XMM and Chandra observations of Nearby Poor Clusters

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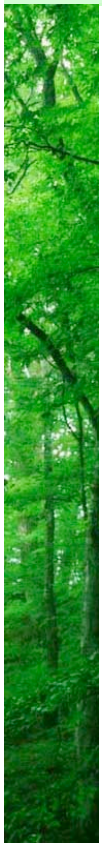
Topics



Poor clusters : kT~3 keV, relatively little cool components

cluster	redshift	kT (keV)	data	
A1060	0.011	3.2	Chandra	Our data
AWM7	0.017	3.6	Chandra, XMM	Our data
MKW4	0.020	2.6	XMM	Published
AWM4	0.032	2.4	XMM	Published
2A0335	0.035	3.8	Chandra	Published

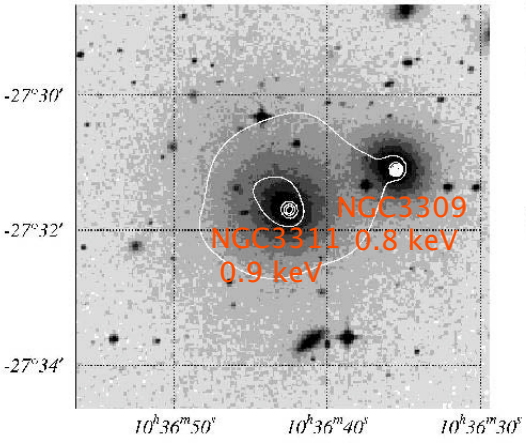
- Substructure and blobs in the center
- Temperature distribution
- Abundance distribution

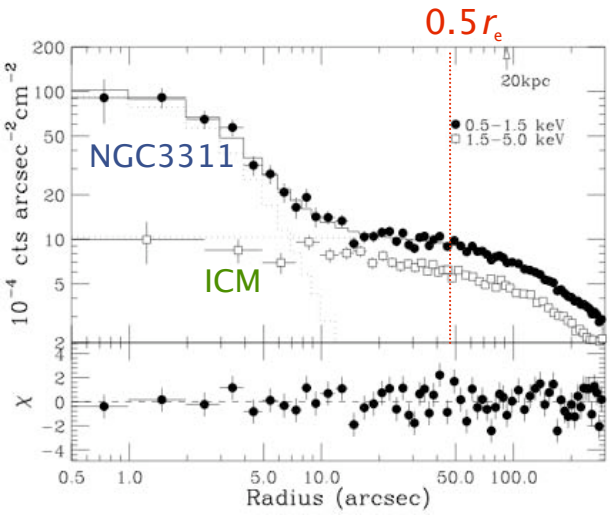
A1060 : Central structure

Yamasaki, Ohashi, & Furusho (2002)

Very compact X-ray emission from the 2 ellipticals < 0.5r_e .
The brightness profile of the core is represented by a 2β-model, not by NFW model.

Chandra (contours) + Optical

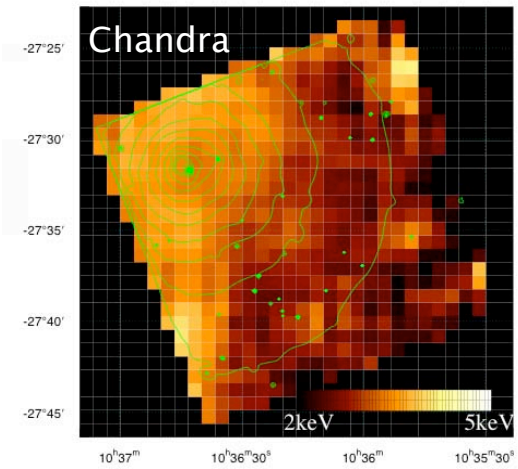




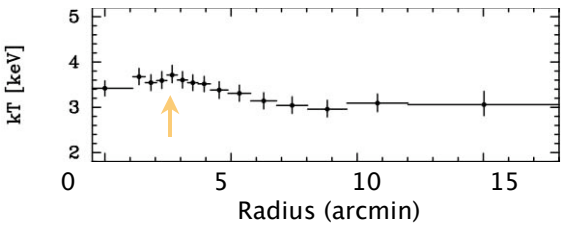
A1060 : Temperature distribution

Hayakawa et al. (2004, will be submitted soon)

kT=3.4 keV even in the central 20 kpc (excl. the ellipticals)
Almost isothermal with kT~ 3 keV with a slight gradient in the core from r=2.5' to the center.



