EXPLORING THE MULTIPHASE MEDIUM IN MKW 08: FROM THE CENTRAL AGN UP TO CLUSTER SCALES

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Clusters of Galaxies

- The largest comprehensive samples of the universe;
  - What happens in a cluster, stays in a cluster.
- Probes of;
  - Chemical enrichment histories (nucleosynthesis)
  - Cosmological constraints (growth of structure over cosmological time)
  - Galaxy and cluster evolution
- Hot (10^7-10^8 K) and dilute (density: $10^{-4} - 10^{-2}$ cm^{-3}) gas of ICM

  → emission via X-rays
- Baryonic content (~12%) H & He, all elements except for H and He are "metals"!
- ICM emission;
  - thermal bremsstruhlung (free-free) and line emission
- Surface brightness & temperature→ electron density, pressure, entropy, mass..

X-ray Emission from the ICM

X-ray emission → Cooling of densest ICM regions

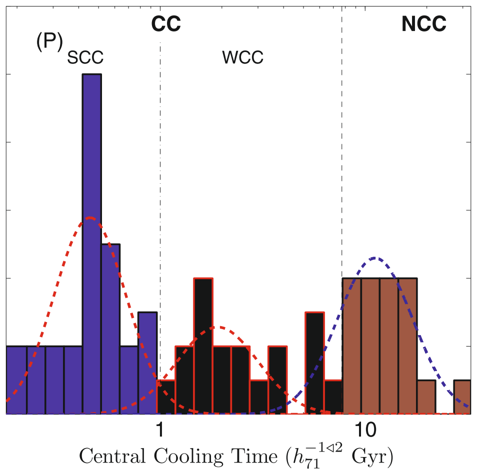
Short cooling time (inside CC) → Cooling Flow (CF)?

But they are still hot! + CF unobserved → Core heating, CF quenching mechanism

Possible heating mechanisms

- Supernovae
- Thermal conduction
- AGN
- Turbulent heating

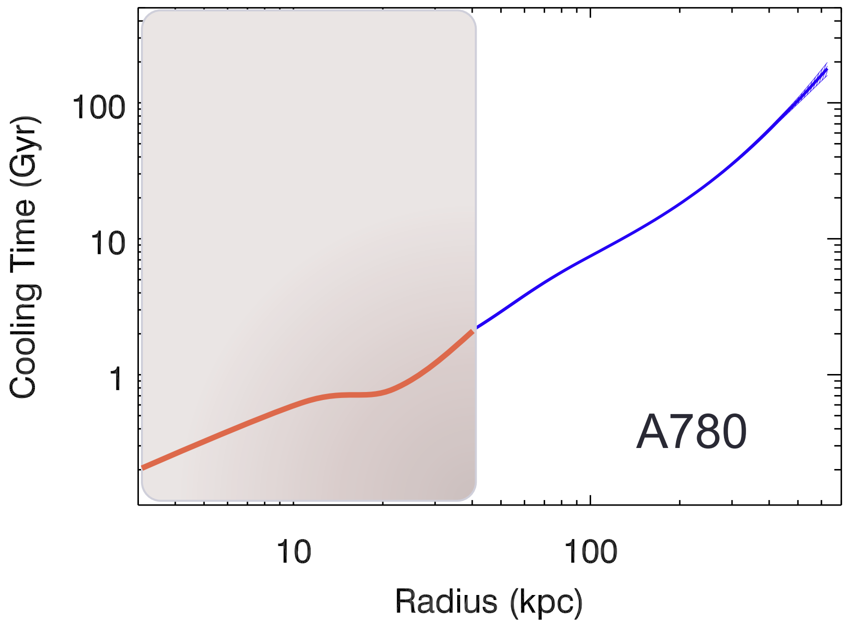
Cool Core vs. Non-Cool Core



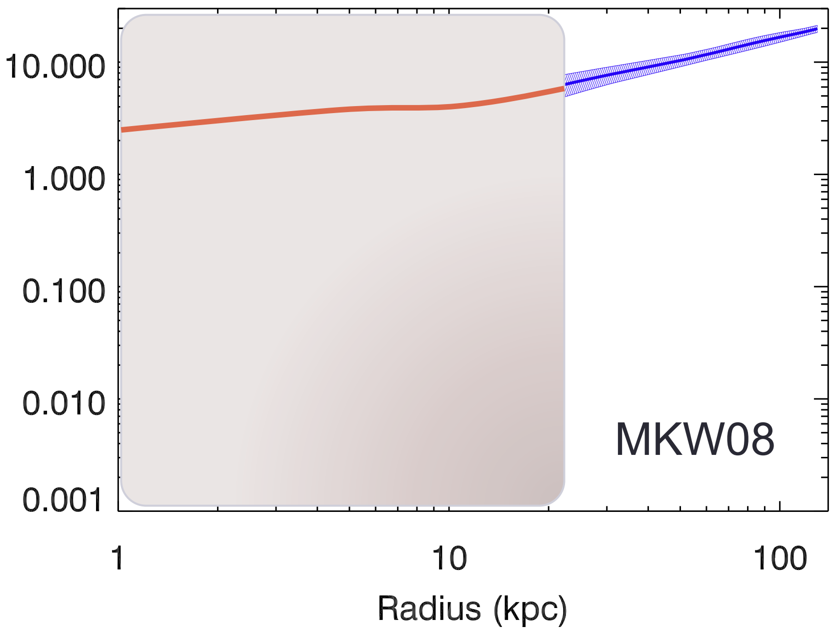
For low redshift clusters, central cooling time (at 0.4%R_{500}) (Hudson + 2010)

