December 4, 2008

Article: ApJS 295532

Title: Intracluster Medium Entropy Profiles for a Chandra Archival Sample of Galaxy Clusters

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Dear Editor and Referee,

Below is our reply to the Referee's Report for ApJS Article 295532. The referee's comments are in quotes and *italicized*, while our replies are in regular font. We have found the referee's comments to be very helpful in making the focus and discussion of our paper more concise and thorough.

"1) Section 3.4, describes how the values of K0 were derived and shows in Figure 2 the ratio of the core entropy using the two methods. I count about 40/239 systems for which the ratio is significantly different from unity, which is a non-negligible fraction. While it's pointed out in the text that the different interpolation schemes do not affect the conclusion of non-sero core entropy, I am wondering how the different temperature interpolation schemes affect the bimodality in the K0 distribution. Since the bimodality is the principal result of the paper, I think the effect of the temperature interpolation on this result should be investigated."

Shown in Figure 1 is the histogram of K_0 values derived for the temperature interpolation scheme which assumes the temperature is not a constant in the centralmost bins. The bimodal behavior is still present, but with a second peak which is broader compared to the same peak shown in the paper. Our KMM test using these K_0 values does not yield results which significantly differ from those presented in the paper. That the K_0 bimodality is not significanty affected by the different T_X interpolation schemes is an important point, and we have added a paragraph of discussion to the section on bimodality (§sec:bimod) to emphasize this point.

"2) Related to this, Section 4, on systematics, is very interesting. However, the entire Section is based on the systematics introduced by angular resolution effects on the density profiles, yet there are clusters in the sample for which there are only three temperature bins. I would like to see some discussion added on the effect of finite binning of temperature profiles. This is especially important because the temperature bins are (rightly) defined according to a total count criterion, meaning that clusters with centrally peaked emission will yield entropy profiles of generally better resolution than those with flat central emission. For instance, what happens when the temperature profile of a cluster with centrally peaked emission is binned to the typical resolution of a cluster with flat central emission?"

- added section Temperature Profile Resolution + tried this with degraded profiles + refit sbr using only deg tx prof + what do I find? - if temp fell signif in center: + given stats, fits would be poor + possible to hide dens, low-T coronae (Sun grp paper) + take for example A160 and A2462 + k0 would be lower, but it would lose meaning

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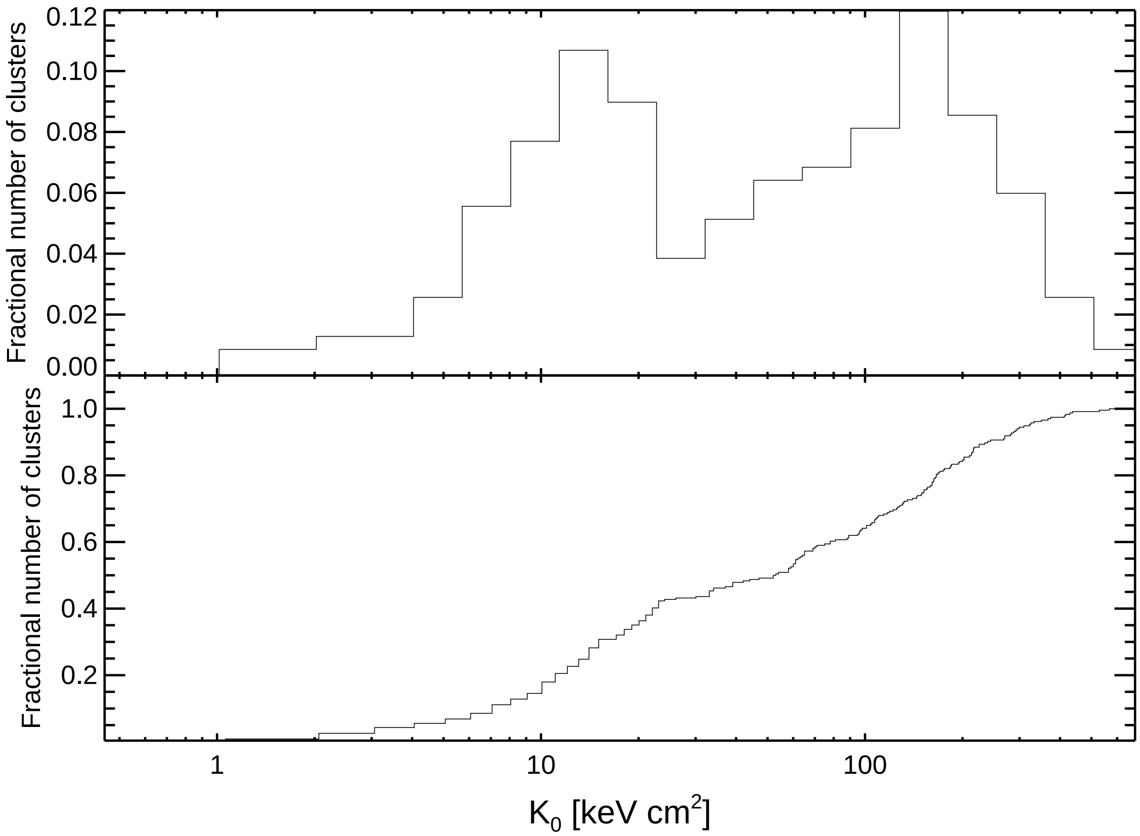

