Using Chandra X-ray Observation to Characterize Planck Clusters

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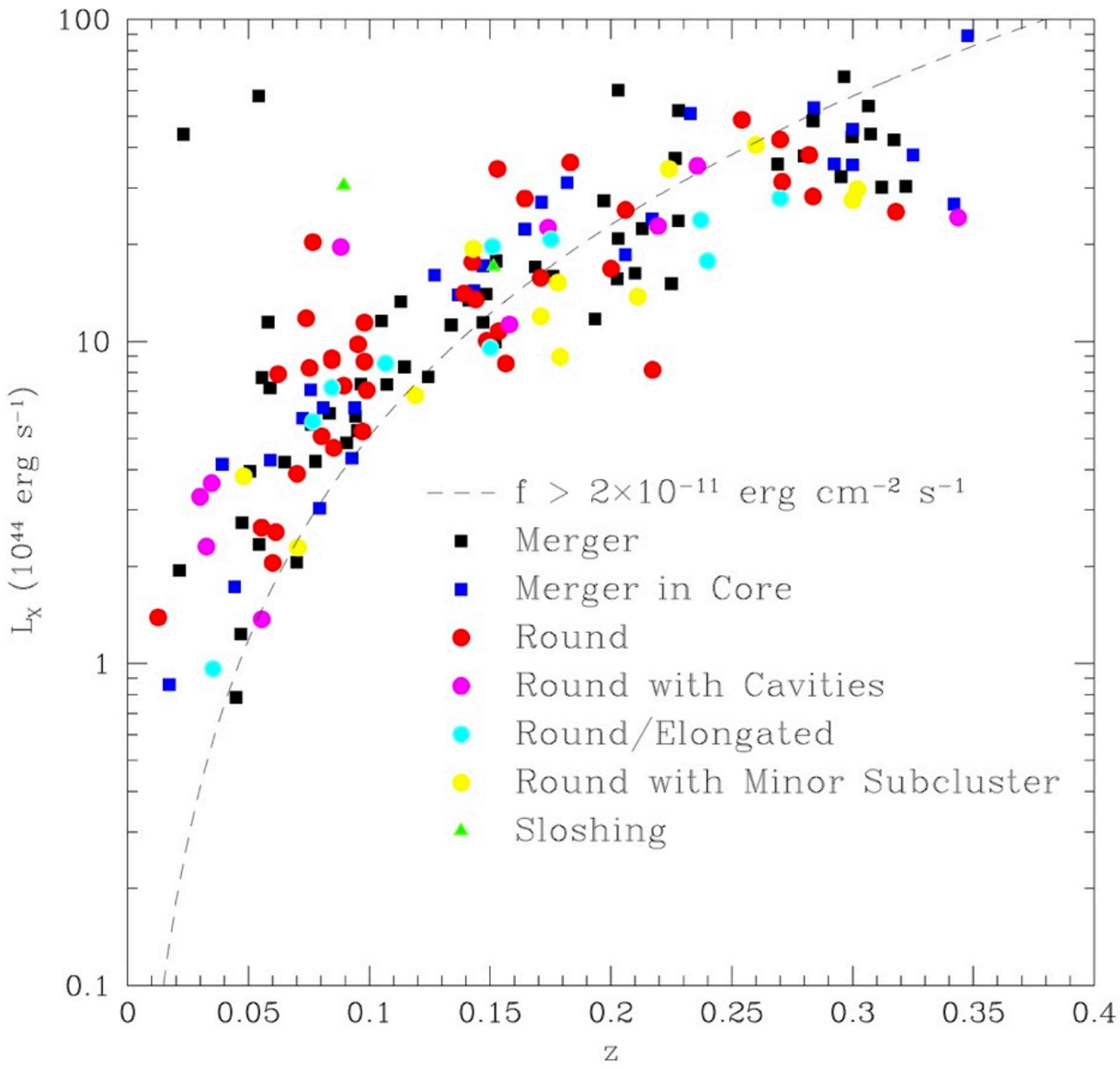
for the Chandra-Planck Collaboration

SZ surveys can provide "clean" cluster samples, close to an unbiased mass-limited selection.

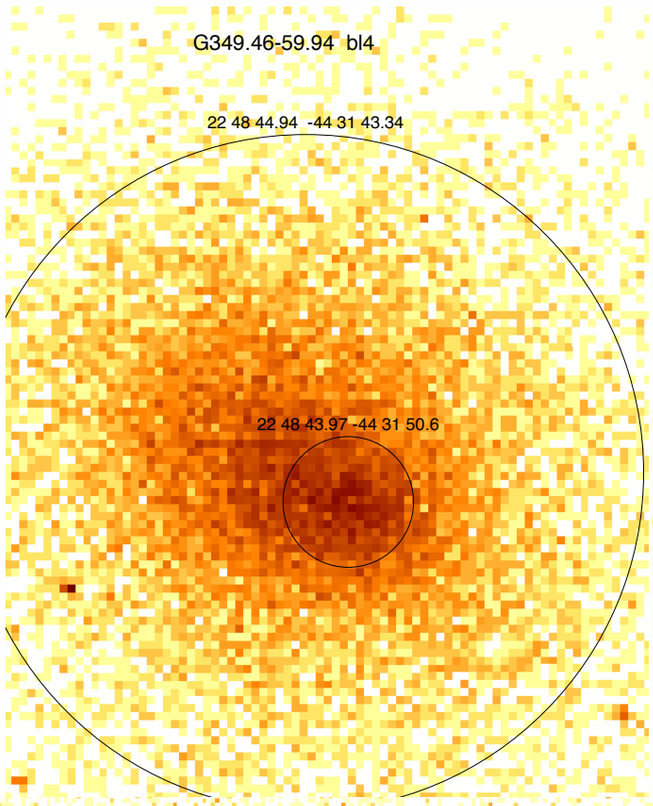
Although the SZ effect is redshift independent, detection limit depends on instrument angular resolution.

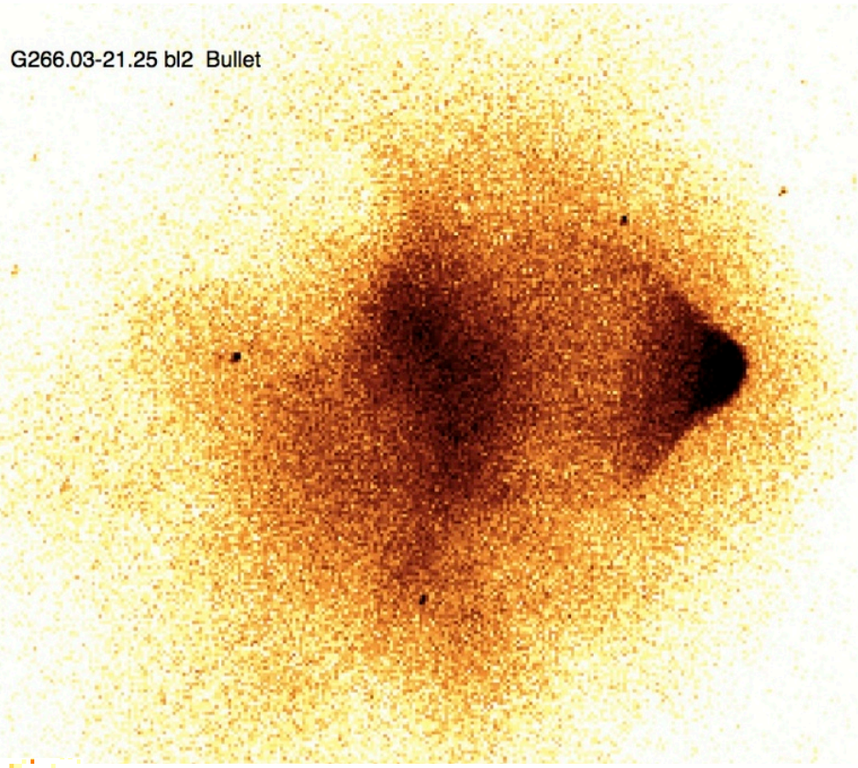
Planck provides a statistically representative sample of massive clusters over the full sky (|b|>15 deg)