- t_{cool} < 7.0 Gyr → Cool Core (***CC***)
- 7.0 Gyr < t_{cool} →Non-Cool Core (***NCC***)

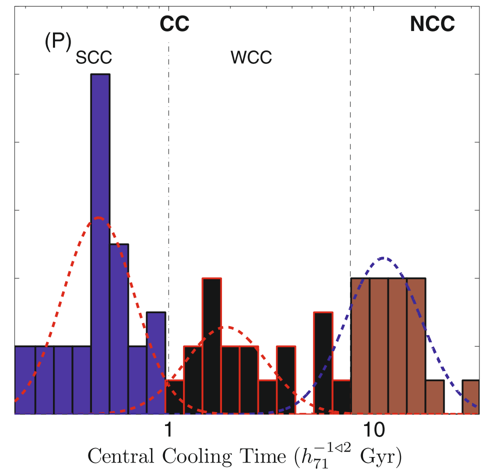
CC



NCC



Cool Core vs. Non-Cool Core



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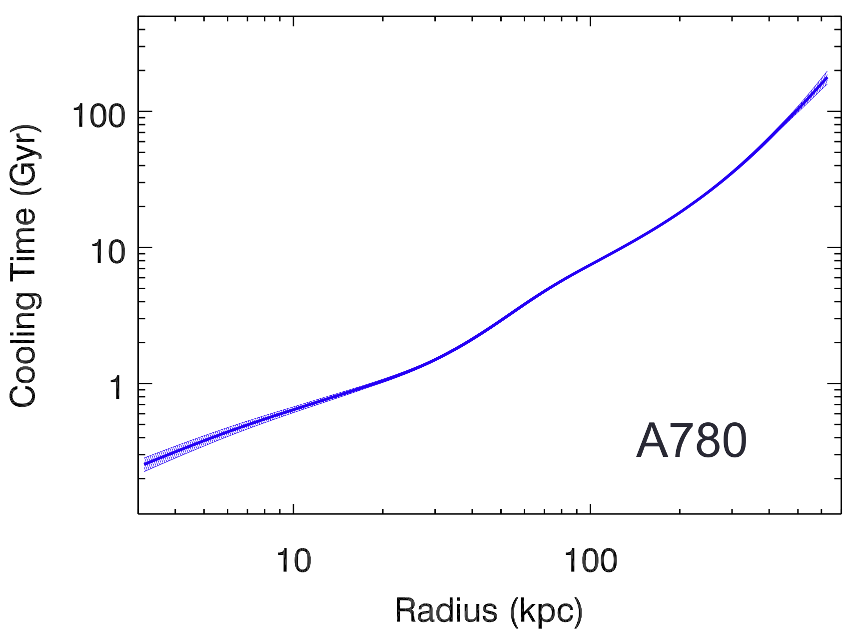
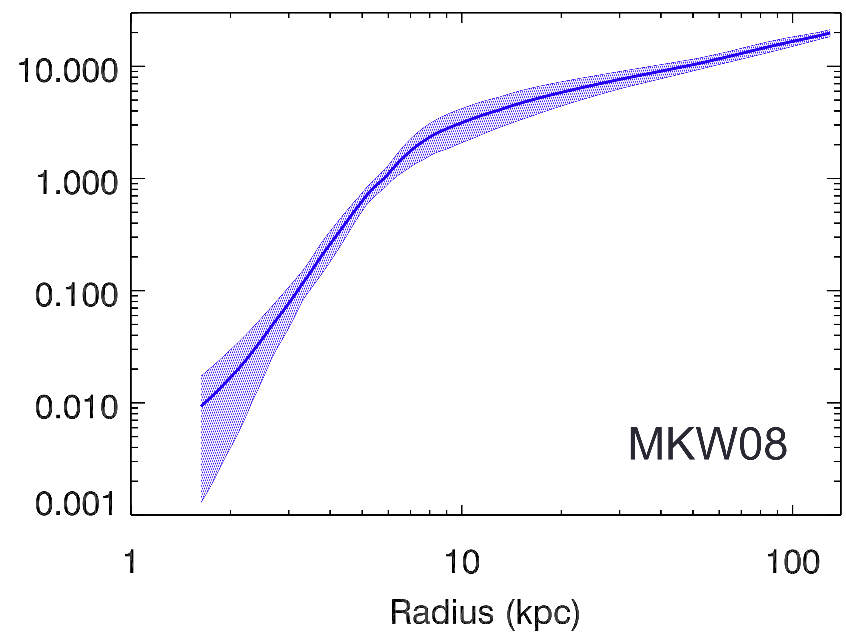
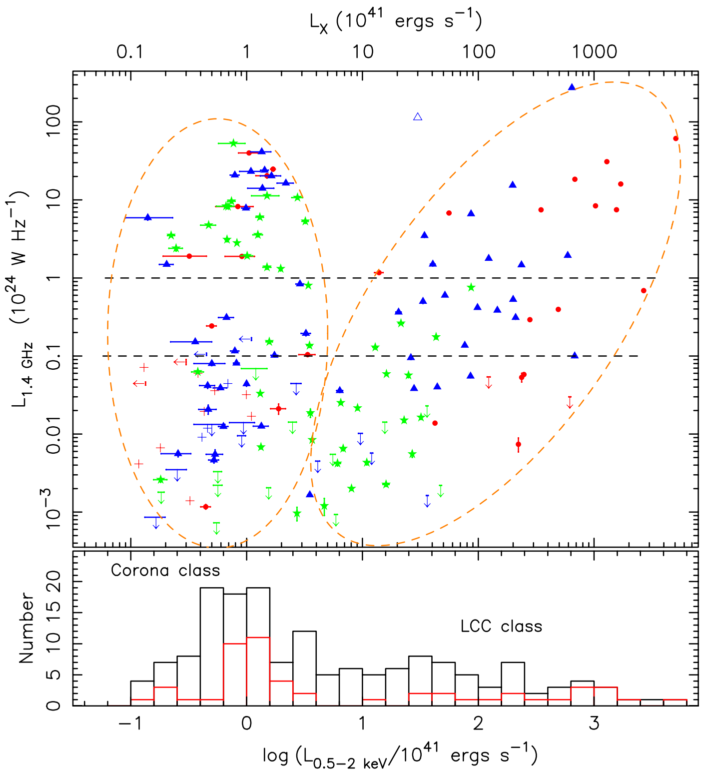


