Planck Early Results:
Calibration of the local galaxy cluster SZ scaling relations

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on behalf of the
Planck Collaboration

Argument

We want to measure SZ scaling relations for local clusters:

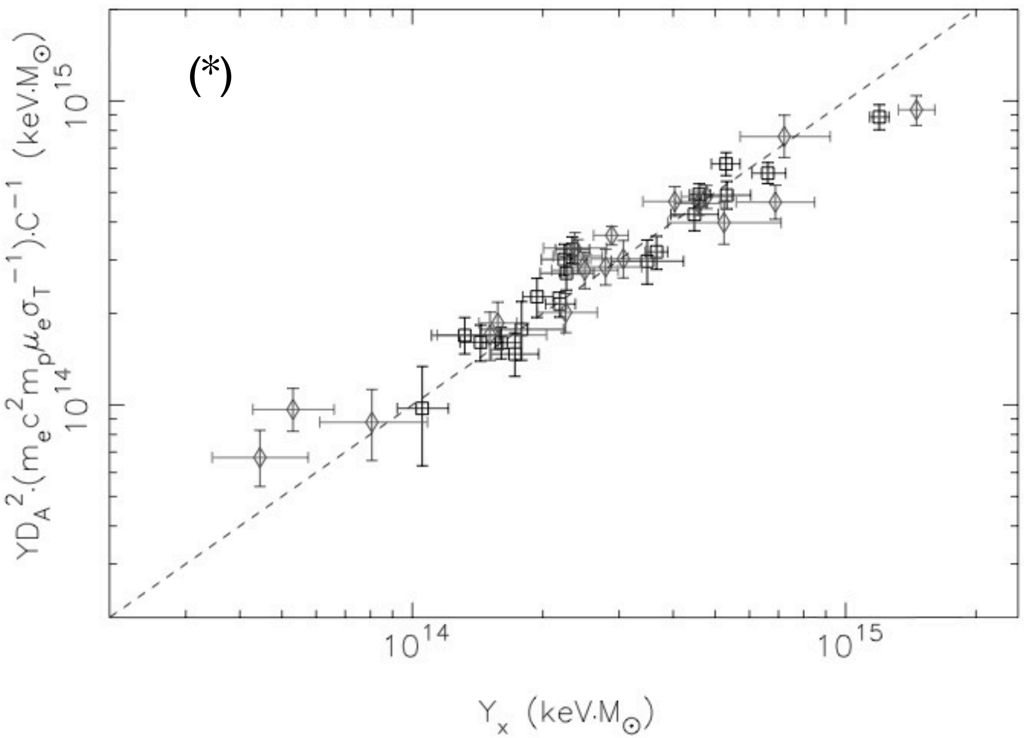
- Astrophysics
  - ratio between gas mass weighted and X-ray spectroscopic weighted temperature depends on cluster thermodynamics
  - X-ray predictions for pressure signal vs SZ

- Cosmology
  - robust local constraint on relationship between global observable (Y_{SZ}) and mass (via low-dispersion mass proxy, Y_X)
  - baseline for further evolution studies...

→ investigate correlations between: Y_{SZ} and M, T_X, L_X, M_{gas}...
→ key relation: Y_{SZ}-Y_X

Earlier works

- 15 Suzie+OVRO/BIMA clusters Benson et al. 2004
- 24 Suzie+OVRO/BIMA Morandi et al. 2007
- 38 OVRO/BIMA clusters Bonamente et al. 2008 (*)

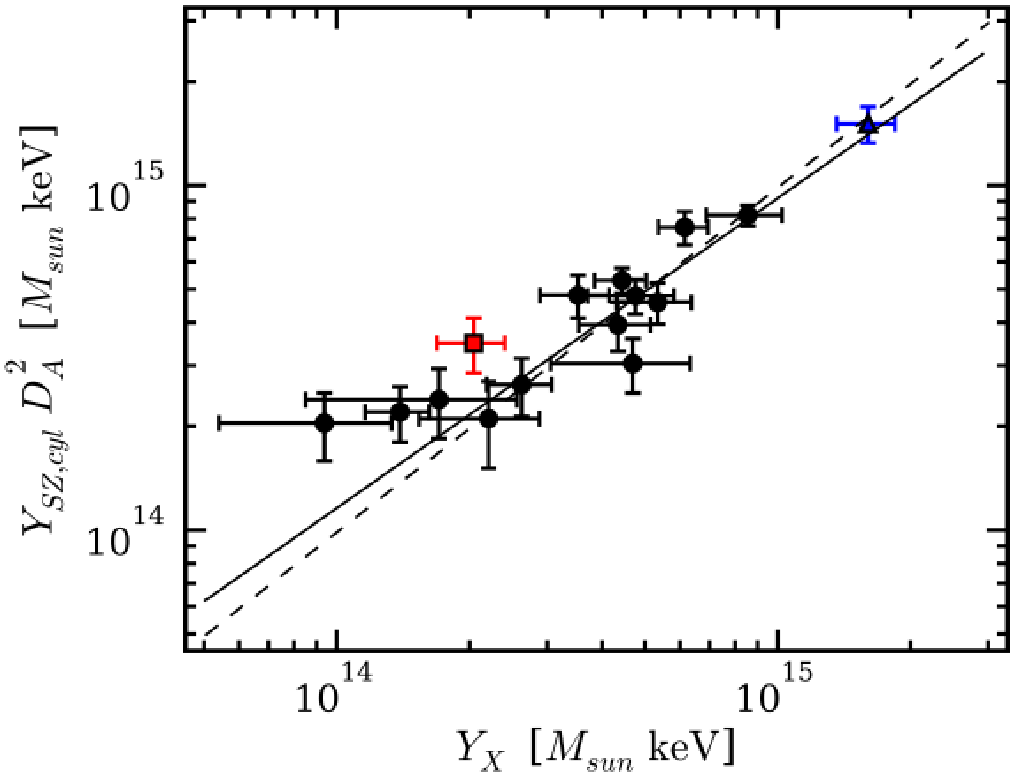


β-model
up to δ=2500
0.1 < z < 0.9

State of the Art

- AMiBA
  - observation of 6 nearby massive clusters (Liao et al. 2010)