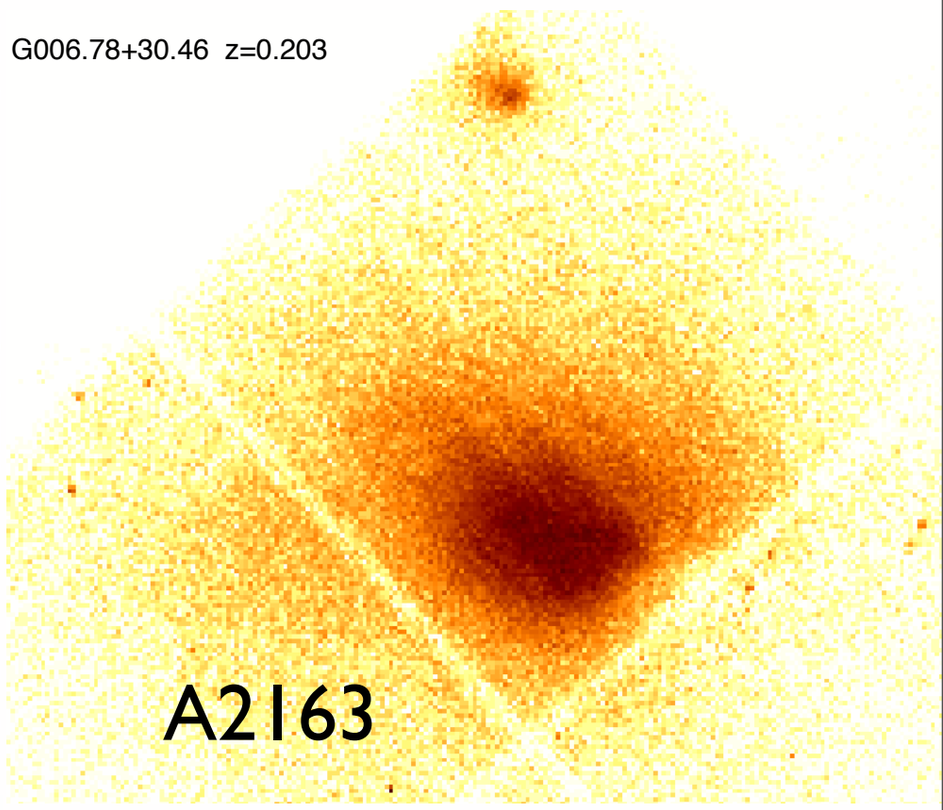
165 z<0.35 clusters Chandra observations with 10,000 source counts

