average

Larger $M–L_X$ dispersion and smaller normalisation than thought?

Dynamically perturbed clusters under-represented at limit of X-ray surveys ?

# XMM-LP on disturbed Planck clusters




• 5 objects with lowest scaled central density ($L_X$) in first Planck sample

• 250 ks XMM ; VRI multi-band imaging with ESO WFI

[*PI G. Pratt & PC]*

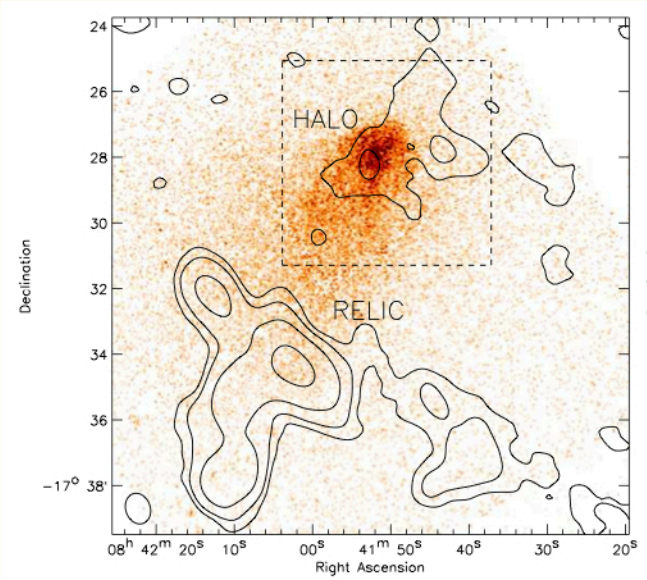
⇒ Pressure centrally suppressed

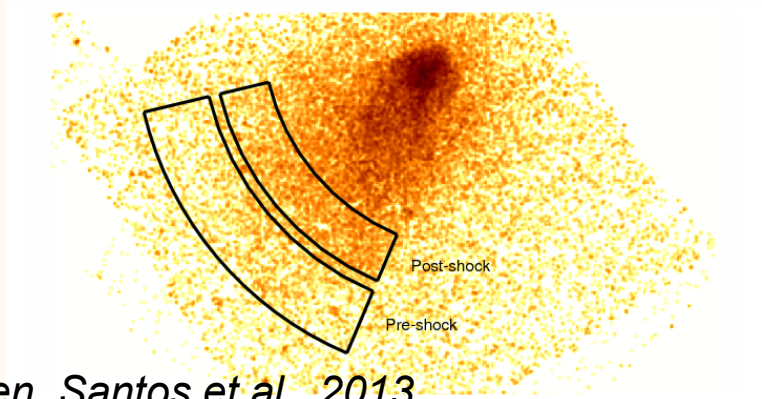
⇒ High central entropy; structure in kT maps

⇒WL analysis to be added in near future

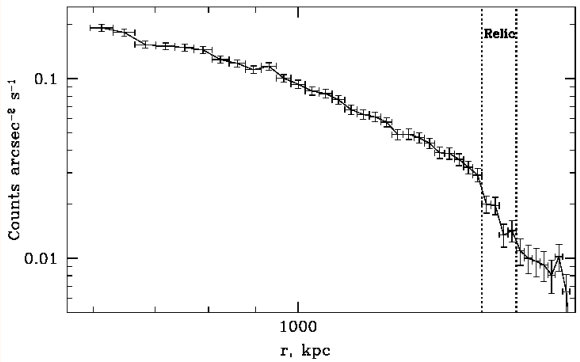
# A new merging galaxy cluster found with Planck/Chandra/VLA