- SPT
  - observations of 15 clusters, 0.25 < z < 1.0
    only 1 below z < 0.3



(Vanderlinde et al. 2010, Andersson et al. 2010)

We can do far better with *Planck*

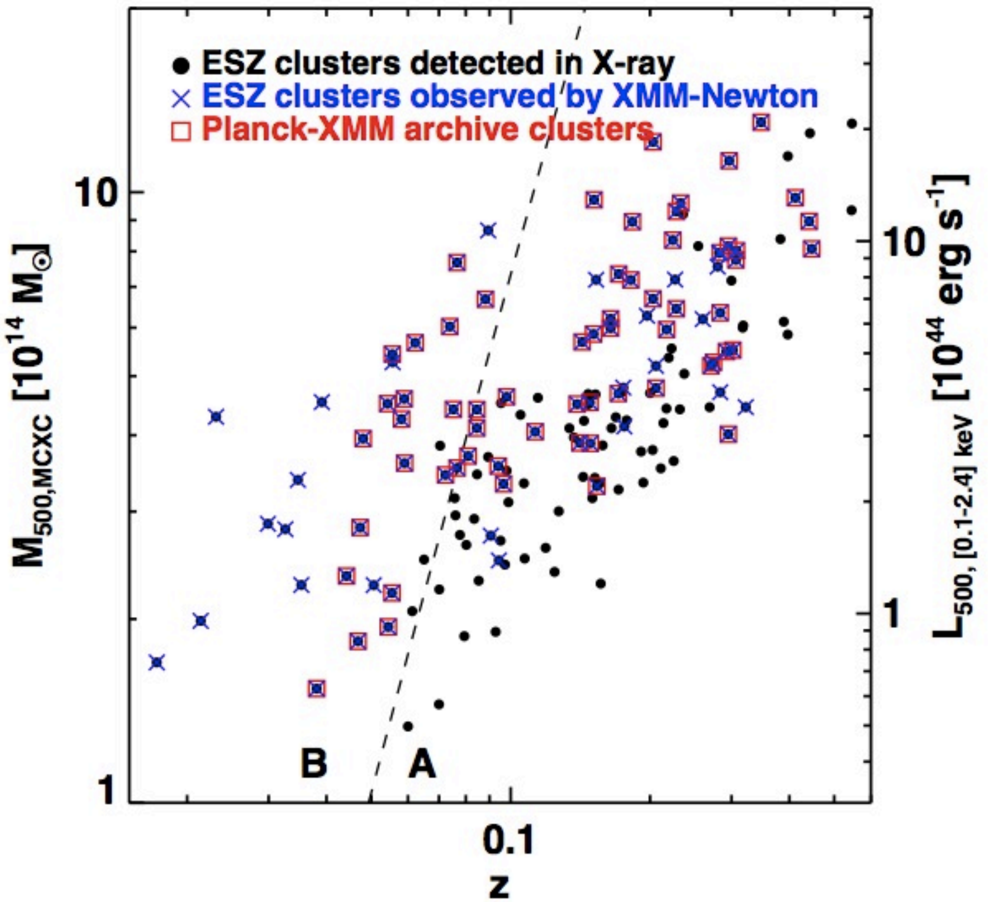
- Combining a high S/N *Planck* sample...
  - Very high-quality data
  - All sky survey (16 times larger than SPT)
  - Largest local sample (i.e. most with $z \leq 0.3$)

...with deep X-ray observations with XMM-*Newton*

  - Very high-quality data ; superior spectroscopic capabilities
  - Break certain innate degeneracies in *Planck* data (e.g., size - flux)

Initial data - ESZ sample

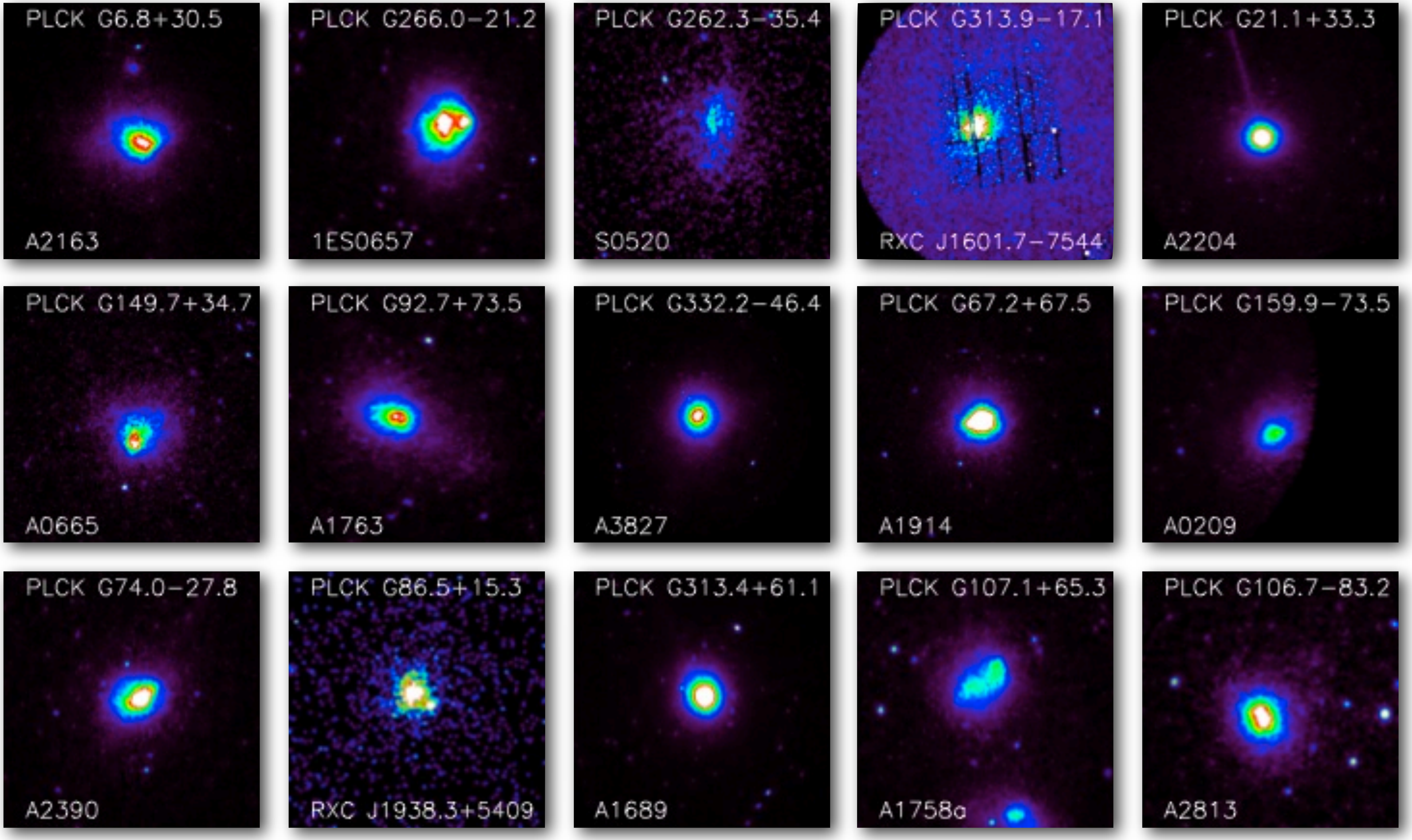
- *Planck* data
  - 158 known X-ray clusters in ESZ: S/R > 6
  - 62 Planck clusters (ESZ) with fitted XMM-*Newton* data



