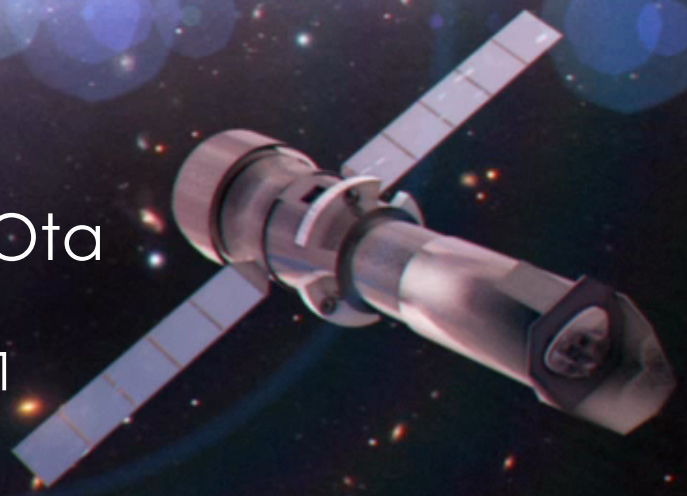
Evolution of groups and clusters of galaxies with Athena

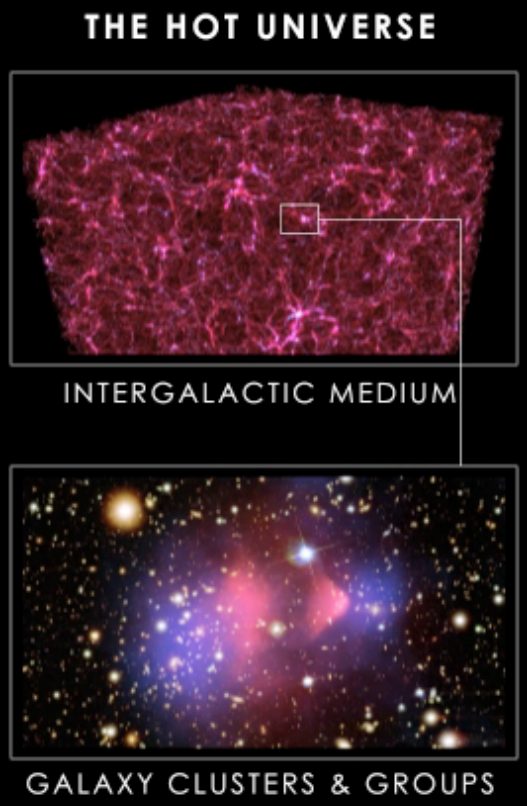


E. Pointecouteau, S. Allen, N. Ota

on behalf of the Athena SWG-1.1

ATHENA

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



- A hierarchical process, gravitation driven
- Evolution though constant accretion and mergers
- Groups and clusters are the last to form
- Mass of halos: 85% DM, 12% gas, 3% galaxies

➡ Laboratories to test the physics of structure formation (from dark matter and baryons)

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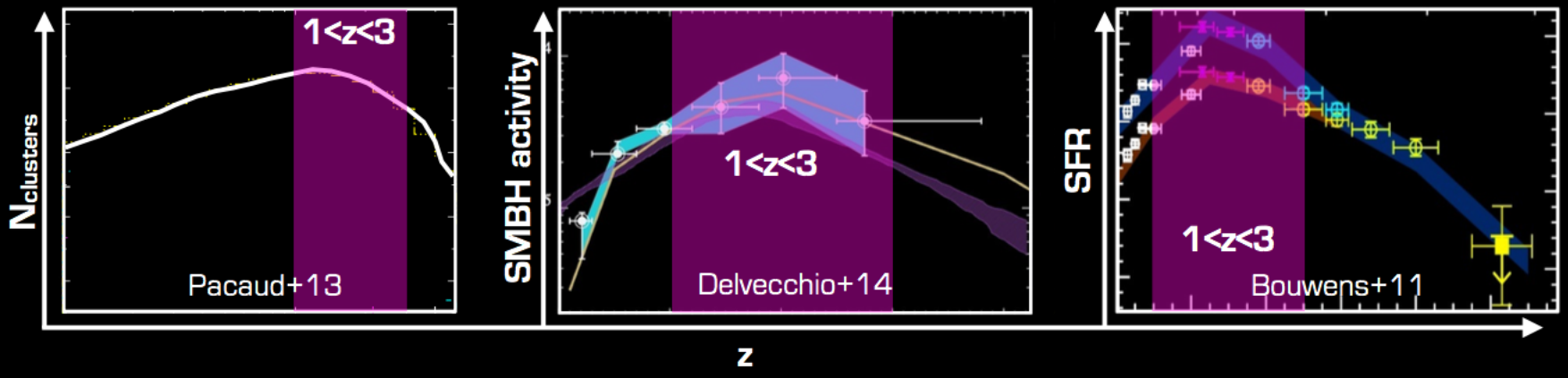
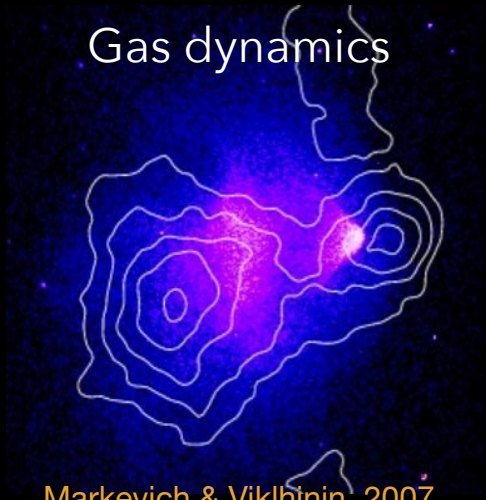
Formation of groups and clusters and baryons physics



Gas dynamics

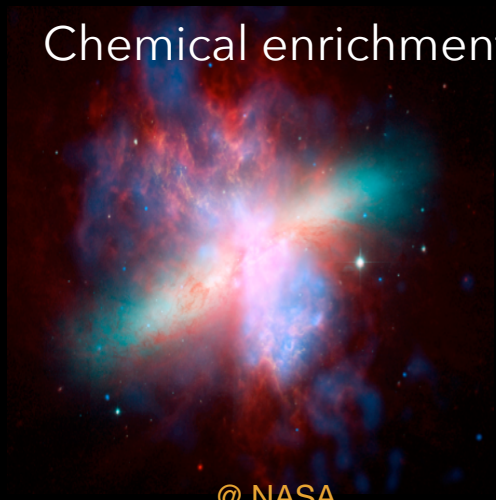


Markevich & Vikhlinin 2007

AGN feedback

McNamara & Nulsen 2012

Chemical enrichment



@ NASA

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Athena Key questions

How do the mechanisms that govern the physics of hot gas impact the process of the formation and evolution of large scale structures ?

