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# THE X-RAY LUMINOSITY/TEMPERATURE RELATION FOR OVER 200 HOMOGENEOUSLY ANALYZED ASCA CLUSTERS AND GROUPS

D.J. HORNER[1,2], W.H. BAUMGARTNER[1,2], K.C. GENDREAU[2], R.F. MUSHOTZKY[2], M. LOEWENSTEIN[2], C.A. SCHARF[3]

[1]*Laboratory for High Energy Astrophysics, Code 662, Goddard Space Flight Center Greenbelt, MD 20771 USA*

[2]*Department of Astronomy, University of Maryland, College Park, MD 20742 USA*

[3]*Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218 USA*

The correlation between x-ray luminosity and x-ray temperature (the L-T relation) for galaxy clusters and groups reflects the underlying physics in their formation and evolution. We present a uniform and systematic analysis of galaxy clusters and groups observed by the ASCA x-ray satellite and preliminary results of a study of the L–T relation using this sample. Currently the sample includes more than 200 clusters with measured x-ray temperature and luminosity from ASCA GIS spectra.

## 1 Introduction

The x-ray luminosity and temperature of galaxy clusters have long been known to be strongly correlated although with a large amount of intrinsic scatter. While the average x-ray temperature of the gas is simply related to the the dark matter in the cluster, $T_{\rm x} \propto M_{\rm vir}/r_{\rm vir} \propto M_{\rm vir}^{2/3}$, the x-ray luminosity depends on the baryons in the cluster, $L_{\rm x} \propto \rho_{gas}^2 T_{\rm x}^{1/2}$ and is thus influenced by hydrodynamical and other effects which are not well understood (e.g., cooling flows, energy injection by early supernovae). Theories and simulations with only gravitational heating predict $L_{bol} \propto T^2$ while the observed relationship is closer to $L_{bol} \propto T^3$.

Recent work has concentrated on obtaining the underlying L-T relation and decreasing the scatter. For rich clusters, this has meant removing the effects of cooling flows (e.g., Markevitch 1998; Arnaud & Evrard 1999; Allen & Fabian 1998) after which the L-T flattens toward $L \propto T^2$. At groups scales, work has concentrated on whether groups lie on an extension of the rich cluster L-T (e.g., Mulchaey & Zabludoff 1998; Helsdon & Ponman 2000). For poor groups, removal of the contribution of galaxies to the x-ray emission becomes an issue. Helsdon & Ponman have reported a steepening of the L-T for poor groups (L-T$^{\sim 5}$) attributed to preheating of the gas due to early supernovae.

The ASCA Cluster Project (hereafter ACP) was started at GSFC with the goal of compiling and homogeneously analyzing all of the clusters in the ASCA public archives. As part of this project, we have examined the L-T relationship. Instead of concentrating on either extreme of