NCC



Large Cool Core vs. Corona Class



Sun, 2009

BCG corona / hot ISM

- r < 4 kpc
- Temperature; 0.3 < kT < 1.7 keV
- Metallicity; ~ 0.8 solar
- Luminosity; < 4 x 10^{41} erg/s

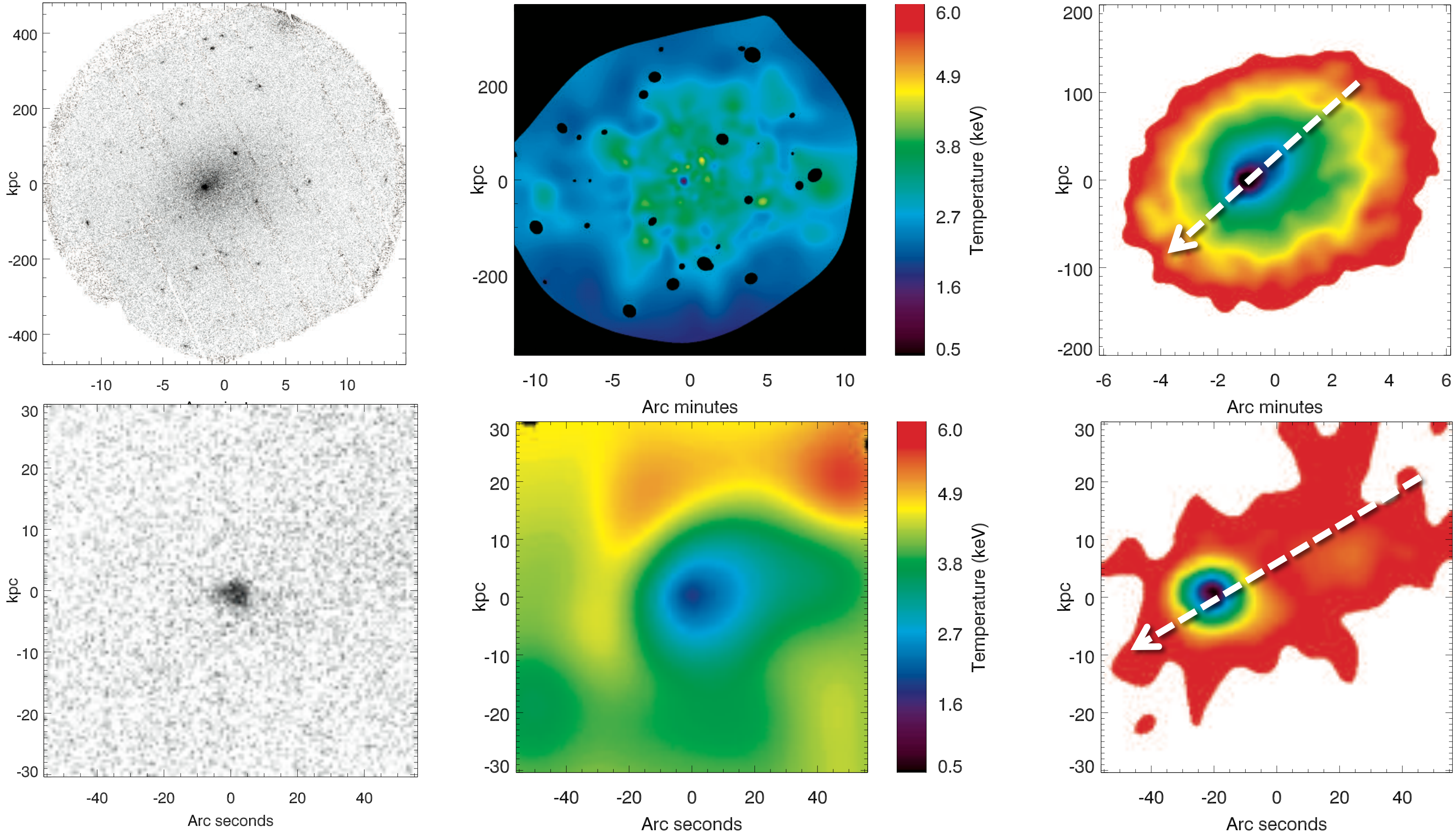
Basically a cool core, but at a smaller spatial scale…

