Metal abundances in the Intracluster medium observed with XMM and Suzaku

Kyoko Matsushita, K. Sato, M. Komiyama, K. Hayashi, K. Tokoi, T. Ohashi, H. Murakami

Outline

Radial profiles of Fe abundance up to 0.3-0.5r_{180} with XMM satellite

O and Mg in the ICM up to 0.2-0.3r_{180} with Suzaku satellite

Groups vs. clusters observed with Suzaku
Metals in the ICM

Iron mass in the ICM is comparable to that in stars in cluster galaxies.

Clusters of galaxies contain all the metals synthesized in cluster galaxies?

Iron mass in the ICM

---

\[
\text{Iron mass in the ICM} = \text{stellar luminosity}
\]

ASCA Makishima et al. (2001)
Fe abundance of the ICM in 28 nearby clusters with XMM $z<0.08$

Matsushita submitted to A&A

We derived Fe abundances from the flux ratios of Fe lines to the continuum within an energy range of 3.5–6 keV to minimize and evaluate systematic uncertainties due to background and temperature structure.
Systematic uncertainty in the Fe abundance
He-like vs. H-like

He-like and H-like Fe lines give consistent Fe abundances

Small systematic uncertainty, since temperature dependences of the two lines are different
Radial dependence of the Fe abundances

Fe abundances are derived from the flux ratios of He-like Fe line and the continuum.

\(<0.06r_{180}\)

- Scatter
- Difference in recent metal enrichment from the cD galaxies

\(0.1-0.3r_{180}\)

- Small scatter
The observed flatter radial profile of the Fe abundance at 0.1-0.5$r_{180}$ indicates early metal enrichment than numerical simulation.

The Fe abundance derived from numerical simulations by Fabjan+08.

cD clusters with cooling cores.

others.


error 68%
EvoluMon of Fe abundance of ICM

Maughan et al. 2008

$z < 0.08$
Matsushita

cooling core
others

solar abundance:
Anders&Grevesse(1989)

Maughan et al. 2008

error 68%

consistent with no evolution at least up to $z = 0.6$
excluding the central region
Metals in the Intracluster medium

- From SN II
- Formation history of high mass stars in clusters

Star formation and chemical evolution history in clusters

- From SN Ia and SN II
- History of SN Ia and SN II

Suzaku satellite provides better sensitivity to O and Mg lines

O, Mg

Si, S, Fe, Ni
Advantages of Suzaku satellite

The XIS instrument onboard Suzaku (2005-) has

– an better line spread function due to a very small low-pulse-height tail below 1 keV energy range around O lines is not suffered by strong Fe-L lines
– a very low background.

Response of a line at 0.65 keV (Kα line of H-like O) of XMM-MOS and Suzaku XIS detectors
O and Mg in ICM within 0.1$r_{180}$ observed with Suzaku
solar abundance table by Loddars (2003)

Solar abundance pattern!

$kT\sim 2-4$ keV clusters

$kT$ groups $\sim 1$ keV

Sato+07,08 09ab
Tokoi +08, Matsushita+07
Komiyama+08,Hayashi+09

errors 90%
In clusters of galaxies, metals synthesized by SN II tend to be more extended than SN Ia products?

Sato+07,08 09, Tokoi +08, Komiyama+08
Integrated Fe mass to light ratios

Integrated Fe mass in ICM within $r$
Integrated K-band luminosity of galaxies within $r$

Distribution of Fe is more extended than stars.

Sato+09
Komiyama+09
Tokoi+08

Clusters:
- NGC5044
- NGC507
- HCG62
- A262
- A1060
- AWM7

Groups:
- Groups

$r / r_{180}$
Origin of metals in ICM

Abundance pattern of ICM within $0.1r_{180}$ is close to the new solar abundance by Loddars (2003)

- 70-80% of Fe are synthesized by SN Ia (Sato+07)
- Metal supply from cD galaxies are important

Extended distribution of Fe than stars and flatter Fe abundance profile at $0.1-0.5r_{180}$

No evolution until $z=0.6$ excluding the central region

SN II products tend to be more extended than SN Ia products?

- Metal synthesis in early phase in cluster formation
Suzaku observations of Fe abundance profiles of ICM in clusters and groups

similar Fe abundance profiles
O and Mg in ICM within $0.1r_{180}$ observed with Suzaku

similar abundance pattern within $0.1r_{180}$

$kT \sim 2-4$ keV clusters

$kT$ groups $\sim 1$ keV

Sato+07,08 09ab
Tokoi +08, Matsushita+07
Komiyama+08,Hayashi+09

errors 90%
In groups of galaxies, metals synthesized by SN II have similar radial profiles with SN Ia products within $0.3r_{180}$.

Sato+07,08 09, Tokoi +08. Komiyama+08.
Metal mass to light ratio

Mainly low mass stars

Suzaku (<0.1r₁₈₀)

Sato+07,08 09ab
Tokoi +08, Matsushita+07
Komiyama+08, Hayashi+09

OMLR O mass to light ratio ← SN II
IMLR Fe mass to light ratio ← SN Ia, SN II

Temperature (keV)
Metal mass to light ratio \( (\lesssim 0.3 r_{180}) \)

- Iron mass to light ratio
- Oxygen mass to light ratio

**Integrated IMLR**

- NGC 5044
- NGC 1550 relaxed groups
- Fornax not relaxed
- Abell 262 kT=2keV relaxed cluster

**Integrated OMLR**

- NGC 5044
- Fornax
- Abell 262

Komiyama+08
Sato+08
Kawaharada+09
Murakami+ in prep

Difference in metal mass-to-light ratio beyond 0.1\(r_{180}\)

Central region – similar metal supply from central galaxies in relaxed clusters and groups
Groups vs. clusters

- Similar Fe abundance profiles up to $0.3r_{180}$

- SN II products tend to be more extended in clusters?

- The observed metal mass-to-ratio are smaller in groups and poor clusters reflecting that gas fraction is smaller in groups

- Difference in star formation history?
- Same star formation history but difference in the effect of feedback?
Summary

With XMM, the Fe abundances of the ICM in 28 nearby clusters were derived.

With Suzaku, O and Mg abundances of the ICM in several clusters and groups were derived.

• Metal synthesis in early phase in cluster formation
• Difference between clusters and groups