ASCA OBSERVATIONS OF DISTANT CLUSTERS OF GALAXIES

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1. Introduction

Investigation of evolution of X-ray properties of clusters of galaxies is a key study of cosmology. The most important result in this field before *ROSAT* and *ASCA* observatories is the detection of the negative evolution of the X-ray luminosity function at red-shift lower than 0.6 (Gioia *et al.* , 1990). Following it, many groups have been investigating evolution of X-ray luminosity function from various surveys with *ROSAT* observatory (eg. Collins *et al.* , 1997). Many of them indicate no negative evolution at the red-shift lower than 0.7, which is against the *Einstein* result.

ASCA added new and key information to the study of the evolution of clusters; temperature and metal abundance of distant clusters of galaxies. I review it and show new results in this report.

2. Results

2.1. TEMPERATURE AND X-RAY LUMINOSITY

Tsuru *et al.* (1996) and Mushotzky and Scharf (1997) compiled *ASCA* data of distant clusters of galaxies (mostly $0.6 > z > 0.1$). By comparing it with the data of nearby clusters obtained with the previous observatories (eg. David *et al.* , 1993), they suggested no evidence for a change in the temperature and X-ray luminosity relationship. However, it is still doubtful because it is shown without enough cross-calibration among *ASCA* and the other previous observatories. Recently, Fukazawa (1997) compiled *ASCA* data of nearby clusters. Then, I make comparison with the data and show result in this report, which is free from the difficulty of the cross-calibration.

ASCA observations of two very distant clusters, AXJ2019+1127 and MS1054-0321 at the red-shifts of 1.0 and 0.829 respectively, were reported

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very recently (Hattori *et al.* 1997a; Donahue *et al.* 1997). Including the two clusters, I show the temperature and X-ray luminosity relationship in the figure 1. The figure indicates no significant difference among the epochs, which implies no evidence for a strong evolution in this relationship.

2.2. TEMPERATURE AND GAS MASS RELATIONSHIP

Next, I compare the two clusters with nearby clusters in the temperature and gas mass relationship in the figure 2. I also plot data of the clusters at the red-shift of around 0.5. All the temperatures plotted in the figure are obtained with *ASCA*. The gas masses for nearby clusters are calculated from results of imaging analyses of *ASCA* data (Fukazawa 1997). The gas masses of the other (distant) clusters are obtained with *ROSAT* observatory except for that of 3C295 which is determined with *Einstein* observation (Hughes and Birkinshaw 1995; Donahue 1996; Schindler *et al.* 1997; Henry and Henriksen 1986; Donahue *et al.* 1997; Hattori *et al.* 1997a; Hattori *et al.* 1997b; Hughes 1997). All the gas masses except for AXJ2019+1127 are defined as those within 1.0 Mpc from cluster center. In the case of AXJ2019+1127, observed $R_{\rm max}$ is 0.5 Mpc. Then, adding to the gas mass actually detected in $R_{\rm max}$ of 0.5M pc, I plot extrapolated gas mass when assuming $R_{\rm max}$ of 1.0 Mpc in the figure.

This figure indicates significant difference between the nearby and distant clusters. The gas mass of the two very distant clusters, AXJ2019+1127 and MS1054-0321, are only 10% or 25% of those of nearby clusters when comparing at the same temperature. Two other distant clusters at the red-shift of around 0.5, 3C295 and MS0451.6-0305 also contain only 20%-50% gas masses of nearby clusters when comparing at the same temperature. Thus, I found a hint of evolution in this relationship.

It is suggestive that their gas masses are much smaller than those of nearby cluster although the no significant difference is seen in the temperature and X-ray luminosity relationship. It should indicate different distribution of ICM between the two groups. Small amount of gas can emit large luminosity if its distribution is compact. The $\beta_{\rm fit}$ of AXJ2019+1127 and MS1054-0321 determined with *ROSAT*/HRI are ~ 0.9 and $0.66 - 1.0$, respectively (Hattori *et al.* 1997a; Donahue *et al.* 1997). The values are larger than the typical value of $\beta = 0.6 - 0.7$ for nearby rich clusters, which indicates the two clusters are compacter than nearby clusters.

2.3. TEMPERATURE AND IRON ABUNDANCE

It has been already reported that no evidence for a change in the iron abundance and temperature relationship as a function of red-shift is seen at $z < 0.6$ (Tsuru *et al.* , 1996; Mushotzky and Loewenstein 1997). In this report, I add the new data of MS1054-0321 and AXJ2019+1127 to the relationship in the figure 3. The iron abundance of MS1054-0321 is consistent with nearby clusters. However, that of AXJ2019+1127 is extremely higher than the relationship.