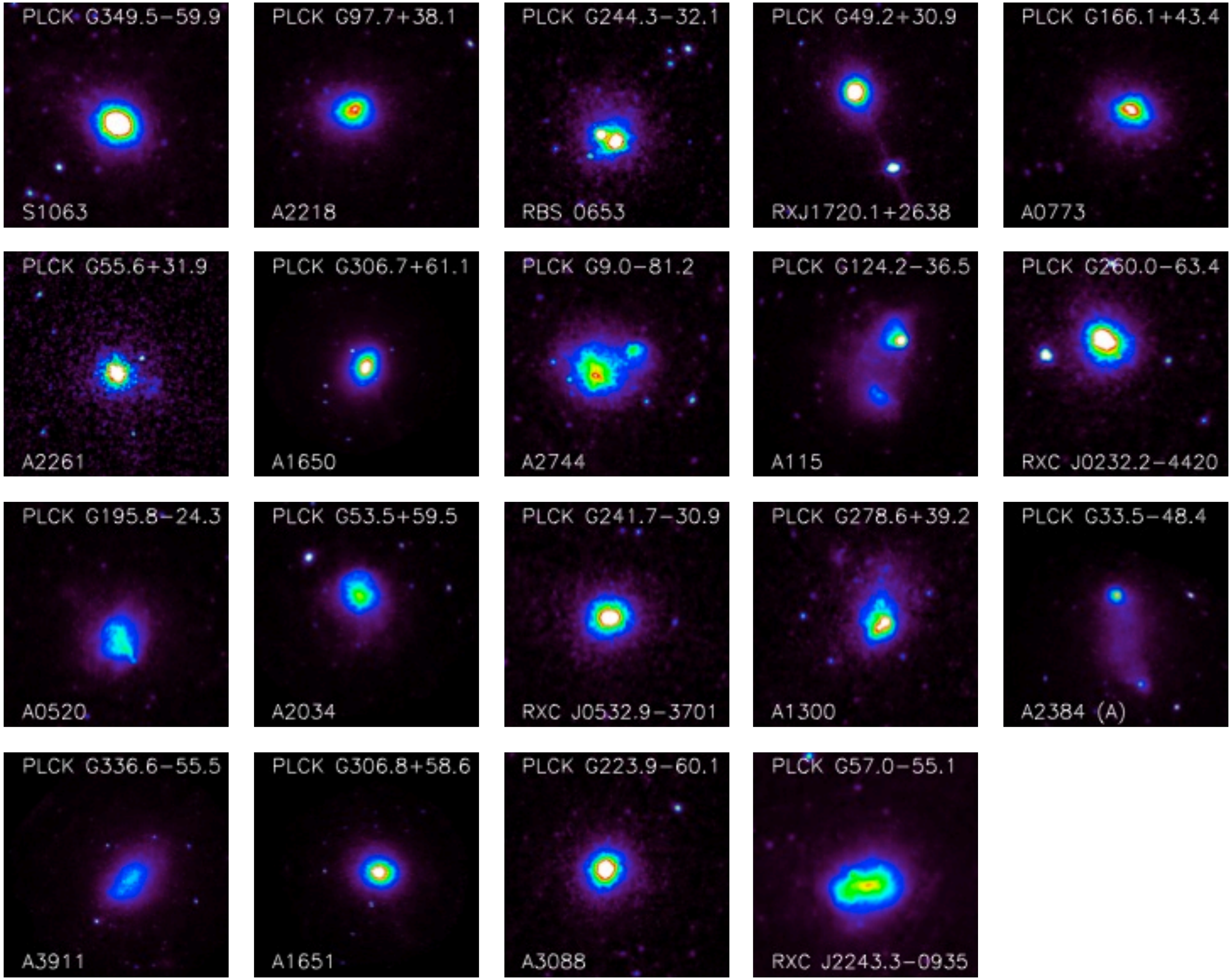
- XMM-*Newton* data
  - archive selected sample
  - X-ray data analysis as in
    Arnaud et al. 2002
    Pointecouteau et al. 2004
    Croston et al. 2006
    Pratt et al. 2007
    Bourdin et al. 2010

- Derived physical quantities
  - ne(r) deprojected + T_X
  - L_X, Y_X, M, M_{gas}
  - refined Y_{SZ} (prior on size and position from X-rays)