MKW 08 * – Non-Cool Core

- Nearby (z = 0.027)
- Non-Cool Core (NCC) galaxy cluster in HIghest X-ray FLUx Galaxy Cluster Sample (Reiprich & Böhringer, 2002)
- NCC; t_{cool} = 10.87 Gyr at 0.4%R_{500} (Hudson+ 2010)
- Brightest cluster galaxy is NGC 5718 → interacting with IC 1042
- BCG corona (Sun+ 2007)

XMM-Newton Observation ID	Equatorial coordinates (J2000)	MOS1 effective exposure time (ks)	MOS2 effective exposure time (ks)	PN effective exposure time (ks)
0300210701	14 40 38.1 +0.3 28 18.1	23.1	23.1	16.5
Chandra Observation ID	Equatorial coordinates (J2000)		ACIS-I effective exposure time (ks)	
4942	14 40 38.3 +0.3 28 18.2		23.1	
18266	14 40 41.9 +0.3 28 04.4		35.6	
18850	14 40 41.9 +0.3 28 04.4		39.6	

MKW 08 * – Non-Cool Core



*Submitted to A&A

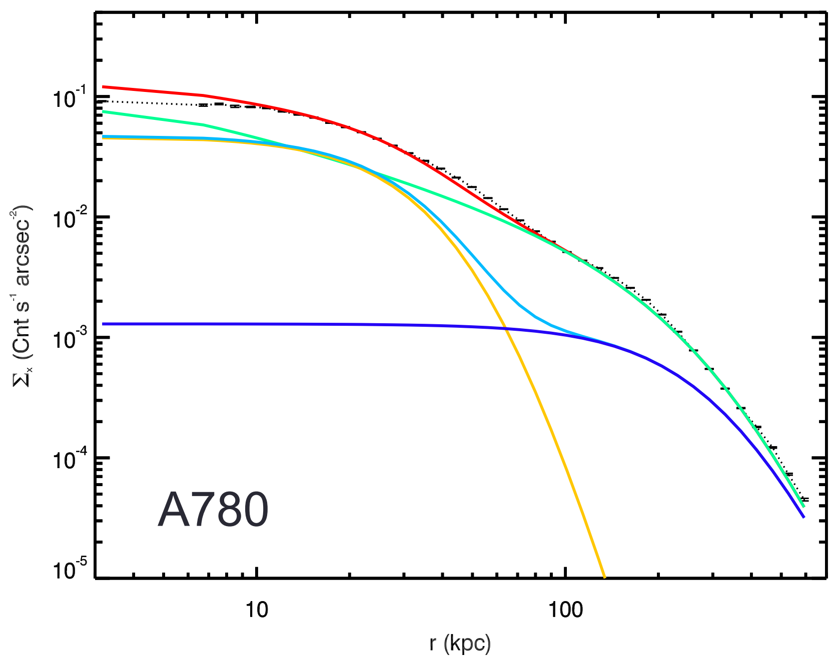
Cool Core vs Non-Cool Core

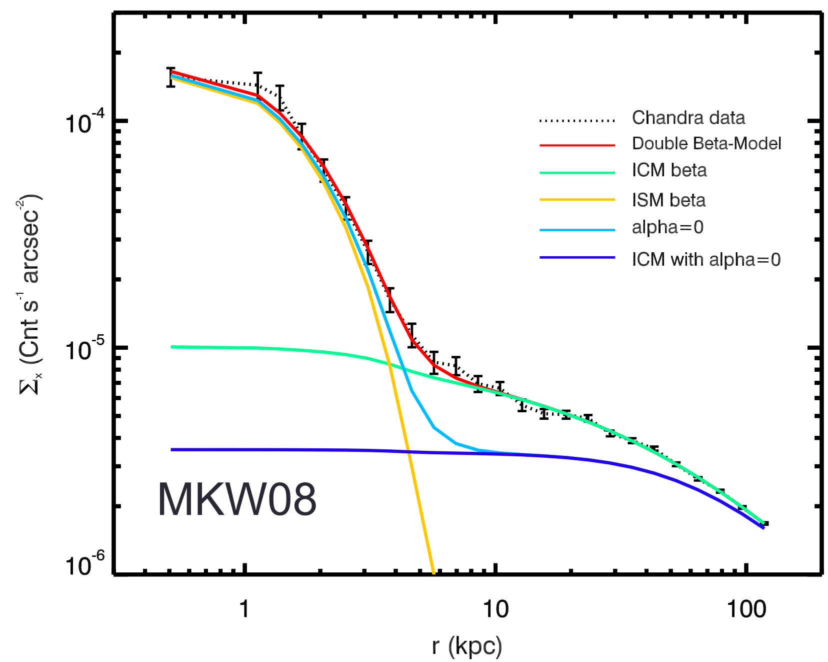
$$[n_e n_p](r) = \underbrace{n_0^2 \frac{(r/r_c)^{-\alpha}}{(1+r^2/r_c^2)^{3\beta-\alpha/2}}}_{\text{ICM}} \underbrace{\frac{1}{(1+r^\gamma/r_s^\gamma)^{\varepsilon/\gamma}}}_{\text{outskirts}} + \underbrace{\frac{n_{02}^2}{(1+r^2/r_{c2}^2)^{3\beta_2}}}_{\text{Central region}}.$$