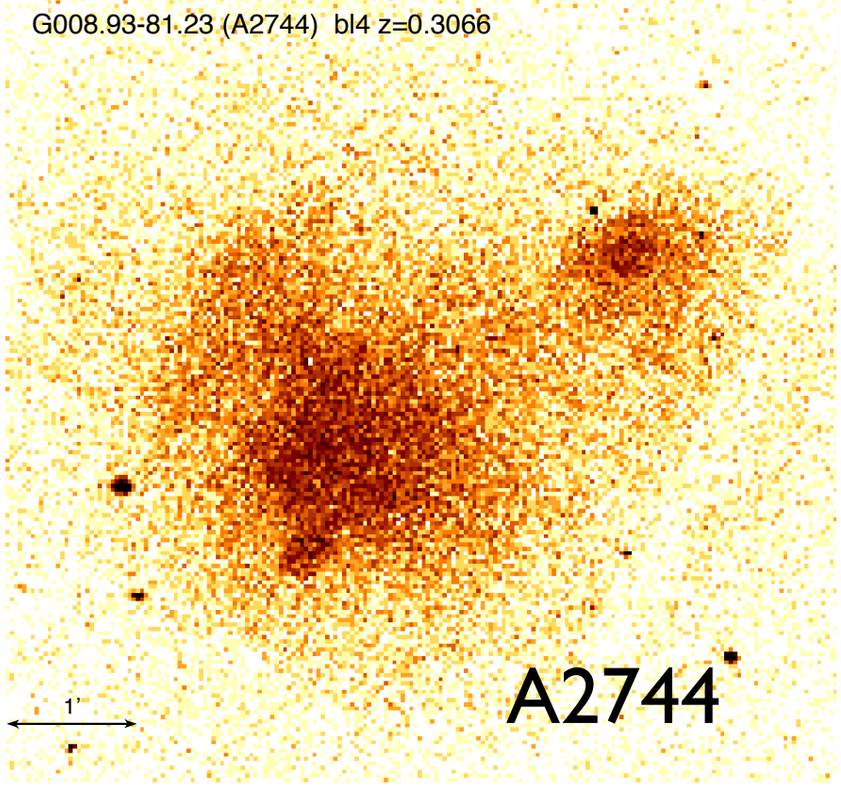


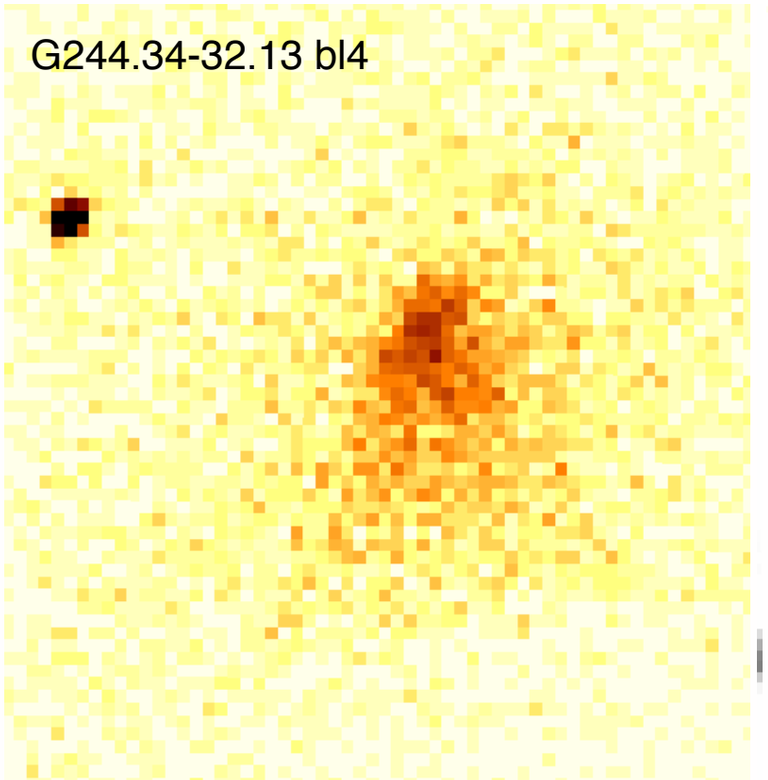
Lx vs z for Planck ESZ clusters

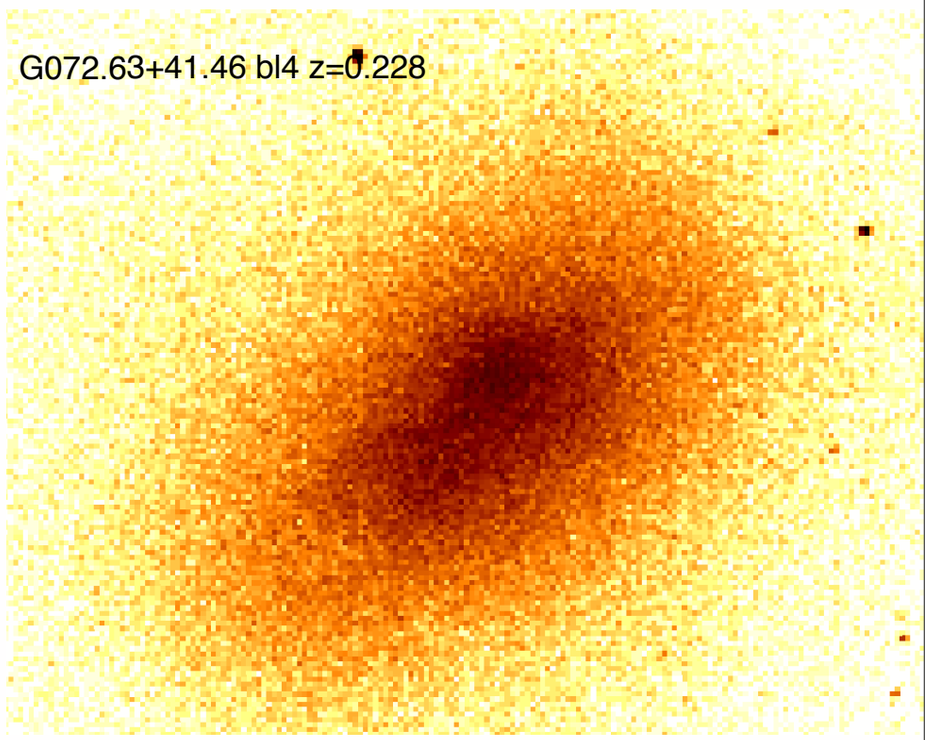












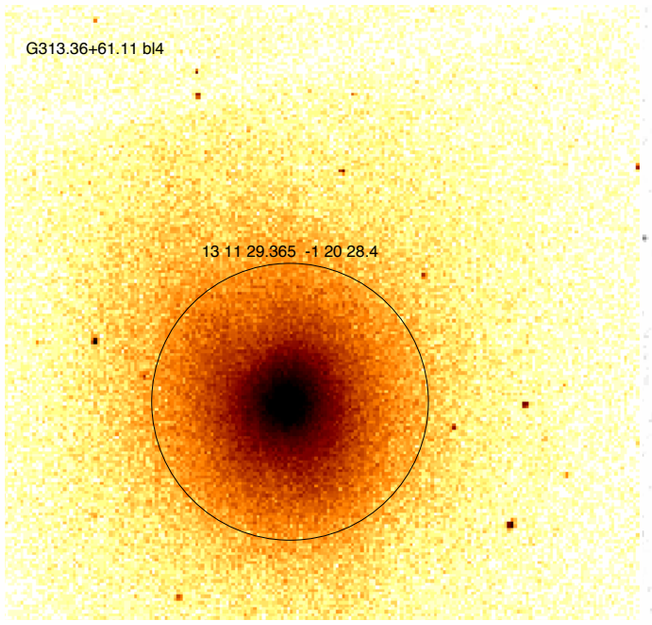
The most X-ray luminous ($z<0.35$) Planck detected clusters
($> 3 \times 10^{45}$ ergs/s)

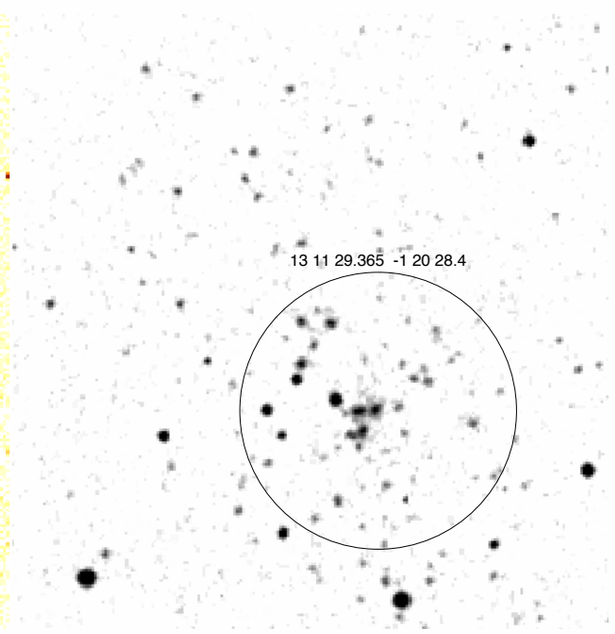
Now characterizing each cluster through
Lx, kT, gas mass, total mass, gas mass fraction,
entropy, central cooling time, and
cluster morphology.

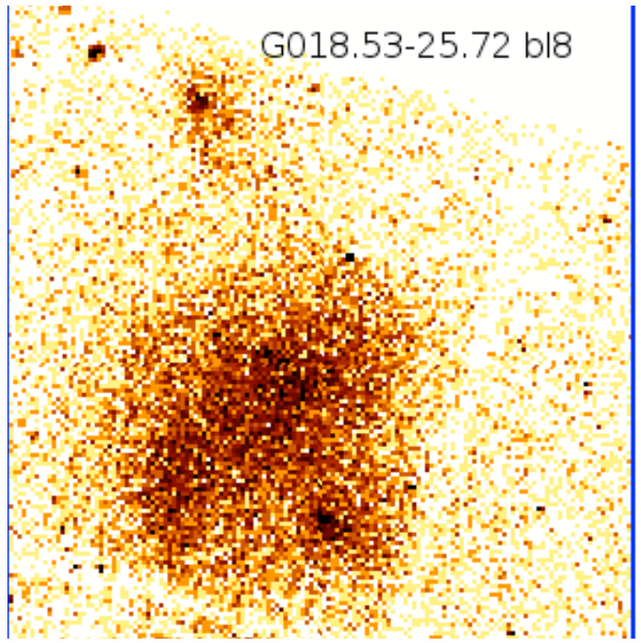
Determine low-z cluster mass functions and
accurate scaling relations between cluster mass and mass proxies (e.g. gas mass, kT, Lx) and the integrated Compton Y parameter
required for future large X-ray (e.g. SXG/eROSITA) and SZ surveys.