X-ray gallery



X-ray gallery



A local sample of 62 *Planck* clusters

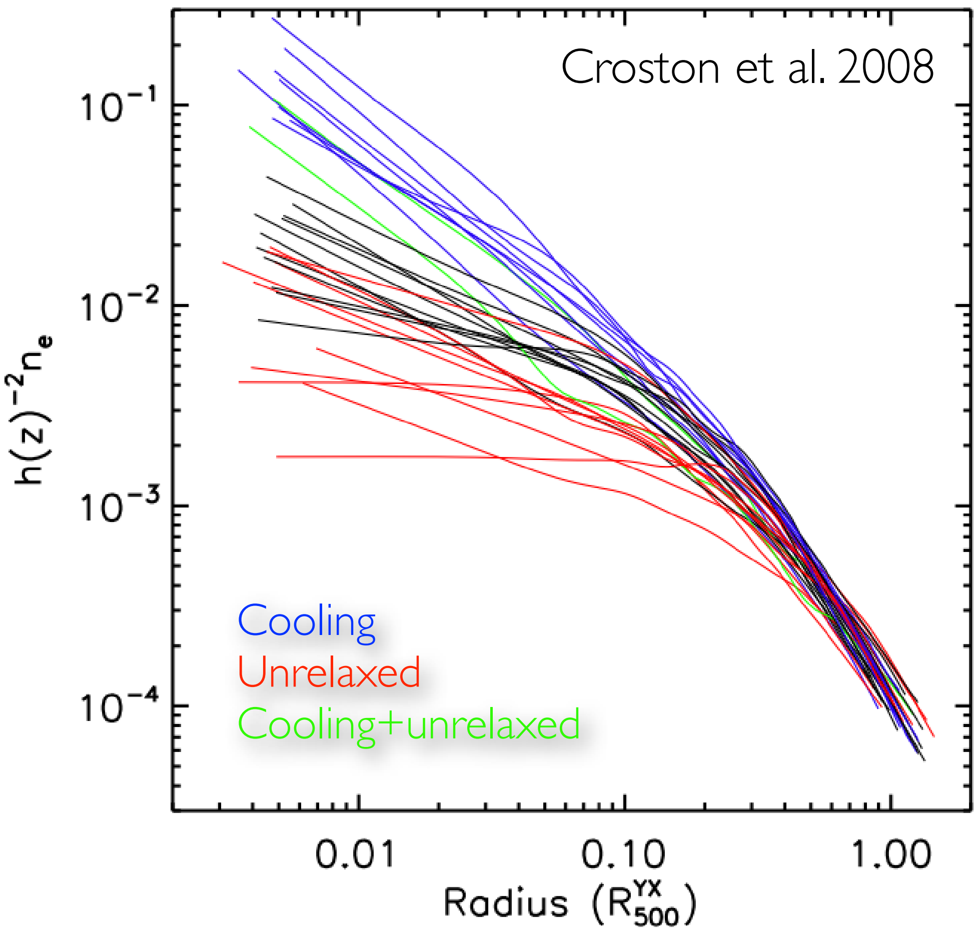
Table 1: X-ray and SZ properties. The temperature T_X is measured in the $[0.15 - 0.75]\,R_{500}$ region, and the luminosity $L_{X,500}$ is measured interior to R_{500} in the $[0.1 - 2.4]$ keV band. The final column indicates whether the cluster is classified as a cool core system, defined as described in Sect. 3.4.