— What is the interplay of galaxy, SMBH and the intergalactic medium in groups and clusters of galaxies?

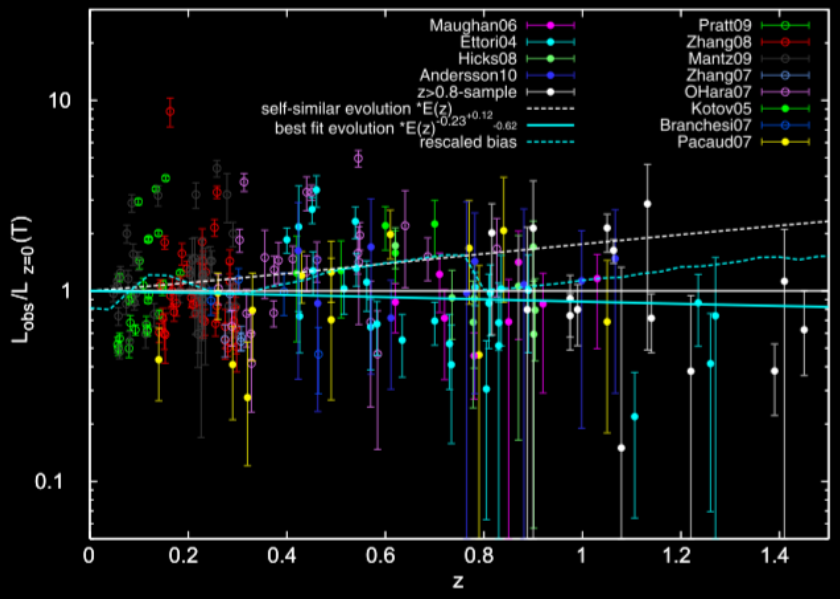
— What are the processes driving the chemical enrichment of the Universe at large scales?

— How and when did form the first galaxy groups binding a hot gaseous atmosphere?

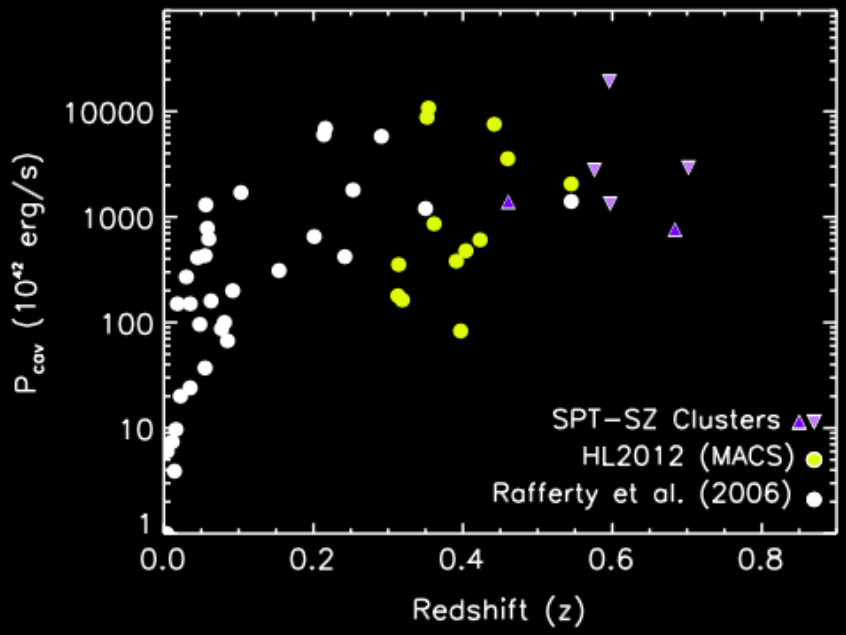
ATHENA

Evolution of cosmic feedback in clusters and groups

How and when was the energy contained in the hot intra-cluster medium generated?



Reichert et al. 2011



Hlavacek-Larrondo et al. 2015

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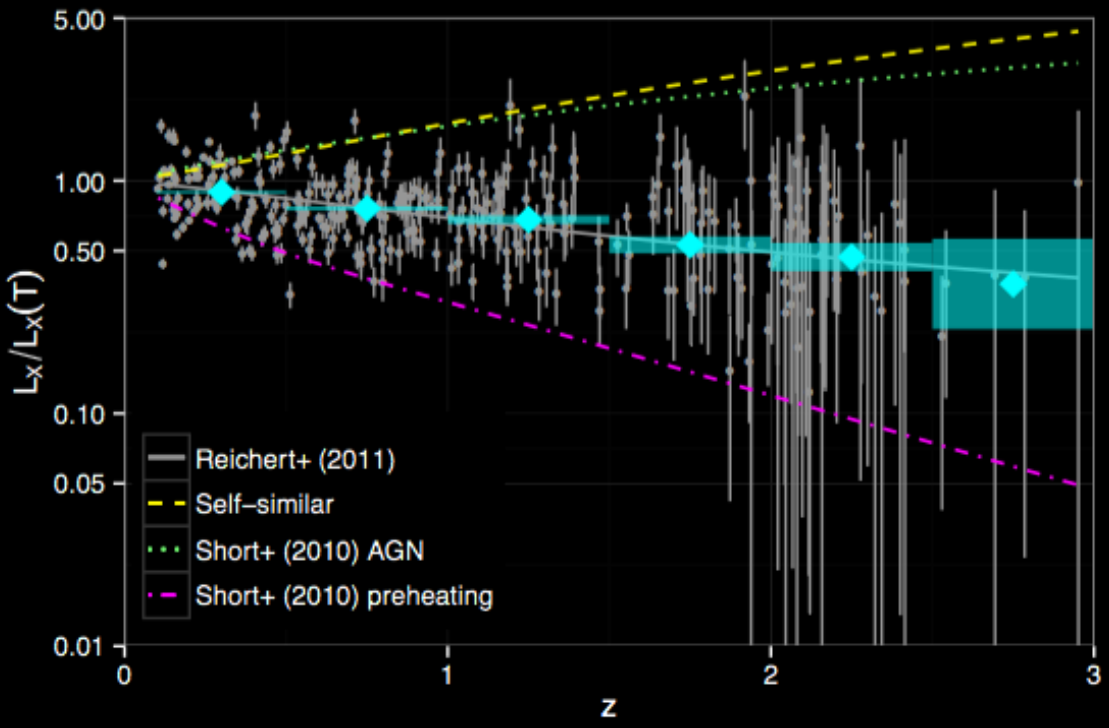

