SWG1.2: *Astrophysics of galaxy groups and clusters*

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+80 members

SWG1.2: *Astrophysics of galaxy groups and clusters*

How does ordinary matter assemble into the large-scale structures we see today?

How do diffuse hot baryons accrete and dynamically evolve in the dark matter potential?

How and when was the energy in the ICM generated and distributed?

When and where are heavy elements produced and how are they circulated?

Level 1 science objectives (post-CORE)

R-SCIOBJ-112 (turbulence; XIFU)

Athena shall measure how gravitational energy is dissipated into bulk motions and gas turbulence, by achieving a 5σ detection of these quantities, and by building the resultant turbulent power spectrum across a significant fraction of the cluster extent.

R-SCIOBJ-122 (metallicity; XIFU)

Athena shall provide a coherent picture of the production and circulation of metals in the deep potential wells of the whole population of galaxy groups and clusters over a large portion of cosmic history. Metal production will be estimated from the relative number of time-integrated SNIa and SNcc products via the constraints (at 5σ) of the abundance pattern of the most common elements (e.g. O, Si, S, Fe). The contribution from AGB stars will be constrained by measurements (5σ) of lighter (C, N) elements. The initial metallicity of the SNIa progenitors will be obtained from measurements (5σ) of trace elements. For the most common elements, these measurements will be spatially resolved at least up to R_{500}, and the evolution derived over 10 Gyr of cosmic time ($0<z<2$). In local systems, the measurement of the overall chemical enrichment will be attempted out to the virial radius (R_{200}).

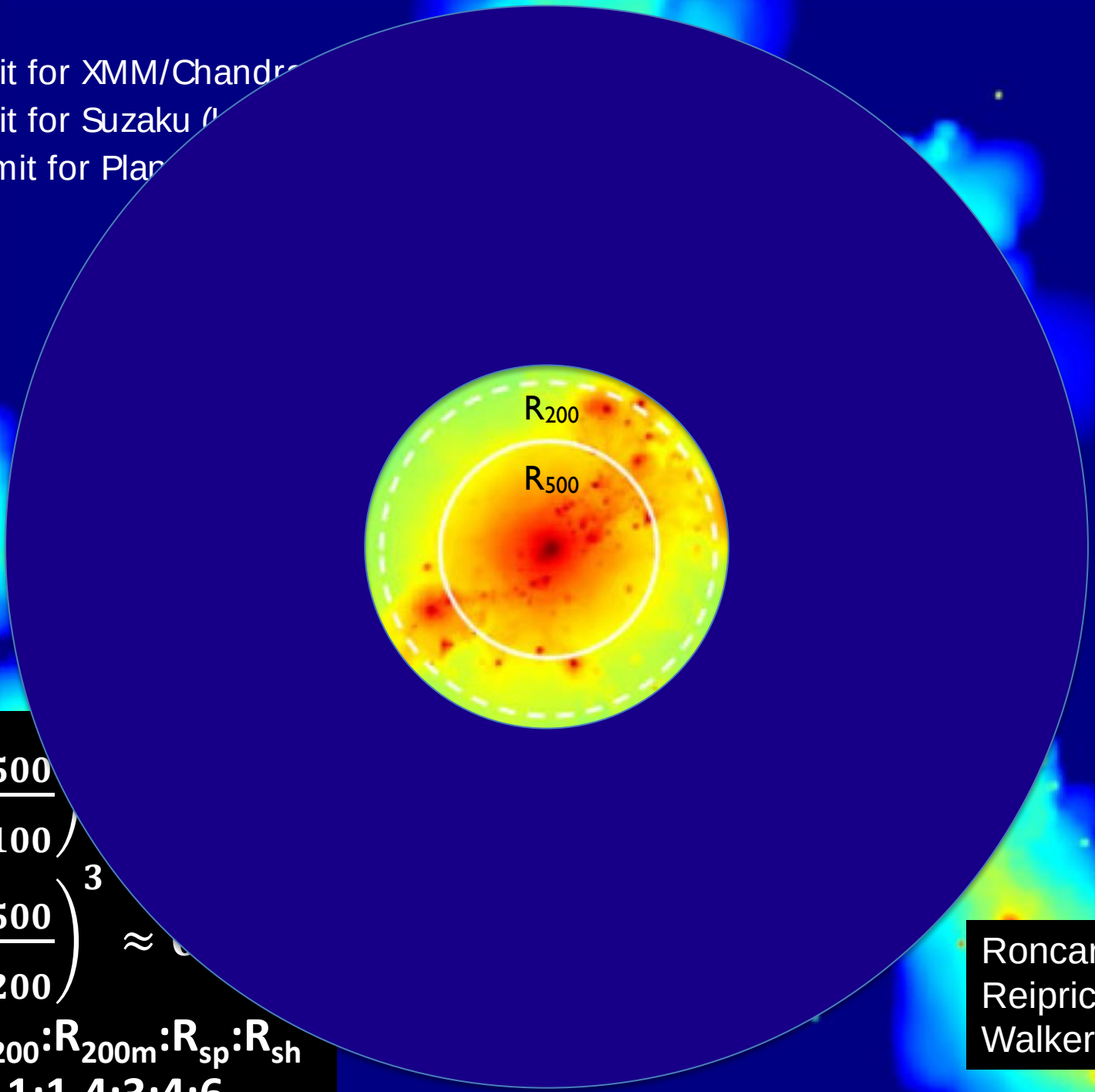
R-SCIOBJ-121 (entropy; WFI)

Athena shall determine which physical processes dominate the injection of non-gravitational energy into the ICM as a function of cosmic epoch and system mass by measuring the structural properties (e.g., the entropy profiles) of a representative sample of galaxy groups and clusters. To differentiate between models of feedback and gas accretion, these measurements shall be achieved to the virial (R_{200}) radius in local clusters and out to R_{500} up to $z\sim2$, with an uncertainty <25% (at R_{500} at $z=2$).

R_{500} - limit for XMM/Chandra

R_{200} - limit for Suzaku (

$3R_{500}$ - limit for Plan



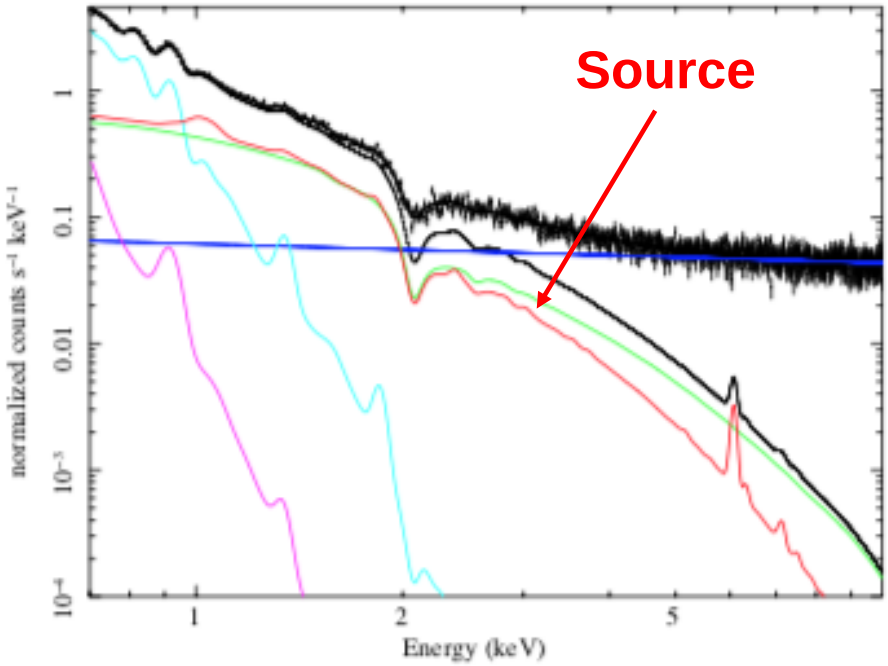
$$\left(\frac{R_{500}}{R_{100}}\right)$$

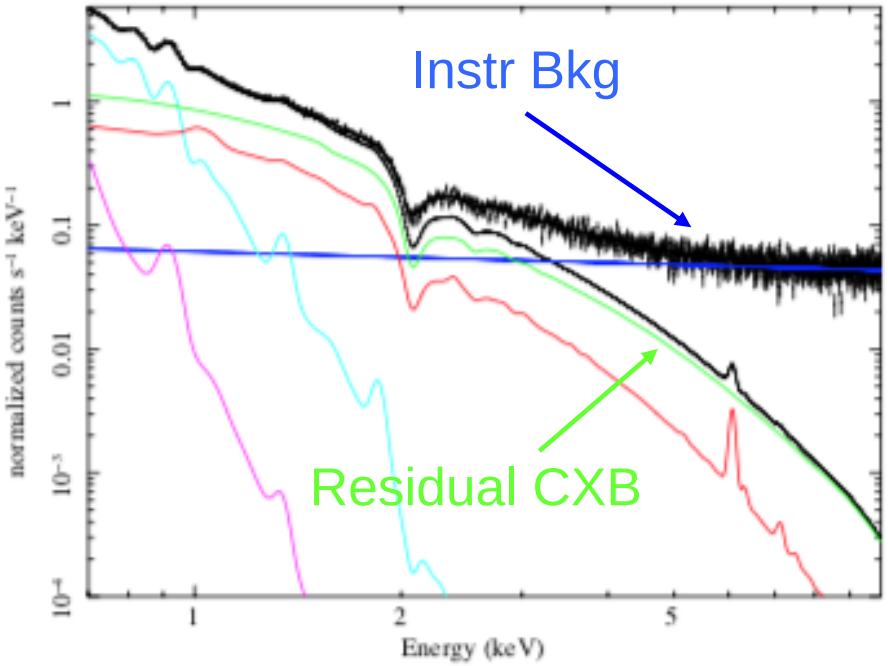
$$\left(\frac{R_{500}}{R_{200}}\right)^{3} \approx$$

R_{500}:R_{200}:R_{200m}:R_{sp}:R_{sh}
= 1:1.4:3:4:6

Roncarelli+06
Reiprich+13
Walker+19?