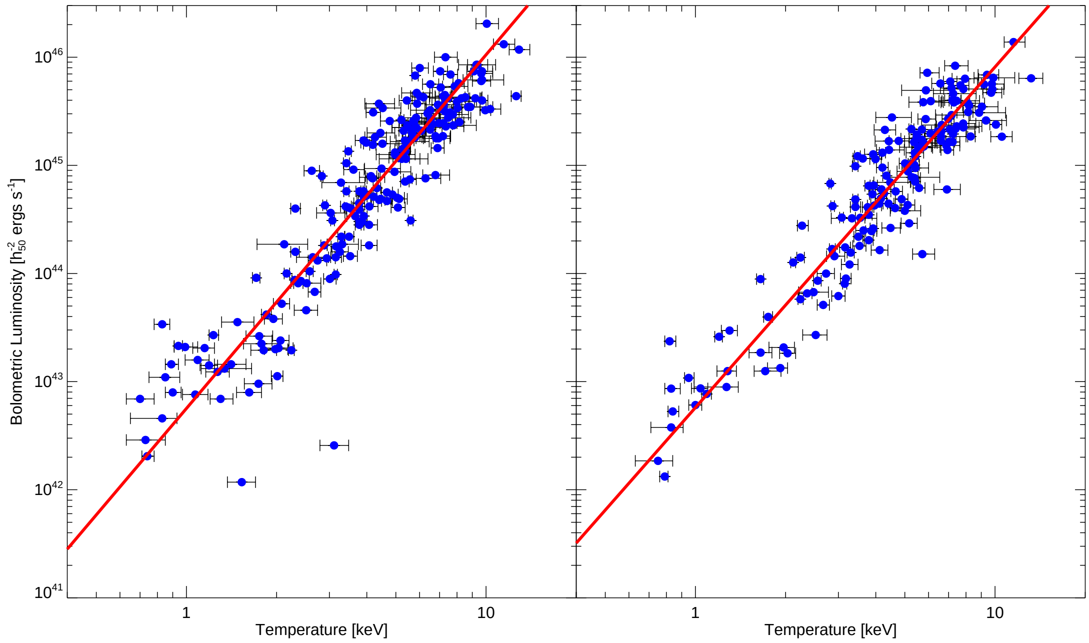


Figure 1: Luminosity – Temperature Relation. (a) ASCA luminosities and temperatures for 208 clusters. (b) ROSAT PSPC luminosities and ASCA temperatures for 162 clusters (see Section 4). Temperature errors bars are 90% confidence limits in both plots. Lines are best fits (see text).

the mass scale, we have examined the L-T relationship over the whole range of objects, from clusters to groups, analyzing them in a homogenous manner. Although a great deal of work remains to be done, we report here some initial results.

## 2 Data Analysis

We constructed the catalog from clusters in the NASA/IPAC Extragalactic Database (NED) that were detected in ASCA public observations. Additional catalogs of clusters and groups (e.g., David et al. 1993, Helsdon & Ponman 2000) were used to add additional clusters. Semi-automated scripts have been developed to process the ASCA data, extract spectrum files, and fit various models to spectra. Some details of our analysis are contained in W. Baumgartner's contribution in these proceedings.

The sample currently contains over 200 clusters and groups. For our L-T study, we are only using the ASCA GIS data (the SIS data require more careful analysis which has not been completed at this time) and have fit a single temperature MEKAL model to the spectra. Extraction regions were chosen to include all the visible emission from the cluster. Blank sky fields were used for the background spectra, although using local backgrounds makes little difference.

## 3 The Luminosity – Temperature Relation

Figure 1a shows the L-T relation for cluster and groups. We have only plotted those clusters for which the fit had a temperature error of less than 20% and a reduced $\chi^2$ value of less than 1.5. We have fit the L-T relation using the BCES bisector method of Akritas & Bershady (1996) which takes into account the measurement errors in both variables and intrinsic scatter. We have assumed 20% errors on the luminosities, but the size of the assumed luminosity error has little effect on the fit. The best fit is $L_{bol} \propto T^{3.3\pm0.1}$, similar to previous results (e.g., White et

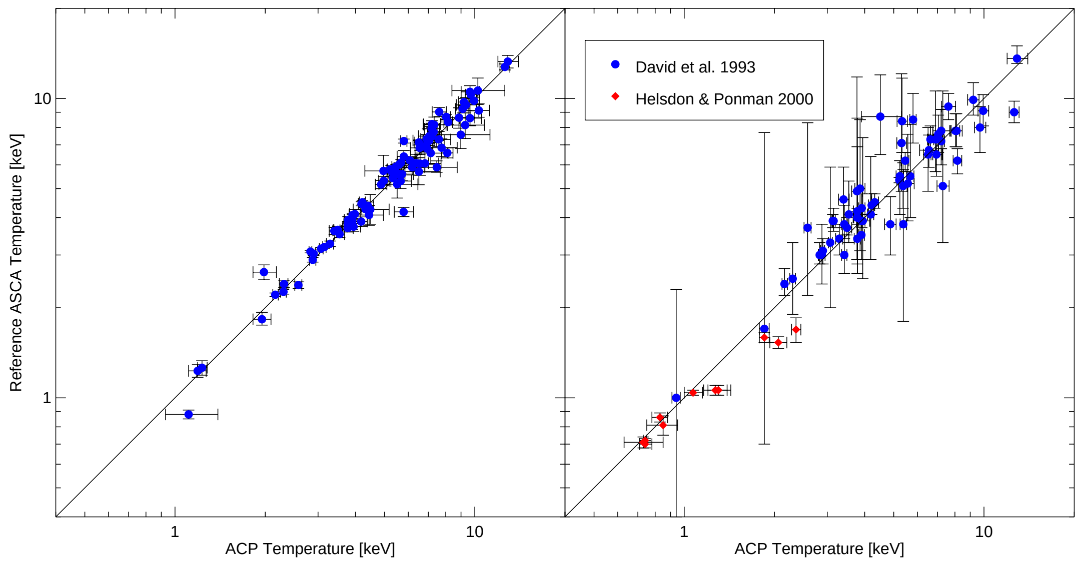


Figure 2: Temperature Comparison. (a) Comparison of our fitted temperatures with other ASCA temperatures taken from the literature. (b) Comparison of our fitted temperatures with non-ASCA temperatures. Circles are from David et al. (1993), diamonds from Helsdon & Ponman (2000). Errors are 90% confidence limits except for the Helsdon & Ponman data which are $1\sigma$.

al. 1997). No steepening of the L-T is seen at lower temperatures although we do not have very low luminosity groups as in other groups samples or the fits for these objects are very poor.