Temperature map from hardness ratio



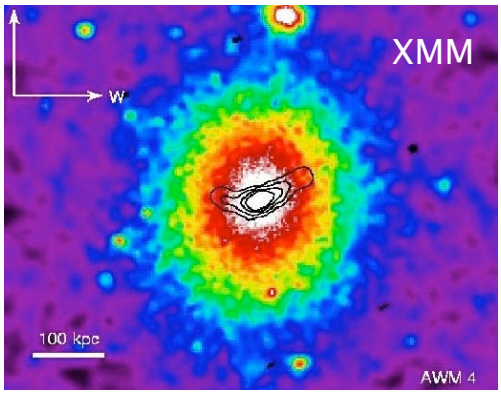
t_{cool}~ 7 Gyr: close to Hubble time of 13 Gyr --> cooling is not a major process.
Energy input from galaxies: ~3e58 erg in 1 Gyr, by SNe may account for the offset of temperature peak.

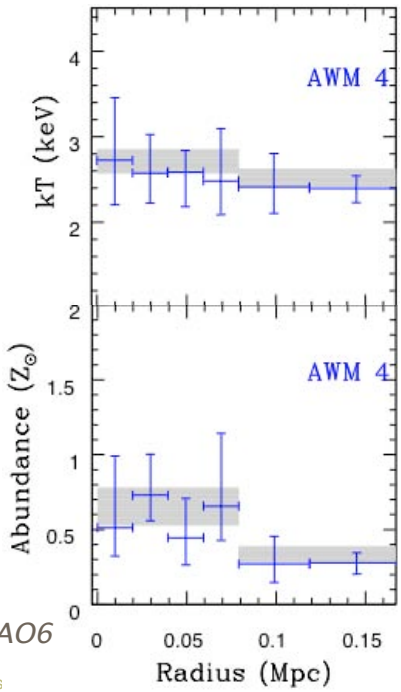
. XMM observation is scheduled in this month

Comparison : isothermality of AWM 4

O'Sullivan & Vrtilek (2003)

Very similar to A1060: isothermal, no cooling at the center, no strong metallicity concentration.





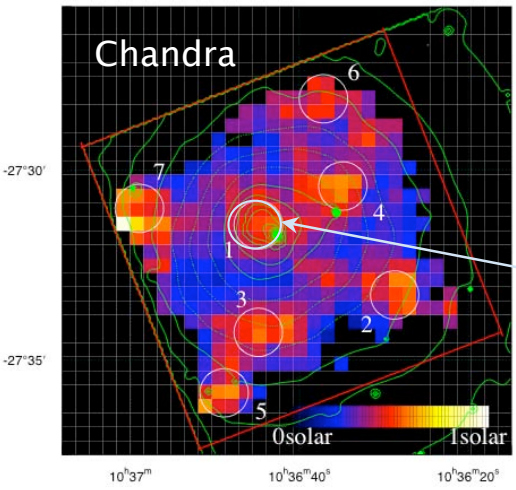
- The cD hosts an active nucleus.
- t_{cool}~2 Gyr: shorter than A1060
- AGN heating of the cD is likely in maintaining the isothermality.