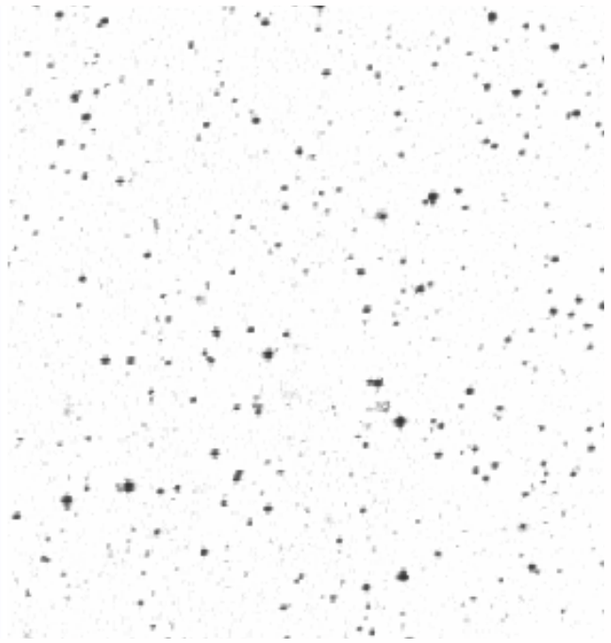
Basic Cluster Morphologies

"single" relaxed cluster vs "disturbed" merging clusters

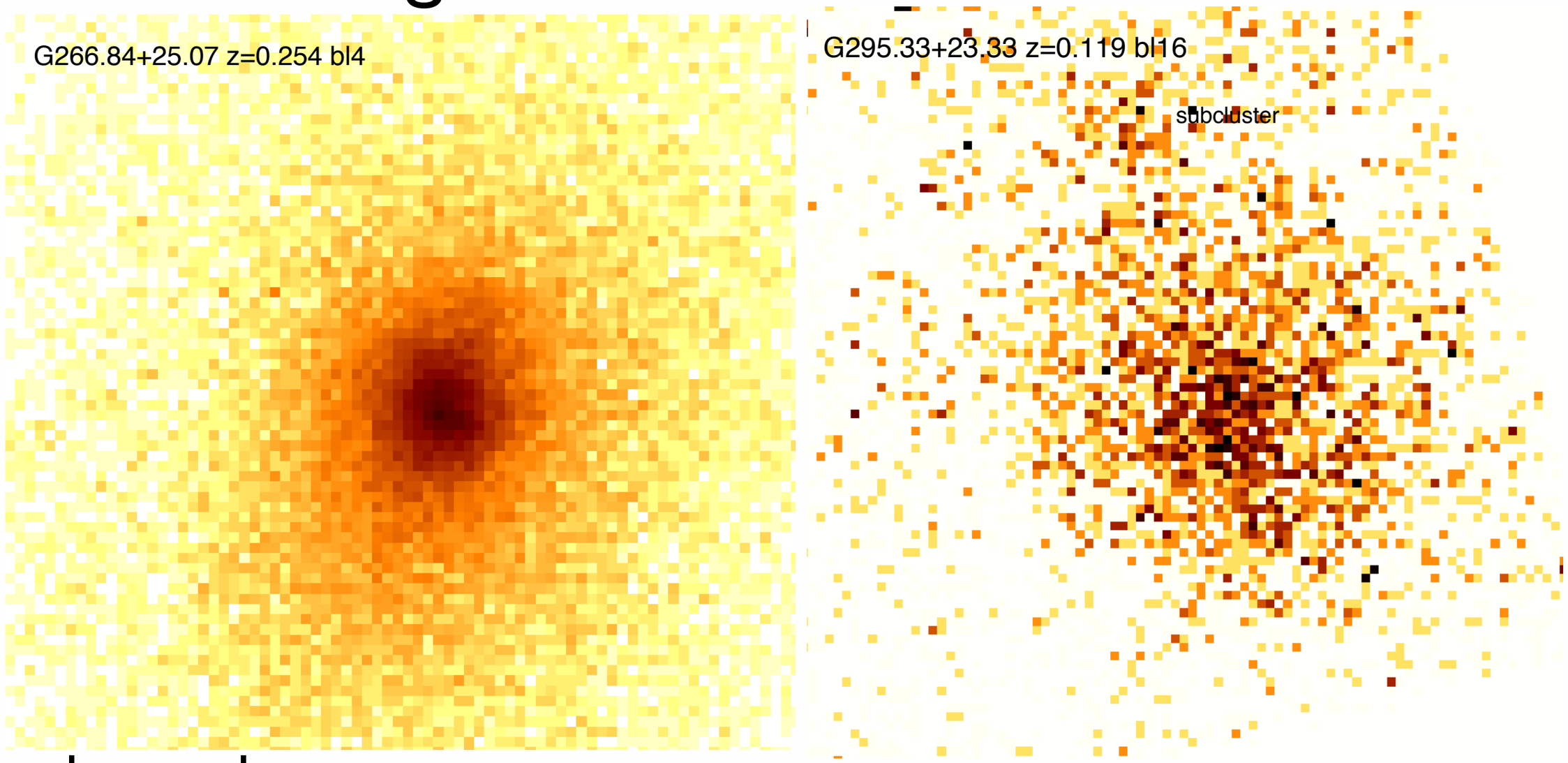








Single “relaxed clusters “