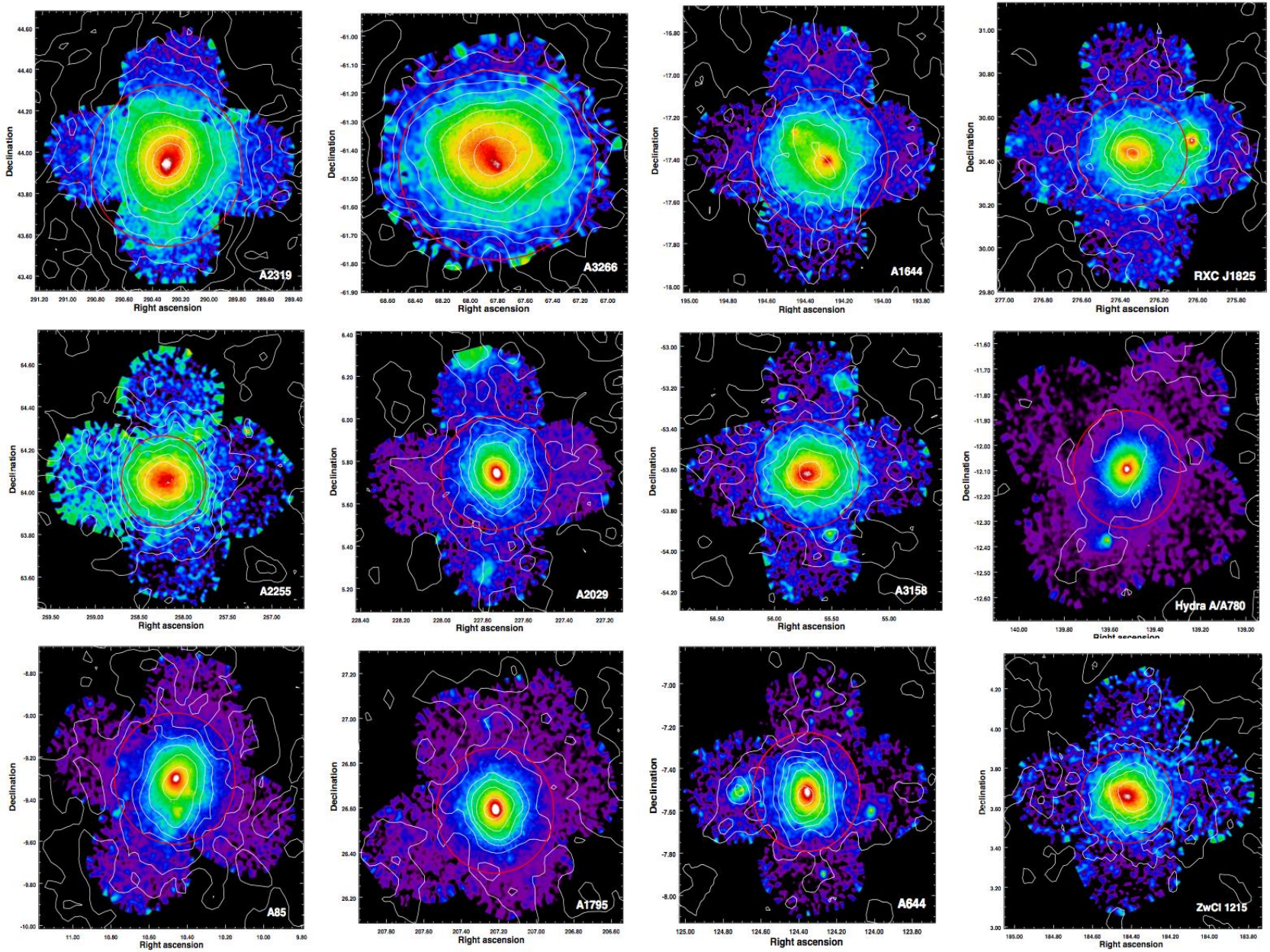
It's all about background…





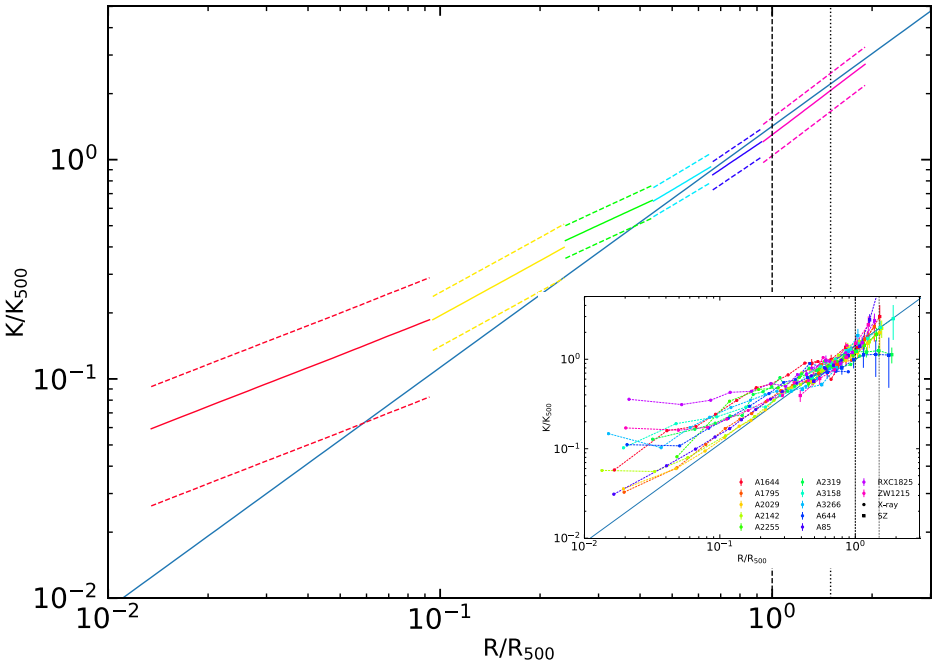
SWG1.2-TN-0005.pdf (on Straylight)

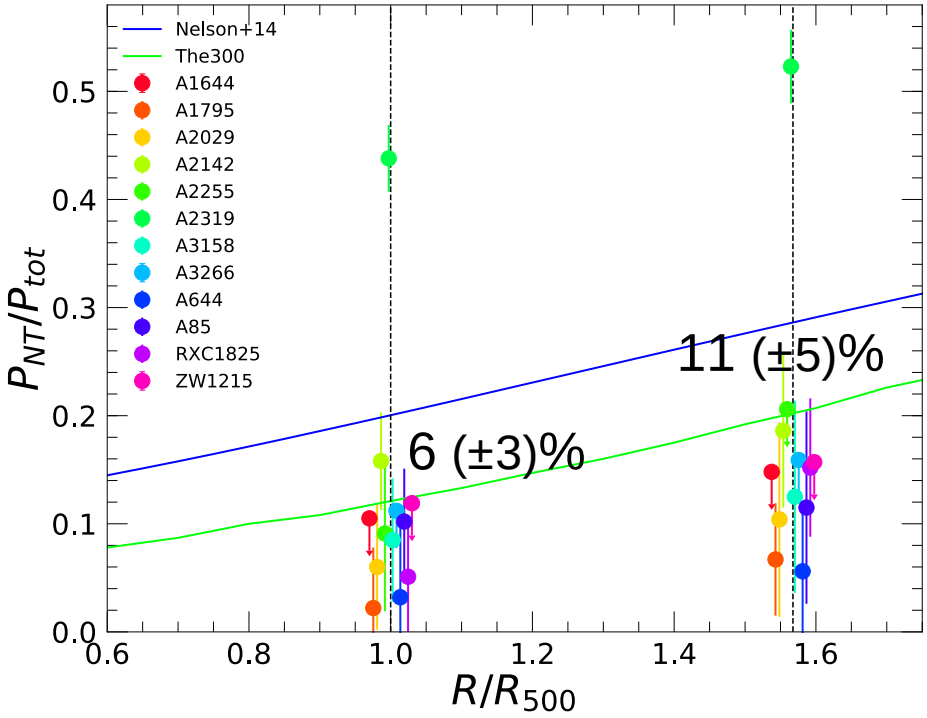
X-COP: *XMM +Planck*



X-COP: "universal" profiles & non-thermal pressure

Eckert, Ghirardini, Ettori et al., arXiv:1805:00034
Ettori, Ghirardini, Eckert et al. arXiv:1805:00035
Ghirardini, Eckert, Ettori et al. arXiv:1805:00042