Figure 1: *Top panel:* Histogram of best-fit K_0 derived using the alternate temperature interpolation scheme. Bin widths are 0.15 in log space. *Bottom panel:* Cumulative distribution of K_0 values.

"3) I'm not sure Section 4.2, on the subject of XMM profiles, is entirely correct. Taking the example of the samples of Piffaretti et al (2005) and Pratt et al. (2006), it is important to note significant differences in the respective analyses. My understanding of Piffaretti et al's analysis is that they derived their gas density profiles from spectral fits to relatively coarse annular bins defined for the temperature profile analysis. However, I understand that Pratt et al. derived their density profiles from deprojected, PSF deconvolved analytic model fits to surface brightness profiles, corrected for radial variations in emissivity due to temperature and abundance gradients, and their temperature profiles are also corrected for PSF effects (as described in Pointecouteau et al 2005). Furthermore, Croston et al (2006) show that their analytic surface brightness models recover the density distribution exceptionally well in comparison to Chandra results, with differences occurring only in the single central surface brightness bin. Thus the Pratt et al analysis is undertaken on a radial surface brightness binning scale that is equivalent to that of the present paper, while the Piffaretti et all analysis is not. Combining a discussion of resolution effects in the context of redshift with a comparison with XMM profiles confuses the issue further. I thus suggest that Section 4.2 should deal only with resolution effects in the context of cluster redshift, and that a separate Section should be added comparing with XMM results. The latter Section will have to discuss the effect of the different analysis methods employed. My belief is that since the XMM profiles were never fitted to anything other than a power law, it is disingenuous to conclude (especially in the case of Pratt et al.) that these results did not find core flattening because of resolution effects. It is more likely because, unlike the present work, they did not think to investigate core flattening."

"4) What are the implications of the bimodality? The existence of a gap in the distribution of core entropies implies that either the gap is intrinsic to the cluster population, or that the entropy in the cluster cores is a constantly evolving property. Both of these possibilities open up intriguing areas for further discussion. If the gap is intrinsic, how is it that some clusters have a high core entropy and some clusters have a low core entropy? The idea suggested by McCarthy and collaborators, that different clusters experience a different level of preheating, may be one explanation. I'm sure the authors could think of others. If the gap is a function of evolving core entropy distributions, the fraction of clusters on one side or the other, and particularly the evolution of that fraction over time, might be indicative of a characteristic timescale. If that timescale is of the order of Gyr, then it would suggest that dynamical (gravitational) processes are modifying the core entropy, through mixing of high and low entropy gas during mergers. If the timescale is of order Myr, then it is possible that AGN-driven feedback is the dominant driver of the distribution of core entropies. Is it possible to investigate this with the current sample? If not, what kind of sample would be needed to do this kind of thing? Is there anything special about the clusters in the gap? I think the paper would benefit from a bit more discussion along these lines added to the text."

"5) This may be a little more work, but I think the paper would also benefit from a cross correlation of K0 with the presence of a compact central radio source. Since AGN are thought to be key to feedback in the ICM, such a cross-correlation seems to be the obvious thing to do with such a large and well-observed sample, especially in the context of an ApJS paper."

This is a very keen observation, one we addressed in the ApJ Letter Cavagnolo et al. 2008 (ApJ 683, 107). We found that K_0 does correlate with the presence of AGN activity (as evidenced by radio emission) and possible star formation (as evidence by Hα emission).