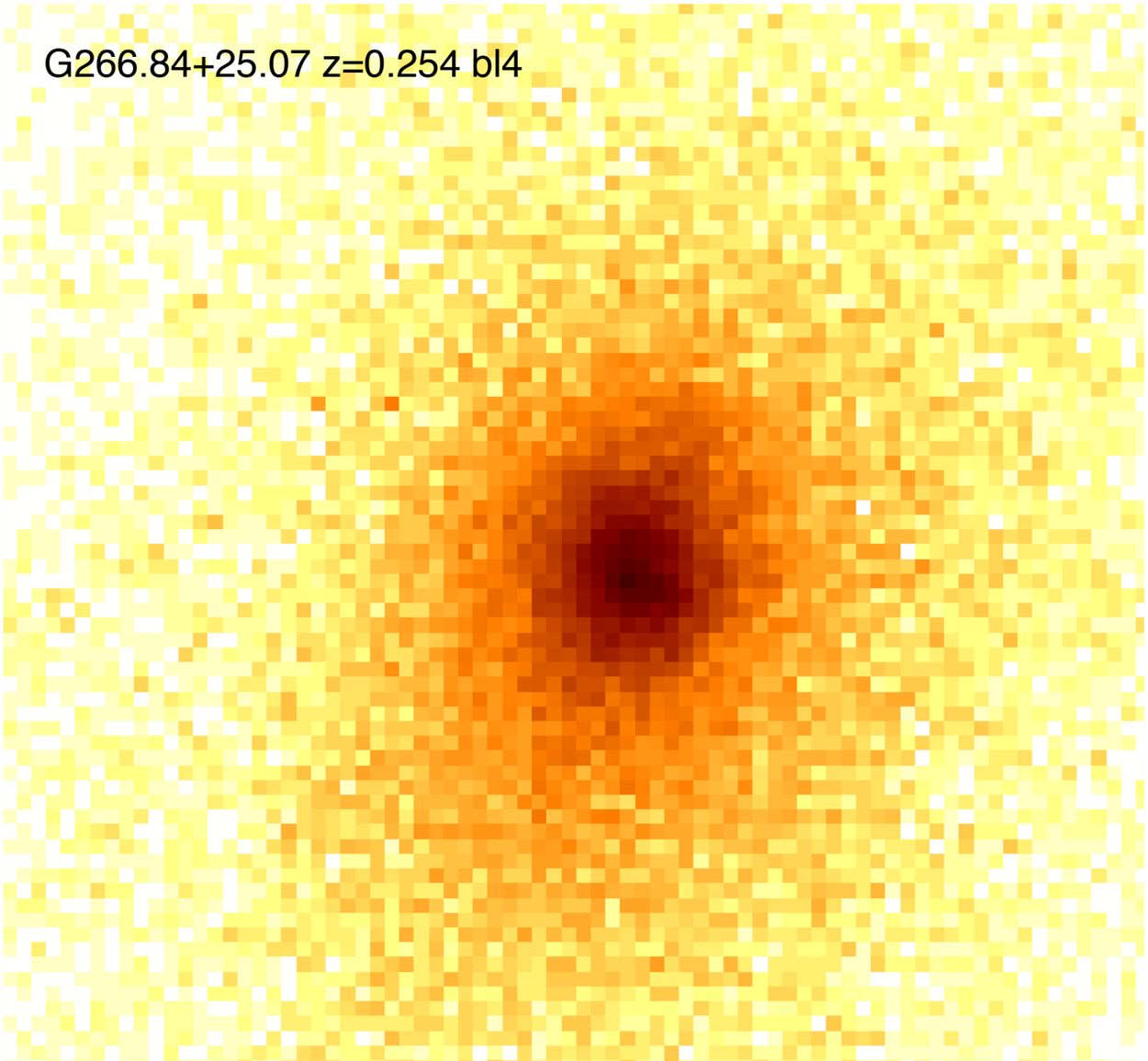


cool core cluster

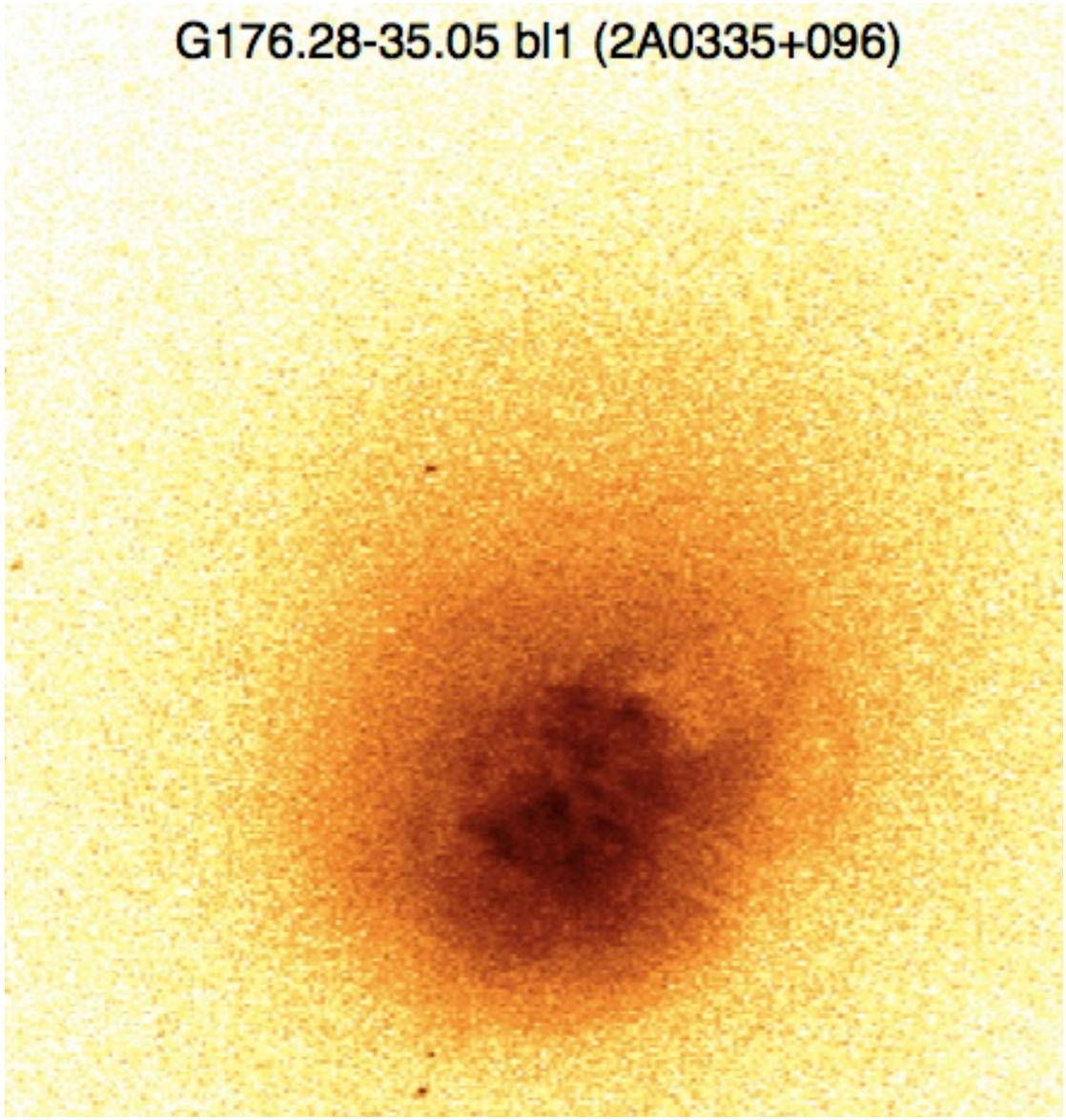
- kT lower in cluster core
- high central gas density
- short central gas cooling time
- low entropy