. .Our team proposed this target for CXO/AO6

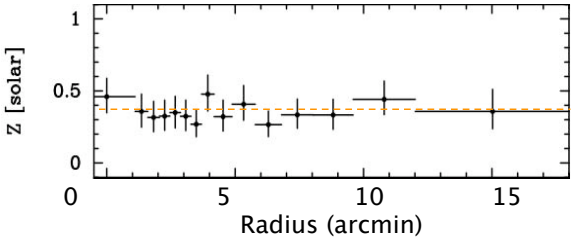
A1060 : Abundance distribution

Hayakawa et al. (2004, will be submitted)

Almost uniform at Z=0.3-0.4 solar + several metal-rich blobs



Abundance map
From hardness ratio



0.74 solar (1.5 solar after correcting for projection effect) with an excess emission extending in r~13 kpc:

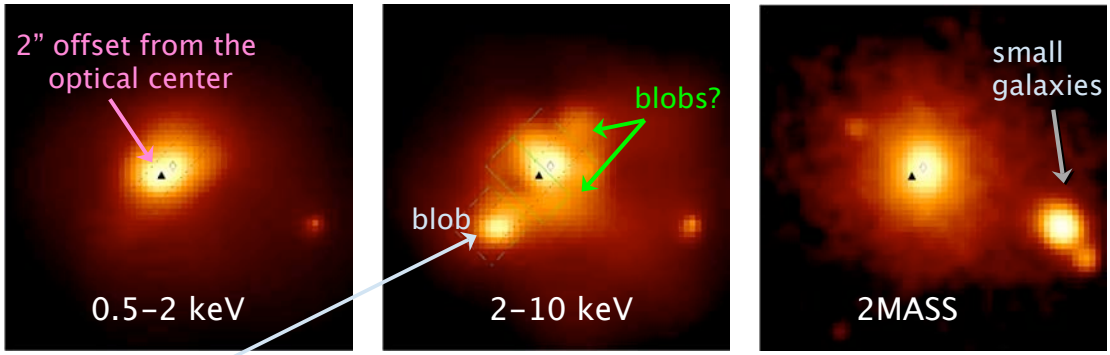
Fe mass = 3e6 solar mass, which is 0.2% of the hot ISM in NGC3311. Possibly this is a part of the halo stripped off from the elliptical galaxy. It has not been disturbed by AGN activity or cooling flow.

AWM7 : Blobs at the center

Furusho, Yamasaki, & Ohashi (2003)

The soft-band peak is offset form the cluster center by 2''(1 kpc). Several possible blobs are seen in the hard band.

Chandra images of 1' sq. (30 kpc)



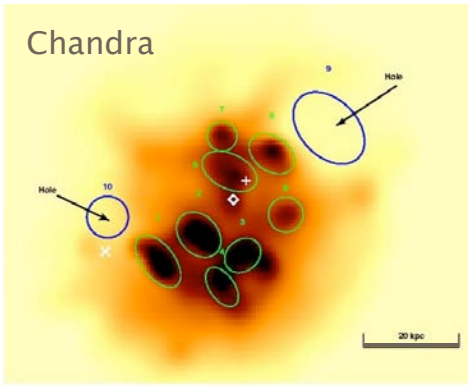
The brightest blob: $kT > 3$ keV, $r > 2$ kpc, L_X~1e40 erg/s, metal-poor (0.3 solar). There is no optical counterpart, nor radio emission. t_{cross}=9Myr. A large twist in the position angle reported w/ the optical band.

Transient phenomenon such as a very recent (<10 Myr) galaxy merger or a turbulence?

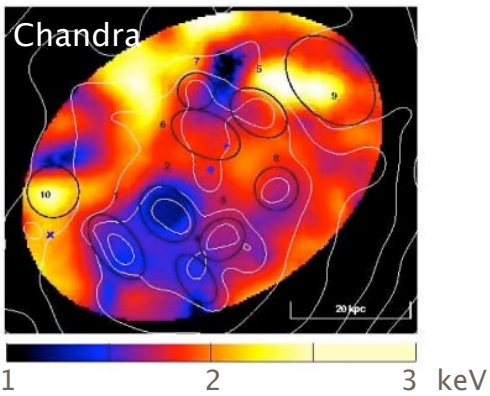
Comparison : Blobs of 2A0335+096

Mazzotta, Edge, & Markevitch (2003)