ICM

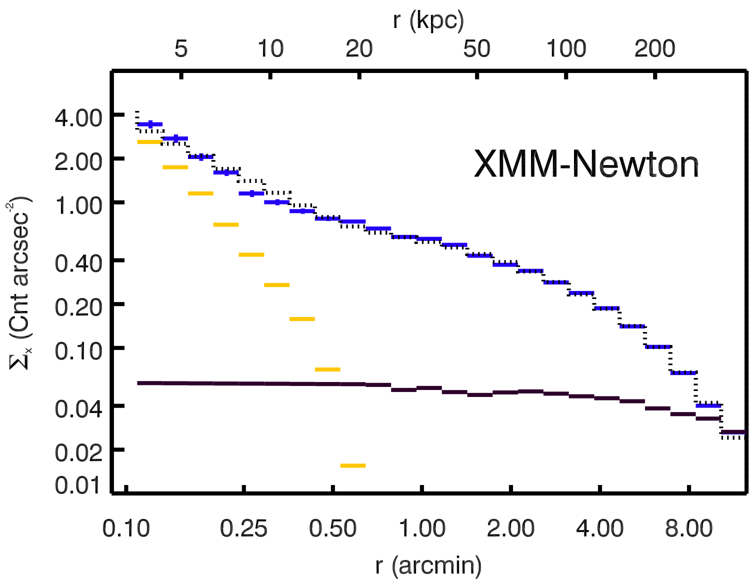
outskirts

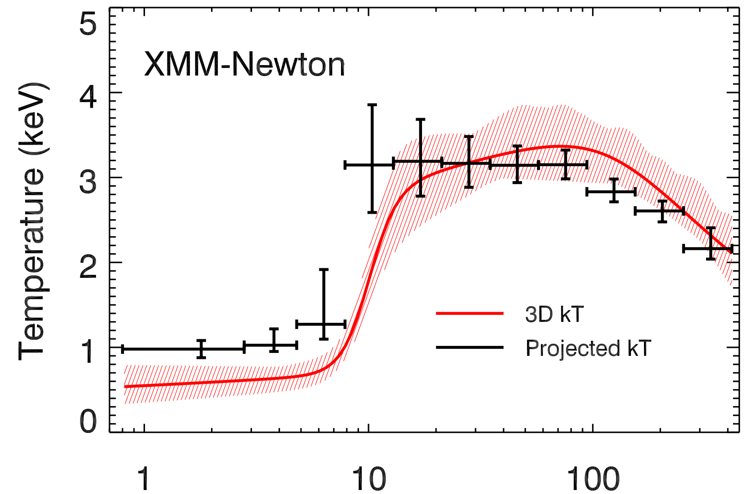
Central region

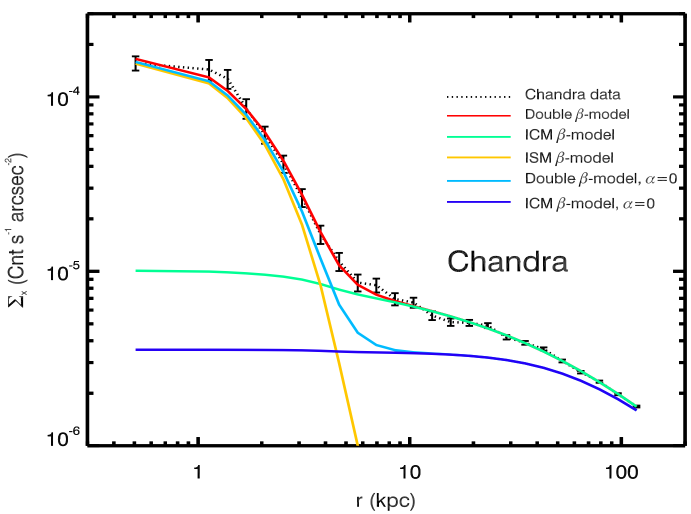


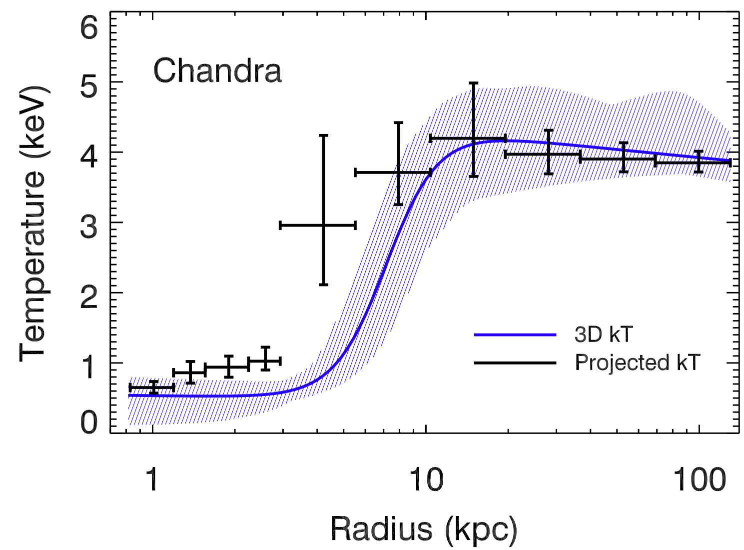


Surface Brightness and Temperature



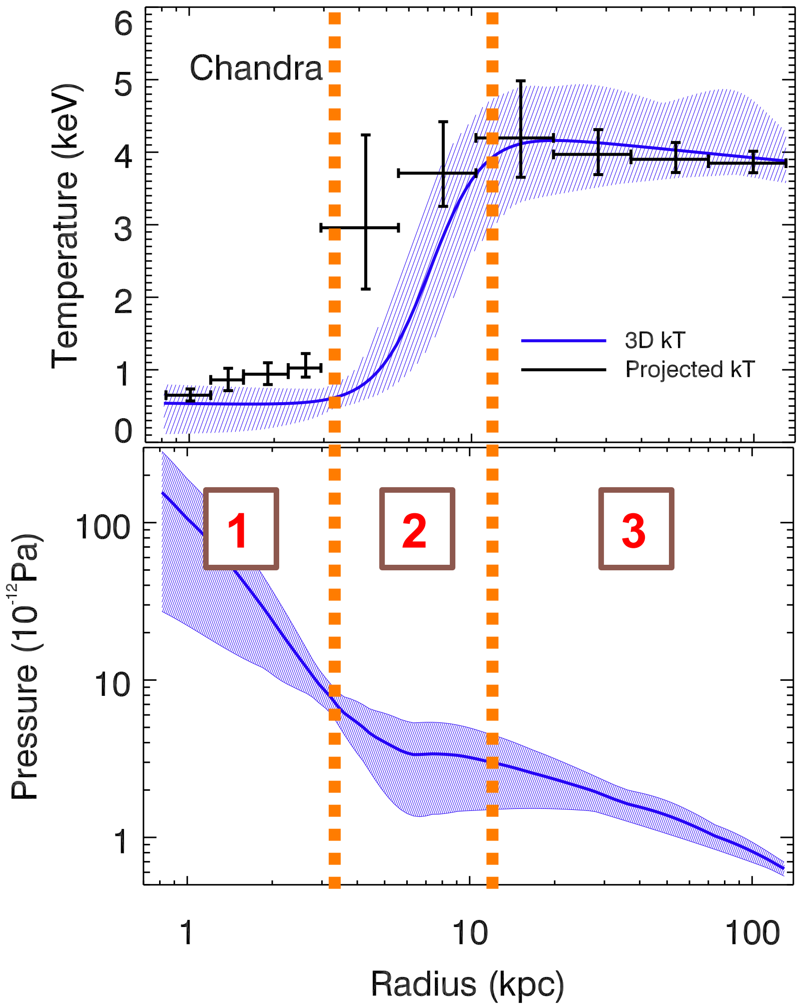


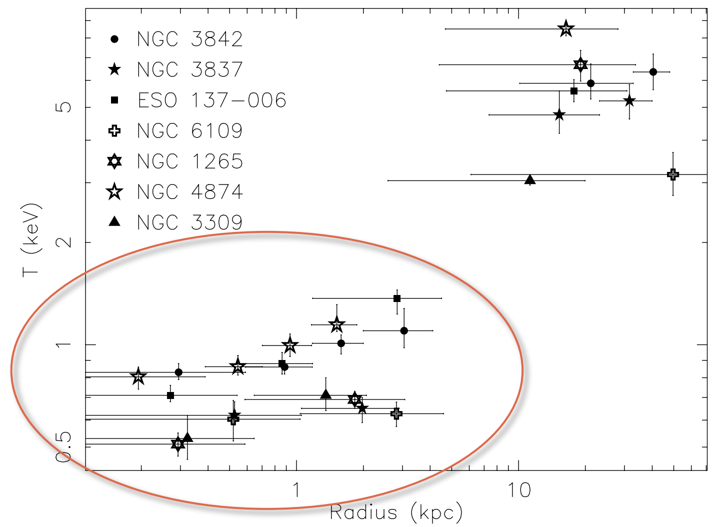




Tümer et al., 12-14 June 2019, Astrophysics of Hot Plasma, Madrid

ISM, ISM/ICM, ICM





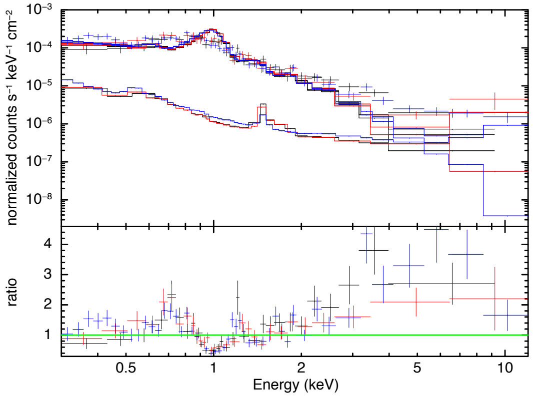
Sun 2009

1 ISOTHERMAL → no thermal conduction