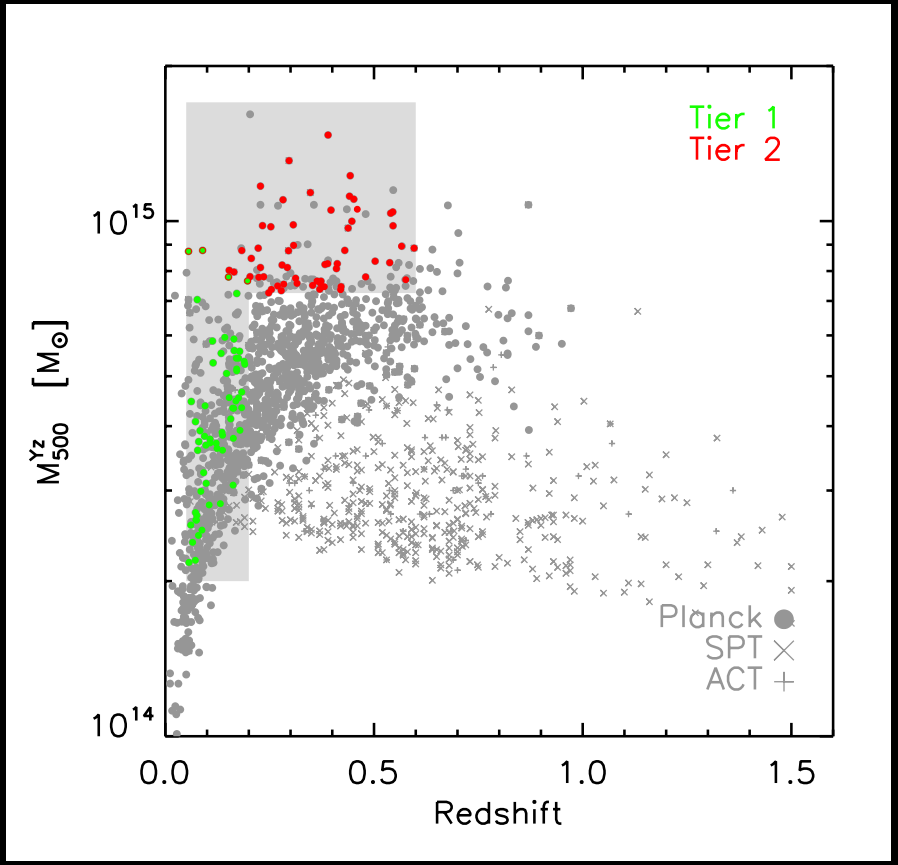


An XMM-Newton Heritage Program

Witnessing the culmination of structure formation in the Universe

Building on the *Planck All sky* SZ effect survey, we plan to observe with *XMM-Newton* the culmination of cosmic structure formation: **118 clusters, comprising an unbiased census of**:

- *the population of clusters at the most recent time (z < 0.2)*,
- *the most massive objects to have formed thus far in the history of the Universe*



An XMM-Newton Heritage Program

Witnessing the culmination of structure formation in the Universe

Steering Committee: M. Arnaud **(PI)**, S. Ettori **(PI)**, D. Eckert, F. Gastaldello, R. Gavazzi, S. Kay, L. Lovisari, B. Maughan, E. Pointecouteau, G. Pratt, M. Rossetti, M. Sereno.

Core X-ray (*chair: Eckert & Pratt*): SC members; Bartalucci; Bourdin; Buote; De Grandi; Donahue; Duffy; Ghirardini; Ghizzardi; Jones; Mazzotta; Molendi; Paltani; Schellenberger; Tozzi

WG-lensing (*chair: Gavazzi & Sereno*): IAC; Jauzac; Maurogordato; Okabe; Pires; Umetsu; van der Burg

WG-hydrosims (*chair: Kay & Rasia*): Borgani; Dolag; Gaspari; LeBrun; Yepes; Vazza

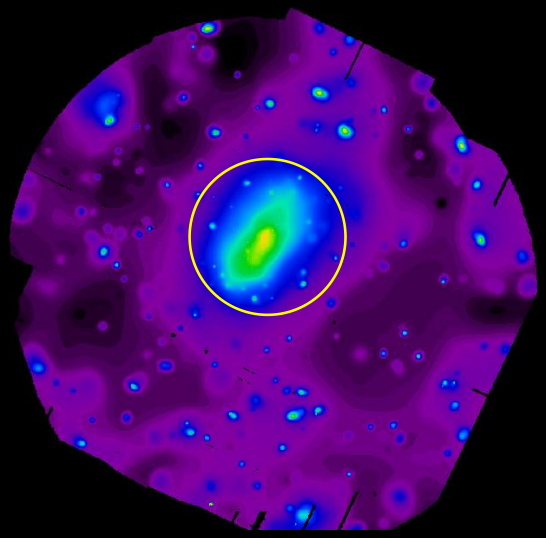
WG-SZ (*chair: Pointecouteau*): Bourdin; Burkutean; Clerc; Macias; Mayet; Mazzotta; Melin; Mroczkowski; Perotto; Sayers

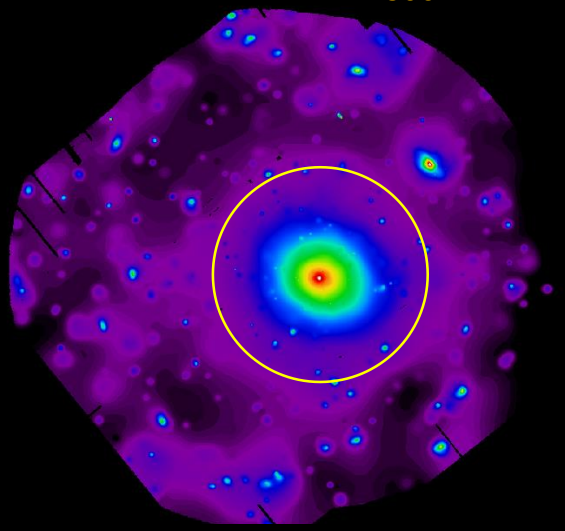
WG-radio (*chair: Bonafede & Cassano*): Vazza; Venturi