Not cool core

Single relaxed “cool core” clusters

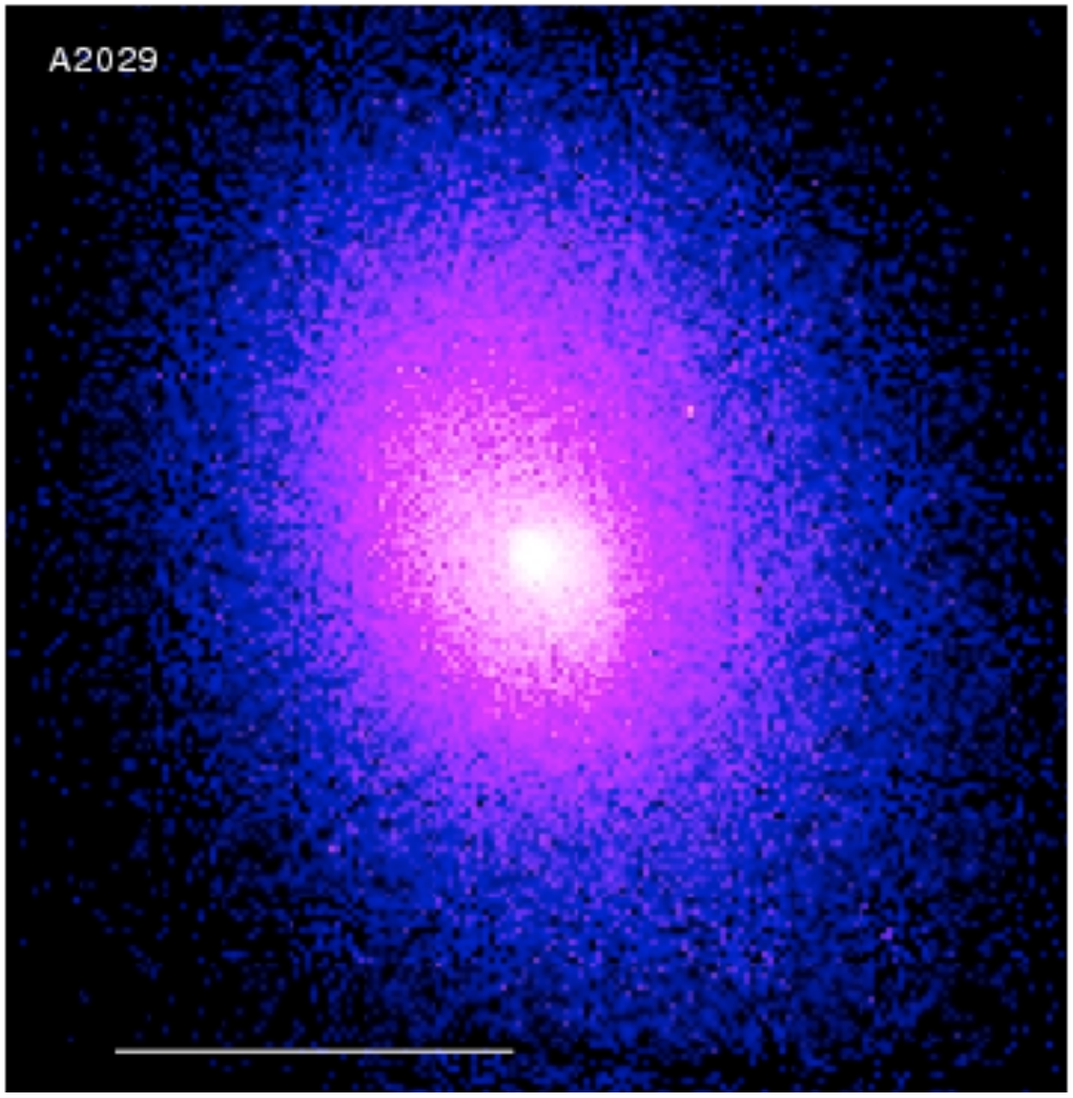


Cool core cluster- no clear cavities

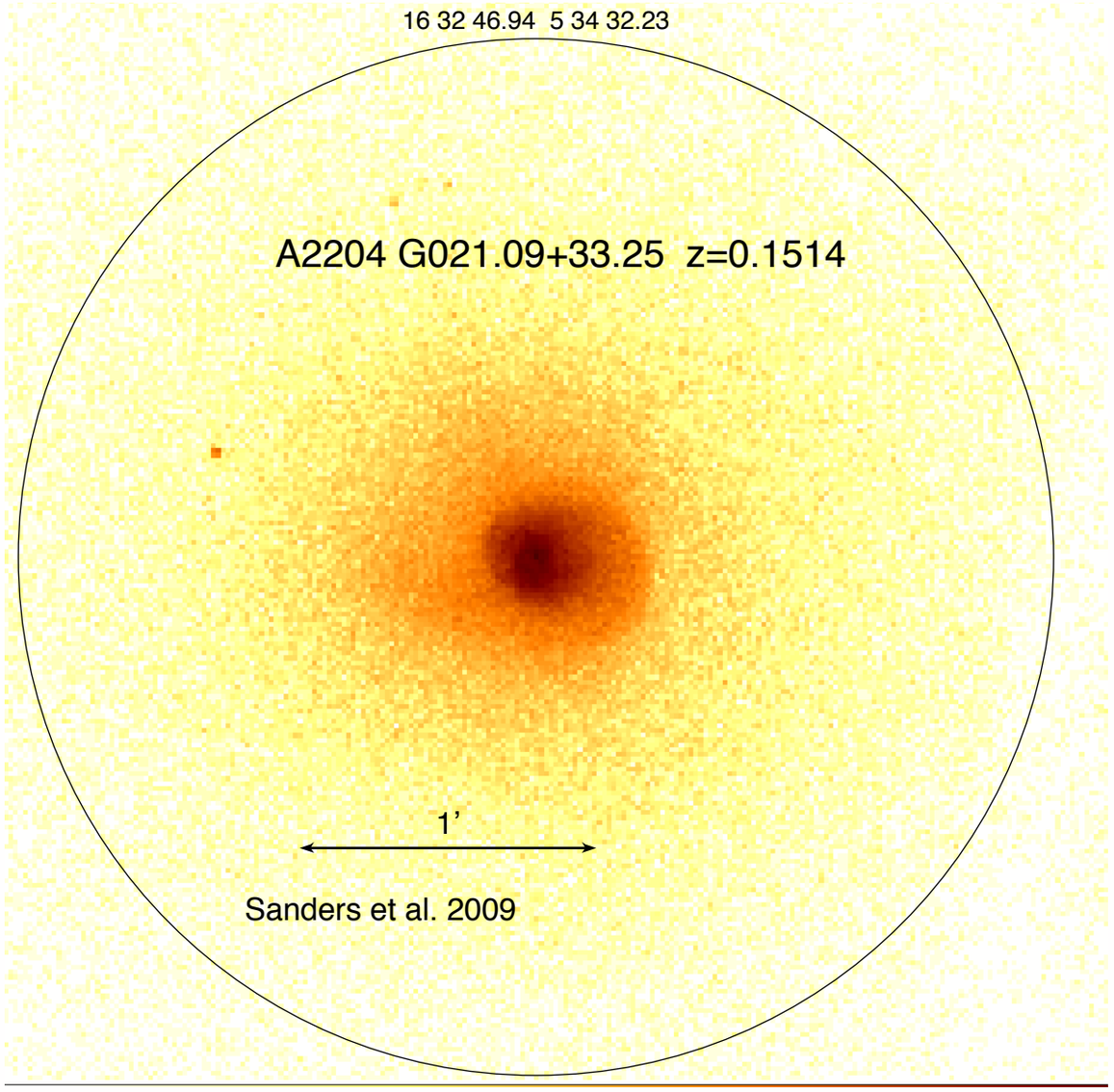


Cool core cluster with cavities

Gas sloshing in “cool core” clusters



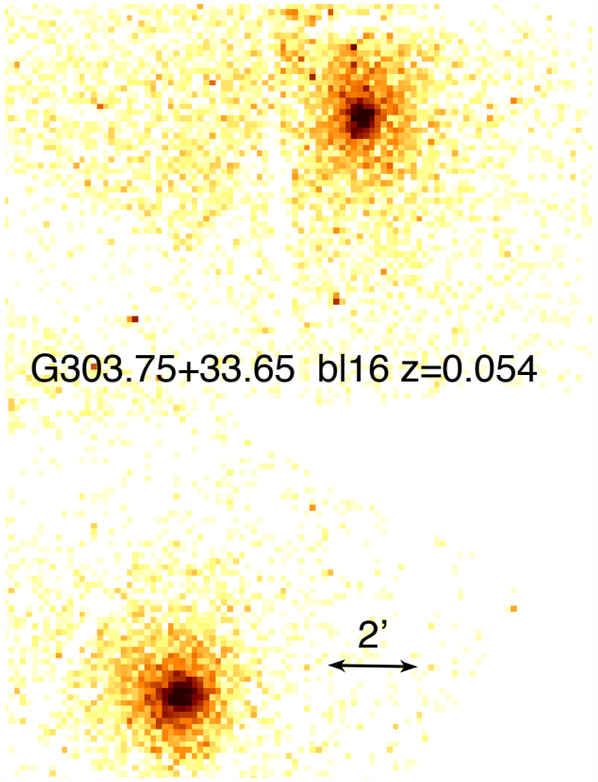
Cool core cluster - gas sloshing

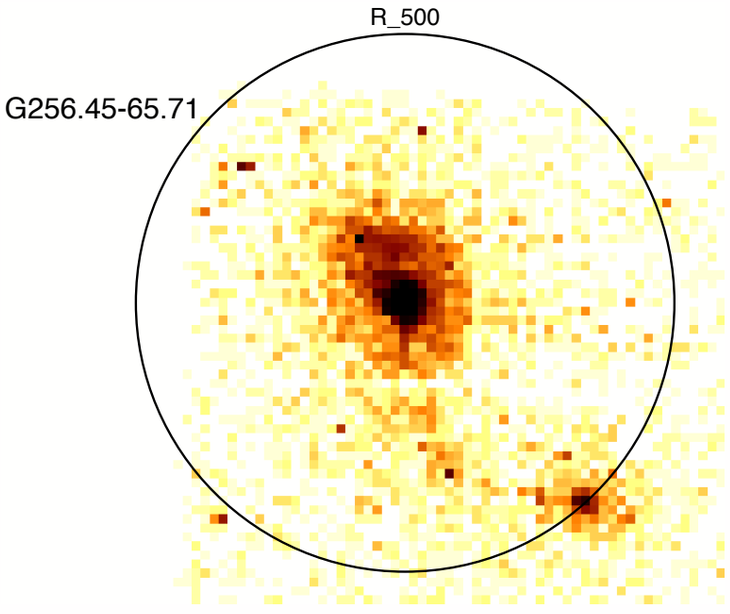