## 4 Comparison with Other Samples

We have checked for any systematic biases in our data by comparing with previous literature results where available. Figure 2a shows the comparison of our GIS temperatures with other ASCA temperatures. They agree quite well with an average and standard deviation of the ratio of T(ACP)/T(REF) = 1.0 $\pm$ 0.10. In Figure 2b, we have compared our temperatures with the earlier catalog of David et al. (1993) which consists mainly Einstein MPC temperatures. The agreement is still quite good but the scatter is approximately twice as large. We have also compared with ROSAT PSPC temperatures for the group sample of Helsdon & Ponman (2000). At low temperatures, we agree very well, but at $T_{\rm x} > 1$ keV, the ASCA temperatures are systematically hotter. This has previously been reported by Hwang et al. (1999) and is probably due to the superior spectral resolution and larger energy range of ASCA doing a better job fitting the continuum, which determines the fitted temperature in this regime.

In Figure 3, we have compared the 0.5–2.0 keV ASCA model flux with the ROSAT PSPC fluxes in various ROSAT All Sky Survey based catalogs (e.g., NORAS Böhringer et al. 2000) and the catalog of Abell clusters in pointed observations by David, Forman, and Jones (1999). This reveals a systematic trend in which the ASCA fluxes are systematically higher at lower fluxes by nearly 40%. The origin of this discrepancy is not yet clearly understood, but does not seem to depend on the fitted temperature.

This bias does not significantly affect the slope of the L–T. In Figure 1b, we plot L-T using ROSAT luminosities and our ASCA temperatures. The ROSAT flux was converted to bolometric luminosity assuming the ASCA fitted temperature and abundance. The fit to this L–T, $L_{bol} \propto T^{3.2\pm0.1}$, is slightly flatter but similar to the fit using ASCA luminosities.

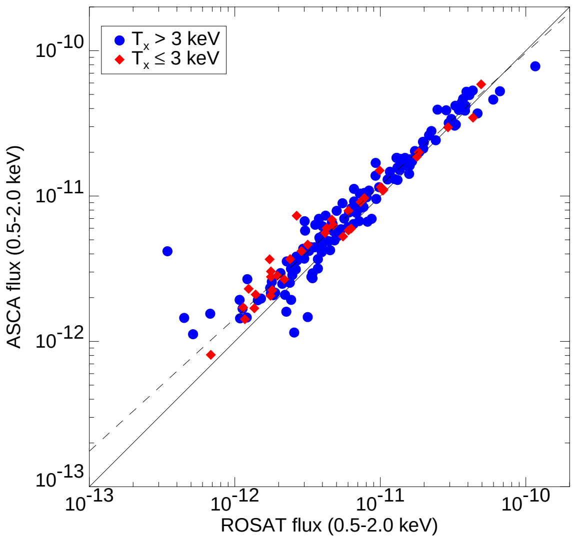


Figure 3: Comparison of our ASCA fluxes to ROSAT PSPC fluxes in the 0.5–2.0 keV band.

## 5 Future Work

The work here is only the beginning of a study of the L–T relation. We will also investigate the effect of cooling flows and check for any evolution of the L–T. However, a better understanding of systematic effects and biases much also be achieved. ASCA SIS data will also be incorporated into the analysis.

## References


1. M.G. Akritas and M.A. Bershady, *ApJ* **470**, 706 (1996)
2. S.W. Allen and A.C. Fabian, *MNRAS* **297**, L57 (1998)
3. M. Arnaud and A.E. Evrard, *MNRAS* **305**, 631 (1999)
4. H. Böhringer *et al*, preprint **astro-ph/0003219**, (2000)
5. L.P. David, W. Forman and C. Jones, *ApJ* **519**, 533 (1999)
6. L.P. David *et al*, *ApJ* **412**, 479 (1993)
7. S.F. Helsdon and T.J. Ponman, *MNRAS* **315**, 356 (2000)
8. U. Hwang *et al*, *ApJ* **516**, 604 (1999)
9. M. Markevitch, *ApJ* **504**, 27 (1998)
10. J.S. Mulchaey and A.I. Zabludoff, *ApJ* **496**, 73 (1998)
11. D.A. White, C. Jones and W. Forman, *MNRAS* **292**, 419 (1997)