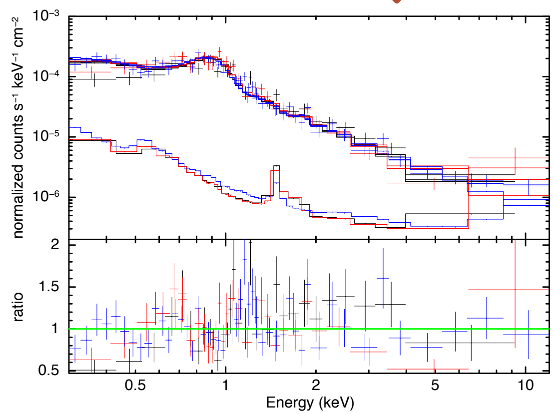
2 GRADIENT → transition from ISM to ICM

3 ISOTHERMAL → ICM

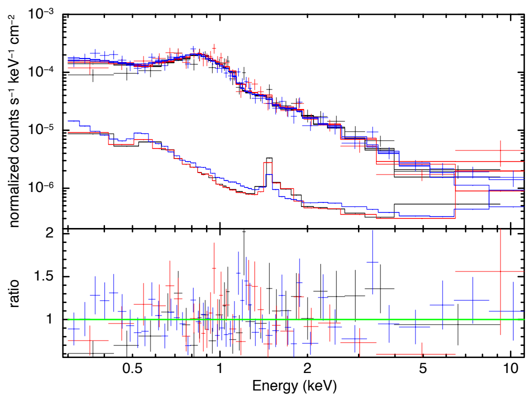
XMM-Newton Spectra, central region, r = 10 kpc



Add Powerlaw

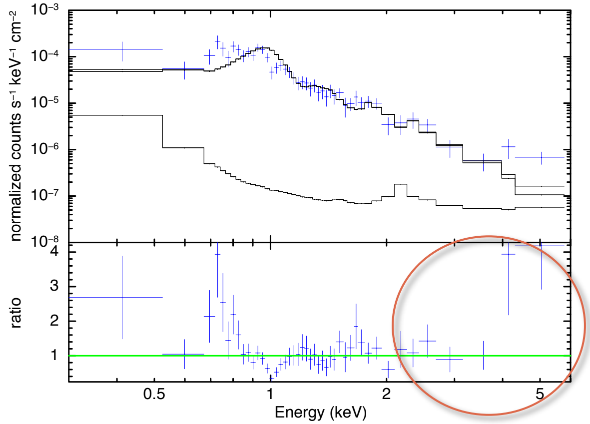


Add 2nd T



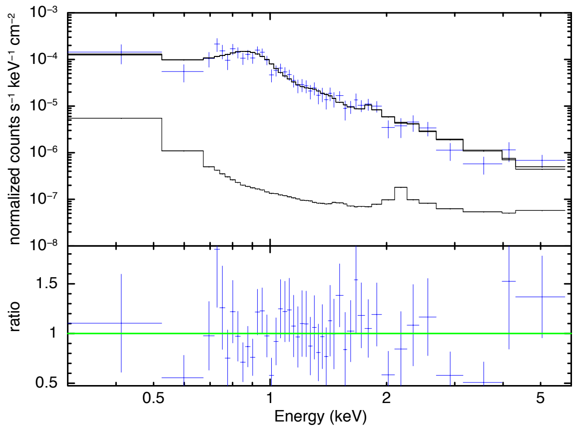
Model 1: phabs × apec		
kT (keV)	ISM T ←	1.32 ±0.02
Z ($Z_\odot$)		1 (fixed)
$norm$ (10^{-5})		$7.67^{+0.45}_{-0.31}$
C/ν		747.79/189
Model 2: phabs × (apec + powerlaw)		
kT (keV)		0.98 ±0.03
Z ($Z_\odot$)		1 (fixed)
$norm$ (10^{-5})		$2.38^{+0.18}_{-0.14}$
Γ	AGN ←	$1.81^{+0.05}_{-0.09}$
κ (10^{-5})		$2.28^{+0.12}_{-0.17}$
C/ν		239.80/187
Model 3: phabs × (apec + apec + powerlaw)		
kT (keV)		$0.84^{+0.08}_{-0.05}$
Z ($Z_\odot$)		1 (fixed)
$norm$ (10^{-5})		$1.64^{+0.12}_{-0.13}$
Γ		$1.62^{+0.29}_{-0.26}$
κ (10^{-5})		$0.88^{+0.43}_{-0.34}$
kT_2 (keV)	ICM T ←	$2.37^{+0.79}_{-0.37}$
Z_2 ($Z_\odot$)		1 (fixed)
$norm$ (10^{-5})		$5.39^{+1.19}_{-1.43}$
C/ν		204.59/185