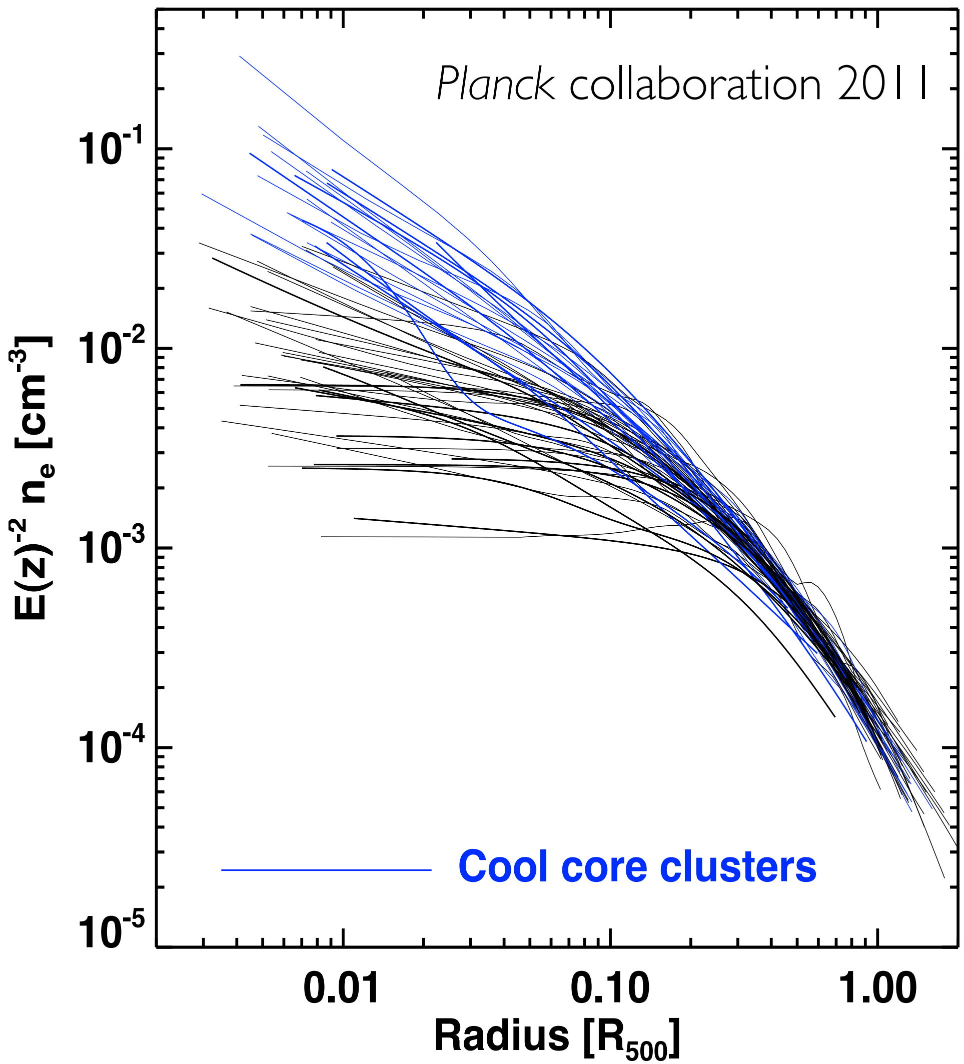
Name	RA (deg)	Dec (deg)	z	R_{500} (kpc)	T_X (keV)	$M_{g,500}$ (10^{14} M$_\odot$)	$Y_{X,500}$ (10^{14} M$_\odot$ keV)	$D_A^2\,Y_{500}$ (10^{-4} Mpc^2)	M_{500} (10^{14} M$_\odot$)	$L_{X,500}$ (10^{44} erg s^{-1})	CC
RXC J0014.3-3022	3.58	-30.38	0.307	1358	7.72± 0.25	1.65± 0.01	12.73± 0.51	1.74± 0.21	9.78± 0.21	13.35± 0.09	...
A85	10.44	-9.37	0.052	1206	5.78± 0.22	0.66± 0.01	3.84± 0.19	0.47± 0.05	5.30± 0.31	4.65± 0.02	✓
RXC J0043.4-2037	10.84	-20.61	0.292	1152	5.82± 0.20	0.88± 0.01	5.10± 0.20	1.40± 0.17	5.88± 0.14	8.26± 0.08	...
A119	14.02	-1.30	0.044	1114	5.40± 0.23	0.45± 0.01	2.45± 0.14	0.27± 0.03	4.12± 0.23	1.52± 0.01	...
RXC J0232.2-4420	38.06	-44.37	0.284	1223	6.41± 0.20	1.07± 0.01	6.86± 0.26	0.86± 0.13	6.95± 0.15	12.53± 0.09	✓
A401	44.73	13.56	0.075	1355	7.26± 0.44	1.02± 0.04	7.43± 0.58	0.83± 0.08	7.65± 0.67	5.82± 0.04	...
RXC J0303.8-7752	46.00	-77.88	0.274	1251	7.88± 0.36	0.96± 0.02	7.58± 0.45	1.09± 0.13	7.37± 0.25	7.39± 0.07	...
A3112	49.51	-44.26	0.070	1062	5.02± 0.15	0.40± 0.01	2.03± 0.07	0.18± 0.03	3.67± 0.16	3.84± 0.02	✓
A3158	55.72	-53.60	0.060	1124	5.00± 0.18	0.53± 0.01	2.66± 0.12	0.35± 0.03	4.29± 0.23	2.66± 0.01	...
A478	63.35	10.45	0.088	1326	6.43± 0.19	1.06± 0.03	6.81± 0.26	0.92± 0.08	7.23± 0.48	12.33± 0.05	✓
A3266	67.83	-61.42	0.059	1354	7.46± 0.22	0.96± 0.02	7.17± 0.30	0.90± 0.07	7.51± 0.51	4.22± 0.01	...
A520	73.55	2.96	0.203	1325	7.74± 0.22	1.13± 0.01	8.75± 0.32	0.99± 0.14	8.11± 0.16	7.11± 0.04	...
RXC J0516.7-5430	79.17	-54.52	0.295	1266	7.11± 0.67	1.20± 0.06	8.50± 1.06	1.29± 0.10	7.82± 0.60	7.27± 0.38	...
RXC J0528.9-3927	82.22	-39.44	0.284	1218	6.04± 0.32	1.11± 0.02	6.73± 0.46	1.18± 0.13	6.88± 0.25	10.55± 0.11	✓
RXC J0532.9-3701	83.23	-37.02	0.275	1190	6.84± 0.26	0.85± 0.01	5.82± 0.28	0.97± 0.13	6.35± 0.17	8.40± 0.07	✓
RXC J0547.6-3152	86.89	-31.90	0.148	1150	6.10± 0.14	0.60± 0.01	3.63± 0.10	0.45± 0.07	5.01± 0.08	3.89± 0.02	...
A3376	90.47	-39.99	0.045	930	3.39± 0.09	0.28± 0.01	0.94± 0.03	0.10± 0.02	2.39± 0.06	0.92± 0.01	...
RXC J0605.8-3518	91.48	-35.29	0.139	1059	4.93± 0.11	0.46± 0.01	2.29± 0.07	0.47± 0.06	3.87± 0.06	4.74± 0.02	✓
RXC J0645.4-5413	101.39	-54.21	0.164	1303	7.26± 0.18	1.01± 0.01	7.33± 0.24	1.09± 0.07	7.40± 0.14	7.59± 0.04	✓
RXC J0658.5-5556	104.63	-55.96	0.296	1527	11.19± 0.25	2.08± 0.02	23.22± 0.64	2.66± 0.14	13.73± 0.21	20.05± 0.10	...
A665	127.75	65.88	0.182	1331	7.64± 0.46	1.12± 0.03	8.55± 0.61	1.09± 0.11	8.04± 0.37	6.81± 0.10	...
A754	137.24	-9.65	0.054	1423	8.93± 0.24	1.04± 0.03	9.28± 0.39	0.86± 0.05	8.69± 0.63	4.68± 0.02	...
A773	139.49	51.69	0.217	1228	6.78± 0.16	0.89± 0.01	6.01± 0.18	0.86± 0.11	6.55± 0.11	6.80± 0.04	...
A781	140.09	30.49	0.298	1114	5.72± 0.10	0.76± 0.01	4.32± 0.10	0.72± 0.14	5.35± 0.07	4.75± 0.03	...
A868	146.36	-8.64	0.153	1058	4.63± 0.16	0.51± 0.01	2.34± 0.08	0.41± 0.07	3.91± 0.10	3.18± 0.03	...
A963	154.24	39.01	0.206	1123	5.49± 0.11	0.66± 0.01	3.63± 0.09	0.41± 0.09	4.95± 0.07	6.40± 0.03	✓
RXC J1131.9-1955	173.00	-19.92	0.308	1300	7.75± 0.31	1.30± 0.02	10.11± 0.53	1.30± 0.23	8.59± 0.26	11.01± 0.09	...
A1413	178.81	23.39	0.143	1144	6.59± 0.07	0.53± 0.01	3.49± 0.05	0.69± 0.08	4.90± 0.04	3.39± 0.01	✓
RXC J1206.2-0848	181.59	-8.81	0.441	1334	10.15± 0.32	1.59± 0.02	16.13± 0.63	1.70± 0.30	10.83± 0.24	19.65± 0.12	✓

...

