Mass-to-Light-Ratios of the galaxy clusters and groups observed with Suzaku


Submitted to PASJ.
Thanks to the low background level, *Suzaku* enables us to detect the ICM emission out to the virial radius. The Fe abundances beyond $r_{500}$ are about 0.2-0.3 solar (e.g., Fujita+08, Werner+13)

**Purpose**

We analyzed 13 clusters and groups observed with *Suzaku* beyond $r_{500}$, and derived the total gas and Fe mass in the ICM.

To study the slope of stellar Initial-Mass-Function of the cluster galaxies

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**Introduction**

Solar abundance table = Lodders 2003
The Galactic emissions

Since the X-ray emissions from the outskirts are faint, the background and foreground estimation is vitally important.

Foreground emissions

= Local Hot Bubble(0.1 keV)  
+ Milky Way Halo(0.2-0.4 keV)

0.5~1 keV component possibly come from our Galaxy sometimes appears in the blank-sky observations with Suzaku

We included the systematic uncertainties of the Galactic emissions
Radial profiles of Fe-K lines

We investigated the Fe-K line surface brightness profiles.

- Fe abundances of clusters derived from Fe-K line ($>0.2 \ r_{500}$) are 0.2-0.3 solar
- Fe abundances of groups $<r_{500}$ are also 0.2-0.3 solar
Iron-Mass-to-Light-Ratios (IMLRs)

The metals had been synthesized in the stars of the member galaxies

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M_{\text{Fe}}/L_K = \frac{\text{Cumulative Fe mass in the ICM} (< r)}{\text{Cumulative K-band luminosities} (< r)}
\]

From the Fe masses and luminosities profiles, we calculated the \( M_{\text{Fe}}/L_K \) of the clusters and groups at the virial radius.
$M_{Fe}/L_K$ at $1.6 \ r_{500}$ as a function of $M_{500}$.

- Most amount of Fe are in the ICM.
- $M_{Fe}/L_K$ of the clusters does not depend on the $M_{500}$.

Using $M_{Fe}/L_K$ of the ICM and stars, and the Si/Fe ratios of the ICM (next slides), we constrain the stellar initial mass function of cluster galaxies.
Core-collapse SNe (Z=0.02, Nomoto+06)

Type-Ia SNe (W7, Iwamoto+99)

Suzaku and XMM-Newton measured Si/Fe ratios up to $\sim r_{500}$.

The Si/Fe ratios are almost the solar ratio up to $\sim r_{500}$.

Fe fraction synthesized by SN$_{\text{Ia}}$
Estimation of total Silicon-Mass-to-Light-Ratios ($M_{\text{Si}}/L_K$)

Assuming Si/Fe ratio beyond $r_{500}$, we estimated the “total (ICM+star)” $M_{\text{Si}}/L_K$ to reveal the IMF slope.

$M_{\text{Si}}/L_K$ in the ICM

Estimate $M_{\text{Si}}/L_K$ assuming Si/Fe ratios beyond $r_{500}$

$M_{\text{Si}}/L_K$ in the stars of the member galaxies

Assumed the solar metallicity

Case 1

Core-collapse SNe ($Z=0.02$, Nomoto+06)

Case 2

Coma (Matsushita+13b)
Perseus (Matsushita+13a)
AWM7(Sato+08)
A262(Sato+09)
Virgo (Simionescu+15)
MKW4, HCG62, NGC1550, NGC5044(Sasaki+14)
Renzini (2005) showed that $M_{Si}/L_K$ is very sensitive to the slope of IMF of stars.
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The IMF slope of the clusters are close to the Salpeter IMF.
Summary

We analyzed 13 clusters and groups observed with Suzaku beyond $r_{500}$.

- We detected the Fe-K line up to $\sim r_{500}$ for the clusters, and $\sim 0.5 \ r_{500}$ for the groups.
- Fe abundances of clusters derived from Fe-K line ($>0.2 \ r_{500}$) are 0.2-0.3 solar.
- Fe abundances of groups $<r_{500}$ are also 0.2-0.3 solar.
- $M_{\text{Fe}}(<1.6 \ r_{500})/L_K(<1.6 \ r_{500})$ in the ICM of the clusters are several times greater than that in the stars.
- Most amount of Fe are in the ICM.
- $M_{\text{Fe}}(<1.6 \ r_{500})/L_K(<1.6 \ r_{500})$ of the clusters does not depend on $M_{500}$.

Assuming the solar Si/Fe ratios in the ICM and stars, the slope of IMF in the clusters are agree with the Salpter IMF.

Poor systems have smaller IMLRs and GMLRs than these of the clusters.
The dependence of the IMLRs on entropy

The poor systems have smaller $M_{\text{Fe}}/L_K$ than the clusters.

Non-gravitational energy input is more important in poorer systems

Poor systems would have shallower gas and metal distributions than stars

$S = \frac{E_{\text{temp}}}{E_{\text{int}}} = \frac{T}{k} \rho^{-2/3}$

$E_{\text{temp}} = \frac{3}{2} k T$