2.4. TEMPERATURE AND IRON MASS RELATIONSHIP

Next, I show the temperature and iron mass relationship in the figure 4. The iron mass of AXJ2019+1127 is consistent with the relationship of the nearby clusters. Since its low gas mass and high iron abundance counterbalances each other, the iron mass comes on the relationship. In the case of MS1054-0321, the abundance is consistent with nearby clusters but the gas mass is very low. Then, the iron mass becomes very low.

The result of AXJ2019+1127 indicates that the metal injection process into its ICM through its life had already finished before the red-shift of 1.0. On the other hand, it is suggested that the metal injection in MS1054-0321 has not started yet.

3. Summary

(1) No evidence for a change in the k_BT-L_X relationship or k_BT- iron abundance at $z < 0.6$ is found. (2) No significant change in k_BT-L_X relationship at $z > 0.6$ is seen, either. However, the gas masses of very distant clusters at $z \sim 0.8 - 1.0$ and some clusters around $z \sim 0.6$ are significantly lower than those of nearby clusters, which indicates a hint of evolution. (3) The iron masses of the two clusters at $z \sim 0.8 - 1.0$ are significantly different, which suggests that the epoch of the metal injection into ICM is different from cluster to cluster.

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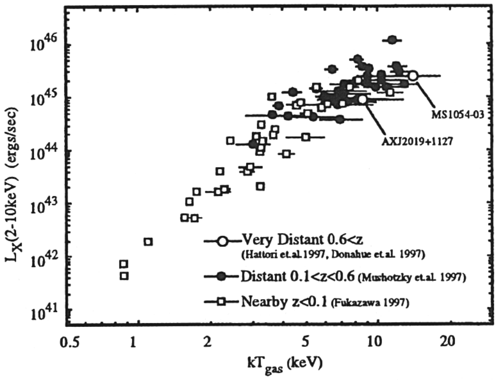

Figure 1. The temperature and X-ray luminosity relationship. Since all the data were obtained with *ASCA* observatory, the result is free from difficulty of cross-calibration (Fukazawa 1997; Mushotzky and Scharf 1997; Donahue *et al.* 1997; Hattori *et al.* 1997a).

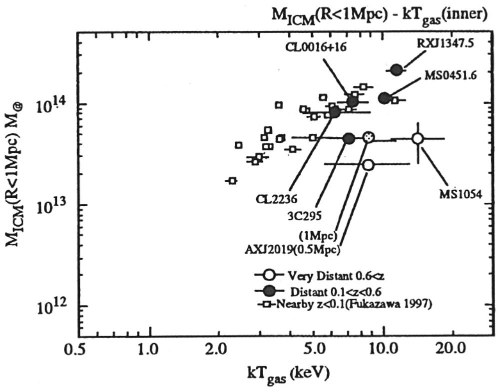

Figure 2. The temperature and gas mass relationship. All the temperatures were obtained with *ASCA*. The gas masses for the nearby clusters were calculated from the results of imaging analysis of *ASCA*data (Fukazawa 1997). The gas mass of 3C295 is derived with *Einstein* result (Henry and Henriksen 1986). The other masses are adopted from *ROSAT* results (Hughes and Birkinshaw 1995; Donahue 1996; Schindler *et al.* 1997; Donahue *et al.* 1997; Hattori *et al.* 1997a; Hattori *et al.* 1997b; Hughes 1997).

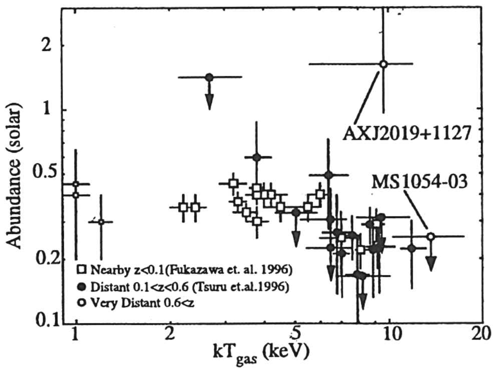

Figure 3. The temperature and iron abundance relationship. All the data were determined with *ASCA* (Fukazawa 1997; Tsuru *et al.* 1996; Donahue *et al.* 1997; Hattori *et al.* 1997a)

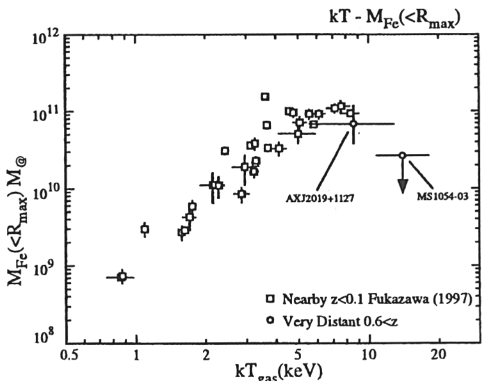

Figure 4. The temperature and iron mass relationship. The iron mass is defined as that with in R_{max} (Fukazawa 1997; Donahue *et al.* 1997; Hattori *et al.* 1997a).