Comparison to X-rays: density profiles

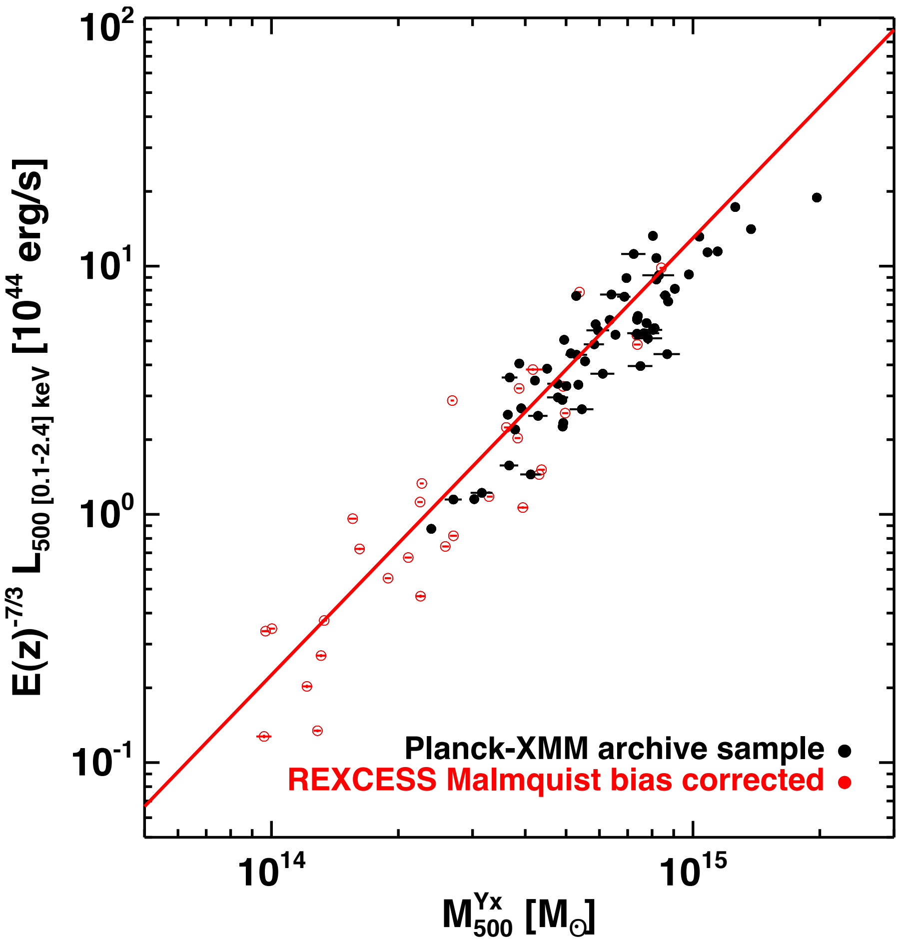
- **REXCESS** (Böhringer 2007)
  - X-ray selected representative sample of 31 clusters, z < 0.2





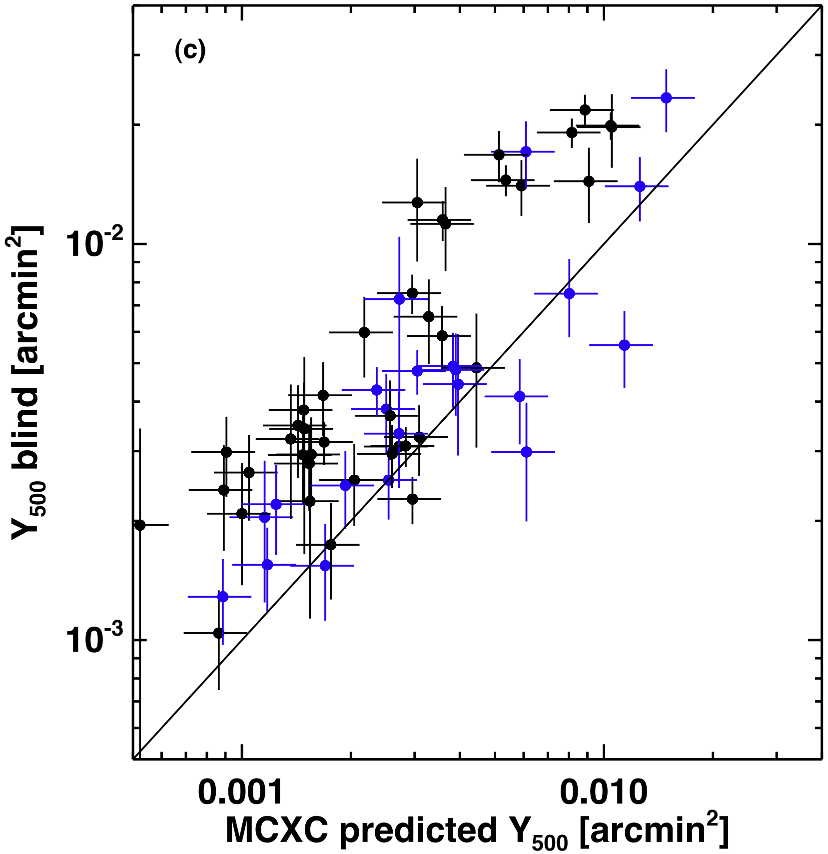
Comparison to X-rays: L_X-M_{500}

- M_{500} from M-Y_X relation
  (Arnaud et al. 2007, 2010)

