Evolution of Entropy Profiles in Simulated Clusters

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Cosmological simulations as asset for Athena Collaboration & scientific definition of Key Science Project

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Athena swg1.1 & swg1.2
[121- Evolution of Entropy Profiles
122 Evolution of metal production]
Entropy @ $z \sim 0$

$K = kT / n^{2/3}$

Gravity drives structure formation.

Simply gravity-only models do not explain the observed gas profiles from the core to the outskirts.

Delicate balance between heating and cooling is in place.

Entropy quantifies the history of the energy deposited in the intra-cluster medium.
Entropy @ $z \sim 0$
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CC-\(\rightarrow\) NCC-\(\rightarrow\) CC

Pseudo-Entropy Maps

Rasia et al.
Iron Abundance at $z \approx 0$

Process driving evolution of chemical enrichment:
- Initial Mass Function
- SNIa, SNcc, AGB yields (and evolution)

Metal diffusion into the intra-cluster medium:
- Early superwinds
- Late ram pressure stripping
- Minor mergers in the core
- Uplift by AGN bubbles
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CC in Ettori et al. 2015
CC in Simulation
NCC in Ettori et al. 2015
NCC in Simulation
Rasia et al. sub
Few $z=0$ comparisons

ICM enrichment

Not only Iron and Silicon individual profiles profiles but also their ratio

$T_{sl,500}>3$ keV

$\frac{Z_{Si}}{Z_Fe}$

$\frac{Si}{Fe}$

$\frac{M_{star}}{M_{tot}}$ vs. $M_{500}$

Stellar Scaling Relation

$M_{BH}$-$M_*$ relation to calibrate feedback parameters:
$v_w=350$ km s$^{-1}$ & $\epsilon_f=0.05$

Observations from McConnell & Ma 2013

$M_{*BCG}$-$M_{500}$ in agreement with observations (Kravtsov+14)

Total stellar mass also close to observations (Gonzalez+13, Kravtsov+14)

Not only Iron and Silicon individual profiles profiles but also their ratio
Few Scaling Relation at $z \sim 1$

**MT-T Relation**

\[ M_{500} \times \frac{E(z)}{E(z=1)} [M_{\odot} h^{-1}] \]

\[ T_{sl,500} \text{[keV]} \]

Maughan+12

**M-Yx Relation**

\[ M_{500} \times \left( \frac{E(z)}{E(z=1)} \right)^{2/5} [M_{\odot} h^{-1}] \]

\[ Y_{X,500,sl}[M_{\odot} h^{-1} \text{keV}] \]

Andersson+11

**OSS**

**SIM**

**AGN**

Truong et al. in preparation

\[ Y_x = T \times M_{gas} \]
Zoom-in simulations

Bonafede+12
24 massive clusters + 5 groups
GADGET3 with modifications:
• **Artificial conduction term**
• A high-order interpolating kernel
• A time-dependent artificial viscosity

Metal-dependent radiative cooling
Kinetic feedback from SN (v=350 km/s)
Metal production from SNII, SNIa, AGB:
  C, Ca, O, N, Ne, Mg, S, Si, Fe, Na, Al, Ar, Ni

AGN feedback with cold and hot accretion

NOT INCLUDED
• Inflation of bubbles of high-entropy gas from the shocks of sub-relativistic jets
• Gas circulation and turbulence triggered by the bubbles
• Magnetic field
• Thermal Conduction
• Cosmic ray
The capability of generating a realistic CC population is due to *combined* action of AGN feedback and the artificial conduction term in SPH equation.

![Graphs showing the effect of AGN and AC on CC population](image-url)
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Pointecouteau, Reiprich+2013