Courtesy of B. Maughan
(in Pointecouteau, Reiprich et al., 2013)

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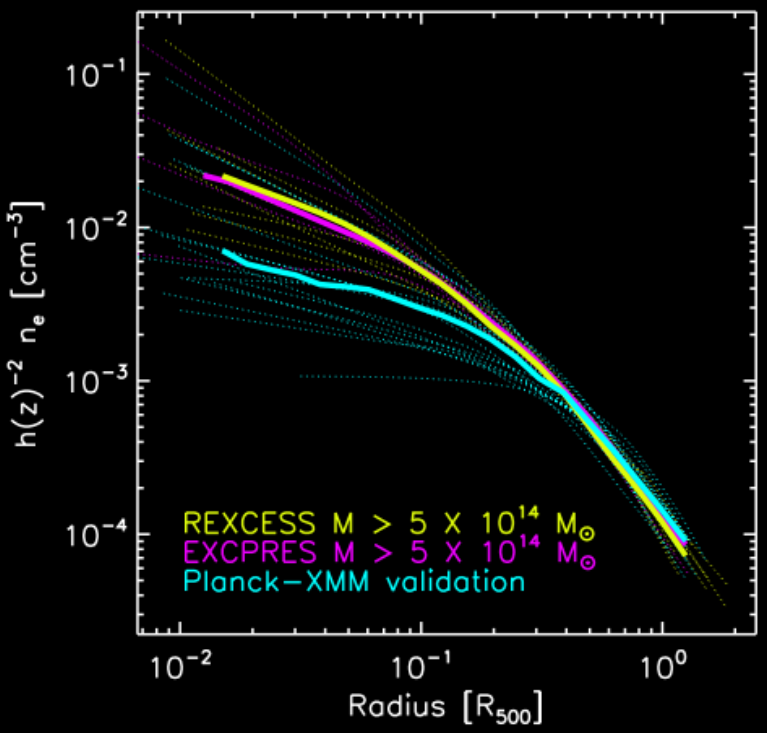
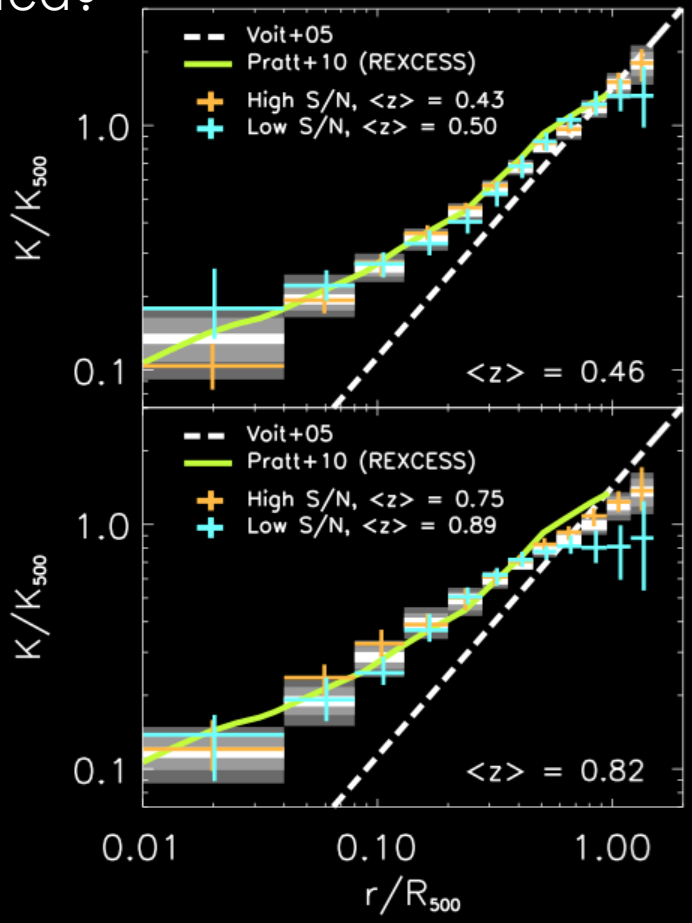


EXCPRESS collaboration
(in Planck Collaboration, PEP-IX, 2011)