Similarity with AWM7: a number of X-ray blobs with no optical counterparts



X-ray image



Temperature map

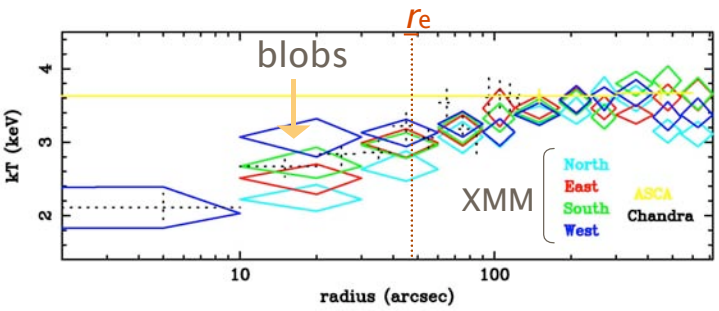
- The cD galaxy hosts an active nucleus.
- Blobs: kT=1~2 keV =surrounding ICM, r=4~9 kpc, L_X~1e41 erg/s.
- Shreds of a cooling core disturbed by AGN bubbling, and in pressure equilibrium with the non-thermal pressure to maintain the blob-shape.

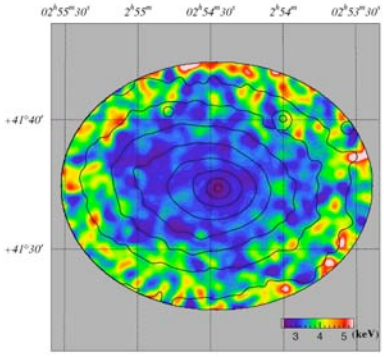
AWM7 : Temperature profile

New analysis

Annularly divided spectra are fitted well with single temperature models

Smooth decline to the center, symmetric profile





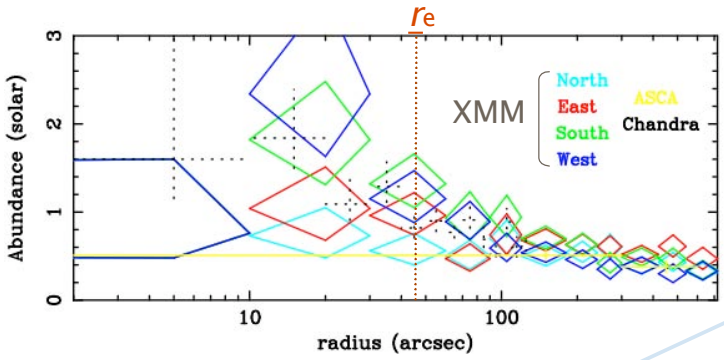
XMM hardness map

- Same feature is observed in many other rich clusters.
- The central temperature is a little higher than other clusters.
- Gas motion related with a galaxy merger may be the heat source

AWM7 : Offset peak and metal-rich blobs

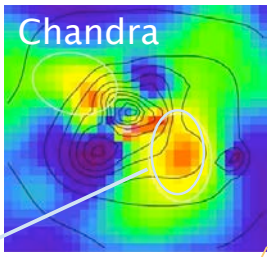
Strong gradient from 0.4 to ~1.5 solar ! (Centaurus, MKW4)

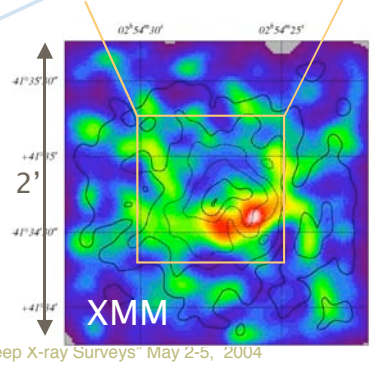
Offset peak in the abundance profile and metal-rich blobs