Cool core cluster with sloshing/ cavities

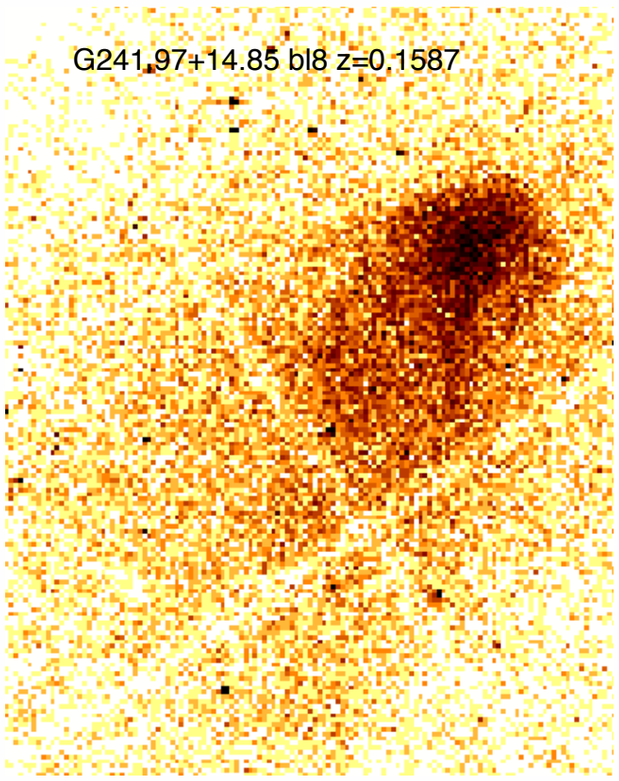
Merging clusters

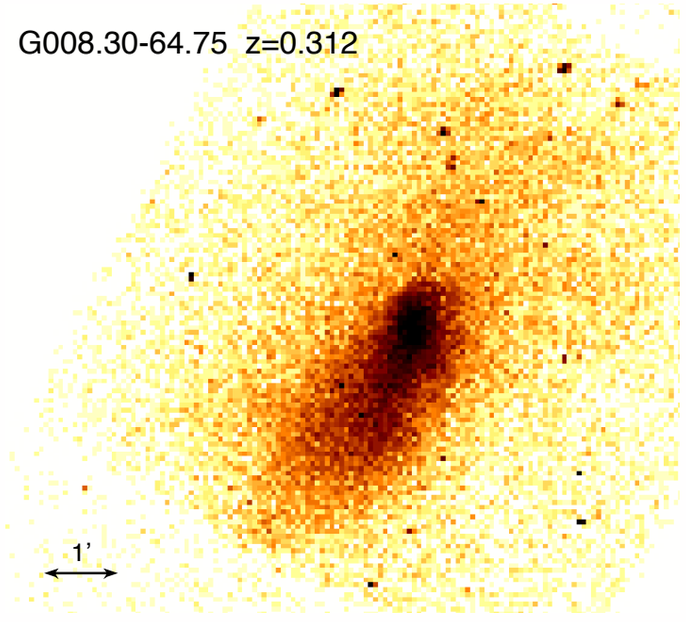
Pre-merger clusters



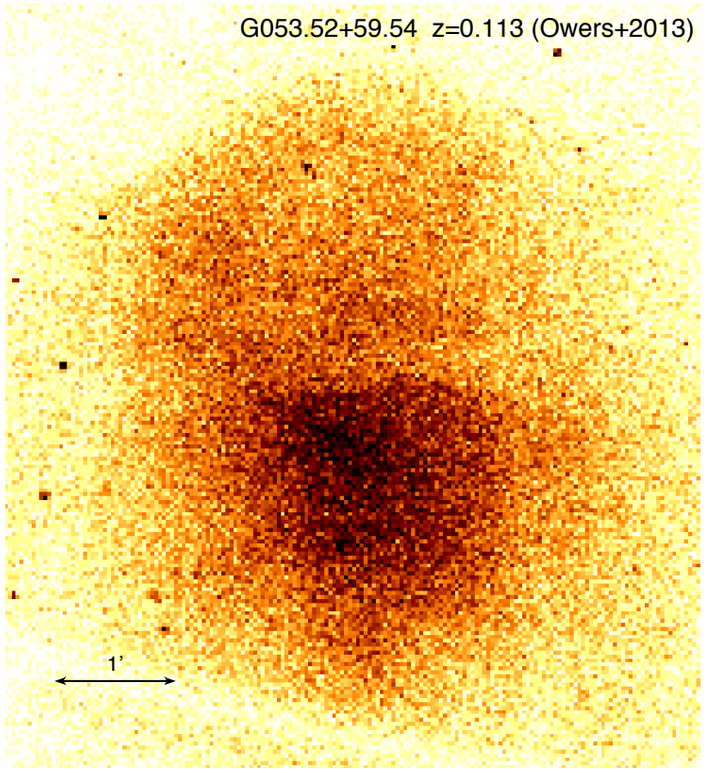


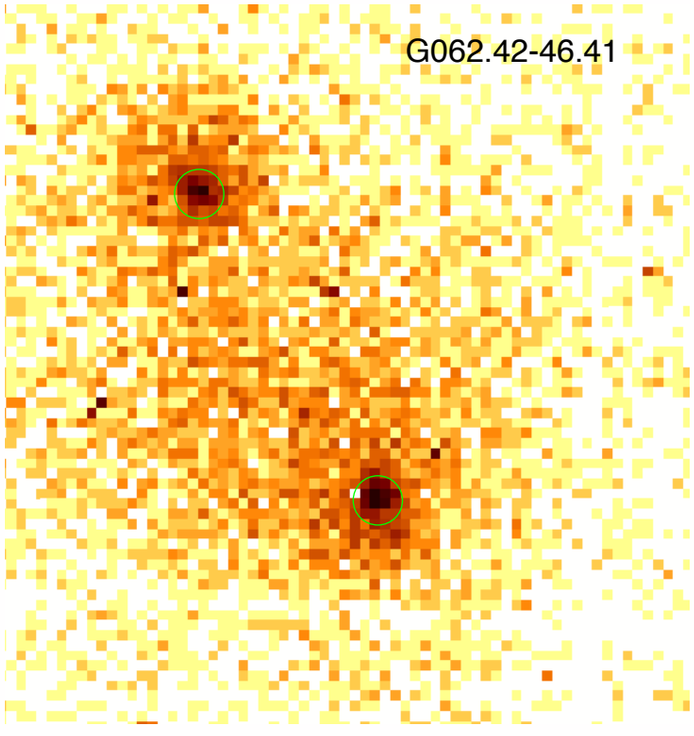
Merging





Post-merger clusters





Are cluster morphologies different in low redshift SZ, X-ray and optically selected samples?