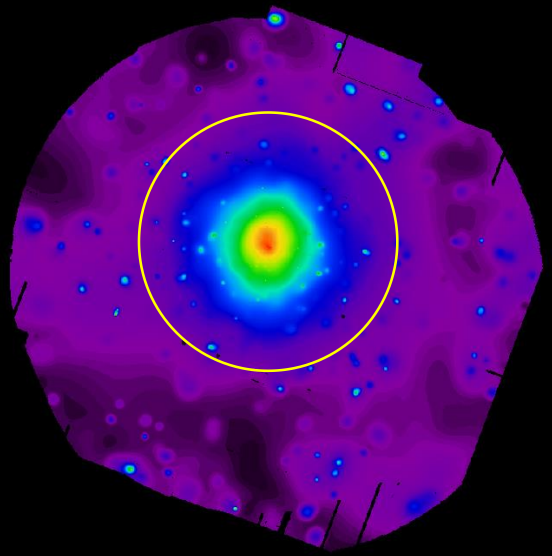
The XMM-Newton Heritage Project

PSZ2G008, **z=0.312**, M_{500}=7.4e14

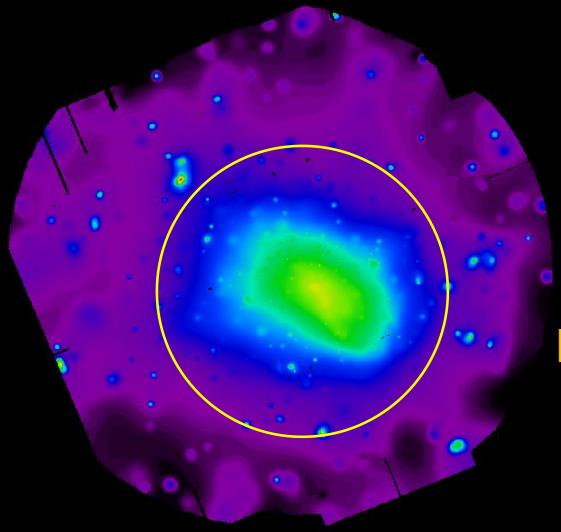
PSZ2G066, **z=0.163**, M_{500}=3.8e14

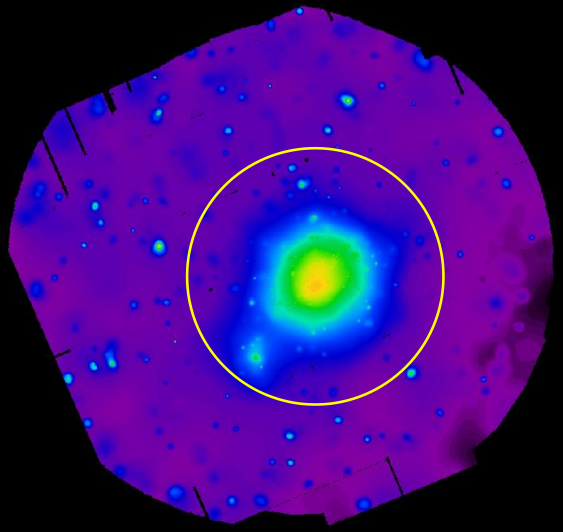






PSZ2G077, **z=0.147**, M_{500}=5e14





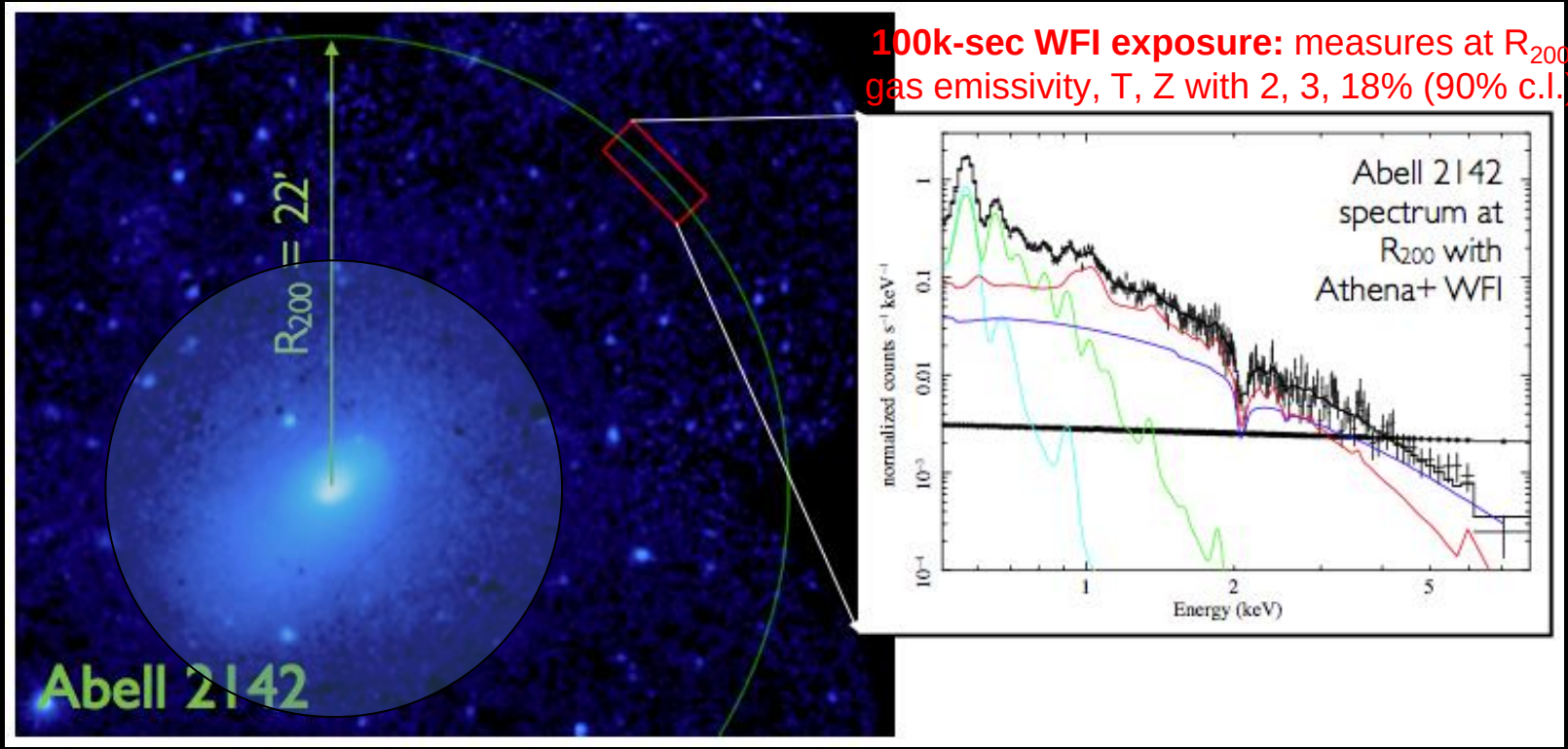
PSZ2G273, **z=0.134**, M_{500}=5.5e14

PSZ2G285, **z=0.165**, M_{500}=6.5e14

The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot ICM generated?

Ettori, Pratt et al., 2013 arXiv1306.2322

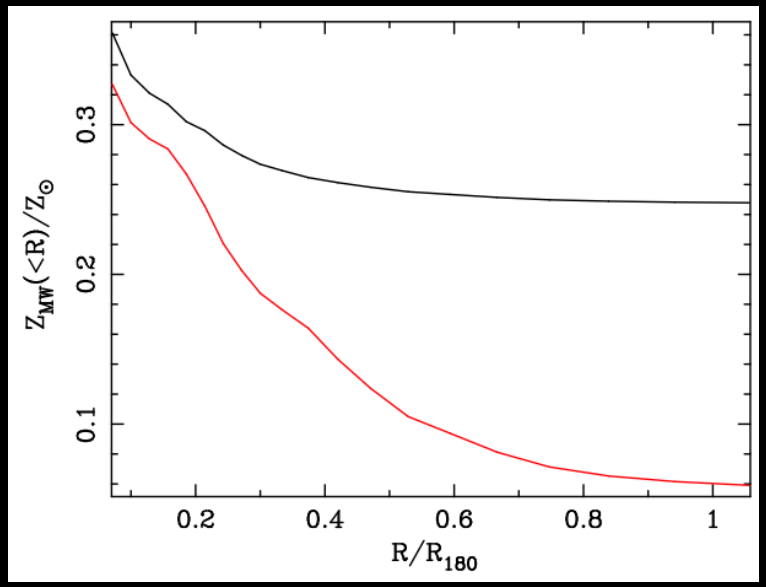


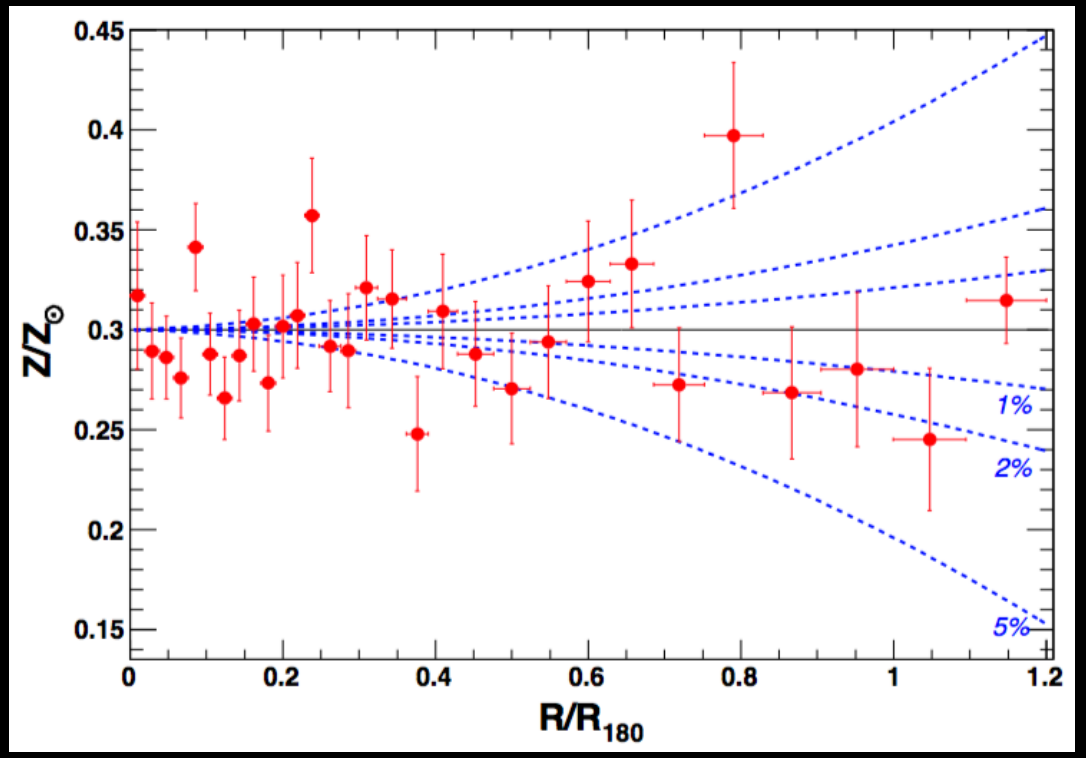
How does ordinary matter assemble into the large-scale structures that we see today?

The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot ICM generated?