Chandra image with VLA radio contours




*van Weeren, Santos et al., 2013*



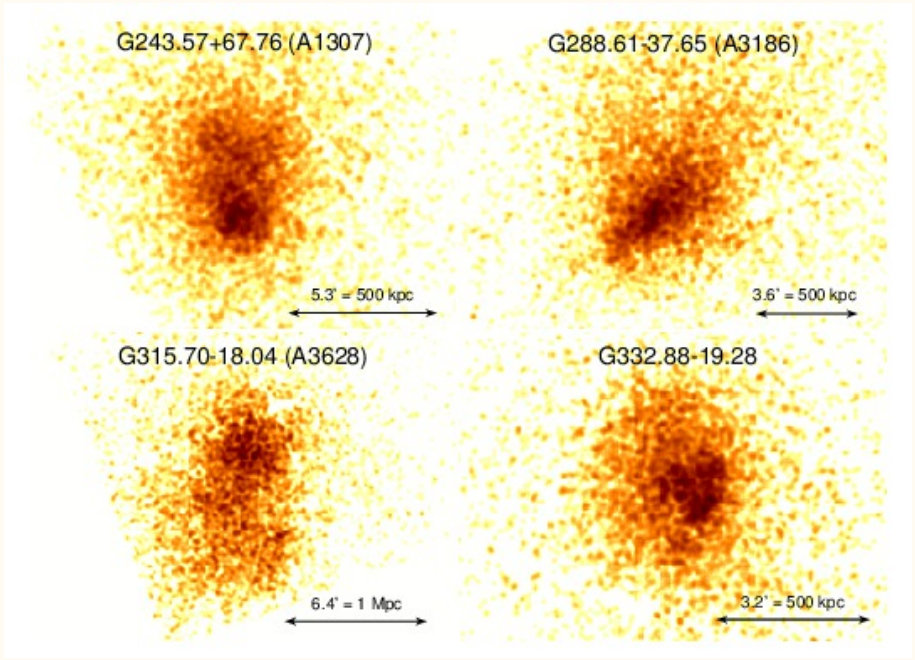

PLCK- ESZ G241.97+14.85 = Abell 3411 = RXC J0841.9-1729
Z=0.17

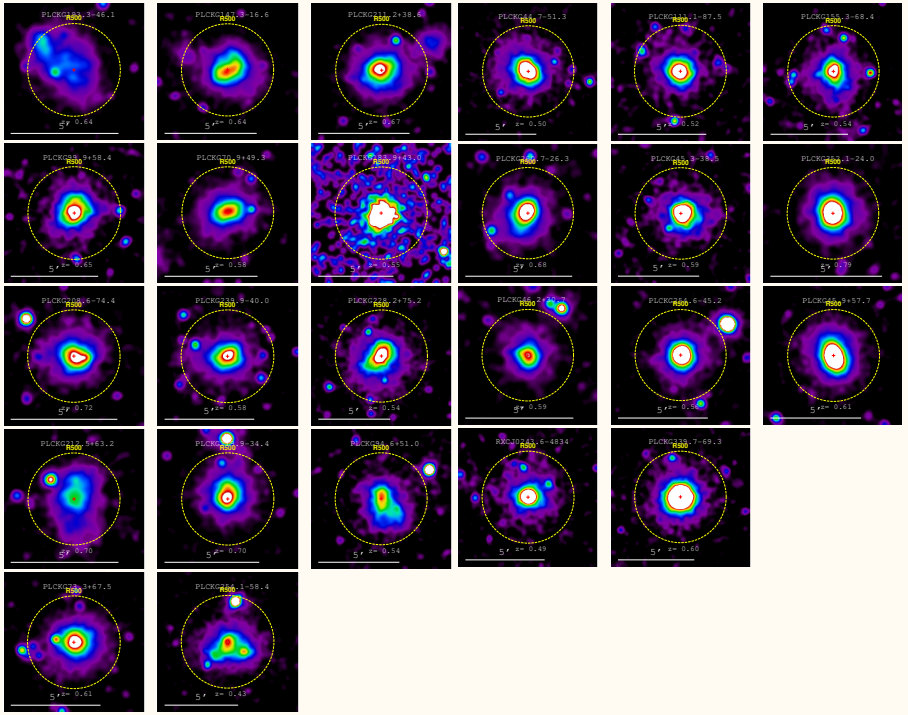
Key objects to understand merger physics and non thermal phenomena

*See also Bagchi et al, 2012 PLCK G287.0+32.9*

# Clusters scaling properties of purely SZ (Planck) selected sample

As probe of formation physics & inputs for cosmology



Chandra XVP(PI C.Jones)
GT (S.Murray) + Archive (P.Mazzotta)
*All ESZ z<0.35 clusters*

XMM LP (PI M.Arnaud & PC)

*33 0.5<z<0.9 clusters*

# Conclusion

**Strong synergy between SZ+X-ray**

- Consistent X+SZ view of the average thermal content of clusters within [0.01-3] $R_{500}$ ($\delta \approx$ 50-100)

- Local $Y_{SZ}$-$M/Y_X$ scaling laws (now) dominated by systematics

- Some evidence of a more perturbed cluster population than previously thought BUT $Y_{SZ}/Y_X$ good mass proxy

- SZ surveys do provide representative (mass selected) samples.

- Planck (+) catalogue plus multi-$\lambda$ follow-up: a gold mine for understanding cluster formation.

**The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada**

Planck is a project of the European Space Agency, 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.