McDonald et al., 2014

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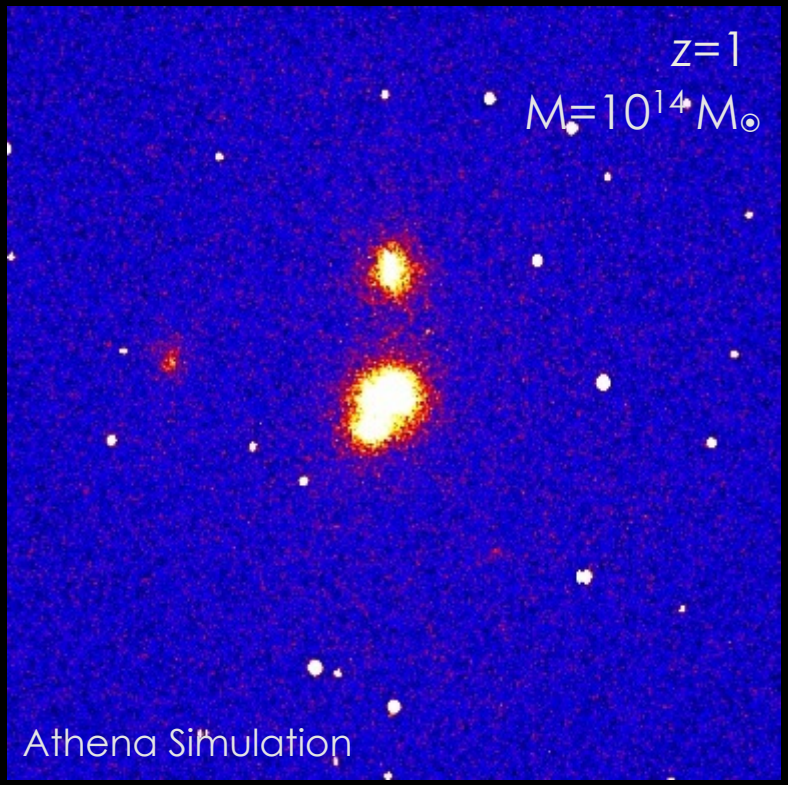
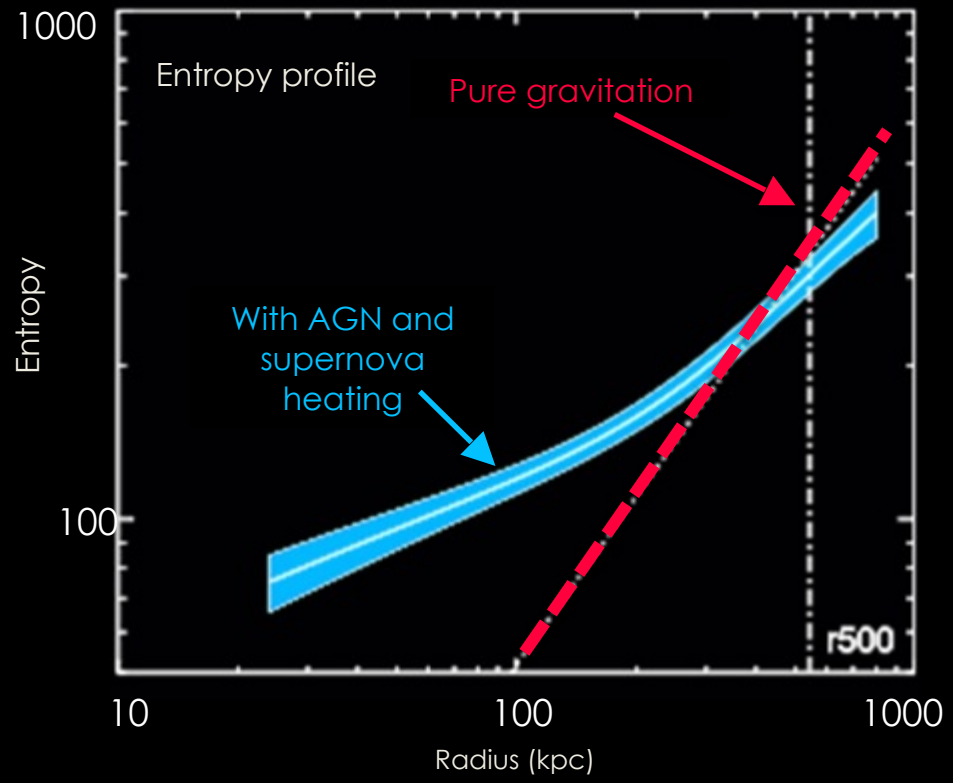


Courtesy of H. Bourdin, H, Rasia, P. Mazzotta
(in Pointecouteau, Reiprich et al., 2013)



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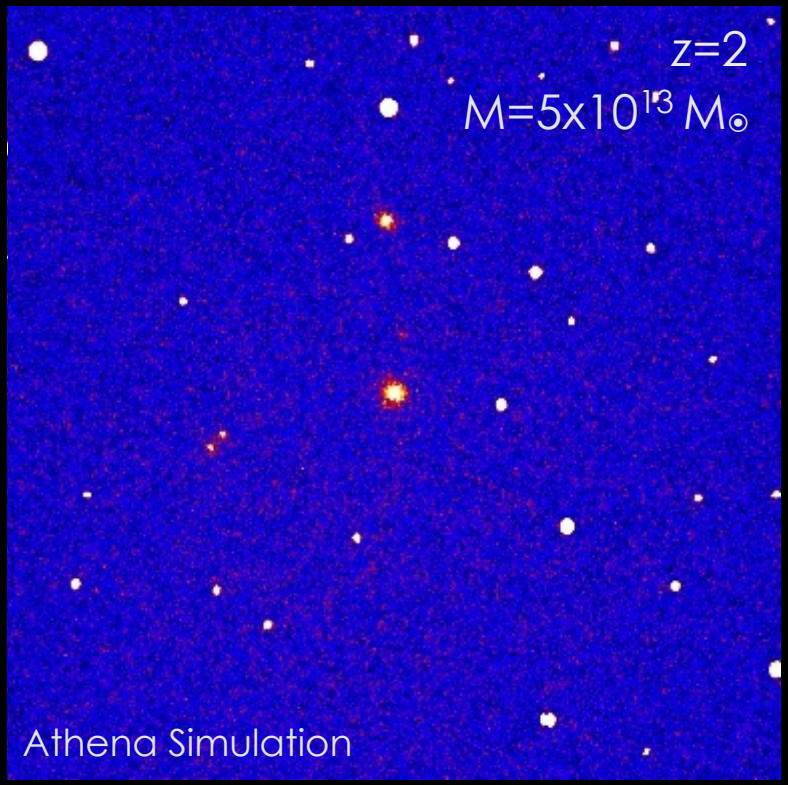