Molendi+16

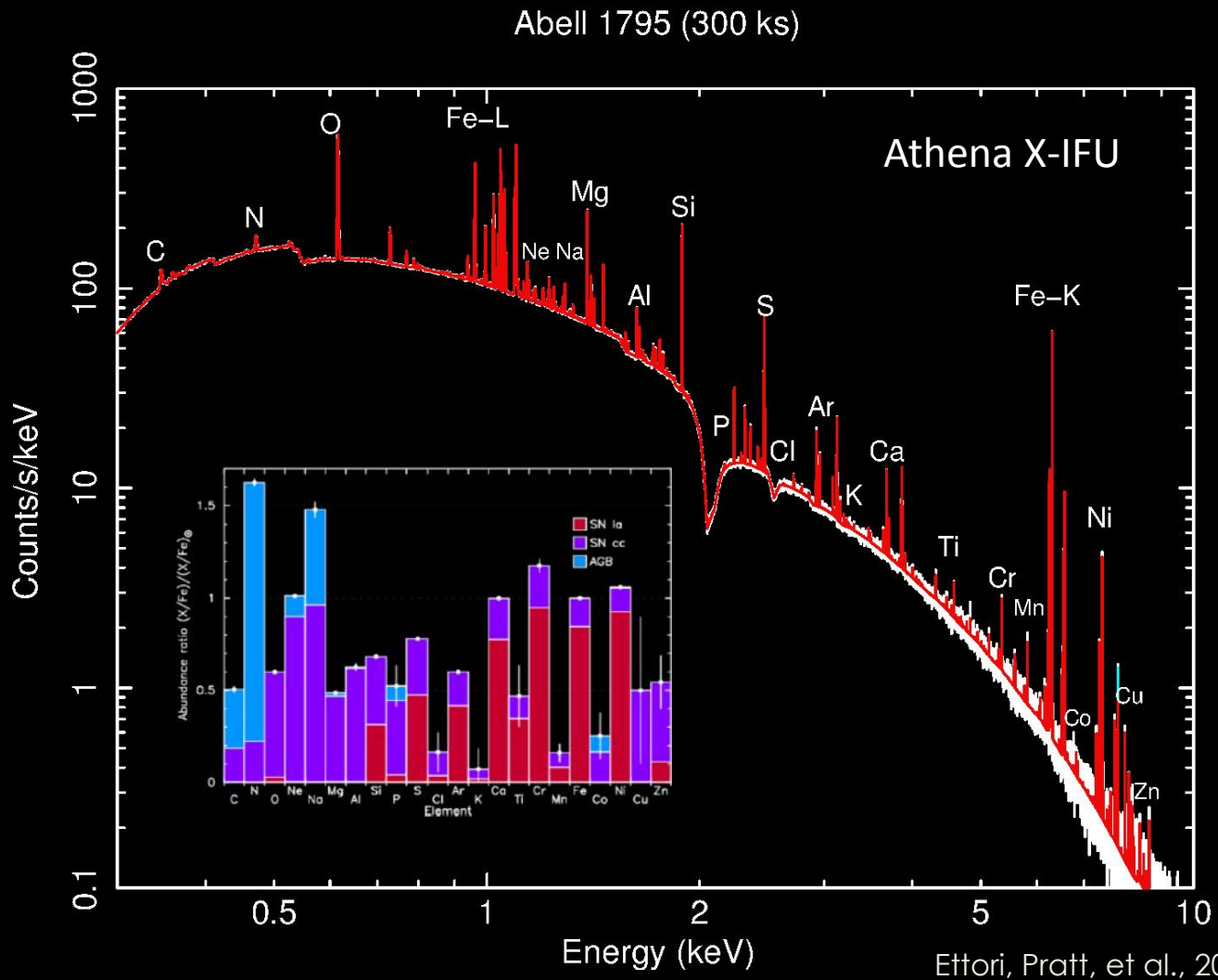




How does ordinary matter assemble into the large-scale structures that we see today?

The chemical evolution of hot baryons

When and how were the largest baryon reservoirs in galaxy clusters chemically enriched?



Ettori, Pratt, et al., 2013 arXiv1306.2322

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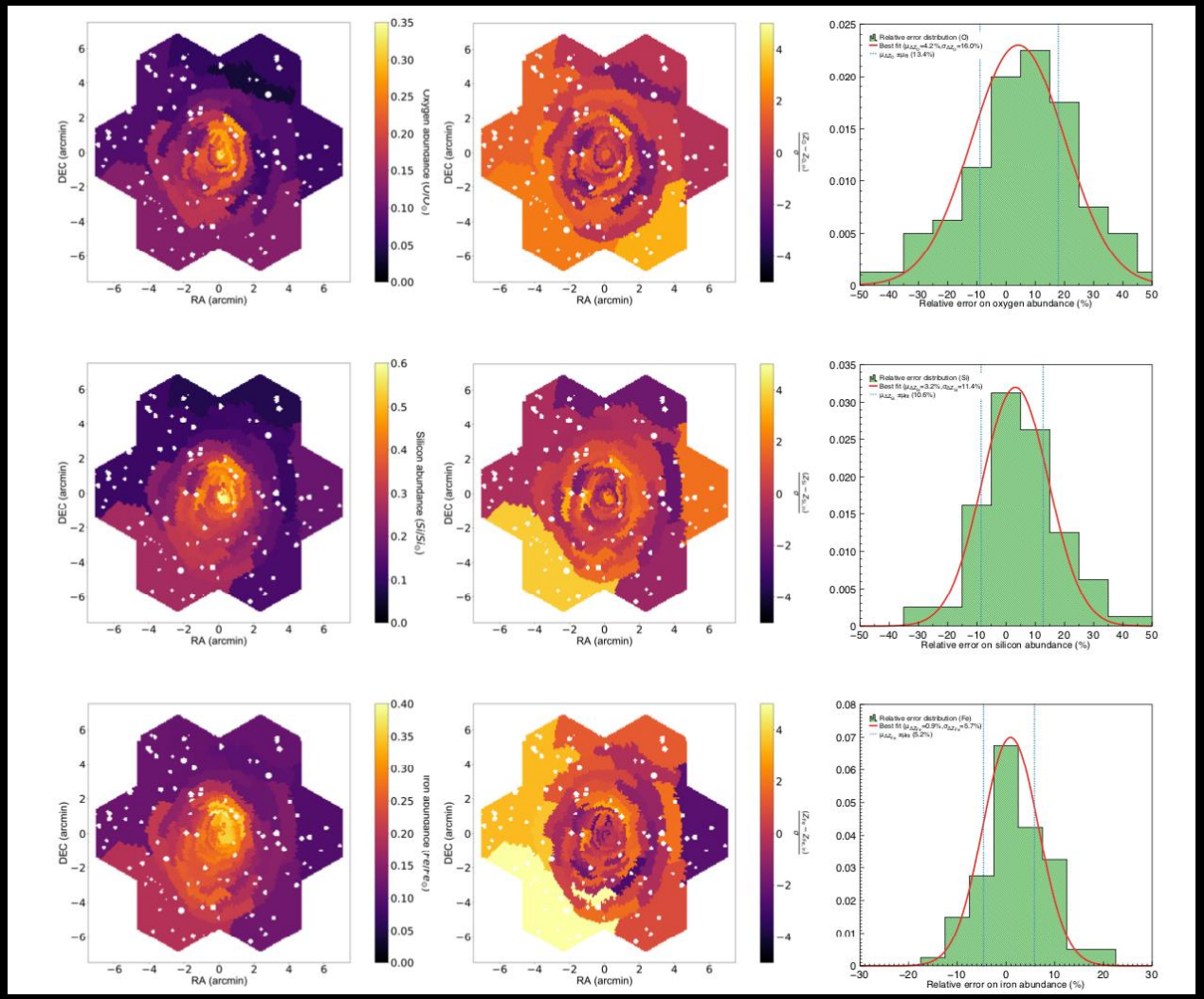

Cucchetti et al. 2018 (subm; *arXiv:1809.08903*)

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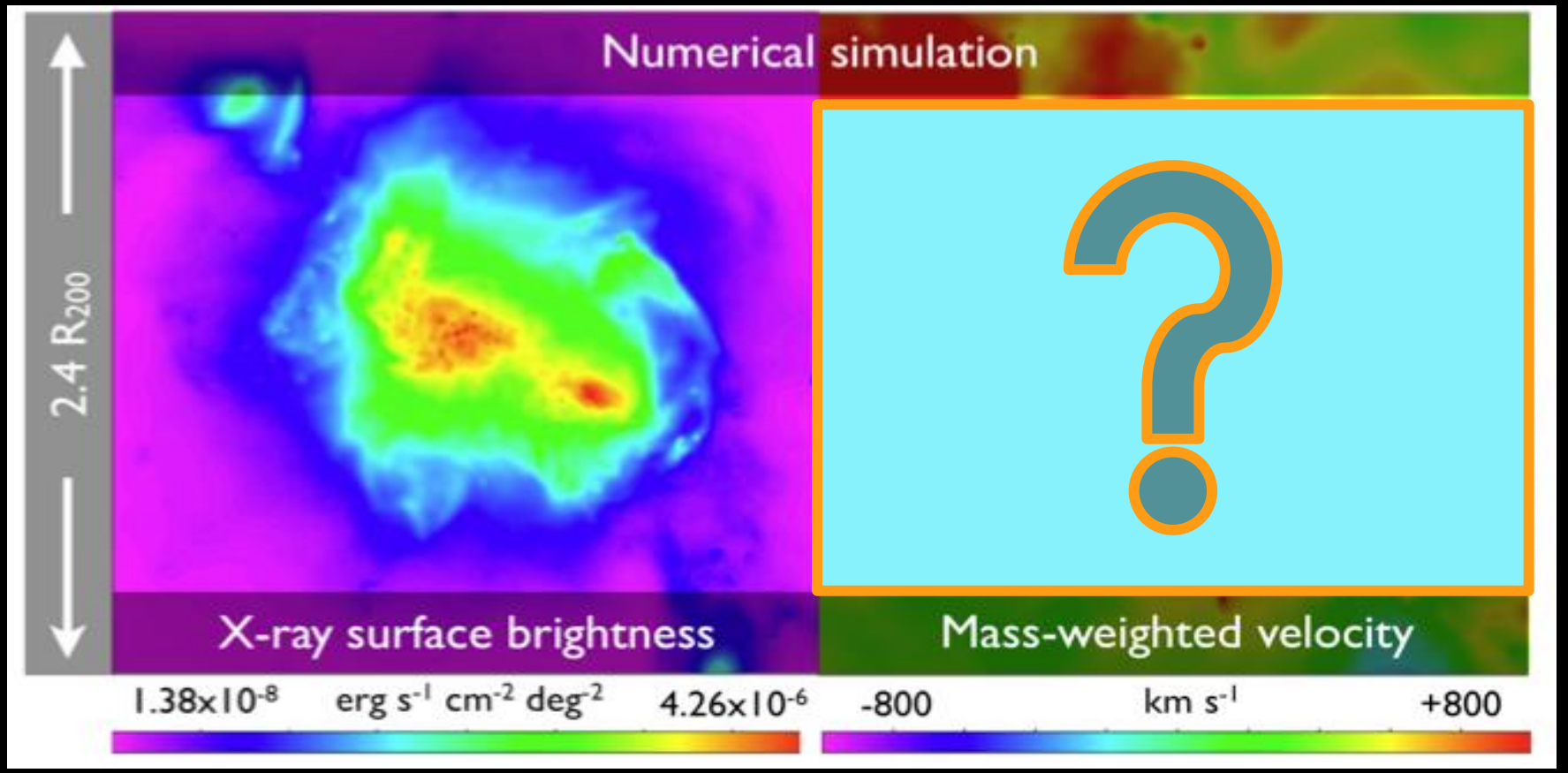