Chandra Spectra, central region, r = 3 kpc



Model 1: phabs × apec	
kT (keV)	$1.21^{+0.04}_{-0.06}$
Z ($Z_\odot$)	1 (fixed)
norm (10^{-5})	$3.25^{+0.12}_{-0.17}$
C/ν	111.70/44

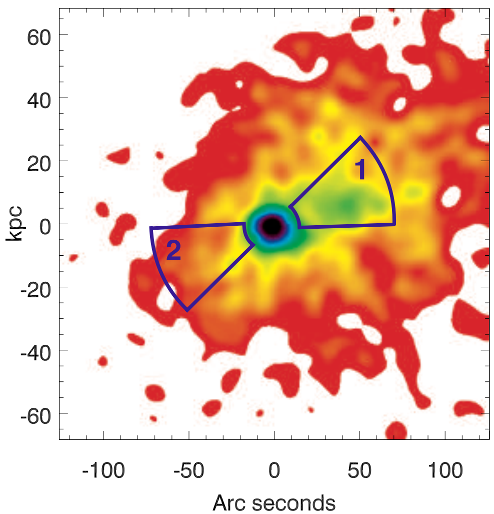
Add Powerlaw

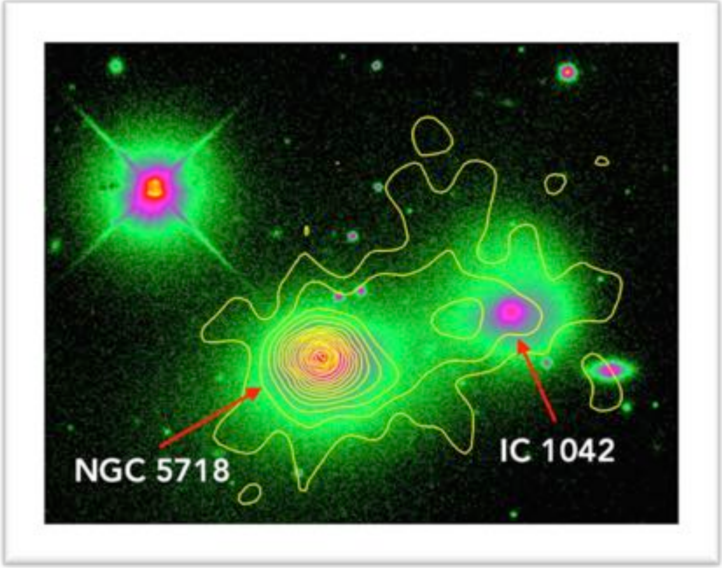


Model 2: phabs × (apec + powerlaw)	
kT (keV)	$0.91^{+0.08}_{-0.09}$
Z ($Z_\odot$)	1 (fixed)
norm (10^{-5})	$1.51^{+0.20}_{-0.21}$
Γ	$2.49^{+0.26}_{-0.34}$
κ (10^{-5})	$1.13^{+0.25}_{-0.22}$
C/ν	39.60/42

2nd APEC was not required → we are within the BCG corona

MKW 08– 40kpc tail





Sector 1	*Chandra*	*XMM-Newton*
kT (keV)	$4.65^{+0.39}_{-0.36}$	3.62 ± 0.23
Z ($Z_\odot$)	$0.90^{+0.35}_{-0.22}$	$0.49^{+0.13}_{-0.11}$
norm (10^{-4})	$1.30^{+0.08}_{-0.11}$	1.48 ± 0.08
C/ν	61.69/87	205.18/198
Luminosity ($10^{41} ergs^{-1}$)	1.68 ± 0.05	1.76 ± 0.08

Sector 2	*Chandra*	*XMM-Newton*
kT (keV)	$4.09^{+0.48}_{-0.43}$	$2.90^{+0.26}_{-0.28}$
Z ($Z_\odot$)	$0.22^{+0.19}_{-0.16}$	$0.20^{+0.10}_{-0.09}$
norm (10^{-4})	$1.06^{+0.07}_{-0.08}$	0.90 ± 0.07
C/ν	39.60/42	155.45/163
Luminosity ($10^{41} ergs^{-1}$)	1.16 ± 0.05	0.96 ± 0.06

Abundance is of ISM origin

→ RAM pressure stripping and/or Bridge between the two galaxies

Conclusion & Discussion (open ends)

- BCG AGN is the most likely heating mechanism in action for MKW 08
- No gradient in the radial temperature profile inside ISM → projection effect, no heat conduction
- BCG tails may not be as rare as previously thought
- High resolution studies of BCG coronae; interesting laboratories to disentangle mechanical AGN feedback from cluster merger related mechanisms (core sloshing, merger induced turbulence in the ICM)

- What is the exact mechanism keeping the central regions of the clusters hot?
- Is CC/NCC a dichotomy or merely an evolutionary stage?

Co-authors & Acknowledgements

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