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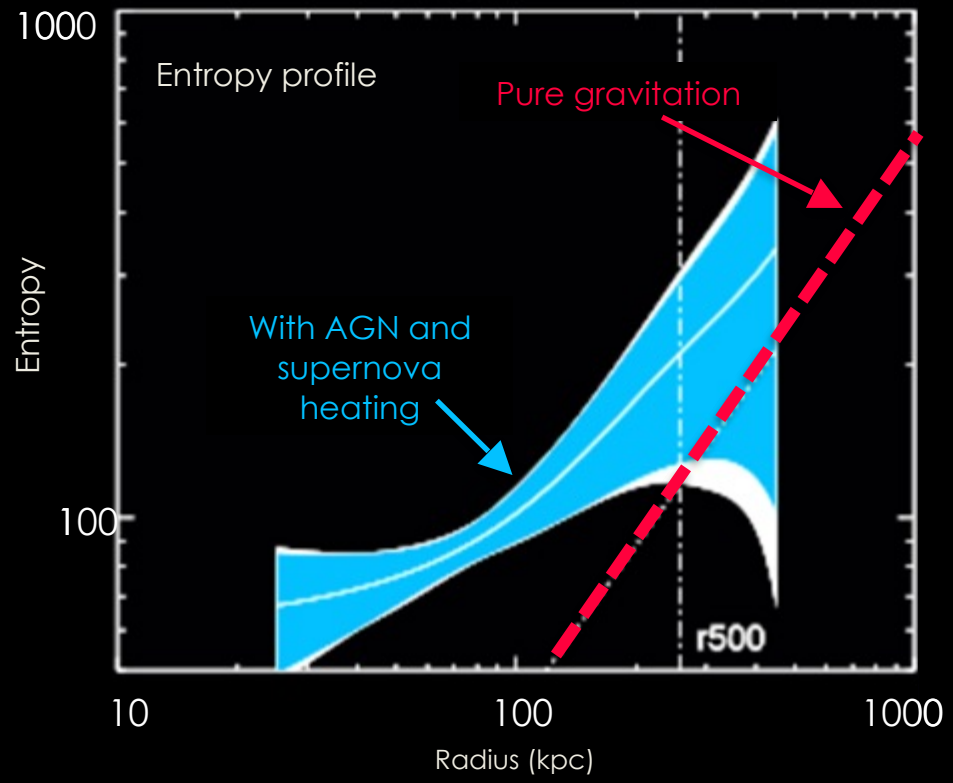

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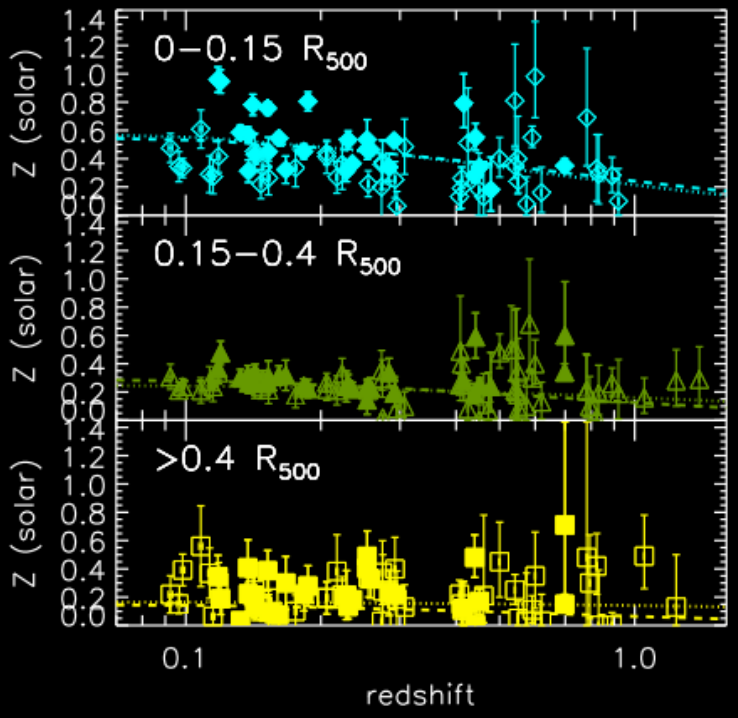
Chemical enrichment of the intra-cluster medium