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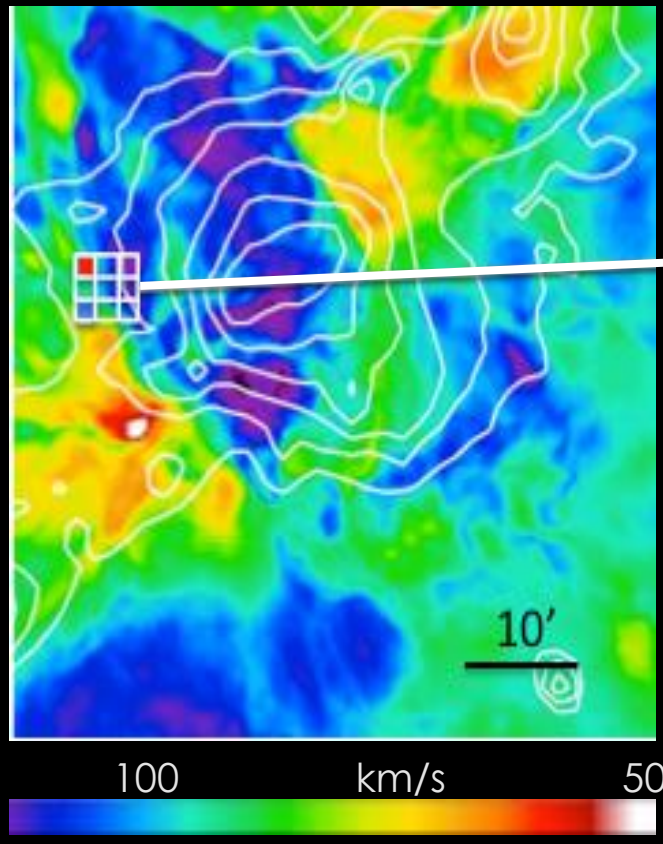
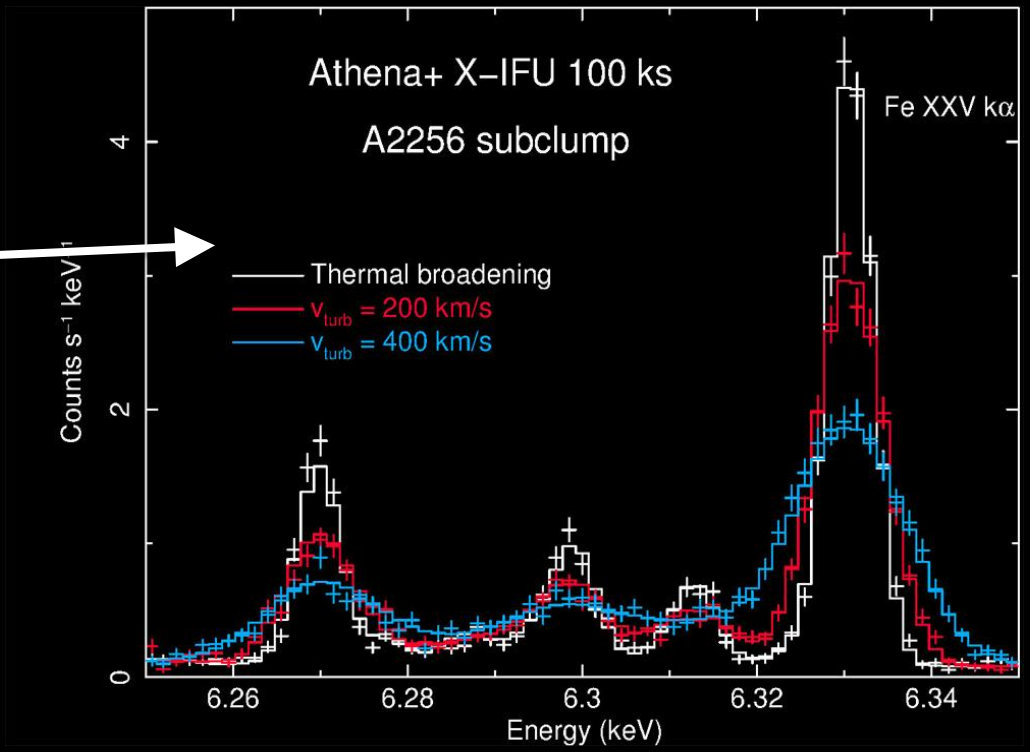
The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot ICM generated?

Simulated Velocity map



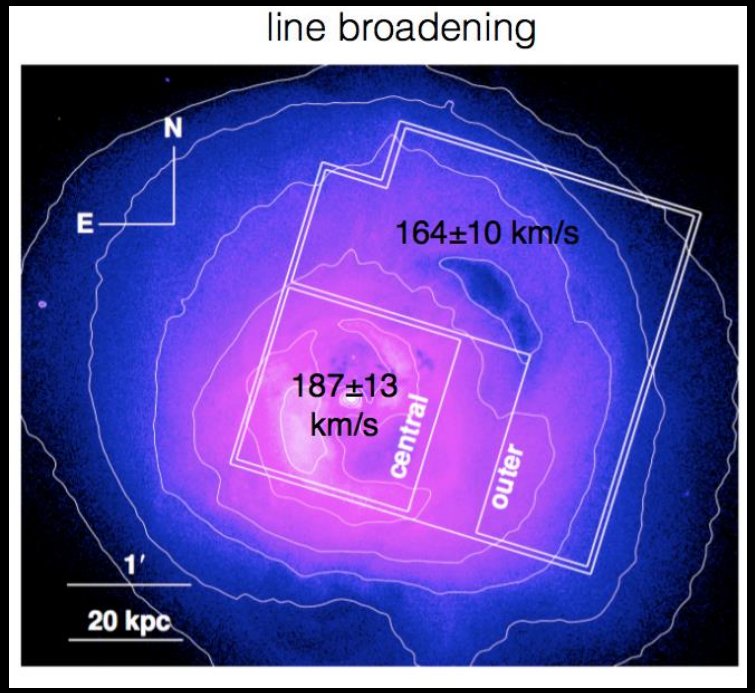
Ettori, Pratt, et al., 2013 arXiv1306.2322