SZ - Planck detected

X-rays - ROSAT HIFLUGCS (Reiprich & Bohringer 2002, Ikebe+ 2002, Zhang+ 2011), B55 (Edge+ 1990), BCS and MACS (Ebeling+),

Optical - Abell catalog - Einstein X-ray observations (Jones & Forman 1999)

Cluster morphologies in low redshift SZ, X-ray and optically selected samples

	Planck cluster sample (165 clusters)	X-ray HIFLUGCS (62 clusters)	Abell/Einstein (198 clusters)
"relaxed"	44% (73 clusters)	66% (41 clusters)	61% (127)
"disturbed"	56% (92 clusters)	34% (21 clusters)	39% (81)

BUT, Planck observed with Chandra (1" resolution), HIFLUGCS (Zhang+) with XMM (15" resolution) and Abell with Einstein IPC (1' resolution)

Of the 165 Planck detected clusters, there are 27 where substucture would not be identified with 15" spatial resolution

Cluster morphologies in low redshift cluster samples

	Planck clusters with 1" res	Planck clusters with 15" res	X-ray HIFLUGCS	Abell/Einstein
"relaxed"	44% (73)	61% (100)	66% (41)	61% (127 clusters)
"disturbed"	56% (92)	39% (65)	34% (21)	39% (81 clusters)

In Chandra Planck sample, 27 disturbed clusters have mergers in their cores. Most not identified with XMM (none through Einstein/IPC!) Without Chandra's resolution, 60% "relaxed" 40% disturbed clusters in Planck sample.

While Planck has many merging clusters, SZ selected cluster samples are not significantly different in the percentage of disturbed cluster compared to X-ray (or optical) cluster catalogs

Clusters with Cool Cores

In X-ray samples
75 clusters from HIFLUGCS and B55 (Birzan+ 2012)
60% have cool cores
(same percentage classified as "relaxed" in HIFLUGCS by Zhang+)

Planck detected cluster sample
Of relaxed clusters (44% of Planck clusters),
~40% no cool cores (28 clusters)
Of total Planck sample ~70% do NOT have cool cores

Planck cluster sample has a significantly smaller percentage (~30%) of cool core clusters than X-ray selected samples.

Understandable, since clusters with centrally peaked X-ray emission more readily detected in X-ray surveys.

Clusters with AGN produced cavities

X-ray samples
75 clusters from HIFLUGCS and B55
41% (31 clusters) have bubbles (Birzan+ 2012)

For B55 sample, Dunn & Fabian (2008) found 14 of 20 (70%) of clusters with t_cool < 3 10^9 years have bubbles

Planck detected cluster sample
clear bubbles in 10 clusters, candidate bubbles in10 more clusters
14 - 28% of Planck clusters with bubbles

(due to smaller percentage of cool core clusters in Planck sample then in X-ray sample)

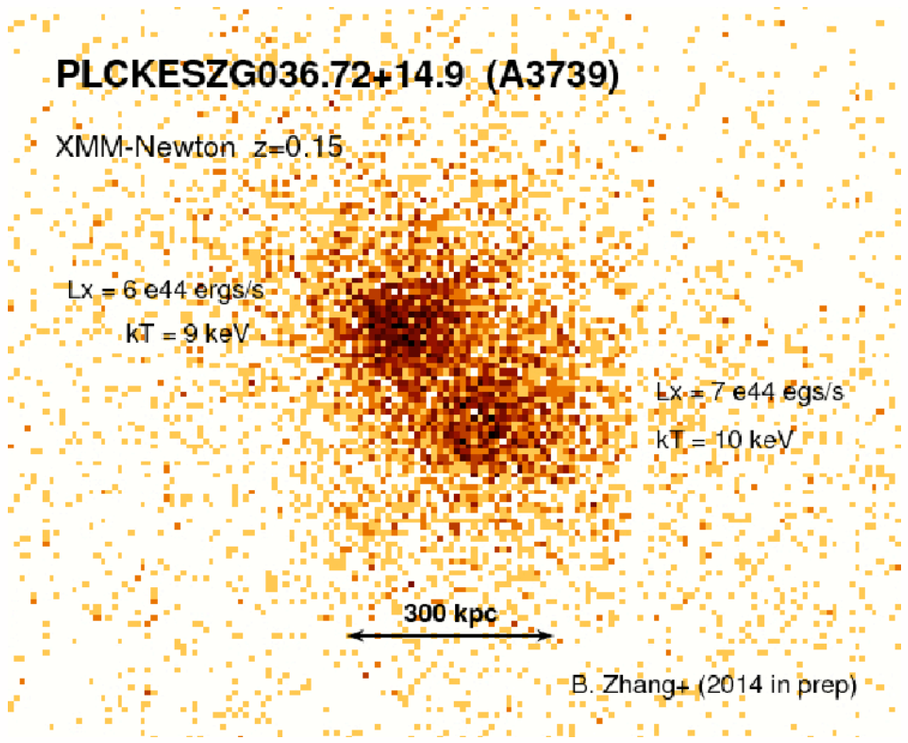
Future work with Chandra-Planck cluster sample

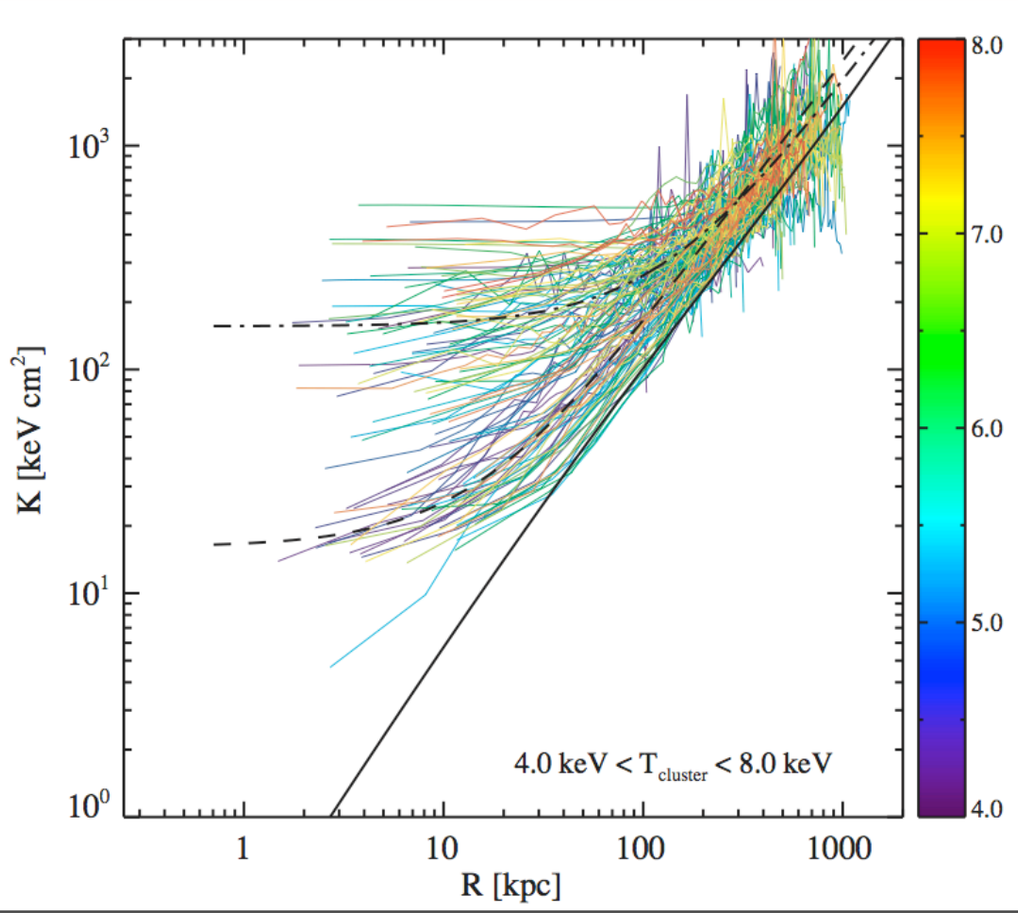
Rich data set

Analysis of individual interesting cluster mergers

Generation of low redshift mass function, cluster scaling relations

Investigate causes of increased entropy in cluster cores





Thanks!