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

Iron abundance measurements



Ettori et al. 2015

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ATHENA

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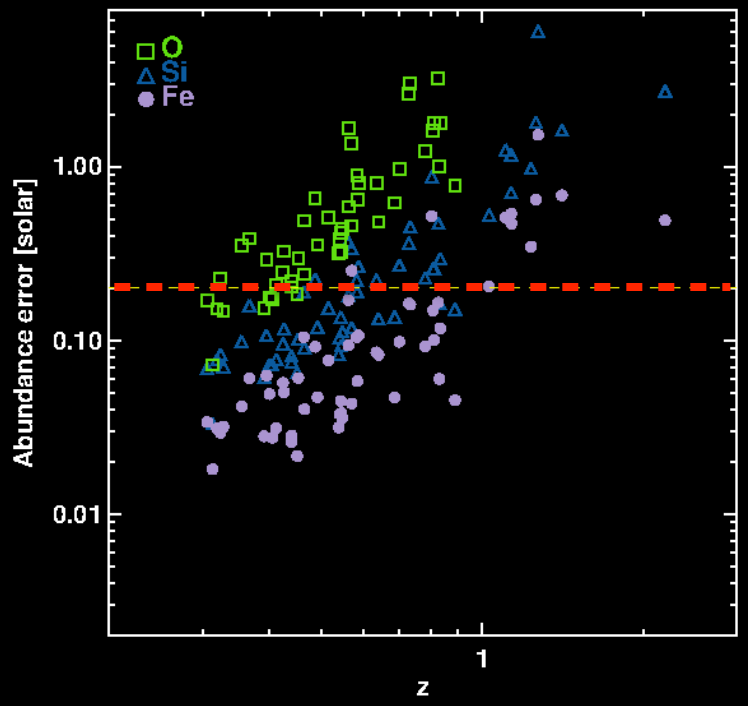
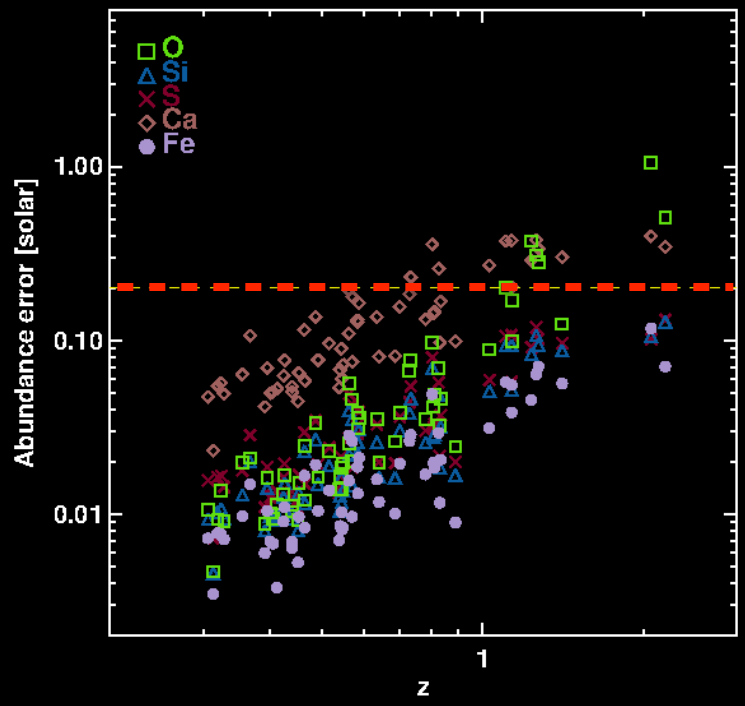
Astro-H/SXS 100 ksec



(in Kitayama et al. 2015)

Athena/X-IFU 100 ksec



(in Pointecouteau, Reiprich, et al. 2013)

Courtesy of J. de Plaa

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ATHENA Chemical enrichment of the intra-cluster medium

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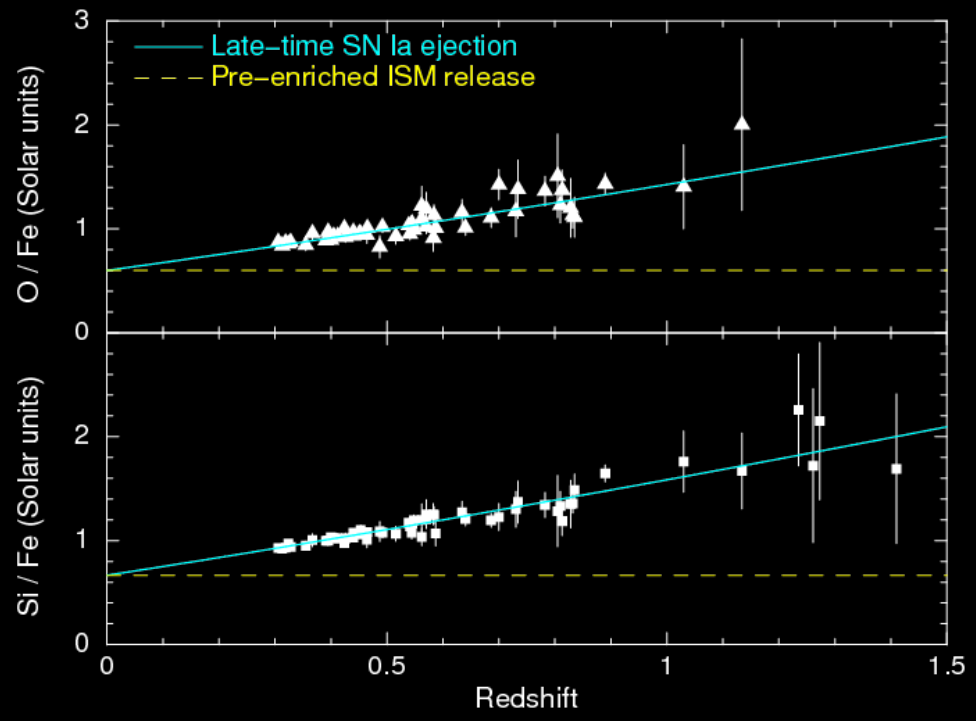

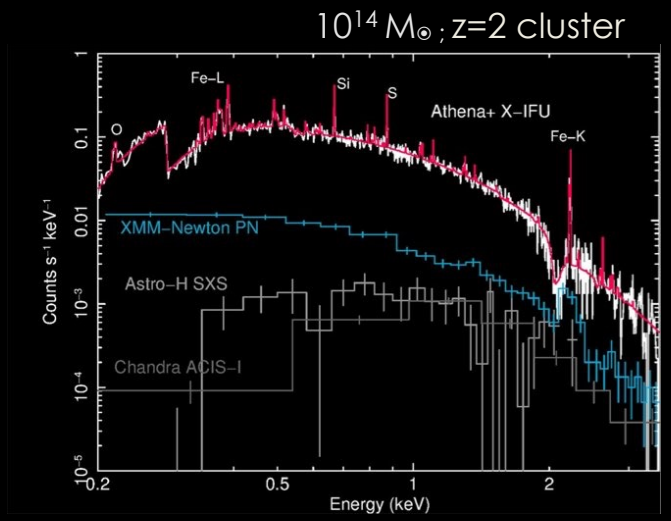

Coutesy of J. de Plaa
(in Pointecouteau, Reiptich et al., 2013)