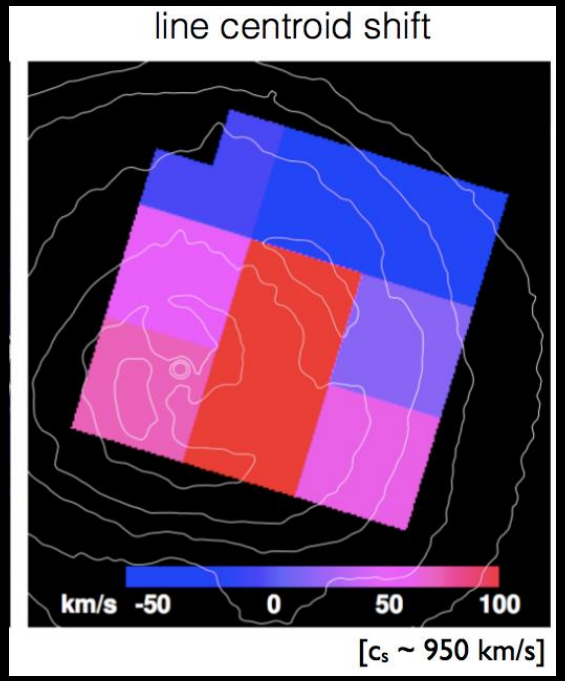


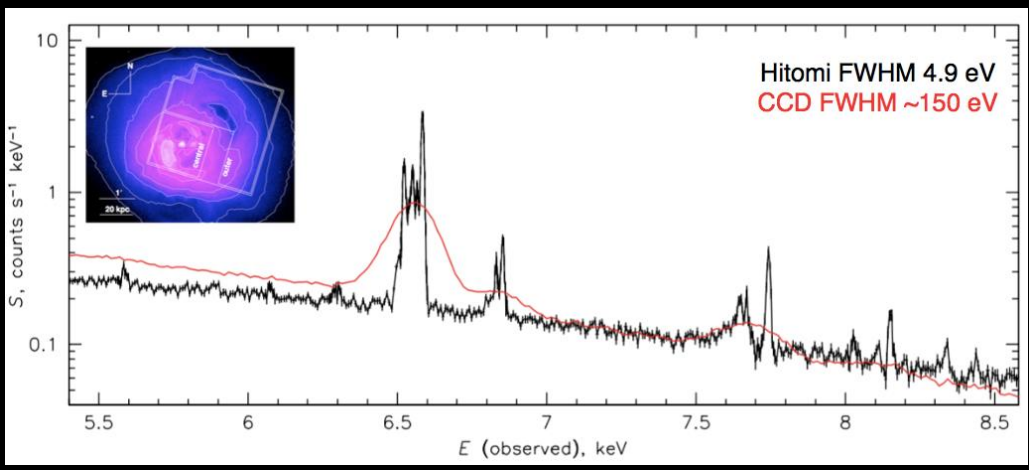
How does ordinary matter assemble into the large-scale structures that we see today?

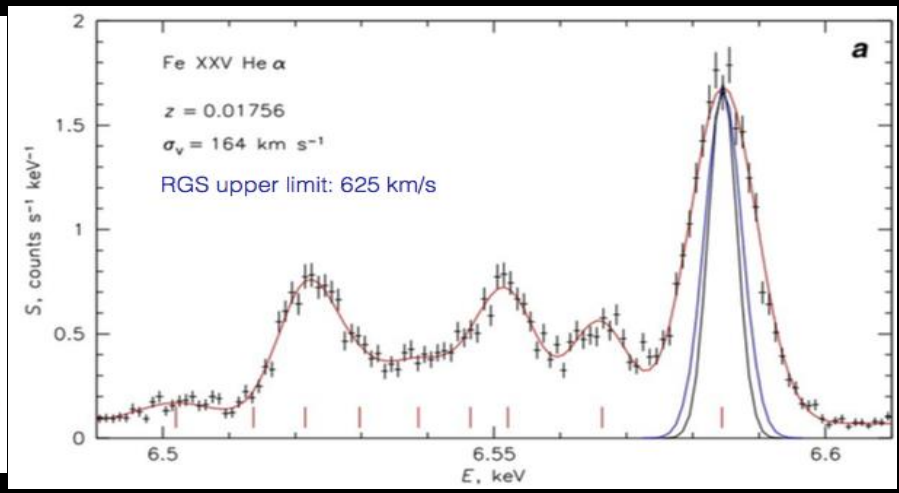
Turbulence in the ICM

Hitomi collaboration, Nature 2016



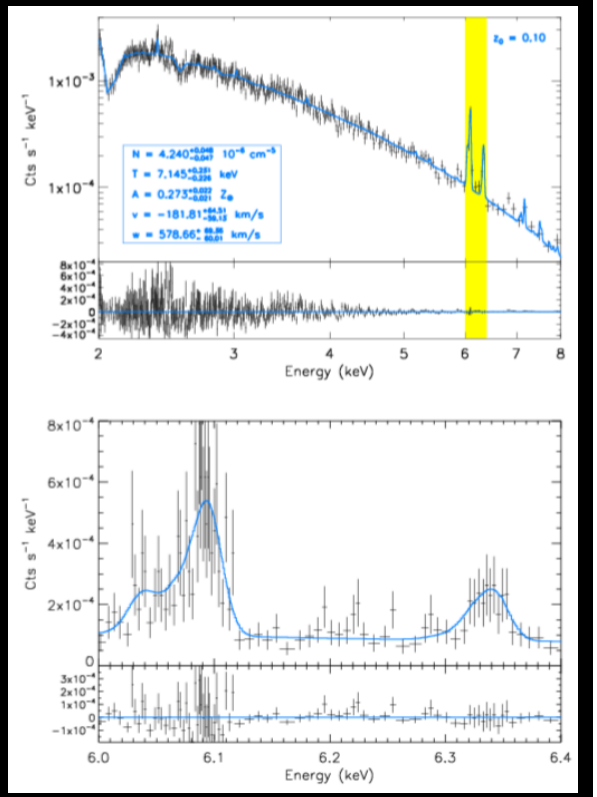


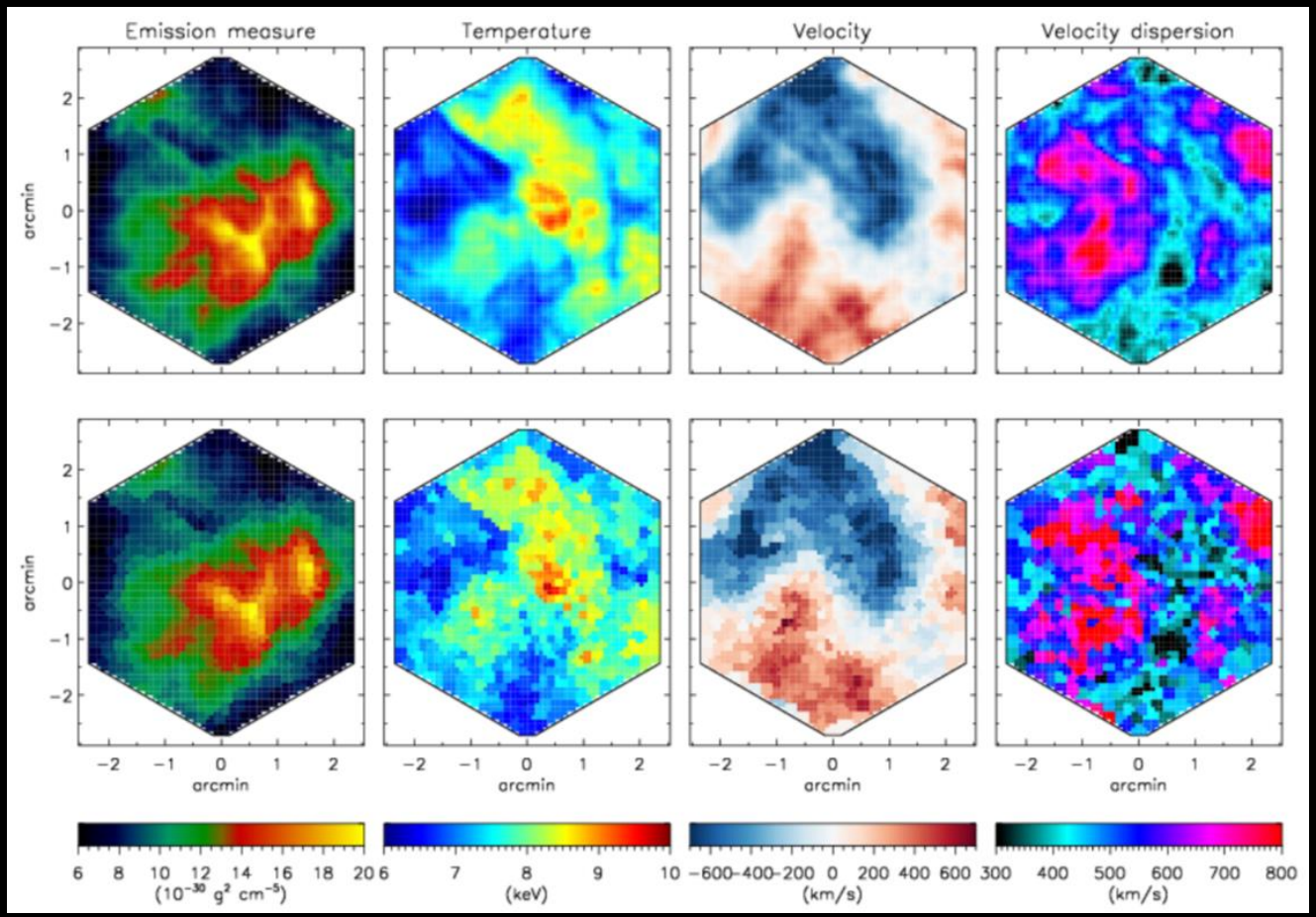




The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot ICM generated?





XIFU, SIXTE & simulated Velocity map

Roncarelli, Gaspari, Ettori et al., *arXiv:1805.02577*

The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot ICM generated?