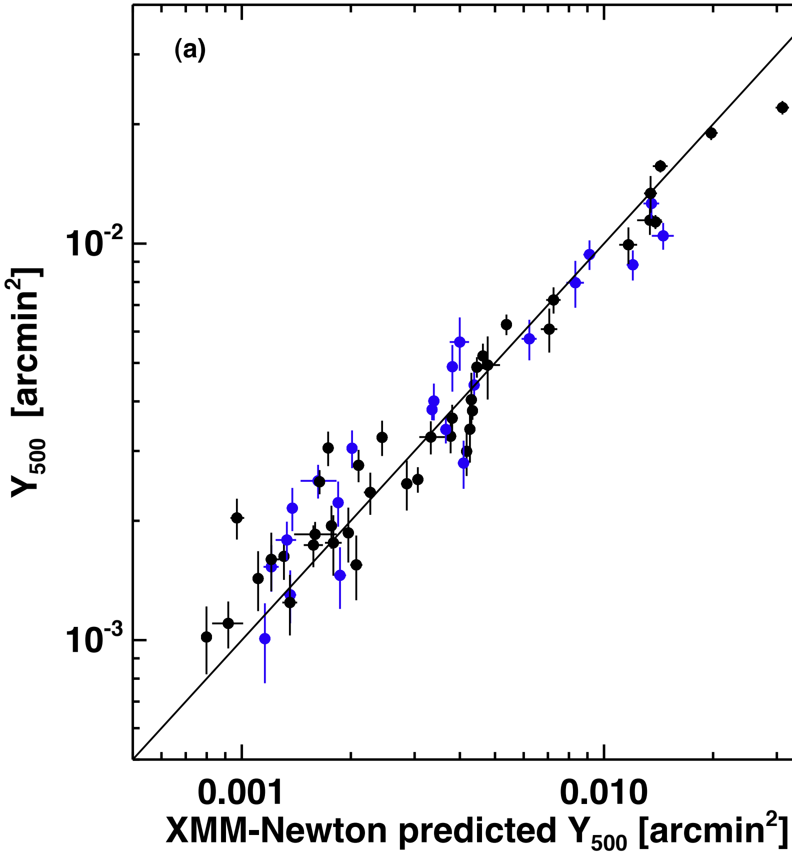


XMM-*Newton* + *Planck* added value

Blind Y_{500}



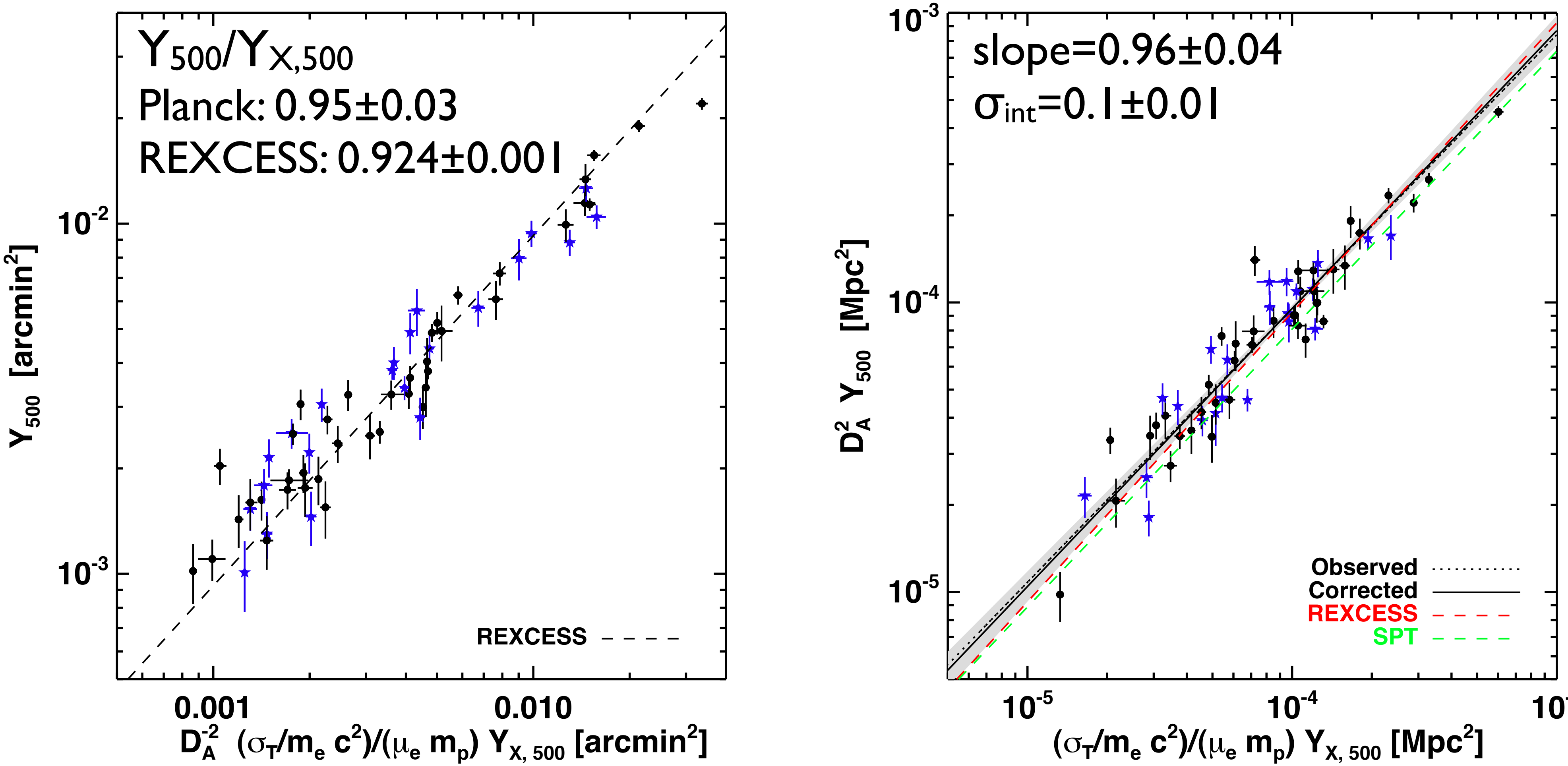
Y_{500} with X-ray size prior



see MCXC (Piffaretti et al 2011)