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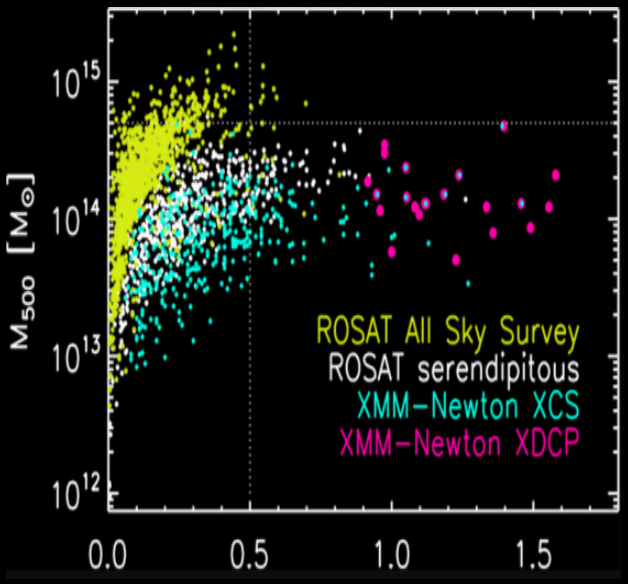
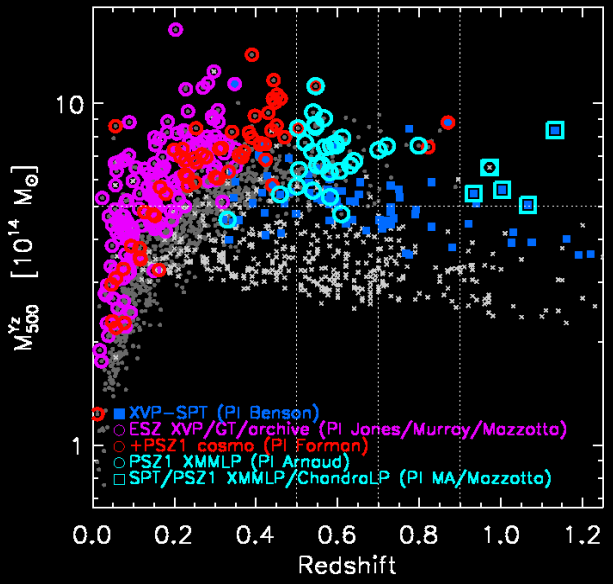
Finding the earliest galaxy groups

A few tens of spectroscopically confirmed clusters beyond z=1

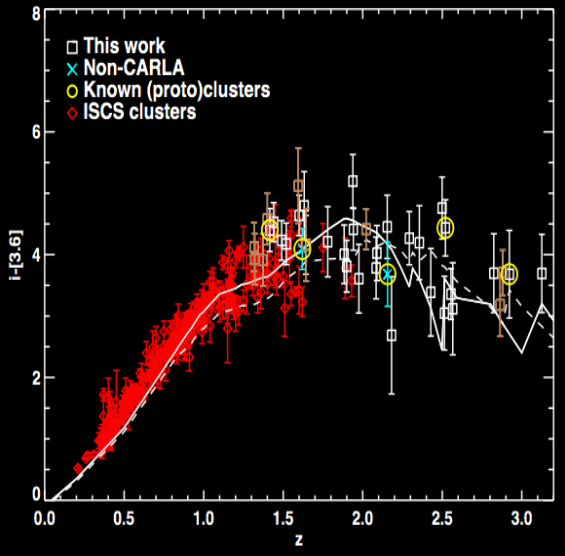
X-ray selected



SZ selected



Optical/NIR selected



Courtesy of M. Arnaud

Cooke et al. 2015

see also: Stanford+06; Tanaka+10; Llyods-Davies+11; Gobat+11; Mehrtens+12; Fassbender+12, Bayliss+13; Erfanianfar+13; Santos+13+14; Mantz+14, Tuckey+14; Clerc+12 +14

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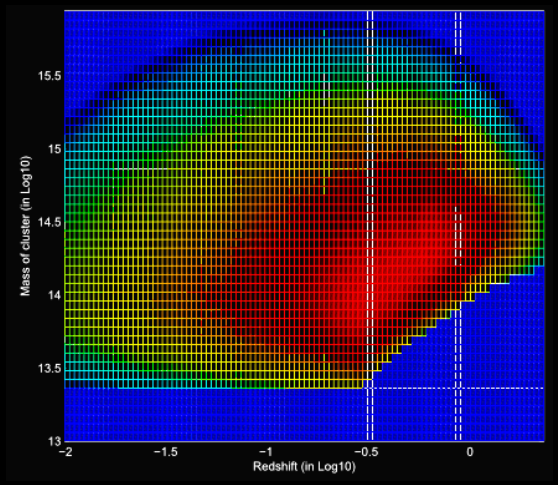
ATHENA Finding the earliest galaxy groups

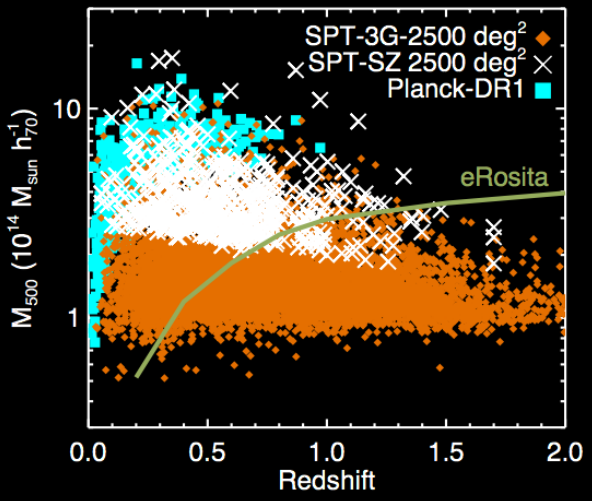
Need for a representative sample of the population of groups and clusters

