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Relations of X-ray Properties of 150 Galaxy Clusters Observed with *ASCA*

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Abstract. 150 clusters of galaxies observed with *ASCA*(including group of galaxies 20%, binary galaxies a few %, galaxy 10%) are analyzed, using common manner to minimize systematic deviation due to instrumental characteristics. Obtained correlation between X-ray luminosity and temperature(Lx–kT) enables us to discuss formation and evolution of a gravitationally bounded system above $10^{12}M_\odot$. The slope of this relation becomes to be steeper below 3keV. It is because the gas fraction $f_{\rm gas}$ is smaller than that of a large system. It can be described that a small system is much affected by preheating. However obtained correlation between central entropy S_0 and kT shows no sign of the preheating.

1. Introduction

Lx–kT relation is the most studied correlation so far(Markevitch 1998; Arnaud & Evrard 1999; Mulchaey 2000) and has been used as a tool for testing evolution. A theoretical model based on the self-similar hierarchies predicts $L\text{x} \propto kT^2$(Kaiser 1986) on the assumptions that $f_{\rm gas}$ is constant and the energy input into cluster gas other than the gravity is negligibly small. However, observations show Lx $\propto kT^3$. This discrepancy is not easy to resolve without relaxing the assumptions. One proposed source of the heat-input is super-galactic wind, so called preheating, produced by the initial starburst in proto-galaxies at high redshift. Preheating make a steeper Lx–kT relation especially in small systems like a galaxy group. Observational indication is given by Ponman et al. (1999).

2. Statistical *ASCA* Data Analysis

ASCA images are distorted by Point Spread Function(PSF) of X-ray telescope, characterized by a sharp central peak(FWHM$\sim$0.′6) and a significant scattering tail. The blured images were deconvoluted with Richardson-Lucy Algorithm(Lucy 1974; Sato et al. 2000). *ASCA* images of 3C273 were used for PSF correction. After the deconvolution with 100 times iteration, the radial profiles of surface brightness were made and evaluated with β model (core radius Rc and β). X-ray spectra are accumulated within a circle involving 90% flux of clusters and fitted with absorbed Raymond-Smith model. From image and spectral parameters, assuming the hydrostatic equilibrium, the isothermality and spherical symmetry of the system, we estimated the radial distributions of gas density n, gas mass $M_{\rm gas}$ and gravitational mass $M_{\rm grav}$. (H_0 = 50 km sec^{-1} Mpc^{-1}, $q_0 = 0$.)

3. Results and Discussion

According to standard cold dark matter model, $Lx \propto kT^2$. However our result needs powerlaw index of >3(fig 1a). This is interpreted that small systems are much affected by heatings except for gravitational heating, for example, preheating. As the result, the gas heated by SN wind can not concentrate, and thus Lx is left to be low. Therefore, $f_{\rm gas}$ of cool cluster is smaller than that of hot one. Obtained $f_{\rm gas}(<3Rc)$ actually shows this tendency;$f_{\rm gas} \propto M_{\rm grav}^{0.2}$(fig 1b).

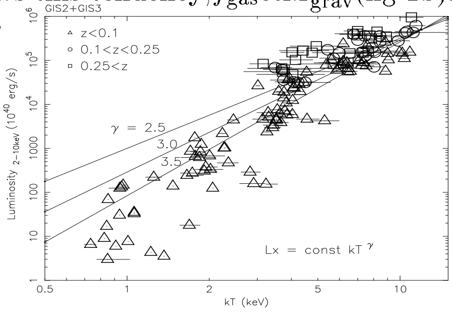
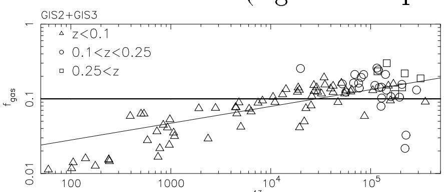
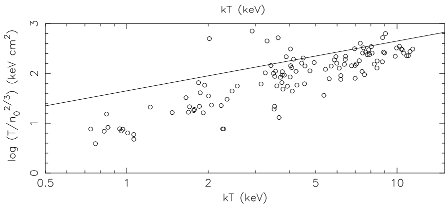


Figure 1. (a)Lx–kT relation. Triangles are nearby targets(z<0.1), squares are distant targets(z>0.25), and circles are targets of z=0.1–0.25.(right panel) (b)$f_{\rm gas}$–$M_{\rm grav}$ relation. These are averages within $r<3Rc$. Marks are the same as (a). (left down panel) (c)S_0–kT relation. A line shows the self similar case.(right down panel)





Ponman et al. (1999) found an entropy excess at cool system and claimed non-gravitatonal processes play a important role in determining an entropy S. They estimated the S at 0.1 $r_{\rm vir}$ by excluding central excess component. On the other hand, we estimated a central entropy $S_0 \propto \log(kT/n_0^{2/3})$ with single β model without ignoring central excess component. Obtained correlation between S_0 and kT needs no entropy excess at cool system(fig 1c). The disagreement would be due to whether a central excess component is excluded or included rather than the diference of mesured radius. Namely, the disagreement suggests obtained global density profile depends on a size of central excess component especially in the case of a small system, therefore, an determination of the S at outer part of a small system has large uncertainty. Thus, Ponman et al. may overestimate an entropy floor value. If the floor value is smaller, other mechanisms are needed to understand obtained $f_{\rm gas}$–$M_{\rm grav}$ and Lx–kT relations.

4. Summary

Correlations of Lx, kT, S and $f_{\rm gas}$ are important for the investigation of formation and evolution of galaxy and cluster. Obtained $f_{\rm gas}$ has varied continuously as the system size. This variation determines powerlaw index and deviation of Lx–kT relation. But we do not know why the $f_{\rm gas}$ of cool small system is small.

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