List of projects proposed during the SWG1 workshop in Sexten (8-12 Jan 2018)

- ✓ **Measuring turbulence and gas motions in galaxy clusters via synthetic X-IFU observations** (Roncarelli et al., A&A in press)
- ✓ **Measuring chemical abundances with X-IFU** (Cucchetti et al., A&A subm)
- ✓ **Overlap/synergy cosmic web cluster outskirts SKA—Athena** (Vazza, Ettori, et al.; in prep.)
- ✓ **Multitemperature structure as seen by Athena** (Gastaldello –see poster)

- ✓ SWG1.2-TN-0006.pdf: **Some considerations for measurements of turbulence in galaxy clusters: requirements on line centroid and line width measurements**


“But ease isn’t the goal; excellence is”
Ed Catmull, “Creativity Inc.”

The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot ICM generated?

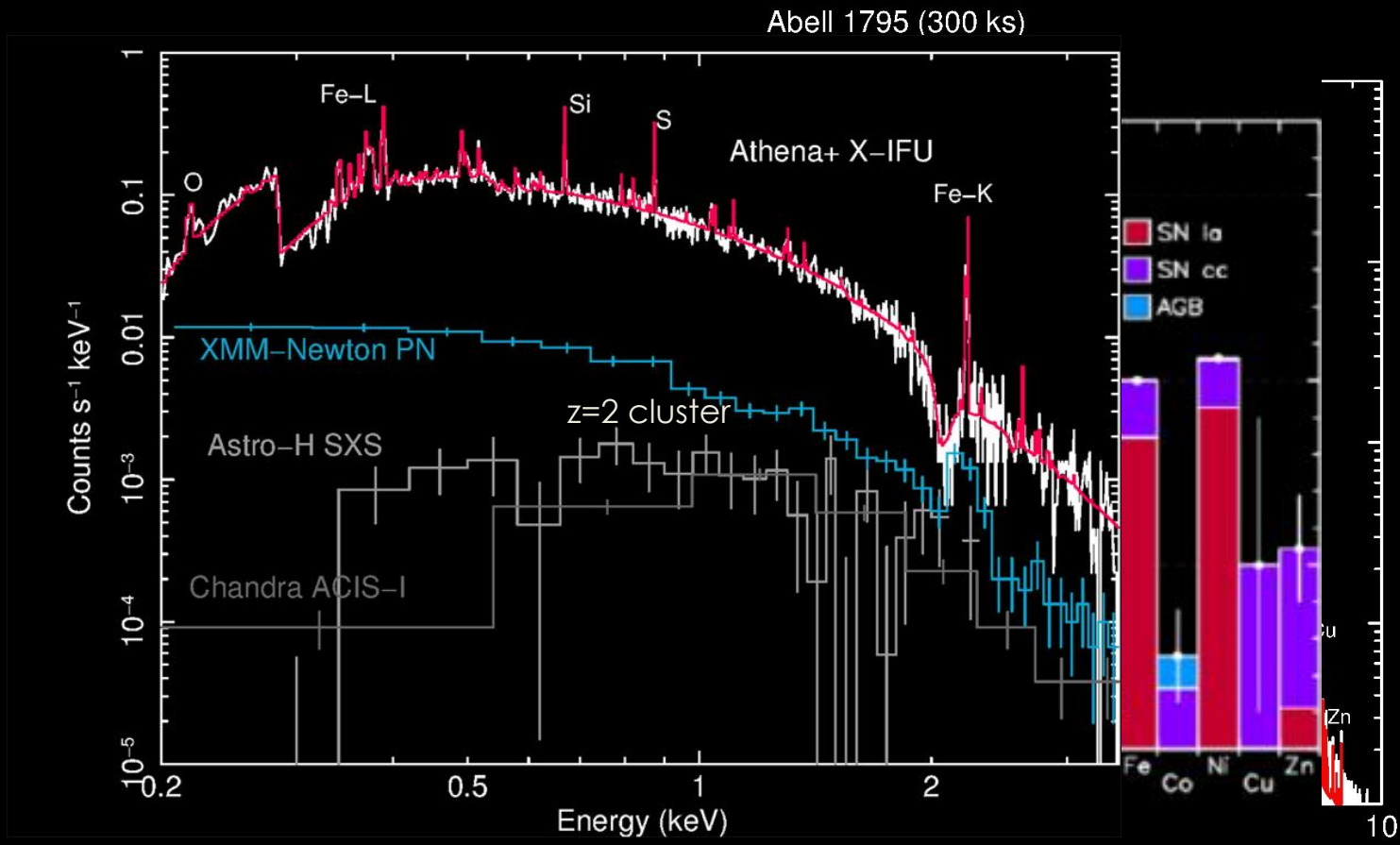
SCI-OBJ 112-turbulence:
- Tier 1: sample (A0) with 4 exposures with XIFU; t_{exp} = 10*4*100ks = 4Ms
- Tier 1.5: sample (A0) with 6 exposures with XIFU; t_{exp} = 10*6*100ks = 6Ms
- Tier 2: sample (A0) with 8 exposures with XIFU; t_{exp} = 10*8*100ks = 8Ms

SCI-OBJ 121-entropy:
- Tier 1: sample (A0) with a single WFI exposure centred on R200; t_{exp} = 10*100ks = 1Ms
- Tier 1.5: sample (A1) with a single WFI exposure centred on R200; t_{exp} = 20*100ks = 2Ms
- Tier 2: sample (A2) with a single WFI exposure centred on R200; t_{exp} = 30*100ks = 3Ms

SCI-OBJ 122-metal:
- Tier 1: sample (A0) with 4 exposures with XIFU; t_{exp} = 10*4*100ks = 4Ms
- Tier 1.5: sample (A0) with 6 exposures with XIFU; t_{exp} = 10*6*100ks = 6Ms
- Tier 2: sample (A0) with 8 exposures with XIFU; t_{exp} = 10*8*100ks = 8Ms

The chemical evolution of hot baryons

When and how were the largest baryon reservoirs in galaxy clusters chemically enriched?



Ettori, Pratt, et al., 2013 arXiv1306.2322

How does ordinary matter assemble into the large-scale structures that we see today?

Turbulence in the ICM

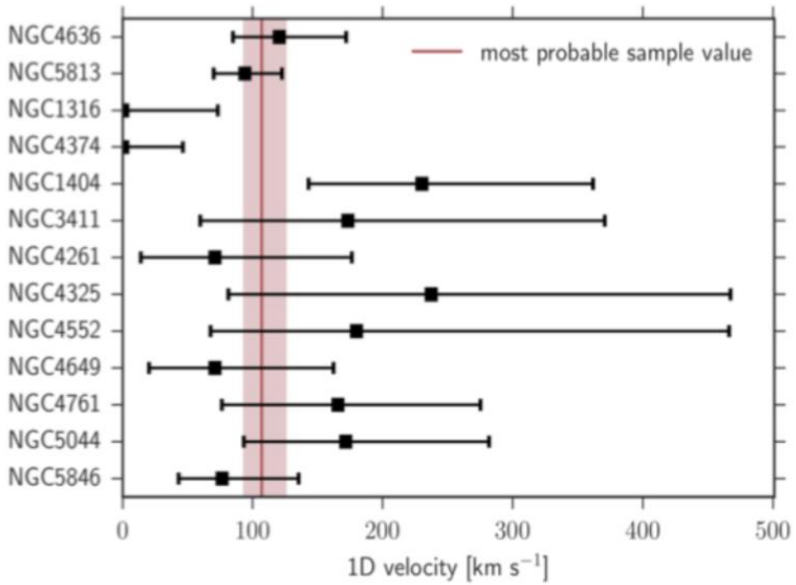


Figure 1: Turbulence limits from resonant scattering and line widths (XMM-Newton high-resolution X-ray spectra, Pinto et al. 2015, Ogorzalek et al. 2017)

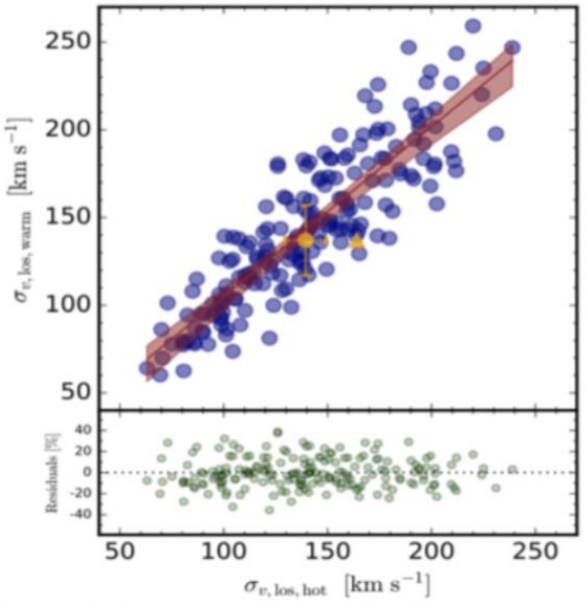


Figure 2: Turbulence limits from AGN self-regulated feedback simulations vs. Hitomi (Gaspari et al. 2017b).

Target	Typical velocities	Typical spatial scales
v_{500} (velocities @ R_{500})	0.3 – 0.7 c_s	100-1000 kpc
AGN interaction in cool-cores (center, jet & shocks)	0.3 – few c_s	1-20 kpc
Cool-cores (bulk)	0.2 - 0.6 c_s	few – 100 kpc
Merger shocks & flows	1 – few c_s	30 – 1000 kpc

SWG1.2-TN-0006.pdf