Color: 6-7 keV

Contours: 2-10 keV





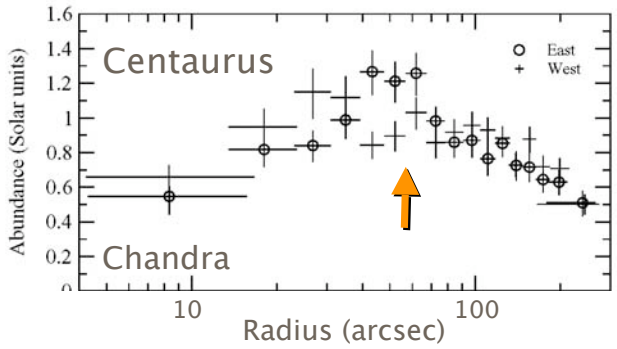
~1.6 solar, extent *r*~5 kpc, sitting next to the cD, Fe mass = 2e4 solar mass

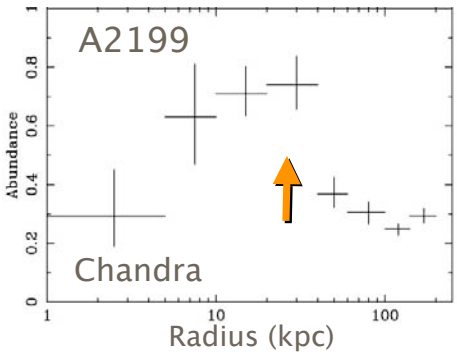
Very similar to the metal-rich blob of A1060, but not accompanied by a clear excess emission.

MKW4 also shows similar metal-rich blobs (by Chandra: Fukazawa et al. 2004, submitted)

Comparison: offset peaks of Cen and A2199

AWM7 :	10 kpc	Furusho, Yamasaki, & Ohashi (2002)
Centaurus :	15 kpc	Sanders and Fabian (2002)
A2199 :	30 kpc	Johnstone et al. (2002)
Perseus :	60 kpc	Schmidt, Fabian & Sanders (2002)



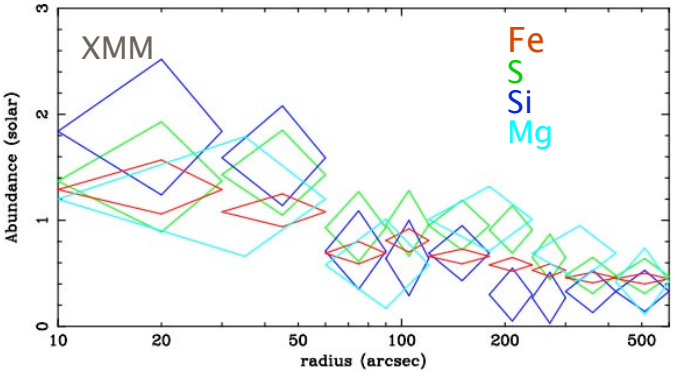


Richer systems show larger peak radii : cooling evolution with small-scale inhomogeneity in metal distributions? (Morris & Fabian, 2003)
Or, related to past AGN activities?

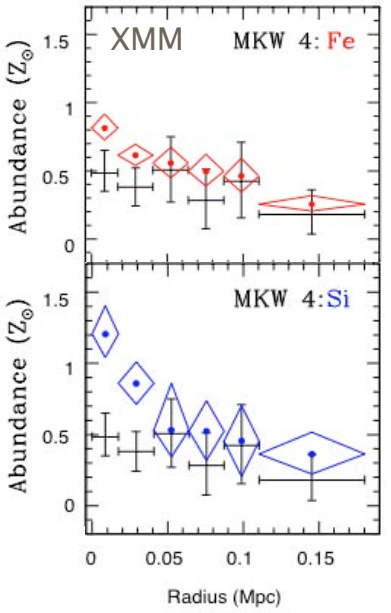
AWM7 : Mg, Si, S, and Fe profiles

Abundance profiles of S, Si, and Fe show strong gradients.
Si is the highest at the center, lowest in the outskirt.