** Sect 1, para 2 (page 2): "...otherwise tight mass observable relations...", I would say "otherwise theoretically tight". O'Hara et al. (2006) could be added to the list of references concerned with reduction of scatter about scaling relation.*

We agree that it is true the expectation for tight scaling relations comes from theory, hence we have altered the wording and added the reference.

** Sect 1, para 7 (page 4) Pratt et al. (2006) could be added to studies showing core entropy has larger dispersion than at large radii.*

An oversight on our part, the reference has been added.

** Sect 3, para 1 (page 7) The effect of the choice of center is another source of systematics. Clusters with a large-scale centroid far away from the surface brightness peak will have flatter central entropies, or central entropies that yield physically impossible values on deprojection. Also, within what radius was the centroid defined?*

The centroid is defined via an iterative process which is detailed in Cavagnolo et al. 2008 (ApJ 682, 821). We have added this reference for interested readers and quote the relevant section from Cavagnolo et al. 2008 (ApJ 682, 821) below:

"Defining the cluster "center" is essential for the later purpose of excluding cool cores from our spectral analysis (see §**??**). To determine the cluster center, we calculated the centroid of the flare cleaned, point-source free level-2 events file filtered to include only photons in the $0.7-7.0$ keV range. Before centroiding, the events file was exposure-corrected and "holes" created by excluding point sources were filled using interpolated values taken from a narrow annular region just outside the hole (holes are not filled during spectral extraction discussed in §**??**). Prior to centroiding, we defined the emission peak by heavily binning the image, finding the peak value within a circular region extending from the peak to the chip edge (defined by the radius R_{max}), reducing R_{max} by 5%, reducing the binning by a factor of two, and finding the peak again. This process was repeated until the image was unbinned (binning factor of one). We then returned to an unbinned image with an aperture centered on the emission peak with a radius R_{max} and found the centroid using CIAO's DMSTAT. The centroid, (x_c,y_c), for a distribution of N good pixels with coordinates (x_i,y_j) and values f(x_i,y_j) is defined as:

$$\begin{aligned} Q &= \sum_{i,j=1}^{N} f(x_i, y_i) \qquad (1) \\ x_c &= \frac{\sum_{i,j=1}^{N} x_i \cdot f(x_i, y_i)}{Q} \\ y_c &= \frac{\sum_{i,j=1}^{N} y_i \cdot f(x_i, y_i)}{Q}. \end{aligned}$$

If the centroid was within 70 kpc of the emission peak, the emission peak was selected as the center, otherwise the centroid was used as the center. This selection was made to ensure all "peaky" cool cores coincided with the cluster center, thus maximizing their exclusion later in our analysis. All cluster centers were additionally verified by eye."

** Sect 3.1, para 8 (page 9) Regarding deprojection, steeply declining T gradients would have lower central entropy, but increasing T gradients would have higher central entropy.*

The wording in the paper was ambiguous, as we meant to convey exactly what the referee has stated above. We have altered the wording to be clearer.

** Sect 3.2, para 3 (page 10) The T profile interpolation scheme is not particularly well described, particularly outside the core regions. Was there a model used? How well did this perform for the case of T profiles with 3 radial bins? Also, were the interpolated abundances also used to correct for emissivity variations or was it just the T variations? Abundance variations have more of an effect on emissivity than T variations.*

** Sect 3.3, para 1 (page 11) Quantitatively, how suitable an approximation were the beta models, i.e., in terms of chi squared?*

** Sect 5.2, para 5 (page 23) The fact that the KMM test indicates that two statistically different populations are not present at z¿0.4 warrants more discussion. Is this due to resolution effects, or is it an evolutionary effect? If the latter, what does this tell us?*

** Sect 5.5, para 1 (page 26) I would specify that the Tozzi & Norman results were for semi-analytic models and the Voit et al results were for cosmological simulations with only gravitational effects included.*

We ahve amended the section to point out this difference.

** Sect 5.6, (page 27) This section should be revised as per point 3 above.*

- Fig4: The legend (T_x ¡ 4.0; 8.0 ¡ T_x) is a bit confusing.

We have changed T_X to $T_{cluster}$, added units, and rearranged the legend to read $T_{cluster} > 8.0$ keV.

- Fig 4: I suggest addition of two more panels showing the subsamples with z¡0.4 and z¿0.4

As addressed in the section above, the lack of bimodality at $z > 0.4$ cannot be attributed to a physical cause as the statistics are poor. Hence examining the two populations, $z < 0.4$ and $z > 0.4$, loses its appeal and we have decided not to add the two panels to Fig. 4.