X-ray selected
e.g., eRosita



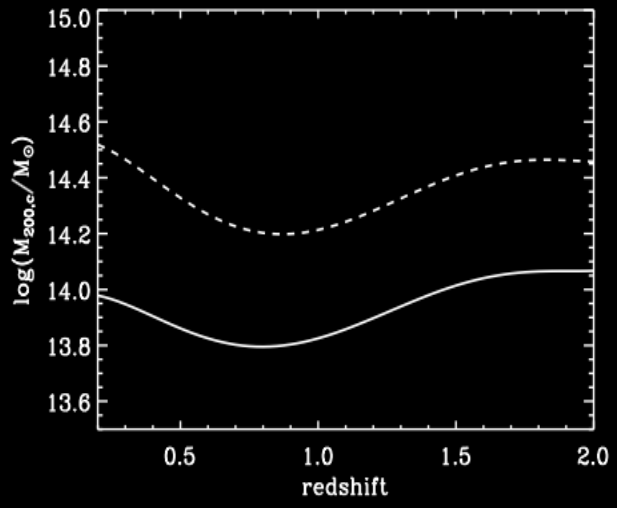
Borm et al., 2014

SZ selected
e.g., SPT 3G



Benson et al. 2014

Optical/NIR selected
e.g., Euclid



Sartoris et al., 2015

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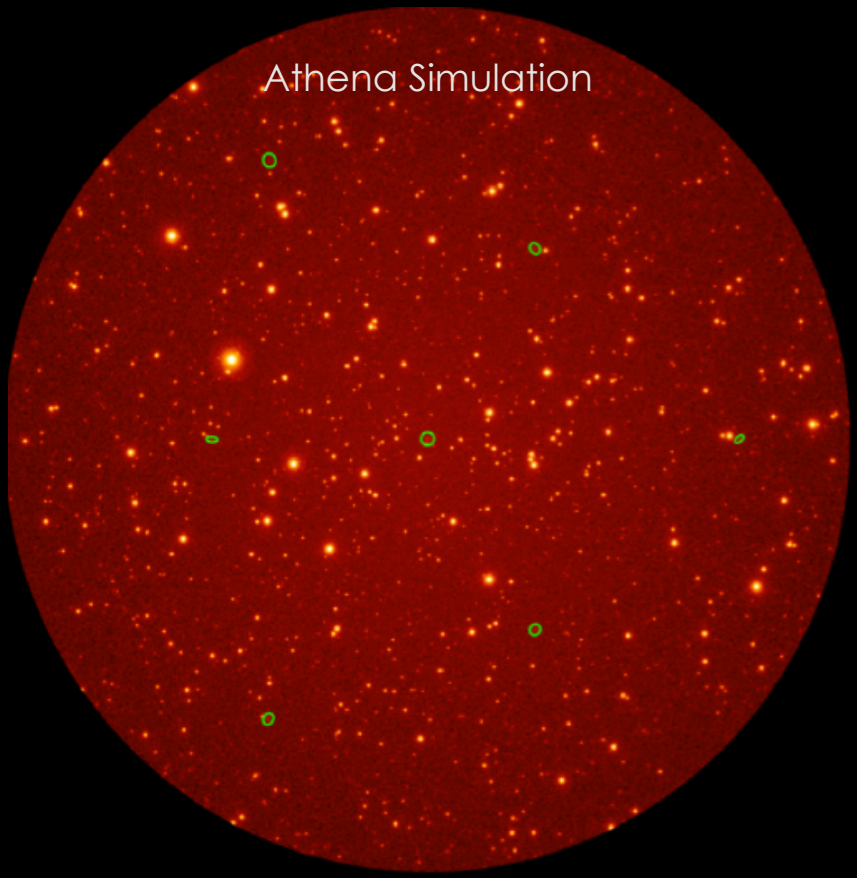
ATHENA Finding the earliest galaxy groups

Testing astrophysical cosmology at the largest scales

As a way to constrain models of large-scale structure formation, find the first building blocks of the dark matter structure filled with hot gas.

Athena will be able to detect ~ groups with mass $M_{500} > 5 \times 10^{13} M_{sun}$ at z>2. And measure T of ~50% of them



Courtesy of M. Ramos-Ceja, F. Pacaud
(in Pointecouteau, Reiprich et al., 2013)

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ATHENA

Conclusions

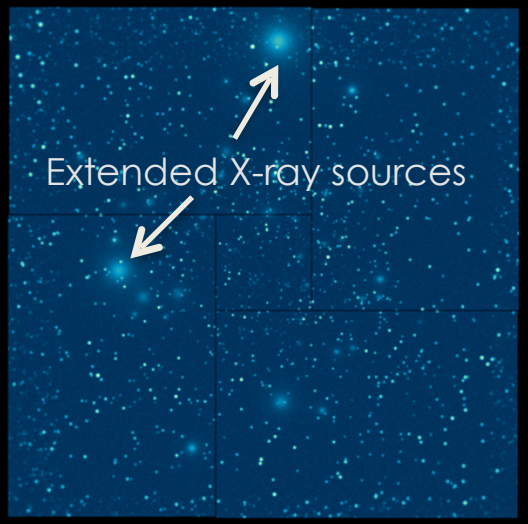
How does ordinary matter assemble into the large scale structures we see today?

Constraint the processes driving the evolution of the physical properties of dark matter and hot gas in groups and clusters of galaxies.

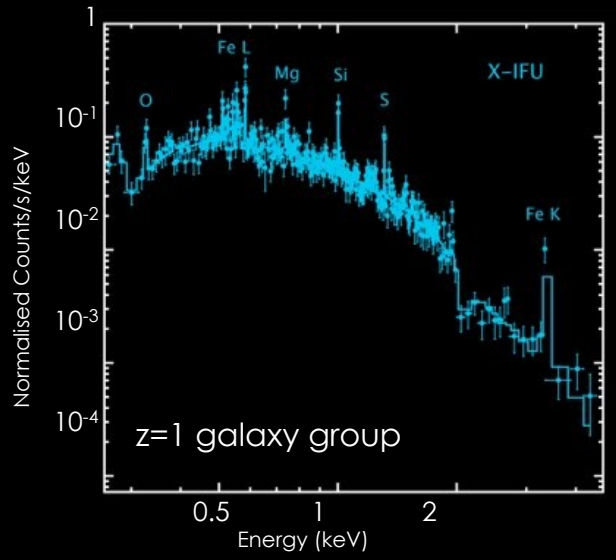
Characterise the content of the first groups and clusters formed in the Universe and understand how super-massive black holes, galaxies and hot gas co-evolve.

Search for the first collapsed massive halos retaining a hot gaseous atmosphere through their X-ray emission.

Athena/WFI



Athena/X-IFU



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