AWM7

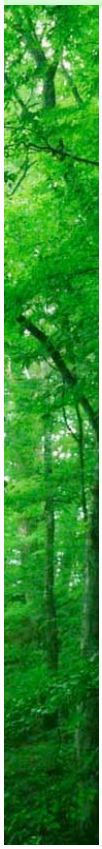


MKW4
O'Sullivan et al. (2003)



M87 also shows similar abundance gradients.
SNIa production of Si higher than Fe?

Summary : Blobs at the cluster center



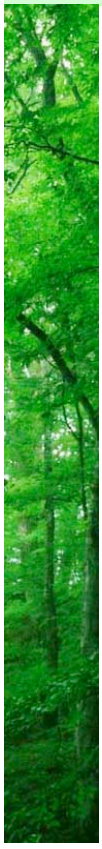
Observed properties

A1060	AWM7	AWM7	2A0335
metal-rich	metal-rich	metal-poor	---
~3 keV	~3 keV	> 3 keV	1-2 keV
R=13 kpc	5 kpc	2 kpc	4-9 kpc
no AGN	no AGN	no AGN	with AGN

Origin of the blobs

1. Blob size <10 kpc, gas mass << galaxy mass, some blobs show high metal abundance: likely to have origin in central elliptical galaxies.
2. The life time of blobs estimated to be ~10Myr, very short. They are just created indeed, or, non-thermal pressure keeps the structure.
3. If these are a part of gas stripped from galaxies or gas bubbling from AGN, how blob-like shapes are formed?
4. The hard blob in AWM7 shows very high temperature, which requires some heating: a galaxy merger, or, past AGN activity?

Summary : Other characteristics



Isothermality into the very center

A1060 with no AGN, AWM4 with AGN

Cooling has not started yet, or, strong heating by central AGN activity

Simple decline of temperature to the center

AWM7, MKW4, 2A0335, and many other rich clusters

Still require heat sources to keep kT >1 keV

By past or current AGN activity or mergers.

High Si abundance at the center

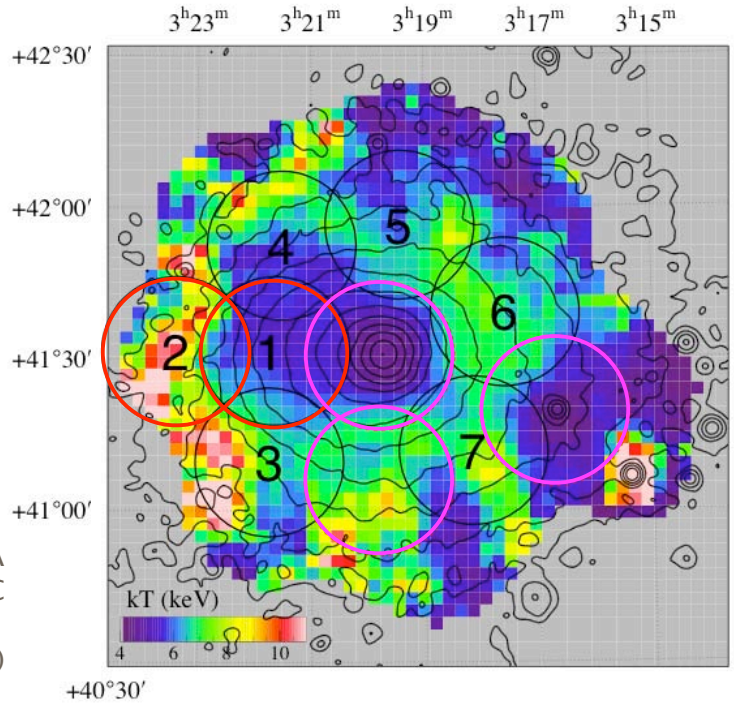
AWM7, MKW4, and M87

Strong enrichment of Si by SNIa?

Perseus cluster mapping with XMM

2 offset observations performed in Feb 2004 for 15 and 25 ks

Archived
New (AO3)



Color: kT by ASCA
Contours: SB of PSPC

Furusho et al. (2001)

Perseus cluster mapping with XMM

XMM image of
the 5 pointings