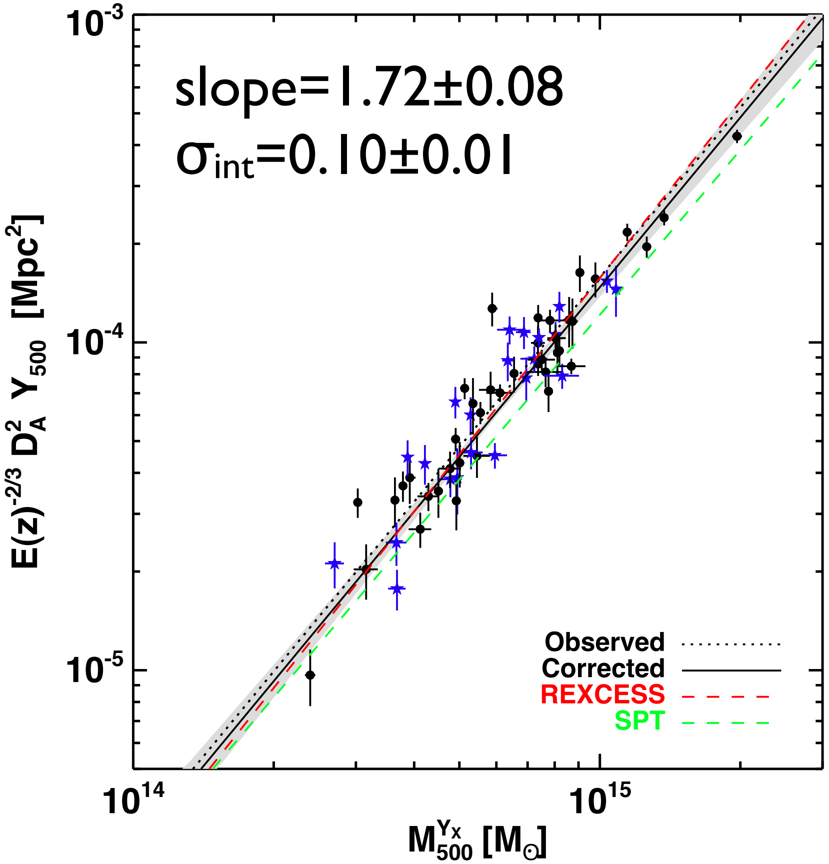
The key result: Y_{500} - Y_X relation

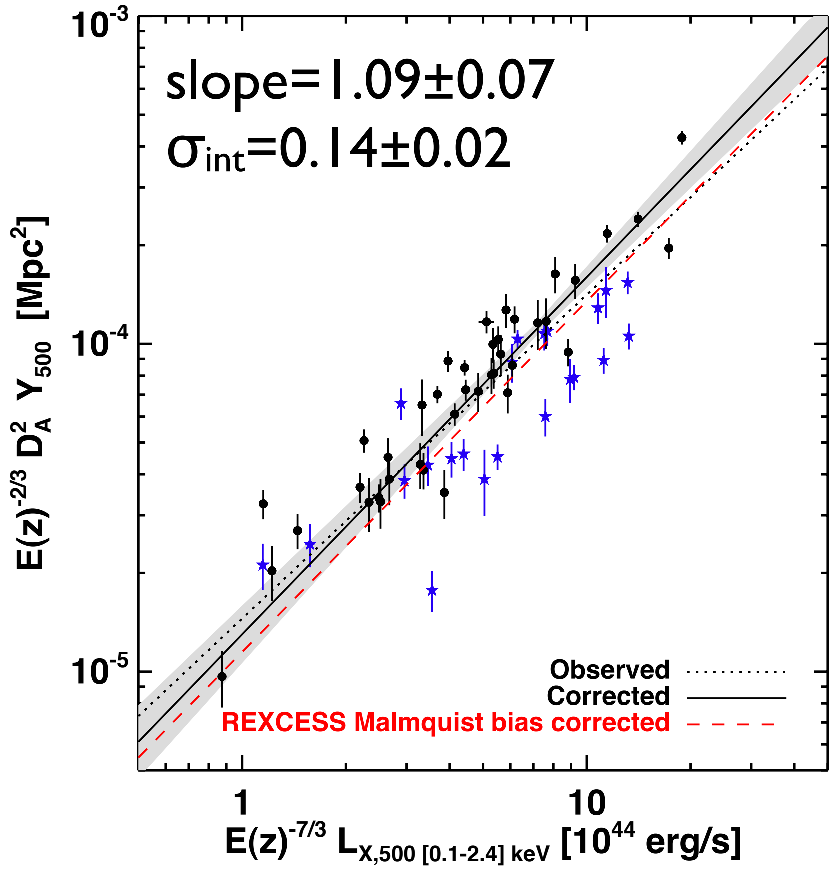
$$E(z)^{\gamma} Y_{500} = 10^{A} [E(z)^{\kappa} X / X_0]^{B}$$



very low scatter relation

The Y_{500} - M_{500} and Y_{500} - L_X relations





very low scatter relation

higher scatter linked to the dynamical state

Conclusions

- 62 local clusters ESZ based
  - 55 with z < 0.3
  - a decade in mass: 2-20 × 10^{14} M_{sol}
- Selection effects investigated
  - minor corrections
- Well constrained scaling relations
  - Y_{500}-$L_{X,500}$: fully compatible with X-ray relation (note the lack of CC wrt to X-ray samples)
  - Y_{500}-Y_X and Y_{500}-M_{500}

    slope consistent with self-similar expectations

    normalisations compatible with other works
    (Arnaud et al. 2010, Andersson et al. 2010)

    small intrinsic scatter ~0.1

Perspectives

- A superior robust and unique local reference
  - Y_{SZ} versus M_{500}, $M_{gas,500}$, $L_{X,500}$, T_X
  - for lower mass systems to probe cluster astrophysics
  - for evolution studies
  - the largest, highest-quality SZ-X-ray dataset currently-available

- Agreement between the present results, ground-based results and X-ray predictions augurs well for our understanding of cluster astrophysics.

- Promising for the use of *Planck* clusters for precision cosmology

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Planck Early Results: Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations

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The *Planck* Collaboration SZ Early Papers

- *Planck* Early Results: The all-sky Early Sunyaev-Zeldovich cluster sample (arXiv:1101.2024)
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- *Planck* early results: XMM-Newton follow-up for validation of Planck cluster candidates (arXiv:1101.2025)
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- *Planck* early results: statistical analysis of SZ scaling relations for X-ray galaxy clusters (arXiv:1101.2043)
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- *Planck* Early Results: Cluster SZ-Optical Scaling Relations (arXiv:1101.2027)
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- *Planck* Early Results: Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations (arXiv:1101.2026)
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